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MINERAL AND ENERGY RESOURCE ASSESSMENT OF THE HELENA NATIONAL FOREST, WEST-CENTRAL MONTANA

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NONTECHNICAL EXECUTIVE SUMMARY

MINERAL AND ENERGY RESOURCE ASSESSMENT OF THE HELENA NATIONAL FOREST, WEST-CENTRAL MONTANA

U.S. GEOLOGICAL SURVEY OPEN-FILE REPORT 96-683-A

* The Helena National Forest (the Forest) covers about 975,000 acres (1,520 square miles) in west-central Montana. It lies in the vicinity of Helena, the capitol city of Montana, and includes Federal lands within parts of five counties: Broadwater, Jefferson, Meagher, Powell, and Lewis and Clark.

* Gold was discovered in the region in Powell County in 1852. Mining began in the 1860's, and since then the Forest has produced gold, silver, copper, lead, zinc, molybdenum, and phosphate minerals.

* At the time of this study, the only mineral production within the Forest is gold from small-scale placer operations, although exploration continues. Minerals are produced from areas adjacent to the Forest. Properties where significant production is most probable in the immediate future are on land adjacent to the Forest.

* Estimates of undiscovered resources contained in seven types of mineral deposits are made. Statistical descriptions of the estimates are given for each deposit type (table G3). Gold and copper are the commodities most likely to be present in the Forest in significant quantities.

* Geologic maps, and maps that show areas where undiscovered deposits may exist, are presented for a variety of types of mineral deposits. These are provided in hard copy and are available in digital form (on a CD-ROM of companion report: U.S. Geological Survey Open-File Report 96-683-B) for use in land management by hydrologists, soils scientists, biologists, botanists and other scientists of the Forest Service and other entities.

* The distribution of carbonate rocks (limestone and dolomite) is shown on a separate map (also in digital form). These rock types act to neutralize acid, thus fix (chemically bind) potentially hazardous chemical elements present in surface and ground waters.

* Only part of the Forest is considered to have potential for oil and gas.

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CHAPTER A

THE HELENA NATIONAL FOREST STUDY AREA

By R.G. Tysdal and Steve Ludington

INTRODUCTION

The geology and mineral and energy resources of the Helena National Forest (the Forest) (975,088 acres; fig. A1) were studied by the U.S. Geological Survey (USGS) during 1993-1995. The study was conducted to assess the undiscovered mineral resources of the Forest and to provide minerals information to the U.S. Forest Service (USFS) for land-use planning in the management of Forest lands. The study did not assess the mineral resource potential of the few large tracts of private land that exist within the Forest boundary, mainly in the southern part of the Big Belt Mountains (fig. A2). Mineral resources of lands adjacent to the Forest were considered in the assessment process, however, because the resource potential of the Forest lands were evaluated within a regional geologic context. The study used published geologic mapping that was supplemented with new mapping where needed. The study integrated existing geochemical data with newly obtained data; conducted local detailed gravity, magnetic, and gamma-ray aeroradiometric geophysical studies for specific areas of the Forest, augmenting a Forest-wide database that had been acquired previously; and assembled pre-existing mineral occurrence and current exploration data.

Importance of the Study

Mining and exploration activity and other lines of evidence from geologic, geochemical, and geophysical data indicate the Forest has significant potential for the occurrence of undiscovered resources. The Forest contains mining districts/areas that historically have produced metals from both lode mines and placer deposits. No lode mines were in production during the course of this study, small-scale placering operations exist, mainly in Confederate Gulch in the Big Belt Mountains. Properties where exploration/development is concentrated currently are on land adjacent to the Forest--at McDonald Meadows, near Lincoln; the Elkhorn mine, on the southern flank of the Elkhorn Mountains; and the Diamond Hill prospect, on the eastern flank of the Elkhorn Mountains. The McDonald Meadows hot-spring gold deposit contains about 8.2 million ounces of gold within 414 million tons of rock, of which about 5.2 million ounces of gold can be mined economically at present (Canyon Resources Corporation, 1993). At a price of $375 per ounce, economically recoverable gold of the deposit has a value of about $2 billion.

This study of the Helena National Forest is primarily concerned with mineral and energy resources. However, the geologic, geochemical, and geophysical components that make up parts of the report also constitute fundamental building blocks that pertain to other, related scientific studies that may be undertaken--for example, mine remediation. The foundation of the mineral resource assessment is a geologic map (scale 1:126,720, where 1 in.

equals 2 mi), shown on plate 1. A derivative of the geologic map shows the geologic formations that are largely composed of limestone and (or) dolomite (plate 3, map C). The derivative map is important because calcareous rocks act to fix (chemically bind) potentially hazardous chemical elements present in streams, thus the rocks are naturally occurring remediation substances. The geologic map also can be a fundamental building block for USFS hydrologists, soils scientists, biologists, and botanists to use in conjunction with other scientific studies conducted for effective management of Federal lands. Rock chemistry is a primary control of the types of soils and plants that exist in an area, the quality of water, and ultimately the health of wildlife in an area. Maps of this report show the distribution of tracts of rock permissive for different types of mineral deposits in the Forest, but they also give clues to the distribution of naturally occurring chemical elements.

Location

The Helena National Forest is comprised of 975,088 acres that lie within parts of seven counties: Broadwater, Cascade, Gallatin, Jefferson, Meagher, Powell, and Lewis and Clark (fig. A1). No Federal land is present in the parts of Cascade and Gallatin Counties that lie within the Forest boundary. The Forest includes virtually all of the Big Belt Mountains; most of the Elkhorn Mountains; and, west of 112° longitude, mountainous terrain that extends from about 46° 20′ N. latitude, southwest of Helena, to about 47° 15′ N., north of Lincoln, Mont. (fig. A2). The Gates of the Mountains Wilderness lies within the Forest in the northern extent of the Big Belt Mountains, and the southern part of the Scapegoat Wilderness lies within the Forest in the mountains north of Lincoln (fig. A2).

Previous and Concurrent Studies

Mineral resource assessment studies were conducted previously in three regions of the Forest under consideration for Wilderness status, as mandated by the Wilderness Act of 1964 (public law 88-577). Two of the three regions were designated as wilderness and their boundaries are shown in figure A1. The Gates of the Mountains Wilderness (about 45 sq mi; 28,600 acres), and proposed additions thereto (about 16 sq mi; 10,000 acres), in the northern part of the Big Belt Mountains, were examined in 1976 (Reynolds and Close, 1984; Close and Rigby, 1984). The Scapegoat Wilderness (375 sq mi; 240,000 acres), which includes about 130 sq mi (83,000 acres) in the Helena National Forest north of Lincoln, was studied in the early 1970's (Mudge and others, 1974). Two proposed additions to the Scapegoat (totaling 84 sq mi; 53,750 acres), which includes about 60 sq mi (38,000 acres) within the Helena National Forest, were examined in the mid-1970's (Earhart and others, 1977). Neither of the two proposed additions is recommended for wilderness status by the Forest Service, and their boundaries are not shown in figure A1; one area adjoined the wilderness to the south and the other adjoined to the southeast. A large part of the Elkhorn Mountains also was studied under the Wilderness Act (Greenwood and others, 1978, 1990), although the area has not been designated a wilderness. This study encompassed about 135 sq

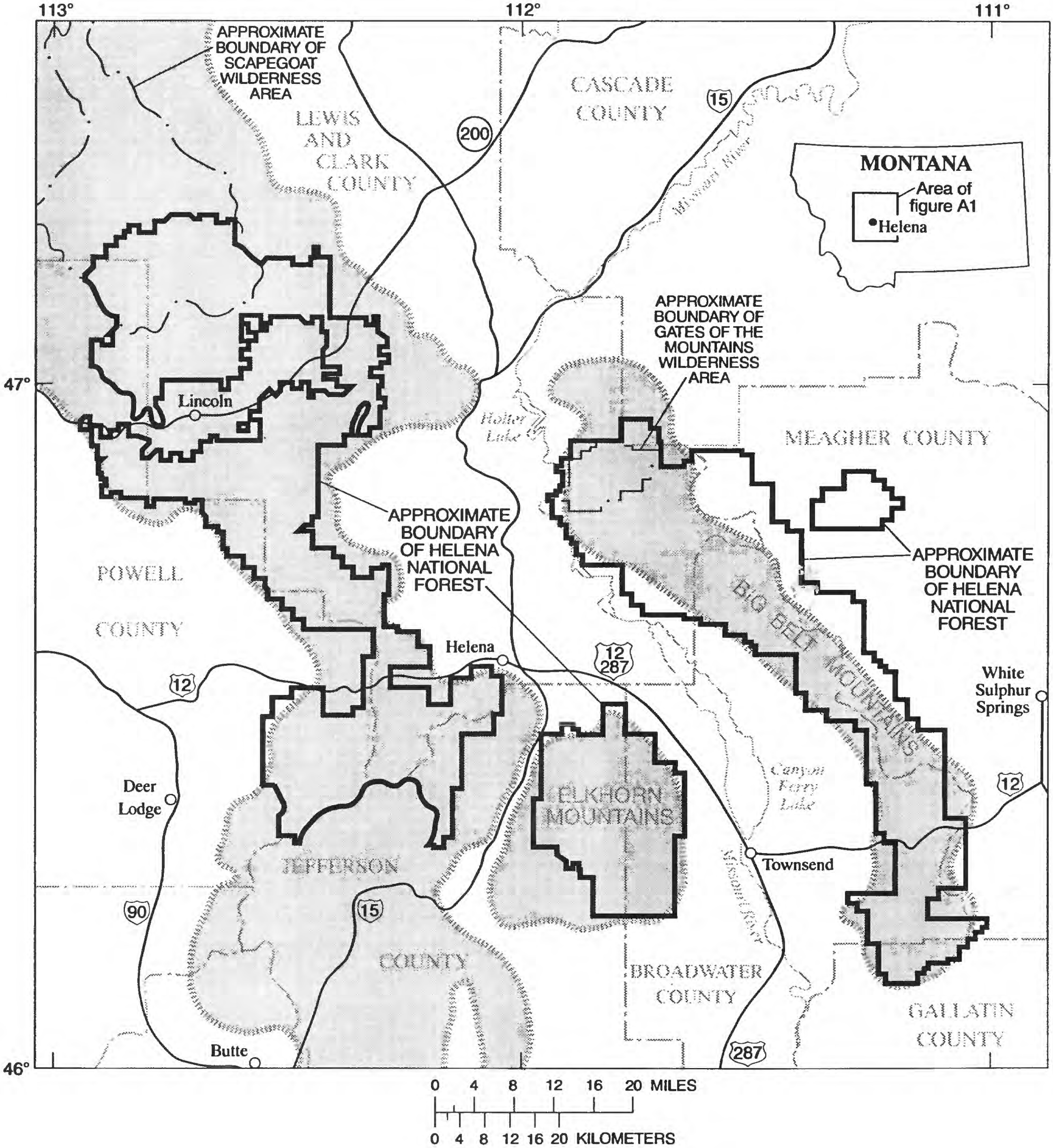

Figure A1. Index map of Helena National Forest and vicinity, showing Gates of the Mountains Wilderness, Scapegoat Wilderness, principal towns, county boundaries, and highways. Shading shows mountainous terrain.

mi (87,000 acres), which mostly lies in the Helena National Forest. No new data were acquired from the two wildernesses during the present study, or proposed additions thereto, but new data were obtained from the Elkhorn study area. The previously collected data from all three regions were incorporated into the present study.

The Forest lies within parts of three 1° x 2° quadrangles (fig. A2). Two of the quadrangles have been examined under Geological Survey CUSMAP (Continental United States Mineral Resource Appraisal Program) projects, in which delineated terranes were rated as having a low, medium, high, and locally very high, resource potential for specific types of mineral deposits. The Choteau 1° x 2° quadrangle was examined in the late 1970's (Earhart and others, 1981; Mudge and others, 1982). The Butte 1° x 2° quadrangle was the focus of extensive study in the 1980's (Elliott and others, 1992; Elliott and others, 1993a,b,c; Wallace and others, 1986). Publications of the two CUSMAP projects provide extensive citation to previous topical and areal geologic work conducted within the respective quadrangles. Results from the CUSMAP studies were incorporated into the present study, supplemented by new data obtained during the 1993 and 1994 field seasons.

In addition to previous wilderness and CUSMAP studies, topical and areal studies conducted by the U.S. Geological Survey, either within the Forest or including areas within the Forest, contributed data to this report. The first comprehensive compilation of mining and mineral exploration in the Forest region was by Pardee and Schrader (1933), who visited mines and prospects when they were actively being examined, mined, and (or) developed. Many of the mine workings are no longer accessible. Detailed mineral resource and map data were obtained from reports on the Elkhorn Mountains by Klepper and others (1957, 1971). Several geologic maps, in addition to those cited previously, were used to compile the geologic map of this report; the area and reference for each is shown in the "Index map showing sources of geologic data" on plate 1.

An extensive compilation of historical data on placer gold operations was made by Lyden (1948) of the Montana Bureau of Mines and Geology. These data form the basis of maps D and E (plate 3), which show the distribution of deposits that historically produced placer gold in and adjacent to the Forest.

The Forest overlies parts of several regional "plays," which are geologic provinces that are evaluated for their petroleum potential. The petroleum plays are discussed in Chapter J, which makes use of the previous assessment of Perry (1989) and the more recently completed study of Perry (1995).

Methodology

The assessment of mineral resources makes use of all of the previous studies as well as data collected during this and concurrent studies within the Forest and adjacent areas. Geophysical (Chapter C) and geochemical (Chapter D, plates 3, 4) data were compiled from a variety of sources. These data are shown in a variety of figures and tables. Mines, prospects, and mineral occurrences data are presented in a lengthy table in Chapter E, with locations shown on plate 2. Mineral resource data are presented and discussed in Chapter F, which is arranged by regions and by mining district or mining area. This arrangement permits discussion of the geology in a geographic scheme designed for ease of use by USFS personnel and, simultaneously, for convenience in discussing geology.

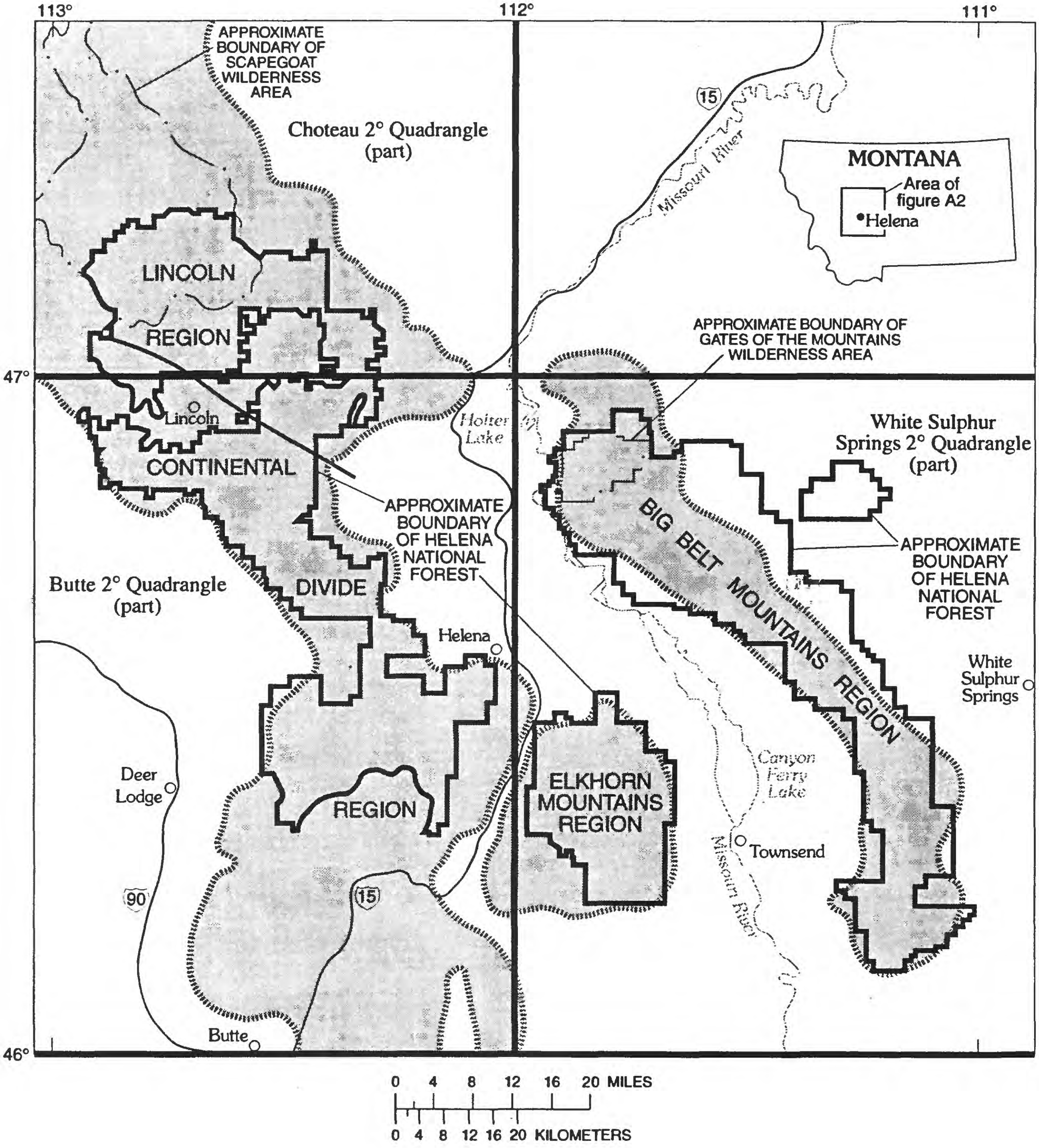

Figure A2. Map of Helena National Forest, showing regional subdivisions of the Forest used for discussion of geologic characteristics, and boundaries of the Choteau, Butte, and White Sulphur Springs 1° x 2° quadrangles. Shading shows mountainous terrain.

In the assessment process, mineral deposits of the Forest were classified into types (table A1) based on mineral deposit models (Cox and Singer, 1986), which describe the essential characteristics of a class of mineral deposits. Each of the mines, prospects, and mineral occurrences listed in table E1 are classified as to deposit type, except for a few that are listed as unclassified. The study region was delineated into tracts (areas) of land that contain attributes typical of deposits of a particular type. A permissive tract may contain known deposits of the type, and (or), based on geologic evidence, deposits can reasonably be inferred to exist within the tract even though none have been found (tracts are "permissive" for their existence). Terranes deemed permissive for the occurrence of one or more mineral deposit types are shown as mineral resource assessment tracts (plates 4, 5, 6, maps K through R). Although the tracts are delimited to include all rocks considered likely to host the deposit type(s), the boundaries could change in the future if new data became available. Some areas within tracts are shown as favorable, meaning that a combination of criteria suggest that deposits are more likely to be present in this part of the permissive tract. The criteria used to define each tract and favorable area are discussed in Chapter G.

For several deposit types present in the Forest, a subjective, quantitative estimate was made of the number of undiscovered deposits of a particular type that may lie beneath a tract. The estimate was made only for those types of deposits for which grade and tonnage data exist. The quantitative methodolgy, explained in Chapter G, has been described in Singer and Cox (1988), Menzie and Singer (1990), and Ludington and others (1992).

Undiscovered Resources

Definitions for resource classification for minerals are as follows, based on the scheme devised jointly by the U.S. Bureau of Mines and the U.S. Geological Survey (1980). A diagram of the resource/reserve classification scheme is presented in the Appendix.

Resource--A concentration of naturally occurring minerals in or on the Earth's crust in such form and amount that economic extraction of a commodity from the concentration is currently or potentially feasible.

Identified Resources--Resources whose location, grade, quality, and quantity are known or estimated from specific geologic evidence. Identified resources may be economic, marginally economic, or subeconomic. To reflect varying degrees of geologic certainty, these economic divisions can be subdivided into demonstrated (measured and indicated) and inferred resources.

Undiscovered Resources--Resources whose existence is only postulated; these postulated resources may be in deposits that are economic, marginally economic, or subeconomic.

Table A1. Mineral deposit types known or suspected to occur within the Helena National Forest, and principal commodities expected.

Deposit type	Commodities expected
Porphyry copper-molybdenum	Copper, molybdenum
Climax molybdenum	Molybdenum
Skarn gold	Gold
Skarn tungsten	Tungsten
Breccia pipe, tourmaline	Gold
Breccia pipe, polymetallic	Gold, silver, lead, zinc
Vein, gold-bearing	Gold
Vein and desseminated, gold-bearing	Gold
Vein, polymetallic	Gold, silver, copper, lead, zinc
Vein, polymetallic, uranium-bearing	Uranium
Polymetallic replacement	Gold, silver, copper, lead, zinc
Hot-spring gold-silver	Gold, silver
Epithermal vein, quartz-adularia	Gold, silver
Epithermal manganese	Manganese
York-type exhalative(?) gold	Gold
Sedimentary exhalative zinc-lead	Zinc, lead
Redbed sediment-hosted copper	Copper, silver
Sediment-hosted copper, veins	Copper
Quartz veins	High-purity silica
Vein, barite	Barite
Bog copper	Copper
Bog manganese	Manganese
Shoreline placer	Titanium, iron, zircon
Limestone	Limestone
Phosphate, upwelling type	Phosphate
Placer gold	Gold
Placer sapphire	Sapphires
Stone, building	Building stone

Digital Products

The geologic map (plate 1) also was prepared in digital form (ARC/INFO) at the request of the USFS. Several other maps, of plates 2-6, also are on the same disk. Many figures, some of which contain closely spaced patterns (shading) that does not reproduce well in black-and-white, also are contained on the same CD-ROM (Green and Tysdal, 1996). A listing of the contents of the disk is provided in the Appendix of this report.

ACKNOWLEDGMENTS

Many individuals in private industry, in the U.S. Forest Service, and within the U.S. Geological Survey provided essential information for this study or assisted the authors in various aspect of data compilation and mineral resource assessment. The initial meeting concerning the mineral resource assessment of the Forest benefited from input of representatives of the Montana Bureau of Mines and Geology, Butte; personnel from the U.S. Bureau of Mines, Spokane; U.S. Forest Service representatives from the Deer Lodge and Helena National Forests, and from the Region 1 Office, Missoula; and representatives from the mining industry, including Noranda Mining Co., Phelps Dodge Corporation, and Pegasus Gold, Incorporated.

U.S. Forest Service geologists Beth Ihle of the Townsend Ranger District and Bill Straley of the Helena Supervisors Office were especially helpful in providing information on active prospecting and exploration. Beth also very kindly arranged for our use of Forest Service storage facilities, facilitated arrangements with other USFS personnel and with private property owners, and provided lively discussions of geologic exploration activities and needs of the USFS. Several owners of private property permitted USGS personnel to cross their land to gain access to Forest land that otherwise was not readily accesible. We thank these persons for their cooperation.

Information of much significance to the mineral resource assessment of the Forest was gained through discussions and visits to mines and exploration projects. Geologists of the Phelps Dodge Corporation provided access and shared information on the McDonald Meadows gold property adjacent to the Forest, near Lincoln. Mike Maslowski, Greg Wittman, and Steve Petroni of Pegasus Resources provided access to exploration properties, shared information, and conducted field excursions to several properties on or adjacent to the Forest. Jeff Brooks of Santa Fe Minerals Corporation conducted a field excursion to the Elkhorn mine, adjacent to the Forest, on the south flank of the Elkhorn Mountains. Operators of the French Bar and Lovestone placer sapphire mines, on alluvial bars adjacent to the Missouri River, kindly provided access to their producing properties.

The assessment of oil and gas resources was aided by David W. Ballard, Bradford R. Burton, and John R. Warne, geologists from industry, who provided source-rock samples. Subsurface data was provided by Melody R. Holm (U.S. Forest Service) and James W. Halvorson, Montana Board of Oil and Gas Conservation.

G.N. Green of the USGS worked carefully and patiently to digitize maps shown on plates in this report. These maps and a digital geologic map are available on compact disk (Green and Tysdal, 1996). G.I. Selner of the USGS provided advice on use of GSPOST and GSMAP used in compilation of some maps and files. C.A. Wallace provided unpublished descriptions of Proterozoic and Phanerozoic strata of the Butte 1° x 2° quadrangle, from which shortened descriptions of rock units were derived for the geologic map; he also provided an advance copy of a map that was subsequently published. Timothy Hall, a seasonal geologist with the USGS, performed excellent field and laboratory assistance to the geochemical part of this study. Steven S. Smith donated several days of time to revise digital geochemical maps (plate 3 and 4, maps F, G, H, I, J), and Gregory Lee provided help with the digital files of geochemical data. Several of the figures were drafted by W.R. Stephens and later revised by D.A. Lindsey of the U.S.G.S.

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CHAPTER B

GEOLOGIC SETTING OF THE HELENA NATIONAL FOREST STUDY AREA

By R.G. Tysdal

GEOLOGIC MAPPING

The geologic map compiled for this study (pl. 1) is at a scale of 1:126,720 (1 in. equals 2 mi), in accord with the scale of the "Forest Use Map of the Helena National Forest", published by the U.S. Forest Service. No geologic map with the appropriate geologic detail was available for the entire Helena National Forest (the Forest). The database of maps used to compile the geologic map, and the area covered by each map, is shown on plate 1. A geologic time chart is given in the Appendix.

REGIONAL GEOLOGIC SETTING

Strata of Middle Proterozoic and younger age form a package of rocks tens of thousands of feet thick in western Montana and an area of central Montana that is delimited by the Wagner Gulch-Volcano Valley fault on the north and by faults of the southwestern Montana Transverse Zone on the south (fig. B1). The Forest overlies this thick package of strata and the eastern part of the Forest lies within the fault-bounded area. The faults at the north and south margins of the fault-bounded area were active intermittently from the Proterozoic to the present and influenced the distribution, facies, and thickness of sediments. Strata of the Middle Proterozoic Belt Supergroup, and some Paleozoic and younger stratigraphic units as well, accumulated to a much greater thickness in the fault-bounded area of west-central Montana than in regions to the north and south.

The rocks of western Montana and the fault-bounded area of west-central Montana lie within the Cordilleran thrust belt terrane, in which large-scale thrust faults displaced strata eastward during the Late Cretaceous to early Tertiary. The Wagner Gulch-Volcano Valley fault and faults of the southwestern Montana Transverse Zone, which delimit the north and south margins of the central Montana area, also delimit the north and south margins of thrust terrane within central Montana. This eastern protrusion of thrusted terrane is known as the Helena structural salient, or simply the Helena salient (fig. B1).

STRATIGRAPHY

Sedimentary rocks exposed in the Forest and directly adjacent areas include Precambrian, Paleozoic, Mesozoic, and Cenozoic strata. Unconsolidated rock materials such as gravels are present locally in the mountains, where they mainly form veneers, and on mountain flanks and within intermontane valleys where they form thick deposits. Individual rock units present in the Forest are described on plate 1 and the descriptions are not repeated here. Where appropriate, however, map symbols from plate 1 (for example, Kk, for Cretaceous Kootenai Formation) appear in parentheses in the text that follows. Carbonate (limestone and dolomite) rock units are shown on a derivative geologic map (pl. 3, map C). This derivative map was prepared at the request of the Forest Service for applications in their ongoing botanical, biological, hydrologic, and soil studies. Rocks shown as calcareous or dolomitic generally contain a small percentage of calcite or dolomite.

Precambrian sedimentary rocks are comprised of the Middle Proterozoic Belt Supergroup that, in aggregate, is several tens of thousands of feet thick in the overthrust belt of western Montana, where these strata comprise the majority of rocks (Harrison, 1972). This sequence extends well eastward within the embayment into central Montana (McMannis, 1965). Belt strata constitute more than half of the areal extent of rocks in the Forest and underlie the younger rocks in the remainder of the Forest. The maximum thickness of the Belt strata exposed within or directly adjacent to the Forest is greater than 35,000 ft. The lower two units, the Newland and Greyson Formations, crop out only in the Big Belt Mountains, except for slivers of the Greyson north of Lincoln. The two formations total about 20,000 ft in combined thickness in the central to southern part of the Big Belt Mountains (Nelson, 1963; Skipp and Peterson, 1965). Belt Supergroup rocks only as young as the Helena Formation are present in the Big Belt Mountains, whereas younger formations of the Supergroup are present in the western part of the Forest, in the region north from U.S. Highway 12 to the northern extent of the Forest. Several formations of the Belt Supergroup contain mineral occurrences and the distribution of the minerals was determined by processes that took place during sedimentation or shortly thereafter. Throughout the region, rocks of the Belt Supergroup were metamorphosed to the lower greenschist facies prior to deposition of Paleozoic and younger strata.

Paleozoic rocks of the Forest range from Middle Cambrian through Permian. All systems except the Ordovician and Silurian are represented. Thickness of the Paleozoic sequence generally is in the range of 4,500-6,000 ft. Facies changes and erosional unconformities between and within formations account for part of the variability, and juxtaposition via thrust faults of rock sequences originally deposited distant from one another account for other thickness changes. Greater than three-fourths of the thickness of the sequence is limestone and dolomite (pl. 3, map C), and one-third to one-half of which is composed of the Mississippian Madison Group (Mm); the remainder of the sequence is largely sandstone and clay shale.

Mesozoic rocks are Jurassic and Cretaceous in age; no Triassic rocks are known in the Forest. Mesozoic sedimentary rocks are exposed mainly in the Elliston area of the southwestern part of the Forest, locally in the Elkhorn Mountains, and at the northernmost and southernmost parts of the Big Belt Mountains. The sedimentary rocks are chiefly sandstone, siltstone, mudstone, and shale. The only limestones are a thin unit in the upper part of the Cretaceous Kootenai Formation (Kk), and the lower part of the Jurassic sequence, in which the 50-200 ft thick Jurassic Ellis Group (Sawtooth, Rierdon, and Swift Formations; part of unit Ju) is chiefly limestone, very calcareous shale, and calcareous sandstone. Dolomite is absent or uncommon in both Jurassic and Cretaceous rocks. Orogenic conglomerate, an outlier of the Golden Spike Formation (Kgs) that is widespread west of the Forest, crops out in the Priest Pass area northeast of Elliston. The maximum thickness of the preserved Mesozoic sedimentary rocks is about 4,000 ft, attained in the vicinity of Elliston and at the southern end of the Big Belt Mountains.

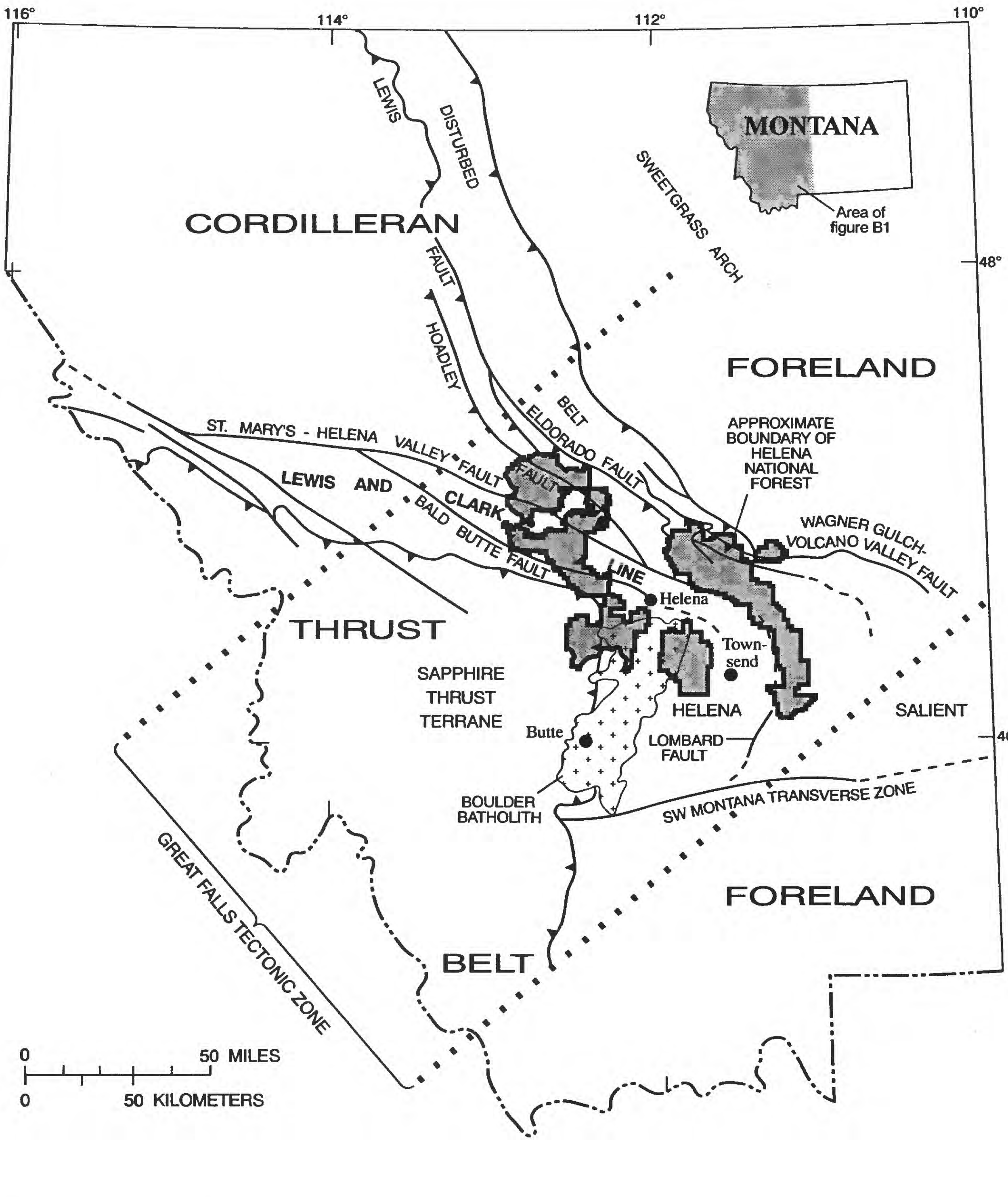

Figure B1. Map of major geologic features in western Montana and area of Helena National Forest.

Cenozoic units include Tertiary sedimentary rocks and Quaternary unconsolidated (surficial) deposits. Miocene rocks of the Bozeman Group (Tbz) crop out on the flanks of the southernmost part of the Big Belt Mountains. The unit is comprised of conglomeratic strata representative of the middle to upper part of the group (Robinson, 1967; Skipp and Peterson, 1965), which is common within the nonmarine strata of the Tertiary basins of southwestern Montana. Mountain flanks in the northern and westernmost parts of the Forest contain isolated deposits and aprons of nonmarine rocks (Ts).

Quaternary unconsolidated deposits are widespread in the Forest. Due to the scale of the map, however, they are shown only where they cover extensive areas and (or) along stream drainages where they form narrow but thick deposits. The deposits are separated into terrace gravels, alluvium, colluvium, alluvium and colluvium undivided, landslides, and four types of glacial deposits. The unconsolidated materials were separated because the properties of each type of deposit shown are somewhat different and this distinction may prove useful in determining potential sources of road metal, potential for placer deposits, relationships to hydrologic properties, relationships to distribution of plants, erosion, or other correlations.

Quaternary and (or) Tertiary terrace gravels (QTg) are present mainly at the western edge of the Forest, northward from the vicinity of Elliston, where they form a veneer on terraces flanking the mountains. Unconsolidated gravels assigned to this unit also are present locally in the Big Belt Mountains.

Alluvial deposits (Qa) mainly consist of long, narrow deposits within stream channels and adjacent flood plains of modern stream courses. Colluvium (Qc) forms veneers on mountain flanks in some areas. Generally, however, alluvium and colluvium are combined in an undivided unit (Qac) because colluvium and alluvial fans commonly form a mixture of the two types of deposit. Only areally large landslide deposits (Qls) are shown and are of the earth flow variety. Glacial deposits are grouped into four units: undivided deposits (Qg), which includes all types of glacial deposits; till (Qgt), composed of unstratified deposits; outwash (Qgo), composed of stratified deposits; and glacial-lake sediments (Qgs). Glacial deposits are thickest and areally most extensive in and adjacent to the northwestern part of the Forest where they occupy broad valleys.

VOLCANIC ROCKS

Volcanic activity was widespread in western Montana in the Late Cretaceous and Tertiary (Chadwick, 1981). Late Cretaceous through Oligocene volcanic rocks form areally extensive fields that are concentrated in certain areas of the Forest. These fields are briefly described below.

Late Cretaceous volcanic and volcaniclastic rocks are extensive in the area south of U.S. Highway 12; and in the Elkhorn Mountains, where the Elkhorn Mountains Volcanics (Kev) are of widely variable thickness but in aggregate total as thick as 15,000 ft. These volcanic rocks are remnants of an extensive volcanic field that may have covered as much as 10,000 sq mi (Smedes, 1966). They formed between about 81 and 76 million years ago (Ma), partly coincident with intrusion of the Boulder batholith (described below), to which they are genetically related (Tilling, 1968; Rutland and others, 1989). The volcnic sequence constitutes more than half of the rocks at the surface in the Elkhorn

Mountains part of the Forest. Several large intrusive bodies (Ki), compositionally similar to the volcanics, intrude the sequence in the Elkhorn Mountains (Klepper and others, 1971; Greenwood and others, 1990). Only the larger intrusive bodies are shown on the geologic map (pl. 1).

Two areas of Cretaceous volcanic rocks (Kv) are present in the Big Belt Mountains. Volcanic rocks at the southernmost part of the range are several thousand feet thick, but mostly lie outside the Forest boundary. These rocks, part of the Maudlow Formation, are considered to be remnants of the Elkhorn Mountains Volcanics field (Skipp and Peterson, 1965; Skipp and McGrew, 1977). An area of andesitic volcanic rocks on the west flank of the range, northwest of Confederate Gulch (pl. 1) (Mertie and others, 1951; Gualtieri, 1975), is included within the Kv map unit because it probably also is an erosional remnant of the same volcanic field.

Late Cretaceous to Paleocene lava flows, breccias, tuff, and associated small intrusions of basalt to andesite composition (TKbv) lie unconformably on lower rocks of the Elkhorn Mountains Volcanics in the area south of Elliston (Ruppel, 1963; Schmidt and others, 1994). Widespread, isolated patches of Eocene rhyolite (Tr) of 37-40 Ma (Schmidt and others, 1994, and references cited therein) occur in the area from Helena to west and south of Elliston and locally in the western part of the Elkhorn Mountains. These rocks are remnants of the Helena volcanic field and probably had multiple sources.

The Lowland Creek Volcanics (Tlv), in the southernmost part of the Forest west of the Elkhorn Mountains, are northern remnants of a large Oligocene volcanic field that covered at least 600 sq mi. The field consists mainly of extrusive rocks but contains related intrusives as well (Smedes, 1962; Becraft and others, 1963; Wallace and others, 1986). The Lowland Creek Volcanics probably had many sources.

The Lincoln volcanic field covers an extensive area of the Forest east of Lincoln. It consists of early Eocene or late Paleocene andesitic flows and tuffs (Ta) and late Oligocene rhyolitic volcanic rocks (Tr). The volcanic centers for these rocks are within the areas where the field is preserved.

PLUTONIC ROCKS

Plutonic rocks that range from mafic to felsic in composition are abundant in the Forest. The oldest known plutonic rocks are Middle Proterozoic sills of andesite, basaltic andesite, and dacite that locally intrude strata of the Middle Proterozoic Belt Supergroup in the northwestern part of the Forest. Late Proterozoic sills of gabbro, microgabbro, diorite, and locally diabase (Zd) intrude Belt strata throughout the Forest. The sills, which range up to 1,500 ft thick, are present mainly in the northwestern part of the Forest and in the Big Belt Mountains. Radiometric dates on the Late Proterozoic sills are in the 750-850 Ma range. A sill in the northwestern part of the Forest yielded a date of 740 $\pm$ 31 Ma (Earhart and others, 1977). On the southwest flank of the central part of the Big Belt Mountains, two sills yielded dates of 826 $\pm$ 41 and 744 $\pm$ 37 Ma (Marvin and Dobson, 1979, p. 20).

The Cretaceous Boulder batholith is a granitic mass about 60 mi long and 30 mi wide, extending from south of Butte to directly south of Helena (fig. B1). It crops out extensively in the Elkhorn Mountains and in the southern part of the Forest south of U.S. Highway 12 (pl. 1). The batholith is a composite of several intrusions, but the Butte Quartz Monzonite (Kmgd) makes up three-fourths of the mass (Knopf, 1963; Becraft and others, 1963; Ruppel, 1963; Rutland and others, 1989). The thickness of the batholith is estimated to range from 3 mi (Hamilton and Meyers, 1967) to 9 mi (Klepper and others, 1974), based mainly on gravity and magnetic data; to 10-11 mi, based on seismic and gravity data (Schmidt and others, 1990). The batholith was intruded between about 80 and 70 Ma (Tilling and others, 1968; Tilling, 1974; Rutland and others, 1989).

The origin of the Boulder batholith, associated rocks, and structures has been the subject of extensive study and debate over the years. The following publications, in addition to those cited above, provide a sampling of the literature: Knopf (1957), Klepper and others (1971), Tilling (1973), and Hyndman (1978).

In addition to the main mass of the Boulder batholith, several satellite intrusions (Kgd, Kgdm, Kgdo, Kgdb, Kgdd), generally more mafic and older than the Butte Quartz Monzonite, are present near the eastern, northern, and western margins of the batholith (pl. 1). North of the batholith, these intrusions are mainly granodiorite in composition and most are of Late Cretaceous age (Schmidt and others, 1994); one, the Heddleston intrusive complex (Tmp) about 14 mi northeast of Lincoln, is Eocene (Miller and others, 1973).

Granitic intrusions of similar age also are present in the central part of the Big Belt Mountains. One of these, centered near Boulder Baldy, has a range of compositions that form a concentric pattern of rock types (pl. 1) (Gualtieri, 1975; du Bray, 1995). The other major pluton of the Big Belt Mountains crops out in the Mount Edith area. It is compositionally similar to a phase of the Boulder Baldy pluton and to a third pluton (not shown on pl. 1) that lies west of the Forest and yielded radiometric dates of about 64 and 72 Ma (Daniel and Berg, 1981, p. 80; du Bray, 1995).

STRUCTURE

The Forest overlies folds and thrust faults of the Cordilleran thrust belt of western Montana and the area of central Montana delimited by the Wagner Gulch-Volcano Valley fault on the north and faults of the Southwest Montana Transverse Zone on the south. This eastward protrusion of the Cordilleran thrust belt is known as the Helena structural salient. Across the north-south width of the salient, the general structural pattern is one of faults and folds that are convex to the east (fig. B1).

The faults that delimit the north and south boundaries of the salient separate it from the stable craton (foreland) of central and southwestern Montana, respectively. The craton is composed of Archean metamorphic rocks, which are widely exposed in southwestern Montana but in central Montana are largely concealed beneath a thin sequence of Middle Proterozoic and Paleozoic strata, and Mesozoic strata that are predominantly of Cretaceous age. During Late Cretaceous-early Tertiary deformation, plates of strata were thrust eastward within the Helena salient. As the plates moved eastward past the stable, resistent, cratonic areas north and south of the salient, complex patterns of faults and folds formed at the mutual edges of the salient and the cratonic areas (Bregman, 1976; Schmidt, 1977; Woodward, 1981; Schmidt and O'Neill, 1982; Schmidt and others, 1988; Banowsky and others, 1989; and references cited in these publications).

For the sequence of strata within the Helena salient to have moved eastward, it must be underlain by a fault(s) that separates ("decouples") the displaced sequence from rocks that lie still deeper. Such a fault(s) likely would be present deep within the Proterozoic strata, the oldest rocks of the displaced sequence, or at the base of the Proterozoic strata, at their contact with deeply buried Archean metamorphic rocks (Robinson, 1959; Woodward, 1981, 1983; Schmidt and O'Neill, 1982; Schmidt and others, 1990).

General descriptions of structures within the Forest are presented in the following order (fig. B1): Lewis and Clark line, a several-mile-wide belt of deformed rock that trends northwest across the Forest; Sapphire thrust terrane; region north of the St. Marys-Helena Valley fault, which is the northernmost fault of the Lewis and Clark line in the Forest; Big Belt Mountains; and the large area south of the St. Marys-Helena Valley fault (exclusive of Sapphire thrust terrane), including structures in the Elkhorn Mountains. The Forest also lies within a northeast-trending, diffuse zone of structural features known as the Great Falls tectonic zone, which is described briefly. Basins that separate the forest into eastern and western parts are described last.

Lewis and Clark Line

The Forest is transected by northwest-trending, steeply dipping strike-slip faults that are part of the Lewis and Clark line, a several-mile-wide belt of structural weakness that extends for about 250 mi across west-central Montana into Idaho (Billingsley and Locke, 1939) (fig. B1). Reynolds (1979) considered the principal faults of the line to terminate in the vicinity of Townsend Valley, which lies southeast of Helena. Conversely, some workers (for example, Smith, 1965; Lorenz, 1984) considered the Lewis and Clark line to extend more than 100 mi farther east, into south-central Montana. Differing interpretations also exist concerning displacement of rocks along the line, and faults within it. Some believe it is right-lateral, others suggest left-lateral. Faults along this line have been active since the Middle Proterozoic (Hobbs and others, 1965; Harrison and others, 1974; Reynolds, 1979; Wallace and others, 1990).

Two principal faults of the Lewis and Clark line are exposed within the western part of the Forest. Farther east they are concealed beneath unconsolidated rocks of the Helena Valley, then, still farther east, the northern of the two faults is again exposed on the west flank of the Big Belt Mountains. One of these faults, which forms the northern boundary of the Lewis and Clark line in the study area, is the St. Marys-Helena Valley fault. A segment of this fault trends northwest across the western part of the Forest (pl. 1). Within the Forest it is a Tertiary right-slip fault that is downthrown on its south side. The St. Marys-Helena Valley fault is concealed beneath unconsolidated deposits of the Helena Valley directly east of the western part of the Forest, is exposed locally farther east (Bregman, 1976, 1981) (in an area of the Helena Valley for which rocks are not shown on pl. 1), and is exposed again along the western margin of the Big Belt Mountains (Schmidt, 1977, 1986). The easternmost segment of the St. Mary's-Helena Valley fault is a right-slip feature that becomes a dip-slip fault where it turns south along the west side of the Big Belt Mountains (Reynolds, 1979). Most of the right-slip offset along this fault took place between Late Cretaceous and early Eocene time (Wallace and others, 1990, p. 1026), but the fault may have experienced some recent movement because the epicenter of the 1935 Helena earthquake lies near the fault trace (Schmidt, 1986, p. 16).

The St. Mary's-Helena Valley fault truncates the thrust faults in the northern part of the Forest (pl. 1), shown by the maps of Mudge and others (1982) and Whipple and others (1987). It also truncates thrust faults at the northwestern margin of the Big Belt Mountains, as shown by the maps of Schmidt (1977, 1986).

The Bald Butte fault (fig. B1, pl. 1) is the other principal fault of the Lewis and Clark line within the Forest area (Schmidt, 1986). Within the western part of the Forest, Schmidt and others (1994) concluded that sedimentary rocks on the north side of this steeply dipping strike-slip fault were displaced southeastward about 17 mi relative to correlative rocks on the south side. Major movement on the fault is not well confined, but it occurred between about 97 and 47 Ma, during the Late Cretaceous to middle Eocene (Wallace and others, 1990; Schmidt and others, 1994). From the edge of the Forest about 10 mi northwest of Helena, to the Helena Valley southeast of Helena, the Bald Butte fault is concealed by unconsolidated deposits. The southeastern limit of this concealed fault is uncertain; the fault is shown as ending in the Townsend Valley on the geologic map of plate 1. The fault may continue along the south margin of the Helena Valley and join a fault along the northern front of the Elkhorn Mountains (Schmidt, 1986; Smedes, 1966), and then turn southward into the Townsend Valley (Reynolds, 1979).

Sapphire Thrust Terrane

Rocks west of the Boulder batholith and south of the Lewis and Clark line (fig. B1) form a distinctive sequence that here is termed the Sapphire thrust terrane. These rocks were called the Sapphire thrust plate by Wallace and others (1989). The Sapphire thrust terrane is a deformed package of thrust faults and associated folds (Hyndman, 1980; Ruppel and others, 1981; Sears, 1988; Wallace and others, 1989). The thrust faults delimit thrust plates, which were displaced eastward during Late Cretaceous compressional deformation (Ruppel and others, 1981; Wallace and others, 1989). The leading edge of the package of structures is at the western boundary of the Forest, in the vicinity of Elliston (pl. 1), where it consists of a zone of anastamosing, gently westward dipping imbricate thrust slices (Schmidt and others, 1994). The zone turns south near Elliston and is truncated by granitic rocks of the Boulder batholith (Wallace and others, 1989).

Rocks within the thrust slices have been displaced eastward over younger strata, and contain strata originally deposited west of their present location. The strata commonly are distinctly different from time-correlative strata east of the frontal zone of this thrust terrane, as described in the "Rock Unit Descriptions" that accompany the geologic map of Plate 1.

North of the St. Mary's-Helena Valley Fault

In the northern part of the Forest, northeast from the St. Mary's-Helena Valley fault, overthrust terrane is comprised of parts of three thrust plates (pl. 1; fig B1). From south to north, they are the Scapegoat, Hoadley, and

Eldorado plates (Mudge and others, 1974, 1982; Earhart and others, 1977; Whipple and others, 1987). (The eastern edge of each of the three thrust plates is delimited by the fault of the same name; the Scapegoat fault is not labeled on figure B1, however.) Northward from the Forest, the Hoadley fault dies out and displacement is taken up by the Lewis thrust fault (fig. B1). In the Forest, the thrust plates are comprised mainly of Proterozoic rocks, but two small areas of Paleozoic carbonate strata also are present. Only the thrust faults at the base of the Scapegoat and Hoadley plates are exposed in the Forest. The Hoadley thrust is the westernmost fault of the Montana disturbed belt, a zone of closely spaced folds and imbricate thrust faults that extends from the Canadian border southward along the eastern front of the Rocky Mountains into the area north of Helena (Mudge and Earhart, 1980).

Eastward transport on the Hoadley thrust fault has been estimated to be as great as 45 mi (Mudge and Earhart, 1980). Stratigraphic displacement of Proterozoic strata is greatest across the Hoadley thrust: lithofacies of Proterozoic rocks on the Hoadley and Scapegoat plates are from a more basinward facies than equivalent lithofacies on the Eldorado plate (Whipple and others, 1987). The relative displacement between the Hoadley and the Scapegoat plates is uncertain, but the Helena Formation is nearly twice as thick in the Scapegoat plate as in the Hoadley plate, suggesting significant transport on the Scapegoat thrust fault (Mudge and Earhart, 1980; Whipple and others, 1987).

An exploratory borehole for petroleum was drilled about 18 mi due east of Lincoln, less than 1 mi east of the Forest boundary. The borehole went through 12,000 ft of Proterozoic rocks of the thrust plates, through the Eldorado thrust fault at the base of the Eldorado plate, and then penetrated Cretaceous, Jurassic, and Paleozoic strata (Peterson and Sims, 1992). The findings demonstrated that the Proterozoic rocks are allochthonous--they have been thrust into their present position--displaced eastward during the Late Cretaceous to early Tertiary (Whipple and others, 1987).

Big Belt Mountains

The Big Belt Mountains lie in the northwestern part of the Helena structural salient. Here thrust faults and folds change orientations from the northwesterly trends typical of the northern part of the Helena salient to the northerly trends of the Montana disturbed belt and terrane present to the west and northwest. The gently westward dipping Eldorado thrust fault, the major discontunity penetrated by the borehole about 10 mi to the west, comes to the surface in and adjacent to the westernmost part of the Forest in the Big Belt Mountains (pl. 1). Geologic studies of M.W. Reynolds in the Big Belt Mountains suggest that rocks above the Eldorado thrust fault have been displaced eastward a minimum distance of 20 mi (Tysdal and others, 1991, p. 14).

Within the northern part of the Big Belt Mountains, rocks east of (and structurally below) the lower plate of the Eldorado thrust are deformed into complex geologic structures that include more thrust faults and intensely folded strata, thrust faults overriding other thrusts, and refolding of thrust plates. Folds beneath one of the thrust faults can be traced for at least 18 mi southeast from the Gates of the Mountains Wilderness. Progressively older formations are exposed southeastward along the principal fold (Reynolds and Close, 1984). The oldest strata of the Big Belt Mountains, Middle Proterozoic strata, are exposed in the central area of the southern part of the range.

Compressional structures in the Big Belt Mountains are genetically related to associated thrust faults, folds, and plates that formed between the range and the stable craton north of the Helena salient, as shown by Banowsky and others (1989). The Volcano Valley segment of the Wagner Gulch-Volcano Valley fault forms the north edge of the Helena salient (fig. B1). This segment was active during deposition of Middle Proterozoic sediments and active intermittently in the Paleozoic, Mesozoic, and Tertiary as well (Godlewski and Zieg, 1984). The Wagner Gulch-Volcano Valley fault, which is 65 mi long, was an active thrust fault during the Late Cretaceous-early Tertiary deformation. The Volcano Valley fault segment, which displays a left-slip component of movement, formed as the overlying thrust plate moved east-northeastward onto and south of the cratonic area north of the salient. Strata north of the fault are not severely deformed (Woodward, 1981; Banowsky and others, 1989).

South of St. Marys-Helena Valley Fault, exclusive of Sapphire Thrust Terrane

For the western part of the Forest exclusive of the Sapphire terrane, the entire region south of the St. Marys-Helena Valley fault is underlain by thrust faults (pl. 1). Within the Choteau and Butte 1° x 2° quadrangles (fig. A2), the most intense development of thrusts and associated folds took place during the Late Cretaceous. Most Late Cretaceous granitic stocks and the Boulder batholith intruded the already deformed terrane (Ruppel, 1963; Wallace and others, 1986; Elliott and others, 1992; Schmidt and others, 1994). Steep, northeast-trending gravity gradients at the northern, northeastern, and eastern margins of the Boulder batholith are evidence that emplacement of this intrusion was strongly influenced by steeply dipping faults that bordered these sides (Hanna and others, 1994). Some faulting and folding also took place concurrently with extrusion of the Elkhorn Mountains Volcanics (Ruppel, 1963).

In the Elkhorn Mountains, directly east of the Butte 1° x 2° quadrangle, geologic mapping demonstrates again that deformation preceded intrusion of the Boulder batholith. It also shows that deformation preceded deposition of the Late Cretaceous Elkhorn Mountains Volcanics and that tectonism took place concurrently with volcanism and plutonism (Klepper and others, 1957; 1971; Freeman and others, 1958; Knopf, 1963; Smedes, 1966; Robinson and others, 1968; Greenwood and others, 1978, 1990; Hanna and others, 1994). Schmidt and others (1990) recently suggested that, based on data from an unpublished seismic line, a nearly horizontal detachment fault lies at a depth of 10-11 mi beneath the Boulder batholith, and that the batholith was emplaced as the sedimentary rocks were translated eastward several miles on the fault surface.

Great Falls Tectonic Zone

A broad belt of diverse types of geologic structures that trend northeast across central Idaho into western and central Montana has been named the Great Falls tectonic zone (O'Neill and Lopez, 1985). The zone ranges from about 90 to 150 mi wide and, in west-central Montana, includes the entire area of the Forest (fig. B1).

The Great Falls tectonic zone is inferred to constitute a genetic association of structures that reflect some fundamental weakness of the earth's crust. The weakness served as a locus of high-angle faults, shear zones, depositional patterns of Paleozoic and Mesozoic sedimentary rocks, Late Cretaceous to Early Tertiary igneous intrusions and volcanic rocks, linear gravity and aeromagnetic anomalies in basement rocks, and associated mineralization (O'Neill and Lopez, 1985; Foster and Childs, 1993, and references cited therein). Some features of the zone formed as early as the Middle Proterozoic and have been active recurrently throughout Paleozoic, Mesozoic, and Tertiary time (O'Neill and Lopez, 1985).

Extensional Faulting

The two principal basins in the map area of plate 1, the Helena and Townsend Valleys, separate the Forest area of the Big Belt Mountains from the Forest of the Elkhorn Mountains and the region to west and north. These basins are near the end of the Lewis and Clark Line, which ends in west-central Montana in a series of basins and ranges; the faults display dip-slip movment that developed during regional extension (Reynolds, 1979). The basins contain Tertiary sedimentary, volcanic, and volicaniclastic rocks up to several thousand feet thick. The rocks are largely concealed beneath unconsolidated sediments (Pardee, 1950; Mertie and others, 1951; Nelson, 1963; Reynolds, 1979; Schmidt, 1986). The structures that form the mutual boundaries of the basins and the ranges generally are steeply dipping normal faults along which the basins have been downdropped relative to the ranges.

The timing of fault movement coincident with basin development has been ascribed variously to middle Eocene and younger, Oligocene and younger, and Miocene and younger ages (Reynolds, 1979; Fields and others, 1985; Ruppel, 1993; and many references cited in these papers). Based on studies in the Butte 1° x 2° sheet, in and adjacent to the western part of the Forest, Wallace and others (1990) and Schmidt and others (1994, p. 20-22) found that the earliest slip on normal faults took place in the Late Cretaceous, and they suggested that outlines of the main ranges and valleys in the region predate volcanic rocks of middle Eocene age.

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CHAPTER C

GEOPHYSICS OF THE HELENA NATIONAL FOREST

AEROMAGNETIC AND GRAVITY STUDIES

By Anne E. McCafferty

Aeromagnetic and Gravity Data

Aeromagnetic anomaly data are available for the Helena National Forest and surrounding area. Aeromagnetic anomaly maps show changes in the earth's magnetic field that reflect variations in the amounts of magnetic minerals in rocks, typically the mineral magnetite. Most sedimentary rocks have low to negligible amounts of magnetic minerals and therefore contribute little to a study of magnetic anomalies. A magnetic anomaly map primarily reflects abrupt lateral lithologic, hydrothermal, and structural changes related to the magnetic rock properties of volcanic and crystalline rocks that contain enough magnetic minerals to produce anomalies. Aeromagnetic anomaly maps are particularly useful in identifying buried geologic features such as intrusive bodies, which commonly have strong magnetization contrasts with the surrounding rock.

Figure C1 is a magnetic anomaly map of the Forest compiled from ten separate surveys, represented at a constant elevation of 1000 ft (305 m) above the ground. The data are from a larger regional aeromagnetic compilation of Idaho and southwest Montana (McCafferty, 1992). Table C1 shows surveys used in the compilation and the index map (fig. C2) shows area of the original survey.

Gravity anomaly data were compiled for the Helena National forest and surrounding area (fig. C3) from regional compilations covering most of Idaho and southwest Montana (Bankey, 1992) and from a gravity study of the Choteau 1° x 2° quadrangle (Kulik, 1983). In general, gravity anomalies are primarily a response to lateral density variations in rocks and provide useful information regarding the distribution and configuration of geologic features that have strong density contrasts. Because different rock types are often characterized by contrasting densities, gravity maps are useful in extending the geologic mapping into areas covered by surficial deposits and in determining the subsurface position and attitude of such density boundaries.

The gravity station distribution (see Bankey, 1992 and Kulik, 1983 for gravity station locations) and flight line spacing of the magnetic anomaly data (figure C2) does not allow a detailed interpretation of the structural and lithologic complexities of the Forest and adjacent area. However, the anomaly maps point to large geologic units that have strong magnetization or density contrasts. The aeromagnetic data are especially useful in determining the lateral extent of buried and partially exposed plutons, many of which have spatially and genetically associated mineralization.

Previous Aeromagnetic and Gravity Studies

Aeromagnetic and gravity data for the northern and western parts of the

Forest have been previously studied as parts of U.S. Aeromagnetic data over the valleys east of the Big Belt Mountains were studied in the 1960's to delineate igneous rock masses and determine the configuration of the bedrock surface beneath the Cenozoic sedimentary rocks in the main valleys (Kinoshita and others, 1964, 1965; Davis and others, 1963).

Magnetization and Densities of Rocks

The physical properties that relate aeromagnetic and gravity anomalies to their sources are magnetization and density, respectively. Rocks of the Forest area exhibit a wide range of physical properties, reflecting the diverse geology. Magnetization values measured from rock samples collected within and around the study area (Hanna and others, 1994, and for this study, samples collected by E. du Bray and Steve Ludington) range over five orders of magnitude. There are too few measurements to permit average estimates of magnetization for different rocks units, but some qualitative generalizations can be made. The most magnetic rock units are, as expected, the more mafic igneous units. Induced magnetization is the main contributor to the overall magnetic anomaly patterns in the Forest area; remnant magnetization contributes only a minor amount to the overall total magnetization. Exceptions to this are seven rock units within the Elkhorn Mountain Volcanics and five units within the Lowland Creek Volcanics in which remnant magnetization is dominant. However, only two of these units have sufficient intensity to cause anomalies (Hanna and others, 1994).

Hanna and others (1994) summarized investigations from the past 30 years of measured densities of various rock types within the Butte 1^0 x 2^0 quadrangle and they updated this information with their own study of additional rock samples. Although only about one-third of the Helena National Forest lies within the Butte 1^0 x 2^0 quadrangle, the same rock types occur within the Forest adjacent to the quadrangle. Densities of the diverse suite of rocks in the Butte quadrangle are assumed to be characteristic of the surrounding region, including the remainder of the Forest; these densities are summarized in table C2.

Terrace Maps

"Terracing" is a data processing technique (Cordell and McCafferty, 1989) that converts potential field data into maps of physical properties. When applied to gravity data, the technique results in a "terrace-density" map showing large, sharply bounded domains of similar density. When applied to magnetic data, the result is a "terrace-magnetization" map. For this study, the aeromagnetic and gravity data were converted to terrace maps in order to (1) map physical property domains corresponding to both known and unknown geologic structures; and (2) objectively locate positions of boundaries between geologic units with differing physical properties. The terrace method assumes the physical property domain edges are steeply dipping to nearly vertical. If the boundaries are not steeply dipping, location of the domain edge will be offset slightly down dip from the contact (Grauch and Cordell, 1987). Terrace-density and terrace-magnetization maps were calculated from the aeromagnetic and gravity data of the Forest, leading directly to inferred physical-property (density and magnetization) maps. The terrace-magnetization was used in the resource assessment

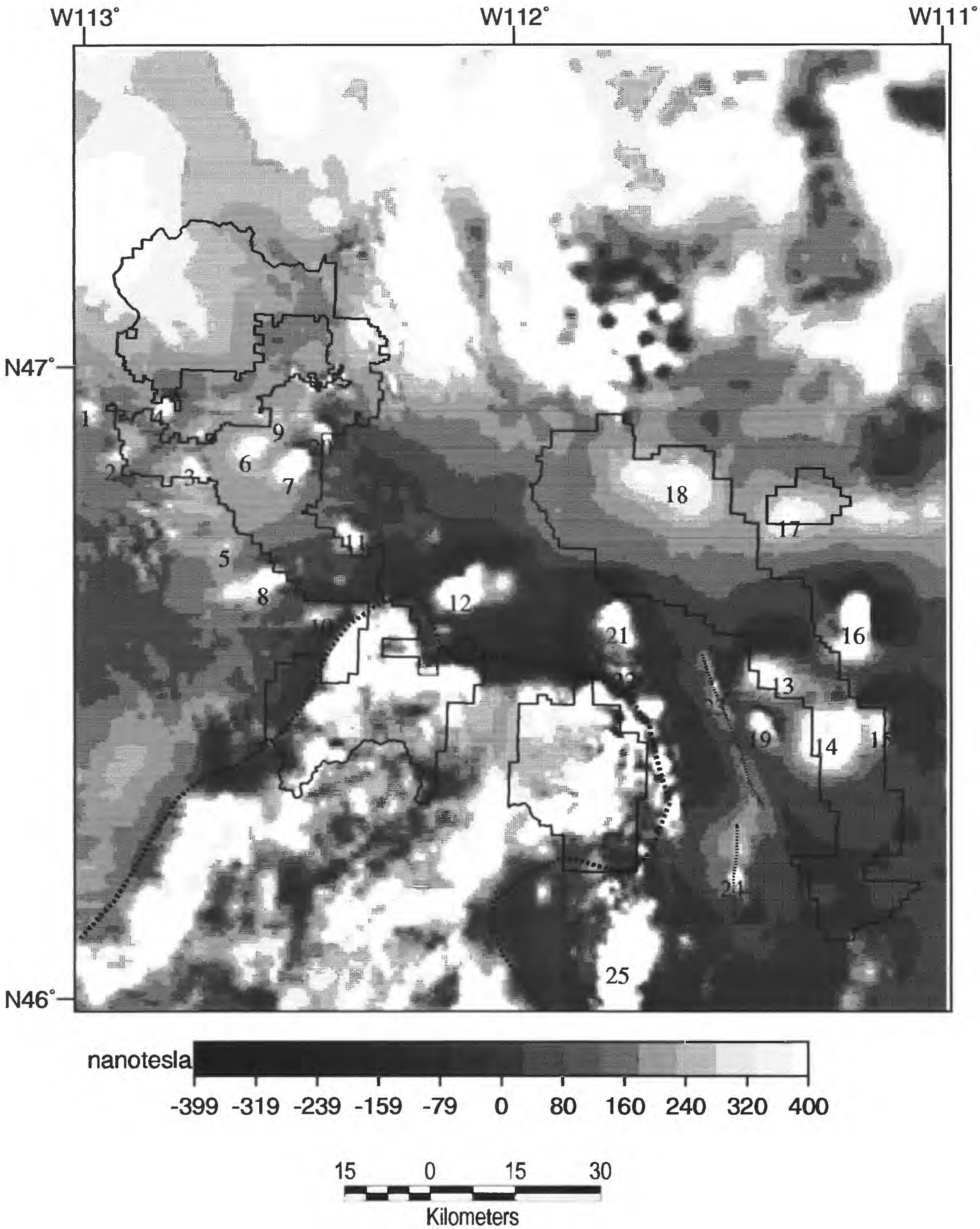

Figure C1. Merged aeromagnetic anomaly map of the Helena National Forest and vicinity. Map is a synthesis of surveys described in Table C1 and index map (fig. C2). Surveys have been corrected for the earth's regional geomagnetic reference field and represented at a constant datum of 1,000 ft (305 m) above the ground surface. Numbers refer to locations of exposed and buried igneous features described in text. Heavy dashed line shows extent of Boulder batholith.

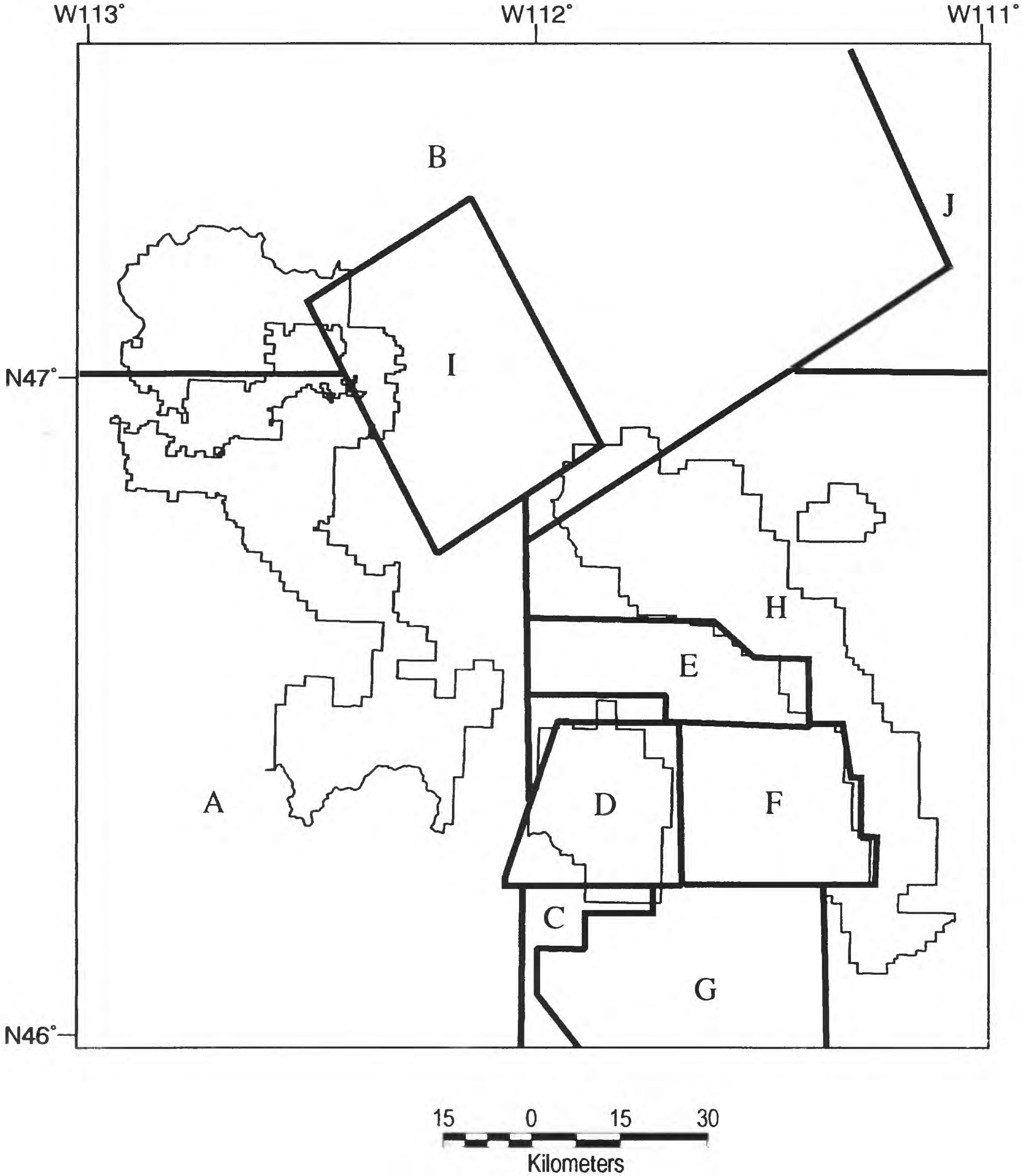

Figure C2. Index map of aeromagnetic surveys used in the compilation of data for the Helena National Forest. Survey specifications are summarized in table C1.

Table C1. Flight specifications for aeromagnetic surveys used in the compilation of data for this study.

Survey[1]	Line direction	Flight altitude[2] ft (m)	Line spacing mi (km)	Data type[3]	Reference cited
A	E-W	9,000 (2,740) B	1 (1.6)	D	USGS (1984)
B	NE-SW	9,000 (2,740) B	2 (3.2)	A	Kleinkopf and Mudge (1972)
C	E-W	10,500 (3200) B	2 (3.2)	A	Johnson and others (1965)
D	E-W	9,000 (2,740) B	.5 (0.8)	D	USGS (1978)
E	E-W	500 (150) AG	.5 (0.8)	A	Kinoshita and others (1964)
F	E-W	500 (150) AG	.5 (0.8)	A	Davis and others (1963)
G	E-W	500 (150) AG	.5 (0.8)	A	Kinoshita and others (1965)
H	E-W	400 (120) AG	3 (4.8)	D	Geodata International (1979)
I	NE-SW	7,000 (2,134) B	.75 (1.2)	D	USGS (1980)
J	E-W	400 (120) AG	3 (4.8)	D	Geodata International (1979)

[1]Surveys refer to figure C2.

[2]Flight-altitude: AG; survey originally flown "above ground" in a draped mode above the topographic surface. B; survey flown at a constant barometric elevation.

[3]Data type: A, data are in "analog" form only. Subsequently, maps were digitized from published versions; D, data exist as original "digital" flight-line data.

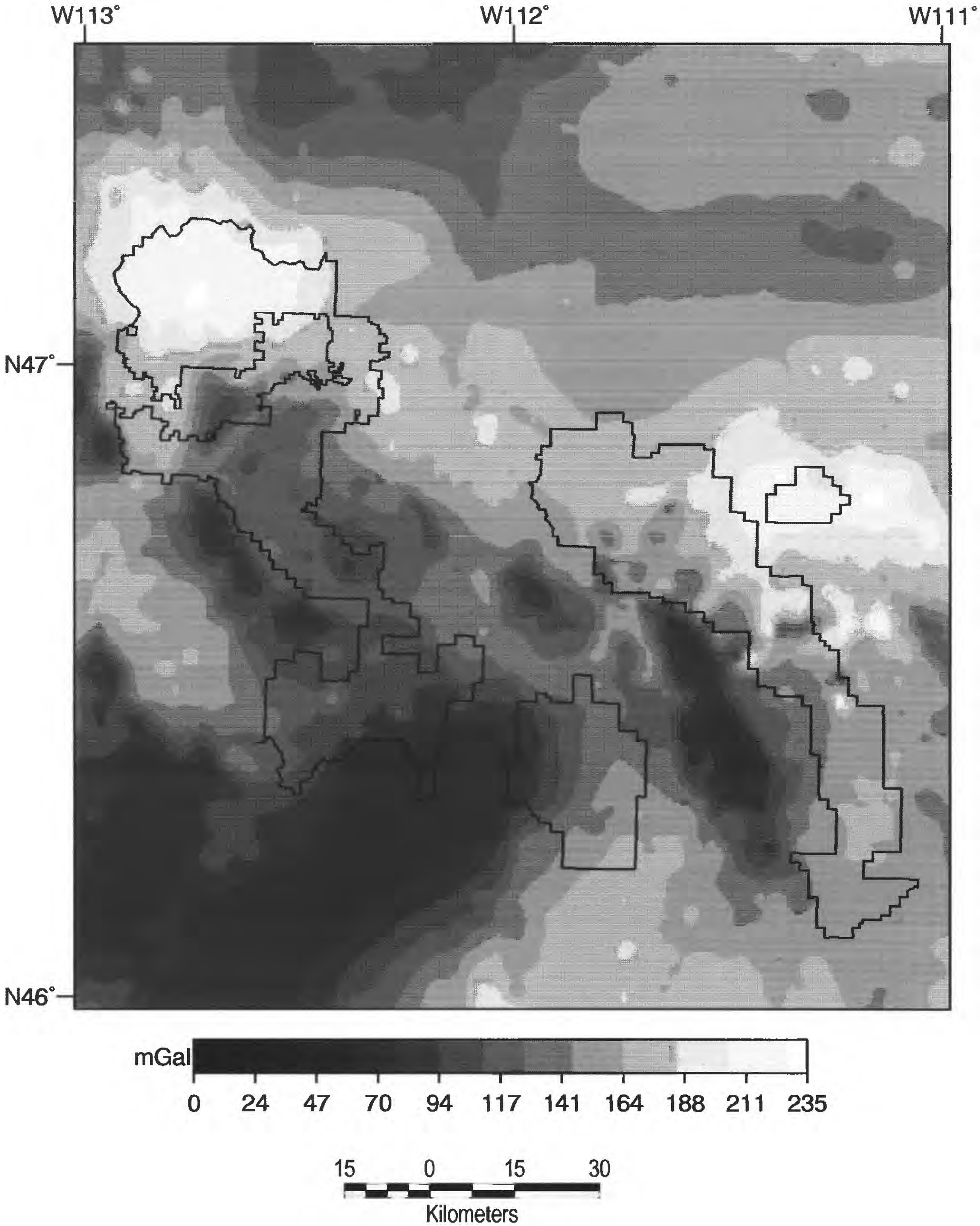

Figure C3. Bouguer gravity anomaly map of the Helena National Forest and vicinity. Data are from Bankey (1992) and Kulik (1983). Approximate forest boundary shown in black.

Table C2. Densities (g/cm³) from samples within and surrounding the study area (Hanna and others, 1994)

Rock type	Density (g/cm³)
Sedimentary and Metasedimentary Rocks	
shale	2.56
quartzite, sandstone, siltstone, siltite	2.62
hornfels (slightly metamorphosed rocks)	2.64
limestone (and slightly metamorphosed marble)	2.68
argillite	2.70
marble	2.80
dolomite	2.80
hornfels and skarn (intensely metamorphosed rocks)	2.97
phosphatic rock	3.40
Average	**2.70**
Basin fill (unconsolidated sediments)	**2.25-2.30**
Volcanic Rocks	
Tertiary rhyolite and latite	2.40
Cretaceous and Tertiary rhyodacite	2.65
Cretaceous andesite	2.80
Cretaceous non-vesicular basalt	2.90
Average for Cretaceous volcanic rocks	**2.65**
Average for Early Tertiary volcanic rocks	**2.40**
Plutonic Rocks	
syenite	2.44
alaskite, granite, quartz monzonite	2.60
quartz monzonite	2.65
granodiorite	2.70
mafic granodiorite, monzodiorite, and lamprophyre	2.78
monzogabbro, sulfide-enriched quartz monzonite	2.85
gabbro	3.10
pyroxenite	3.44
Average	**2.67**

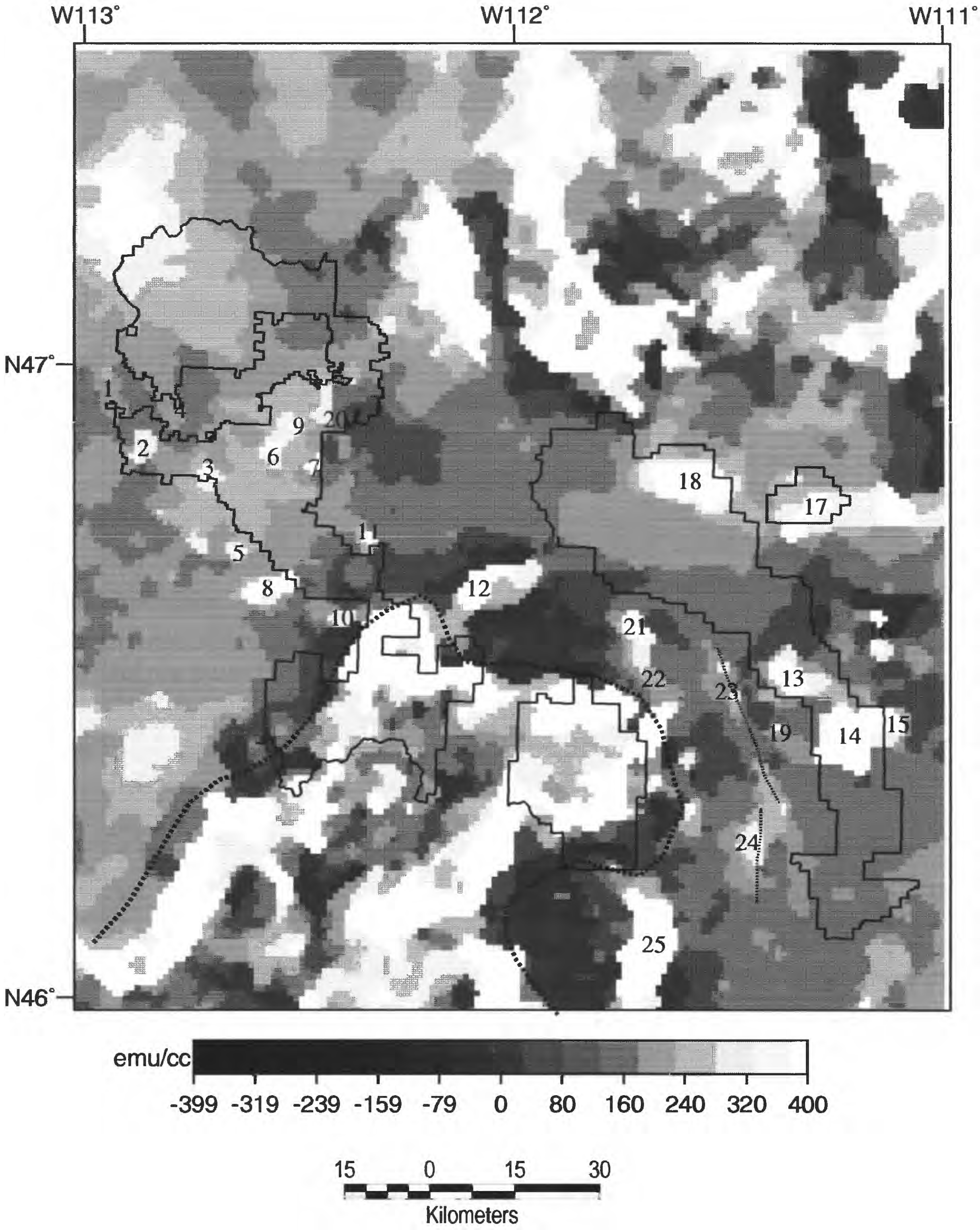

Figure C4. Terrace-magnetization map calculated from the aeromagnetic data (fig. C1). The map emphasizes large, sharply bounded domains of similar magnetization. The edges of the domains are inferred to mark steeply dipping lithologic and structural boundaries. Units are relative magnetization in electomagnetic units per centimeter-cubed (emu/cc). Data from this map were used as input to the geochemical-geophysical Pb and Au models (Chapter D, this report), to map the lateral extent of buried and partially exposed plutons to refine favorable and permissive tracts for selected deposit models. Heavy dashed line outlines the Boulder batholith. Numbers correspond to features described in table C3.

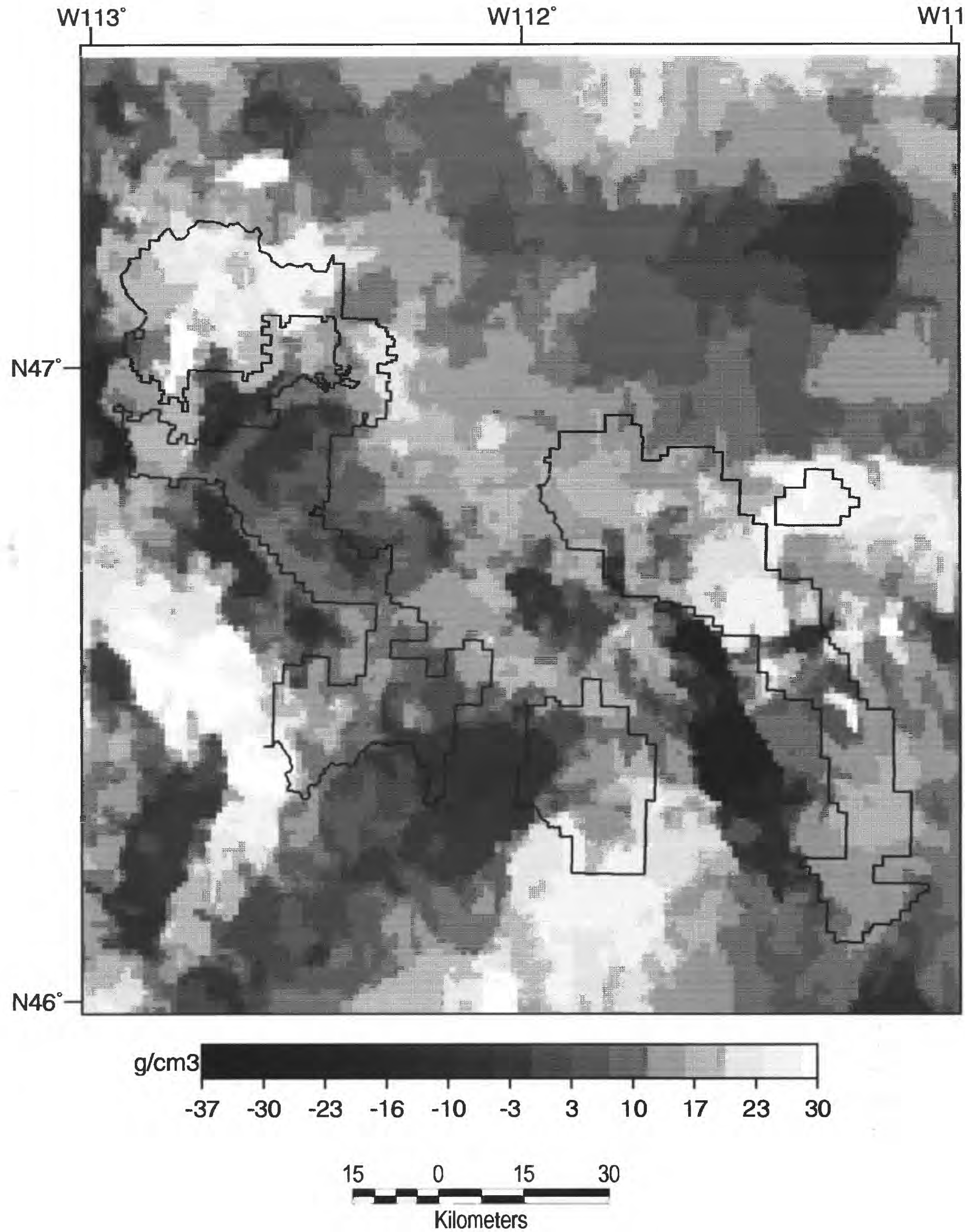

Figure C5. Terrace-density map of residual Bouguer gravity. Map shows areas of constant density separated by hard, steeply dipping edges. The edges of the density domains are inferred to represent geologic boundaries such as faults, lithologic contacts, and igneous intrusive bodies. Values within domains are relative densities in grams per centimeter-cubed. Data from this map were used in the geochemical-geophysical Pb and Au models described by Alminas (Chaper D, this report).

Table C3. Summary of the aeromagnetic anomalies for the Forest area. Numbered anomalies are indicated on figures C1 and C4. Refer to Plate 1 for geologic mapping and rock descriptions.

Anomaly	Source or location of aeromagnetic anomaly	Composition of anomaly source
1	Mineral Hill stock	hornblende-biotite granodiorite
2	Ogden Mountain stock	hornblende-biotite granodiorite
3	Dalton Mountain stock	granodiorite
4	mostly buried	granodiorite
5	buried under Avon valley	?
6	Silver Bell stock	granodiorite
7	Granite Butte stock	hornblende-clinopyroxene-biotite granodiorite
8	Blackfoot City stock	hornblende-biotite granite/granodiorite
9	buried under Lincoln volcanic field	?
10	mostly buried	granodiorite
11	Marysville stock	quartz monzonite/mafic granodiorite
12	Scratch Gravel Hills stock	augite-hornblende monzonite
13	Boulder Baldy intrusive suite	granodiorite-monzodiorite-monzonite
14	Mount Edith stock	monzodiorite
15	buried source along eastern flank of Big Belt Mts	high magnetization, likely a different age from 13 and 14, or structurally rotated
16	buried source east of Big Belt Mountains	high magnetization, likely related to anomaly 15
17	buried source under Mississippian sedimentary rocks	?
18	buried source under Tertiary Bozeman Group sedimentary rocks	?
19	buried source under Middle Proterozoic Belt sedimentary rocks	?
20	buried source under Middle Proterozoic sedimentary rocks and Lincoln Volcanic field rocks	?
21	Intrusives in Spokane Hills	monzonite
22	Antelope Creek stock	monzonitic
23	partly exposed intrusive bodies	monzonitic and lamprophyre
24	buried under valley-fill sedimentary rocks	coincides with axis of Deep Creek anticline, dike?
25	partly exposed intrusive rocks related to Elkhorn Mountain Volcanics	monzodiorite and granodiorite

process to refine the lateral extent of known igneous intrusions and to locate inferred plutons in evaluating certain deposit types. Both terrace data sets were statistically integrated with geochemical data to produce the geochemical-geophysical Pb and Au models described by Alminas (Chapter D of this report).

Before terracing, the aeromagnetic anomaly data were transformed to a form equivalent to a vertically incident magnetic field, often referred to as "having been reduced to the magnetic north pole." The reduction-to-pole transformation corrects for anomaly distortion caused at the geomagnetic latitude of the Forest and, assuming induced magnetization, shifts and centers anomalies over their source. Figure C4 shows a terrace-magnetization map of the reduced-to-pole magnetic field. Details on the steps involved to calculate terrace data from potential field grids are given in Cordell and McCafferty (1989).

A third-order regional field was analytically subtracted from the grid of Bouguer gravity data (fig. C3) before terracing to enhance shorter wavelength anomalies that map shallow crustal density sources. The resulting terrace-density map of the residual gravity field is shown in figure C5.

No attempt was made to calculate values of magnetization and density within domain boundaries. In order to obtain physical property values, one needs to make assumptions regarding the depth to and thickness of the anomaly sources. Such assumptions were not made for the Forest because the depth and thickness of density and magnetization sources are usually not known, due to the complex geology and lack of detailed drill hole information. Consequently, the gray-scale bar on both the terrace-magnetization map (fig. C4) and terrace-density map (fig. C5) label the physical properties as "relative".

Data from both terrace maps were statistically integrated with geochemical data to determine associations between intrusive bodies, defined from the terrace data as areas of relatively high magnetization and low density, and high concentrations of select geochemical elements. The geochemical-geophysical models are described in Alminas (Chapter D of this report) and shown on plate 4 (maps I, J).

Sources of Aeromagnetic Anomalies

Many of the aeromagnetic anomalies in and surrounding the Forest can be directly correlated to known geologic features. Isolated, large amplitude aeromagnetic anomaly highs occur over many known igneous plutons . Additional plutons are inferred from the aeromagnetic data based on similarity in anomaly patterns and proximity to the exposed plutons. Table C3 summarizes aeromagnetic anomalies associated with known and inferred buried plutons in and around the Forest. Based on the lateral extent of the magnetization domains (fig. C4) in comparison with the mapped, exposed rocks, the subsurface horizontal cross section areas of many of the plutons (for example, the Marysville, Silver Belle, Dalton Mountain, Mineral Hill, Blackfoot City, and Scratch Gravel Hills plutons) are inferred to be twice their mapped surface exposures. The magnetic anomalies in the northwestern part of the study area are primarily the result of the magnetization contrast of the Cretaceous or Tertiary plutons in contact with the nonmagnetic metasediments of the Middle Proterozoic Belt Supergroup. Induced magnetization (normal polarization) is the primary contributor to the anomalies.

The aeromagnetic and gravity maps covering the southwest and Elkhorn Mountain parts of the Forest area (figs. C1 and C4) are dominated by physical properties of the northern part of the Boulder batholith. On a regional scale, the northeast trending horseshoe-shaped aeromagnetic high extends 25 mi from the center of the study area southward into the adjacent Dillon 1° x 2° quadrangle (McCafferty, 1992; Hanna and others, 1993). The Bouguer gravity map (fig. C3) shows a coincident large amplitude gravity low that extends to the Idaho-Montana border (Bankey, 1992).

On a local scale, the anomalies form a complicated pattern of highs and lows that reflect magnetic properties of the Elkhorn Mountains Volcanics, Boulder batholith rocks, and the Lowland Creek Volcanics. Descriptions of individual anomalies for the northern batholith as outlined in figures C1 and C3 are provided in Hanna and others (1994) for the Butte 1° x 2° quadrangle and by Hanna (1990) for the Elkhorn Mountains.

Sources for magnetic and gravity anomalies in the Big Belt Mountains

Table C3 includes anomalies and their known or inferred sources for the Big Belt Mountains region of the Forest. Two prominent, large amplitude magnetic anomaly highs occur in the central part of the Big Belt Mountains (anomalies 13 and 14, fig. C1). The northern anomaly corresponds to the Boulder Baldy pluton and the southern anomaly is located over the Mount Edith stock (plate 1; du Bray, 1995). The terrace-magnetization map (fig. C4) shows that the horizontal mapped exposure of the Boulder Baldy pluton is equivalent in diameter to that of the magnetization domain (13 on fig. C4). However, the Mount Edith stock is laterally more extensive in the subsurface (14 on fig. C4) than in its mapped outcrop. The terrace magnetization domain associated with Mount Edith pluton exceeds the mapped diameter by 2.5 mi. Additionally, from the terrace-magnetization map, it appears that the smaller satellite stock 1 mi east of the Boulder Baldy pluton is connected at depth to the Mount Edith pluton (note the north projection of the Mount Edith pluton magnetization domain 14 on fig. C4).

A 2.5-dimensional model was constructed across each of the central Big Belt Mountains plutons to estimate their thickness and subsurface configuration. Magnetizations of samples were acquired by laboratory measurements (I. Judy, 1995, written commun.) from samples collected by E. du Bray from both plutons and average values were used for each model (Mount Edith: 0.002 emu/cm^3; Boulder Baldy: 0.0025emu/cm^3). The magnetic property measurements show that the remanent magnetization component of the total magnetization is negligible.

Results of the models suggest both plutons are thick, extending to depths greater than 4 mi below sea level. This suggests the plutons are rooted and were emplaced after thrusting ceased. The small satellite pluton to the east of Boulder Baldy is a relatively thin body, modeled with a thickness of less than 1.2 mi and using an equivalent magnetization as the Mount Edith pluton. Results of the geophysical modeling support du Bray's (1995) geologic observations that both plutons are likely related to a single intrusive event.

Magnetic sources 15 and 16, located along the east flank of the Big Belt Mountains (figs. C1 and C4), are buried and appear to have radically different magnetic properties from the Big Belt plutons as evidenced by the distinct, large amplitude, dipole low associated with each anomaly. This observation suggests the following possibilities: (1) the east flank sources have a high component of remanent magnetization implying they were emplaced when the earth's magnetic field had a different polarity from the time when the Big Belt plutons were emplaced; or (2) the sources are similar in age to the Big Belt plutons but were structurally rotated after emplacement. Physical property information from a well located drill hole is needed to confirm either possibility presented.

GAMMA-RAY RADIOACTIVITY

By James A. Pitkin

Introduction

Gamma-ray radioactivity data for the Helena National Forest consists of aerial spectrometer surveys flown during the U.S. Department of Energy National Uranium Resource Evaluation (NURE) program (ca 1974-1983). NURE surveys that include parts of the Forest are those conducted for the Butte (Texas Instruments, Inc., 1979), Choteau (Texas Instruments, Inc., 1979), and White Sulphur Springs (High Life Helicopters and Geodata International, Inc., 1979) 1° x 2° quadrangles. Aerial gamma-ray data (aeroradioactivity) from these surveys were used to prepare an aeroradioactivity database for the Forest. The database also includes the NURE survey for the Great Falls 1° x 2° quadrangle (Texas Instruments, Inc., 1979), which was used to provide a rectangular database. Other compilations of NURE aerial gamma-ray data that include the Forest are those of Duval and others (1995) and Phillips and others (1993).

Aeroradioactivity is the measurement of terrestrial radioactivity with instruments operated in low-flying aircraft. The source of the radioactivity measured is the near-surface rock and soil (to 12-in depth) where the primary gamma-ray emitting isotopes are from the natural radioelements potassium (K), uranium (U), and thorium (Th). NURE aerial systems were quantitatively calibrated at sites of known radioelement concentrations, permitting quantitative reporting of survey data in percent for K and parts per million (ppm) for U and Th (assuming equilibrium in the respective decay series). The near-surface distribution of K, U, and Th generally corresponds to bedrock lithology and modifications due to weathering, erosion, rock transport, ground water movement, and hydrothermal alteration.

Aerial flight-line spacing for the Forest database is 3-mi for east-west lines except for the area of the Choteau quadrangle, which is 6-mi for east-west lines; all north-south flight lines are 12 mi apart. A minimum-curvature algorithm (Webring, 1981) was applied to the flight line data, producing K, U, and Th 1.8 mi square grids, which comprise the Forest aeroradioactivity database. The grids were used to prepare K, U, and Th color and black-and-white maps at 1:250,000-scale for use in the assessment and grey-scale maps at 1:1,000,000-scale for inclusion in this report. Grids of the ratios U:Th and K:Th were also prepared and maps were made at several scales.

Discussion

Aeroradioactivity grey-scale contour of K, U, Th, U:Th and K:Th are shown (respectively) in figures C6, C7, C8, C9, and C10. Bodies of water, such as Canyon Ferry Lake, have no measureable aeroradioactivity. The grids used to make figures C6-10 were not masked to delete data for lakes and reservoirs, however, and the discernable grey-scale values for the water should be ignored.

The near-surface distribution patterns of K, U, and Th displayed by the aeroradioactivity maps are often similar, but discontinuities in the patterns can reflect significant mineralogic discontinuities, such as the contrasting properties of felsic and mafic igneous rocks. The distribution pattern for Th generally is more consistent than that for K or U, likely because Th is the least mobile of these elements. For this reason, Th is used as the stable denominator in U:Th and K:Th ratios, thereby highlighting subtle variations in U and K distribution. Of particular interest are variations from the 0.25 ratio on figure C9. While the crustal ratio of U:Th most commonly ranges from 1:2 to 1:8 (Hoover and others, 1992, fig. 25, p. 68-69), a value of 1:4, or 0.25 in the case of figure C9, has been chosen arbitrarily for use in the following interpretive discussion. Values greater than 0.25 on figure C9 may indicate relative enrichment of U, values less than 0.25 may indicate relative depletion of U.

Interpretation

Natural radioelement distribution for the area that includes the Forest has a diverse pattern that reflects the complex geology of the area, as demonstrated in the grey-scale contour maps (figs C6-10). These maps show few linear features of more than about 30-mi length because of the paucity of geologic features with lithologic and thus radioelement continuity. Generally higher radioelemment concentrations are west of the east side of the Boulder batholith and its extension to the north-northeast; generally lower concentrations are to the east. Faults locally have radioelement expression as linear features 5- to 15-mi long, and lithologies with distinct radioelement character occur throughout the area.

The Boulder batholith (fig. B1) underlies much of the Butte-Boulder-Helena region that is depicted on figures C6-10. The west side of the south-central part of the Forest (i.e., west half of the Elkhorn Mountains) displays prominent, higher radioelement concentrations (2 to 2.6 percent K, 2.6 to 3.8 ppm U, 9 to 14 ppm Th) that correspond to the felsic rocks of the Butte quartz monzonite; this rock type comprises most of the batholith. The U:Th ratio ranges between .22 and .28, which does not indicate an excess of U relative to Th (crustal ratio ~.25). The batholith was determined favorable for U vein deposits by the NURE program study of the Butte 1° x 2° quadrangle (Sartoris and others, 1982, p. 15-18). The remainder of this part of the Forest has relatively lower radioelement concentrations (1 to 1.6 percent K, 1.4 to 2 ppm U, 4 to 6 ppm Th) that are associated with less felsic, andesitic Elkhorn Mountain Volcanics and, at the southeast side of the Elkhorn Mountains, Paleozoic and Mesozoic sedimentary rocks, including the Permain Phosphoria Formation (pl. 1). The uraniferous character of the Phosphoria is not apparent in the aeroradioactivity data because the formation is thin and discontinuous (see Chapter H for discussion of Phosphoria Formation). The Elkhorn Mountain Volcanics have prominent expression in the U:Th (>.31) and K:Th (>.16) ratios, indicating relative enhancement of U and K compared to Th.

The pattern of higher radioelement concentrations associated with felsic igneous rocks continues to the west to include an appreciable area in the southwest part of the Forest. Values of 1.8 to 2.6 percent K, 2.6 to 3.8 ppm U, and 11 to 14 ppm Th relate to more rocks of the Cretaceous Boulder batholith and to Tertiary plutonic rocks. The U:Th ratio is relatively constant around .25 in this area, indicating a radioelement lithology different from the Th-dominant feature at the west side of the south-central part of the Forest. The K:Th ratio is relatively uniform, continuing the pattern from the south-central part. Elkhorn Mountain Volcanics in this part of the Forest differ from those in the south-central part, as K is higher at 2 to 2.6 percent, and U and Th are moderate at 2 to 2.8 ppm and 7 to 10 ppm, respectively. The volcanic rocks have a distinctive K:Th pattern of .26 to .36 that reflects their more felsic character; the U:Th ratio has no signficant character.

A pattern of somewhat lower aeroradioactivity values (1.4 to 1.8 percent K, 1.4 to 2 ppm U, 5 to 8 ppm Th) occurs at the west side of the southwest part of the Forest, extending to the north across Avon Valley (directly west of the Forest), between 46° 32′ and 46° 50 N.lat., and into the west-central part of the Forest. Source rocks for this feature are Paleozoic and Mesozoic sedimentary strata of the eastern part of the Sapphire thrust terrane and Cretaceous and Tertiary mafic volcanic rocks due southwest of the southwest part of the Forest. The Phosphoria Formation of the sedimentary sequence of rocks may be contributing to this aeroradioactivity feature; however its surface expression is limited.

A circular aeroradioactivity high (2 to 2.4 percent K, 2.6 to 3.8 ppm U, 9 to 13 ppm Th) occurs directly west of the previously discussed sedimentary rock feature in the Sapphire terrane. The high is outside of the Forest centered at about 112° 35′ W. long, and 46° 35′ N.lat. It is about 10-mi in diameter, has a central area of lower values, and is best expressed in U and Th, especially at its southeast side. Source rocks for the aeroradioactivity feature are not obvious. The feature lies outside the area of the geology shown on the geologic map (pl. 1). Tertiary rhyolites of the Helena volcanic field occur in the area, as do other volcanic rocks of less felsic composition (Wallace and others, 1986) that probably contain lesser radioelement concentrations. Tertiary sedimentary rocks and Quaternary sediments are also present.

Continuing to the north, aeroradioactivity data for the west-central part of the Forest, south of Lincoln, is characterized by moderate to low values (1.2 to 2 percent K, 2 to 2.8 ppm U, 5 to 8 ppm Th, somewhat higher U:Th) for mostly Proterozoic metasedimentary rocks. Within the Forest, east and southeast of Lincoln, an area of relatively higher values (1.6 to 2.2 percent K, 2.6 to 3.2 ppm U, 10 to 13 ppm Th) corresponds to Cretaceous granite and Tertiary rhyolite of the Lincoln volcanic field, which have a Th-distinctive lithology as indicated by relatively lower U:Th and K:Th ratios. At Lincoln and in the surrounding valley eastward to about 112° 30′ W. long., outside the Forest, a three-element relative high (1.8 to 2.2 percent K, 2.6 to 3.2 ppm U, 9 to 11 Th) suggests source rock of felsic or similar composition. Lack of expression in either ratio indicates a non-Th distinctive lithology for the Quaternary sediments in the valley as compared to the igneous rocks east and southeast of Lincoln.

Aeroradioactivity data for the northwest part of the Forest include a northwest-trending linear feature, most apparent in K and U, which relates to the Hoadley thrust fault that bisects this part of the Forest (pl. 1). Rocks northeast of the fault have somewhat higher values of K (1.8 to 2.4 percent), U (2.4 to 3 ppm), and Th (7 to 10 ppm), rocks on the southwest side have somewhat lower values (1.2 to 2 percent K, 1.8 to 2.4 ppm U, and 6 to 9 ppm Th), and the ratios are not distinct for either side. Although Proterozoic Mount Shields Formation, Spokane Formation and associated metasedimentary rocks crop out on both sides of the fault, the strata of each side are from different depositional facies (see Chapter B of this report). The radioelement data reflect this by showing slightly enhanced K and U lithologies for the northeast side.

Noteworthy aeroradioactivity features in the north-central part of the study area, outside the Forest, include a prominent K (2 to 2.4 percent) and K:Th (>.30) feature east and northeast of Craig that reflects Cretaceous Adel Mountain Volcanics (not shown or described on pl. 1). These probable intermediate (andesitic) rocks (Schmidt, 1978) have slight expression in U and none in Th. South of Craig and north of Helena is a large area of relatively higher aeroradioactivity (2 to 2.4 percent K, 2.8 to 3.2 ppm U, 9 to 11 ppm Th) whose source rocks are primarily shale of the Proterozoic Spokane Formation. East of Helena, a strong aeroradioactivity feature (2.2 percent K, 2.6 to 3.4 ppm U, 10 to 13 ppm Th) relates to tuffaceous sedimentary rocks of the Tertiary Bozeman Group in the Helena basin, considered favorable for the occurrence of "..Wyoming roll-type uranium deposits.." (Dodd and Wopat, 1982, p. 27). The elevated K and Th relate to felsic volcanic rocks. The Townsend basin to the southeast (west of the Big Belt Mountains and east of about 110° 40′ W.long.) contains similar rocks, and is considered favorable for uranium deposits (Dodd and Wopat, 1982, p. 28). The basin has an aeroradioactivity expression only as a local U-high (3 ppm) north of Winston (not shown figs. C6-10) and as a prominent U:Th (>.37) linear feature along the west side of Canyon Ferry Lake.

The western part of the Big Belt Mountains, in the eastern region of the Forest, includes a prominent northwest-trending linear area of relatively high radioelement concentrations (1.6 to 2.2 percent K, 1.8 to 2.2 ppm U, 8 to 10 ppm Th) that is most distinct in K. The linear K anomaly reflects potassium feldspar zones, which are Au-bearing in the York mining district, in siltite and argillite of the lower part of the Proterozoic Greyson Formation. The slightly elevated U and Th possibly correspond to black siltite rather than the K-rich rocks. The feature extends northwest and southeast from York (not shown on figs. C6-10) for about 20 mi as it follows the outcrop of the Greyson, and turns to a southerly trend outside of the Forest due east from Helena. Here the aeroradioactivity pattern associated with the Greyson becomes obscure, especially in U and Th, where Tertiary Bozeman Group rocks of the Townsend Valley have similar values.

An aeroradioactivity feature also occurs within the southern area of the eastern region of the Forest, northeast of Cedar Hill, as indicated by locally elevated values of 1.6 to 2 percent K, 1.6 to 2 ppm U, and 8 to 9 ppm Th; this feature reflects Greyson and upper Newland Formation strata. This feature is apparent in the aeroradioactivity data because most Proterzoic metasedimentary rocks of the Big Belt Mountains have low radioelement concentrations (0.8 to 1.2 percent K, 0.8 to 1.2 ppm U, 3 to 5 ppm Th). The feature has no expression in the ratios; however, there are a number of prominent U:Th features (>.39) around the northern border, as well as at the south end of the Forest. These features are associated mainly with Paleozoic and Mesozoic sedimentary rocks at the northwest area of the Forest, with Paleozoic sedimentary rocks along the northern area where Tertiary volcanic rocks are ratio lows (Th-distinctive), and with Paleozoic and Mesozoic sedimentary rocks at the south end.

Near the east-central side of the Big Belt Mountains region of the Forest, southwest and south of Fort Logan, a distinctive aeroradioactivity relative high (1.8 to 2.4 percent K, 2.4 to 3.2 ppm U, 9 to 13 ppm Th) has an arcuate shape open to the northwest. The feature occurs at the northeast side of the Boulder Baldy pluton and extends in an arcuate manner to Fort Logan, mostly in Newland Formation. It is most clearly expressed in U and Th, and the area of highest K occurs between two areas of higher U and Th at each end of the feature.

The Boulder Baldy and Mount Edith plutons (plate 1) have aeroradioactivity expressions that reflect their intermediate composition. They have no expression in K, have distinctly low U (each 1.2 to 1.6 ppm) and Th (4 to 5 ppm and 5 to 6 ppm, respectively). They have an expression in K:Th only because of the generally low K background levels of the intruded Proterozoic metasedimentary rocks, which include calcareous to dolomitic siltite and argillite.

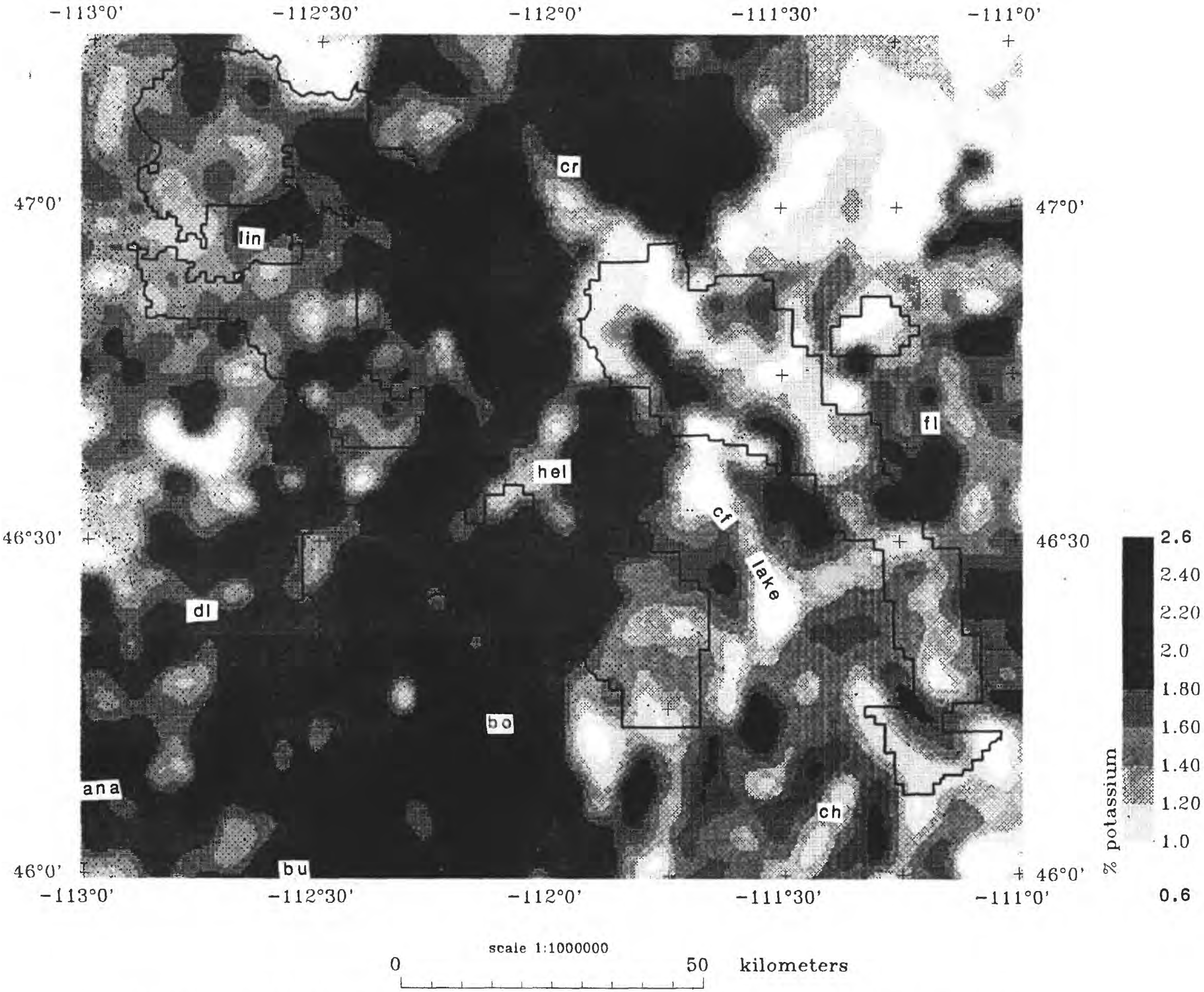

Figure C6. Potassium aeroradioactivity map of the Helena National Forest, Montana. Contour interval 0.2 and 0.4 percent K. Geographic locations: ana = Anaconda, bo = Boulder, bu = Butte, cf lake = Canyon Ferry Lake, ch = Cedar Hill, cr = Craig, dl = Deer Lodge, fl = Fort Logan, hel = Helena, lin = Lincoln. (Ignore grey-scale values for lakes and reservoirs.)

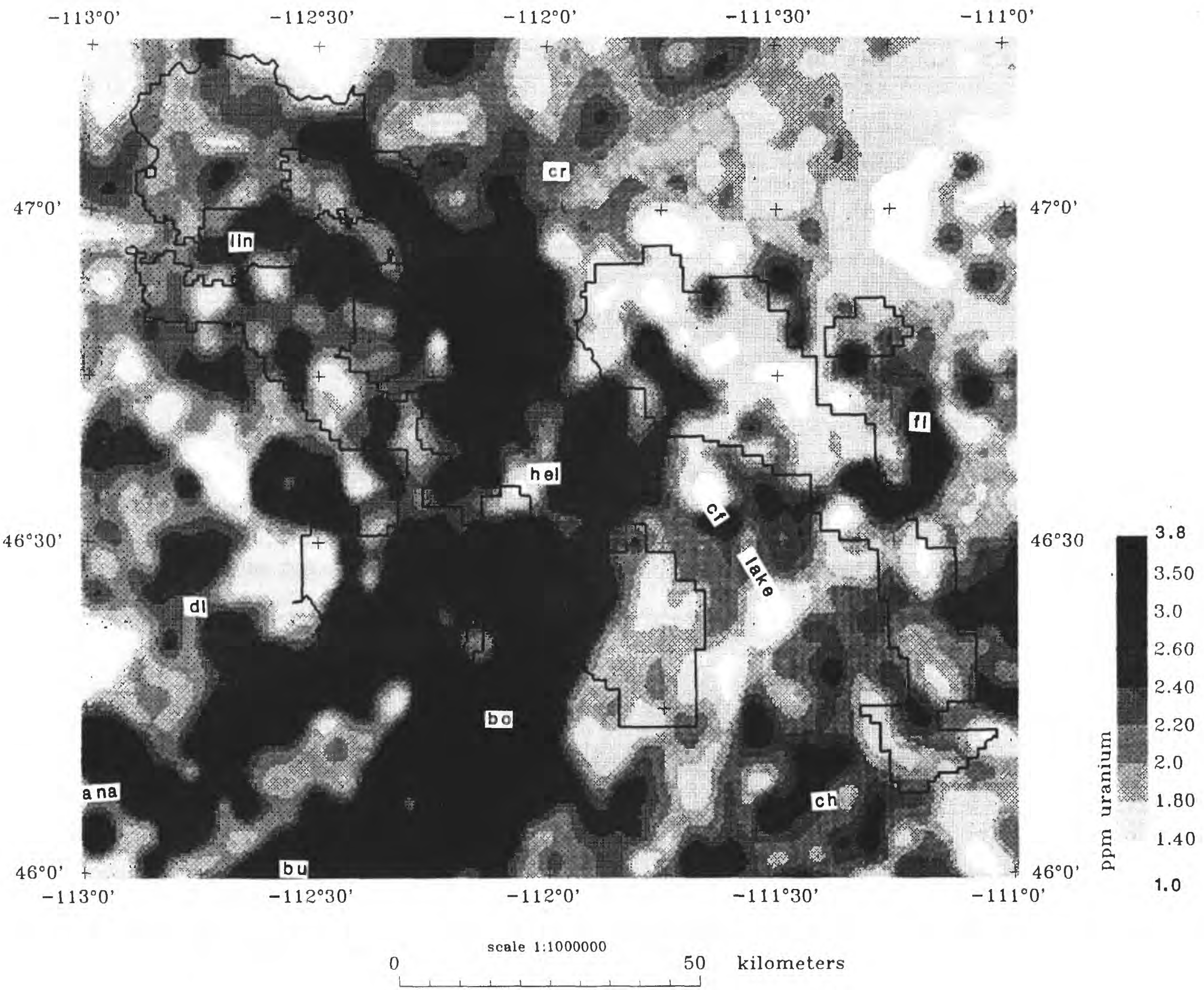

Figure C7. Uranium aeroradioactivity map of the Helena National Forest, Montana. Contour interval 0.2, 0.3, 0.4, and 0.5 ppm U (assuming equilibrium in the U decay series). Geographic locations: same as for figure C6. (Ignore grey-scale values for lakes and reservoirs.)

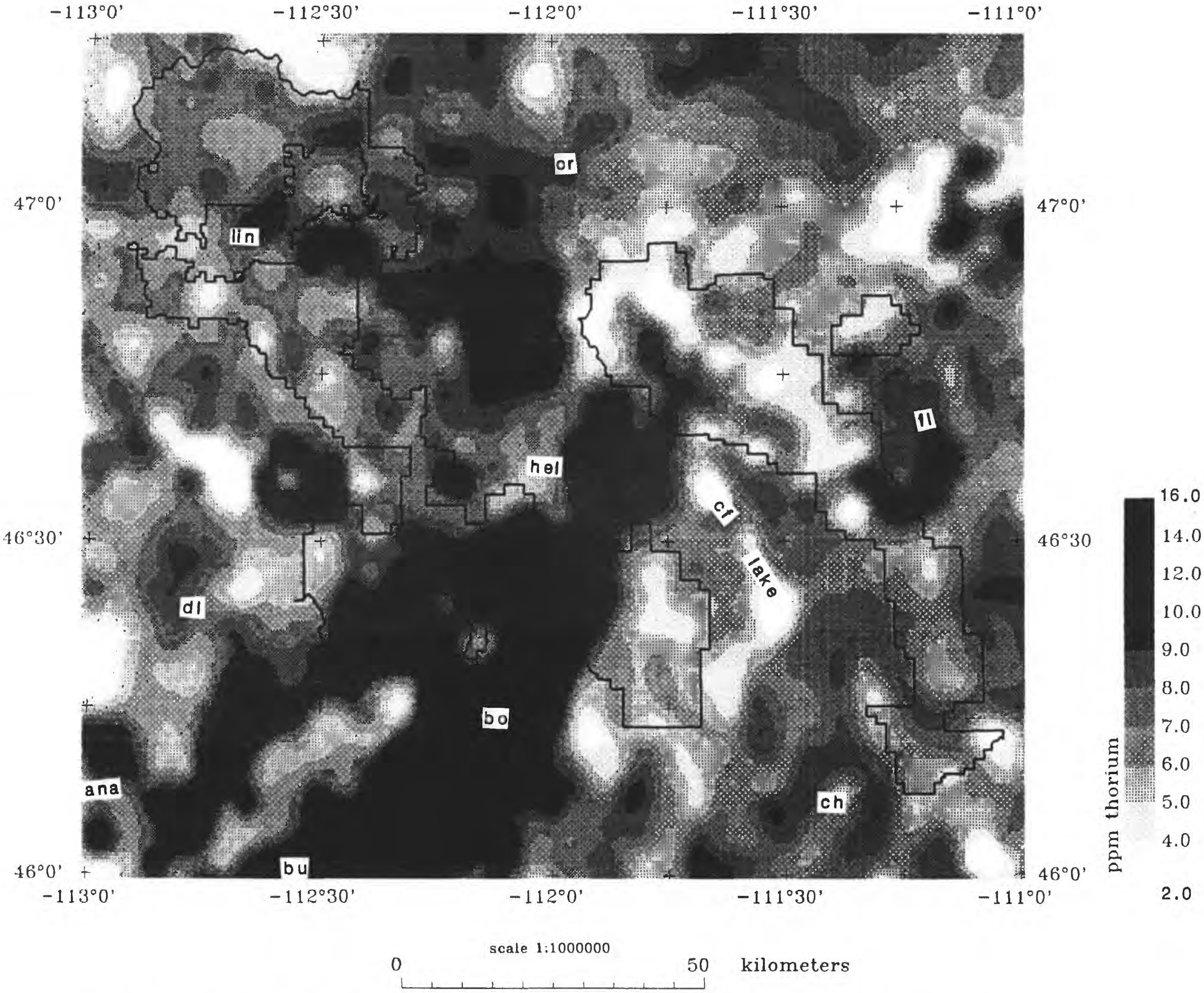

Figure C8. Thorium aeroradioactivity map of the Helena National Forest, Montana. Contour interval 1 and 2 ppm Th (assuming equilibrium in the U decay series). Geographic locations: same as for figure C6. (Ignore grey-scale values for lakes and reservoirs.)

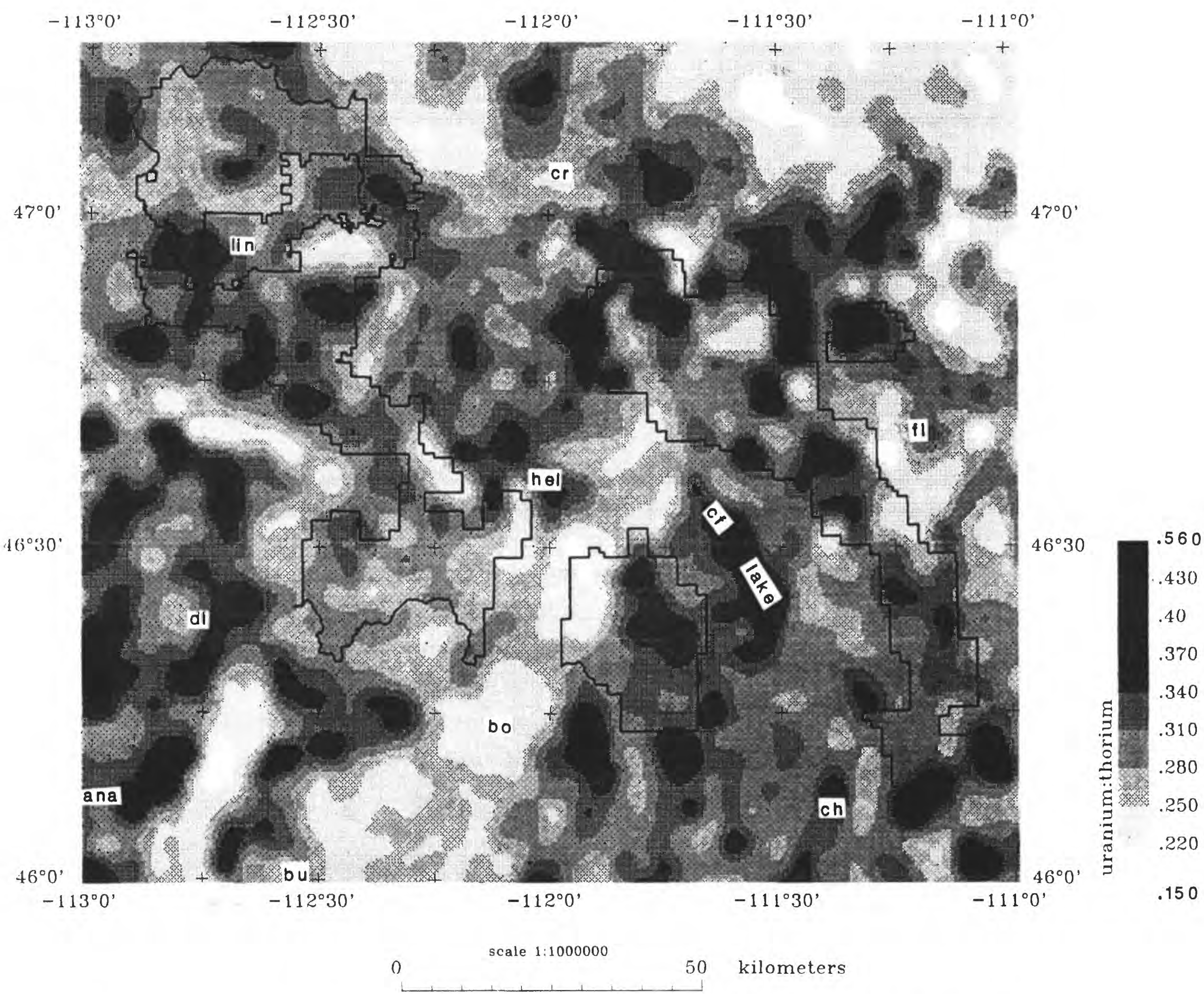

Figure C9. Uranium:Thorium aeroradioactivity map of the Helena National Forest, Montana. Contour interval 0.03, 0.07, and 0.13 percent U: ppm Th. Geographic locations: same as for figure C6. (Ignore grey-scale values for lakes and reservoirs.)

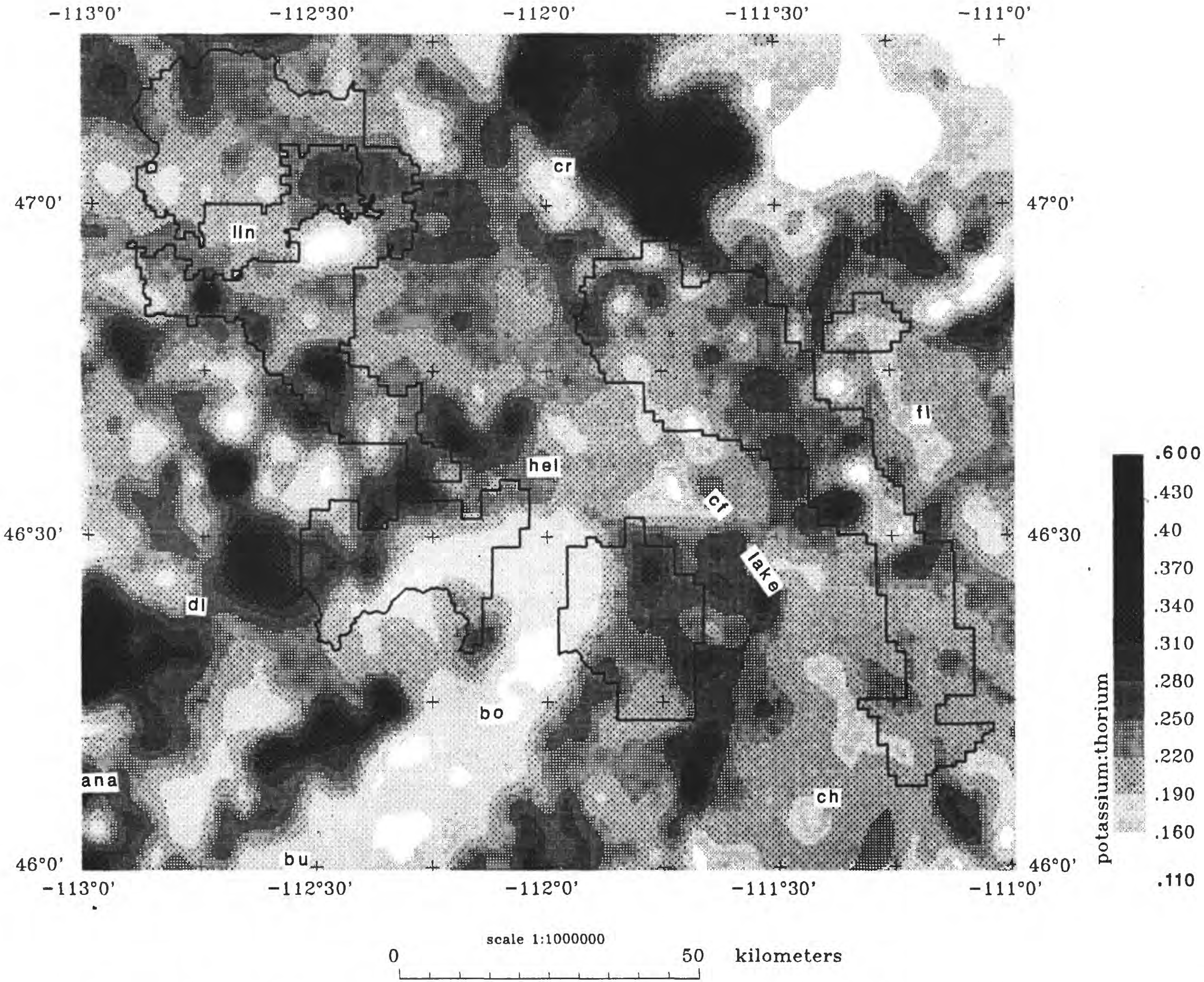

Figure C10. Potassium:Thorium aeroradioactivity map of the Helena National Forest, Montana. Contour interval 0.03, 0.05, and 0.17 percent U: ppm Th. Geographic locations: same as for figure C6. (Ignore grey-scale values for lakes and reservoirs.)

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CHAPTER D

GEOCHEMISTRY OF THE HELENA NATIONAL FOREST

By H.V. Alminas

INTRODUCTION

A geochemical survey of the Helena National Forest was designed to determine the broad regional mineral trends that impinge on or cross the Forest. The study area includes the western half of the White Sulphur Springs, eastern half of the Butte, and the southeastern corner of the Choteau 1° x 2° quadrangles (fig. D1). The study area encompasses approximately 4,623,360 acres of which the Forest constitutes 975,088 acres.

Sample Types

This study is based (1) primarily on stream sediment samples collected under U.S. Geological Survey (USGS) mineral resource projects that cover the Butte 1° x 2° quadrangle (McDanal and others, 1985), the Elkhorn Wilderness Study Area (Greenwood and others, 1990), the Choteau 1° x 2° quadrangle (Grimes and Leinz, 1980a, 1980b; Leinz and Grimes, 1980a, 1980b, 1980c), and (2) 151 samples collected during the Department of Energy NURE (National Uranium Resource Evaluation) studies within the Butte, Choteau, and White Sulphur Springs 1° x 2° quadrangles. USGS and NURE data are augmented by samples collected for this study, chiefly within the Big Belt Mountains. The USGS sample types are sieved <80-mesh and <100-mesh stream-sediments and were collected predominantly from 2nd and 3rd order streams. The NURE samples are sieved <100-mesh stream-sediments.

Results of rock and stream sediment samples analyzed within USGS geochemistry laboratories or labatories under contract to the USGS are retained as part of the RASS (rock analysis storage system) data base. Descriptors of "USGS" and "RASS" describe the source of the geochemical data bases and are used interchangeably throughout this report.

In addition to the USGS and NURE stream-sediment samples, data from spectrographic analyses of 1,916 outcrop samples collected during the course of the previous USGS studies were incorporated. The sample site distribution of these outcrop samples is extremely non-uniform and the data were used only for statistical purposes. The sample site distribution for the outcrop samples is shown in figure D2.

A data set consisting of selected elements from the USGS and NURE stream-sediment samples was created to investigate base-metal distribution within the study area. For this study, the NURE samples were reanalyzed in the USGS laboratories to bring the analyses into conformance with the existing USGS spectrographic analyses (Arbogast, 1996). The resultant data set incorporates 3,282 samples. Sample-site distribution is relatively uniform throughout the study area (fig. D3).

Taking care to maintain relatively uniform sample-site distribution, 1,901 samples were selected from the combined USGS/NURE sample collection to study gold distribution. These samples were analyzed for gold spectrographi-cally and by flameless atomic absorption. Sample-site distribution for these data set is shown in figure D4.

The original NURE data from all of the 2,151 stream-sediments within the study area are incorporated into one data set. This data set was used to investigate the distribution of those elements not analyzed for by spectrographic means. Figure 5 shows the distribution of the NURE sample-sites.

Analytical Procedures

All of the outcrop and stream-sediment samples (fig. D3) were analyzed for 31 elements using a six-step semi-quantitative spectrographic technique described by Grimes and Maranzino (1968). In this technique a 10 mg powdered sample is mixed with a buffer and placed into a cup-shaped graphite electrode. A direct-current arc volatizes the sample and the resultant spectra are recorded on a photographic film. Results are obtained by a visual comparison of spectra derived from the sample and that derived from standards made from pure oxides and carbonates. Results of these spectrographic analyses are read within geometric intervals having the boundaries of 1200; 830; 560; 380; 260; 120; and so on in parts per million, but are reported by approximate geometric midpoints, such as 1000; 700; 500; 300; 200; 150; and 100. Precision of a reported value is approximately plus or minus one reporting interval at the 83 percent confidence level, and plus or minus two reporting intervals at the 96 percent confidence level (Motooka and Grimes, 1976). Values determined for the major elements (calcium, iron, magnesium, sodium, phosphorus, and titanium) are given in weight percent. Table D1 lists the elements analyzed and the lower limits of detection.

Gold content of the outcrop and stream-sediment samples (fig. D4) was determined using an atomic-absorption spectrographic method. In this method a 10-g sample is roasted for 1 hour at 700°C; gold is then extracted with hydrobromic acid-0.5 percent bromine solution and MIBK (methyl isobutyl ketone). Electrothermal atomic-absorption spectroscopy, using background correction, is used to determine gold to 0.001 ppm (1 ppb) (O'Leary and Meier, 1986). In the case of the <100 mesh NURE stream-sediments, due to a shortage of sample material, only 5 g of sample was used for the gold analysis and the lower limit of determination is 0.002 ppm or 2 ppb.

Table D2 lists the types of NURE analytical techniques and the elements analyzed for by each method in the analysis of the 2,151 NURE <100-mesh stream-sediment samples (fig. D5).

Statistical Summary

Data Sets

Four distinct data sets were utilized for the purposes of this study. The data sets include the following sample types and analyses:

1. Spectrographic analyses of 1,916 USGS (RASS) outcrop samples.

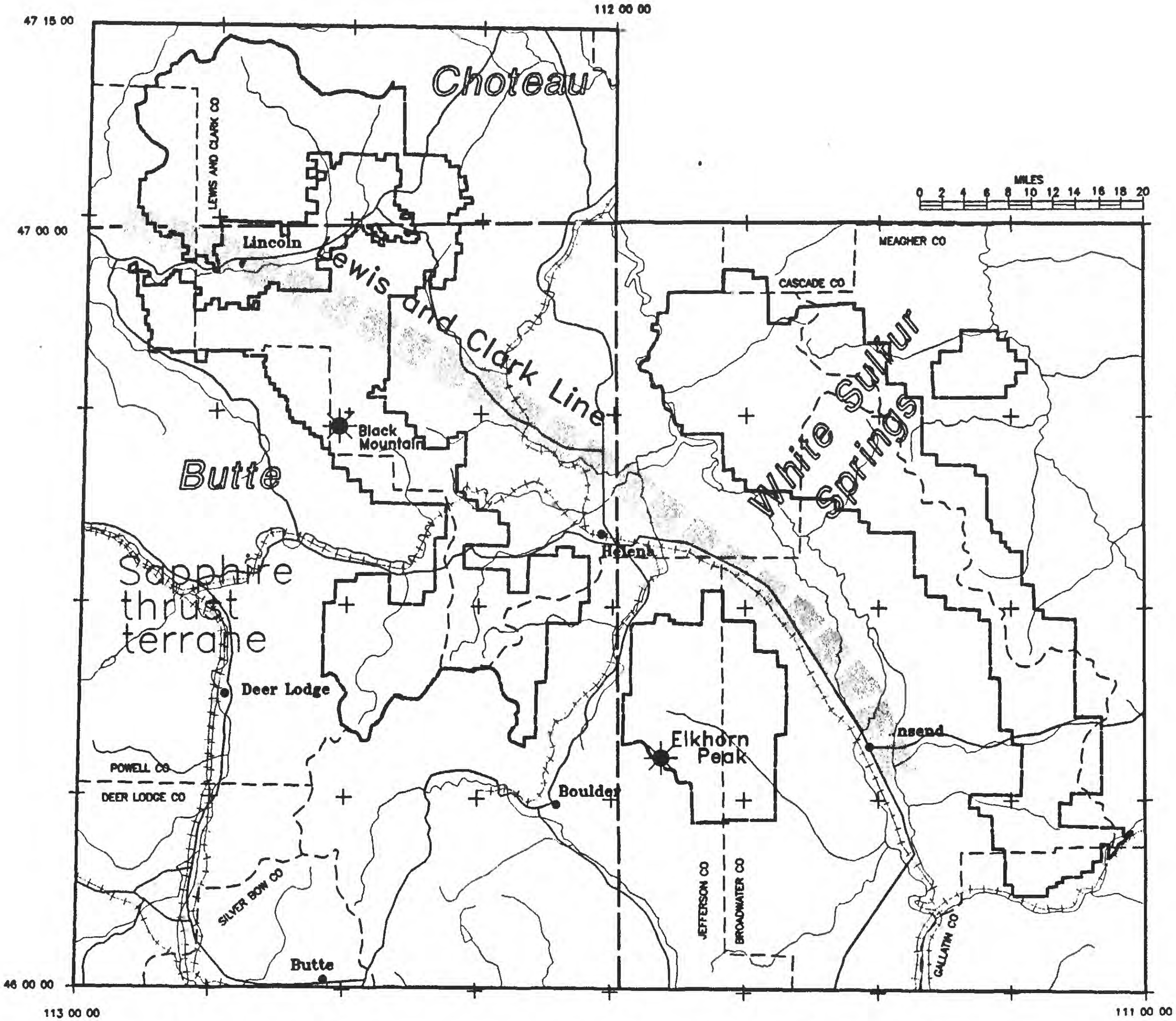

Figure D1. Geochemical study area showing location of Helena National Forest (long and short dashed black lines), major geologic and physiographic features, and locations of 1° x 2° quadrangles.

2. Spectrographic analyses of 3,282 USGS (RASS) and NURE stream-sediments
3. Gold and spectrographic analyses of 1,901 USGS (RASS) and NURE stream-sediments
4. Various NURE analyses of 2,151 NURE stream-sediments.

The geochemical data that comprise these four sets are contained on the companion CD-ROM release (Green and Tysdal, 1996).

Basic Statistics

A statistical summary of each of the four data sets was calculated using the STATPAC statistical evaluation library (Van Trump and Miesch, 1977; Grundy and Miesch, 1988) and is given in table format. A statistical summary of the 30 elements analyzed in the outcrop data set is given in table D3. The corresponding correlation table is given in table D4 and frequency distributions for all analyzed elements are given in table D5.

Table D6 summarizes the combined NURE and RASS spectrographically analyzed stream-sediment data set consisting of 3,282 sample analyses. Table D7 shows the correlations for this data set and table D8 shows the frequency distributions for the respective elements.

Table D9 summarized the spectrographic data of all the USGS and NURE samples analyzed for gold. Table D10 shows the corresponding correlation coefficients and table D11 shows the percent frequency distributions of all the analyzed elements.

The original NURE analyses are summarized in table D12. The corresponding correlation table is shown in table D13. The percent frequency distributions of the NURE analyzed elements are shown in table D14. For purposes of this report, the data has been grouped into spectrographic reporting classes.

Gold values, determined by the USGS on selected NURE and RASS stream-sediments, are summarized in table D15. Gold correlation coefficients are shown in table D16 and the gold value frequency distribution is shown in table D17.

GEOCHEMICAL EXPLORATION

Geochemical anomalies are extensive and intense within the study area. Anomalous values of many geochemical elements are far more extensive within the eastern part of the Butte 1° x 2° quadrangle than in the western part of the White Sulfur Springs 1° x 2° quadrangle or the southeastern corner of the Chotoeau 1° x 2° quadrangles. The anomaly-rich area is bounded on the north east by the Lewis and Clark line and dies out on the west in the Sapphire thrust terrane (fig. D1). Nearly all the geochemical anomalies occur over, or immediately adjacent to, Tertiary rhyolites (porphyry flows, porphyry plugs, breccia plugs, dikes) or Tertiary to Late Cretaceous plutonic rocks--predominantly of monzonitic to monzodioritic composition (plate 1). Some geochemical anomalies occur over exposed sedimentary units that have distinct aeromagnetic highs (fig. C1) and gravity lows (fig. C3), which is suggestive of intrusives emplaced at some depth.

Geochemical Models Based on Statistical Analysis of NURE Stream Sediment Data

Mineralized areas are often defined on the basis of an assemblage of geochemical elements as well as the relative amounts of individual elements within the assemblage. The REM (relative element magnitude) method of Van Trump and Alminas (1978) mathematically combines individual elements to form multi-element geochemical anomalies. Results are elemental assemblages referred to as "association" models. The individual elements that make up the assemblage are defined on the basis of one principal element that forms an association with other elements in the suite. Associations can be determined either by a: (1) statistical correlation with other geochemical elements that may characterize the expected mineralization; or (2) by geological/geochemical knowledge of processes that associate one element with another; or (3) by a combination of (1) and (2). The REM method also calculates the relative magnitude or contribution of each individual element within the overall association.

For the study area, three association models based on three principal elements were derived with the REM computer program (Van Trump and Alminas, 1978) using data from NURE stream sediment analyses: one model based on lanthanum (La), a second based on lead (Pb), and a third on gold (Au). The La-association model combines many rare earth elements to map locations of exposed and shallowly buried intermediate-composition plutons that can act as hosts to metal sulfide minerals. The Pb-association model is based on a geochemical assemblage that combines a suite of metals for the purpose of mapping metal-rich areas related to sulfide mineralization. The Au-association model combines elements commonly associated with gold.

Geochemical Association Model Methodology

REM values for the La-, Pb-, and Au-association models were derived by calculating two parameters for each element in the assemblage. The first parameter is called the "intensity factor" (Ii) and is calculated by dividing the mean of all anomalous values for a given element by its threshold value. "Anomalous value" is defined as being equal to or greater than a subjectively defined threshold value. For this study, the threshold value was defined to be any value that exceeded the 75th percentile within the data set. Thus,

$$Ii = \frac{\text{mean of all anomalous values}}{\text{threshold value of the sample}}$$

The second parameter is termed the "area factor" (c) and is a constant value defined by dividing the number of anomalous sample elements that exceed the threshold value by the total number of samples:

$$c = \frac{\text{Number of anomalous samples greater than the threshold value}}{\text{Total number of samples within study area}}$$

The intensity factor (Ii) is multiplied by the area factor to obtain the "element magnitude" (Ei):

$$Ei = c\ (Ii)$$

The "anomaly magnitude" (A) is calculated by summing all the element magnitudes in the assemblage:

$$A = E_1 + E_2 + E_3 + \ldots\ldots E_j \quad \text{, where } j = \text{total number of samples}$$

Finally, the element magnitude (Ei) is divided by the anomaly magnitude (A) and expressed in percent to obtain the "relative element magnitude" (REM) value for each sample location:

$$REM = \frac{Ei}{A} * 100$$

REM values for the three association models of this study were gridded onto rectangular 1- by 1-km grids using the commercial software package EarthVision[1] and presented as gray-level contour plots.

La-Association Model

The La-association model was derived from the NURE stream sediment data set and consists of the following geochemical elements: La, Ce, Dy, Eu, Hf, Lu, Sm, U, and Yb. Figure D6 contains graphs showing lanthanum against the contribution of each individual element and its magnitude (Ei) within the overall association.

A contour plot of the distribution of the derived La-association values is shown in figure D7. The La-association model is composed of a suite of rare earth elements that characterize the nearly all of the mentioned intrusive types, many of which are mineralized. Many of the La-association anomalies correspond to areas delineated by terrace-magnetization domains with relatively high values (fig. C4) and low value terrace-density domains (fig. C5).

Pb-Association Model

Lead is the most abundant ore-forming element within the study area. It has the most intense and extensive anomalies in comparison with other base metals and apparently occurs in most every type of mineral deposit within the study area. A Pb-based geochemical association derived from the combined NURE and USGS data set consisting of Ag, As, B, Be, Bi, Cu, Mn, Mo, Sb, Sn, W, and Zn (fig. D8) characterizes most areas of known past mineral exploitation within the study area, as well as some areas that were not developed. The Pb-association values were calculated in the same manner as the La-association values.

A contour map of Pb-association value distribution relative to known mine and prospect pits within the Forest boundary is shown in figure D9. High value Pb-association anomalies occur to the west of a line defined by Wolf Creek, Helena, and Townsend, which roughly coincides with the St. Mary's-Helena Valley fault (plate 1 and fig. B1). Although every mining district is characterized by

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[1]Any use of trade names is for descriptive purposes only and does not imply endorsements by the USGS.

this association to some degree, Pb-association anomalies with high REM values occur over the following districts (plate 2 and fig. F1) and are ranked according to highest (1) to lowest REM values:

1. Marysville
2. Winston - Indian Creek-Park
3. Stemple-Gould
4. Wickes
5. North Boulder Mountain (west of Helena National Forest)
6. Elkhorn
7. Heddleston
8. Warm Springs
9. Montana City

In addition, numerous high amplitude Pb-association anomalies occur outside mining district boundaries and are interpreted as possible areas of unknown or unmapped mineralization. The anomalous concentration of Pb in rocks and (or) stream sediments is not necessarily indicative of anthropomorphic, mining-related contamination. Pb occurs naturally in several different forms (chemical compounds, or minerals) and the mobility of Pb is dependent on mineralogic siting and a wide variety of local geochemical conditions.

Au-Association Model

Gold is also widespread within the study area. A Au-association was determined and calculated in the same manner as described for the La-association and includes Ag, As, Cd, Cu, Mn, Pb, Sn, Sr, and Zn (fig. D10). A contour plot of the Au-association (fig. D11) tends to delineate the same general areas as the Pb-association (fig. D9). As in the case of the Pb-association, the Au-association characterizes all defined mining districts to some degree, and in addition, delineates other areas falling outside the known districts (plate 2 and fig. F1). Major Au-association anomalies with relatively high REM values occur over the following known mining districts and are ranked from high (1) to low (9) based on REM values:

1. Marysville
2. Elkhorn
3. Heddleston
4. Stemple-Gould
5. North Boulder Mountain (west of Helena National Forest)
6. Winston
7. Montana City
8. Elliston
9. Wickes

Although the ranking varies somewhat, the areas defined are essentially the same ones as were defined by the Pb-association. Generally, the Au-association anomalies occur over or near the mapped intrusives (Plate 1). Positive spatial relationships can be seen between the Au-association, distributions of terrace-magnetization domains with relatively high values (fig. C4), and distributions of low values of terrace-density domains (fig. C5).

Element Plots

Selected individual element plots are shown in figures D12 through D21 and at a scale of 1:250,000 on maps F and G (plates 3 and 4). These elements were selected on the basis of their relationship with the Pb- or Au- associations as well as on the basis of widespread occurrence. Below is a list of the elements shown and the corresponding figure numbers.

Figure	Element	Map	Plate
D12	gold	G	4
D13	silver		
D14	lead	F	3
D15	bismuth		
D16	copper		
D17	molybdenum		
D18	tin		
D19	zinc		
D20	iron		
D21	manganese		

Heavy-Metal Analyses from Stream Sediments and Outcrop Samples

Forty-four heavy-mineral concentrates from stream-sediments collected within the Forest were examined by scanning electron microscope (SEM) and concurrently analyzed by energy dispersive spectrometry (EDS). Only minerals incorporating elements with atomic weights equal to or greater than that of iron were examined. The results are summarized in the graphs in figure D22. It can be seen that barite is a very wide-spread mineral in stream sediments followed immediately by galena, then zircon, pyrite, monazite, scheelite, and gold and silver.

Slabs from 53 outcrops from the Forest were also investigated in this manner. The results (fig. D23) show that the major "heavy metal" mineralogy is similar to that seen in the heavy-mineral concentrates derived from stream-sediments. The weathering and transport processes operating in the surficial environment have had minor effect on the relative abundance of these minerals in the stream-sediments. This lends substantial credibility to the geochemical and derivative plots base on the analyses of stream-sediments collected within the area.

Heavy-mineral concentrates were also collected from the Elliston, Marysville, and the Stemple-Gould districts (plate 2, fig. F1). The results of these SEM-EDS studies are shown in figures D24, D25, and D26, respectively. It is immediately apparent that the similarity in geochemical signatures seen within the study area as a whole is reflected by the essentially identical "heavy metal" mineralogy seen between the various mining districts.

Geochemical-Geophysical Association Models

Grids of the three defined geochemical associations (La-, Pb-, and Au-)

were mathematically combined with grids of the terrace-magnetization and terrace-density data. In general, terrace-density and terrace-magnetization data emphasize large, sharply bounded domains of density and magnetization. The domains and their edges often delineate known geologic features such as faults, contacts, or intrusive igneous bodies. In this study the terrace data are used primarily to define magnetization and density domains associated with igneous plutonic bodies. A description of the derivation of terrace maps is given in McCafferty (Chapter C of this report).

The resulting integrated products are referred to as the La-terrace, Pb-terrace, and Au-terrace association models and plots are shown on maps H, I, and J (plate 4), respectively.

The La-terrace association model (map H, plate 4) delineates the outer margins of the Boulder batholith (fig. B1,plate 1) and numerous mapped intrusives throughout the study area. In addition, three to four northwesterly trends are delineated in the west-central part of the study area along which a number of intrusives occur. These lineaments are parallel to a line extending from Black Mountain in the northwest over Elkhorn Peak in the southeast (plate 1). These same northwesterly trends occur in a plot of the Pb-terrace association model (map I, plate 4). Essentially every major Pb-terrace association anomaly occurs along the lineaments which appear to transect the Boulder batholith. A plot of the Au-terrace association model (map J, plate 4) shows essentially the same northwesterly linear pattern as that of the Pb-terrace association model. Here again all the major anomalies occur along the northwesterly trends seeming to transect the Boulder batholith.

Geochemical-Geophysical Association Model Summary

Areas delineated by these 3 geochemical-terrace models (maps H, I, and J, plate 4) are deemed to be the most affected by mineralizing processes. The intense geochemical anomalies are due in part to natural processes acting within the weathering environment and in part to past and present mineral exploitation activities. All of the delineated areas, and especially those outside known mining districts, may be potential areas of future mineral exploration. Time was not available to conduct the necessary follow-up studies to determine the possible resource potential of the identified anomalous areas. The results are reported for future reference.

Modified versions of the La-terrace and Pb-terrace association models presented in this report have been calculated and extended to include data covering the state of Montana as part of a regional mineral-environmental study (McCafferty and others, 1996).

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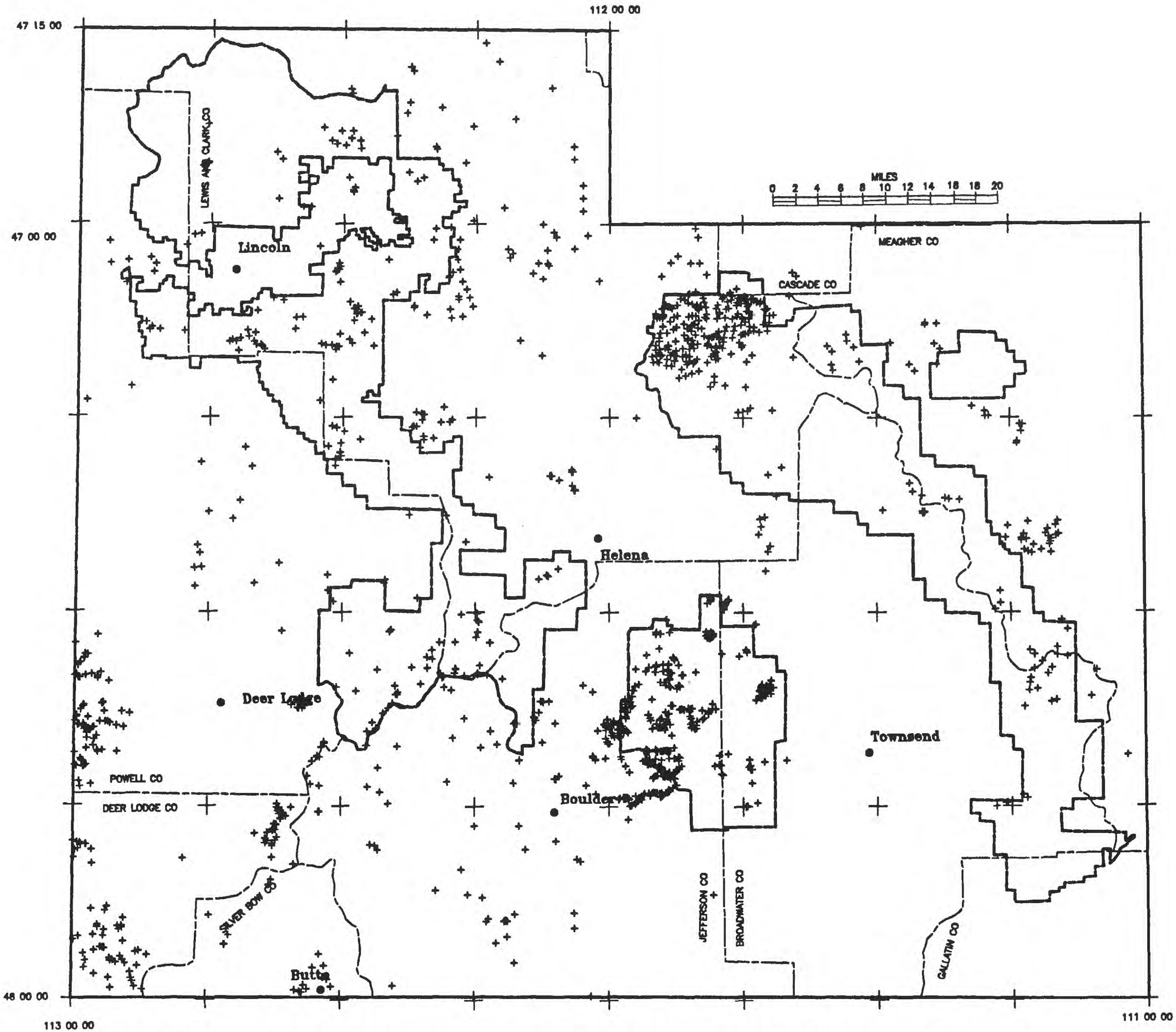


Figure D2. USGS (RASS) outcrop sample localities (+) for the Helena National Forest and surrounding area. Forest boundary is shown as heavy long and short dashed line. All samples collected at these sites were analyzed for 30 elements by emission spectography. Results of spectrographic and statistical analyses are given in tables D3, D4, and D5.

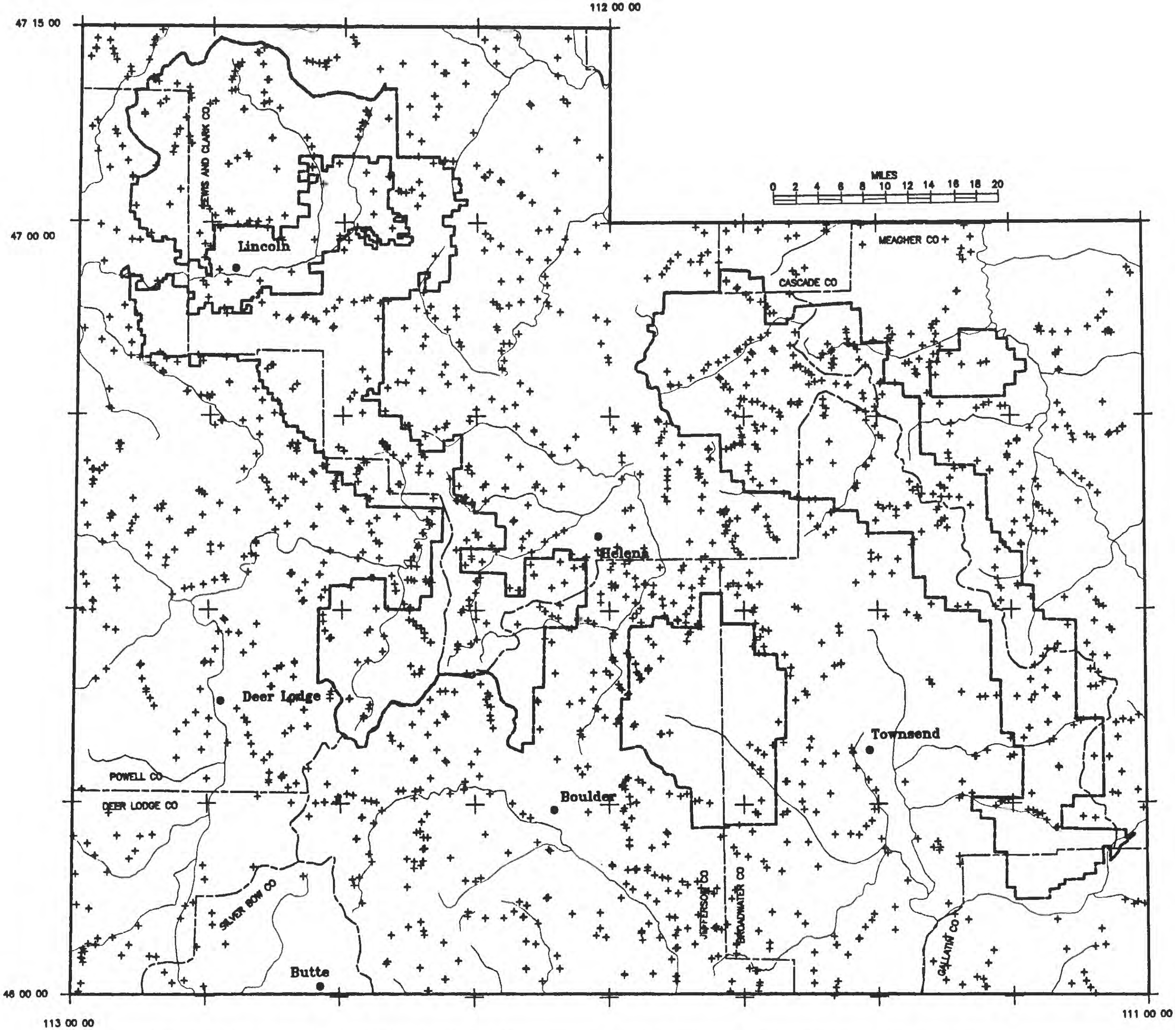


Figure D3. NURE and USGS (RASS) stream-sediment sample sites (+) for the Helena National Forest and surrounding area. Forest boundary is shown as heavy long and short dashed line. All samples collected at these sites were analyzed for 31 elements by emission spectrography. Results of spectrographic and statistical analyses are given in tables D6, D7, and D8.

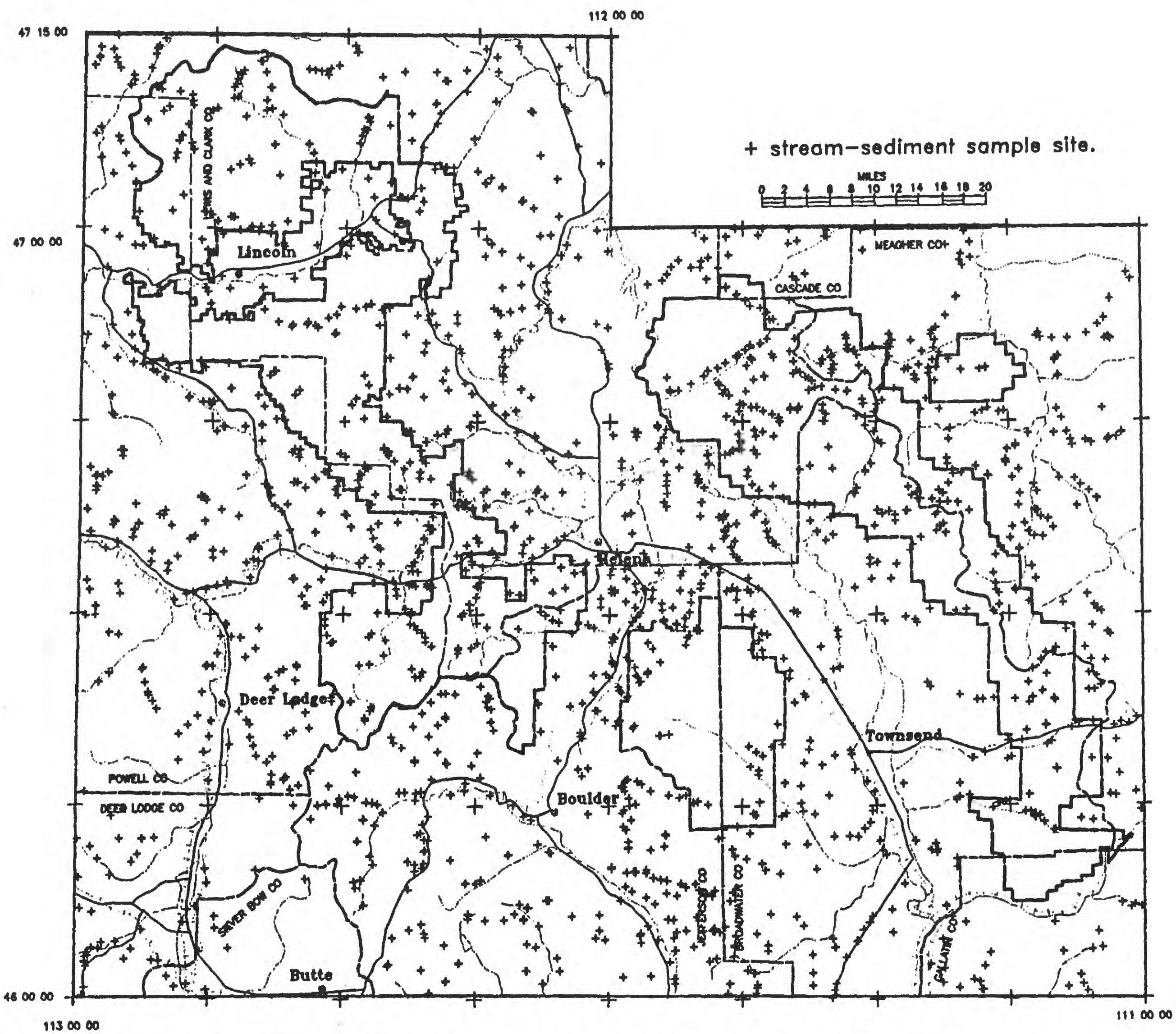


Figure D4. NURE and USGS (RASS) stream-sediment sample sites (+) for the Helena National Forest and surrounding area analyzed for gold by atomic absorption. Results of spectrographic and statistical analyses are given in tables D9, D10, and D11.

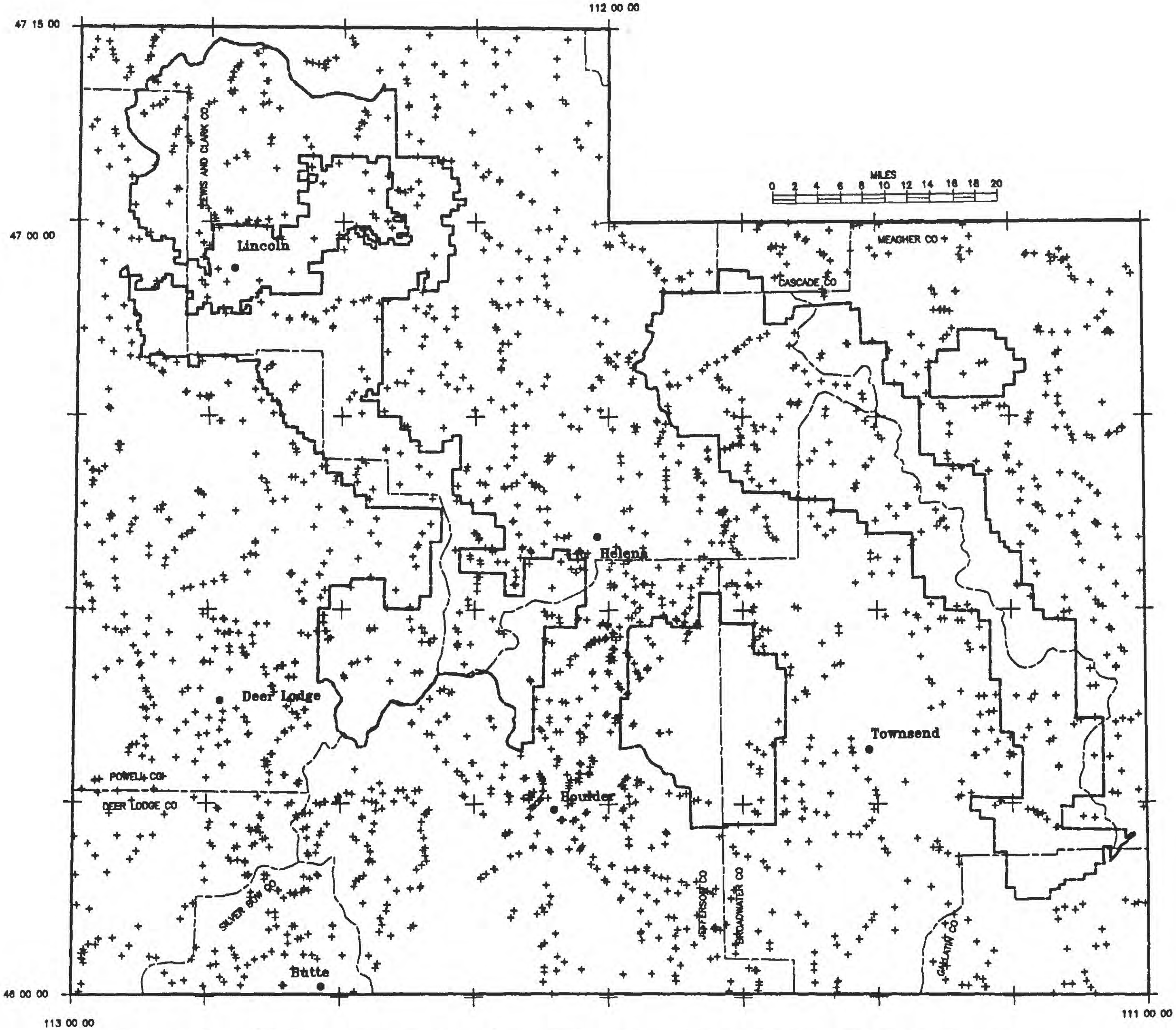


Figure D5. NURE stream sample sites (+) analyzed for 43 elements by various analytical methods described in text. Results of statistical analyses of NURE stream-sediment samples are given in tables D12, D13, and D14.

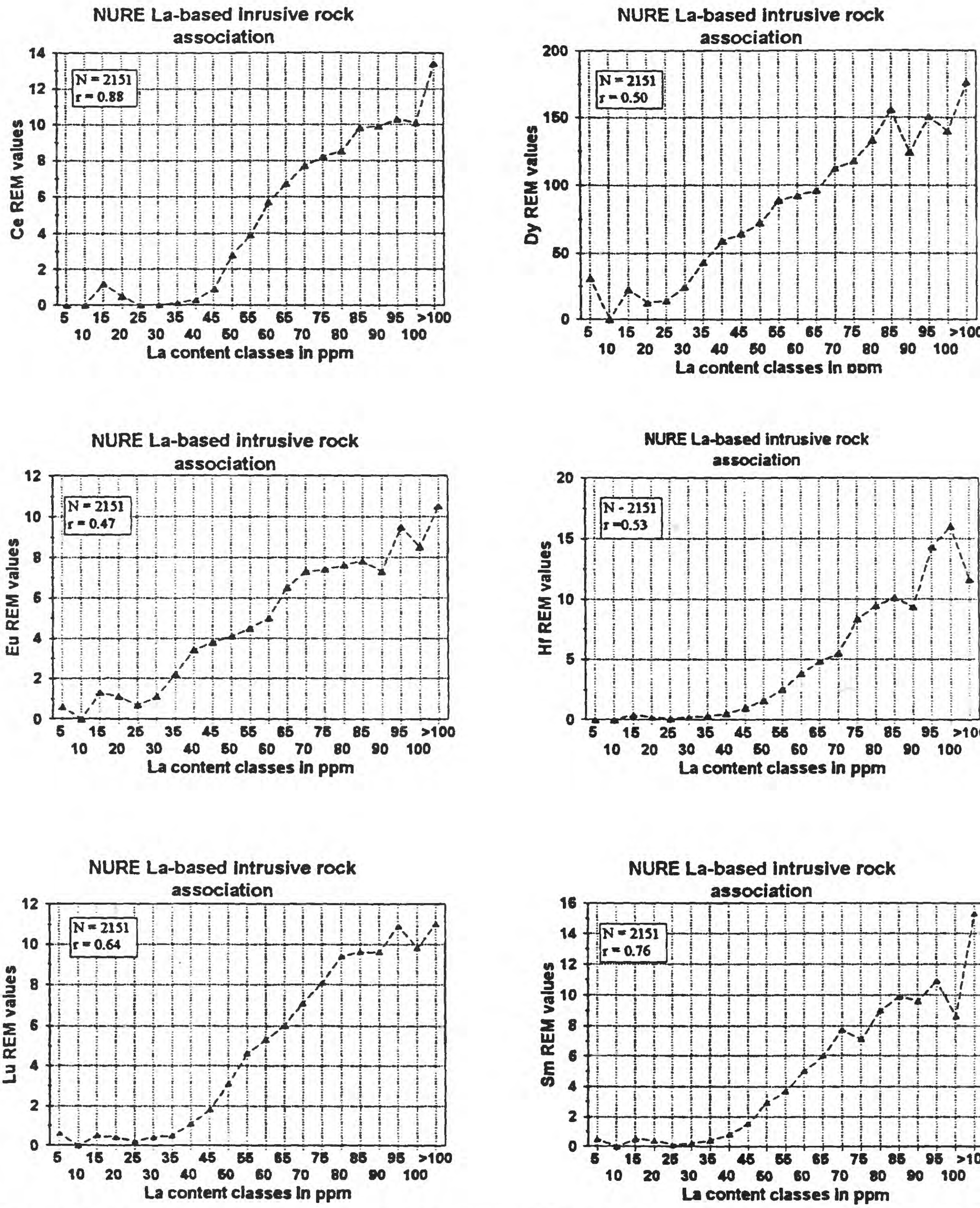


Figure D6. Graphs showing the relationship between lanthanum and suite of individual elements used in the La-association model for the study area. Values for the individual elements (on the vertical axis) are presented as "element magnitudes" and were calculated using the REM (relative element magnitude) method of Van Trump and Alminas (1978) using NURE stream sediments. The element magnitude values indicate the relative amount of each element within the overall elemental assemblage that define the La-association model. This particular suite of elements tends to map locations of plutons with intermediate compositions. Many of the plutons are host to major mineral deposits in the study area.

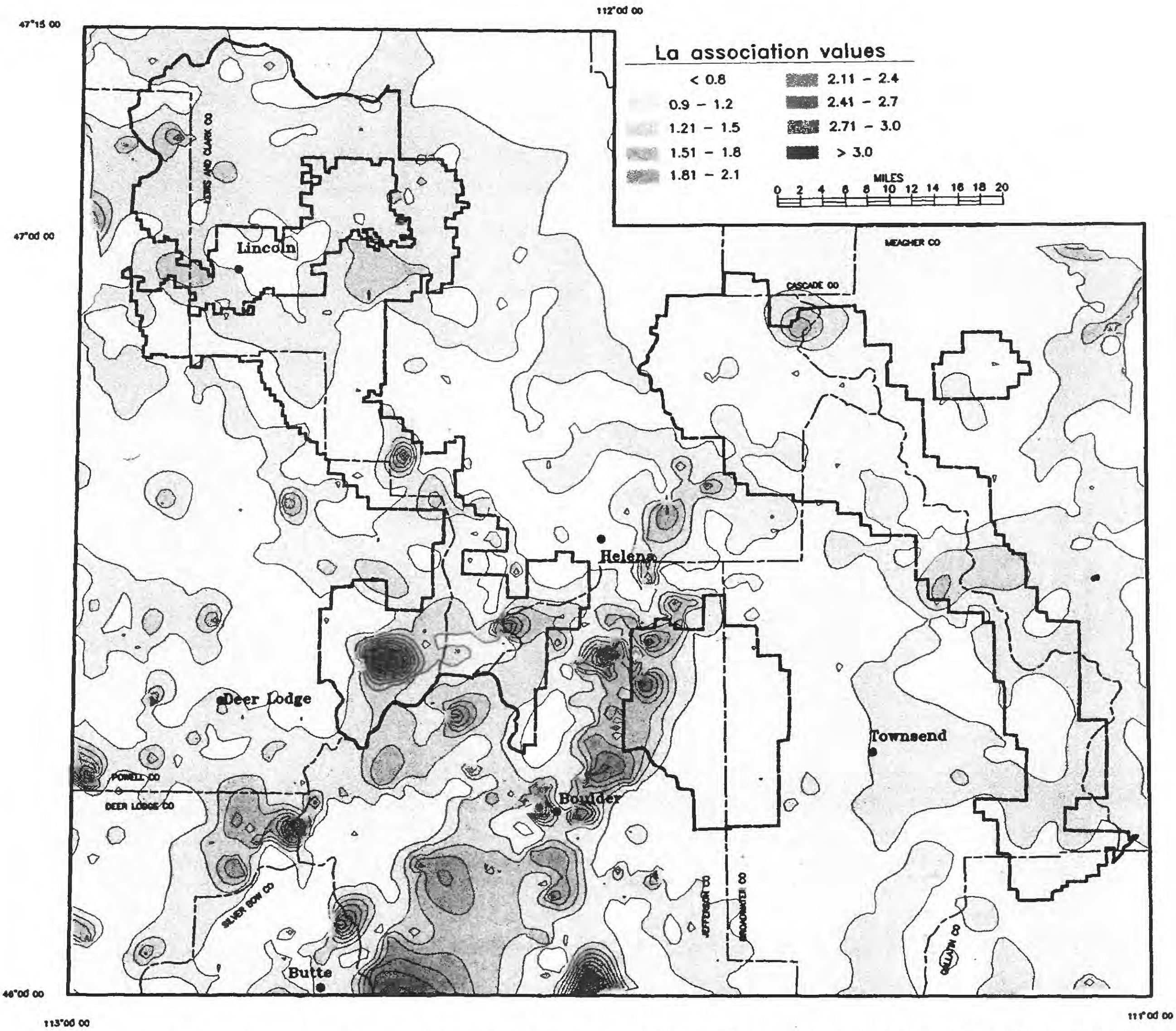


Figure D7. Map showing distribution of La-association anomalies for the study area. Values are in "relative element magnitudes" (unitless) and represent high concentrations of an assemblage of rare earth elements (Ce, Dy, Eu, Hf, La, Lu, Sm, U, and Yb) in stream sediments.

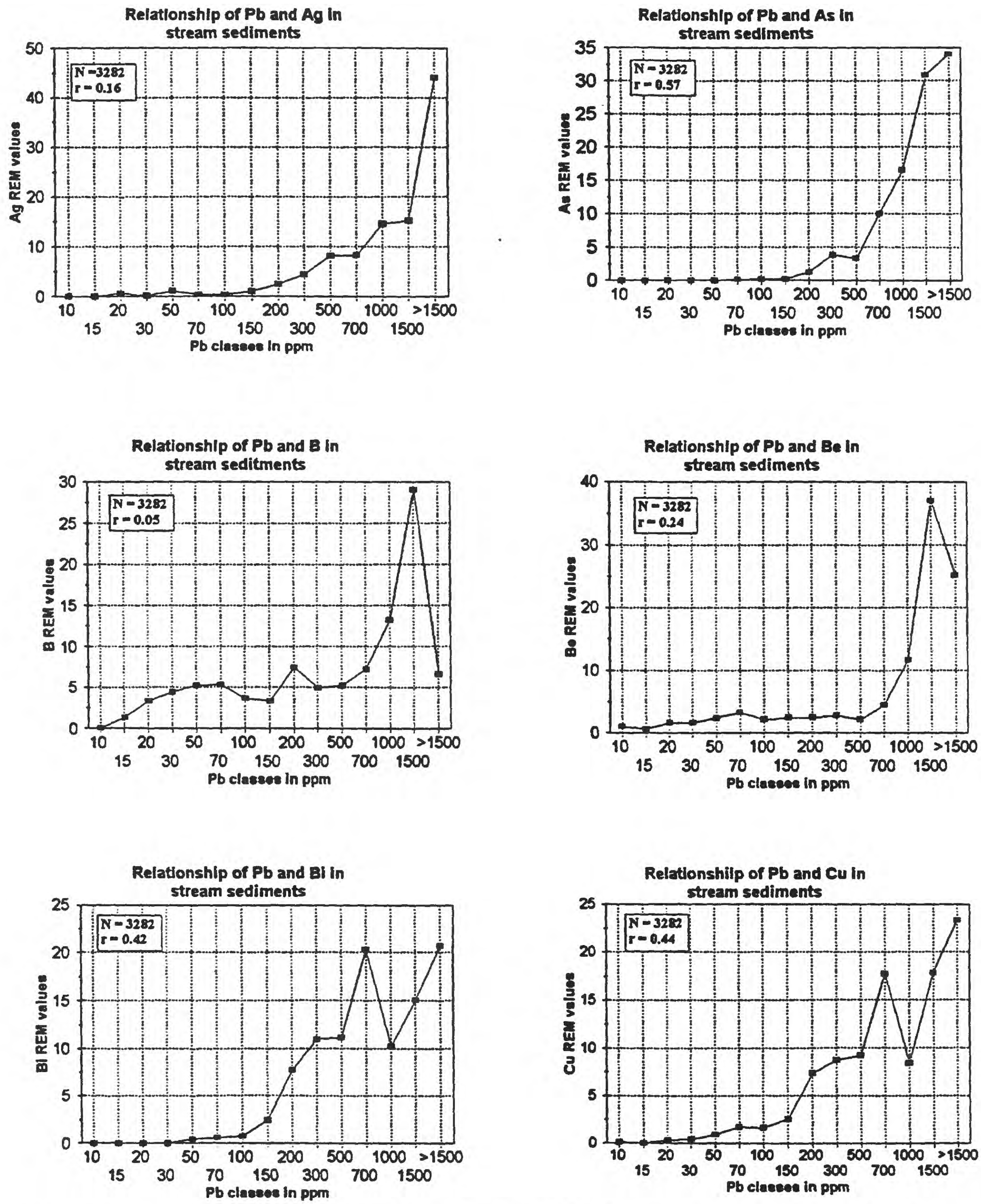


Figure D8. Graphs showing the relationship between lead and suite of individual elements used in the Pb-association model for the study area. Values for the individual elements (on the vertical axis) are presented as "element magnitudes" and were calculated using the REM (relative element magnitude) method of Van Trump and Alminas (1978) using USGS and NURE stream sediments. The element magnitude values indicate the relative amount of each element within the overall elemental assemblage that define the Pb-association model. This particular elemental assemblage characterizes many of the known deposit types in the study area, the majority of which relate to sulfide mineralization.

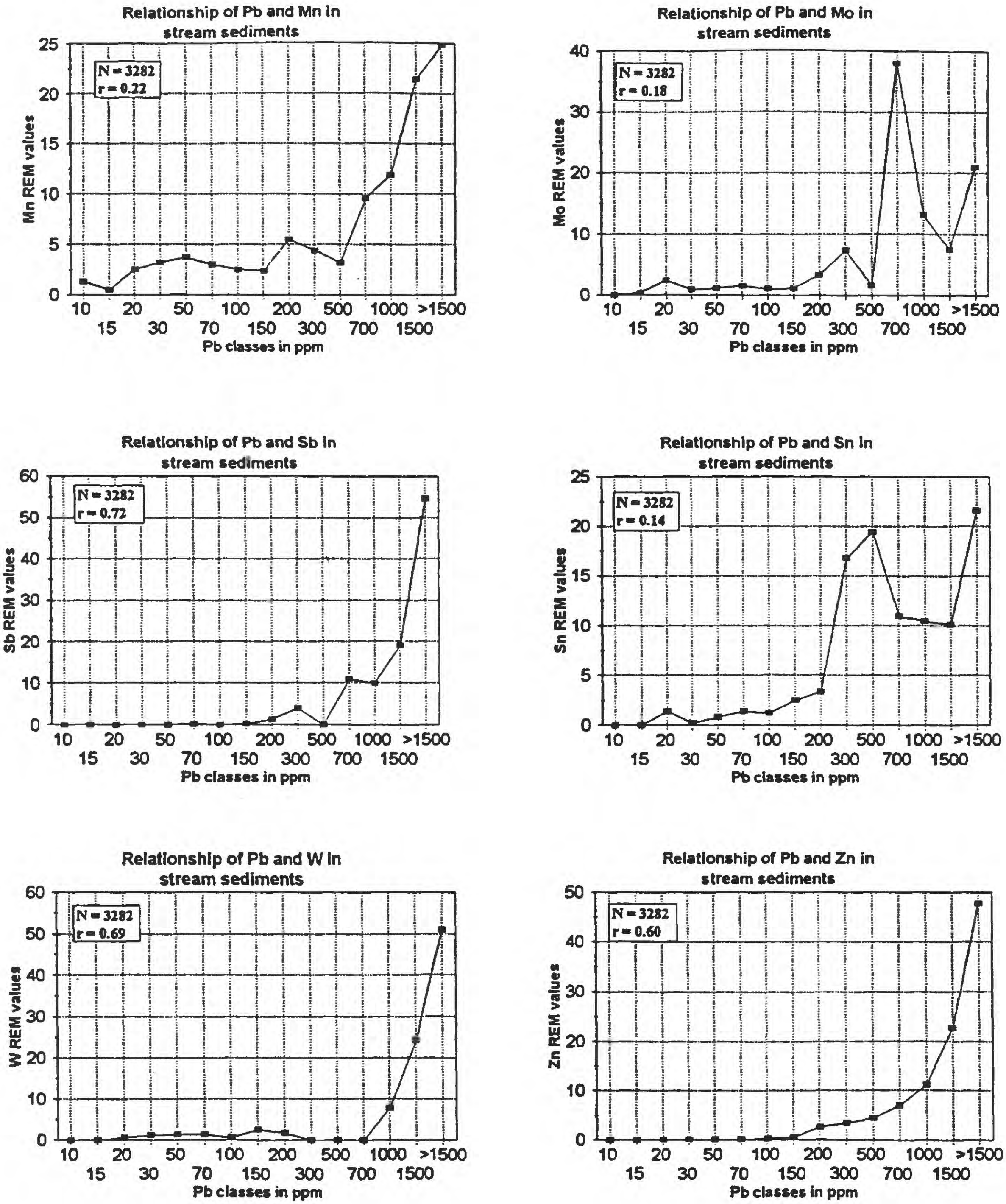


Figure D8 (continued). Graphs showing the relationship between lead and suite of individual elements used in the Pb-association model for the study area. Values for the individual elements (on the vertical axis) are presented as "element magnitudes" and were calculated using the REM (relative element magnitude) method of Van Trump and Alminas (1978) using USGS and NURE stream sediments. The element magnitude values indicate the relative amount of each element within the overall elemental assemblage that define the Pb-association model. This particular elemental assemblage characterizes many of the known deposit types in the study area, the majority of which relate to sulfide mineralization.

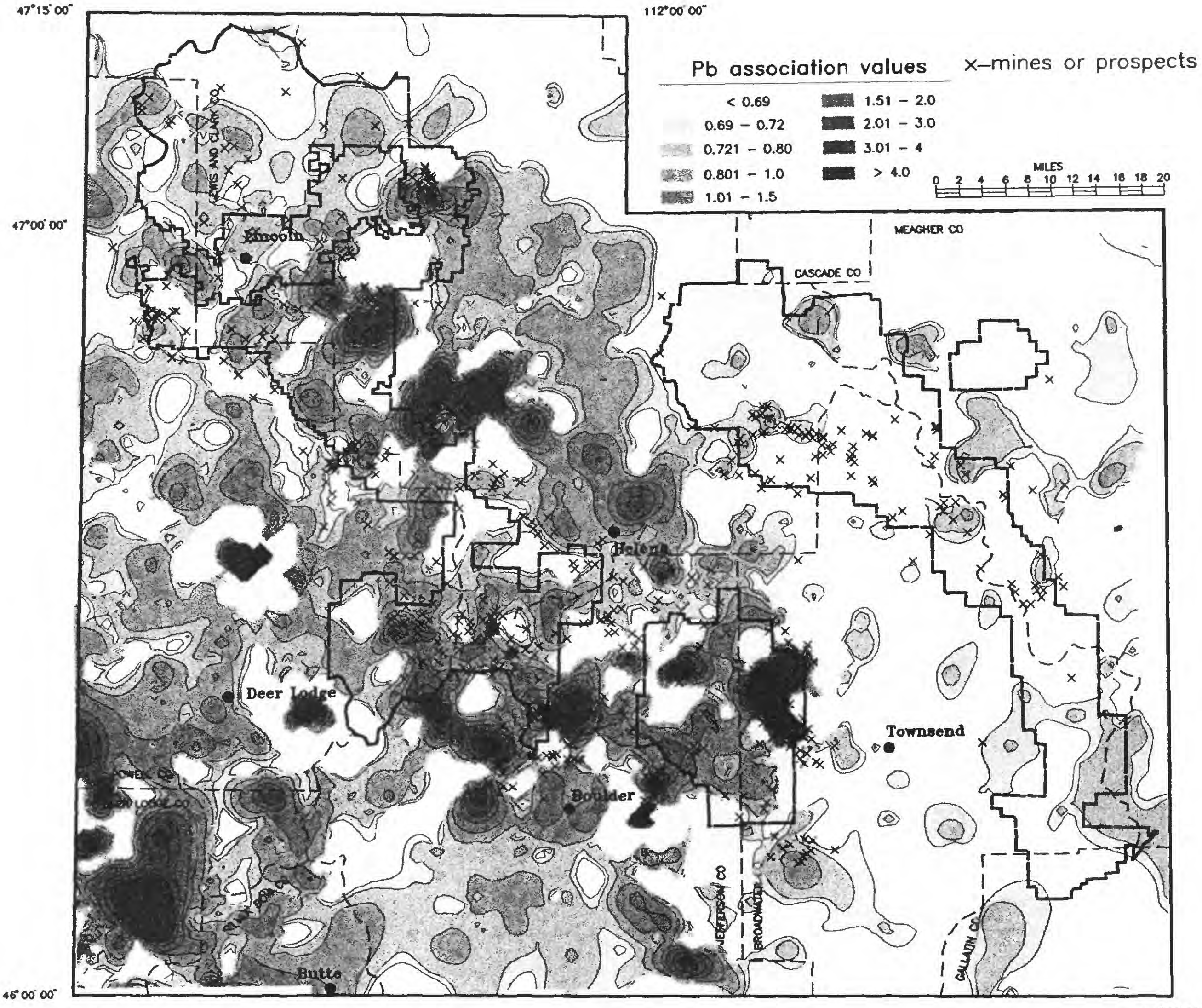


Figure D9. Map showing distribution of Pb-association anomalies with values indicating relatively high concentrations of a metal suite (Ag, As, B, Be, Bi, Cu, Mn, Mo, Pb, Sb, Sn,- W, and Zn) within stream sediment samples. Values are in "relative element magnitudes" (unitless). Mines and prospects (x) are plotted within forest boundary.

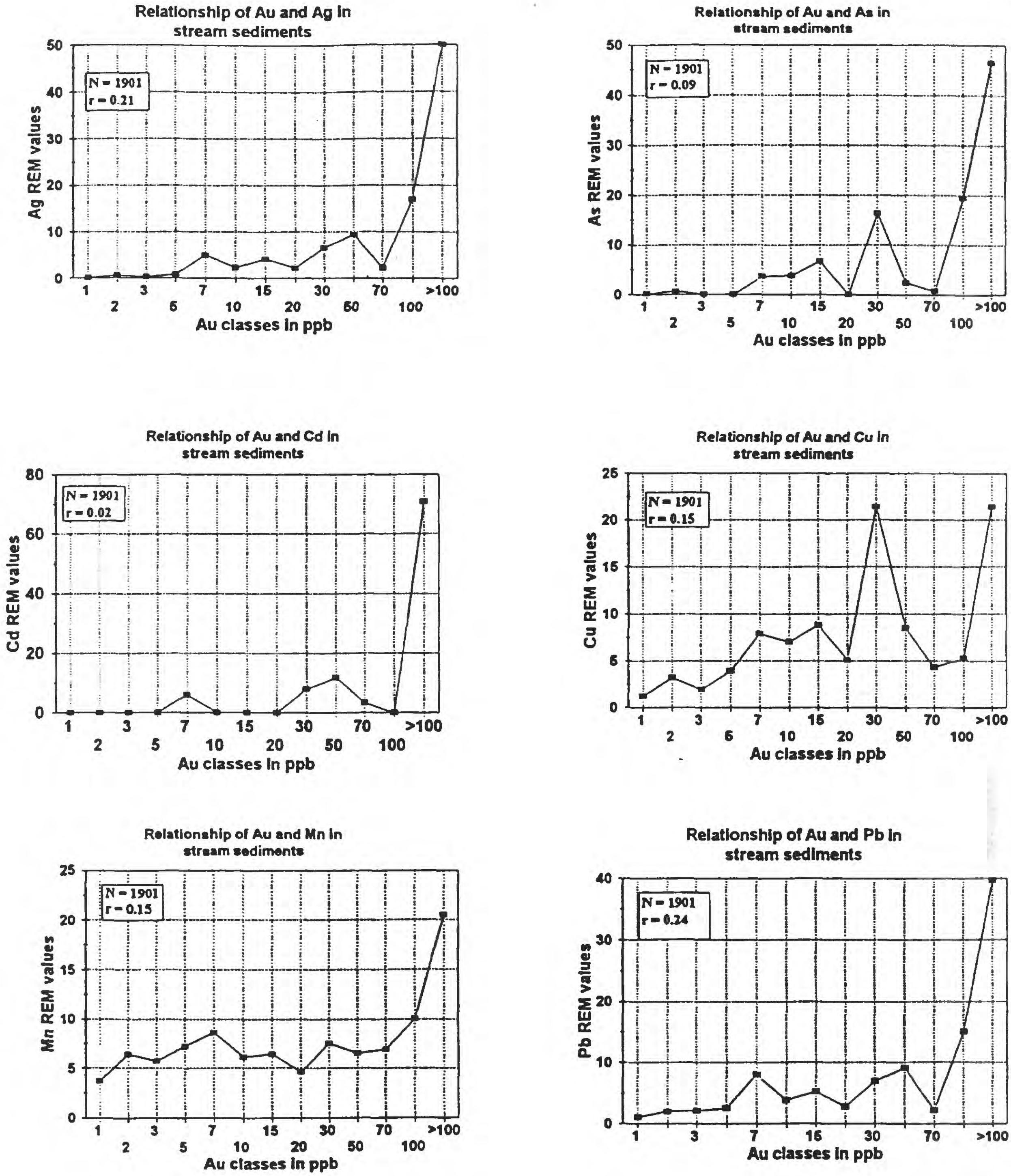
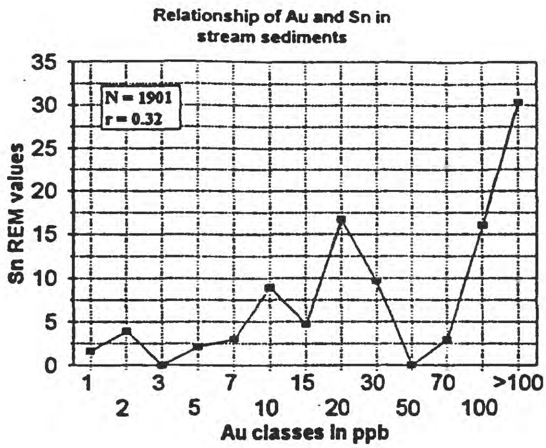
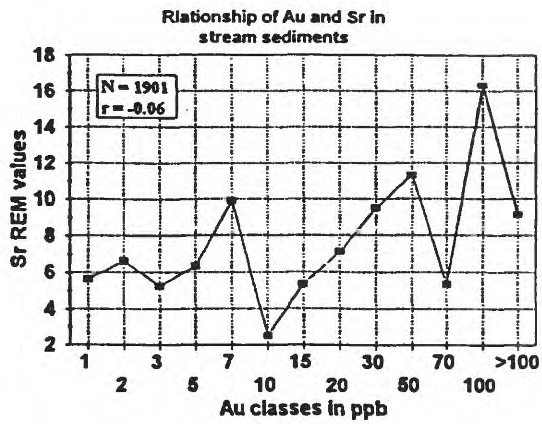


Figure D10. Graphs showing the relationship between gold and suite of individual elements used in the Au-association model for the study area. Values for the individual elements (on the vertical axis) are presented as "element magnitudes" and were calculated using the REM (relative element magnitude) method of Van Trump and Alminas (1978) using USGS and NURE stream sediments. The element magnitude values indicate the relative amount of each element within the overall elemental assemblage that define the Au-association model. This particular elemental assemblage characterizes many of the known deposit types hosting gold within the study area.





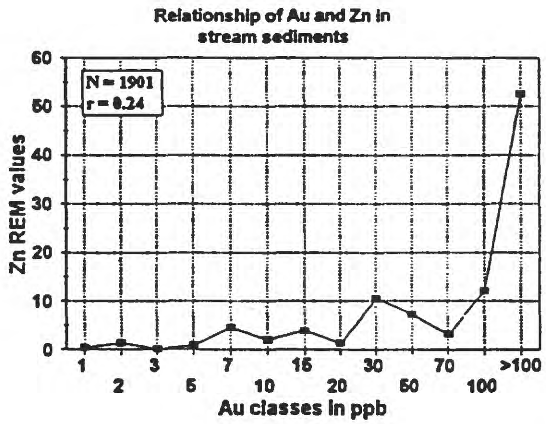


Figure D10 (continued). Graphs showing the relationship between gold and suite of individual elements used in the Au-association model for the study area. Values for the individual elements (on the vertical axis) are presented as "element magnitudes" and were calculated using the REM (relative element magnitude) method of Van Trump and Alminas (1978) using USGS and NURE stream sediments. The element magnitude values indicate the relative amount of each element within the overall elemental assemblage that define the Au-association model. This particular elemental assemblage characterizes many of the known deposit types hosting gold within the study area.

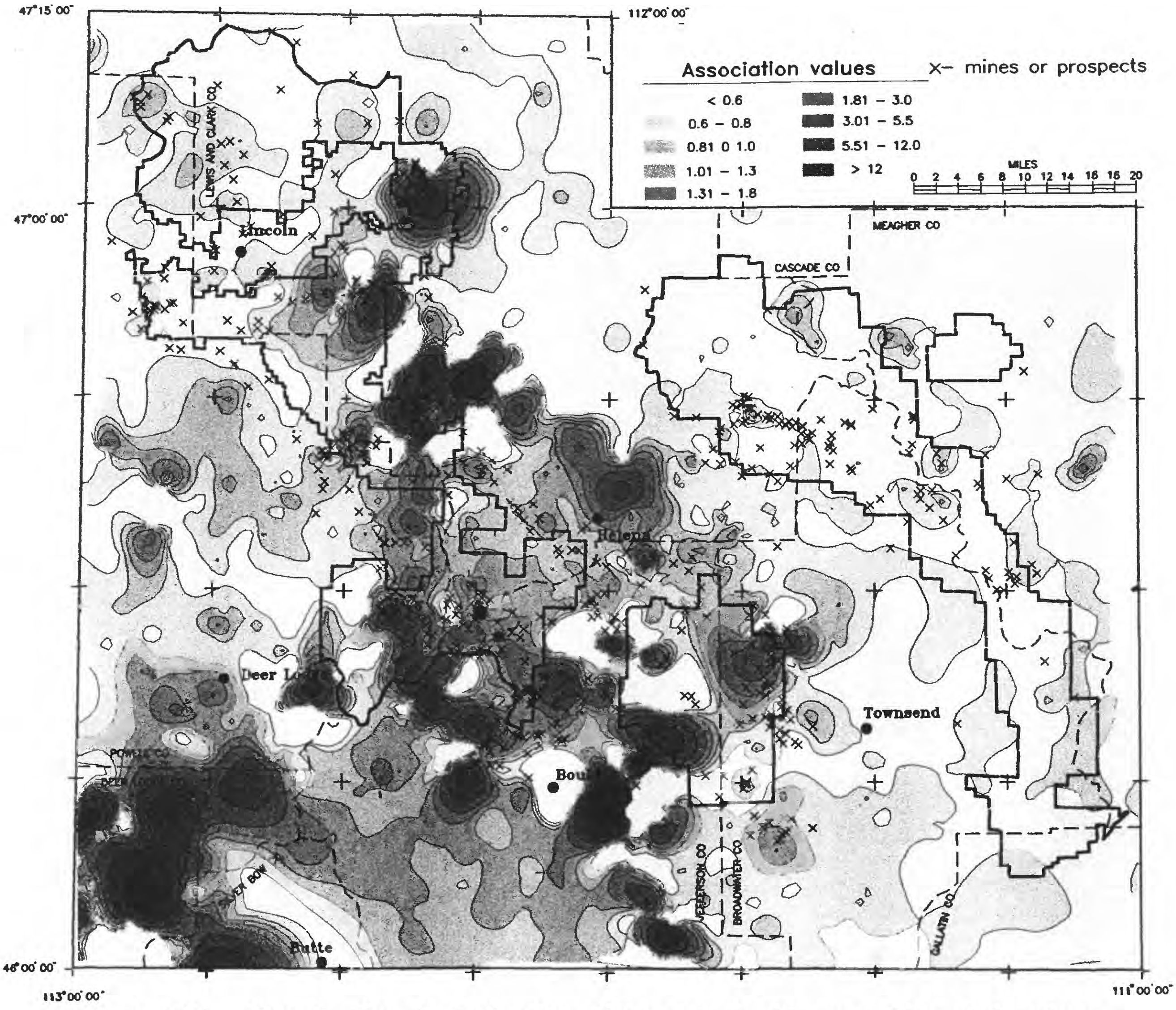


Figure D11. Map showing distribution of Au-association anomalies with values indicating relatively high concentrations of elements (Ag, As, Cd, Cu, Mn, Pb, Sn, Sr, and Zn) within stream sediment samples. Values are in "relative element magnitudes" (unitless) and are from an assemblage of elements expected to occur with gold mineralization. Mines and prospect pits (x) within forest boundary are plotted.

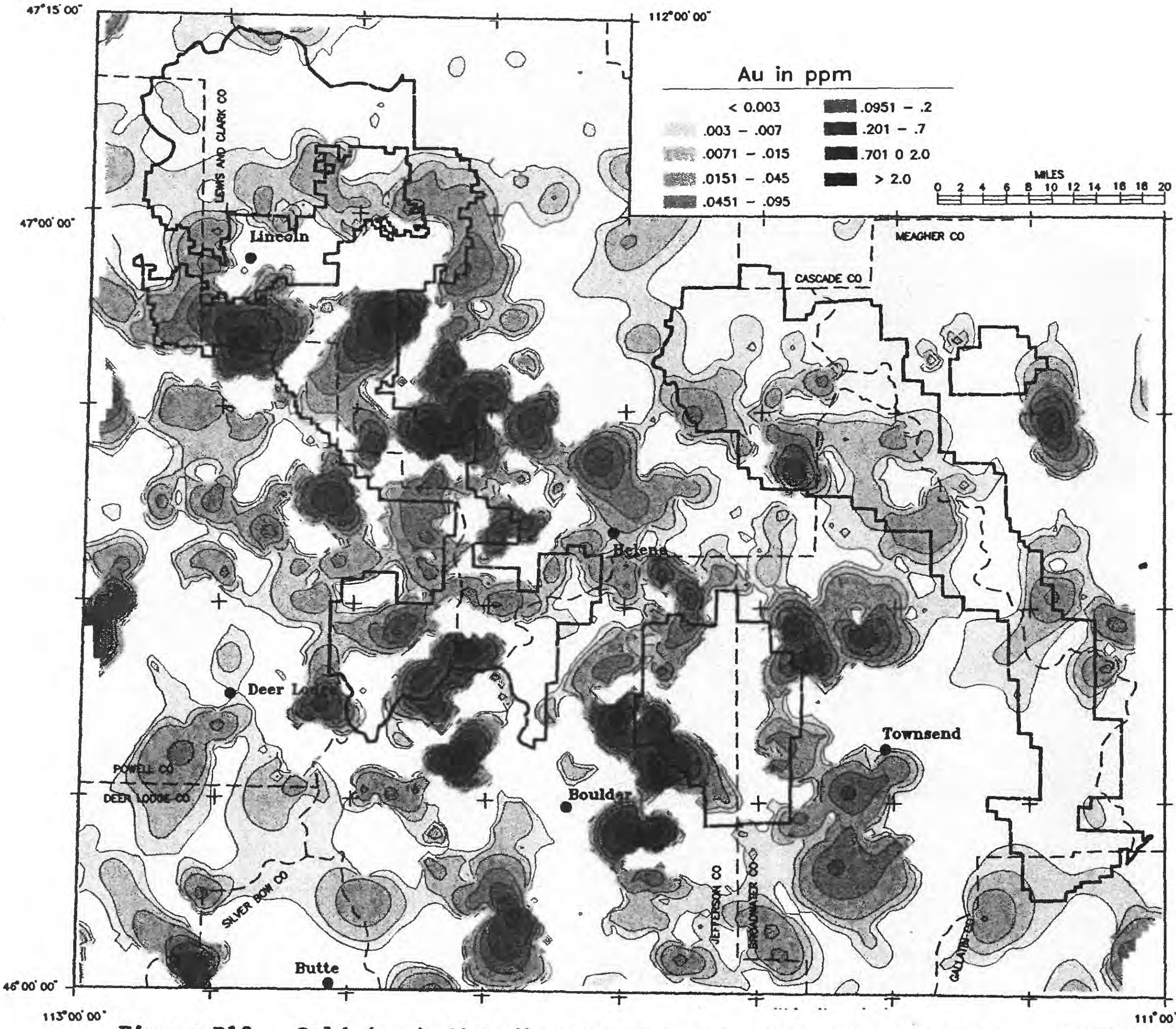


Figure D12. Gold (ppm) distribution in stream sediments from USGS and NURE data within study area.

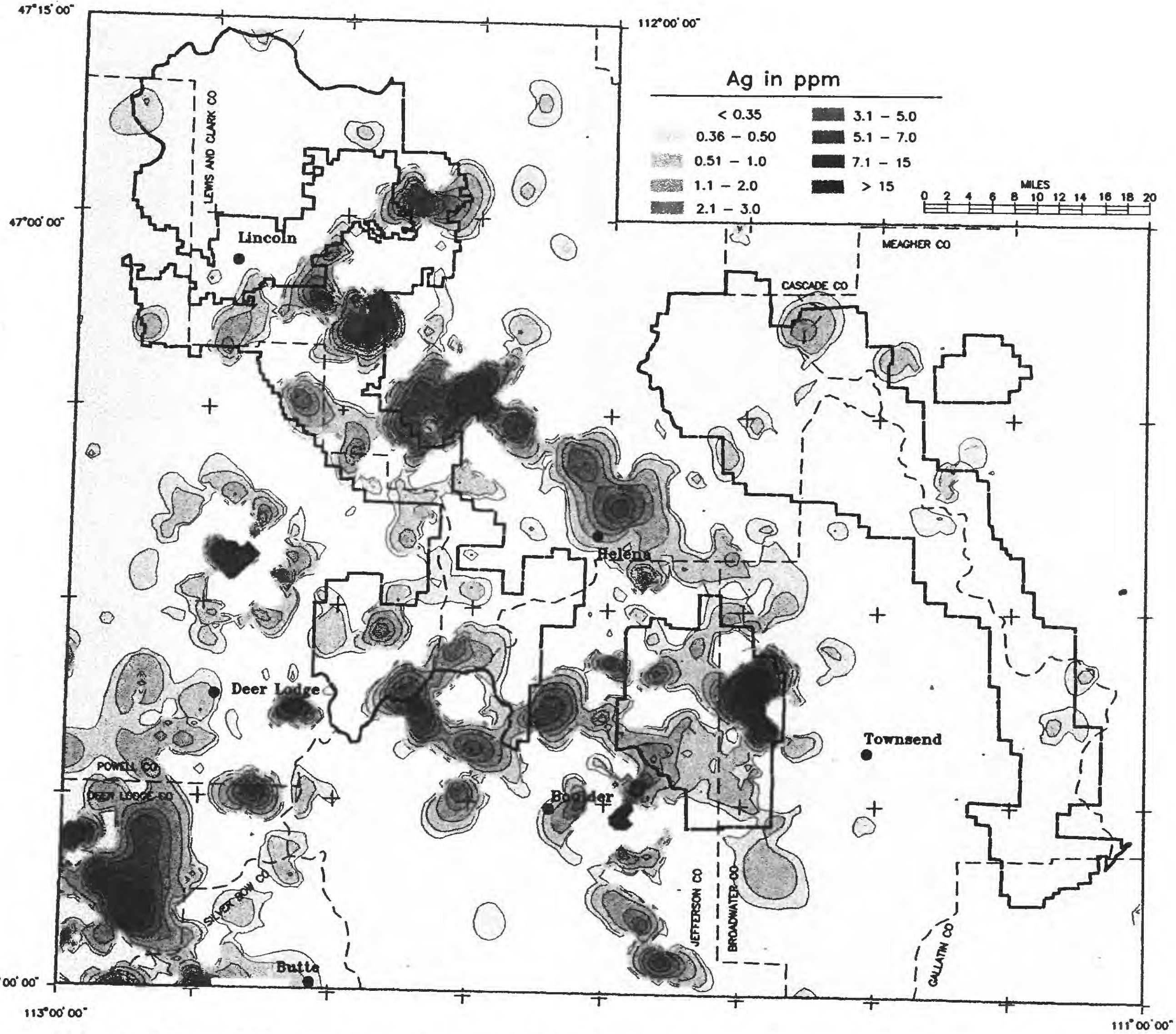


Figure D13. Silver (ppm) distribution in stream sediments from USGS and NURE data within study area.

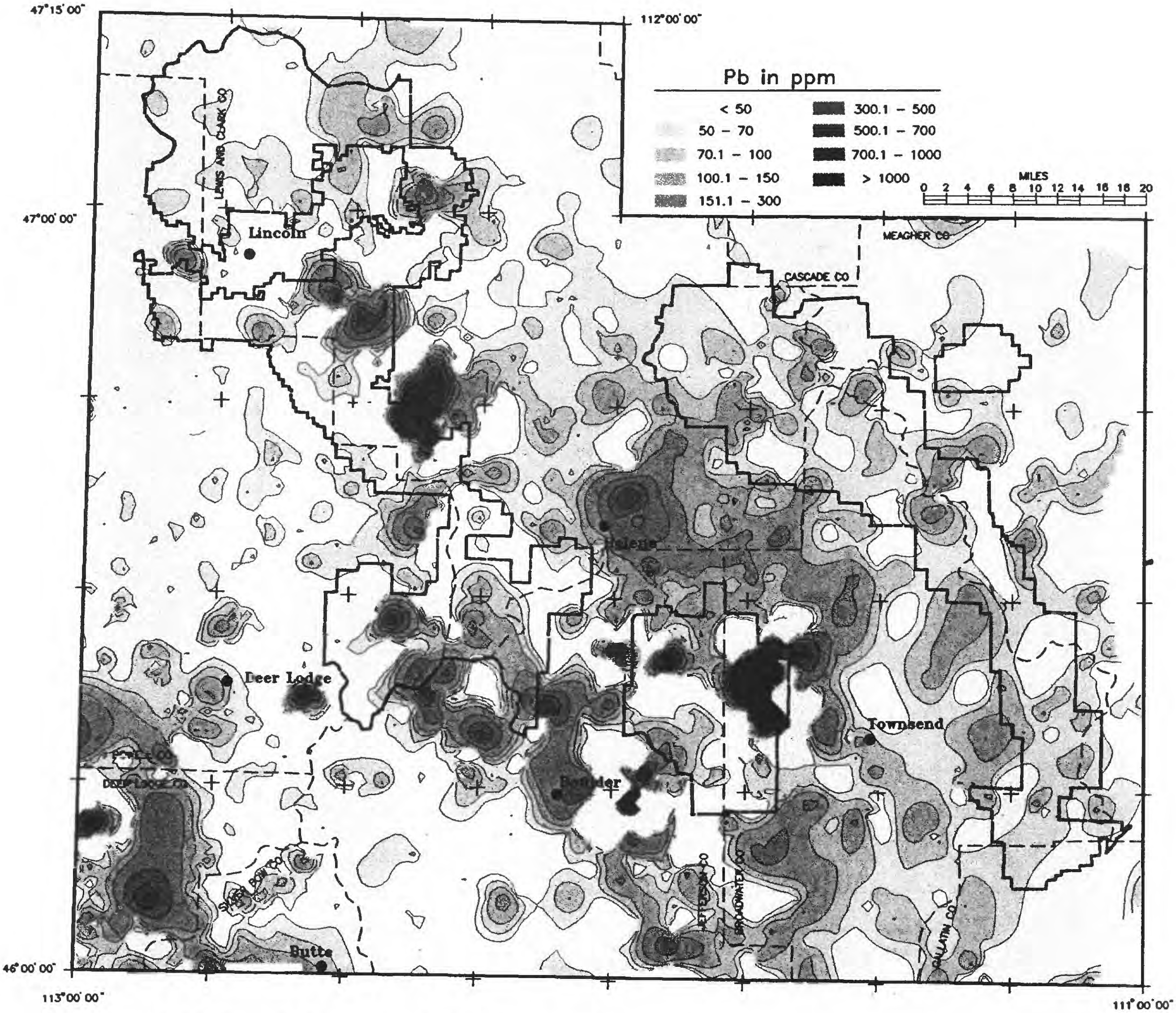


Figure D14. Lead (ppm) distribution in stream sediments from USGS and NURE data within study area.

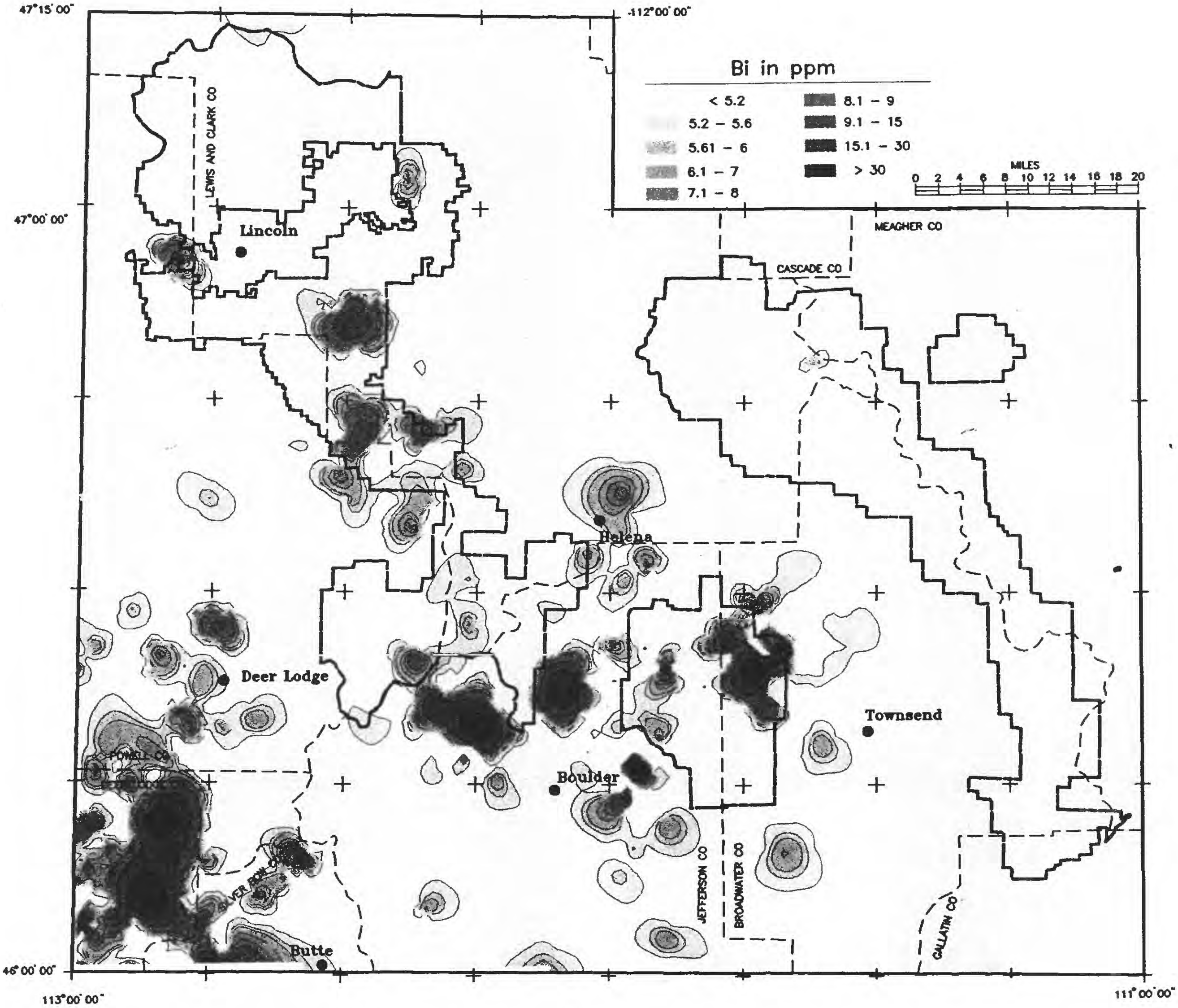


Figure D15. Bismuth (ppm) distribution in stream sediments from USGS and NURE data within study area.

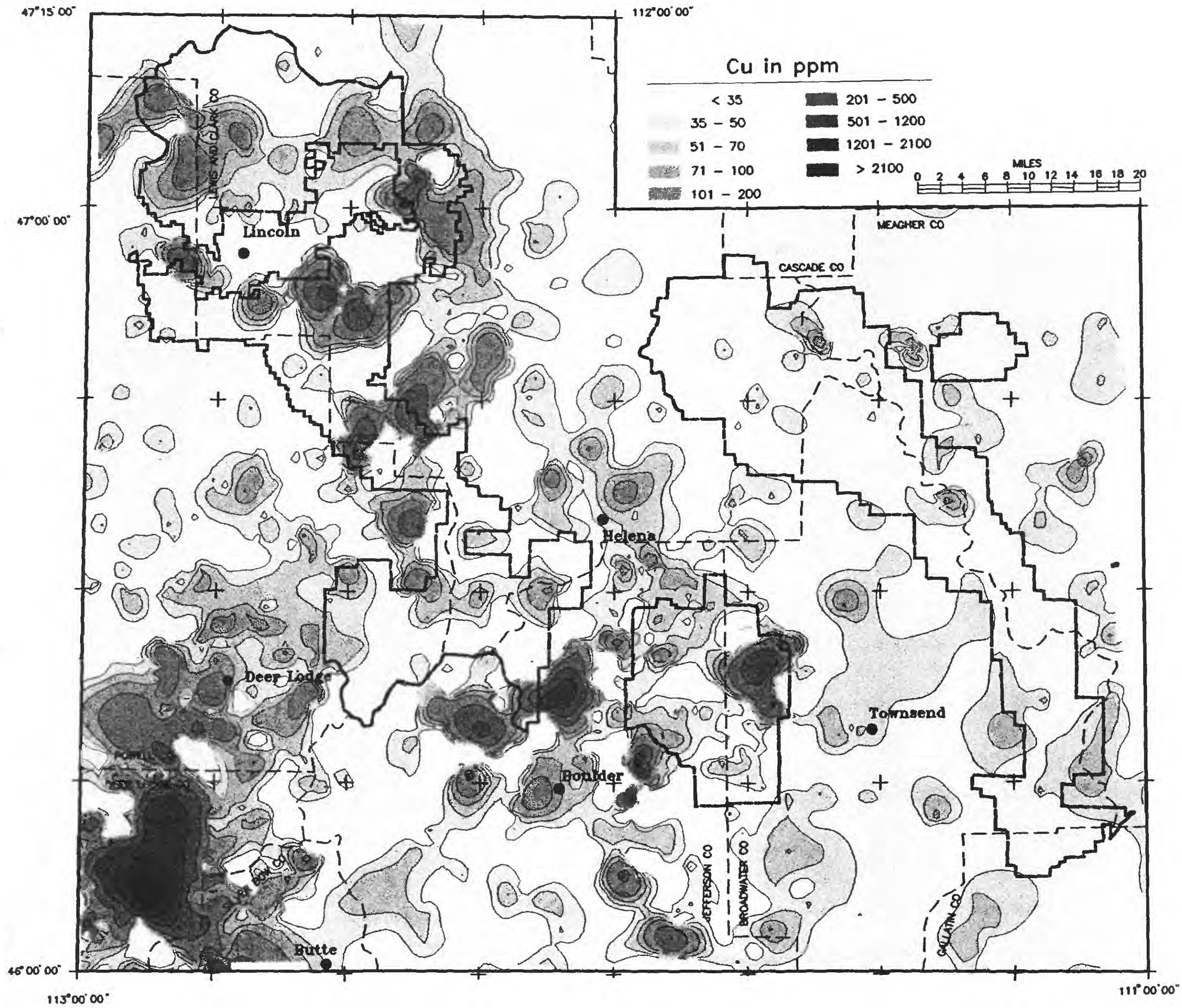


Figure D16. Copper (ppm) distribution in stream sediments from USGS and NURE data within study area.

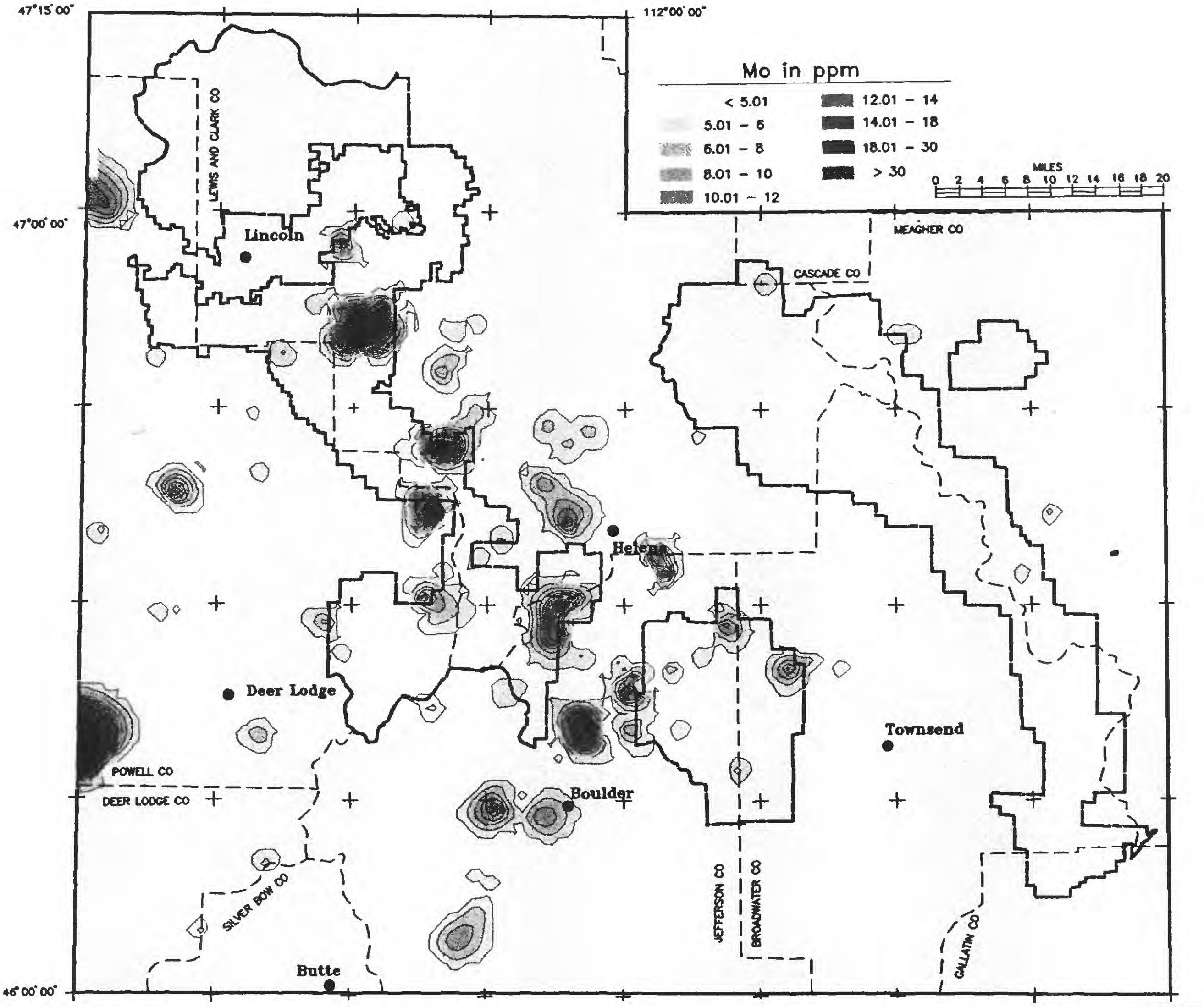


Figure D17. Molybdenum (ppm) distribution in stream sediments from USGS and NURE data within study area.

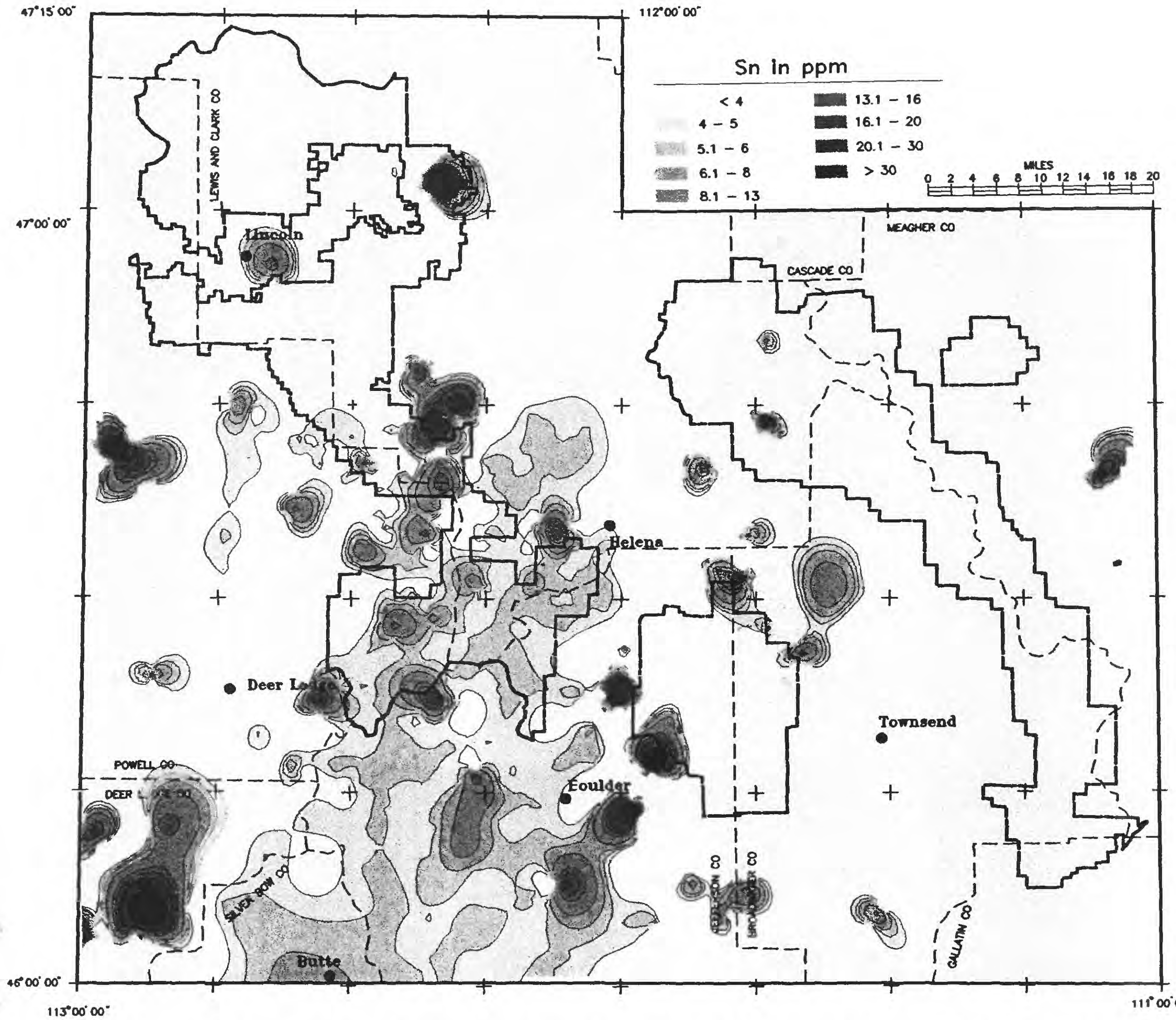


Figure D18. Tin (ppm) distribution in stream sediments from USGS and NURE data within study area.

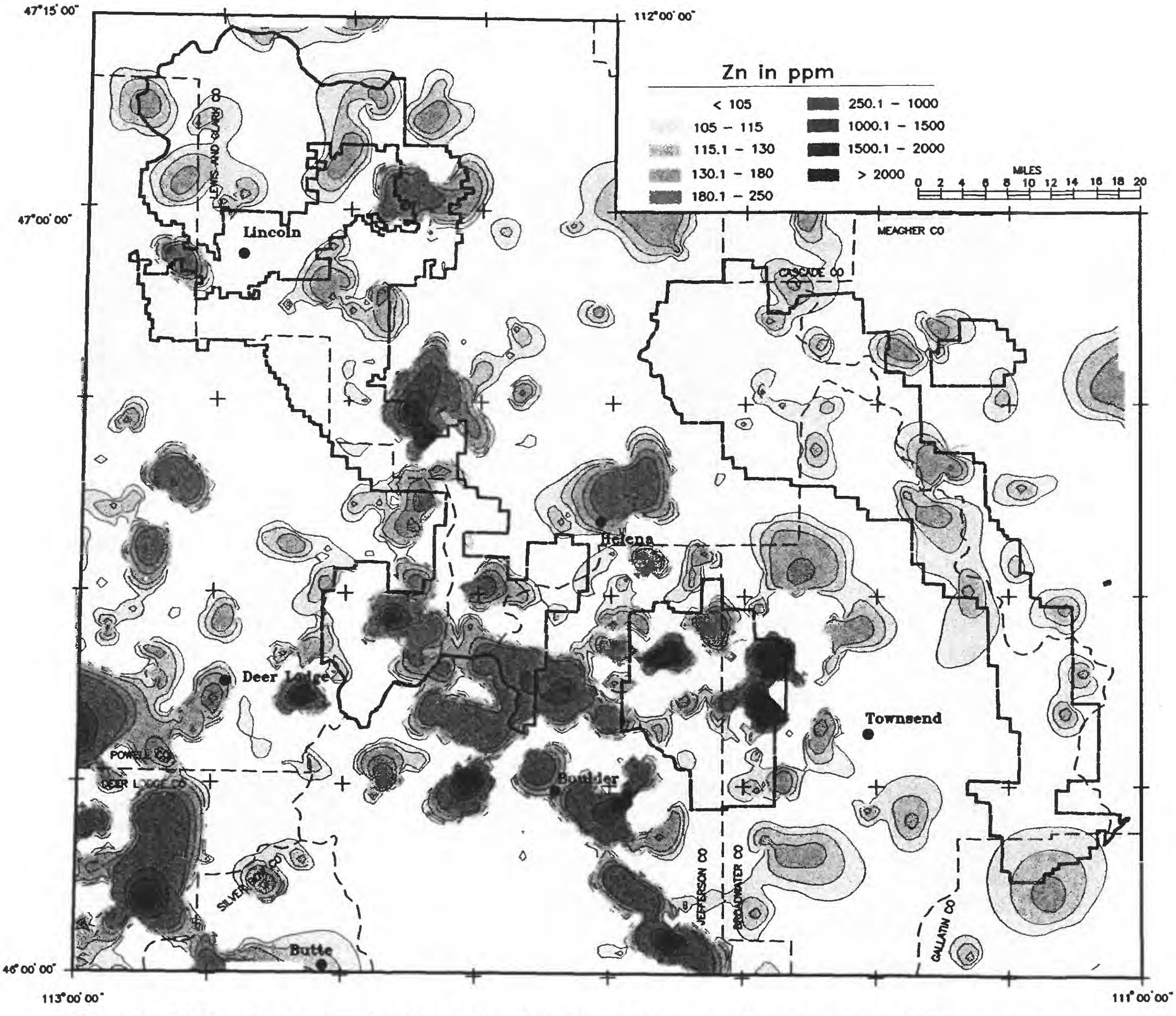


Figure D19. Zinc (ppm) distribution in stream sediments from USGS and NURE data within study area.

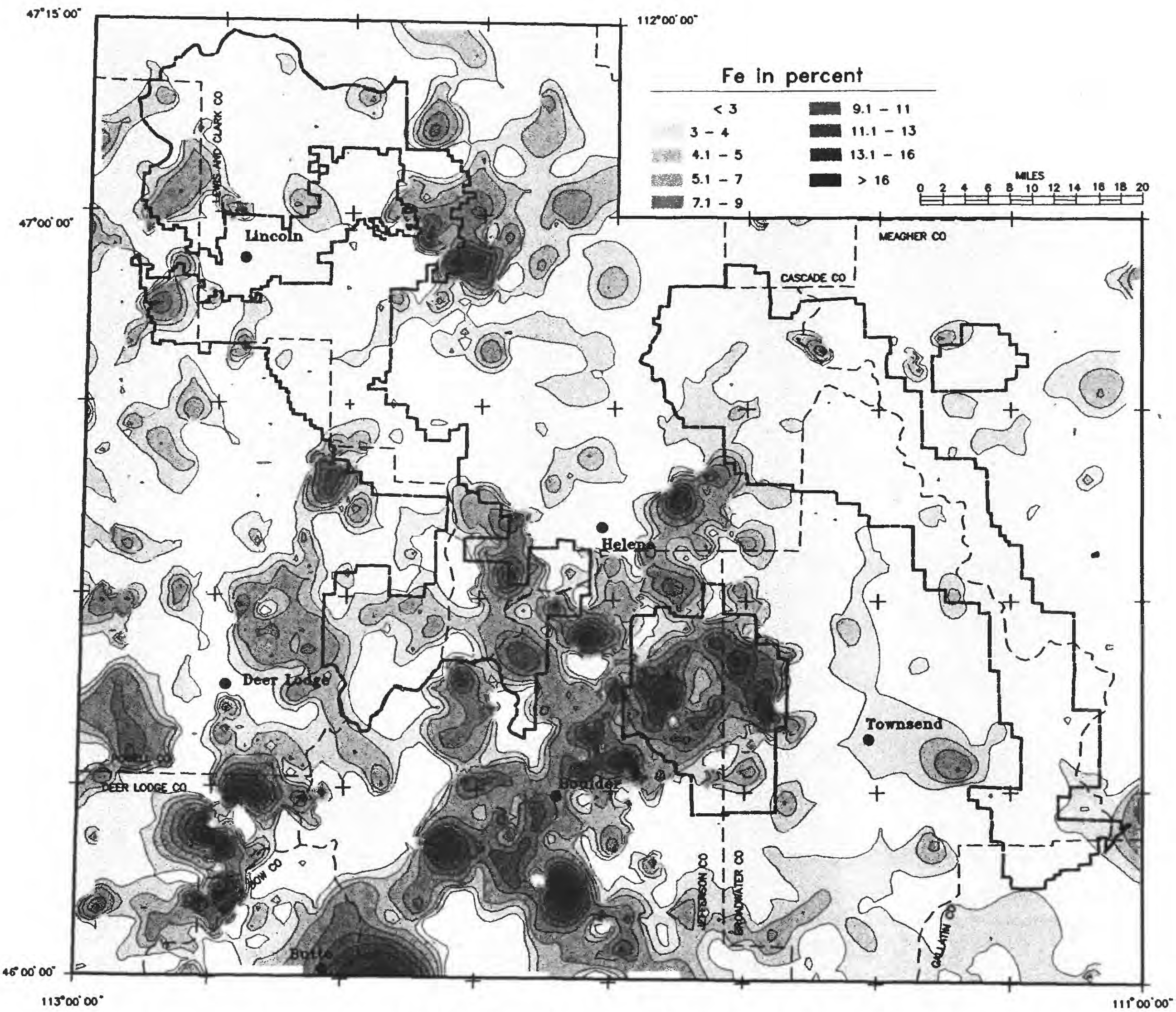


Figure D20. Iron (%) distribution in stream sediments from USGS and NURE data within study area.

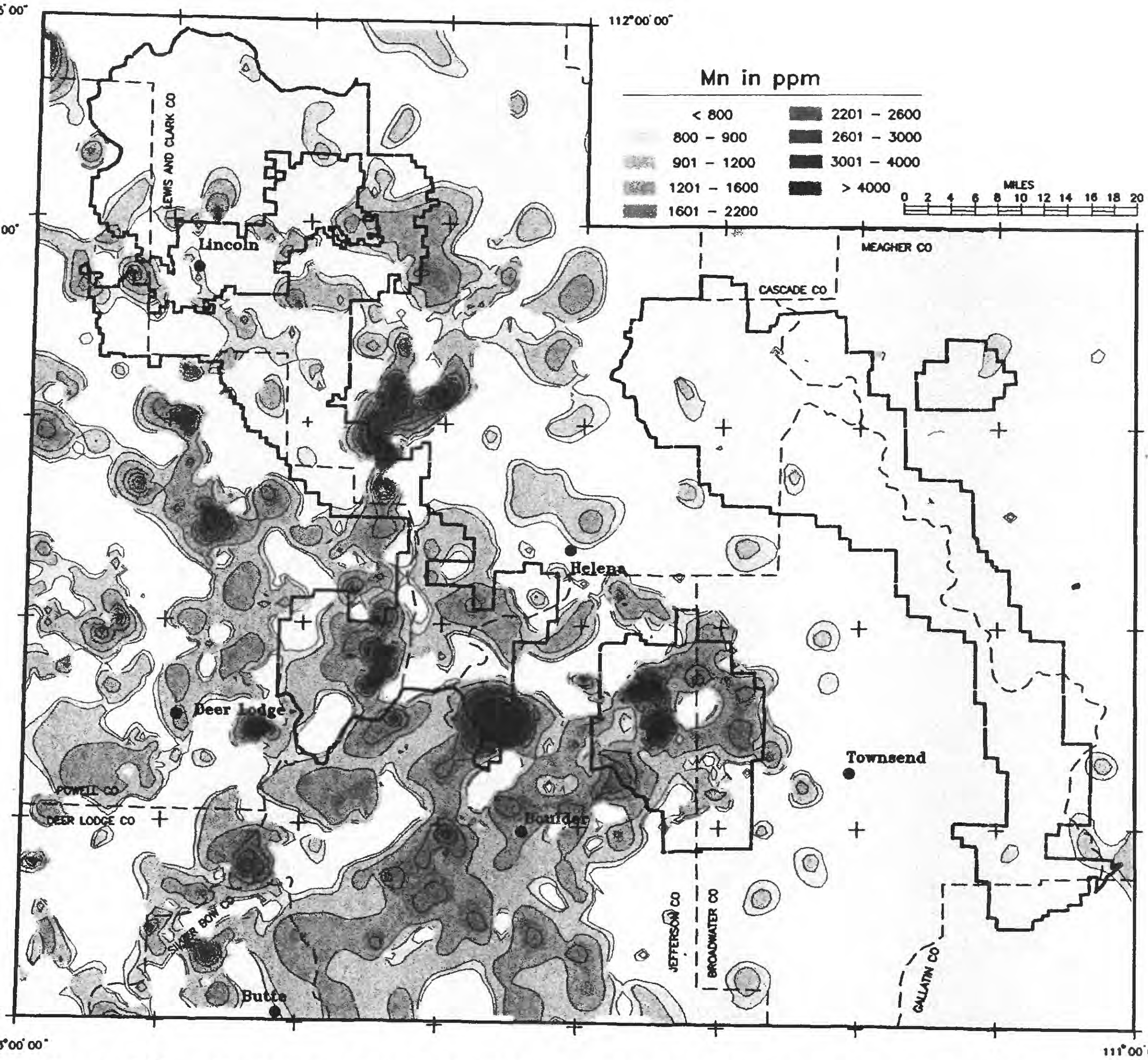
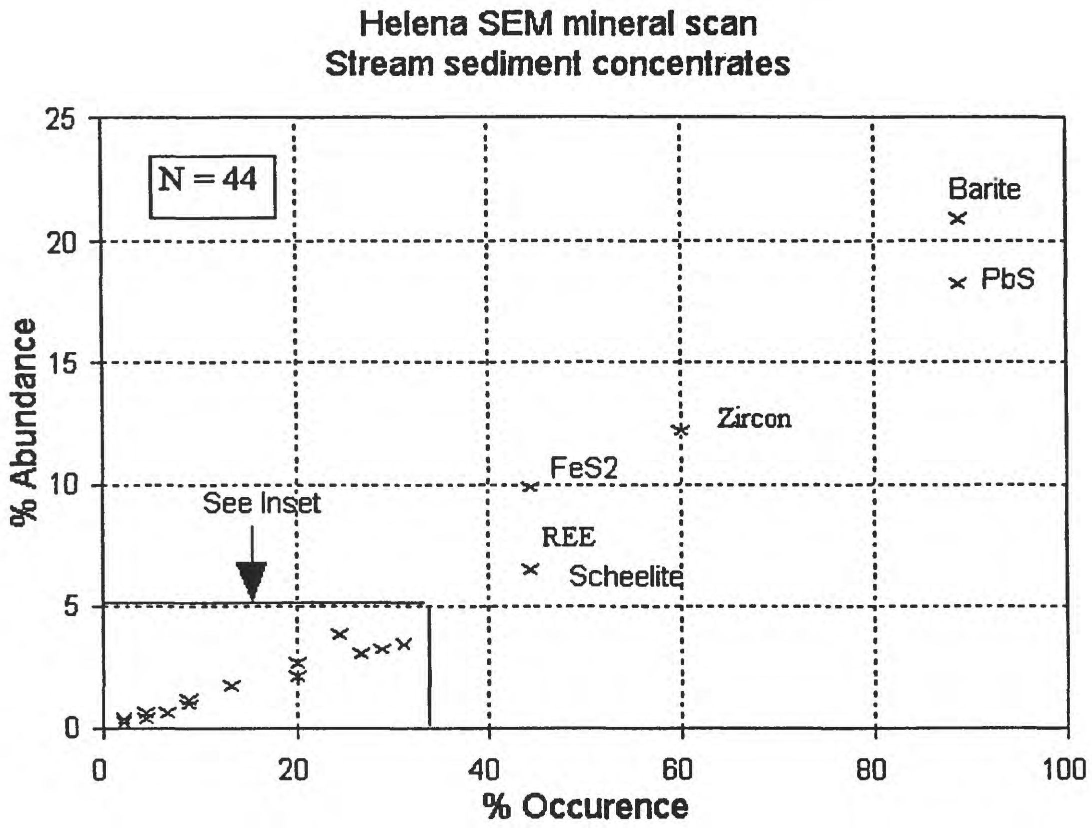


Figure D21. Manganese (ppm) distribution in stream sediments from USGS and NURE data within study area.



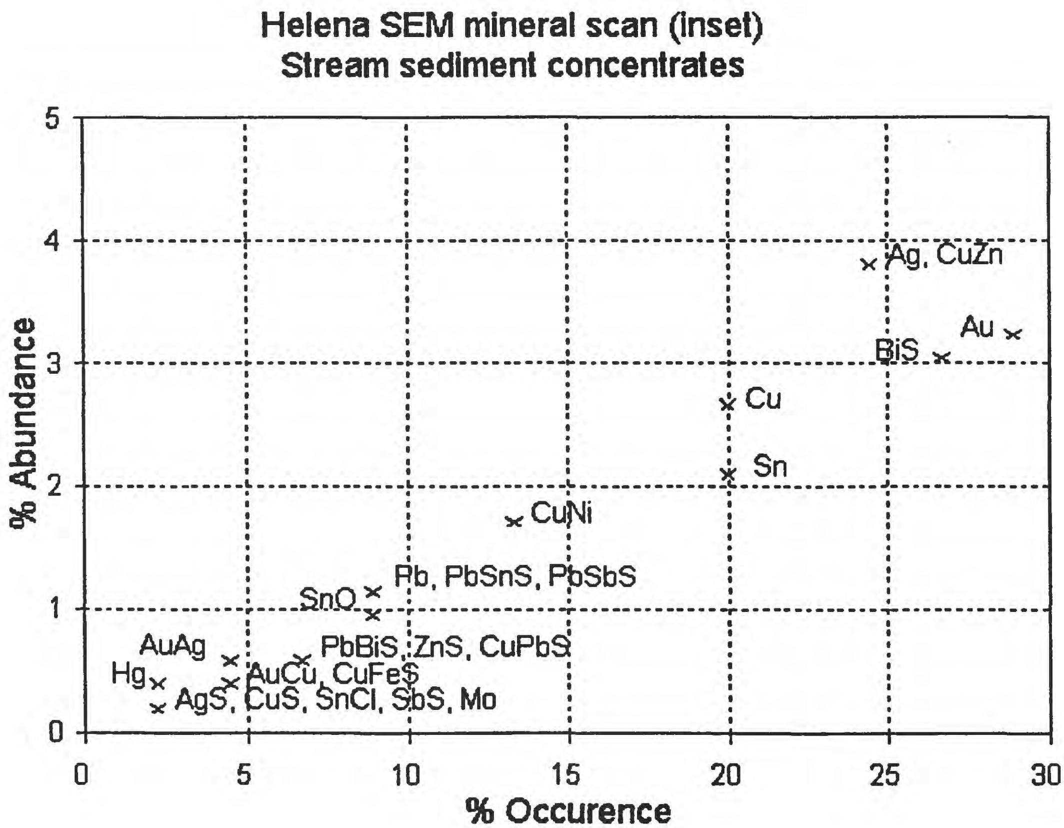
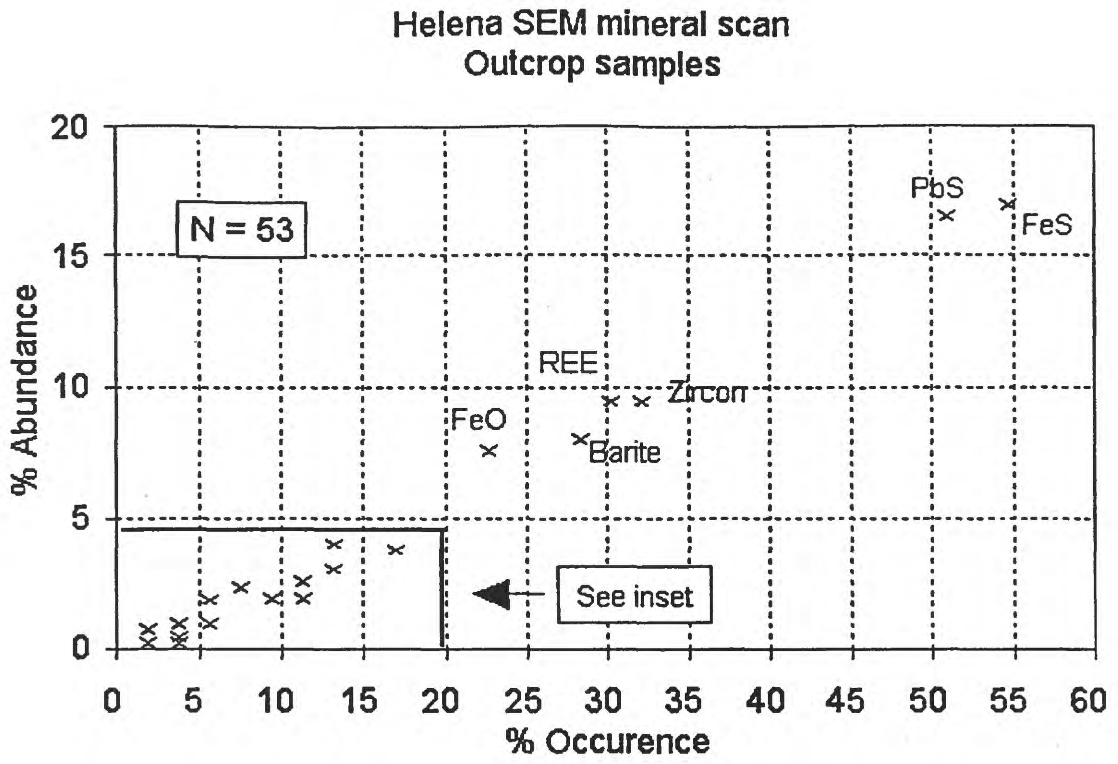


Figure D22. Graphs showing the SEM-EDS determined major composition of heavy mineral concentrates from the study area.



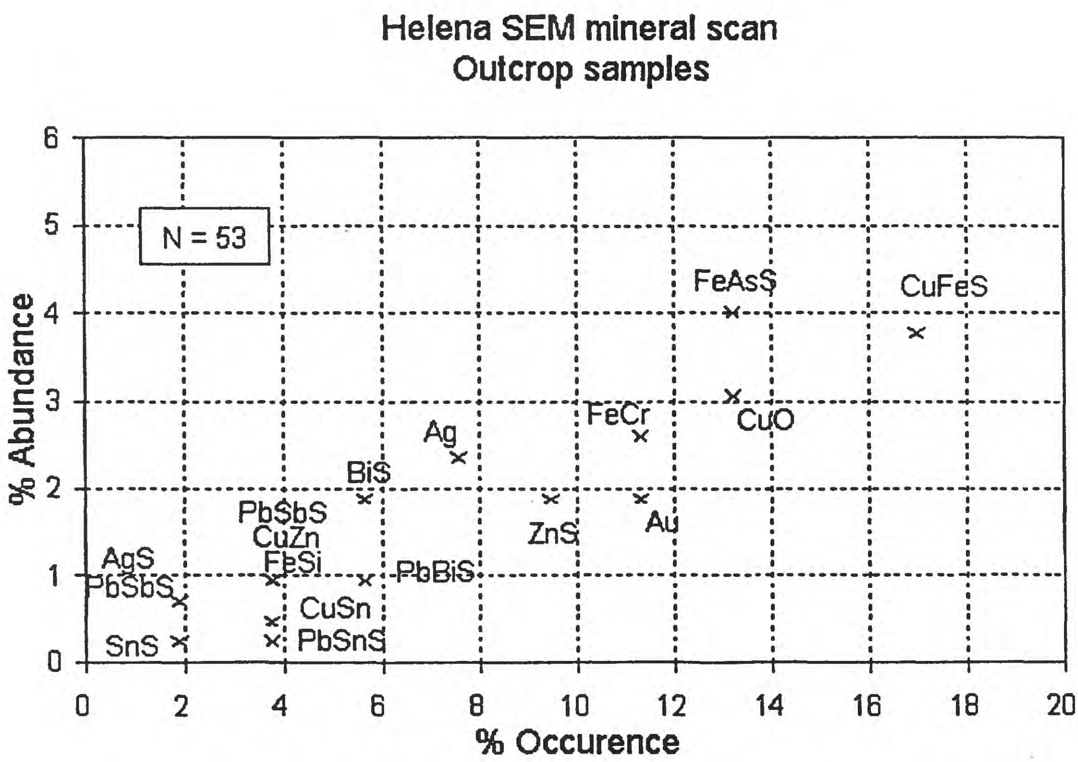


Figure D23. Graphs showing the SEM-EDS determined major composition of slabbed outcrop samples from the study area.

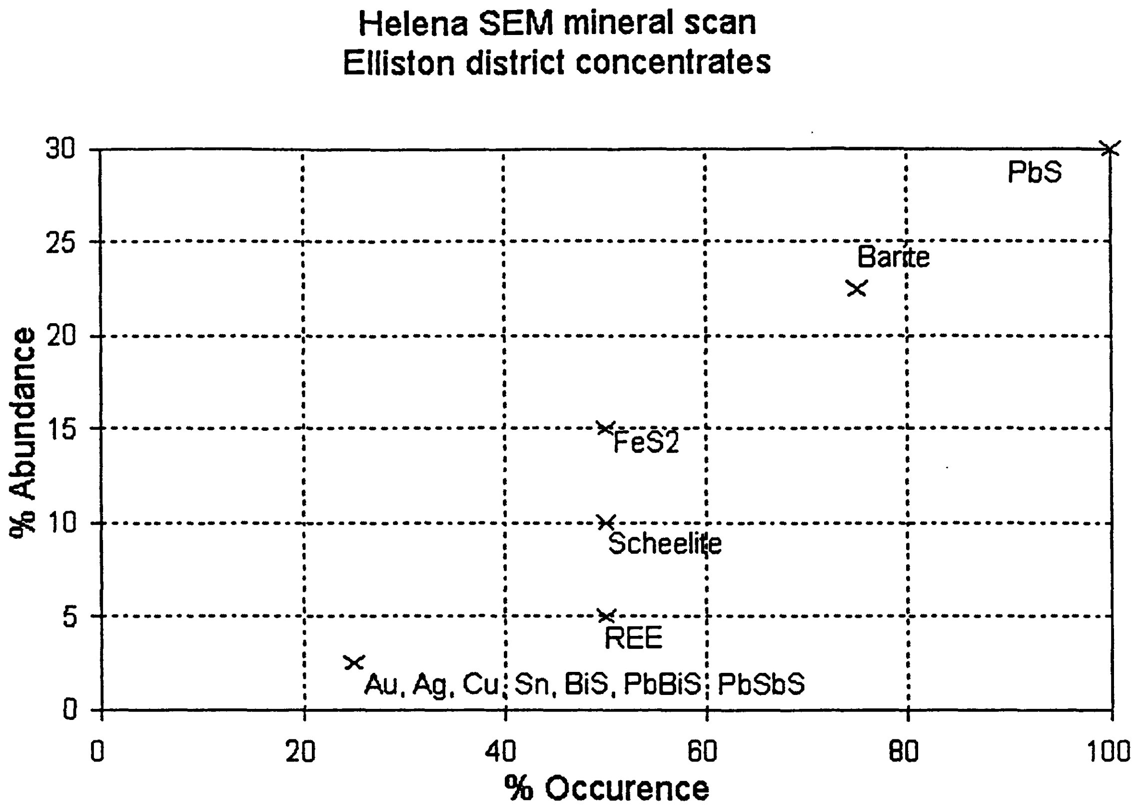


Figure D24. Graphs showing the SEM-EDS determined major composition of heavy mineral concentrates from the Elliston mining disrict.

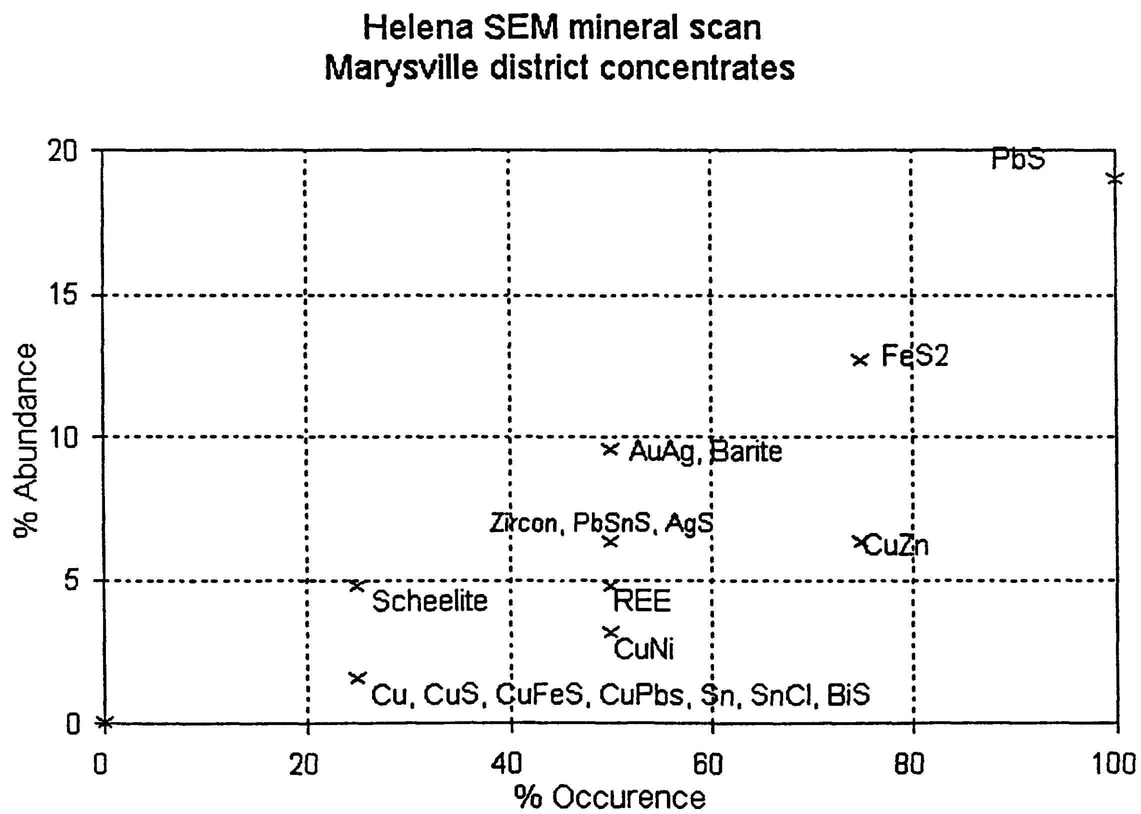


Figure D25. Graphs showing the SEM-EDS determined major composition of heavy mineral concentrates from the Marysville mining district.

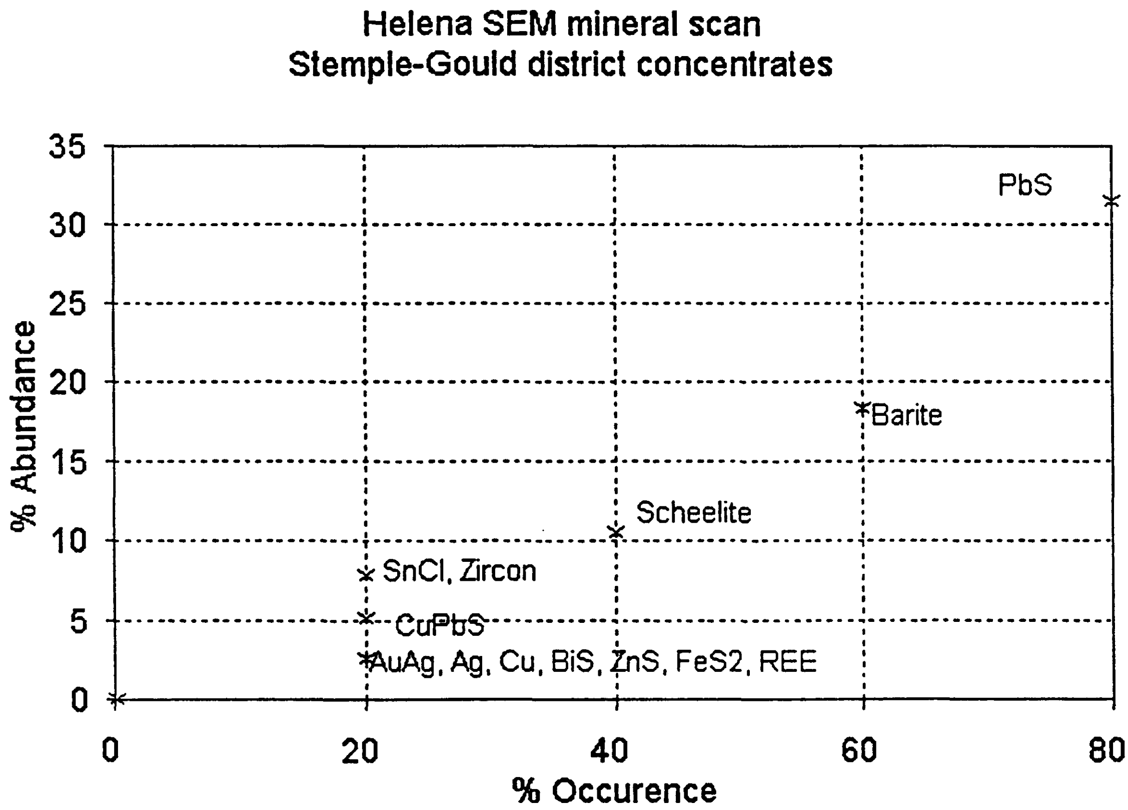


Figure D26. Graphs showing the SEM-EDS determined major composition of heavy mineral concentrates from the Stemple-Gould mining district.

Table D1. Lower limits of determination for the six-step semi-quantitative emission spectrographic analytical method (%, weight percent; ppm, parts per million).

Element	Minimum limit of detection		Element	Minimum limit of detection	
Ca	%	0.05	Ge	ppm	10.0
Fe	%	0.05	La	ppm	50.0
Mg	%	0.02	Mn	ppm	10.0
Na	%	0.20	Mo	ppm	5.0
P	%	0.20	Nb	ppm	10.0
Ti	%	0.02	Ni	ppm	5.0
Ag	ppm	0.50	Pb	ppm	10.0
As	ppm	100.00	Sb	ppm	100.0
Au	ppm	10.00	Sc	ppm	5.0
B	ppm	5.00	Sn	ppm	5.0
Ba	ppm	50.00	Sr	ppm	100.0
Be	ppm	1.00	V	ppm	10.0
Bi	ppm	10.00	W	ppm	20.0
Cd	ppm	20.00	Y	ppm	10.0
Co	ppm	10.00	Zn	ppm	200.0
Cr	ppm	10.00	Zr	ppm	10.0
Cu	ppm	5.00	Th	ppm	100.0
Ga	ppm	5.00			

Table D2. A list of the NURE analytical techniques and elements analyzed for the 2,151 stream sediments used in this report (Grimes, 1984).

Analytical technique	Elements analysed for
Delayed-Neutron Counting	U
Energy Dispersive X-ray Flourescence	Ag, As, Bi, Cd, Cu, Nb, Ni, Pb, Se, Sn, W, Zr
Neutron Activation Analysis	Al, Au, Ba, Ca, Ce, CI, Co, Cr, Cs, Dy, Eu, Fe, Hf, K, La, Lu, Mg, Mn, Na, Rb, Sb, Sc, Sm, Sr, Sr, Ta, Tb, Th, Ti, V, Yb, Zn.

Table D3. Statistical summary of the spectrographic analysis of USGS (RASS) outcrop samples collected within the study area. The list below gives the minimum, maximum, and mean values (in %, weight percent; all other values are in ppm, parts per million) as well as the standard deviations of all unqualified values in addition to the numbers of qualified values.

[Qualifiers on data include: Valid, number of samples used in statistical analysis; B, number of samples not analyzed; L, number of samples detected with spectrographic analysis but measured below lowest standard; N, number of samples not detected; G, number of samples with values greater than the highest standard]

Element	Min.	Max.	Mean	Standard Dev.	Valid	B	L	N	G
Fe%	0.02	50	4.755227	5.111292	1833	0	19	29	35
Mg%	0.03	10	1.502993	1.850895	1862	0	50	0	4
Ca%	0.01	20	4.013549	5.318001	1696	1	148	11	60
Ti%	0.005	1	0.291861	0.253625	1852	0	33	28	3
Mn	5	10000	676.2856	829.7076	1845	10	11	2	48
Ag	0.5	5000	142.8114	435.6688	721	0	111	1080	4
As	50	10000	2132.5	2684.14	240	0	11	1611	54
Au	10	150	26.66667	26.45121	51	7	20	1838	0
B	10	2000	91.11324	226.7479	1307	0	171	376	62
Ba	20	5000	823.6401	830.1956	1728	0	66	108	14
Be	1	150	3.718049	11.25167	1025	0	443	448	0
Bi	10	10000	154.5561	699.767	214	0	49	1642	11
Cd	20	500	136.4835	132.5257	91	0	16	1780	29
Co	5	1500	20.42153	52.18093	1217	0	205	494	0
Cr	7	5000	151.294	322.8122	1439	0	284	193	0
Cu	5	20000	761.5003	2711.267	1599	0	211	97	9
La	20	700	40.32441	41.88604	1233	68	243	372	0
Mo	5	5000	62.46192	290.6244	407	0	66	1440	3
Nb	10	150	41.58333	27.19354	120	0	447	1349	0
Ni	5	700	34.48748	66.0005	1477	0	333	106	0
Pb	10	50000	749.6122	2875.64	1599	10	119	114	74
Sb	30	10000	1248.049	2349.765	164	1	42	1706	3
Sc	5	70	13.08982	8.050104	1258	0	229	429	0
Sn	10	1000	49.54546	113.5765	143	0	36	1737	0
Sr	100	5000	544.0618	406.4169	1263	1	136	516	0
V	10	5000	125.0593	236.9372	1772	0	102	37	5
W	50	1000	120.3571	151.5132	56	0	77	1783	0
Y	7	1000	28.2159	44.54991	1459	1	175	281	0
Zn	200	20000	2282.449	3098.476	245	0	57	1553	61
Zr	10	1000	127.967	105.6292	1697	0	46	172	1

Table D4. Correlation coefficients (given in the upper part of matrix) and number of correlating pairs (given in lower part of matrix) from statistical summary of spectrographic analyses of outcrop samples collected within study area.

	Fe	Mg	Ca	Ti	Mn	Ag	As	Au	B	Ba	Be	Bi	Cd	Co	Cr	Cu
Fe		0.21	-0.01	0.37	0.36	0.22	0.18	0.19	0.18	0.04	0	-0.05	0.04	0.21	0.37	0.07
Mg	1783		0.39	0.31	0.24	-0.14	-0.06	-0.09	-0.06	0.15	0.03	-0.07	-0.01	0.05	0.43	-0.05
Ca	1638	1667	--	-0.04	0.12	-0.08	-0.06	0.26	-0.1	0.01	0.07	-0.05	-0.18	0.02	0.16	-0.09
Ti	1805	1806	1655		0.23	-0.19	-0.14	0.15	0.01	0.36	-0.1	-0.11	-0.04	0	0.28	-0.17
Mn	1768	1794	1635	1789		0.14	-0.02	-0.07	0	0.12	0.09	-0.06	-0.14	0.02	0.1	0.12
Ag	690	694	587	696	676		0.15	0.02	0	-0.13	-0.02	0.04	0.08	-0.01	-0.08	0.22
As	226	229	177	228	220	217		-0.28	0.04	-0.21	0.09	0	0.4	0.07	-0.05	0.09
Au	45	45	33	48	47	50	13		-0.12	0.35	-0.13	-0.09	-0.17	-0.12	-0.25	0.07
B	1296	1284	1204	1306	1270	471	162	23		-0.05	-0.03	0.02	-0.1	0.13	0.07	0
Ba	1697	1691	1545	1699	1669	670	216	46	1254		0.1	-0.17	-0.06	-0.05	0.02	-0.02
Be	1011	1002	944	1015	984	417	142	28	771	978		-0.07	0.15	-0.01	-0.04	0.01
Bi	194	201	154	201	200	197	81	23	123	185	124		0.09	0	-0.07	0.01
Cd	88	85	70	88	78	87	57	10	63	84	53	34		-0.11	-0.24	0.35
Co	1190	1205	1137	1200	1173	467	173	32	939	1182	687	153	67		0.15	0.06
Cr	1411	1421	1317	1413	1397	547	179	29	1060	1381	758	139	70	1057		-0.09
Cu	1563	1570	1435	1568	1542	694	232	51	1137	1520	884	205	87	1133	1302	
La	1217	1214	1128	1221	1199	424	143	19	956	1184	802	107	45	916	994	1075
Mo	397	392	341	400	383	299	114	22	269	375	265	91	43	251	305	386
Nb	120	102	102	119	117	35	4	1	98	96	111	5	0	34	50	69
Ni	1451	1458	1357	1452	1423	576	198	33	1082	1415	801	163	74	1128	1263	1342
Pb	1568	1567	1464	1575	1558	621	194	34	1173	1516	963	171	62	1110	1264	1406
Sb	151	147	115	153	146	156	100	34	102	145	95	73	46	115	106	159
Sc	1241	1255	1203	1253	1222	443	149	18	998	1230	732	118	53	1050	1114	1156
Sn	141	117	116	141	133	101	38	14	87	121	99	41	17	69	87	112
Sr	1216	1257	1187	1229	1234	356	93	13	873	1151	650	80	30	869	1001	1061
V	1707	1750	1599	1728	1709	673	219	47	1243	1638	952	191	85	1202	1397	1524
W	50	53	51	53	52	51	18	1	27	54	37	18	6	38	50	55
Y	1432	1434	1364	1441	1410	508	164	23	1122	1401	865	128	59	1064	1201	1282
Zn	235	237	202	239	219	213	107	19	171	227	168	86	60	173	179	237
Zr	1675	1666	1544	1691	1650	622	206	33	1273	1611	973	162	74	1153	1346	1463

Table D4 (continued). Correlation coefficients (given in the upper part of matrix) and number of correlating pairs (given in the lower part of matrix) from statistical summary of spectrographic analyses of outcrop samples collected within study area.

	La	Mo	Nb	Ni	Pb	Sb	Sc	Sn	Sr	V	W	Y	Zn	Zr
Fe	-0.03	0.05	-0.25	0.31	0.22	0.11	0.5	0.36	0.23	0.22	0.24	-0.05	0.14	0.11
Mg	-0.05	-0.1	-0.28	0.35	-0.17	0.03	0.46	-0.09	0.11	0.09	-0.07	-0.01	-0.09	0.01
Ca	0.06	-0.06	-0.22	0.12	-0.15	0.1	0.2	0.09	0.05	-0.01	0.29	0.15	-0.14	-0.09
Ti	0.08	-0.05	-0.39	0.25	-0.15	-0.1	0.63	-0.12	0.36	0.3	-0.1	-0.03	-0.13	0.37
Mn	-0.03	0.19	-0.09	0.11	0.05	0.16	0.26	0.29	0.17	0.1	0.05	0.03	0.15	0.1
Ag	-0.03	0.53	0.36	0.01	0.29	0.3	-0.14	0.18	-0.02	0.04	0.09	0.03	0.29	0.06
As	-0.15	0.08	0.94	0.09	0.34	0.15	-0.02	0.01	-0.07	-0.02	0.59	-0.06	0.27	-0.02
Au	-0.21	-0.14	*****	0.05	0.3	-0.08	-0.28	0.05	-0.05	0.31	*****	0.65	-0.12	0.4
B	0	-0.04	-0.15	0.06	0.16	-0.08	-0.02	-0.07	-0.13	0.12	-0.04	0	-0.01	-0.01
Ba	0.11	-0.03	-0.36	0.02	-0.16	-0.01	0.12	-0.15	0.3	0.04	-0.21	0.02	-0.04	0.19
Be	-0.02	0.08	0.15	0.01	-0.01	-0.07	0.03	-0.01	-0.1	0.06	0.19	0.05	-0.08	-0.03
Bi	-0.17	-0.08	-0.28	0.06	0.06	-0.04	-0.11	-0.08	-0.11	-0.03	0.47	-0.1	-0.11	-0.14
Cd	-0.26	-0.02	*****	0.04	0.33	0.06	-0.35	0.06	-0.33	-0.12	0.24	-0.17	0.4	0.03
Co	0.01	-0.01	0.26	0.15	0.03	0.01	0.12	-0.08	-0.02	0.05	-0.05	-0.02	-0.06	-0.06
Cr	0.04	-0.06	-0.22	0.65	-0.07	-0.11	0.5	-0.12	0.11	0.21	-0.05	0.08	-0.1	-0.05
Cu	-0.05	0.03	-0.16	0.07	0.23	0.52	-0.14	0.09	-0.12	-0.04	0.12	-0.02	0.21	-0.06
La		0.03	-0.26	0.02	-0.05	-0.05	-0.04	-0.13	0.08	0.09	-0.14	0.78	-0.06	0.18
Mo	259		-0.22	0.07	0.01	-0.06	-0.11	-0.09	0.14	0.2	0.04	0.11	0.49	0.19
Nb	82	22		0.34	0.11	*****	-0.25	0.12	-0.14	-0.23	-1	0.47	-0.03	-0.11
Ni	1016	319	48		-0.06	-0.06	0.39	-0.09	0.09	0.49	-0.08	0	-0.09	0
Pb	1124	364	114	1310		0.08	-0.13	0.2	-0.11	-0.03	-0.08	-0.04	0.25	0.05
Sb	83	68	1	124	109		-0.04	0.14	-0.21	-0.09	0.51	0	0.18	-0.09
Sc	957	262	45	1135	1151	78		-0.25	0.27	0.29	-0.3	0.06	-0.12	0.06
Sn	85	45	44	86	114	43	69		-0.15	-0.14	0.61	-0.11	0.18	-0.22
Sr	888	230	41	995	1091	43	956	44		0.12	-0.01	0.04	-0.04	0.09
V	1181	389	71	1430	1502	147	1252	104	1221		0.21	0.15	0.06	0.1
W	32	30	2	49	50	9	41	13	26	52		0.07	-0.07	0.19
Y	1092	282	110	1206	1315	90	1166	114	1044	1388	41		-0.02	0.11
Zn	153	115	9	207	214	78	159	26	107	234	16	178		0.14
Zr	1191	362	117	1379	1496	112	1240	122	1163	1610	46	1408	212	

Table D5. Percent frequency distributions of spectrographic analyses of USGS (RASS) outcrop samples. Scale: reported spectrographic intervals in % (weight percent) or ppm (parts per million) by element.

	Fe	Mg	Ca	Ti
Scale	%	%	%	%
				N 1.5
				L 1.7
0.002				1.15
0.003				0.78
0.005				1.2
0.007				0.89
0.01				1.98
0.015				3.03
0.02	N 1.5	L 2.6	N 0.6	2.3
0.03	L 1.0	2.77	L 7.7	4.65
0.05	0.99	3.29	5.06	4.59
0.07	0.68	3.91	4.44	5.74
0.1	84	4.44	4.28	6.78
0.15	0.94	3.08	2.71	7.52
0.2	1.83	5.43	3.76	11.22
0.3	3.44	7.83	3.97	14.04
0.5	3.29	6.89	3.71	14.77
0.7	5.58	6.58	3.65	13.83
1	6.05	8.87	5.17	1.98
1.5	9.5	11.59	6.11	G 0.2
2	10.59	11.33	7.67	
3	11.43	8.14	9.34	
5	12.47	4.91	8.87	
7	9.13	3.91	6.21	
10	11.12	0.78	5.01	
15	5.79	G 0.2	3.65	
20	1.62		4.85	
30	0.16		G 3.1	
50	0.21			
70	G 1.8			
N = not detected				
L = detected but below lowest standard				
G = above highest standard				

Table D5 (continued). Percent frequency distributions of spectrographic analyses of USGS (RASS) outcrop samples. Scale: reported spectrographic intervals in % (weight percent) or ppm (parts per million) by element.

	Mn	Ag	As	Au	B	Ba	Be	Bi	Cd	Co	Cr	Cu	La
Scale	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
0.02													
0.03													
0.05													
0.07													
0.1													
0.15													
0.2		N 56.4											
0.3		L 5.8											
0.5		3.59					N 23.4						
0.7		2.09					L 23.1						
1		3.29					15.71						
1.5		1.72					11.9						
2	N 0.1	1.46					11.22			N 25.8		N 5.1	
3	L 0.6	2.3					6.84			L 10.7	N 10.1	L 11.0	
5	0.05	2.35		N 95.9	N 19.6		2.82	N 85.7		10.44	L 14.8	6.21	
7	0.05	1.72		L 1.0	L 8.9		2.35	L 2.6		9.34	0.05	5.58	
10	1.46	2.71		0.63	13	N 5.6	0.99	1.88	N 92.9	12.37	9.34	6.52	N 19.4
15	0.57	1.67		0.73	8.92	L 3.4	0.42	1.2	L 0.8	10.54	8.4	8.09	L 12.7
20	1.72	1.62	N 84.1	0.52	11.33	2.87	0.37	1.46	0.57	9.34	8.87	10.28	22.76
30	2.45	1.88	L 0.6	0.31	7.25	2.51	0.21	1.1	0.42	5.58	11.22	9.13	18.53
50	3.34	1.25	0.1	0.31	7.83	2.92	0.21	0.94	0.78	3.65	9.13	7.83	14.98
70	4.23	1.04	0	0	5.27	4.33	0.1	0.73	0.42	1.2	7.31	5.43	5.22
100	4.65	1.36	0.05	0.1	4.59	4.54	0.21	1.04	0.78	0.31	4.75	3.24	1.67
150	8.72	1.83	0	0.05	2.35	4.53	0.16	1.04	0.57	0.21	2.92	3.29	0.73
200	8.77	1.3	1.51		2.97	5.27		0.37	0.42	0.26	2.87	2.04	0.1
300	9.24	1.3	1.36		1.88	6.47		0.78	0.42	0.1	2.45	1.57	0.16
500	11.64	0.84	1.62		1.2	8.3		0.21	0.37	0.1	1.88	1.77	0.1
700	12.47	0.78	1.04		0.31	11.9		0.1		0	1.3	2.04	0.1
1000	13.26	0.63	1.04		0.47	13.1		0.26		0	3.18	1.46	
1500	7.2	0.52	1.93		0.37	15.15		0		0.05	1.15	1.46	
2000	7.39	0.31	0.78		0.47	6.05		0			0.21	1.51	
3000	1.67	0.16	0.84		G 3.2	2.09		0			0	1.72	
5000	1.46	0.1	0.73			1.15		0			0.05	1.2	
7000	0	G 0.2	0.78			G 0.7		0				0.78	
10000	0.05		0.73					0.05				0.78	
15000	G 2.5		G 2.8					G 0.6				0.68	
20000												0.84	
30000		N = not detected		L = detected but below lowest standard				G = above highest standard				G 0.5	

Table D5 (continued). Percent frequency distributions of spectrographic analyses of USGS (RASS) outcrop samples.
Scale: reported spectrographic intervals in % (weight percent) or ppm (parts per million) by element.

	Mo	Nb	Ni	Pb	Sb	Sc	Sn	Sr	V	W	Y	Zn	Zr
Scale	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
0.02													
0.03													
0.05													
0.07													
0.1													
0.15													
0.2													
0.3													
0.5													
0.7													
1													
1.5													
2	N 75.2		N 5.5			N 22.4							
3	L 3.4		L 17.4			L 12.0					N 14.7		
5	3.97	N 70.4	15.19	N 5.9		12.79	N 90.7		N 1.9		L 9.1		N 9.0
7	2.92	L 25.3	7.76	L 6.2		11.27	L 1.9		L 5.3		0.05		L 2.4
10	3.29	0.37	12.27	6.94		11.33	1.77		6.37		11.17		2.4
15	2.19	0	10.65	7.31	N 89.0	14.2	2.04		6.32		11.27		1.46
20	2.56	2.14	8.66	14.04	L 2.2	10.33	1.25		5.9	N 93.1	25.57		4.12
30	1.83	1.2	6.47	16.54	0.05	5.27	0.68		10.44	L 4.0	18.89		5.22
50	1.3	0.89	4.23	8.72	0	0.37	0.57	N 26.9	9.92	1.1	5.22		6.26
70	0.94	1.2	4.28	6.94	0	0.1	0.37	L 7.1	10.86	0.63	2.14		11.74
100	0.42	0.42	2.61	4.7	1.36		0.26	7.46	9.03	0.52	0.89	N 81.1	18.63
150	0.37	0.05	2.92	2.97	1.2		0.16	5.9	12.06	0.26	0.47	L 3.0	19.36
200	0.73		1.2	1.88	1.25		0.05	6	13.36	0.21	0.21	1.46	12.73
300	0.21		0.26	1.83	0.94		0.1	8.09	5.38	0.05	0	1.46	4.85
500	0.26		0.26	1.51	0.84		0.16	10.13	1.72	0.1	0.1	1.83	0.89
700	0		0.31	0.89	0.89		0	16.81	0.31	0	0.1	1.36	0.63
1000	0.1			1.3	0.31		0.05	8.25	0.31	0.05	0.05	1.36	0.26
1500	0.05			1.25	0.37			2.61	0.16			0.99	G 0.1
2000	0.05			0.99	0.26			0.52	0.21			0.78	
3000	0			1.04	0.16			0.1	0.05			1.04	
5000	0.05			0.99	0.37			0.05	0.1			0.94	
7000	G 0.2			1.1	0.21				G 0.3			0.78	
10000				1.15	0.37							0.68	
15000				0.73	G 0.2							0	
20000				0.57								0.1	
30000				0								G 3.2	
50000				0.05									

N = not detected; L = detected but below lowest standard; G = above highest standard

Table D6. Statistical summary of combined NURE and USGS (RASS) stream-sediment samples collected within the study area. The list below gives the minimum, maximum, and mean values (in %, weight percent; all other values are in ppm, parts per million) as well as the standard deviations of all unqualified values in addition to the numbers of qualified values.

[Qualifiers on data include: Valid, number of samples used in statistical analysis; B, number of samples not analyzed; L, number of samples detected with spectrographic analysis but measured below lowest standard; N, number of samples not detected; G, number of samples with values greater than the highest standard]

Element	Min.	Max.	Mean.	Standard Dev.	Valid	B.	L.	N.	G.
Ca%	0.05	20	1.916317	2.346737	3280	1	1	0	0
Fe%	0.05	30	3.636581	2.832488	3279	1	0	0	2
Mg%	0.07	10	1.17808	0.891853	3281	1	0	0	0
Ti%	0.02	1.428	0.394584	0.210705	3223	3	0	0	56
Ag	0.25	700	3.532681	26.45591	895	1	293	2093	0
As	100	5000	218.1604	459.2371	424	1	24	2832	1
Au	5	30	5.080429	1.319404	373	1	1	2907	0
B	5	1500	48.80307	49.55005	3189	1	27	65	0
Ba	50	3000	678.4487	338.8028	3281	1	0	0	0
Be	0.5	200	2.18178	5.315732	3101	1	144	36	0
Bi	5	100	9.542116	12.71643	463	1	85	2733	0
Cd	10	150	11.76166	11.4871	386	1	4	2891	0
Co	2.5	200	12.54923	9.800403	2783	1	377	119	2
Cr	7	5000	91.84223	153.6821	3277	1	4	0	0
Cu	5	3000	59.17993	136.1145	3279	1	2	0	0
La	14	700	49.52067	44.61053	2395	1	815	71	0
Mn	30	7142.8	895.9095	637.4252	3263	1	0	0	18
Mo	2.5	100	5.90689	9.804083	537	1	147	2597	0
Nb	10	200	16.83667	11.63898	600	1	1487	1194	0
Ni	3.5	200	23.92787	18.01722	3244	1	33	4	0
Pb	10	10000	98.83547	363.6122	3276	1	4	0	1
Sb	50	1500	62.34694	88.69674	392	2	5	2883	0
Sc	3.5	50	9.352137	4.200612	3182	1	96	3	0
Sn	5	150	10.65217	17.08012	460	2	27	2793	0
Sr	50	1500	351.6862	207.9662	2651	1	185	445	0
Th	50	500	53.29787	33.53448	376	162	5	2739	0
V	7	1500	125.0997	119.219	3280	1	1	0	0
W	20	150	26.05943	8.106421	387	2	39	2854	0
Y	5	1500	30.24885	39.98839	3251	1	27	3	0
Zn	100	10000	446.5549	1134.97	537	2	208	2532	3
Zr	15	1428.5	225.4268	169.511	3220	1	0	0	61

Table D7. Correlation coefficients (given in the upper part of matrix) and number of correlating pairs (given in lower part of matrix) from statistical summary of spectrographic analyses of combined NURE and USGS (RASS) samples within study area.

	Ca	Fe	Mg	Ti	Ag	As	Au	B	Ba	Be	Bi	Cd	Co	Cr	Cu
Ca		0.1	0.6	-0.01	-0.02	-0.06	-0.01	-0.05	-0.13	0	-0.07	0.03	-0.03	0.08	-0.03
Fe	3278		0.22	0.58	0	0.13	0.01	0.06	0.01	-0.04	0.09	0.13	0.25	0.3	0.09
Mg	3280	3279		0.14	-0.02	-0.06	0.03	0.05	-0.07	0.07	-0.08	0.01	0.04	0.24	-0.02
Ti	3222	3222	3223		0	0.05	-0.04	0.17	0.13	-0.05	-0.02	-0.07	0.12	0.2	0
Ag	894	894	895	887		0.44	0.24	0.04	0.01	0.05	0.24	0.74	-0.01	-0.01	0.15
As	424	424	424	423	421		0.83	0.09	0.07	0.04	0.49	0.37	0.07	-0.02	0.29
Au	373	373	373	372	373	372		0.01	0.03	-0.01	0.08	1	0	0.02	0.03
B	3189	3187	3189	3134	890	424	373		0.11	0.01	0.03	-0.01	-0.07	0	0.12
Ba	3280	3279	3281	3223	895	424	373	3189		0.05	0.13	0.08	0.02	0.02	0.05
Be	3101	3100	3101	3069	877	422	373	3039	3101		0.06	0.03	-0.03	-0.04	0.11
Bi	462	462	463	461	458	406	372	460	463	457		0.45	0.07	-0.03	0.77
Cd	386	386	386	385	386	379	372	386	386	386	378		0.05	-0.03	0.37
Co	2783	2781	2783	2725	819	416	373	2695	2783	2623	450	385		0.16	0.06
Cr	3276	3275	3277	3219	894	424	373	3186	3277	3097	463	386	2783		0
Cu	3278	3277	3279	3221	895	424	373	3187	3279	3099	463	386	2782	3275	
La	2395	2394	2395	2352	760	409	373	2314	2395	2259	440	382	2287	2392	2394
Mn	3262	3261	3263	3205	884	417	373	3173	3263	3083	459	383	2766	3259	3261
Mo	537	537	537	531	435	378	371	528	537	526	385	379	523	537	537
Nb	600	599	600	585	416	373	371	596	600	587	377	374	573	600	600
Ni	3244	3242	3244	3186	890	424	373	3155	3244	3073	462	386	2774	3242	3243
Pb	3275	3274	3276	3218	894	424	373	3184	3276	3098	462	386	2782	3273	3274
Sb	392	392	392	391	392	386	371	391	392	391	383	375	387	392	392
Sc	3181	3180	3182	3124	879	424	373	3097	3182	3018	462	385	2755	3181	3181
Sn	460	459	460	457	417	389	371	456	460	453	389	379	445	460	460
Sr	2651	2649	2651	2625	832	422	373	2564	2651	2511	453	382	2380	2649	2650
Th	376	376	376	375	371	371	371	376	376	375	371	371	376	376	376
V	3279	3278	3280	3222	895	424	373	3188	3280	3101	463	386	2783	3276	3278
W	387	387	387	386	383	376	371	387	387	386	380	374	385	387	387
Y	3251	3249	3251	3193	890	424	373	3162	3251	3080	462	386	2771	3248	3250
Zn	537	536	537	532	498	412	371	533	537	525	418	383	522	536	537
Zr	3219	3219	3220	3166	878	424	373	3135	3220	3062	461	386	2722	3216	3218

Table D7 (continued). Correlation coefficients (given in the upper part of matrix) and number of correlating pairs (given in the lower part of matrix) from statistical summary of spectrographic analyses of combined NURE and USGS (RASS) samples within study area.

	La	Mn	Mo	Nb	Ni	Pb	Sb	Sc	Sn	Sr	Th	V	W	Y	Zn	Zr
Ca	-0.04	0.04	-0.08	-0.15	0	0	0.02	0.07	-0.03	0.09	-0.02	0.08	-0.04	-0.02	-0.06	-0.05
Fe	0.25	0.35	-0.02	0.2	0.14	0.07	0	0.55	0.09	0.16	0.34	0.83	0.21	0.2	0.03	0.34
Mg	-0.08	0.12	-0.09	-0.17	0.26	0.02	0	0.27	0.01	0.08	-0.04	0.15	0.02	0.01	-0.05	0
Ti	0.15	0.31	-0.07	-0.01	0.14	-0.03	-0.1	0.54	-0.07	0.17	0.16	0.52	0.02	0.16	-0.11	0.37
Ag	-0.01	0	0.29	0.06	0	0.16	0.82	-0.02	0.28	-0.05	-0.01	-0.02	0.7	0	0.36	-0.02
As	0.01	0.15	0.06	0.08	0.05	0.57	0.2	0.12	0.2	0	-0.01	0	0.21	-0.03	0.44	-0.05
Au	-0.02	-0.02	*****	*****	0.13	0.14	*****	0.02	*****	-0.03	*****	-0.02	*****	-0.04	*****	-0.02
B	-0.04	0.21	-0.01	-0.02	-0.02	0.05	0.04	0.01	-0.03	-0.15	0.04	0.02	-0.05	0.05	0.04	0.08
Ba	-0.01	0.17	0.04	-0.08	0.23	0.04	0.01	0	0.12	0.41	-0.11	-0.06	0.05	-0.02	0.1	0.07
Be	-0.02	0.23	0.27	0.19	-0.03	0.24	0.3	-0.07	0.08	-0.05	-0.02	-0.06	0.04	0.03	0.24	-0.02
Bi	0.09	0.03	0.2	0.12	0	0.42	0.26	0	0.44	0.02	-0.01	-0.03	0.59	-0.03	0.32	-0.05
Cd	0.02	0.04	0.11	0.41	0	0.67	0.94	0.02	0.28	0.03	*****	-0.05	0.99	0.16	0.73	-0.05
Co	0.05	0.22	0.23	0.08	0.32	0.01	0.02	0.29	0.03	0.02	0	0.19	0.03	0.05	0.05	0.07
Cr	-0.01	0.1	-0.05	0.05	0.45	-0.02	-0.02	0.29	0.01	0.05	0.03	0.35	0.02	0.02	-0.04	0.05
Cu	0	0.14	0.34	0	0	0.44	0.34	0.02	0.26	0	-0.01	0.02	0.51	0	0.37	-0.02
La		0.05	-0.01	0.36	-0.04	-0.01	0	0.11	0.16	0.08	0.74	0.17	0.18	0.18	0	0.2
Mn	2381		0.16	0.03	0.04	0.22	0.05	0.24	0.06	0.13	0.02	0.26	0.09	0.13	0.28	0.12
Mo	518	530		0.06	0.12	0.18	0.22	-0.04	0.17	0	0.01	-0.05	0.06	0.03	0.55	-0.02
Nb	560	598	406		0.04	0.08	0	0.09	0.59	-0.09	0.03	0.04	0.12	0.22	0.22	0.12
Ni	2379	3226	533	592		-0.04	0.01	0.29	0.12	0.09	-0.05	0.1	0.04	-0.02	0.03	0
Pb	2394	3258	537	600	3241		0.72	0	0.14	-0.01	-0.02	-0.02	0.69	0.05	0.6	-0.02
Sb	383	386	377	372	392	392		-0.04	0.28	-0.11	0	-0.06	-0.04	-0.07	0.7	-0.06
Sc	2356	3164	530	587	3168	3181	391		-0.02	0.15	0.04	0.45	0.18	0.15	-0.03	0.3
Sn	431	452	388	386	459	460	380	459		-0.04	0.13	-0.04	0.09	0.07	0.32	-0.03
Sr	2089	2637	509	574	2635	2650	387	2600	441		-0.01	0.07	0.07	-0.02	-0.04	0
Th	376	376	373	373	376	376	371	376	373	375		0.25	0	0.61	-0.01	0.25
V	2395	3262	537	600	3244	3275	392	3182	460	2651	376		0.09	0.15	-0.08	0.31
W	384	386	380	375	387	387	372	386	374	384	371	387		0.1	0.1	0.04
Y	2382	3233	536	600	3222	3248	391	3171	459	2636	376	3251	387		0.24	0.19
Zn	507	523	409	383	537	536	388	532	402	516	371	537	377	536		-0.07
Zr	2336	3202	525	571	3183	3215	392	3122	456	2592	375	3219	383	3190	530	

Table D8. Percent frequency distributions of spectrographic analyses of combined NURE and USGS (RASS) stream-sediment samples.

[Scale: reported spectrographic intervals in % (weight percent) or ppm (parts per million) by element.

	Ca	Fe	Mg	Ti	Ag	As	Au	B	Ba	Be	Bi	Cd	Co	Cr	Cu	La
Scale	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
0.02				0.03												
0.03				0.03												
0.05	0.03	0.03		0.15												
0.07	0.03	0	0.12	0.7												
0.1	0.34	0	0.24	1.25	N 63.8											
0.15	1.16	0.12	0.43	6.55	L 8.9											
0.2	1.86	0.03	0.94	13.32	9.2					N 1.1						
0.3	7.65	0.09	4.51	37.75	1.01					L 4.4						
0.5	7.77	0.12	8.59	23.1	4.39					0.79						
0.7	12.74	1.31	26.51	11.06	3.38					1.55						
1	11.7	1.89	25.17	4.17	2.41					12.92			N 3.6			
1.5	22	12.52	18.25	0.09	1.77					39.79			L 11.5			
2	16.64	23.28	9.81	G 1.7	1.16			N 2.0		27.42	N 83.8		0.15			
3	9.57	32.91	3.84		0.79		N 88.6	L 0.8		7.07	L 2.6		0.06		L 0.1	
5	3.11	14.72	0.82		0.88		11.3	0.79		2.47	10.69	N 88.1	3.9	L 0.1	0.52	
7	2.59	6.76	0.61		0.46		0	0.12		1.49	0.27	L 0.1	16.76	0.03	0.85	N 2.2
10	1.58	3.93	0.12		0.58		0.03	4.72		0.49	1.1	11.3	31.9	0.55	1.16	L 24.8
15	0.82	1.61			0.4		0	6		0.06	0.43	0	19.71	1.89	5.55	0.4
20	0.37	0.55			0.27		0	16		0.09	0.55	0.18	9.45	3.63	18.22	9.2
30		0.03			0.3		0.03	26.97		0.03	0.49	0	2.25	7.86	36.38	21.69
50		G 0.1			0.09	N 86.3		17.06	0.12	0.12	0.3	0.09	0.27	20.48	18.71	30.2
70					0.06	L 0.7		13.59	0.06	0.09	0.21	0.09	0.18	32.27	6.2	6.58
100					0.06	10.94		6.64	0.15	0.06	0.06	0.06	0	20.81	3.72	1.98
150					0	0		3.17	2.1	0		0.03	0.03	6.95	2.96	2.04
200					0	0.34		1.58	3.9	0.03			0.12	2.22	1.4	0.46
300					0.03	0.39		0.4	13.65				g 0.1	1.31	0.34	0.12
500					0	0.21		0.09	22.27					0.94	0.64	0.21
700					0.03	0.24		0	32.27					0.46	0.7	0.09
1000						0.18		0	19.53					0.27	0.27	
1500						0.4		0.03	5.12					0	0.15	
2000						0.03			0.7					0.09	0.12	
3000						0.03			0.09					0.06	0.03	
5000						0.06								0.03		
		N = not detected		L = detected but below lowest standard					G - above highest standard							

Table D8 (continued). Percent frequency distributions of spectrographic analyses of combined NURE AND USGS (RASS) stream-sediment samples.

[Scale: reported spectrographic intervals in % (weight percent) or ppm (parts per million) by element.

	Mn	Mo	Nb	Ni	Pb	Sb	Sc	Sn	Sr	Th	V	W	Y	Zn	Zr
Scale	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
0.02															
0.03															
0.03															
0.05															
0.07															
0.1															
0.15															
0.2															
0.3															
0.5															
0.7															
1		N 79.1													
1.5		L 4.5		N 0.1			N 0.1								
2		8.65		L 1.0			L 2.9	N 85.1					N 0.1		
3		0.98		0.43			0.34	L 0.8					L 0.8		
5		2.93	N 36.4	3.87			13.32	10.66					0.03		
7		1.83	L 45.3	4.54	L 0.1		28.85	0			0.03		0.06		
10		0.91	7.01	10.94	0.64		26.6	0.67			0.18	N 87.0	2.5		
15		0.43	3.6	21.72	1.31		12.43	0.91			0.12	L 1.2	8.65		0.18
20		0.24	6.06	24.68	5.42	N 87.8	4.88	0.7	N 13.6	N 83.5	0.58	11.4	31.51		0.12
30	0.03	0.03	1.13	20.35	30.2	L 0.2	0.52	0.49	L 5.6	L 0.2	4.24	0.09	41.8		0.76
50	0.03	0.27	0.34	7.31	24.59	11.12	0.03	0.24	0.55	11.18	9.78	0.18	9.96	N 77.1	1.28
70	0.27	0	0.09	3.69	14.69	0.06		0.06	0.34	0.06	26.66	0.09	3.5	L 6.3	4.02
100	0.52	0.09	0.03	0.98	10.21	0.34		0.21	5.48	0.12	25.75	0	0.7	9.9	8.5
150	1.65		0.03	0.3	7.53	0.21		0.06	8.99	0.03	18.19	0.03	0.12	0.3	29.62
200	2.41			0.03	2.16	0.06			13.01	0	7.62		0.12	1.92	28.61
300	6.61				0.85	0.03			24.71	0	3.63		0.03	0.82	16.61
500	13.41				0.49	0.06			18.37	0.06	1.55		0	0.61	4.02
700	35.31				0.37	0.03			7.19		1.16		0	1.1	2.65
1000	21.6				0.55	0			1.95		0.37		0	0.58	1.4
1500	11.49				0.3	0.03			0.18		0.09		0.06	0.43	0.34
2000	4.11				0.15									0.06	G 1.9
3000	1.31				0.09									0.37	
5000	0.43				0.18									0.12	
7000	0.24				0.06									0	
10000	G 0.5				0.03									0.15	
		N = not detected		L = detected but below lowest standard				G = above highest standard						G 0.1	

Table D9. Statistical summary of spectrographic analyses of combined NURE and USGS (RASS) stream sediments analyzed for gold. The list below gives the minimum, maximum, and mean values (in %, weight percent; all other values are in ppm, parts per million) as well as the standard deviations of all unqualified values in addition to the numbers of qualified values.

[Qualifiers on data include: Valid, number of samples used in statistical analysis; B, number of samples not analyzed; L, number of samples detected with spectrographic analysis but measured below lowest standard; N, number of samples not detected; G, number of samples with values greater than the highest standard]

ELEMENT				STANDARD					
	MIN.	MAX.	MEAN	DEV.	VALID	B	L	N	G
CA	0.050	20.000	1.713	2.277	1899	1	1	0	0
FE	0.050	20.000	3.082	2.155	1900	1	0	0	0
MG	0.070	10.000	1.025	0.788	1900	1	0	0	0
TI	0.020	1.428	0.347	0.186	1880	2	0	0	19
AG	0.250	100.000	1.947	6.558	641	1	149	1110	0
AS	100.000	3000.000	163.092	272.092	401	1	22	1477	0
AU	5.000	5.000	5.000	***	371	1	1	1528	0
B	5.000	500.000	38.400	30.742	1896	1	3	1	0
BA	50.000	3000.000	611.994	293.187	1900	1	0	0	0
BE	0.500	100.000	1.915	3.247	1861	1	38	1	0
BI	5.000	70.000	8.002	9.734	419	1	34	1447	0
Cd	10.000	150.000	10.765	8.618	379	1	4	1517	0
CO	2.500	200.000	14.094	9.313	1435	1	358	105	2
CR	7.000	2000.000	83.618	85.722	1899	1	1	0	0
CU	5.000	3000.000	56.112	126.270	1899	1	1	0	0
LA	14.000	700.000	52.867	38.889	1040	1	793	67	0
MN	30.000	7142.857	760.761	631.421	1896	1	0	0	4
MO	2.500	100.000	4.240	6.841	403	1	77	1420	0
NB	10.000	70.000	14.733	6.587	499	1	1008	393	0
NI	3.500	150.000	23.476	15.832	1881	1	15	4	0
PB	10.000	7000.000	101.031	310.170	1896	1	4	0	0
SB	50.000	1500.000	59.267	85.849	382	1	3	1515	0
SC	3.500	30.000	9.037	3.815	1846	1	52	2	0
SN	5.000	100.0000	8.289	11.232	415	1	12	1473	0
SR	50.000	1000.000	297.317	171.563	1465	1	135	300	0
TH	50.000	500.000	51.586	23.641	372	1	1	1527	0
V	10.000	1500.000	110.826	91.198	1899	1	1	0	0
W	20.000	70.000	25.250	3.082	380	1	13	1507	0
Y	5.000	200.000	27.781	13.201	1887	1	11	2	0
ZN	100.000	10000.000	326.773	869.953	437	1	168	1295	0
ZR	15.000	1428.571	219.906	175.282	1884	1	0	0	16

Table D10. Correlation coefficients (given in the upper part of matrix) and number of correlating pairs (given in the lower part of matrix) from statistical summary of spectrographic analyses of combined NURE and USGS (RASS) samples for gold within study area.

	Ca	Fe	Mg	Ti	Ag	As	Au	B	Ba	Be	Bi	Cd	Co	Cr	Cu
Ca		0.05	0.63	-0.09	-0.02	-0.09	*****	-0.02	-0.2	-0.05	-0.12	0.05	-0.07	0.09	-0.04
Fe	1899		0.17	0.56	0	0.01	*****	0.04	0.06	-0.08	-0.02	0.01	0.26	0.37	0.11
Mg	1899	1900		0.03	0.03	-0.09	*****	0.03	-0.17	-0.02	-0.1	0.02	0.01	0.23	-0.02
Ti	1879	1880	1880		-0.12	-0.01	*****	0.19	0.12	-0.09	-0.11	-0.09	0.1	0.2	0.03
Ag	640	641	641	639		0.4	*****	0	0.03	0.24	0.41	0.88	0.04	-0.01	0.36
As	401	401	401	400	400		*****	0.07	0.05	0.05	0.6	0.1	0.06	0	0.39
Au	371	371	371	370	371	371		*****	*****	*****	*****	*****	*****	*****	*****
B	1896	1896	1896	1876	640	401	371		0.07	0	-0.06	0	-0.09	-0.02	-0.03
Ba	1899	1900	1900	1880	641	401	371	1896		0.09	0.06	-0.06	0.1	0.08	0.09
Be	1861	1861	1861	1846	640	401	371	1858	1861		0.07	0.01	-0.04	-0.06	0.18
Bi	418	419	419	418	419	394	371	418	419	418		0.24	0.07	-0.03	0.85
Cd	379	379	379	378	379	376	371	379	379	379	375		0.02	-0.01	0.29
Co	1435	1435	1435	1415	571	393	371	1432	1435	1412	406	378		0.23	0.08
Cr	1898	1899	1899	1879	641	401	371	1895	1899	1860	419	379	1435		0.01
Cu	1898	1899	1899	1879	641	401	371	1895	1899	1860	419	379	1435	1898	
La	1040	1040	1040	1033	513	386	371	1040	1040	1033	398	376	960	1040	1040
Mn	1895	1896	1896	1876	637	398	371	1892	1896	1857	417	378	1432	1895	1895
Mo	403	403	403	402	380	374	371	402	403	403	374	373	392	403	403
Nb	499	499	499	492	390	372	371	498	499	495	375	371	478	499	499
Ni	1881	1881	1881	1861	639	401	371	1878	1881	1847	418	379	1435	1880	1881
Pb	1895	1896	1896	1876	641	401	371	1892	1896	1859	419	379	1435	1896	1895
Sb	382	382	382	381	382	380	371	382	382	382	378	375	378	382	382
Sc	1845	1846	1846	1826	635	401	371	1843	1846	1817	419	379	1433	1846	1846
Sn	415	415	415	414	399	385	371	415	415	415	385	376	400	415	415
Sr	1465	1465	1465	1455	606	400	371	1462	1465	1447	414	377	1217	1465	1465
th	372	372	372	371	371	371	371	372	372	372	371	371	372	372	372
V	1898	1899	1899	1879	641	401	371	1895	1899	1861	419	379	1435	1898	1898
w	380	380	380	379	378	375	371	380	380	380	377	373	378	380	380
Y	1887	1887	1887	1867	639	401	371	1884	1887	1854	418	379	1435	1887	1886
Zn	437	437	437	435	425	394	371	437	437	435	397	379	425	437	437
Zr	1883	1884	1884	1864	639	401	371	1880	1884	1848	418	379	1419	1883	1883

Table D10 (continued). Correlation coefficients (given in the upper part of matrix) and number of correlating pairs (given in the lower part of matrix) from statistical summary of spectrographic analyses of combined NURE and USGS (RASS) samples for gold within study area.

	La	Mn	Mo	Nb	Ni	Pb	Sb	Sc	Sn	Sr	Th	V	W	Y	Zn	Zr
Ca	-0.1	0.02	-0.06	-0.25	-0.01	0.01	0.04	-0.03	-0.08	0.04	-0.01	0.04	-0.03	-0.11	-0.05	-0.08
Fe	0.19	0.28	-0.03	-0.02	0.21	0.05	0.01	0.57	-0.05	0.2	0.24	0.82	0.1	0.39	-0.01	0.38
Mg	-0.12	0.08	-0.08	-0.23	0.15	0.09	0.01	0.14	-0.03	0	-0.03	0.11	0.11	-0.06	-0.05	-0.03
Ti	0.09	0.25	-0.06	0.02	0.11	-0.04	-0.09	0.49	-0.11	0.14	0.1	0.53	-0.02	0.36	-0.13	0.37
Ag	0.03	0.14	0.22	0.05	0.02	0.66	0.84	-0.05	0.33	-0.12	-0.01	-0.06	0.51	-0.07	0.74	-0.06
As	0.04	0.13	0.04	0.06	0.07	0.44	0.23	0.04	0.22	-0.04	-0.01	-0.01	-0.16	-0.03	0.39	-0.06
Au	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
B	-0.03	0.21	-0.03	-0.08	-0.04	0.04	0	-0.02	-0.05	-0.17	0.02	0.01	-0.05	0.17	0.02	0.1
Ba	0	0.16	0.02	-0.03	0.23	0.05	-0.02	0.07	0.08	0.29	-0.08	0.02	-0.02	0.08	0.05	0.13
Be	-0.03	0.4	0.35	0.09	-0.05	0.44	0.2	-0.09	0.09	-0.1	-0.02	-0.09	0.13	0.03	0.36	-0.03
Bi	0.07	-0.02	0.11	0.08	0.05	0.34	0.24	-0.05	0.29	-0.03	-0.01	-0.08	0.09	-0.11	0.36	-0.05
Cd	0.01	-0.02	0.01	*****	0.03	0.62	0.94	-0.03	0.3	-0.08	*****	-0.05	0.93	-0.05	0.68	-0.05
Co	0.06	0.26	0.31	0.14	0.42	0.01	0.02	0.32	0.03	0.08	0	0.17	0.05	0.13	0.07	0.06
Cr	0.02	0.05	-0.04	-0.02	0.59	0	-0.01	0.34	-0.03	0.12	0.02	0.31	0.06	0.06	-0.02	0.08
Cu	0.02	0.16	0.38	0.01	0.01	0.41	0.32	0.03	0.29	0.03	-0.01	0.04	0.09	0	0.5	-0.01
La		-0.02	0	0.13	0.02	0	0.01	0.11	0.03	0.11	0.62	0.14	0.07	0.36	0	0.21
Mn	1040		0.29	-0.15	0.01	0.33	0.05	0.17	0.01	0.11	0.01	0.21	0.14	0.17	0.31	0.1
Mo	385	402		-0.01	0.06	0.22	0.03	-0.01	0.13	-0.03	0	-0.05	0.07	0.02	0.64	0.01
Nb	460	499	378		0.12	0	0	0.12	0.02	-0.14	0.02	-0.05	0.06	0.31	-0.01	0.13
Ni	1039	1877	402	496		-0.01	0.03	0.32	0.13	0.06	-0.04	0.12	0.14	0.03	0.07	0.04
Pb	1040	1892	403	499	1879		0.7	-0.01	0.2	-0.04	-0.01	0	0.28	0	0.71	-0.02
Sb	373	378	372	372	382	382		-0.03	0.28	-0.1	0	-0.05	-0.04	-0.06	0.72	-0.06
Sc	1036	1842	400	493	1841	1846	382		-0.05	0.2	0.02	0.49	0.05	0.37	-0.05	0.31
Sn	387	412	375	375	414	415	379	414		-0.12	0.09	-0.09	0.09	0.01	0.38	-0.05
Sr	925	1462	398	486	1463	1465	381	1450	406		0	0.15	0.04	-0.06	-0.12	0.03
Th	372	372	372	372	372	372	371	372	371	372		0.18	0	0.47	-0.01	0.25
V	1040	1895	403	499	1881	1895	382	1846	415	1465	372		0.08	0.35	-0.08	0.35
W	378	379	376	372	380	380	372	380	374	377	371	380		0	0.11	0.07
Y	1040	1883	403	499	1874	1885	382	1843	414	1465	372	1887	380		-0.06	0.4
Zn	409	434	379	375	437	437	381	435	389	427	371	437	376	437		-0.08
Zr	1024	1880	403	492	1865	1880	382	1830	415	1449	372	1883	380	1871	434	

Table D11. Percent frequency distributions of spectrographic analyses of combined NURE and USGS (RASS) stream-sediment samples analyzed for gold.

[Scale: reported spectrographic intervals in % (weight percent) or ppm (parts per million) by element.

	Ca	Fe	Mg	Ti	Ag	As	Au	B	Ba	Be	Bi	Cd	Co	Cr	Cu	La	Mn	Mo
Scale	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
0.02				0.05														
0.03	L .1			0.05														
0.05	0.05	0.05		0.16														
0.07	0.05	0	0.21	0.95														
0.1	0.58	0	0.37	1.58	N 58.4													
0.15	1.84	0.21	0.68	7.89	L 7.8													
0.2	2.74	0.05	1.16	15.2	15.89					N 0.1								
0.3	11.15	0.11	5.79	46.82	1.74					L 2.0								
0.5	9	0.21	10.31	17.15	4.1					1.37								
0.7	14.62	2.05	33.82	6.15	3.58					2.68								
1	11.84	2.42	24.41	2.74	2.26					13.63			N 5.5					N 74.7
1.5	22.78	15.1	13.15	0.16	1.79					44.03			L 18.8					L 4.1
2	11.36	26.51	6.1	G 1.0	0.79		N 80.4	N 0.1		26.62	N 76.1		0.26					14.94
3	5.79	33.72	2.89		0.53		L .1	L 0.2		6.21	L 1.8		0.11		L 0.1			1.68
5	2.42	11.57	0.58		0.84		19.52	1.37		1.58	18.46		1.42	L 0.1	0.53			2
7	2.95	5.21	0.37		0.42			0.21		0.84	0.47		6.47	0.05	0.84	N 3.5		1.37
10	1.74	1.84	0.11		0.58			3.31		0.32	0.79	N 79.8	27.88	0.37	1.21	L 41.7		0.47
15	0.79	0.68			0.26			6.42		0.11	0.47	L 0.2	23.99	1.84	7.21	0.68		0.37
20	0.21	0.21			0.37			19.62		0.16	0.53	19.52	11.73	3.1	19.2	4.21		0.11
30					0.37			36.56		0	0.74	0	3.1	8.63	34.61	8.26	0.05	0.05
50					0.16	N 77.7		18.52	0.16	0.05	0.37	0.32	0.32	20.09	19.99	32.77	0.05	0.16
70					0	L 1.2		9.15	0.11	0.05	0.21	0.05	0.11	34.03	7.15	5.37	0.47	0
100					0.05	18.88		2.68	0.21	0.05		0.05	0	20.94	3.21	1.32	0.89	0.05
150						0		0.95	2.74				0	6.1	2.79	1.58	2.68	
200						0.42		0.68	4.63				0.11	2.31	1	0.32	3.63	
300						0.68		0.21	15.73				G 0.1	1.37	0.26	0.05	7.68	
500						0.21		0.05	25.09					0.68	0.53	0.11	17.2	
700						0.26			34.46					0.11	0.84	0.05	45.13	
1000						0.16			14.2					0.21	0.37		12.99	
1500						0.37			2.31					0	0.11		5.31	
2000						0.05			0.21					0.05	0		2.21	
3000						0.05			0.11						0.05		0.63	
5000																	0.37	
7000																	0.42	
		N = not detected		L = detected but below lowest standard				G - above highest standard									G 0.2	

Table D11 (continued). Percent frequency distributions of spectrographic and analyses of combined NURE USGS (RASS) stream sediment samples analyzed for gold. Scale: reported in % spectrographic intervals (weight percent) or ppm (parts per million) by element.

	Nb	Ni	Pb	Sb	Sc	Sn	Sr	Th	V	W	Y	Zn	Zr
Scale	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
0.02													
0.03													
0.05													
0.07													
0.1													
0.15													
0.2													
0.3													
0.5													
0.7													
1													
1.5		N 0.2			N 0.1								
2		L 0.8			L 2.7	N 77.5					N 0.10		
3	N 20.7	0.74			0.58	L 0.6					L 0.60		
5	L 53.0	2.58			11.1	18.41					0.05		
7	12.1	4.21	L 0.2		44.03	0			L 0.10		0.11		
10	6.21	9	1.05		26.72	0.53			0.21	N 79.3	2.05		
15	6.58	22.99	1.95		10.73	1.05			0.11	L 0.70	10.47		0.32
20	1.1	27.51	5.68	N 79.7	3.47	0.79	N 15.8	N 80.3	0.37	19.67	32.3		0.16
30	0.21	20.67	24.78	L 0.20	0.47	0.47	L 7.1	L 0.10	4.63	0.16	42.82		1.05
50	0.05	7.36	21.04	19.2		0.37	0.95	19.31	10.42	0.11	8.78	N 68.1	1.68
70		3	15.41	0.11		0.05	0.58	0.11	30.14	0.05	2.31	L 8.8	5.63
100		0.79	13.62	0.42		0.16	6.47	0.11	26.72		0.21	17.1	8.94
150		0.11	10.73	0.16			12.1	0	17.57		0.11	0.53	31.51
200			2.47	0			14.57	0	5		0.05	1.42	25.3
300			0.74	0.05			24.41	0	3.05			0.63	16.36
500			0.63	0.05			13.36	0.05	0.84			0.47	3.79
700			0.37	0.05			3.95		0.74			1.16	2.74
1000			0.53	0			0.68		0.05			0.53	1.05
1500			0.21	0.05					0.05			0.42	0.58
2000			0.16									0.11	G 0.8
3000			0.16									0.42	
5000			0.16									0.11	
7000			0.05									0	
	N = not detected		L = detected but below lowest standard					G = above highest standard				0.11	

Table D12. Statistical summary of spectrographic analyses of NURE stream sediments. The list below gives the minimum, maximum, and mean values (in ppm, parts per million) as well as the standard deviations of all unqualified values in addition to the numbers of qualified values.

[Qualifiers include: Valid, number of samples used in statistical analysis; B, number of samples not analyzed; N, number of samples not detected]

ELEMENT	MIN.	MAX.	MEAN	STANDARD DEV.	VALID	B	N
Ag	5.00	69.00	11.95	11.39	98	22	2031
Al	11390.00	114200.00	62843.35	11246.82	2151	0	0
Au	0.06	9.07	0.85	1.32	102	0	2049
Ba	197.00	3572.00	662.95	266.01	1963	0	188
Bi	5.00	143.00	9.15	9.53	511	22	1618
Ca	2310.00	264400.00	26846.90	24025.95	2135	0	16
Cd	5.00	75.00	8.33	8.27	188	22	1941
Ce	16.00	307.00	75.77	29.79	2140	0	11
Cl	64.00	1194.00	195.95	89.77	451	0	1700
Co	1.70	51.50	11.77	4.99	2144	0	7
Cr	9.00	947.00	62.052	59.81	2077	0	74
Cs	1.50	592.30	8.12	14.59	2088	0	63
Cy	10.00	3617.00	69.66	137.83	2114	22	15
Dy	1.00	40.00	4.79	2.13	2090	0	61
Eu	0.30	3.90	1.19	0.32	2137	0	14
Fe	4186.00	387100.00	29909.82	19769.24	2150	0	1
Hf	0.90	229.10	11.33	14.07	2140	0	11
K	4370.00	51720.00	18471.23	4554.96	2103	0	48
La	9.00	254.00	43.25	18.44	2109	0	42
Lu	0.10	3.60	0.42	0.22	2089	0	62
Mg	2093.00	108800.00	15963.79	10377.38	2084	0	67
Na	408.00	36760.00	11123.03	5137.46	2150	0	1
Nb	20.00	83.00	32.53	11.54	263	22	1866
Ni	15.00	153.00	27.72	18.11	893	22	1236
Pb	5.00	6896.00	60.75	292.66	2000	22	129
Rb	22.00	231.00	77.83	30.57	1641	0	510
Sb	2.00	804.00	19.26	74.15	344	4	1803
Sc	1.90	34.30	10.35	4.14	2151	0	0
Sm	1.00	42.60	5.93	2.84	2100	0	51
Sn	10.00	344.00	28.45	47.16	60	22	2069
Sr	219.00	1246.00	609.88	205.29	294	10	1847
Ta	1.00	10.00	2.04	1.39	182	26	1943
Tb	1.00	6.00	1.40	0.81	147	21	1983
Th	1.70	213.00	14.85	15.90	2145	0	6
Ti	727.00	32410.00	3759.69	2251.01	2063	0	88
Nu	0.84	153.00	6.20	7.51	2151	0	0
V	13.00	791.00	98.19	74.25	2136	0	15
W	15.00	166.00	29.64	20.75	141	22	1988
Yb	1.10	26.80	4.29	2.02	1844	0	307
Zn	23.00	9536.00	171.97	426.75	1350	6	795

Table D13. Correlation coefficients (given in the upper part of matrix) and number of correlating pairs (given in the lower part of matrix) from statistical summary of NURE analyses of stream sediments within study area.

	Ag	Al	Au	Ba	Bi	Ca	Cd	Ce	Cl	Co	Cr	Cs	Cu	Dy	Eu
Ag		-0.41	0.14	-0.17	0.49	0.13	0.75	-0.2	0.45	-0.3	-0.02	0.47	0.14	-0.18	-0.13
Al	98		-0.21	0.22	-0.04	-0.45	-0.41	0.28	0	0.19	-0.02	0.06	0.03	0.15	0.24
Au	33	102		-0.04	-0.07	-0.11	-0.01	-0.07	-0.1	-0.11	0.02	0.01	0.23	0.09	0.02
Ba	77	1963	86		-0.11	-0.26	-0.12	-0.06	-0.09	-0.04	0	0.01	0	-0.07	0.14
Bi	48	511	46	465		-0.01	0.29	0	0.25	0.11	-0.07	0.1	0.42	-0.08	-0.05
Ca	94	2135	97	1955	503		0.1	-0.22	0.08	-0.09	0.04	-0.04	-0.06	-0.21	-0.23
Cd	40	188	32	158	86	180*		0.16	0.32-	0.08-	0.03	0.43	0.24-	0.08	-0.07
Ce	98	2140	102	1953	509	2125	187		0.07	0.22	-0.02	0.09	-0.01	0.49	0.53
Cl	37	451	35	411	113	450	59	451*		0.24	0.13	0.11	0.07	0.02	0.09
Co	98	2144	102	1959	510	2129	187	2135	448		0.42	0.07	0.13	0.12	0.26
Cr	95	2077	95	1903	488	2063	176	2073	426	2074		-0.09	-0.03	-0.1	0.07
Cs	98	2088	99	1911	501	2073	184	2080	437	2085	2026		0.16	0.13	0.03
Cu	97	2114	101	1932	507	2098	188	2103	443	2107	2044	2057		-0.02	0
Dy	88	2090	93	1956	492	2081	173	2082	443	2086	2023	2032	2054		0.35
Eu	98	2137	102	1955	506	2122	187	2129	447	2133	2074	2081	2103	2081	
Fe	98	2150	102	1962	511	2134	188	2140	451	2143	2077	2088	2113	2090	2137
Hf	98	2140	102	1957	508	2125	186	2132	447	2136	2075	2082	2103	2083	2131
K	86	2103	91	1953	495	2095	168	2095	447	2098	2036	2044	2068	2069	2092
La	96	2109	101	1926	505	2094	184	2101	441	2106	2045	2053	2074	2052	2100
Lu	97	2089	100	1914	492	2074	181	2083	434	2086	2034	2048	2057	2033	2083
Mg	85	2084	88	1942	491	2077	164	2074	443	2079	2018	2024	2047	2054	2073
Na	98	2150	102	1963	511	2135	187	2140	451	2144	2077	2088	2113	2090	2137
Nb	28	263	25	246	61	260	43	263	106	262	251	259	263	261	263
Ni	35	893	44	822	223	891	82	891	153	892	879	854	890	868	890
Pb	77	2000	94	1831	483	1985	172	1992	409	1994	1931	1953	1990	1943	1989
Rb	72	1641	82	1502	389	1626	147	1633	332	1641	1606	1632	1617	1594	1640
Sb	49	344	55	302	138	336	101	344	78	343	339	342	338	329	344
Sc	98	2151	102	1963	511	2135	188	2140	451	2144	2077	2088	2114	2090	2137
Sm	98	2100	101	1927	489	2085	185	2098	439	2095	2046	2055	2070	2043	2096
Sn	16	60	15	46	20	57	20	60	15	60	57	57	60	54	60
Sr	7	294	11	286	89	294	20	293	58	294	289	277	291	293	294
Ta	28	182	20	158	51	181	20	180	54	181	172	180	178	179	182
Tb	12	147	12	133	40	145	18	143	44	147	136	147	142	143	147
Tm	98	2145	102	1958	509	2130	187	2137	451	2140	2076	2085	2108	2086	2133
Ti	85	2063	91	1940	488	2055	166	2054	444	2058	1994	2002	2028	2045	2052
U	98	2151	102	1963	511	2135	188	2140	451	2144	2077	2088	2114	2090	2137
V	93	2136	97	1962	507	2124	182	2126	451	2130	2064	2074	2099	2087	2123
W	32	141	14	123	66	140	34	140	37	141	130	134	141	137	139
Yb	83	1844	82	1695	438	1832	162	1836	398	1843	1799	1818	1818	1805	1842
Zn	63	1350	78	1222	316	1340	147	1343	274	1347	1311	1329	1333	1304	1349

Table D13 (continued). Correlation coefficients (given in the upper part of matrix) and number of correlating pairs (given in the lower part of matrix) from statistical summary of NURE analyses of stream sediments within study area.

	Sr	Ta	Tb	Th	Ti	U	V	W	Yb	Zn
Ag	-0.1	0.09	0.57	0.04	-0.18	-0.08	0.08	0.32	0.14	0.56
Al	0.47	-0.24	0.28	0.19	0.06	0.18	0.03	-0.06	0.17	-0.13
Au	-0.23	-0.12	0.26	-0.06	-0.14	-0.03	0	0.23	-0.03	0.13
Ba	0.26	0.16	-0.03	-0.22	0.04	-0.12	-0.19	-0.15	-0.15	-0.04
Bi	-0.16	-0.18	0.13	0.07	0.01	0.12	0.03	-0.06	0.04	0.33
Ca	-0.04	-0.13	-0.07	-0.08	-0.11	-0.11	-0.02	-0.08	-0.17	0.03
Cd	-0.14	0.91	0.11	-0.09	-0.2	-0.07	-0.06	0.2	-0.03	0.86
Ce	-0.1	0.02	0.25	0.69	0.16	0.41	0.39	0.26	0.67	-0.02
Cl	0.08	0.32	0.16	0.06	0.11	0.08	0.19	-0.02	0.07	0.2
Co	0.06	0.05	0.15	0.26	0.47	0.15	0.55	0.17	0.28	0.09
Cr	0.03	-0.01	0.2	-0.02	0.11	-0.09	0.32	0.18	-0.01	0.02
Cs	0.01	0.3	0.24	0.11	0.02	0.12	0.03	0.26	0.35	0.61
Cu	-0.06	-0.01	0.09	0.01	0.06	0.05	0.06	0.02	0.05	0.33
Dy	-0.38	0.25	0.62	0.43	0.14	0.43	0.21	0.29	0.71	-0.01
Eu	-0.08	0	0.38	0.35	0.19	0.14	0.3	0.35	0.45	0.01
Fe	-0.22	0.02	0.08	0.53	0.39	0.13	0.75	*****	0.48	0.12
Hf	-0.19	-0.01	0.01	0.82	0.14	0.35	0.65	0.65	0.66	0
K	-0.22	0.02	-0.07	-0.02	-0.08	-0.09	-0.2	-0.09	0.06	-0.03
La	-0.06	0.02	0.35	0.66	0.09	0.54	0.32	0.24	0.62	0.02
Lu	-0.19	0.23	0.69	0.71	0.17	0.55	0.41	0.52	0.84	0.03
Mg	0.09	-0.21	0.01	0	0.04	0	0.09	-0.24	-0.08	0.05
Na	0.49	-0.24	-0.02	0.33	0.08	0.28	0.19	0.02	0.21	-0.08
Nb	0.06	0.23	-0.01	0.16	-0.06	0.22	0.07	0.06	0.25	0.11
Ni	0.11	0.22	0.02	-0.03	0.09	-0.05	0.22	0.24	-0.05	0.03
Pb	-0.04	0.08	0.13	0	-0.04	0.04	-0.01	0.19	0.02	0.53
Rb	-0.4	0.4	0.38	0.11	-0.02	0.02	-0.03	0.18	0.3	0.04
Sb	-0.41	0.62	0.6	-0.05	-0.04	0	-0.06	0.07	0	0.8
Sc	-0.1	-0.07	0.24	0.41	0.47	0.18	0.62	0.14	0.45	0.05
Sm	-0.16	0.34	0.6	0.59	0.13	0.59	0.27	0.2	0.75	-0.02
Sn	-0.19	-0.19	0.74	-0.15	-0.13	-0.17	-0.18	-0.13	-0.15	-0.03
Sr		0	0.06	-0.14	-0.16	0.01	-0.13	-0.07	-0.15	-0.1
Ta	21		0.29	-0.01	0.05	0.12	-0.1	-0.03	0.24	0.37
Tb	13	37		0.2	-0.05	0.36	-0.06	-0.24	0.72	0.36
Th	293	180	146		0.12	0.5	0.55	0.54	0.74	0
Ti	294	176	140	2058		0.06	0.61	-0.06	0.17	-0.02
U	294	182	147	2145	2063		0.22	0.21	0.51	0.02
V	294	180	147	2131	2063	2136		0.42	0.44	-0.01
w	13	26	13	141	136	141	140		0.5	0.21
Yb	212	177	139	1841	1778	1844	1833	128		0.07
Zn	201	127	105	1349	1282	1350	1338	82	1175	

Table D14. Percent frequency distributions of NURE analyses of NURE stream sediment samples. Scale: reported spectrographic intervals in % (weight percent) or ppm (parts per million) by element.

	Ag	Au	Ba	Bi	Cd	Ce	Cl	Co	Cr	Cs	Cu	Dy	Eu	Hf	La	Lu	Nb
Scale	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
0.02																	
0.03																	
0.05		N = 95.3															
0.07		0.19														N 2.90	
0.1		0.19														1.3	
0.15		0.84														0	
0.2		0.7											N = 0.7			11.34	
0.3		0.65											0.09			28.13	
0.5		0.56											0.98			39.75	
0.7		0.42										N 2.8	9.3	N 0.50		12.18	
1		0.37						N = 0.3		N = 2.9		0.37	53.6	0.05		3.49	
1.5		0.28						0.09		0.42		0	31.1	0.05		0.7	
2		0.09						0.09		3.11		5.63	4.04	0.84		0.19	
3	N 94.4	0.33		N 75.2	N = 90.2			0.98		16.23		14.13	0.19	5.11		0.05	
5	1.02	0.09		6.97	3.95			4		28.03		53	0.05	17.71			
7	1.35	0		9.53	2.93			18.13	N = 3.4	22.97	N 0.7	21.06		32.68	N 2.0		
10	0.93	0.05		4.46	0.88	N = 0.50		38.45	0.14	12.65	0.42	2.37		22.69	0.23		
15	0.6			1.21	0.42	0.09		26.36	1.53	6.79	2.19	0.33		9.16	1.26		N 86.8
20	0.28			0.84	0.28	0.56		10	7.21	3.91	11.81	0.09		4.42	8		4.6
30	0.19			0.33	0.14	3.86		1.49	19.39	2	28.31	0.14		3.07	38.03		4.93
50	0.09			0.28	0.09	19.48	N = 79.0	0.09	32.91	0.7	24.08	0.05		1.72	33.84		2.19
70	0.09			0.09	0.05	44.68	0.51		22.22	0.23	15.25			1.3	13.39		0.46
100				0		24.17	3.02		6.65	0	7.25			0.42	2.6		0.05
150			N = 8.7	0.05		5.72	6.14		3.02	0	4			0.23	0.56		
200			0.84			0.79	7.76		2.05	0	1.95			0.05	0.14		
300			7.11			0.14	3.21		0.84	0	1.39						
500			25.06				0.23		0.37	0	0.6						
700			41.24				0.05		0.19	0.05	0.46						
1000			14.04				0.05		0.05		0.37						
1500			2.46								0.09						
2000			0.37								0.05						
3000			0.14								0.05						
		N = not detected															

Table D14 (continued). Percent frequency distributions of NURE analyses of NURE stream-sediment samples. Scale: reported spectrographic intervals in % (weight percent) or ppm (parts per million) by element.

	Ni	Pb	Rb	Sb	Sc	Sm	Sn	Sr	Ta	Tb	Th	U	V	W
Scale	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
0.02														
0.03														
0.05														
0.07														
0.1														
0.15														
0.2														
0.3														
0.5														
0.7						N 2.4			N 90.3	N 92.2				
1						0.09			3.35	4.93	N 0.30	0.37		
1.5				N 83.8		0.09			0	0	0.05	2.56		
2				2.56	0.42	3.25			3.3	1.44	0.05	13.62		
3		N 6.0		3.11	1.39	11.72			1.02	0.23	1.21	39.33		
5		1.3		4.09	6.56	28.73			0.46	0.19	5.35	16.92		
7		6.09		2.88	21.48	31.61	N 96.2		0.23	0.05	21.39	8.93		
10	N 57.5	12.18		1.12	45.93	9.25	0.98		0.09		39.42	6.93	N 0.7	N 92.4
15	9.93	17.71	N 23.7	0.7	17.53	2.09	0.56				13.9	5.02	0.19	1.67
20	17.85	22.22	0.23	0.79	6.37	0.6	0.7				6.97	3.49	0.93	2.32
30	6.14	13.2	5.16	0.28	0.33	0.14	0.19				5.11	2.19	3.93	1.3
50	3.21	8.04	16.88	0.19		0.05	0.19				3.81	0.42	18.32	0.65
70	1.3	4.79	22.5	0.23			0.05				1.3	0.19	33.84	0.42
100	0.7	2.19	25.29	0.28			0				0.88	0	21.11	0.09
150	0.37	1.77	5.95	0.05			0.09	N 85.9			0.19	0.05	11.72	0.09
200		1.07	0.28	0.09			0	0.28			0.09		5.63	
300		0.46		0.05			0.05	1.53					2.28	
500		0.37		0.05				4.46					1.07	
700		0.6		0.14				5.35					0.28	
1000		0.37						2						
1500		0.19						0.05						
2000		0.14												
3000		0.14												
5000		0.05												
7000		0.09												
10000				N = not detected										

Table D14 (continued). Percent frequency distributions of NURE analyses of NURE stream sediment samples. Scale: reported spectrographic intervals in % (weight percent) or ppm (parts per million) by element.

Scale	Al %	Ca %	Fe %	K %	Mg %	Na %	Ti %
0.05						0.05	N 4.1
0.07						0.09	0.05
0.1						0.23	0.23
0.15		N 0.7			N 3.1	0.46	1.86
0.2		0.05			0.09	0.74	17.02
0.3		0.93		N 2.2	0.33	3.39	44.72
0.5		1.91	0.09	0.09	2.19	8.51	25.38
0.7		5.16	0.79	0.37	13.11	17.99	4.56
1	0.05	10.83	5.81	4.93	25.66	31.57	1.07
1.5	0.09	17.02	15.48	41.1	27.01	26.5	0.46
2	0.56	30.03	24.78	45.84	17.62	9.53	0.37
3	1.63	18.64	34.77	5.3	7.72	0.88	0.19
5	22.59	7.25	11.95	0.14	2.09		
7	71.22	3.58	4.14		0.74		
10	3.86	2.42	1.49		0.33		
15		1.21	0.51				
20		0.19	0.09				
30		0.05	0				
50			0.05				
70							
100			N = not detected				

Table D15. Statistical summary of atomic absorption spectrographic analyses of combined NURE and USGS (RASS) stream sediments. For qualified values.

[Valid, number of samples used in statistical analysis; B, number of samples not analyzed; L, number of samples detected with spectrographic analysis, but measured below lowest standard; ppb, parts per billion]

Element (ppb)	Minimum (ppb)	Maximum (ppb)	Mean (ppb)	Standard deviation	Valid	B	L
Au	0.001	14.0	0.70	0.58	1683	94	124

Table D16. Correlation coefficients ("Au") and numbers of correlating pairs ("Pairs") of stream-sediment gold values as determined by atomic-absorption spectrographic methods.

[N.D., not determined]

Element	Au	Pairs	Element	Au	Pairs
Ca	0	1682	Mn	0.15	1679
Fe	0.06	1683	Mo	0.19	350
Mg	0.04	1683	Nb	0.02	440
Ti	0.01	1664	Ni	-0.03	1667
Ag	0.21	581	Pb	0.24	1679
As	0.09	355	Sb	0.09	336
Au	N.D.	325	Sc	-0.02	1653
B	0.01	1680	Sn	0.32	367
Ba	0.03	1683	Sr	-0.06	1347
Be	0.22	1655	Th	-0.01	326
Bi	0.09	373	V	0.04	1682
Cd	0.02	333	W	-0.05	334
Co	-0.04	1306	Y	0.01	1677
Cr	0	1682	Zn	0.24	390
Cu	0.15	1682	Zr	0.04	1667
La	-0.01	963			

Table D17. Percent frequency distribution of gold values in NURE and USGS (RASS) stream-sediments as determined by atomic-absorption spectrographic analyses.

Au class	Percent frequency	Au class	Percent frequency
<0.001	6.5	0.15	0.26
0.001	22.09	0.2	0.68
0.002	25.09	0.3	0.05
0.003	5.21	0.5	0.63
0.005	10.99	0.7	0.32
0.007	8.15	1	0.42
0.01	4.58	1.5	0.21
0.015	2.42	2	0.11
0.02	2.31	3	0.11
0.03	1.26	5	0.42
0.05	1	7	0.05
0.07	1.05	10	0.05
0.1	1	15	0.05

CHAPTER E

MINES AND PROSPECTS IN AND ADJACENT TO THE HELENA NATIONAL FOREST

By Christopher Osterman, R.G. Tysdal, J.E. Elliott, and Steve Ludington

INTRODUCTION

A wide variety of sources were used to compile information on deposit types, mineral commodities, and production history of the mines and prospects in and adjacent to the Helena National Forest (the Forest). These sources include the U.S. Geological Survey Mineral Resource Data System (MRDS); the Anaconda Documents Collection maintained by the American Heritage Center at the University of Wyoming, Laramie, Wyo.; publications from previous mineral resource assessment studies; county records; research reports; theses; data of private industry; and records of current and recent activity maintained by the U.S. Forest Service. Several mining companies allowed us access to their properties and company geologists conducted tours for members of the assessment team, providing information on geology, exploration, and mine and prospect development.

Mines and prospects in and adjacent to the Forest are listed in table E1. Site locations of the properties are shown on plate 2 (map scale 1:126,720). Site numbers start from the northwest corner of the map and are grouped by mining district/area. Some sites include more than one property, and other sites have had several names over their history; alternate names are shown in parentheses. The table was compiled from the geologic literature. It is not a compilation of mining claims. Small exploration pits (1-2 ft deep) are widespread in the Forest, but are not cited in this tabulation.

Assignment to a probable deposit type is made for sites where sufficient data exist. Other sites are left as unclassified. Patterns of the distribution of the different deposit types can indicate areas where different types of mineralizing processes were operative. Publically available tonnage and grade data for production, reserves, and identified resources for individual mines and prospects are also included in table E1. These data provide a basis for comparing grades and tonnages of identified resources in and adjacent to the Forest with models developed from a worldwide database.

Analysis of the type and distribution of identified resources is an essential, fundamental step in the process of assessesing for undiscovered mineral resources within a region. Identified resources provide clues to the types and sizes of mineral deposits that may be present but are yet to be discovered. These data are useful in the determination of areas (tracts) that are permissive or favorable for deposit types. The data also are fundamental to understanding the distribution of chemical elements that occur naturally in geologic terranes, whether or not disturbed by humans. From undisturbed areas, such data provide the background (baseline) geochemical characteristics needed for comparison with characteristics that potentially could be produced by disturbance or development.

Table E1. Location and description of mines and prospects, Helena National Forest, Montana

[*, mine or prospect on or just outside Forest boundary; (r), reserves; Mt, million short tons; oz, troy ounces; Moz, million troy ounces; in., inches; ft, feet; ppm, parts per million; <, less than; >, greater than; ~, about; MRDS, Mineral Resource Data System, a computer file available from U.S. Geological Survey, Reston, Va.]

[1] Alternate name(s) in parentheses; [2] Value given only when recorded in data source.

No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	Production and Reserves [2] (tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
1	Mineral Hill	Scapegoat (Mineral Hill) Area	47	8	26	112	54	47	Sediment-hosted Cu, veins	None						Aplite dike nearby.	Mudge and others (1974), Rosenkranz and Lyden (1920)
2	Klondike	Scapegoat (Mineral Hill) Area	47	8	38	112	53	5	Sediment-hosted Cu, veins	0.7 Mt (r)			2100 (r)			Channel samples in Klondike Tunnel averaged 0.68 percent Cu over 118 ft. Siliceous dike.	Mudge and others (1974), Rosenkranz and Lyden (1920)
3	Porto Rico	Scapegoat (Mineral Hill) Area	47	8	2	112	53	57	Sediment-hosted Cu, veins	Unknown, but minor						Mineralization associated with shear zone in Proterozoic diorite sill; quartzite strikes N60W, dips 45N.	Mudge and others (1974), Rosenkranz and Lyden (1920)
4	Montezuma	Scapegoat (Mineral Hill) Area	47	7	38	112	53	57	Sediment-hosted Cu, veins							Prospect in diorite sill.	Rosenkranz and Lyden (1920)
5	Fisher Group prospect	Scapegoat (Mineral Hill) Area	47	6	34	112	50	55	Sediment-hosted Cu, veins	None							Mudge and others (1974), Rosenkranz and Lyden (1920)
6	Bugle Mountain/ Fisher Group	Scapegoat (Mineral Hill) Area	47	6	53	112	50	41	Sediment-hosted Cu, veins	0.11 Mt (r)			1100 (r)			Shear zone associated mineralization.	Mudge and others (1974), Rosenkranz and Lyden (1920)
7	Name unknown	Scapegoat (Mineral Hill) Area	47	9	26	112	45	12	Sediment-hosted Cu, redbed	None						1-in.-thick bed assayed 3.3 percent Cu.	Mudge and others (1974), Rosenkranz and Lyden (1920)
8	Red Mountain	Scapegoat (Mineral Hill) Area	47	5	2	112	43	40	Sediment-hosted Cu, reduced facies							Location is approximate.	Lange and Eby (1981), Lange and Sherry (1986)
9	Copper Camp	Scapegoat (Mineral Hill) Area	47	4	51	112	44	40	Sediment-hosted Cu, veins	None						Shear zone associated mineralization.	Mudge and others (1974), Rosenkranz and Lyden (1920)
10	Cotter Basin mine	Scapegoat (Mineral Hill) Area	47	4	1	112	42	4	Sediment-hosted Cu, veins	1.0 Mt (r)		200000 (r)	8500 (r)			Northwesterly striking veins, dip 25-55SW, containing bornite, carbonate. Adjacent to small unmapped exposure of quartz monzonite.	Earhart and others (1977)
11	Theodore Creek	Scapegoat (Mineral Hill) Area	47	3	9	112	44	16	Unclassified	None						Consists of a caved shaft about 100 ft deep.	Earhart and others (1977)

										Production		and		Reserves [2]			
No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	(tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
12	Giant	Scapegoat (Mineral Hill) Area	47	2	2	112	43	12	Vein, polymetallic							Diorite intrudes argillite of Spokane Formation. Discontinuous quartz veins contain Au, Ag, Cu minerals. Grab sample of quartz vein assayed 0.59 oz per ton Au.	Earhart and others (1977)
13	Rose claims	Scapegoat (Mineral Hill) Area	47	0	20	112	42	46	Unclassified								MRDS
14	Nellie Miles Lode	Scapegoat (Mineral Hill) Area	47	13	46	112	39	1	Sediment-hosted Cu, veins							Quartz vein.	Mudge and others (1974)
15	Hector Lode	Scapegoat (Mineral Hill) Area	47	12	54	112	36	11	Sediment-hosted Cu, veins							Quartz-barite vein.	Mudge and others (1974)
16	Landers Fork	Scapegoat (Mineral Hill) Area	47	9	10	112	37	54	Sediment-hosted Cu, redbed							Location is approximate; shear zone.	Earhart and others (1981)
17	Red Rock prospect	Scapegoat (Mineral Hill) Area	47	10	24	112	29	38	Sediment-hosted Cu, veins	None						Small chalcopyrite-bearing calcite veins in diorite at argillite contact.	Earhart and others (1977)
18	Byrnes Creek copper occurrence	Scapegoat (Mineral Hill) Area	47	6	34	112	33	38	Sediment-hosted Cu, redbed	None							Earhart and others (1977)
19	Hayworth Claim Group (Alice)	Scapegoat (Mineral Hill) Area	47	6	37	112	27	52	Sediment-hosted Cu, redbed			195000	925			Mineralization in quartzite beds striking N5E, dipping 5-7E. Best intercept 24 ft at 0.52 percent Cu, 1.38 oz per ton Ag.	Connor and McNeal (1988), Rankin and Whitcomb (1971), Trammell (1975)
20	Copper Bowl	Scapegoat (Mineral Hill) Area	47	6	48	112	24	10	Sediment-hosted Cu, veins								Earhart and others (1981)
21	Iron Hill	Scapegoat (Mineral Hill) Area	47	2	35	112	31	31	Sediment-hosted Cu, veins								Earhart and others (1981)
22	Name unknown	Lincoln Gulch Area	46	59	8	112	46	56	Vein, polymetallic							Andesite porphyry nearby.	Elliott and others (1992)
23	Blackfoot (Big Blackfoot mine)	Lincoln Gulch Area	46	56	36	112	45	23	Vein, polymetallic		100000 (r)						Frishman and others (1992), McCulloch (1989), Pardee and Schrader (1933), Rocky Mountain Pay Dirt (1987)

No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	Production and Reserves [2] (tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
24	Lincoln Gulch (Lincoln Creek) placer	Lincoln Gulch Area	46	56	30	112	45	5	Placer Au		350000					Rich gravels mined underground.	Dingman (1932), Earhart and others (1977, 1981), Elliott and others (1992), Frishman and others (1992), Lyden (1948), Pardee and Schrader (1933), Reyner and Trauerman (1949), Walker (1963)
25	Seven-Up Pete (Last Chance)	Seven-Up Pete Gulch Area	46	56	28	112	31	27	Epithermal vein, quartz- adularia	Combined with Columbia						North-trending quartz vein up to 7 ft wide.	Elliott and others (1992), Pardee and Schrader (1933)
26	Seven-Up Pete (Rover)	Seven-Up Pete Gulch Area	46	56	35	112	30	21	Epithermal vein, quartz- adularia	Combined with Columbia							Elliott and others (1992), McClernan (1983), Pardee and Schrader (1933)
27	Seven-Up Pete (Columbia)	Seven-Up Pete Gulch Area	46	56	55	112	30	30	Epithermal vein, quartz- adularia	1987; 11.0 Mt (r)	647; 600000 (r)	7457				Northwest-trending quartz vein bordered by zone of stockwork veining.	Elliott and others (1992), McClernan (1983), Pardee and Schrader (1933), Phelps Dodge Corporation (1992)
28	Carbonate Hill	Heddleston	47	3	32	112	22	17	Vein, polymetallic							North-striking, steeply dipping, 1 in. vein of galena.	McClernan (1983), Pardee and Schrader (1933)
29	Milliron	Heddleston	47	3	22	112	22	19	Vein, polymetallic							18-in.-wide vein strikes N20W, dips 40-50W; contains pyrite and galena in ankerite gangue.	Pardee and Schrader (1933)
30	Eureka	Heddleston	47	3	9	112	22	26	Vein, polymetallic							Oxidized outcrop.	Pardee and Schrader (1933)
31	Calliope	Heddleston	47	3	2	112	22	18	Vein, polymetallic		~550					Oxidized outcrop of vein was very high grade in gold.	Frishman and others (1992), McClernan (1983), Pardee and Schrader (1933)
32	Carbonate	Heddleston	47	2	42	112	23	44	Vein, polymetallic							750-ft-long vein, strike N45W, dip 80NE, contains pyrite, galena, sphalerite in a quartz-sericite gangue.	McClernan (1983), Pardee and Schrader (1933)
33	Midnight	Heddleston	47	2	51	112	22	8	Vein, polymetallic							N35W-striking mineralized shear zone with disseminated pyrite and veinlets of pyrite, bornite, and quartz.	Pardee and Schrader (1933)
34	Rex Beach	Heddleston	47	2	51	112	21	37	Vein, polymetallic							Strike N15E, dip 90 vein along porphyry dike; strike N15W, dip 90 vein with pyrite, galena, sphalerite.	McClernan (1983), Pardee and Schrader (1933)

										Production		and		Reserves [2]			
No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	(tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
35	Consolidation	Heddleston	47	2	44	112	21	45	Vein, polymetallic							Strike N50W, dip 85SW vein containing pyrite, galena, sphalerite	McClernan (1983), Pardee and Schrader (1933)
36	Skyscraper	Heddleston	47	2	37	112	21	29	Vein, polymetallic							40-ft-deep shaft shows iron oxides and galena.	Pardee and Schrader (1933)
37	Bobby Boy Lode	Heddleston	47	2	12	112	24	40	Vein, polymetallic	None						Near quartz monzonite intrusion.	Elliott and others (1992)
38	Paymaster	Heddleston	47	2	23	112	23	14	Vein, polymetallic	100						Ore consists of pyrite, tetrahedrite, galena, and sphalerite.	Pardee and Schrader (1933)
39	Iron Hill	Heddleston	47	2	19	112	21	57	Vein, polymetallic							Strike N35E, dip 70SE sheared vein, 3-4 ft wide, containing pyrite, galena, sphalerite.	McClernan (1983), Pardee and Schrader (1933)
40	Anaconda	Heddleston	47	2	9	112	21	33	Vein, polymetallic	1660	419	17968	12.5	18.8		Strike N40E, dip 75SE vein breccia with fragments of wall rock replaced by galena, sphalerite, chalcopyrite, bornite, arsenopyrite, calcite, and rhodochrosite.	Frishman and others (1992), McClernan (1983), Pardee and Schrader (1933)
41	Red Wing	Heddleston	47	2	4	112	21	12	Vein, polymetallic							Southward-trending vein with sphalerite, galena, pyrite.	Pardee and Schrader, 1933
42	Heddleston	Heddleston	47	1	50	112	22	44	Porphyry Cu-Mo	245 Mt (r)		44.0 Moz	1.2 Mt			51350 tons of Mo. 44.5+/-1.2 Ma (age of mineralization).	Anonymous (1972), McClernan (1983), Parker (1968), Potter (1971), Schassberger (1971)
43	Mike Horse	Heddleston	47	1	33	112	21	36	Vein, polymetallic	42000 (production and reserves, 1940)		261000		3600	2860	Strike N65-70W, dip 75S, 1,000-ft-long vein (Mike Horse vein). Trace Bi, Cu associated with Ag.	Frishman and others (1992), Goddard (1940b), McClernan (1983), Miller and others (1973), Pardee and Schrader (1933)
44	Kleinschmidt	Heddleston	47	1	35	112	21	56	Vein, polymetallic							Contains sphalerite, galena, and pyrite.	McClernan (1980), Pardee and Schrader, (1933)
45	Hogall	Heddleston	47	1	19	112	21	27	Vein, polymetallic							Eastward continuation of the Mike Horse vein.	McClernan (1983), Pardee and Schrader (1933)
46	Oker	Heddleston	47	0	32	112	23	21	Vein, polymetallic							Indicated on map only.	McClernan (1983), Pardee and Schrader (1933)
47	Marcum Hill*	Blackfoot River Area	46	57	5	112	56	58	Vein, polymetallic	100	42	292		6		Quartz vein was open pitted.	Elliott and others (1992), McClernan (1976)
48	Moose Creek placer	Blackfoot River Area	46	55	5	112	50	51	Placer Au								Elliott and others (1992), Frishman and others (1992), Lyden (1948), Stout (1949)

No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	Production and Reserves [2] (tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
49	Sauerkraut Creek placer	Blackfoot River Area	46	54	53	112	45	15	Placer Au							Gravel deposit 15 ft deep.	Elliott and others (1992), Frishman and others (1992), Lyden (1948), McCulloch (1993b), Pardee and Schrader (1933)
50	Stonewall Creek placer	Blackfoot River Area	46	57	50	112	42	5	Placer Au		703					Worked by dryland dredges.	Dingman (1932), Earhart and others (1977, 1981), Elliott and others (1992), Frishman and others (1992), Lyden (1948), Pardee and Schrader (1933)
51	Liverpool Creek placer	Blackfoot River Area	46	58	27	112	41	7	Placer Au							No production since 1904. Reportedly the deposits are low grade and irregular.	Earhart and others (1977, 1981), Elliott and others (1992), Lyden (1948), Pardee and Schrader (1933)
52	Keep Cool Creek placer	Blackfoot River Area	46	58	0	112	39	25	Placer Au							Bedrock reported at 70 ft; low grade and irregular.	Earhart and others (1981), Elliott and others (1992), Lyden (1948), Pardee and Schrader (1933)
53	McDonald Meadows*	Blackfoot River Area	46	59	39	112	32	0	Hot-spring Au-Ag	414 Mt (r)	8200000 (r)						Canyon Resources Corporation (1993), Enders and others (1995), Phelps-Dodge Corporation Annual Report (1991)
54	Seven-Up Pete Creek Placer	Blackfoot River Area	46	57	44	112	34	4	Placer Au								Pardee and Schrader (1933)
55	Prospect (name unknown)	Blackfoot River Area	46	55	19	112	38	41	Epithermal vein, quartz- adularia							Lamellar, northerly striking quartz vein with calcite casts.	This report
56	Gold Dollar	Blackfoot River Area	46	54	30	112	39	16	Epithermal vein, quartz- adularia	None						Adit with 1,000 ft of workings along vein in argillite.	Elliott and others (1992)
57	Baldy Mtn. Claims #1	Blackfoot River Area	46	54	22	112	38	45	Vein, polymetallic	None						Vein in limestone.	Elliott and others (1992)
58	Baldy Mtn. Claims #2	Blackfoot River Area	46	54	37	112	37	27	Epithermal vein, quartz- adularia							Inclined shaft developed on flat-lying drusy quartz vein. Breccia fragments of Helena Formation in vein may be related to a thrust fault.	This report
59	Mammoth	Blackfoot River Area	46	54	46	112	31	25	Vein, polymetallic							Vein in shear zone.	Elliott and others (1992)

No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	Production and Reserves [2] (tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
60	Poorman Creek placer	Blackfoot River Area	46	52	32	112	36	15	Placer Au	Minor	36						Dingman (1932), Elliott and others (1992), Lyden (1948), Pardee and Schrader (1933)
61	Butterfly Quartz Lode	Blackfoot River Area	46	52	46	112	34	48	Vein, polymetallic							Vein along shear zone.	Elliott and others (1992)
62	Rochester	Blackfoot River Aree	46	53	4	112	34	18	Porphyry Cu-Mo	None						Porphyry intrudes impure limestones and dolomite of Helena Formation. Well-defined stream sed. geochemical halo.	Brannon (1981), Crebs (1981), McClernan (1983)
63	Prospect (name unknown)	Blackfoot River Area	46	52	8	112	30	37	Vein, polymetallic							Auriferous pyrite veinlets along the contact between the granodiorite porphyry and Helena Formation.	This report
64	McCacran	Big Blackfoot (Ogden Mtn)	46	54	13	112	50	57	Vein, polymetallic							Quartz veins contain galena, tetrahedrite, and minor scheelite.	Elliott and others (1992), McClernan (1976), Stout (1949)
65	Wasson Creek placer	Big Blackfoot (Ogden Mtn)	46	54	0	112	52	50	Placer Au								Elliott and others (1992), Frishman and others (1992), Lyden (1948)
66	Wilson Creek (Kilburn, Raleigh) placer	Big Blackfoot (Ogden Mtn)	46	52	46	112	53	27	Placer Au							Ground sluicing of placers in alluvium.	Elliott and others (1992), Frishman and others (1992), McClernan (1976), Stout and Ackerman (1959)
67	Roselle mine	Big Blackfoot (Ogden Mtn)	46	52	1	112	53	5	Vein, polymetallic	None						Vein also contains tungsten.	Elliott and others (1992), Walker (1963)
68	C.D. Hurd placer*	Big Blackfoot (Ogden Mtn)	46	51	35	112	54	27	Placer Au								Elliott and others (1992), Geach and Chelini (1963)
69	Corbin	Big Blackfoot (Ogden Mtn)	46	52	22	112	52	30	Vein, polymetallic							Strike N15E, dip 16E 10-in.-thick quartz vein with limonite and native gold.	McClernan (1976), Stout (1949)
70	Higgins	Big Blackfoot (Ogden Mtn)	46	52	11	112	52	0	Vein, polymetallic	16	10	33				Strike N35W, dip 50N quartz 10-in.-thick vein with native gold, pyrite, galena, and scheelite.	Elliott and others (1992), McClernan (1976), Stout (1949), Walker (1963)

										Production		and		Reserves [2]			
No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	(tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
71	Plutarc	Big Blackfoot (Ogden Mtn)	46	52	6	112	51	55	Vein, polymetallic							Quartz vein with pyrite, galena, and scheelite.	McClernan (1976), Stout (1949), Stout and Ackerman (1959), Walker (1963)
72	Last Chance mine (Christine mine)	Big Blackfoot (Ogden Mtn)	46	52	0	112	51	45	Vein, polymetallic							Quartz veins.	Elliott and others (1992), Stout (1949)
73	Hobby Horse	Big Blackfoot (Ogden Mtn)	46	51	45	112	52	0	Vein, polymetallic	480	376	177		0.4		Quartz vein.	Blake (1888), Geach and Chelini (1963), McClernan (1976), Stout (1949), Walker (1963)
74	Smith-Jones mine	Big Blackfoot (Ogden Mtn)	46	51	43	112	52	25	Vein, polymetallic								Elliott and others (1992)
75	New Progress and Old Time prospects	Big Blackfoot (Ogden Mtn)	46	52	18	112	50	12	Skarn W							Quartz vein along bedding plane fault in limestone; scheelite occurs in skarn between limestone and granodiorite.	Elliott and others (1992), Walker (1963)
76	Hunter mine	Big Blackfoot (Ogden Mtn)	46	52	20	112	49	50	Vein, polymetallic							Veins in argillite near contact with granodiorite.	Elliott and others (1992), Stout (1949)
77	Blackfoot (Blackfoot gold mine)	Big Blackfoot (Ogden Mtn)	46	51	50	112	50	48	Vein, polymetallic	1235	570	908	0.1	0.2		Strike N80W to N40W quartz vein containing Au, Ag, Pb; scheelite in nearby prospect pits.	Elliott and others (1992), Frishman and others (1992), McClernan (1976), Stout (1949)
78	Canarway Gulch Placer	Big Blackfoot (Ogden Mtn)	46	51	8	112	52	37	Placer Au							Extensive placer workings several hundred feet along the headwaters of Canarway Gulch.	This report
79	Chimney Creek placer	Big Blackfoot (Ogden Mtn)	46	50	15	112	53	27	Placer Au								Elliott and others (1992), Frishman and others (1992), Lyden (1948)
80	Deer Creek placer	Big Blackfoot (Ogden Mtn)	46	48	48	112	50	14	Placer Au		Minor						Elliott and others (1992), Frishman and others (1992), Lyden (1948), Stout (1949)
81	Chicken Creek placer	Big Blackfoot (Ogden Mtn)	46	48	40	112	49	0	Placer Au		Minor						Elliott and others (1992), Frishman and others (1992), Lyden (1948)

No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	Production and Reserves [2] (tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
82	Deer Creek mine	Big Blackfoot (Ogden Mtn)	46	50	48	112	48	42	Vein, polymetallic							Quartz veins occur along argillite-granodiorite contact.	Elliott and others (1992), Stout (1949)
83	Illini	Finn	46	51	1	112	43	44	Vein, polymetallic								McClernan (1983)
84	Humdinger	Finn	46	50	17	112	41	66	Vein, polymetallic	None						1-in.-wide vein of quartz with limonite and possible free gold.	Crowley (1960), Elliott and others (1992), Foote and Vandeveer (1957)
85	Name unknown	Finn	46	51	0	112	40	6	Vein, polymetallic								Elliott and others (1992)
86	All Placer	Finn	46	50	27	112	40	13	Placer Au								McClernan (1983)
87	Buffalo Gulch placer*	Finn	46	48	38	112	44	30	Placer Au		230						Elliott and others (1992), Lyden (1948), Pardee and Schrader (1933)
88	Jefferson Creek placer	Finn	46	47	33	112	42	56	Placer Au		15						Crowley (1962a), Frishman and others (1992), Geach and Chelini (1983), Lawson (1976), Lyden (1948), Pardee and Schrader (1933)
89	Madison Gulch placer	Finn	46	47	38	112	42	50	Placer Au		75						Elliott and others (1992), Frishman and others (1992), Lyden (1948)
90	Washington Creek placer	Finn	46	45	52	112	41	11	Placer Au		5300						Dingman (1932), Geach and Chelini (1983), Lyden (1948), McCulloch (1993b), Pardee and Schrader (1933), Trauerman and Waldron (1940)
91	American Gulch placer	Finn	46	46	27	112	38	52	Placer Au		Minor						Elliott and others (1992), Frishman and others (1992), Lyden (1948)
92	Wiggins	McClellan Gulch	46	50	18	112	38	55	Vein, polymetallic							Quartz veins containing Au, Ag, Pb, Cu, and Bi.	Elliott and others (1992)
93	McClellan Gulch (Creek) placer	McClellan Gulch	46	52	54	112	37	53	Placer Au		350000					57-oz Au nugget found in 1927.	Dingman (1932), Elliott and others (1992), Frishman and others (1992), Lyden (1948), Pardee and Schrader (1933)
94	Silver Bell (Swansea)	Stemple-Gould	46	53	22	112	32	42	Epithermal vein, quartz- adularia	3013	739	45220	13	11.4		Vein within a N10E-striking shear zone. Minor pyrite, chalcopyrite; silver up to 10 oz per ton in vein.	Elliott and others (1992), Frishman and others (1992), McClernan (1983), McKee (1978)

										Production		and		Reserves [2]			
No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	(tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
95	Cyclone	Stemple-Gould	46	51	32	112	30	32	Epithermal vein, quartz- adularia								McClernan (1983)
96	Victory	Stemple-Gould	46	53	17	112	29	29	Epithermal vein, quartz- adularia							Eastern extension of Homestake Bachelor mineralization.	McClernan (1983)
97	Gold Creek placer (Blue Jay)	Stemple-Gould	46	54	10	112	28	59	Placer Au								Elliott and others (1992)
98	Homestake	Stemple-Gould	46	53	18	112	29	0	Epithermal vein, quartz- adularia							Adit follows 1 ft ore shoot for 300 ft.	Elliott and others (1992), Pardee and Schrader (1933)
99	Bachelor	Stemple-Gould	46	54	20	112	28	55	Epithermal vein, quartz- adularia								McClernan (1983)
100	Badger	Stemple-Gould	46	53	25	112	28	23	Epithermal vein, quartz- adularia								McClernan (1983)
101	Alpha	Stemple-Gould	46	53	28	112	27	58	Epithermal vein, quartz- adularia								McClernan (1983)
102	Golconda (Nakoma)	Stemple-Gould	46	52	42	112	28	4	Epithermal vein, quartz- adularia							4-ft-wide quartz vein with calcite similar to Jay Gould vein.	Frishman and others (1992), McClernan (1983), Pardee and Schrader (1933)
103	Rooster Bill Creek placer, Margaret	Stemple-Gould	46	54	3	112	27	3	Placer Au								Elliott and others (1992)
104	Omega	Stemple-Gould	46	53	30	112	27	14	Epithermal vein, quartz- adularia							Western extension of Homestake mineralization.	McClernan (1983)
105	Jay Gould	Stemple-Gould	46	52	55	112	27	31	Epithermal vein, quartz- adularia	Unknown (1884-1914); 0.36 Mt (1900-1948)	118700 (1884-1914) ; 101101 (1900-1948)	125000 (1884-1914); 459487 (1900-1948)				Strike N70W, dip 80N quartz-calcite vein with native gold, argentite, chalcopyrite. Workings are about 2,800 ft along strike of vein and about 700 ft deep. Vein in Empire Formation near Granite Butte stock.	Frishman and others (1992), McClernan (1983), Pardee and Schrader (1933)
106	Fool Hen Creek placer	Stemple-Gould	46	53	36	112	25	55	Placer Au								Dingman (1932), Frishman and others (1992)
107	Hubbard (Mill Tunnel)	Stemple-Gould	46	52	15	112	27	13	Epithermal vein, quartz- adularia	6105	2198	11284		0.7		South-trending vein, 57E dip, 2-6 ft wide with quartz and pyrite, workings are 1,000 ft along strike, 500 ft deep.	Frishman and others (1992), Pardee and Schrader (1933)

No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	Production and Reserves [2] (tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
108	Prize	Stemple-Gould	46	51	12	112	28	20	Epithermal vein, quartz- adularia							Vein quartz on dump contains copper carbonates.	Elliott and others (1992), Frishman and others (1992), McClernan (1983), Pardee and Schrader (1933)
109	Crown	Stemple-Gould	46	51	6	112	28	13	Epithermal vein, quartz- adularia	Minimal	5					3-ft-wide vein with iron oxides.	Elliott and others (1992), Frishman and others (1992), McClernan (1983), Pardee and Schrader (1933)
110	Name unknown	Stemple-Gould	46	50	53	112	27	14	Vein, polymetallic							Quartz veins near contact of limestone and granodiorite stock of Granite Butte.	Elliott and others (1992)
111	Gould Creek placer	Stemple-Gould	46	53	3	112	23	19	Placer Au								Dingman (1932), Elliott and others (1992), Frishman and others (1992), Lyden (1948), US Forest Service (1981-1983)
112	Copper Hill (McVay)	Little Prickly Pear Area	46	59	40	112	19	2	Sediment-hosted Cu, redbed	94000 (r)		56000	1050			Malachite, chalcopyrite, bornite in metasandstone and siltite of Spokane Formation. Best sampled thickness 50 ft at 1.52 percent Cu, 0.93 oz per ton Ag, 0.005 oz per ton Au.	Braun and Lange (1984), Brox and Guilbert (1960), Brox and Potter (1965), Lange and others (1986, 1989)
113	Specimen Creek placer	Little Prickly Pear Area	46	56	16	112	20	44	Placer Au								Elliott and others (1992), Frishman and others (1992), Lyden (1948), Pardee and Schrader (1933)
114	Tarhead Creek placer	Little Prickly Pear Area	46	54	39	112	21	10	Placer Au								Elliott and others (1992), Frishman and others (1992), Lyden (1948), Pardee and Schrader (1933)
115	Virginia Creek placer	Little Prickly Pear Area	46	52	56	112	20	40	Placer Au								Elliott and others (1992), Frishman and others (1992), Lyden (1948), Pardee and Schrader (1933)
116	Canyon Creek gold prospect*	Little Prickly Pear Area	46	49	26	112	18	52	Unclassified	None						Thin quartz veins.	Elliott and others (1992)

No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	Production and Reserves [2] (tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
117	Big Ox mine*	Little Prickly Pear Area	46	47	30	112	17	43	Unclassified							Diorite nearby.	Barrell (1907), Elliott and others (1992), U.S. Geological Survey (1885-1923)
118	Little Ox mine*	Marysville (Silver Creek)	46	46	22	112	19	12	Vein, polymetallic							Dump contains galena, cerussite, covellite, tetrahedrite, quartz-calcite.	Barrell (1907), Elliott and others (1992), McClernan (1983), Stout and Ackerman (1959), U.S. Geological Survey (1885-1923), Young and others (1962)
119	Piegan-Gloster mine*	Marysville (Silver Creek)	46	45	43	112	20	27	Epithermal vein, quartz- adularia	0.32 Mt	156980	320822	0.9			Quartz-calcite vein which averaged 3 ft in width and contained disseminated pyrite.	Elliott and others (1992), Frishman and others (1992), Knopf (1913), McClernan (1983), Pardee and Schrader (1933)
120	Empire Creek placer (Lost Horse Creek)*	Marysville (Silver Creek)	46	45	20	112	21	32	Placer Au	Unknown, but minor							Elliott and others (1992), Frishman and others (1992), Lyden (1948)
121	American Flag*	Marysville (Silver Creek)	46	45	13	112	20	58	Vein, polymetallic							2-ft-wide vein parallel to the vein developed by the Empire mine workings.	McClernan (1983), Pardee and Schrader (1933)
122	Empire*	Marysville (Silver Creek)	46	45	21	112	20	52	Vein, polymetallic	36087	5683	19666	42.9	624	18	Strike N80W, dip 70S vein of brecciated country rock averaging 6 ft thick.	Beadle (1893), Frishman and others (1992), Hansen (1971), Knopf (1913), McClernan (1983), Pardee and Schrader (1933), Sizer (1914)
123	M + L*	Marysville (Silver Creek)	46	45	10	112	20	40	Vein, polymetallic							Southeastward extension of the Empire vein.	Elliott and others (1992), Knopf (1913), McClernan (1983), Pardee and Schrader (1933)
124	Guerin Lode	Marysville (Silver Creek)	46	44	21	112	22	56	Vein, polymetallic	None							Elliott and others (1992)
125	Earthquake	Marysville (Silver Creek)	46	44	17	112	22	9	Vein, polymetallic							Strike N35-40E vein of breccia with altered wall-rock fragments cemented by quartz, calcite, fluorite, galena, chalcopyrite, pyrite.	Elliott and others (1992), McClernan (1983), Pardee and Schrader (1933)

No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	Production and Reserves [2] (tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
126	Mammoth claim*	Marysville (Silver Creek)	46	44	18	112	22	7	Epithermal vein, quartz- adularia	1562	1969	540	0.1	0.1		N55E, 70E-striking vein; continuation of Nile vein.	Elliott and others (1992), McClernan (1983), Pardee and Schrader (1933), U.S. Geological Survey (1885-1923)
127	Shakopee*	Marysville (Silver Creek)	46	44	24	112	22	5	Vein, polymetallic							Same vein as mined at the Earthquake mine.	Elliott and others (1992), McClernan (1983), Pardee and Schrader (1933)
128	Nile*	Marysville (Silver Creek)	46	44	17	112	21	55	Vein, polymetallic	6067	500	5154	17.7	304	10.6	Strike N70E, dip70S vein containing breccia of altered wall rock in a matrix of finely ground wall rock with galena.	Elliott and others (1992), McClernan (1983), Pardee and Schrader (1933)
129	Towsley*	Marysville (Silver Creek)	46	44	27	112	21	47	Vein, polymetallic	Combined with Nile						Same vein as mined at Earthquake and Shakopee; breccia matrix is galena and cerussite.	Elliott and others (1992), McClernan (1983), Pardee and Schrader (1933)
130	Bell Boy mine*	Marysville (Silver Creek)	46	44	22	112	21	42	Vein, polymetallic	Combined with Nile						Strike N50W, dip 65-70SW vein of breccia with fluorite, galena, and chalcopyrite.	Elliott and others (1992), Gilbert (1935), McClernan (1983), Pardee and Schrader (1933)
131	Penobscot*	Marysville (Silver Creek)	46	43	50	112	21	22	Vein, polymetallic	52570	22560	57165	1	9.4	0.2	Three parallel veins of porous manganiferous quartz with lamellar calcite. Near diorite porphyry intrusion.	Elliott and others (1992), Frishman and others (1992), Goodale (1914), Knopf (1913), McClernan (1983), McDermott (1914), Pardee and Schrader (1933)
132	Bald Butte	Marysville (Silver Creek)	46	43	37	112	21	2	Vein, polymetallic	0.17 Mt	55390	49020	17.4	145.2		Short, narrow, gold-bearing quartz veins adjacent to 60-ft-wide diorite porphyry dike. Veinlets associated with the dike contain banded quartz and fluorite with molybdenite.	Barrell (1907), Elliott and others (1992), Frishman and others (1992), Knopf (1913), McClernan (1983), Ross (1950), Rostad (1969), Sahinen (1962), Weed (1903)
133	Bald Butte	Marysville (Silver Creek)	46	43	22	112	20	47	Climax Mo							Short, narrow, gold-bearing quartz veins adjacent to 60-ft-wide diorite porphyry dike. Veinlets associated with the dike contain banded quartz and fluorite with molybdenite. Near microdiorite; diorite porphyry dike.	Barrell (1907), Elliott and others (1992), Frishman and others (1992), Knopf (1913), McClernan (1983), Ross (1950), Rostad (1969), Sahinen (1962), Weed (1903)

No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	Production and Reserves [2] (tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
134	Shannon mine*	Marysville (Silver Creek)	46	44	0	112	20	6	Epithermal vein, quartz- adularia	Unknown, but large						Veins occur along shear zones.	Barrell (1907), Elliott and others (1992), Frishman and others (1992), Trauerman and Waldron (1940), U.S. Geological Survey (1885-1923)
135	Cruse (Bald Mountain mine)*	Marysville (Silver Creek)	46	44	56	112	19	14	Epithermal vein, quartz- adularia	Combined with Belmont						Veins perpendicular to granodiorite contact. Near granodiorite intrusion.	Barrell (1907), Elliott and others (1992), Frishman and others (1992), Knopf (1913), McClernon (1983), Pardee and Schrader (1933)
136	Belmont*	Marysville (Silver Creek)	46	44	42	112	19	2	Epithermal vein, quartz- adularia	0.12 Mt	25810	61219	0.7			NW-striking veins perpendicular to the hornfels-granodiorite contact. Near granodiorite intrusion.	Barrell (1907), Elliott and others (1992), Frishman and others (1992), Knopf (1913), McDermott (1914), McClernan (1983), Pardee and Schrader (1933), U.S. Geological Survey (1885-1923)
137	Calumet mine*	Marysville (Silver Creek)	46	45	15	112	17	40	Epithermal vein, quartz- adularia							Platy calcite and quartz veins stained with iron and manganese oxides containing 0.1-1.0 oz per ton Au.	Elliott and others (1992), McClernan (1983), Pardee and Schrader (1933)
138	Staples mine*	Marysville (Silver Creek)	46	45	18	112	17	36	Epithermal vein, quartz- adularia								Elliott and others (1992), Pardee and Schrader (1933)
139	Drumlummon*	Marysville (Silver Creek)	46	44	36	112	17	45	Epithermal vein, quartz- adularia	0.48 Mt	115694 (1901-48); 800,000 (1876-1900)	852666	11.6	15		N15E- and N45E-striking veins containing quartz, calcite, fluorite, galena, pyrite, sphalerite, chalcopyrite, tetrahedrite. Near granodiorite intrusion. Production figures from McClarenan(1983), except that 1876-1900 Au figure is from Goodale (1914)	Barrell (1907), Clayton (1888), Efraimson (1936), Elliott and others (1992), Frishman and others (1992), Goodale (1914), Hansen (1971), Knopf (1913), McClernan (1983), Pardee and Schrader (1933), Weed (1903)
140	Three Mile Creek placer	Ophir	46	41	47	112	35	36	Placer Au		250						Elliott and others (1992), Loen (1989), Lyden (1948), Pardee and Schrader (1933)
141	Ajax	Ophir	46	42	32	112	29	30	Skarn Au		2400					Irregular cylindrical body from 6 in. to 2 ft in diameter, plunging vertically, magnetite-garnet-malachite.	Elliott and others (1992), Loen (1989), McClernan (1976), Pardee and Schrader (1933)

No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	Production and Reserves [2] (tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
142	Victory	Ophir	46	42	20	112	30	20	Skarn Au		2000					Occurs at contact porphyritic quartz monnzonite and limestone in sheared rock. Vertical pipe, 2-12 ft in diameter, with quartz, pyrite, and chalcopyrite.	Elliott and others (1992), Pardee and Schrader (1933), Renouard and Shea (1935)
143	Nugget Gulch placer	Ophir	46	42	14	112	29	53	Placer Au		250						Elliott and others (1992), Loen (1989)
144	Nora Darling	Ophir	46	42	8	112	30	15	Polymetallic replacement								Elliott and others (1992), Loen (1989), U.S. Geological Survey (1885-1923)
145	El Dorado	Ophir	46	42	0	112	30	13	Skarn Au	370	84	297	16			Occurs at contact with small granodiorite intrusion. Irregular contact skarn with diopside, garnet, magnetite, hematite with chalcopyrite.	Elliott and others (1992), Freshman (1950), Loen (1989)
146	Cyclone (Whirlwind)	Ophir	46	42	0	112	30	15	Skarn Au	31	8	100	2.3			Contained tungsten. Near granodiorite intrusion.	Elliott and others (1992), Geach and Chelini (1963), McClernan (1976)
147	Bumblebee (Morning Star)	Ophir	46	41	45	112	30	45	Skarn Au							Near granodiorite intrusion.	Bondurant and Lawson (1969), Elliott and others (1992), McClernan (1976)
148	Nancy Helen	Ophir	46	41	28	112	31	8	Vein, polymetallic							Veins in shear zones within granodiorite.	Elliott and others (1992), Loen (1989)
149	Coon's Tungsten*	Ophir	46	41	18	112	31	50	Skarn W							Tungsten, manganese, molybdenum. Near granodiorite intrusion.	Elliott and others (1992), McClernan (1976), Walker (1963)
150	Fairview (Coulson)*	Ophir	46	40	55	112	32	47	Epithermal vein, quartz- adularia	445	207	9294	0.1	3.2		Vuggy banded quartz vein contains: pyrite, tetrahedrite, gold tellurides, ruby silver minerals.	Elliott and others (1992), Lawson (1979), McClernan (1976), Pardee and Schrader (1933)
151	Denver*	Ophir	46	40	54	112	32	32	Vein, polymetallic							4-ft-wide quartz vein along the quartzite-granodiorite contact dips 58SW; quartz contains pyrite and tetrahedrite.	Elliott and others (1992), Pardee and Schrader (1933)
152	Opsata*	Ophir	46	40	36	112	32	26	Vein, polymetallic	10						Quartz vein formed at quartzite-granodiorite contact.	Elliott and others (1992), Pardee and Schrader (1933)
153	Ophir (Reservoir)*	Ophir	46	40	27	112	32	23	Vein, polymetallic							Vein occurs at contact between quartzite and quartz monzonite.	Elliott and others (1992), Geach and Chelini (1963), McClernan (1976), Pardee and Schrader (1933)

No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	Production and Reserves [2] (tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
154	Katie Allen*	Ophir	46	40	30	112	31	59	Hot-spring Au-Ag							Zones of disseminated pyrite.	Elliott and others (1992), Lawson and others (1987)
155	Tiger Gulch placer*	Ophir	46	40	14	112	33	3	Placer Au		200						Elliott and others (1992), Loen (1989)
156	Butterfly*	Ophir	46	40	19	112	32	4	Vein, polymetallic							Quartz veinlets in limestone containing pyrite, chalcopyrite, tetrahedrite. Possibly old Quigley Mo mine, Mo in garnet skarn locally 2 percent MoS2.	Elliott and others (1992), Loen (1989), McClernan (1976), Sales (1918)
157	Butterfly*	Ophir	46	40	19	112	32	4	Skarn W							Possibly old Quigley Mo mine, Mo in garnet skarn locally 2 percent MoS_2.	Sales (1918)
158	Mexican Gulch placer	Ophir	46	40	55	112	30	40	Placer Au		500						Elliott and others (1992), Loen (1989)
159	Little Daisy (Orient, Maggie, Alice)	Ophir	46	41	10	112	29	45	Vein, polymetallic		150					Four veins containing Au, Ag, Pb, Sb.	Elliott and others (1992), McClernan (1976), Pardee and Schrader (1933)
160	Price	Ophir	46	41	21	112	29	10	Polymetallic replacement							Replacement of carbonate rock near granodiorite stock.	Elliott and others (1992), Geach (1967), Pardee and Schrader (1933)
161	Deadwood Gulch placer	Ophir	46	41	24	112	27	30	Placer Au		500					158.7-oz gold nugget recovered here.	Dingman (1932), Elliott and others (1992), Loen (1989), Lyden (1948), Pardee and Schrader (1933)
162	McKay	Ophir	46	41	52	112	26	15	Skarn Au							Produced specimens of very rich gold ore.	Elliott and others (1992), McClernan (1976), Pardee and Schrader (1933)
163	Esmeralda	Ophir	46	41	17	112	26	30	Skarn Au	10	6	2					Elliott and others (1992), Loen (1989), McClernan (1976)
164	Flagstaff	Ophir	46	40	47	112	28	13	Skarn W							Skarn near contact with granodiorite; W also produced.	Elliott and others (1992), McClernan (1976), Pardee and Schrader (1933)
165	Arnold (Bielenberg, Boulder Ores, Strategic, Snowshoe)	Ophir	46	40	40	112	28	2	Skarn Au	361	5	181	9.4			Produced 1.2 tons of WO_4 from 220 tons of ore.	Elliott and others (1992), McClernan (1976), Pardee and Schrader (1933), Walker (1963)

No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	Production and Reserves [2] (tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
166	Ladysmith	Ophir	46	40	40	112	27	48	Skarn W							Skarn near contact with granodiorite; W also produced.	Elliott and others (1992), McClernan (1976)
167	Jack Pine mine (Trout Creek, Senecal)	Ophir	46	40	0	112	27	30	Phosphate, upwelling								Crowley (1962b), Elliott and others (1992), Popoff and Service (1965), Stone (1952), Swanson (1973)
168	Mine (name unknown)	Ophir	46	39	52	112	29	35	Skarn Au							Skarn near contact with granodiorite.	Elliott and others (1992), Loen (1989)
169	Illinois Gulch placer*	Ophir	46	39	26	112	33	3	Placer Au		500						Elliott and others (1992), Loen (1989), Lyden (1948)
170	Eureka Gulch placer*	Ophir	46	38	30	112	32	20	Placer Au		3000					Bench and creek placers.	Elliott and others (1992), Loen (1989)
171	Ophir Creek placer (Tributary of Carpenter Creek)	Ophir	46	37	55	112	32	32	Placer Au		100000						Dingman (1932), Elliott and others (1992), Frishman and others (1992), Loen (1989), Lyden (1948), Pardee and Schrader (1933)
172	Snowshoe Creek placer	Ophir	46	37	55	112	29	28	Placer Au		25000						Dingman (1932), Elliott and others (1992), Frishman and others (1992), Loen (1989), Lyden (1948), Pardee and Schrader (1933)
173	Carpenter Creek placer*	Ophir	46	36	0	112	33	16	Placer Au		150000					Both bench and creek placers.	Dingman (1932), Elliott and others (1992), Frishman and others (1992), Loen (1989), Lyden (1948), Pardee and Schrader (1933)
174	Gold Canyon Creek placer*	Dog Creek Area	46	36	10	112	28	21	Placer Au		4700						Elliott and others (1992), Frishman and others (1992), Lyden (1948)
175	Dog Creek phosphate	Dog Creek Area	46	40	5	112	23	10	Phosphate, upwelling								Crowley (1962b), Elliott and others (1992), Popoff and Service (1965)
176	Dog Creek placer	Dog Creek Area	46	38	32	112	22	22	Placer Au		Minor						Elliott and others (1992), Lyden (1948)
177	Blossburg mine	Dog Creek Area	46	38	57	112	20	31	Clay							Clay pit supplied material for brickmaking in early Helena.	Rowe (1908), Schmidt and others (1994)

										Production	and		Reserves [2]				
No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	(tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
178	Blue Belle mine	Dog Creek Area	46	37	28	112	18	15	Skarn W							Vein of garnet in the monzonite with disseminated pyrite and molybdenite, trace Cu, Au, Ag, Mo, Zn, Pb, Sn, W.	Elliott and others (1992), Knopf (1913), McClernan (1976), Pardee and Schrader (1933)
179	Sawmill Gulch phosphate mine	Dog Creek Area	46	35	0	112	22	46	Phosphate, upwelling								Elliott and others (1992), Popoff and Service (1965)
180	Newman Brothers	Dog Creek Area	46	34	3	112	25	58	Phosphate, upwelling								Elliott and others (1992), Popoff and Service (1965)
181	Little Blackfoot River placer	Dog Creek Area	46	33	45	112	25	32	Placer Au								Elliott and others (1992), Lyden (1948), Pardee and Schrader (1933)
182	Elliston phosphate mine (Little Blackfoot River mine)	Dog Creek Area	46	33	44	112	25	20	Phosphate, upwelling								Crowley (1962b), Elliott and others (1992), Popoff and Service (1965)
183	Senecal incline	Dog Creek Area	46	33	45	112	24	10	Phosphate, upwelling							Inclined shaft, 80 ft deep, in phosphorite beds.	Elliott and others (1992), Popoff and Service (1965)
184	Elliston quarry	Dog Creek Area	46	33	45	112	23	10	Limestone								Chelini (1965), Elliott and others (1992), Geach (1965, 1967), Kauffman (1952)
185	Boeing prospect	Austin	46	39	0	112	18	15	Vein, polymetallic							Fluorite and base and precious metals in vein and carbonate replacement deposits. Associated with dacite dikes.	Elliott and others (1992), Ross (1950), Sahinen (1962)
186	Strawberry mine	Austin	46	42	24	112	16	35	Vein, polymetallic							N-S vein, dipping 60W, along faulted contact of shale and diorite.	Elliott and others (1992), Knopf (1913)
187	Blue Jay mine (Red Bird mine)	Austin	46	40	55	112	14	35	Polymetallic replacement	Unknown, but considerable						Oxide Cu-Pb minerals in limonite, vertical range 200 ft. Quartz monzonite nearby.	DeMunck (1956), Elliott and others (1992), Pardee and Schrader (1933)
188	Chamounix	Austin	46	39	58	112	16	34	Skarn Au							Irregular lenses of Cu-bearing garnet-epidote skarn along quartz monzonite intrusion limestone contact.	Goddard (1940a)
189	Baldy Smith mine	Austin	46	40	10	112	13	20	Vein, polymetallic							N20E, 45W mineralized fault with disseminated pyrite-sericite.	Elliott and others (1992), Pardee and Schrader (1933)

No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	Production and Reserves [2] (tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
190	King Tut mine	Austin	46	39	43	112	14	10	Polymetallic replacement	2000						Ore occurs in irregular pipes or chimneys containing pyrite, galena, sphalerite, arsenopyrite, and stibnite. Dikes of quartz monzonite.	Elliott and others (1992), Pardee and Schrader (1933)
191	Copper Hill mine	Austin	46	39	25	112	14	25	Polymetallic replacement							Replacement occurs at the contact between quartz monzonite and limestone. Mineralization is mainly hematite with minor pyrite. Associated with quartz monzonite.	Elliott and others (1992), Pardee and Schrader (1933)
192	Osage Chief mine (Crissman mine)	Austin	46	39	2	112	14	39	Polymetallic replacement							Extension of Copper Hill mine.	DeMunck (1956), Elliott and others (1992), Pardee and Schrader (1933)
193	War Eagle mine	Austin	46	38	30	112	13	3	Polymetallic replacement	75000						Mineralized zone occurs at the contact between limestone and intrusive quartz monzonite. Ore has high iron content.	DeMunck (1956), Elliott and others (1992), Pardee and Schrader (1933)
194	Skelly Gulch (Greenhorn Creek) placer	Austin	46	39	30	112	11	35	Placer Au							Tungsten is a by-product.	Elliott and others (1992), Frishman and others (1992), Lyden (1948), Pardee and Schrader (1933), U.S. Geological Survey (1988), Walker (1963)
195	Anderson prospect	Stemwinder Hill Area	46	36	55	112	11	15	Vein, polymetallic							Vein contains gold, scheelite, and molybdenite.	Elliott and others (1992), Frishman and others (1992), Walker (1963)
196	Perry Claims (Fairview Claims)	Stemwinder Hill Area	46	36	28	112	10	20	Vein, polymetallic	None						Vein in shale.	Elliott and others (1992), Walker (1963)
197	Blue Cloud prospect	Stemwinder Hill Area	46	35	55	112	10	10	Skarn W	None						Scheelite-bearing skarn along contact of diorite porphyry (Kd) and limestone (Cs).	Elliott and others (1992), Walker (1963)
198	Dutro (Old Dominion)*	Stemwinder Hill Area	46	35	33	112	9	38	Skarn Au							Gold, bismuth, and tin mineralization associated with jasper and opal in Paleozoic carbonate rock in diorite intrusion.	Elliott and others (1992), Frishman and others (1992), Knopf (1913), Pardee and Schrader (1933)
199	Silver Coin mine	Stemwinder Hill Area	46	36	48	112	8	35	Skarn Au							Granodiorite intrusion nearby.	Elliott and others (1992), Pardee and Schrader (1933), Stout and Ackerman (1959)

										Production		and		Reserves [2]			
No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	(tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
200	Blue Cloud Mining Co. placer*	Stemwinder Hill Area	46	35	40	112	7	53	Placer Au								Elliott and others (1992), Trauerman and Waldron (1940)
201	Nelson Gulch placer	Helena (Last Chance)	46	34	40	112	8	54	Placer Au							100-oz Au nugget found in 1865.	Dingman (1932), Elliott and others (1992), Frishman and others (1992), Lyden (1948), Pardee and Schrader (1933)
202	Orofino, Dry, Grizzly, and Last Chance Gulch placers*	Helena (Last Chance)	46	35	6	112	2	32	Placer Au		800000						Boulter (1950), Dingman (1932), Elliott and others (1992), Frishman and others (1992), Greenfield (1936), Lyden (1948), Pardee and Schrader (1933)
203	Helena Limestone quarry	Helena (Last Chance)	46	34	49	112	3	5	Limestone	Small							Chelini (1965), Elliott and others (1992)
204	Spring Hill	Helena (Last Chance)	46	33	18	112	5	45	Skarn Au	65000	~14000					Massive lenses of pyrite and pyrrhotite in calc-silicate rock. Grades up to 1.5 oz per ton Au. Near fine-grained diorite. Production data incomplete--tonnage and gold recovery figures are approximate.	Efraimson (1936), Elliott and others (1992), Frishman and others (1992), Jones (1934), Knopf (1913), McClernan (1983), Pardee and Schrader (1933)
205	Whitlach-Union	Helena (Last Chance)	46	32	53	112	5	34	Vein, polymetallic	57500 (1901 48)	17390 (1901-48); 300,000 (1864-1913)	8383	9.3	40.5	9.2	Production figures are from McClernan (1983), except that 300,000 oz. is from Knopf (1913) for 1864-1913 period. Overlap of data exists, but > 95 percent of production is pre-1900.	Elliott and others (1992), Frishman and others (1992), Knopf (1913), McClernan (1983), Pardee and Schrader (1933), Reyner and Trauerman (1949)
206	Independent prospect	Helena (Last Chance)	46	33	12	112	4	8	Vein, polymetallic							Veins occur along contact; minor tungsten present.	Elliott and others (1992), Walker (1963)
207	Eula-Homestake	Helena (Last Chance)	46	33	11	112	3	23	Vein, polymetallic							N90E-striking vein, dipping 26-40N, consists of 1.5-2 ft quartz with pyrite containing ~0.1 oz per ton Au.	McDonald (1931)
208	Big Indian*	Helena (Last Chance)	46	32	17	112	1	20	Vein, polymetallic	22000	5500					Porphyry dikes may have introduced tourmaline and pyrite (no quartz).	Becraft and others (1963), Frishman and others (1992), Pardee and Schrader (1933), Roby and others (1960)

No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	Production and Reserves [2] (tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
209	Pretty Girl placer*	Helena (Last Chance)	46	31	55	112	0	15	Placer Au								Frishman and others (1992), USFS (1981-1983)
210	Carbonate King	North Boulder Mountains Area	46	31	43	112	25	54	Vein, polymetallic	150	2	2503		34		NE- to E.-trending vertical vein with pyrite, galena, sphalerite in calcite matrix.	Elliott and others (1992), McClernan (1976)
211	Mike Reinig Gulch placer	North Boulder Mountains Area	46	31	40	112	19	33	Placer Au		180						Elliott and others (1993), Lyden (1948)
212	Clark mine	Elliston	46	30	44	112	24	17	Vein, polymetallic							Described as breccia body with tetrahedrite, pyrite, galena, sphalerite, and quartz cementing andesite fragments.	Elliott and others (1992), McClernan (1976), Robertson (1956)
213	Sadie	Elliston	46	29	55	112	24	5	Vein, polymetallic							Brecciated quartz vein with pyrite, arsenopyrite, galena, sphalerite, and tetrahedrite.	Elliott and others (1992), McClernan (1976), Pardee and Schrader (1933), Ruppel (1983)
214	Charter Oak mine	Elliston	46	29	25	112	24	59	Vein, polymetallic	9127	382	39146	10	336	84.1	Quartz vein with galena, arsenopyrite, pyrite, sphalerite.	Elliott and others (1992), Geach (1966), McClernan (1976), Pardee and Schrader (1933), Ruppel (1963), Young and others (1962)
215	Negros mine	Elliston	46	29	11	112	25	25	Vein, polymetallic	985	170	6118	0.4	66	5	Two N45E-striking veins.	Elliott and others (1992), Lawson (1979), McClernan (1976), Ruppel (1983)
216	Flora	Elliston	46	28	57	112	25	40	Vein, polymetallic							NE-striking vein, dipping 20NW.	Elliott and others (1992), McClernan (1976), Pardee and Schrader (1933), Ruppel (1963), U.S. Geological Survey (1885-1923)
217	Blackfeet Nos. 1 and 3 claims	Elliston	46	28	24	112	25	42	Vein, polymetallic	None							Elliott and others (1992)
218	Brooklyn mine	Elliston	46	28	16	112	25	30	Vein, polymetallic							May be the same property as the Blue Bird.	Elliott and others (1992), Pardee and Schrader (1933), Roby and others (1960)
219	Bluebird	Elliston	46	28	19	112	25	28	Vein, polymetallic							2- to 15-in.-wide quartz-pyrite-galena vein in NE-trending fault zone.	Elliott and others (1992), McClernan (1976), Ruppel (1963)

No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	Production and Reserves [2] (tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
220	Golden Anchor	Elliston	46	28	40	112	24	40	Vein, polymetallic	55	17	424		4.6	2		Elliott and others (1992), McClernan (1976), Pardee and Schrader (1933), Ruppel (1963)
221	Black Jack	Elliston	46	28	42	112	24	15	Vein, polymetallic	412	885	8958		61.7		North-trending vein dipping 30W.	Elliott and others (1992), Frishman and others (1992), McClernan (1976), Pardee and Schrader (1933), Ruppel (1963)
222	Big Dick (Evening Star)	Elliston	46	28	35	112	24	25	Vein, polymetallic	15788	6802	42278	0.9	298.5		Strike N90E, dip 20N vein locally containing 3-5 oz Au/ton.	Elliott and others (1992), Frishman and others (1992), Knopf (1913), McClernan (1976), Pardee and Schrader (1933), Ruppel (1963)
223	Kimball mine	Elliston	46	27	50	112	25	0	Vein, polymetallic							Strike N35E, dip 48-68SE vein containing quartz and pyrite.	Elliott and others (1992), McClernan (1976), Ruppel (1963)
224	Ohio and Speculator	Elliston	46	26	58	112	25	4	Vein, polymetallic							N55W-striking quartz vein containing pyrite.	Elliott and others (1992), McClernan (1976), Ruppel (1963)
225	Third Term mine	Elliston	46	30	10	112	21	8	Vein, polymetallic	50	9	378	0.8	2.5	1.7	N80W-striking quartz vein with pyrite, chalcopyrite, galena, sphalerite, tetrahedrite, and tennantite.	Elliott and others (1992), Lawson (1981), McClernan (1976), Young and others (1962)
226	Telegraph Creek placer	Elliston	46	29	23	112	22	15	Placer Au		12						Elliott and others (1992), Lyden (1948)
227	Hub Camp	Elliston	46	28	56	112	21	33	Vein, polymetallic	52	51	1128		9.8		Strike N65E, dip 60S vein containing quartz and pyrite.	Elliott and others (1992), McClernan (1976), Ruppel (1963)
228	Viking mine	Elliston	46	28	36	112	22	24	Vein, polymetallic							N70W-striking quartz vein with tourmaline and galena.	Elliott and others (1992), McClernan (1976), Ruppel (1963)
229	Julia mine	Elliston	46	27	57	112	22	45	Vein, polymetallic	5233	2250	170345	152	57		Strike N90E, dip 80S quartz vein with galena, sphalerite, pyrite, tetrahedrite.	Elliott and others (1992), Knopf (1913), Lytzen (1919), McClernan (1976), Pardee and Schrader (1933), Ruppel (1963)
230	Wolverine	Elliston	46	26	1	112	23	27	Vein, polymetallic	13	1	318		2.6		N20W-striking mineralized zone in altered andesite cut by quartz stringers.	Bondurant and Lawson (1969), Elliott and others (1992), McClernan (1976), Ruppel (1963)
231	Ontario Creek placer	Elliston	46	25	53	112	23	10	Placer Au		184						Dingman (1932), Elliott and others (1992), Lyden (1948)

No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	Production and Reserves [2] (tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
232	Monarch	Elliston	46	24	25	112	24	10	Vein, polymetallic	1663	157	10677	12.5	48.2		Strike N90E, dip 85N vein in fault zone at contact between quartz monzonite and andesite.	Elliott and others (1992), Frishman and others (1992), Knopf (1913), Lawson (1979), McClernan (1976), Pardee and Schrader (1933), Ruppel (1963)
233	Hard Luck	Elliston	46	25	43	112	22	12	Vein, polymetallic							Strike N70W, dip 70S quartz vein with pyrite and sphalerite.	Lawson (1976), McClernan (1976), Ruppel (1963)
234	Ontario	Elliston	46	25	45	112	20	26	Vein, polymetallic	1092	615	3547		1.1		Quartz vein with pyrite, sphalerite, and galena.	Elliott and others (1992), Frishman and others (1992), Knopf (1913), McClernan (1976), Pardee and Schrader (1933), Ruppel (1963)
235	Surething mine (O'Keefe)	Elliston	46	26	25	112	19	54	Vein, polymetallic	2372	1528	65116		2.2		Quartz vein with pyrite and tourmaline associated with aplite dike.	Elliott and others (1992), Frishman and others (1992), McClernan (1976), Reyner and Trauerman (1949), Ruppel (1963)
236	Lily-Orphan Boy mine	Elliston	46	26	34	112	20	27	Vein, polymetallic	1228	333	12520	1.4	42.7	20	East-trending, high-angle vein with pyrite, galena, sphalerite in quartz tourmaline matrix.	Becraft and others (1963), Elliott and others (1992), Knopf (1913), Lusty (1973), McClernan (1976), Regnier (1951), Ruppel (1963)
237	Anna R. and Hattie M.	Elliston	46	27	17	112	20	36	Vein, polymetallic	1511	672	14917	0.4	1.1		Vein follows contact between quartz monzonite and aplite.	Elliott and others (1992), Frishman and others (1992), Lusty (1973), McClernan (1976), Ruppel (1963), Trauerman and Waldron (1940)
238	Telegraph mine	Elliston	46	27	52	112	18	50	Vein, polymetallic	30	17	339		0.5		Associated with placer working in creek bed.	Elliott and others (1992), McClernan (1976), Ruppel (1963)
239	Bullion mine	Elliston	46	27	45	112	18	20	Vein, polymetallic							East-trending quartz vein containing galena, sphalerite, and pyrite.	Elliott and others (1992), Lusty (1973), McClernan (1976)
240	Lucky Joe mine	Rimini (Vaughn)	46	28	7	112	17	15	Vein, polymetallic								Elliott and others (1992), Lawson (1976), Ruppel (1963)
241	Justice-Clementh	Rimini (Vaughn)	46	28	24	112	16	57	Vein, polymetallic	310	~380					NE-trending quartz vein, dipping 70-80NW, containing pyrite, galena, arsenopyrite, chalcopyrite, and tourmaline.	Elliott and others (1992), Ruppel (1963)

No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	Production and Reserves [2] (tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
242	Armstrong	Rimini (Vaughn)	46	28	51	112	17	1	Vein, polymetallic	10000						Strike N90E, dip 80N quartz vein with pyrite, galena, sphalerite, chalcopyrite with tourmaline.	Elliott and others (1992), Pardee and Schrader (1933), Ruppel (1963)
243	Beatrice	Rimini (Vaughn)	46	28	53	112	18	15	Vein, polymetallic							Strike N80W, dip 80S quartz vein with pyrite, galena, sphalerite, and chalcopyrite. Maximum vein thickness ~4 ft.	Elliott and others (1992), Ruppel (1963)
244	Independence	Rimini (Vaughn)	46	29	25	112	17	55	Vein, polymetallic							Location, but no information.	Ruppel (1963)
245	Alice Lode	Rimini (Vaughn)	46	28	58	112	15	35	Vein, polymetallic	None							Elliott and others (1992)
246	Tenmile Creek (Gould, Monitor, Tucker, and Minnehaha) placer	Rimini (Vaughn)	46	30	28	112	15	38	Placer Au							Tin also recovered.	Dingman (1932), Elliott and others (1992), Frishman and others (1992), Lyden (1948), Pardee and Schrader (1933), Ruppel (1963)
247	Little Lily (Group)	Rimini (Vaughn)	46	29	14	112	14	38	Vein, polymetallic	~3000						Probably branches off Lee Mtn-Valley Forge shear zone.	Becraft and others (1963), Elliott and others (1992)
248	Lee Mountain	Rimini (Vaughn)	46	29	8	112	14	49	Vein, polymetallic		44000	435000		322	363	Located along the Lee Mtn-Valley Forge shear zone, strikes N60E. Faults, veins, and altered rock, several 100 ft wide.	Becraft and others (1963), Elliott and others (1992), Frishman and others (1992), Knopf (1913), Pardee and Schrader (1933), Reyner and Trauerman (1949)
249	Valley Forge	Rimini (Vaughn)	46	29	30	112	14	25	Vein, polymetallic		10000 (gold equiv.)					Located along Lee Mtn-Valley Forge shear zone. Mineralization consists of galena, arsenopyrite, pyrite, quartz, tourmaline.	Becraft and others (1963), Billingsley and Grimes (1918), Elliott and others (1992), Frishman and others (1992), Knopf (1913), Pardee and Schrader (1933)
250	Red Mountain Tunnel (Montana Lead Crosscut Tunnel No. 1)	Rimini (Vaughn)	46	28	50	112	14	40	Unclassified							Access tunnel for Free Speech, Alta, and Eureka veins.	Becraft and others (1963), Elliott and others (1992), Pardee and Schrader (1933)
251	Name unknown	Rimini (Vaughn)	46	29	17	112	13	25	Vein, polymetallic, U-bearing							Quartz vein with meta-autumite (barren of sulfides) assays 0.073 U.	Becraft and others (1963)

No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	Production and Reserves [2] (tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
252	Mammoth	Rimini (Vaughn)	46	28	32	112	14	0	Vein, polymetallic							Strike N85W, dip 83S vein of milky to gray quartz.	Becraft and others (1963), Elliott and others (1992), Pardee and Schrader (1933)
253	Wolftone mine	Rimini (Vaughn)	46	24	47	112	14	34	Vein, polymetallic							Banded siliceous vein with arsenopyrite.	Elliott and others (1992), Pardee and Schrader (1933)
254	Little Sampson mine	Rimini (Vaughn)	46	28	32	112	14	40	Vein, polymetallic							Westward extension of the Free Speech vein.	Elliott and others (1992), Pardee and Schrader (1933)
255	Johny mine (Johnnie)	Rimini (Vaughn)	46	28	24	112	14	56	Vein, polymetallic							Quartz-tourmaline vein with galena and pyrite.	Elliott and others (1992), Pardee and Schrader (1933), U.S. Geological Survey (1885-1923)
256	O.H. Bassett	Rimini (Vaughn)	46	28	26	112	14	36	Vein, polymetallic							Strike N75W, dip 80S vein, with quartz, tourmaline, pyrite, arsenopyrite, galena, sphalerite.	Becraft and others (1963), Elliott and others (1992), Pardee and Schrader (1933)
257	Free Speech	Rimini (Vaughn)	46	28	27	112	14	30	Vein, polymetallic							Strike N83E, dip 77S vein, 6 ft wide, mainly quartz with galena and pyrite, arsenopyrite.	Becraft and others (1963), Elliott and others (1992), Hansen (1971)
258	Eureka	Rimini (Vaughn)	46	28	24	112	14	15	Vein, polymetallic							East-striking vein, dips steeply to south.	Becraft and others (1963), Elliott and others (1992), Pardee and Schrader (1933)
259	Lexington	Rimini (Vaughn)	46	28	21	112	14	24	Vein, polymetallic	2865	610	84450		286		Strike N78W, dip 75S vein containing galena, sphalerite, pyrite, arsenopyrite.	Becraft and others (1963), Elliott and others (1992), Frishman and others (1992), Pardee and Schrader (1933)
260	South Pacific mine	Rimini (Vaughn)	46	28	20	112	14	34	Vein, polymetallic							Vein containing 0.18 oz per ton Au, 35 oz per ton Ag, ~5.0 percent Pb.	Elliott and others (1992), Pardee and Schrader (1933)
261	North Pacific mine	Rimini (Vaughn)	46	28	20	112	14	10	Vein, polymetallic							Probably on the same vein as South Pacific and American Flag.	Elliott and others (1992), Pardee and Schrader (1933)
262	Daniel Stanton (Stanton mine)	Rimini (Vaughn)	46	28	15	112	14	45	Vein, polymetallic							East-striking, 75S-dipping alteration zone, highly sericitized. Uranium found on dump.	Becraft and others (1963), Elliott and others (1992), Pardee and Schrader (1933)
263	McCawber mine (M'Cawber)	Rimini (Vaughn)	46	28	15	112	14	35	Vein, polymetallic							Quartz, pyrite, and tourmaline on dump.	Elliott and others (1992), Pardee and Schrader (1933)
264	American Flag mine	Rimini (Vaughn)	46	28	15	112	14	14	Vein, polymetallic								Elliott and others (1992), Pardee and Schrader (1933)

										Production		and		Reserves [2]			
No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	(tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
265	Bunker Hill	Rimini (Vaughn)	46	28	10	112	14	52	Vein, polymetallic	2563	613	45400	17	265	37	Quartz-tourmaline sulfide vein.	Becraft and others (1963), Elliott and others (1992), Pardee and Schrader (1933), U.S. Geological Survey (1985-1923)
266	Russel mine (98 mine)	Rimini (Vaughn)	46	28	8	112	14	56	Vein, polymetallic							Quartz, pyrite, arsenopyrite with late stage galena and sphalerite.	Elliott and others (1992), Pardee and Schrader (1933)
267	Teal Lake	Rimini (Vaughn)	46	28	10	112	14	42	Vein, polymetallic	14	3	587		2	0.6	Quartz-tourmaline-sulfide vein in shear zone.	Becraft and others (1963), Elliott and others (1992), Pardee and Schrader (1933)
268	Hamlet mine	Rimini (Vaughn)	46	28	10	112	14	32	Vein, polymetallic							Galena, pyrite, and arsenopyrite in a gangue of quartz and tourmaline.	Elliott and others (1992), Pardee and Schrader (1933)
269	Silver Cord mine	Rimini (Vaughn)	46	28	7	112	14	20	Vein, polymetallic							Galena in quartz on dump.	Elliott and others (1992), Pardee and Schrader (1933)
270	Evergreen	Rimini (Vaughn)	46	28	2	112	14	52	Vein, polymetallic	3475	1000	70195	17.4	466	188	Vein zone strikes N70W, dips 80S; quartz-sulfide minerals in intensely altered quartz monzonite. 150 tons of arsenic produced.	Becraft and others (1963), Elliott and others (1992), Frishman and others (1992), Reyner and Trauerman (1949)
271	S.P. Bassett mine	Rimini (Vaughn)	46	28	0	112	14	45	Vein, polymetallic							Quartz vein with boulangerite, arsenopyrite, quartz, galena, chalcopyrite, and sphalerite.	Elliott and others (1992), Pardee and Schrader (1933)
272	Alley	Rimini (Vaughn)	46	27	42	112	14	50	Vein, polymetallic							N73W-striking vein, dipping 75N, up to 10 ft wide. Sulfide veinlets crosscut quartz.	Becraft and others (1963), Elliott and others (1992)
273	Transit mines	Rimini (Vaughn)	46	27	48	112	15	9	Vein, polymetallic								Elliott and others (1992), Ruppel (1963), Stout and Ackerman (1959)
274	Betsy Ross mine	Rimini (Vaughn)	46	27	21	112	16	25	Vein, polymetallic							Quartz vein with abundant disseminated pyrite.	Pardee and Schrader (1933)
275	Travis placer	Rimini (Vaughn)	46	26	42	112	18	10	Placer Au							Sourced by the porphyry dike rhyolite gravels up to 40 ft deep.	Elliott and others (1992), Pardee and Schrader (1933)
276	Monte Christo	Rimini (Vaughn)	46	27	0	112	15	52	Vein, polymetallic							Strike N90E, dip 90, quartz-sulfide vein 10 in. to 7 ft in width; up to 900 oz Ag/ton ore in early days of production.	Becraft and others (1963), Elliott and others (1992), Lawson (1979, 1981), Ruppel (1963)
277	Carlson mine	Rimini (Vaughn)	46	25	17	112	17	47	Hot-spring Au-Ag							Auriferous horizons in rhyolite and vertical zones 15-30 ft wide.	Pardee and Schrader (1933)

										Production		and		Reserves [2]			
No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	(tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
278	Paupers Dream (Basin Creek)	Rimini (Vaughn)	46	25	19	112	17	45	Hot-spring Au-Ag	5 Mt (r) proven; 7.5 Mt probable	210000 (r); 315000					Disseminated gold mineralization, grading ~0.1 oz Au/ton when mined at turn of century.	Elliott and others (1992), Frishman and others (1992), McCulloch (1989), Pardee and Schrader (1933), Ruppel (1963)
279	Porphyry Dike	Rimini (Vaughn)	46	25	40	112	17	15	Hot-spring Au-Ag	50275	2500					Developed to a depth of 600 ft. A large tonnage of ~0.1 oz Au/ton was blocked out in 1926.	Efraimson (1936), Elliott and others (1992), Frishman and others (1992), Knopf (1913), Pardee and Schrader (1933), Ruppel (1963)
280	Woodrow Wilson mine	Rimini (Vaughn)	46	25	18	112	15	50	Vein, polymetallic							Veins in shear zones, contain uranium minerals.	Becraft (1956), Crowley (1962a), Elliott and others (1992), Emerson and Wright (1957), Ruppel (1963)
281	Peerless Jennie (Peerless)	Rimini (Vaughn)	46	25	52	112	14	24	Vein, polymetallic							Strike N70W, dip 70N mineralized zone, traceable for 1 mi at surface.	Becraft and others (1963), Elliott and others (1992), Knopf (1913), Pardee and Schrader (1933)
282	Name unknown*	Rimini (Vaughn)	46	25	50	112	13	52	Vein, polymetallic							Pyrite, arsenopyrite, sphalerite, and galena in quartz vein 1 mi long. One sample ran 0.65 percent U. Intense wall rock sericite alteration.	Becraft and others (1963)
283	Horsefly	Rimini (Vaughn)	46	27	32	112	12	35	Vein, polymetallic							Entire dump is slightly radioactive. Strike N85E, dip 65S quartz vein with pyrite.	Becraft and others (1963), Elliott and others (1992)
284	Loeber mine	Clancy (Lump Gulch)	46	26	50	112	12	30	Vein, polymetallic	60	16	855		9.5	0.2	Strike N76E, dip 60SE quartz vein containing pyrite, galena, and sphalerite.	Elliott and others (1992), Roby and others (1960), U.S. Geological Survey (1885-1923), Young and others (1962)
285	Frohner mine	Clancy (Lump Gulch)	46	26	30	112	12	25	Vein, polymetallic	Two cars of lead ore						Quartz-sulfide vein in intensely altered quartz monzonite, abundant arsenopyrite.	Becraft and others (1963), Elliott and others (1992), Roby and others (1960)
286	Name unknown	Clancy (Lump Gulch)	46	26	28	112	12	26	Vein, polymetallic							Part of Frohner workings.	Becraft and others (1963), Elliott and others (1992), Roby and others (1960)
287	Name unknown	Clancy (Lump Gulch)	46	26	24	112	12	52	Vein, polymetallic							Part of Frohner workings.	Becraft and others (1963), Elliott and others (1992), Roby and others (1960), U.S. Geological Survey (1885-1923), Young and others (1962)

No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	Production and Reserves [2] (tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
288	Name unknown	Clancy (Lump Gulch)	46	26	19	112	12	35	Vein, polymetallic							Part of Frohner workings.	Becraft and others (1963), Elliott and others (1992), Roby and others (1960), U.S. Geological Survey (1885-1923), Young and others (1962)
289	Nellie Grant	Clancy (Lump Gulch)	46	26	27	112	12	5	Vein, polymetallic							Vein striking N72W, dipping 83S; 4 ft wide.	Becraft and others (1963), Elliott and others (1992), Roby and others (1960), U.S. Geological Survey (1885-1923), Young and others (1962)
290	Beaver's prospect	Clancy (Lump Gulch)	46	26	17	112	12	7	Vein, polymetallic							Part of Frohner workings.	Becraft and others (1963), Elliott and others (1992), Roby and others (1960), U.S. Geological Survey (1885-1923), Young and others (1962)
291	Panama	Clancy (Lump Gulch)	46	25	26	112	12	9	Vein, polymetallic								Becraft and others (1963)
292	Yama Group	Clancy (Lump Gulch)	46	24	57	112	12	25	Vein, polymetallic	8						Strike N80E, dip 70SE vein, 5-6 ft wide, outcrops for 1,500 ft.	Elliott and others (1992), Roby and others (1960)
293	Argonne	Clancy (Lump Gulch)	46	26	46	112	10	55	Vein, polymetallic, U-bearing							N75E-striking chalcedony vein with sphalerite, metatorbernite, and uranophane.	Becraft and others (1963), Elliott and others (1992)
294	Name unknown	Clancy (Lump Gulch)	46	26	21	112	9	57	Vein, polymetallic							East-trending zone of veins and faults, contains quartz with pyrite and sphalerite.	Becraft and others (1963), Elliott and others (1992)
295	Chessman	Clancy (Lump Gulch)	46	28	20	112	10	50	Porphyry Cu-Mo	None						Weak Cu-sulfide mineralization under 1,000 x 1,000 ft quartz sericite alteration zone.	Whiteley (1982)
296	Forrest	Clancy (Lump Gulch)	46	27	1	112	9	32	Vein, polymetallic							Veins in shear zones in quartz monzonite.	Becraft and others (1963), Elliott and others (1992)
297	Corral Gulch mine (Leu mine)	Clancy (Lump Gulch)	46	28	0	112	7	42	Silica	None						Quartz body in monzogranite.	Becraft and others (1963), Chelini (1966), Elliott and others (1992), Roby and others (1960)

No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	Production and Reserves [2] (tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
298	Lump Gulch placer	Clancy (Lump Gulch)	46	27	35	112	6	25	Placer Au		27						Becraft and others (1963), Dingman (1932), Elliott and others (1992), Frishman and others (1992), Lyden (1948), Roby and others (1960)
299	Buffalo Creek (Weber) placer	Clancy (Lump Gulch)	46	28	46	112	4	34	Placer Au		Minor						Becraft and others (1963), Dingman (1932), Elliott and others (1992), Lyden (1948), Roby and others (1960)
300	Muskeegan (Muskegon)	Clancy (Lump Gulch)	46	29	0	112	2	42	Vein, polymetallic							Strike N72E, dip 75S 6-in.-wide quartz vein.	Becraft and others (1963), Elliott and others (1992)
301	Free Coinage (Little Alma mine)	Clancy (Lump Gulch)	46	29	10	112	2	0	Vein, polymetallic	1390	14	68611	0.3	23.1	3.8	Vein stoped for 400 ft along strike and 350 ft deep.	Becraft and others (1963), Elliott and others (1992), Roby and others (1960)
302	Mary Tait (prospect)*	Clancy (Lump Gulch)	46	29	25	112	1	57	Vein, polymetallic, U-bearing							Vein traceable for 1/2 mi; composed of chalcedony, barite, limonite, and radioactive material.	Becraft and others (1963), Elliott and others (1992)
303	Roosevelt*	Clancy (Lump Gulch)	46	29	46	112	1	17	Vein, polymetallic							Strike N80E, dip 70S quartz vein with galena, sphalerite, and pyrite.	Becraft and others (1963), Elliott and others (1992)
304	Name unknown*	Clancy (Lump Gulch)	46	29	51	112	0	28	Vein, polymetallic								Becraft and others (1963)
305	Little Nell (Little Nellie)*	Clancy (Lump Gulch)	46	28	48	112	1	35	Vein, polymetallic	7064	10	129214	2.1	37.8	49.8	Strike N70E, dip 85S chalcedonic quartz vein of argentiferous galena-sphalerite.	Becraft and others (1963), Elliott and others (1992), Knopf (1913), Pardee and Schrader (1933), Roby and others (1960), Stout and Ackerman (1959)
306	King Solomon*	Clancy (Lump Gulch)	46	28	0	112	1	51	Vein, polymetallic	287	7	18026	0.3	12.3		Vein strikes almost due east-west and dips 60-70S. Up to 25 ft wide, contains galena, sphalerite, tetrahedrite, and minor molybdenite.	Becraft and others (1963), Bondurant and Lawson (1969), Elliott and others (1992), Geach (1967), Knopf (1913), Pardee and Schrader (1933), Roby and others (1960)

No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	Production and Reserves [2] (tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
307	King Solomon Ridge Group (Hinman mine, Fourty-niner, President Group)*	Clancy (Lump Gulch)	46	28	7	112	1	10	Vein, polymetallic							Veins occur along shear zones.	Becraft and others (1963), Elliott and others (1992), Roberts and Gude (1951), Roby and others (1960)
308	Clancy Creek placer*	Clancy (Lump Gulch)	46	27	59	111	59	15	Placer Au		8600					Tributary of Prickly Pear Creek. 1,628,860 cubic yards of gravel processed.	Becraft and others (1963), Dingman (1932), Elliott and others (1992), Frishman and others (1992), Lyden (1948), Roby and others (1960)
309	G. Washington (Member of Presidents)*	Clancy (Lump Gulch)	46	26	55	112	0	21	Vein, polymetallic, U-bearing							Chalcedony contains sparse metatorbernite crystals.	Becraft and others (1963), Elliott and others (1992), Jarrard (1957)
310	Josephine mine	Basin (Cataract, Comet)	46	24	56	112	18	44	Vein, polymetallic	1489	335	6233	0.3	1	0.6	East-striking quartz vein, dipping 55-70N, contains pyrite, galena, chalcopyrite, radioactive minerals, produced rhyolitic building stone.	Berg (1974), Elliott and others (1992), Roby and others (1960), Ruppel (1963)
311	Venus mine*	Basin (Cataract, Comet)	46	25	4	112	17	20	Hot-spring Au-Ag							Gold in altered rhyolite.	Elliott and others (1992), Pardee and Schrader (1933), Ruppel (1963)
312	Lady Hennessey mine*	Basin (Cataract, Comet)	46	25	6	112	16	55	Vein, polymetallic	89	8	491		0.05		N80W-striking sulfide-bearing quartz vein; dumps contain unidentified radioactive mineral.	Elliott and others (1992), Roby and others (1960), Ruppel (1963)
313	Crescent mine	Basin (Cataract, Comet)	46	25	17	112	14	50	Vein, polymetallic							Two main veins, strike N70W dip to south.	Becraft and others (1963)
314	Ida May	Basin (Cataract, Comet)	46	25	11	112	13	53	Vein, polymetallic							Coarse brown sphalerite on dump. Entire dump is slightly radioactive.	Becraft and others (1963)
315	Bakama mine	Basin (Cataract, Comet)	46	22	15	112	10	47	Vein, polymetallic	26		1385	1.5				Elliott and others (1992), Roby and others (1960)
316	Bell mine	Basin (Cataract, Comet)	46	22	5	112	10	32	Vein, polymetallic	53	13	1048	1.3	3			Elliott and others (1992), Roby and others (1960)

No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	Production and Reserves [2] (tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
317	Eva May	Basin (Cataract, Comet)	46	20	56	112	13	20	Vein, polymetallic							Quartz-pyrite-chalcopyrite-galena-sphalerite-tetrahedrite vein with minor tourmaline.	Becraft and others (1963), Elliott and others (1992), Frishman and others (1992), Hansen (1971), Knopf (1913), Pardee and Schrader (1933), Reyner and Trauerman (1949), Roby and others (1960)
318	Totten mine (Monitor mine)*	Basin (Cataract, Comet)	46	20	45	112	11	15	Vein, polymetallic								Reyner and Trauerman (1949), Trauerman and Waldron (1940)
319	Boulder Chief mine	Basin (Cataract, Comet)	46	19	50	112	12	34	Vein, polymetallic	1500						Galena, sphalerite, pyrite, and arsenopyrite present on dump; minor radioactive minerals in nearby pits.	Becraft (1953), Becraft and others (1963), Elliott and others (1992), Roby and others (1960)
320	Hattie Ferguson mine	Basin (Cataract, Comet)	46	19	58	112	14	51	Vein, polymetallic	1516	313	27982	19.1	155.8	16	Vein strikes N75W, dips steeply, and contains quartz, pyrite, galena, sphalerite, chalcopyrite.	Becraft and others (1963), Elliott and others (1992), Frishman and others (1992), Pardee and Schrader (1933), Roby and others (1960)
321	Morning Glory	Basin (Cataract, Comet)	46	19	1	112	14	36	Vein, polymetallic	19231	2484	268054	2.1	41.5	3.8	Two sets of veins, N55-65W and a NE-trending set, with fine-grained galena and sphalerite.	Becraft and others (1963), Roby and others (1960)
322	Custer*	Basin (Cataract, Comet)	46	18	15	112	13	45	Vein, polymetallic	8472	470	106065				N60E, 3- to 5-ft-wide quartz vein with galena, sphalerite, and pyrite, in 1-mi-long Custer-Hiawatha shear zone.	Becraft and others (1963), Elliott and others (1992), Knopf (1913), Pardee and Schrader (1933), Roby and others (1960)
323	Hiawatha (Hiawattaha)*	Basin (Cataract, Comet)	46	18	22	112	13	15	Vein, polymetallic	4222	577	90713				N70E-striking vein containing quartz, pyrite, galena, and sphalerite, 3-6 ft wide.	Becraft and others (1963), Elliott and others (1992), Roby and others (1960), U.S. Geological Survey (1885-1923)
324	Waldy*	Basin (Cataract, Comet)	46	18	28	112	13	5	Vein, polymetallic							East-trending vein, dipping 68N, 2 ft wide. Quartz, pyrite, galena, and sphalerite on dump.	Becraft and others (1963)
325	Red Wing mine (Group)*	Basin (Cataract, Comet)	46	18	25	112	13	0	Vein, polymetallic	120	15	4367		9.9		Strike N70E, dip 70-80N quartz vein containing minor sphalerite, galena, and pyrite.	Becraft and others (1963), Elliott and others (1992), Roby and others (1960)

										Production	and		Reserves [2]			
No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	(tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
326	Minneapolis*	Basin (Cataract, Comet)	46	17	53	112	14	2	Vein, polymetallic	1113	97	19031	3.3	74.7	16.9	Complex mineralized zone, more than 120 ft wide, striking N75E. Bands of pyrite, sphalerite, and galena, up to 6 ft wide, strike east.	Becraft and others (1963), Elliott and others (1992), Pardee and Schrader (1933), Roby and others (1960)
327	Manhattan*	Basin (Cataract, Comet)	46	17	56	112	13	45	Vein, polymetallic							East-trending quartz vein containing galena, sphalerite, pyrite, and malachite. Probably an extension of the Minneapolis vein.	Becraft and others (1963), Elliott and others (1992)
328	Name unknown*	Basin (Cataract, Comet)	46	17	18	112	13	20	Vein, polymetallic								Becraft and others (1963)
329	Basin Creek placer*	Basin (Cataract, Comet)	46	16	9	112	15	36	Placer Au		1300					Placer cassiterite also produced. Two shipments totaling 3,000 lbs made in 1939 and 1941.	Brinker (1944), Dingman (1932), Elliott and others (1992), Frishman and others (1992), Lyden (1948), Ruppel (1963)
330	Cataract Creek placer*	Basin (Cataract, Comet)	46	16	24	112	14	50	Placer Au								Elliott and others (1993), Lyden (1948)
331	Obelisk*	Basin (Cataract, Comet)	46	16	17	112	13	17	Breccia pipe, polymetallic	342	2	9432		2.4	0.4	100- to 300-ft breccia body with well-rounded quartz monzonite fragments in a sand matrix. Matrix composed of sulfides at east end of body.	Becraft and others (1963), Elliott and others (1992), Geach and Chelini (1963), Roby and others (1960), U.S. Geological Survey (1885-1923), Young and others (1962)
332	High Ore Creek placer*	Boulder (Comet)	46	16	15	112	12	15	Placer Au								Elliott and others (1993), Lyden (1948)
333	Free Enterprise mine (Silver Bell)*	Boulder (Comet)	46	15	21	112	8	52	Vein, polymetallic, U-bearing							Strike N65E, dip 75-90N chalcedony vein with pitchblende, pyrite, galena, Mo, chalcopyrite, barite, and silver minerals.	Becraft and others (1963), Elliott and others (1992), Roberts (1953), Roberts and Gude (1951), Roby and others (1960)
334	Baltimore*	Boulder (Comet)	46	17	13	112	8	59	Vein, polymetallic	22823	1729	273642	135	630.1	104.3	N55-70E-striking quartz vein with chalcopyrite, pyrite, galena, sphalerite in crude layers. Alaskite.	Becraft and others (1963), Elliott and others (1992), Frishman and others (1992), Knopf (1913), Pardee and Schrader (1933), Roby and others (1960)

No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	Production and Reserves [2] (tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
335	High Ore (Hi Ore, Montana Consolidated)*	Boulder (Comet)	46	17	40	112	11	50	Vein, polymetallic							Strike N60E, dip 65-70SE quartz vein, 10 ft wide, with sparse galena and pyrite. Radioactivity detected.	Becraft and others (1963), Elliott and others (1992), Roby and others (1960), U.S. Geological Survey (1885-1923)
336	Gray Eagle*	Boulder (Comet)	46	18	48	112	11	56	Vein, polymetallic	16350	1374	363840	43.6	2169	119.3	Vein system lies parallel and in Comet-Gray Eagle shear zone, Strike N75W, dip 90, up to 40 ft wide; radioactive minerals on dump.	Becraft and others (1963), Elliott and others (1992), Knopf (1913), Pardee and Schrader (1933), Roby and others (1960), Stout and Ackerman (1959)
337	Golden Thread mine*	Boulder (Comet)	46	18	44	112	10	45	Vein, polymetallic	488	44	2675	0.6	9.5	12.2		Elliott and others (1992), Roby and others (1960)
338	Rumley mine*	Boulder (Comet)	46	18	36	112	10	20	Vein, polymetallic	3191	1230	95786	3	310			Elliott and others (1992), Frishman and others (1992), Roby and others (1960)
339	Silver Hill*	Boulder (Comet)	46	18	40	112	10	15	Vein, polymetallic	1447	217	17437	3.7	49.8	77.6	Western extension of the Comet vein system; minor radioactive minerals present.	Becraft (1953), Becraft and others (1963), Hansen (1971), Roby and others (1960)
340	Comet*	Boulder (Comet)	46	18	35	112	10	0	Vein, polymetallic	0.49 Mt (1904-1950)	41754	3152892	1117	14111	11918	Three main veins strike N70W, dipping steeply to south or vertical. Veins contain quartz, galena, sphalerite, pyrite, arsenopyrite, chalcopyrite, tetrahedrite, minor radioactive minerals. Nearby quartz latite dikes.	Becraft (1953), Becraft and others (1963), Billingsley and Grimes (1918), Elliott and others (1992), Frishman and others (1992), Knopf (1913), McCulloch (1989), Pardee and Schrader (1933), Roby and others (1960)
341	Hope and Bullion prospect (Bullion)*	Boulder (Comet)	46	18	30	112	9	30	Vein, polymetallic	None						Minor base-metal-bearing veins at intersection of Comet-Gray Eagle shear zone and split from the zone.	Becraft and others (1963), Elliott and others (1992), Roby and others (1960)
342	Cleveland*	Amazon	46	17	51	112	7	38	Vein, polymetallic							Strike N84E, dip 77S quartz vein, up to 5 ft wide, with pyrite, galena, sphalerite, and chalcopyrite.	Becraft and others (1963), Elliott and others (1992), Roby and others (1960)
343	Mono Group (Mono mine, East Mono mine)*	Amazon	46	17	58	112	6	13	Vein, polymetallic							N65E-striking vein containing pyrite, galena, sphalerite, minor chalcopyrite, tetrahedrite. Sample of vein material contains 0.36 oz per ton Au.	Becraft and others (1963), Elliott and others (1992), Roby and others (1960)

										Production		and		Reserves [2]			
No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	(tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
344	Australian mine*	Amazon	46	18	40	112	8	35	Vein, polymetallic	692	122	8999	1.8	38.4		N75E-striking vein, dipping vertically with quartz, pyrite, chalcopyrite, sphalerite, galena, arsenopyrite; credited with $500,000 production, pre-1900.	Becraft and others (1963), Elliott and others (1992), Roby and others (1960)
345	Bismark*	Amazon	46	18	45	112	7	55	Vein, polymetallic	1342	258	20417	0.25	14.4		Same vein as Australian mine, lies at contact between quartz latite and monzogranite.	Becraft and others (1963), Elliott and others (1992), Roby and others (1960)
346	Van Armin mine*	Amazon	46	18	35	112	7	54	Vein, polymetallic							Strike N80W, dip 90, quartz vein containing galena and sphalerite with minor chalcopyrite, pre-1900 production $480,000.	Becraft and others (1963), Elliott and others (1992)
347	Wilber Silver*	Amazon	46	18	47	112	7	30	Vein, polymetallic	<500	150	5400		60		Strike N85E, dip 90, vein, 1-4 ft wide, extension of the Australian Bismark vein.	Becraft and others (1963), Elliott and others (1992), Roby and others (1960)
348	Pilot and Silver Star mines*	Amazon	46	18	22	112	6	15	Vein, polymetallic	312	29	3542	0.8	9.6		Strike N80E, dip 90, 3- to 5-ft-wide quartz vein with pyrite, galena, sphalerite with uranium minerals.	Becraft and others (1963), Elliott and others (1992), Roby and others (1960)
349	Name unknown*	Amazon	46	18	22	112	5	35	Unclassified								Becraft and others (1963)
350	Name unknown*	Amazon	46	18	17	112	5	12	Unclassified								Becraft and others (1963)
351	Name unknown*	Amazon	46	18	23	112	4	51	Unclassified								Becraft and others (1963)
352	Virginia C. mine*	Amazon	46	19	29	112	6	20	Vein, polymetallic							Vein occurs at the base of a sill and contains quartz, pyrite, arsenopyrite, galena, and sphalerite.	Becraft and others (1963), Elliott and others (1992)
353	Robert Emmet mine*	Amazon	46	19	37	112	5	45	Vein, polymetallic	122	1	1151	1.3	2.9	3.6	Strike N74W, dip 84N vein adjacent to fault. Contains quartz, chalcopyrite, pyrite, sphalerite, and galena.	Becraft and others (1963), Elliott and others (1992), Knopf (1913), Lawson (1976), Pardee and Schrader (1933), Roby and others (1960)
354	Lone Eagle	Wickes (Colorado, Corbin)	46	24	28	112	9	25	Vein, polymetallic, U-bearing							Strike N45E, dip 50-75SE, quartz-chalcedony vein with pitchblende.	Becraft (1956), Becraft and others (1963), Elliott and others (1992), Roby and others (1960), Stout and Ackerman (1959)

No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	Production and Reserves [2] (tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
355	Edelweiss mine (Argentine)	Wickes (Colorado, Corbin)	46	23	22	112	12	10	Vein, polymetallic	None						East-striking quartz vein along fault; quartz contains galena; surrounding quartz monzonite wall rock contains manganese oxide.	Elliott and others (1992), Lawson (1976), Roby and others (1960)
356	Kady Gulch	Wickes (Colorado, Corbin)	46	23	5	112	9	45	Bog manganese							Surface workings in alluvium.	Elliott and others (1992)
357	Wickes-Corbin Copper Company mine (Bunker Hill, Bonanza, Rosalie, Dewey Tunnels)	Wickes (Colorado, Corbin)	46	22	20	112	9	17	Vein, polymetallic							60- to 100-ft-wide shattered zone intruded by a dike of monzogranite.	Becraft and others (1963), Bushnell (1910), Elliott and others (1992), Pardee and Schrader (1933), Roby and others (1960)
358	Bonanza (see 357)	Wickes (Colorado, Corbin)	46	22	18	112	9	2	Vein, polymetallic							N75W strike of shear zone contains galena, chalcopyrite, sphalerite, pyrite, and tourmaline as gangue.	Becraft and others (1963), Bushnell (1910), Elliott and others (1992), Knopf (1913), Pardee and Schrader (1933), Roby and others (1960)
359	Rosalie (see 357)	Wickes (Colorado, Corbin)	46	22	20	112	8	50	Vein, polymetallic							Dewey, Bonanza, Rosalie, a group.	Becraft and others (1963), Bushnell (1910), Elliott and others (1992), Knopf (1913), Pardee and Schrader (1933), Roby and others (1960)
360	Blackbird Group (Wickes-Corben, Wickes manganese property)	Wickes (Colorado, Corbin)	46	22	5	112	9	45	Epithermal Mn							Two veins which strike east and dip 35-70N. They contain pyrolusite and psilomelane. A shipment contained 20 percent Mn and 15 percent Fe.	Becraft and others (1963), Elliott and others (1992), Roby and others (1960)
361	Kathleen	Wickes (Colorado, Corbin)	46	22	11	112	9	13	Unclassified							Indicated on Becraft's map but not in text.	Becraft and others (1963)
362	Dow (Crosscut)	Wickes (Colorado, Corbin)	46	22	6	112	9	4	Unclassified							East-trending, 2-ft-wide vein contains 7 oz Ag/ton, 12percent Pb, 2.5percent Cu.	Becraft and others (1963)
363	Glenberg (Glenbeg mine)	Wickes (Colorado, Corbin)	46	22	8	112	8	50	Unclassified	>500		12500	22	35			Becraft and others (1963), Elliott and others (1992), Roby and others (1960)

No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	Production and Reserves [2] (tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
364	Pen-Yan mine (Penn-Yan)	Wickes (Colorado, Corbin)	46	21	28	112	10	23	Vein, polymetallic	428	79	4268	0.1	0.4		Extension of the Blue Bird Mine.	Becraft and others (1963), Elliott and others (1992), Roby and others (1960), Trauerman and Waldron (1940), Winchell and Winchell (1912)
365	Blue Bird?	Wickes (Colorado, Corbin)	46	21	32	112	9	58	Vein, polymetallic	17989	3454	333393	480	102		Vein occurs along dike-tuff contact. Quartz-tourmaline vein with pyrite, tetrahedrite, sphalerite, arsenopyrite, chalco-pyrite.	Becraft and others (1963), Elliott and others (1992), Frishman and others (1992), Knopf (1913), Pardee and Schrader (1933), Roby and others (1960), Stout and Ackerman (1959), Winchell and Winchell (1912), Young and others (1962)
366	Bluestone	Wickes (Colorado, Corbin)	46	21	5	112	8	51	Vein, polymetallic	25	3	352	1			Vein strikes NW, dips 50NE, and is 3 ft wide; contains arsenopyrite, pyrite, galena, chalcopyrite, sphalerite in quartz.	Becraft and others (1963), Elliott and others (1992), Pardee and Schrader (1933), Roby and others (1960)
367	Salvail mine (Bernice)*	Wickes (Colorado, Corbin)	46	21	2	112	8	38	Vein, polymetallic	Several carloads						Two east-striking veins, dipping 72N, 800 ft long, with chalcocite, chalcopyrite, galena, pyrite, arsenopyrite, ruby silver, and bornite.	Becraft and others (1963), Elliott and others (1992), Geach and Chelini (1963), Pardee and Schrader (1933), Roby and others (1960)
368	Mount Washington mine	Wickes (Colorado, Corbin)	46	21	23	112	8	37	Vein, polymetallic	0.18 Mt	11651	1344082	267	7255	4022	N80W-striking, steeply dipping vein split by quartz latite dike. Vein contains pyrite, galena, sphalerite, chalcopyrite in carbonate quartz gangue.	Becraft and others (1963), Elliott and others (1992), Frishman and others (1992), Pardee and Schrader (1933), Roby and others (1960)
369	Blizzard	Wickes (Colorado, Corbin)	46	21	37	112	8	28	Vein, polymetallic	2149	280	18647	10.7	55.7		Two veins along a shear zone. Smelter returns indicated production of ~7,500 oz Au equivalent, before 1908.	Becraft and others (1963), Elliott and others (1992), Frishman and others (1992), Knopf (1913), Pardee and Schrader (1933), Roby and others (1960)
370	Elkador (Little Nancy)*	Wickes (Colorado, Corbin)	46	21	42	112	8	20	Vein, polymetallic							Elkador vein strikes N85W, dips 68-80N, 1-ft-wide vein of quartz, pyrite, chalcopyrite, and tetrahedrite. Granite porphyry nearby.	Becraft and others (1963), Elliott and others (1992), Roby and others (1960), Stout and Ackerman (1959)

No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	Production (tons ore)	and Au (oz)	Ag (oz)	Cu (tons)	Reserves [2] Pb (tons)	Zn (tons)	Comments	Sources of data
371	Minah (Extension)*	Wickes (Colorado, Corbin)	46	21	43	112	7	45	Vein, polymetallic							Indicated on Becraft's map but not in text.	Becraft and others (1963)
372	Minah mine (Mina mine)*	Wickes (Colorado, Corbin)	46	21	55	112	8	1	Vein, polymetallic	40000	26000 oz Au equiv.					East-west-striking vein, dipping 65N, 2,200 ft long, 1-2 ft wide, containing quartz, arsenopyrite, pyrite, galena, sphalerite, chalcopyrite, tetrahedrite.	Becraft and others (1963), Elliott and others (1992), Frishman and others (1992), Knopf (1913), Loen (1989), Lorain and Hundhause (1948), Pardee and Schrader (1933), Roby and others (1960), Stout and Ackerman (1959)
373	General Harris (prospect)*	Wickes (Colorado, Corbin)	46	22	12	112	8	15	Epithermal Mn							Strike N70E, dip 85N quartz vein containing Mn and Fe.	Becraft and others (1963), Elliott and others (1992)
374	Montana Tunnels mine*	Wickes (Colorado, Corbin)	46	22	17	112	7	35	Breccia pipe, polymetallic	12.0 Mt (1990, 91, 92)	510283 (through 1994)	6786258 (through first quarter 1993)		57560 (through 1994)	134662 (through 1994)	Mineralized tuffaceous breccia pipe. Ore minerals are disseminated and in thin veins cutting breccia.	American Mines Hand-book (1994), Becraft and others (1963), Elliott and others (1992), Frishman and others (1992), Knopf (1913), Pegasus Gold Annual Report (1992), Rocky Mountain Pay Dirt (1988, 1989a, b, c; 1995a), Sillitoe and others (1985)
375	Minnesota*	Wickes (Colorado, Corbin)	46	23	10	112	7	25	Vein, polymetallic	1677	457	8582	1.4	58	3.2	East-striking vein, 80N to 80S dip, containing silver-bearing galena.	Becraft and others (1963), Elliott and others (1992), Frishman and others (1992), Knopf (1913), Pardee and Schrader (1933), Roby and others (1960)
376	Ariadne*	Wickes (Colorado, Corbin)	46	23	19	112	7	17	Vein, polymetallic	153	17	1001	0.3	13.3	7.8	Quartz veins containing pyrite, sphalerite, galena, minor tourmaline, striking east.	Becraft and others (1963), Elliott and others (1992), Roby and others (1960)
377	Gregory mine*	Wickes (Colorado, Corbin)	46	23	24	112	6	53	Vein, polymetallic	18977	1381	66655	19.2	431.2	66.2	Strike N30W, dip 65N vein 4-14 ft wide; Au, Ag, Pb, Zn produced pre-1900. Production not listed but was considerable.	Becraft and others (1963), Elliott and others (1992), Frishman and others (1992), Knopf (1913), Pardee and Schrader (1933), Stout and Ackerman (1959)
378	Monte Christo adits*	Wickes (Colorado, Corbin)	46	23	34	112	5	39	Vein, polymetallic							East-striking vein, 3-4 ft wide, with sulfide minerals.	Becraft and others (1963), Elliott and others (1992)

No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	Production and Reserves [2] (tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
379	Rarus mine (Ratus)*	Wickes (Colorado, Corbin)	46	23	33	112	4	57	Vein, polymetallic	143	2	531	0.6	1.1	7.2	Strike N75-85E, dip 65N quartz vein with pyrite, galena, sphalerite, and some chalcopyrite.	Becraft and others (1963), Elliott and others (1992), Roby and others (1960)
380	Bertha (and Corbin)*	Wickes (Colorado, Corbin)	46	22	49	112	5	14	Vein, polymetallic	90660	279	162043	1211.5	13.3		Strike N40E, dip 80S quartz vein with pyrite, galena, chalcopyrite, sphalerite, tetrahedrite, bornite, up to 14 ft wide, 900 ft deep, cosalite (Bi) reported.	Becraft and others (1963), Bushnell (1910), Elliott and others (1992), Frishman and others (1992), Knopf (1913), Roby and others (1960)
381	Alta*	Wickes (Colorado, Corbin)	46	22	20	112	5	35	Vein, polymetallic	>1.0 Mt	8174 (1902-1957)	1165299 (1902-1957)	273.1	4067.2	617.3	Vein in east-trending shear zone, dipping 60N, 1,400 ft deep, 1,600 ft long. Galena, pyrite, tetrahedrite. Production records incomplete, confusing. Production prior to 1902 is reportedly greater than that of 1902-1957.	Becraft and others (1963), Billingsley and Grimes (1918), Elliott and others (1992), Frishman and others (1992), Hansen (1971), Pardee and Schrader (1933), Roby and others (1960), Young and others (1962)
382	David Copperfield (adit)*	Wickes (Colorado, Corbin)	46	21	30	112	6	0	Vein, polymetallic							Siliceous gossan may overlie quartz-pyrite zone.	Becraft and others (1963), Elliott and others (1992)
383	Daily (Atlas, Dailey)*	Wickes (Colorado, Corbin)	46	21	5	112	6	10	Vein, polymetallic	1081	76	31847	50.2	2.4		Atlas vein strikes N75-90E and dips 70-80S, 5-8 ft wide. Quartz, galena, sphalerite, chalcopyrite, and tetrahedrite occur in veins; radioactive minerals present.	Becraft and others (1963), Elliott and others (1992), Pardee and Schrader (1933), Roby and others (1960), Stout and Ackerman (1959)
384	Beavertown Cu-Mo prospect*	Wickes (Colorado, Corbin)	46	20	30	112	4	45	Porphyry Cu-Mo	55 Mt (r)			275000 (r)			Drilled by Molycorp, Exxon, and Anaconda during 1970's.	Elliott and others (1992), Ludington (oral commun., 1994)
385	Comet Creek (Spring Creek) placer*	Wickes (Colorado, Corbin)	46	23	10	112	2	17	Placer Au		Minor						Becraft and others (1963), Dingman (1932), Elliott and others (1992), Lyden (1948), Roby and others (1960)
386	Polaris*	Wickes (Colorado, Corbin)	46	21	55	112	3	35	Vein, polymetallic							Two northeast-striking veins containing white quartz, pyrite, galena, sphalerite, chalcopyrite, and molybdenite.	Becraft and others (1963), Elliott and others (1993)
387	Helena-Jefferson mine*	Wickes (Colorado, Corbin)	46	21	25	112	2	45	Vein, polymetallic	29		113		2.6	3.1	Strike N45E, dip 50-60N quartz vein with pyrite, galena, sphalerite, and minor molybdenite.	Becraft and others (1963), Elliott and others (1992), Pardee and Schrader (1933), Roby and others (1960)

No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	Production and Reserves [2] (tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
388	Copper Gulch* (Copper Nugget)	Wickes (Colorado, Corbin)	46	20	35	112	3	15	Bog copper							Native copper in interbedded sand and silt.	Becraft and others (1963), Elliott and others (1992), Forrester (1942), Roby and others (1960)
389	Madison (Black Rock)*	Golconda Area	46	22	45	112	0	5	Vein, polymetallic							Quartz vein heavily coated with iron and manganese oxides, minor galena.	Becraft and others (1963), Pardee and Schrader (1933)
390	Reddings (or Silver Tip)*	Golconda Area	46	22	5	112	0	25	Vein, polymetallic	93	18	12995		10.3		Strike N45E, dip 45N, 1- to 2-ft-wide vein with sphalerite, pyrite, and galena.	Becraft and others (1963), Elliott and others (1992), Pardee and Schrader (1933), Roby and others (1960)
391	Big Chief*	Golconda Area	46	21	44	112	0	9	Vein, polymetallic							N75E-striking shear zone with quartz, sphalerite, galena, pyrite, and minor chalcopyrite.	Becraft and others (1992)
392	Golconda porphyry*	Golconda Area	46	20	46	111	59	9	Porphyry Cu-Mo	None						Discovered by Exxon geologists in early 1970's. Represents upper portion of porphyry copper system.	Ludington and Greenwood (1990)
393	Golconda (Golden Assets)*	Golconda Area	46	21	5	111	59	20	Vein, polymetallic	485	55	10122	1.9			Mineralized fault breccia cemented by sulfide minerals; sphalerite, galena, pyrite, arsenopyrite.	Becraft and others (1963), Elliott and others (1992), Lawson (1981), Reyner and Trauerman (1949), Roby and others (1960)
394	Clark Lead*	Montana City	46	33	3	111	58	0	Polymetallic replacement							Pockets of cerussite in jasper gangue along southeast-trending bedding planes.	Roby and others (1960), Smedes (1966)
395	Holmes Gulch placer*	Montana City	46	33	51	111	55	48	Placer Au								Elliott and others (1992), Lyden (1948)
396	Prickly Pear Creek placer	Montana City	46	32	58	111	55	3	Placer Au		59000					7,074,800 cubic yards of gravel processed.	Becraft and others (1963), Dingman (1933), Elliott and others (1992), Frishman and others (1992), Lyden (1948), Pardee and Schrader (1933), Reyner and Trauerman (1949)
397	Montana City mine*	Montana City	46	32	30	111	55	0	Limestone								McCulloch (1992, 1993b)
398	ABC #1	Montana City	46	30	28	111	56	24	Vein, polymetallic, U-bearing								MRDS

No.	Site name	District/ Area[1]	Latitude			Longitude			Probable deposit type	Production and Reserves[2] (tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
399	Mitchell Creek placer*	McClellan-Mitchell Creek	46	32	43	111	50	37	Placer Au		14000						Frishman and others (1992), Lyden (1948), Roby and others (1960), Smedes (1966)
400	McClellan Creek placer*	McClellan-Mitchell Creek	46	32	11	111	52	42	Placer Au		Minor					Origin of the gold may be gold-bearing veins of the monzogranite.	Dingman (1932), Lyden (1948), Roby and others (1960), Smedes (1966)
401	Economy (Last Chance, John and Jim)*	McClellan-Mitchell Creek	46	31	39	111	51	0	Vein, polymetallic	2073	1893	5093	1.5			East-west-striking, mineralized zone contains quartz, pyrite, tetrahedrite, and calcite, along with diopside, hedenbergite, garnet, and tourmaline.	Roby and others (1960), Smedes (1966)
402	Eureka (Montana-Chicago)	McClellan-Mitchell Creek	46	30	40	111	49	0	Vein, polymetallic	89	87	156	0.1	0.2		Narrow east-west-trending vein of quartz and pyrite. Abundant tourmaline, diopside, and carbonate minerals; massive pyrite and arsenopyrite.	Roby and others (1960), Smedes (1966)
403	Bosphorus	McClellan-Mitchell Creek	46	28	37	111	51	26	Vein, polymetallic							East-west-striking mineralized zone, 2 ft thick.	Roby and others (1960)
404	McNary and Cline	McClellan-Mitchell Creek	46	29	0	111	50	0	Vein, polymetallic							Galena, sphalerite, and chalcopyrite.	MRDS
405	Jackson Creek (porphyry)	McClellan-Mitchell Creek	46	28	1	111	48	57	Porphyry Cu-Mo	None						Very disseminated chalcopyrite, pyrite, Mo, minor Bi. Low grade, low potential reported.	Ludington and Greenwood (1990)
406	Iron Side	McClellan-Mitchell Creek	46	27	0	111	51	45	Vein, polymetallic							East-west quartz-pyrite vein reportedly contained 0.30 oz per ton Au, 5 oz per ton Ag over 3 ft width.	Roby and others (1960), Stone (1911)
407	Legal Tender*	Warm Springs	46	27	35	111	58	33	Vein, polymetallic	450	4	38471		5.7	5.9	Galena and tetrahedrite adjacent to aplite dikes in quartz monzonite.	McClernan (1960), Pardee and Schrader (1933), Roby and others (1960)
408	Warm Springs Creek placer	Warm Springs	46	27	2	111	59	0	Placer Au		Minor					Northwest flowing.	Dingman (1932), Lyden (1948), Roby and others (1960)
409	Fleming (Bell, Carbonate Chief, Newburgh)	Warm Springs	46	24	45	111	53	29	Vein, polymetallic	77590	18789	128492	60.8	406.1		Vein contains galena, chalcopyrite, arsenopyrite, pyrite in a quartz gangue. Obsidian observed on many mine dumps.	Pardee and Schrader (1933), Roby and others (1960), Smedes (1966)

No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	Production and Reserves [2] (tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
410	White Pine	Warm Springs	46	24	39	111	53	30	Vein, polymetallic	255	36	4426	0.5	41.4	26.1	East-west-striking quartz vein containing galena, sphalerite, pyrite, chalcopyrite, and arsenopyrite.	Pardee and Schrader (1933), Roby and others (1980), Smedes (1966)
411	B and G (Eagles Nest, R.P. Bland)	Warm Springs	46	24	30	111	54	7	Vein, polymetallic	112	103	1664	1	10.3		N80E-striking vein containing cerussite, pyrite, arsenopyrite.	McClernan (1980), Pardee and Schrader (1933), Roby and others (1980), Smedes (1966)
412	Wilson Creek placer	Tizer Basin Area	46	21	50	111	51	25	Placer Au							Total production probably small.	Dingman (1932), Frishman and others (1992), Klepper and others (1957), Lyden (1948), Reyner and Trauerman (1949), Roby and others (1980)
413	Belle (Golden Age)	Tizer Basin Area	46	21	48	111	50	40	Vein, polymetallic							Gold- and silver-bearing galena in N75E, 50SE vein.	Klepper and others (1957), McClernan (1980)
414	Callahan (Deer Horn)	Tizer Basin Area	46	21	10	111	50	11	Vein, polymetallic	11000	6810	7860	7	23	3	Veins N50E, 70SE; most ore from a shoot 400 ft long and 250 ft deep.	Klepper and others (1957), McClernan (1980)
415	Tizer Creek placer	Tizer Basin Area	46	19	23	111	52	30	Placer Au								Frishman and others (1992), Koschmann and Bergendahl (1968), Lyden (1948), Roby and others (1980), U.S. Geological Survey (1885-1923)
416	Little Tizer Wildcat	Tizer Basin Area	46	19	12	111	51	27	Unclassified								U.S. Forest Service (1991)
417	Center Reef (Ballard)	Tizer Basin Area	46	18	53	111	52	16	Vein, polymetallic	976	2726	6842		5		Vein trends N70E, dips 70SE.	Klepper and others (1957), McClernan (1980)
418	Black Jack	Tizer Basin Area	46	18	47	111	52	45	Breccia pipe, tourmaline							Similar to Skyline breccia pipe but contains only pyrite.	Klepper and others (1957), Ludington and Greenwood (1990), McClernan (1980)
419	Skyline*	Tizer Basin Area	46	17	20	111	53	15	Breccia pipe, tourmaline							Breccia pipe at surface is triangular in shape with 130- to 150-ft sides; matrix is quartz, sphalerite, pyrite, galena, chalcopyrite.	Klepper and others (1957), Ludington and Greenwood (1990), McClernan (1980)
420	Elkhorn Peak Iron*	Elkhorn	46	18	39	111	55	36	Skarn Au							Magnetite intergrown with garnet, epidote, calcite. Alaskite dike.	Klepper and others (1957)

										Production		and		Reserves [2]			
No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	(tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
421	Union*	Elkhorn	46	17	31	111	56	30	Polymetallic replacement								Klepper and others (1957), McClernan (1980)
422	C and D*	Elkhorn	46	17	25	111	56	0	Polymetallic replacement							Limonitic gold-lead replacement along bedding and steeply dipping silver-bearing vein.	Klepper and others (1957)
423	Golden Moss*	Elkhorn	46	17	23	111	56	14	Polymetallic replacement							High-grade gold in silicified limestone.	Klepper and others (1957)
424	Golden Curry (Sourdough, Jacquemin)*	Elkhorn	46	17	3	111	57	43	Skarn Au	98442	23867	11374	325			Veins of magnetite, hydrous ferric silicate, a massive magnetite-pyrrhotite body, pyrrhotite-chalcopyrite in pyroxene.	Klepper and others (1957)
425	Klondyke*	Elkhorn	46	16	59	111	56	26	Skarn Au							Diopside-tremolite host blebs of pyrite-chalcopyrite; ore mineral is a gold-bearing telluride.	Klepper and others (1957)
426	Dolcoath*	Elkhorn	46	16	52	111	56	51	Skarn Au							Orebody is 12-18 in. thick; replacement by andradite, diopside, chalcopyrite, Bi-tellurides carry Au.	Klepper and others (1957)
427	Keene*	Elkhorn	46	16	51	111	56	35	Polymetallic replacement	~500						Mineralization localized at anticlinal crest below shale unit in Pilgrim Dolomite.	Klepper and others (1957)
428	Swissmont-Pittsmont*	Elkhorn	46	16	39	111	56	58	Polymetallic replacement	68580	16214	3100				Ore occurs in discordant near-vertical lenses; trends N35W, 250 ft long, 20 ft thick.	Klepper and others (1957)
429A	Elkhorn (Holter)*	Elkhorn	46	16	34	111	56	33	Polymetallic replacement		20000	1478200 0	83	7000	2900	Mineralization occurs at the contact between host rocks along anticlinal flexures.	Klepper and others (1957), McClernan (1980)
429B	Elkhorn*	Elkhorn	46	16	34	111	56	33	Skarn Au		897000 (r)					Drilling and permitting work ongoing in 1996	American Mines Handbook (1996)
430	Carmody-Papesh*	Elkhorn	46	16	25	111	56	59	Skarn Au	4800	670					High temperature replacement by bornblende-dark silicate minerals, disseminated pyrrhotite, pyrite, chalcopyrite.	Klepper and others (1957)
431	Bulwer*	Elkhorn	46	15	37	111	56	56	Skarn Au	587			54			Ore on dumps associated with garnet-rich calc-silicate rock, stained with malachite and limonite. Near granodiorite porphyry.	Klepper and others (1957), McClernan (1980)
432	Tourmaline Queen*	Elkhorn	46	15	14	111	57	50	Breccia pipe, tourmaline	0.8 Mt (r)	82500 (r)					Significant low-grade gold in fractured, altered, silicified pyritic zone in host rocks.	Klepper and others (1957), Rocky Mountain Pay Dirt (1989b)
433	Elkhorn Queen*	Elkhorn	46	14	47	111	56	48	Breccia pipe, tourmaline	17500	4940	122000	9	1775	140	200 x 1,200 sq ft in plan; mined to 500 ft.	Klepper and others (1957), McClernan (1980)

No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	Production and Reserves [2] (tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
434	Turnley Ridge (porphyry)*	Elkhorn	46	14	5	111	58	7	Porphyry Cu-Mo	None						Best intersection 10 ft at 0.079 percent Mo; small porphyry system.	Ludington and Greenwood (1990)
435	Tacoma*	Elkhorn	46	14	1	111	57	45	Vein, polymetallic							Flat-lying cerussite-bearing vein.	Klepper and others (1957), McClernan (1980)
436	Orphan Boy	Winston	46	28	57	111	43	45	Vein, polymetallic							Pyrite, chalcopyrite, Mo in sheeted zones up to 1,100 ft long, striking N63E, 47SE.	McClernan (1980), Reed (1951)
437	Gold Bug	Winston	46	28	9	111	44	12	Vein, polymetallic							N80E-striking vein.	McClernan (1980), Reed (1951)
438	Homestead*	Winston	46	28	9	111	42	24	Vein, polymetallic							Vein explored for 300 ft along strike, 60 ft vertically; strike N68E, dip 68NE.	Reed (1951)
439	Native Silver	Winston	46	26	40	111	43	41	Vein, polymetallic							Strike N85E, dip 80NW vein.	McClernan (1980), Reed (1951)
440	Beaver Creek placer	Winston	46	27	17	111	42	5	Placer Au		10000					Includes Weasel and Badger Creek placers.	Dingman (1932), Frishman and others (1992), Klepper and others (1971), Lyden (1948), McClernan (1980)
441	Chartam (Custer)*	Winston	46	27	3	111	39	57	Vein, polymetallic	54229; 9.1Mt (r)	12324; 300000 (r)	45057; 591500 (r)	8.8	337	.5	2,400 ft long by 700 ft deep, striking N30E, 62W dipping. Low grade resource includes area of old Custer deposit	Frishman and others (1992), Klepper and others (1971), Reed (1951), American Mines Handbook (1994)
442	Maine-Sullivan	Winston	46	26	35	111	41	52	Vein, polymetallic							Strike N70E, dip 90 vein.	McClernan (1980), Reed (1951)
443	Hyantha*	Winston	46	26	45	111	40	2	Vein, polymetallic							Vein strikes N70E, dips 90. Edna Stock	Klepper and others (1971), McClernan (1980), Reed (1951)
444	Sunshine	Winston	46	26	17	111	41	57	Vein, polymetallic	100	350	3700		17		Vein 600 ft long, striking east-west.	Frishman and others (1992), McClernan (1980), Pardee and Schrader (1933), Reed (1951)
445	Iron Age*	Winston	46	26	24	111	39	54	Vein, polymetallic								McClernan (1980), Reed (1951)
446	Denver	Winston	46	25	47	111	43	51	Vein, polymetallic								Reed (1951)
447	East Pacific	Winston	46	25	10	111	45	55	Vein, polymetallic	35647	10358	364490	59.3	2243	414	Last operated in 1947.	Frishman and others (1992), Klepper and others (1971), McClernan (1980), Pardee and Schrader (1933), Reed (1951)
448	Freiburg	Winston	46	25	24	111	41	42	Vein, polymetallic		250					Mineralized contact strikes N70E, dips 75SE.	McClernan (1980), Pardee and Schrader (1933), Reed (1951)

No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	Production and Reserves [2] (tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
449	Kelly*	Winston	46	25	46	111	39	18	Vein, polymetallic							Vein strikes N65W, dips70NE.	McClernan (1980), Reed (1951)
450	January	Winston	46	24	54	111	41	46	Vein, polymetallic	3106	335	16498	3.3	15.6	106	Last operated in 1931.	Frishman and others (1992), Klepper and others (1971), McClernan (1980), Pardee and Schrader (1933), Reed (1951)
451	Sunrise	Winston	46	24	47	111	41	45	Vein, polymetallic		1400					Strike N40W, dip 60NE, vein along contact fault.	McClernan (1980), Pardee and Schrader (1933), Reed (1951)
452	Little Bonanza	Winston	46	24	35	111	40	57	Vein, polymetallic	273	11	7105	0.8	103	7.1	Vein 500 ft long, 250 ft deep, striking N80W, 60NE.	Klepper and others (1971), McClernan (1980), Pardee and Schrader (1933), Reed (1951)
453	Stray Horse	Winston	46	24	16	111	41	51	Vein, polymetallic	493	185	10420	1.1	52.8		Vein striking N90E, 80N; less than 2 ft wide.	Frishman and others (1992), Klepper and others (1971), McClernan (1980), Pardee and Schrader (1933), Reed (1951)
454	Vosburg	Winston	46	23	58	111	43	12	Vein, polymetallic	23855	6690	34283	2.2	38.4	7.7	Veins strike N10W, dip 30SW.	Frishman and others (1992), Klepper and others (1971), McClernan (1980), Pardee and Schrader (1933), Reed (1951)
455	Little Olga-Kleinschmidt	Winston	46	23	18	111	42	38	Vein, polymetallic	4354	207	81382	4.3	291	1.5	1,200 ft long, 760 ft deep, striking N80W, dipping 70NE.	Klepper and others (1971), Pardee and Schrader (1933),
456	Big Chief	Park	46	22	46	111	42	29	Vein, polymetallic	<360	~280					Strike N55E, dip 32SE vein at least 350 ft along strike, 250 ft deep.	Pardee and Schrader (1933), Reed (1951)
457	Whitehorse	Park	46	22	35	111	42	23	Vein, polymetallic							Strike N10W, dip 70NE vein credited with small output of high-grade lead-zinc.	Reed (1951)
458	New Hope	Park	46	22	35	111	41	54	Vein, polymetallic	None						Strike N25W, dip 30NE vein with limonite, minor pyrite.	Reed (1951)
459	Park-New Era	Park	46	22	0	111	43	0	Vein, polymetallic	11348	3251	7453		38		Vein striking N45E, dipping 50SE.	Ferguson (1908), Frishman and others (1992), Klepper and others (1971), McClernan (1980), Reed (1951), Schell (1963), Stone (1911)
460	Marietta	Park	46	21	53	111	42	21	Vein, polymetallic	5411	6717	40654	2.1	260		Strike N5-20W, dip12SW vein, 8 in. to 3 ft wide.	Frishman and others (1992), Klepper and others (1971), McClernan (1980), Reed (1951), Schell (1963)

No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	Production and Reserves [2] (tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
461	Vulture	Indian Creek	46	22	29	111	44	32	Vein, polymetallic	8	2	46		0.4		Strike N50E, dip 40NW vein.	Klepper and others (1971), McClernan (1980), Reed (1951)
462	MacFadden-Nave	Indian Creek	46	21	10	111	44	55	Vein, polymetallic							Strike N85E, dip 60SW, vein of galena, 3-9 in. wide, in altered andesite, 2-6 ft wide.	Klepper and others (1957)
463	Unnamed placer	Indian Creek	46	19	33	111	45	15	Placer Au								Reed (1951)
464	Mammoth	Indian Creek	46	20	1	111	43	49	Vein, polymetallic							Strike N50W, dip 34SW vein along diorite-andesite contact.	McClernan (1980), Reed (1951)
465	Queen Bee	Indian Creek	46	20	6	111	42	23	Vein, polymetallic	796	491	2083	0.8			Strike N50W, dip 90, vein about 3 ft wide.	McClernan (1980), Reed (1951)
466	Shep	Indian Creek	46	21	28	111	40	28	Vein, polymetallic	Unknown, but minor						Strike N25W, dip 79SW quartz vein with limonite.	Reed (1951)
467	Buckeye	Indian Creek	46	21	1	111	40	27	Vein, polymetallic	<180						Strike N55W, dip 90, vein occupying a weak shear zone.	Reed (1951)
468	Phoenix	Indian Creek	46	20	54	111	40	38	Vein, polymetallic	Unknown, but minor						Strike N25W, dip 75NE vein with minor galena and chalcopyrite.	McClernan (1980), Reed (1951)
469	Iron Mask	Indian Creek	46	20	40	111	39	51	Vein, polymetallic	23454	110	115900	5.5	929	1740	Vein striking N15W, dipping 75-85NE.	Klepper and others (1971), McClernan (1980), Reed (1951)
470	St. Louis	Indian Creek	46	20	20	111	41	42	Vein, polymetallic	148	56	238					Reed (1951)
471	Silver Wave	Indian Creek	46	20	4	111	41	42	Vein, polymetallic	593	453	5380		88.8		2,300 ft long, 350 ft deep vein, striking N50W, dipping 78NE.	McClernan (1980), Reed (1951)
472	John L.*	Indian Creek	46	20	6	111	40	26	Vein, polymetallic	32	15	238	0.7	0.7		Strike N40W, dip 90, quartz vein with pyrite, galena, chalcopyrite along andesite-quartz monzonite contact.	Reed (1951)
473	Lookout*	Indian Creek	46	19	55	111	39	31	Vein, polymetallic	100				~35		Strike N20-30E, dip 74SE vein from 12-16 in. in width.	McClernan (1980), Reed (1951)
474	Silver Dollar	Indian Creek	46	19	46	111	41	39	Vein, polymetallic							Strike N45W, dip 90, vein about 450 ft along strike.	McClernan (1980), Reed (1951)
475	Central	Indian Creek	46	19	36	111	41	42	Vein, polymetallic							Strike N45W, dip 87SW vein with fine-grained pyrite, galena, sphalerite.	Reed (1951)
476	Spring Hill	Indian Creek	46	19	19	111	41	54	Vein, polymetallic							Strike N60W to N90W, dip 76S to 66N, 16-in.-wide vein.	McClernan (1980), Reed (1951)

No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	Production and Reserves [2] (tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
477	Diamond Hill*	Indian Creek	46	19	5	111	40	45	Skarn Au	1.2 Mt (r)	25000; 320,000 (r)					Original mine on shear zone, strike N7W, dip 40-85NE, with Au, Bi, Te, W. New development on pipe-like Au skarn that extends to 500 m depth. Resource of 1.173 million st of mineralized rock, average grade 0.271 oz/ton Au, a resource of 317,800 oz Au.	Frishman and others (1992), Klepper and others (1971), McClernan (1980), Pegasus Gold Annual Report (1992), Reed (1951), Rocky Mountain Pay Dirt (1995b)
478	Last Chance*	Indian Creek	46	18	48	111	40	3	Vein, polymetallic							Strike N53W, dip 65SW, pyrite, chalcopyrite, tetrahedrite in weak shear.	McClernan (1980), Reed (1951)
479	Little Giant	Indian Creek	46	18	25	111	40	45	Vein, polymetallic	399	335	118				Eleven parallel veins 2,700 ft wide, 1,300 ft wide. Aplite dike.	Frishman and others (1992), Klepper and others (1971), McClernan (1980), Reed (1951)
480	Blacksmith*	Indian Creek	46	18	2	111	40	20	Vein, polymetallic		12500 (estima - ted)					Strike N3W to N12E, dip 85E vein in shear zone.	Frishman and others (1992), Klepper and others (1971), McClernan (1980), Reed (1951)
481	Indian Creek mine*	Indian Creek	46	19	22	111	37	0	Limestone	13 Mt (r)						Produces >300,000 tons of burnt lime annually.	McCulloch (1992, 1993a)
482	Indian Creek placer*	Indian Creek	46	18	9	111	39	0	Placer Au		22000						Dingman (1932), Freeman and others (1958), Frishman and others (1992), Klepper and others (1971), Lyden (1948), McClernan (1980), U.S. Geological Survey (1885-1923, 1988)
483	Little Fannie*	Indian Creek	46	17	56	111	38	38	Vein, polymetallic							Strike N20E, dip 30NW vein 160 ft along strike.	McClernan (1960), Reed (1951)
484	Summit (Blacksmith)	Slim Sam Area	46	15	33	111	49	3	Unclassified	None						Dump containing silicified shale, jasper, and limonite.	Klepper and others (1957), McClernan (1980)
485	Bonanza	Slim Sam Area	46	15	32	111	47	0	Unclassified								McClernan (1960), Reed (1951)
486	Prospect (name unknown)	Slim Sam Area	46	16	2	111	43	52	Shoreline placer Ti							Magnetite-bearing beach placer.	This report
487	Sadie S.	Slim Sam Area	46	15	3	111	44	29	Polymetallic replacement								Reed (1951)
488	Mighty Monarch	Slim Sam Area	46	14	32	111	44	48	Skarn Au		280					Pipe-shaped replacement at contact.	McClernan (1980), Reed (1951)
489	Spar	Slim Sam Area	46	13	55	111	47	29	Unclassified	1037	39	23481			2.9		McClernan (1980), Reed (1951)

No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	Production and Reserves [2] (tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
490	Rothfuss Copper*	Radersburg	46	12	24	111	43	34	Skarn Au							Near monzonite stock.	Reed (1951)
491	North Home*	Radersburg	46	10	50	111	44	3	Polymetallic replacement	3830	244	66654	0.7	90	14.4	Near quartz monzonite intrusion.	Frishman and others (1992), Klepper and others (1971), McCleman (1980), Reed (1951)
492	Kahoka*	Radersburg	46	11	29	111	42	41	Vein, polymetallic							Vein striking N16W, dipping 72SW.	McCleman (1980), Reed (1951)
493	Hard Cash*	Radersburg	46	11	50	111	41	55	Vein, polymetallic	1007	1032	466	0.5			Vein striking N43W, dipping 70NE, 560 ft along strike.	Frishman and others (1992), Klepper and others (1971), McCleman (1980), Reed (1951)
494	Iron Cross*	Radersburg	46	12	12	111	40	16	Shoreline placer Ti	4000						Placer sands or magnetite-bearing sandstone. 43 percent Fe, 9 percent TiO2.	Klepper and others (1971), Reed (1951)
495	Rena*	Radersburg	46	12	8	111	39	27	Vein, polymetallic	Unknown, but minor						Strike N12W, dip 80SW.	McCleman (1980), Reed (1951)
496	Keating*	Radersburg	46	11	17	111	39	39	Vein, polymetallic	0.41 Mt	157538	43557	1064			Strike N5E, dip 70W; auriferous pyrite in altered pyritic rock.	Frishman and others (1992), Klepper and others (1971), Reed (1951)
497	Ohio Keating*	Radersburg	46	11	6	111	40	3	Vein, polymetallic	0.19 Mt	58863					Vein striking N15W, dipping 80W; contains auriferous pyrite.	Frishman and others (1992), Klepper and others (1971), McCleman (1980), Reed (1951)
498	Congress*	Radersburg	46	10	56	111	40	31	Vein, polymetallic							Vein N68W.	McCleman (1980), Reed (1951)
499	Black Friday*	Radersburg	46	10	30	111	40	40	Vein, polymetallic	7921	13820	8580	3.2	19.8		Vein striking N10E, 3,500 ft along strike, 700 ft deep.	Frishman and others (1992), Klepper and others (1971), Reed (1951)
500	Bluebird*	Radersburg	46	10	24	111	41	0	Vein, polymetallic							Vein striking N70W, dipping 67NE, 600 ft along strike.	Reed (1951)
501	Crow Creek placer*	Radersburg	46	11	23	111	36	59	Placer Au		25000						Freeman and others (1958), Frishman and others (1992), Lyden (1948), McCleman (1980), U.S. Geological Survey (1885-1923, 1988)
502	Ming's Bar placer*	Missouri River Area	46	53	39	111	56	3	Placer Au		Minor						Lyden (1948), McCleman (1980)
503	American Bar placer	Missouri River Area	46	49	20	111	56	14	Placer sapphires, Au		Minor						Lyden (1948), McCleman (1980), Pardee and Schrader (1933)
504	Dana's Bar placer*	Missouri River Area	46	43	46	111	52	43	Placer Au		Minor						Lyden (1948), McCleman (1980), Pardee and Schrader (1933)

										Production		and		Reserves [2]			
No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	(tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
505	El Dorado Bar placer	Missouri River Area	46	43	40	111	50	15	Placer sapphires, Au, platinum group elements		41000					Sapphires and platinum group elements also produced.	Frishman and others (1992), Lyden (1948), McClernan (1980), McCulloch (1993a), Pardee and Schrader (1933), U.S. Geological Survey (1988)
506	McCune Bar placer*	Missouri River Area	46	41	9	111	48	23	Placer Au								Lyden (1948), Mertie and others (1951), Pardee and Schrader (1933)
507	Spokane Bar placer*	Missouri River Area	46	40	6	111	49	11	Placer Au		27500						Frishman and others (1992), Lyden (1948), McClernan (1980), Pardee and Schrader (1933)
506	Gruel Bar (Gruel's Bar, Metropolitan Bar) placer*	Missouri River Area	46	40	0	111	47	30	Placer Au		2050						Frishman and others (1992), Lyden (1948), McClernan (1980), McCulloch (1993a), Pardee and Schrader (1933)
509	Lovestone*	Missouri River Area	46	40	11	111	45	45	Placer sapphires, Au								McCulloch (1993b)
510	French Bar placer*	Missouri River Area	46	39	24	111	44	45	Placer Au		75000					Three terraces mined at elevations of 200, 240, and 260 ft above the level of the Missouri River. Grade was estimated to be approximately 0.5 oz Au per cubic yard.	Frishman and others (1992), Lyden (1948), McClernan (1980), Pardee and Schrader (1933)
511	Korizek*	Missouri River Area	46	39	3	111	45	2	Sediment-hosted Cu, veins							Strike N55W, dip 60NE, 18-in.-wide vein of barite, galena, chalcopyrite, pyrite. Associated with Spokane Hills Quartz Monzonite.	Pardee and Schrader (1933)
512	Koppen mine*	Missouri River Area	46	33	30	111	41	0	Skarn W	40000						Two stratabound garnet skarn units, one in the Three Forks Shale and the other at the Three Forks-Madison contact, contain 0.2-2.0 percent WO_3 as scheelite. Associated with monzogranite intrusion.	Mertie, and others (1951), Union Carbide Corporation unpub. report (1981)
513	Hauser Lake barite	York	46	42	34	111	47	39	Vein, barite	None						Small pods of barite near the Eldorado thrust fault.	Berg (1986, 1986)

No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	Production and Reserves [2] (tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
514	York Bridge barite	York	46	42	50	111	47	27	Vein, barite	None						14- to 17-in.-wide barite vein, bedding parallel to argillite, traced for 400 ft along strike.	Berg (1986, 1988)
515	Little Jim Lode	York	46	43	8	111	46	0	Vein, Au-bearing							Assays of vein material yielded only trace gold and silver. Near quartz diorite intrusion.	MRDS
516	Trout Creek, York Gulch, Rattlesnake Gulch, Kelly Gulch, and Kingsbury Gulch placers	York	46	43	15	111	45	0	Placer Au		250000						Dingman (1932), Frishman and others (1992), Koschman and Bergendahl (1968), Lyden (1948), McClernan (1980), Mertie and others (1951), Pardee and Schrader (1933)
517	Golden Slipper Lode	York	46	43	22	111	44	40	Vein, Au-bearing							Quartz vein assayed 0.22 oz per ton Au, 4.7 oz per ton Ag, 0.9 percent Cu.	MRDS
518	Prospect (name unknown)	York	46	44	30	111	45	41	Vein, Au-bearing							Flat-lying quartz veins are cross cut and brecciated by veins of specular hematite.	This report
519	Golden Charm mine	York	46	44	39	111	46	8	Vein, Au-bearing		1300					Quartz-gold veins associated with diorite dike mined to a depth of 100 ft.	McClernan (1980), Pardee and Schrader (1933)
520	Fletcher barite	York	46	44	41	111	45	11	Vein, barite	None						Vein of barite, 26 in. wide, striking N55E, dipping 64SE. Minor galena also present. Associated with quartz diorite dike.	DeMunck and Ackerman (1958), Berg (1986, 1988)
521	Big Copper	York	46	44	47	111	44	54	Sediment-hosted Cu, veins							East-trending, 45S-dipping ankerite vein with minor Cu oxides; 500 ft along strike.	Pardee and Schrader (1933)
522	Golden Messenger mine	York	46	44	24	111	44	24	Vein, Au-bearing	34000	10200					Quartz-gold veins, 30 ft x 300 ft, confined to diorite dike.	Frishman and others (1992), McClernan (1980), Pardee and Schrader (1933)
523	Little Dandy mine	York	46	44	24	111	44	1	Vein, Au-bearing		~5000					North-striking, 30-40W-dipping vein, several inches to 3-4 ft in width, with pyrite, Au.	Frishman and others (1992), McClernan (1980), Pardee and Schrader (1933)
524	Prospect (name unknown)	York	46	45	20	111	44	52	Vein, Au-bearing							Caved adits and shaft.	This report
525	Prospect (name unknown)	York	46	45	16	111	44	19	Vein, Au-bearing								This report

No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	Production and Reserves [2] (tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
526	Prospect (name unknown)	York	46	43	52	111	43	17	Vein, Au-bearing							Quartz-Au veins in diorite dike.	This report
527	Copper Queen	York	46	43	33	111	42	23	Sediment-hosted Cu, veins	50						strike N70E, dip 65N, vein of quartz-calcite, 2 ft wide, with minor chalcopyrite.	Pardee and Schrader (1933)
528	Prospect (name unknown)	York	46	43	48	111	42	6	Vein, Au-bearing							Pb mineralization; associated with diorite dike?	This report
529	Old Amber mine (Golden Cloud)	York	46	43	29	111	41	54	Vein, Au-bearing		~5000					Strike N70W, dip 30S quartz-ankerite-pyrite veins up to 4 ft wide.	Frishman and others (1992), McClernan (1980), Pardee and Schrader (1933)
530	Prospect (name unknown)	York	46	43	40	111	41	46	Vein, Au-bearing							Caved adit associated with diorite dike.	This report
531	Prospect (name unknown)	York	46	43	42	111	41	0	Vein, Au-bearing							Caved adit associated with diorite dike.	This report
532	Prospect (name unknown)	York	46	43	7	111	40	51	Vein, Au-bearing							Caved adit.	This report
533	Prospect (name unknown)	York	46	43	4	111	40	9	Vein, Au-bearing								This report
534	Prospect (name unknown)	York	46	42	58	111	40	6	Vein, Au-bearing								This report
535	Potassium-Gold Reef Outcrop Area	York	46	43	19	111	39	44	Vein and disseminated, Au-bearing							Stratabound, resistant features termed reefs consist of potassium feldspar with detrital quartz and minor gold. They are laterally continuous from 1.4 in. to 300 ft thick.	Baitis (1968), Foster and Childs (1993)
536	Prospect (name unknown)	York	46	42	52	111	39	21	Vein, Au-bearing							Caved adits; known as "cabin area" to exploration companies; recent drilling.	This report
537	Cabin Area	York	46	43	11	111	38	56	Vein and disseminated, Au-bearing	1.62 Mt (r)	76300 (r)					Stratabound, resistant features termed reefs consist of potassium feldspar with detrital quartz and minor gold. They are laterally continuous from 1.4 in. to 300 ft thick.	Baitis (1968), Foster and Childs (1993)
538	Walston	York	46	42	58	111	38	11	Vein, Au-bearing							Minor quartz-ankerite-pyrite veins, reported to contain gold.	Pardee and Schrader (1933)

									Production		and		Reserves [2]			
No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	(tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
539	Bar Gulch Area	York	46	42	52	111	38	7	Vein and disseminated, Au-bearing	1.06 Mt (r)	45400 (r)					Stratabound, resistant features termed reefs consist of potassium feldspar with detrital quartz and minor gold. They are laterally continuous from 1.4 in. to 300 ft thick.	Baitis (1988), Foster and Childs (1993)
540	Prospect (name unknown)	York	46	42	21	111	38	20	Vein, Au-bearing							Caved adit; recent drilling.	This report
541	Prospect (name unknown)	York	46	43	26	111	36	6	Vein, Au-bearing							Caved adit; associated with diorite dike.	This report
542	Garnet placer	York	46	42	23	111	37	5	Placer Au								MRDS
543	Sunrise Lode	York	46	42	13	111	37	40	Vein, Au-bearing							Quartz vein assayed 0.04 oz per ton Au, 0.2 oz per ton Ag.	MRDS
544	Bar Gulch placer	York	46	41	51	111	37	22	Placer Au								Pardee and Schrader (1933)
545	Linda Jo placer	York	46	41	34	111	38	13	Placer Au							Three shafts, all caved.	MRDS
546	Ruth placer	York	46	41	27	111	39	5	Placer Au								MRDS
547	Oregon Gulch placer	York	46	41	14	111	43	0	Placer Au		25000						Frishman and others (1992), Koschmann and Bergendahl (1988), Lyden (1948), McClernan (1980), Mertie and others (1951), Pardee and Schrader (1933)
548	Clark Gulch placer	York	46	39	40	111	43	56	Placer Au		15000						Frishman and others (1992), Koschmann and Bergendahl (1968), Lyden (1948), McClernan (1980), Mertie and others (1951), Pardee and Schrader (1933)
549	Cave Gulch, Cooper Gulch placers	York	46	39	13	111	41	54	Placer Au		20000						Frishman and others (1992), Koschmann and Bergendahl (1968), Lyden (1948), McClernan (1980), Mertie and others (1951), Pardee and Schrader (1933)

No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	Production and Reserves [2] (tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
550	Magpie Creek placer	York	46	38	37	111	41	0	Placer Au		14000						Dingman (1932), Frishman and others (1992), Koschmann and Bergendahl (1968), Lyden (1948), McClernan (1980), MRDS, Pardee and Schrader (1933), Reed (1951)
551	Whitmire	York	46	39	49	111	39	35	Sediment-hosted Cu, veins	16			2.7			Strike N45E, dip 50NW vein, up to 3 ft wide; 750 ft along strike. Location is approximate.	McClernan (1980), Pardee and Schrader (1933), Reed (1951)
552	Finchville and Winnie	York	46	43	12	111	33	22	Vein, Au-bearing	None						Opposite Lee Mountain workings. Quartz-calcite veins with galena and pyrite. Location is approximate.	Pardee and Schrader (1933)
553	White	York	46	43	4	111	32	38	Vein, Au-bearing	None						Character sample containing 0.7 oz per ton Au. N45W vein contains sheared country rock and quartz.	McClernan (1980), Pardee and Schrader (1933), Reed (1951)
554	Lee Mountain	York	46	42	57	111	32	40	Vein, Au-bearing							N30W-striking , steeply dipping quartz ankerite vein with galena, pyrite. Location is approximate.	McClernan (1980), Pardee and Schrader (1933)
555	Prospect (name unknown)	York	46	42	12	111	34	49	Vein, Au-bearing								This report
556	Consho-hocken	York	46	41	37	111	34	58	Sediment-hosted Cu, veins	Unknown, but minor						Two veins striking N60E, dipping 80NW, containing chalcopyrite, ankerite, and quartz. Location is approximate.	McClernan (1980), Pardee and Schrader (1933), Reed (1951)
557	Ideal	York	46	41	23	111	35	11	Sediment-hosted Cu, veins	None						Northeast-trending quartz vein with disseminated chalcopyrite. Location is approximate.	McClernan (1980), Pardee and Schrader (1933), Reed (1951)
558	Argo mine	York	46	41	14	111	35	2	Sediment-hosted Cu, veins	31736	15	727	2077			N70E-striking vein, 700 ft long, 600 ft deep.	McClernan (1980), Pardee and Schrader (1933), Reed (1951)
559	Rex	York	46	40	59	111	34	44	Sediment-hosted Cu, veins							NE-striking vein of quartz ankerite and minor chalcopyrite.	Pardee and Schrader (1933)

No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	Production and Reserves [2] (tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
560	Hellgate Gulch placer	York	46	39	57	111	35	5	Placer Au							Production from Hellgate Creek and tributaries.	Dingman (1932), Koschmann and Bergendahl (1968), Lyden (1948), Mertie and others (1951), Pardee and Schrader (1933)
561	Avalanche Creek prospect (Red Tick claims)	York	46	39	37	111	32	42	Vein, barite	None						Discontinuous barite vein, up to 4 ft wide, striking N80E; displaced by high-angle normal fault. Minor chalcopyrite present.	Berg (1986, 1988)
562	Avalanche Creek placer	York	46	39	24	111	32	32	Placer Au		5000						Frishman and others (1992), Lyden (1948), McClernan (1980), McCulloch (1993b), Mertie and others (1951), Pardee and Schrader (1933)
563	Jacksonville prospect	None	46	52	5	111	42	10	Vein, polymetallic							Quartz veins contained traces of gold and silver.	Close and Rigby (1984)
564	Sheep Creek placer	Beaver (Elk Creek)	46	44	15	111	30	12	Placer Au								This report
565	Anna Lode	Beaver (Elk Creek)	46	43	44	111	25	31	Vein, polymetallic	None						Pyrite, galena, and chalcopyrite in vein. Associated with quartz monzodiorite.	MRDS
566	Elsie Lode	Beaver (Elk Creek)	46	43	41	111	25	29	Vein, polymetallic	None						Pyrite, galena, and chalcopyrite in quartz-calcite gangue. Associated with quartz monzodiorite.	MRDS
567	Fig Springs placer	Beaver (Elk Creek)	46	43	40	111	25	40	Placer Au								MRDS
568	Beaver Creek placer	Beaver (Elk Creek)	46	43	25	111	25	30	Placer Au		Minor						Dingman (1932), Lyden (1948), McClernan (1980), Roby (1950)
569	Name unknown	Beaver-Elk Creek	46	41	29	111	25	42	Vein, Au-bearing							Quartz-calcite vein; adit.	Gualtieri (1975), Gualtieri (unpub. field notes)
570	Name unknown	Beaver-Elk Creek	46	40	48	111	26	4	Vein, Au-bearing							Several adits and several prospect pits into gabbro dike; quartz veins.	Gualtieri (1975), Gualtieri (unpub. field notes)
571	Vermont Gulch placer	Beaver (Elk Creek)	46	40	44	111	22	53	Placer Au								This report, McCulloch (1993a)

No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	Production and Reserves [2] (tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
572	Benton Creek placer	Beaver (Elk Creek)	46	40	0	111	22	22	Placer Au		Minor						Dingman (1932), Lyden (1948), McClernan (1980), Roby (1950)
573	Thomas Creek placer	Beaver (Elk Creek)	46	40	38	111	17	25	Placer Au		1100						Frishman and others (1992), Lyden (1948), McClernan (1980), Roby (1950)
574	Big Hat Lode	Beaver (Elk Creek)	46	38	26	111	18	14	Vein, polymetallic							Quartz-calcite vein assayed 0.01 oz per ton Au, 0.1 oz per ton Ag.	MRDS
575	Name unknown	Beaver-Elk Creek	46	38	9	111	17	58	Vein, polymetallic							Pyrite-bearing quartz vein.	Gualtieri (1975), Gualtieri (unpub. field notes)
576	Elk Creek placer	Beaver (Elk Creek)	46	38	45	111	15	0	Placer Au		5						Dingman (1932), Lyden (1948), McClernan (1980), Roby (1950)
577	Camas placer*	Beaver (Elk Creek)	46	39	7	111	11	24	Placer Au		Minor						Lyden (1948), McClernan (1980), Roby (1950)
578	Victory (Whoopie Hill)*	Beaver (Elk Creek)	46	47	14	111	13	0	Polymetallic replacement								McClernan (1980), Roby (1950)
579	White Creek placer	Confederate Gulch	46	36	44	111	30	30	Placer Au		75000					Production figure is average of 60-90,000 oz cited.	Frishman and others (1992), Johnson (1973), Lyden (1948), McClernan (1980), Mertie and others (1951), Pardee and Schrader (1933)
580	Upper No. 2 Gulch	Confederate Gulch	46	37	14	111	29	21	Sediment-hosted Cu, veins							Shear zone at contact between dike and shale. Minor chalcopyrite occurs along this zone.	Pardee and Schrader (1933)
581	Hummingbird	Confederate Gulch	46	37	34	111	25	7	Vein, Au-bearing	43	54	75				Vein strikes N30E, 85NW, 4-18 in. wide, composed of quartz, pyrite, chalcopyrite. Two-ft-wide quartz vein along bedding plane in Newland siltite.	Pardee and Schrader (1933), Reed (1951)
582	Schabert	Confederate Gulch	46	37	50	111	24	44	Vein, Au-bearing							Three-ft-wide quartz-pyrite vein strikes N20E, dips 75E. Quartz-diorite wall rock reported to contain small amounts of gold.	McClernan (1980), Pardee and Schrader (1933), Reed (1951)

No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	Production and Reserves [2] (tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
583	Miller Mountain (Miller, Durant, Dexter, Lonetree, Western Star)	Confederate Gulch	46	37	13	111	24	49	Vein and disseminated, Au-bearing	11.0 Mt (r)	310000 (r)						Frishman and others (1992), Johnson (1973), McClernan (1980), Mertie and others (1951), Pardee and Schrader (1933), Pegasus Gold Annual Report (1992), Reed (1951)
584	Name unknown	Confederate Gulch	46	37	52	111	23	26	Vein, Au-bearing							Adits into altered dike; pyrite.	Gualtieri (1975), Gualtieri (unpub. field notes)
585	Sulliran and Steward claims	Confederate Gulch	46	36	30	111	23	45	Vein, polymetallic							Vein containing galena.	MRDS
586	Baker Group (Sateilite)*	Confederate Gulch	46	36	24	111	26	18	Vein and disseminated, Au-bearing	1291	711	1437		11.8		Vein striking N20W, dipping 33-55SW.	Frishman and others (1992), Mertie and others (1951), Reed (1951)
587	Confederate Gulch placer	Confederate Gulch	46	33	20	111	28	13	Placer Au		600000; 181400 (r)					62 oz Au nugget found in 1947. Reserves are in 6,800,000 cubic yards of gravel.	Engineering and Mining Journal (1993), Koschmann and Bergendahl (1968), Lyden (1948), McClernan (1980), Mertie and others (1951), Pardee and Schrader (1933), U.S. Geological Survey (1988)
588	Prospect (unnamed)	Southern Big Belt Area	46	35	32	111	22	10	Vein, Au-bearing								This report; du Bray (1995)
589	Boulder Mountain	Southern Big Belt Area	46	32	46	111	20	45	Vein, Au-bearing							One- to 2-in.-wide fluorite veinlets in shear, striking N30W, dipping 70SW. Veins contain trace assay values in gold. Lat. and long. general for area.	Sahinen (1962)
590	Atlanta Gulch placer	Southern Big Belt Area	46	33	48	111	14	10	Placer Au		422						Lyden (1948), McClernan (1980), Roby (1950)
591	Prospect (unnamed)	Southern Big Belt Area	46	31	36	111	17	21	Vein, Au-bearing								This report; du Bray (1995)
592	Normandy	Southern Big Belt Area	46	30	58	111	17	0	Vein, Au-bearing							One- to 6-ft-wide NW-striking vein of fluorite and quartz; assayed 35.2 percent CaF over 0.9 ft.	Reed (1951), Sahinen (1962)

No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	Production and Reserves [2] (tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
593	Little Camas Creek placer	Southern Big Belt Area	46	31	26	111	14	43	Placer Au								This report
594	Prospect (name unknown)	Southern Big Belt Area	46	31	4	111	14	35	Vein, polymetallic							Prospect pits in Bigler-Snowbank area.	This report
595	Porcupine mine	Southern Big Belt Area	46	31	5	111	13	52	Vein, polymetallic							Gossanous flat-lying quartz veins in quartz monzodiorite; small prospect pits and adit. Gossanous sample contained 7.7 ppm Au, 14 ppm Ag, 220 ppm Bi.	This report
596	Bigler mine (Snowbank)	Southern Big Belt Area	46	30	33	111	14	3	Vein, polymetallic	373	268	177	0.6	2		Gossanous quartz veins at contact of quartz monzodiorite and Newland Formation. Garnet-epidote skarn with minor copper oxides occurs in Newland Formation near Snowbank mine. Gossanous fracture contained 23 ppm Au, 8 ppm Ag, 35 ppm Bi, 2.5 ppm As.	McClernan (1980), McCulloch (1993b), Roby (1950), this report
597	Prospect (unnamed)	Southern Big Belt Area	46	30	4	111	16	7	Vein, Au-bearing							Prospect pit.	This report; du Bray (1995)
598	Prospect (unnamed)	Southern Big Belt Area	46	30	3	111	15	17	Vein, Au-bearing							Dozer trench.	This report; du Bray (1995)
599	Thompson Creek placer	Southern Big Belt Area	46	32	3	111	12	7	Placer Au		2500						Frishman and others (1992), Lyden (1948), McClernan (1980), Roby (1950)
600	Bourbon mine*	Southern Big Belt Area	46	31	21	111	11	34	Vein and disseminated, Au-bearing							Quartz vein striking N30E, dipping 90 degrees.	Roby (1950)
601	Prospect (name unknown)	Southern Big Belt Area	46	24	26	111	10	44	Vein, polymetallic							inclined shaft at the contact between quartz monzodiorite and Newland Formation. Gossanous stockwork veinlets in the Newland Formation were found on the mine dump.	This report

										Production	and		Reserves [2]				
No.	Site name	District/ Area [1]	Latitude			Longitude			Probable deposit type	(tons ore)	Au (oz)	Ag (oz)	Cu (tons)	Pb (tons)	Zn (tons)	Comments	Sources of data
602	Deep Creek Canyon*	Southern Big Belt Area	46	21	35	111	7	27	Stone, building							Gray-orange-pink plagioclase phenocrysts in a dark-green groundmass could be used as a decorative stone when polished.	Berg (1974)
603	Deep Creek placer*	Southern Big Belt Area	46	19	33	111	20	40	Placer Au		Minor						Freeman and others (1958), Frishman and others (1992), Lyden (1948), McClernan (1980), U.S. Geological Survey (1885-1923, 1988)
604	Josephine	Basin (Cataract, Comet)	46	24	50	112	19	0	Stone, building							Rhyolite "rubble" in talus	Berg (1974)

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CHAPTER F

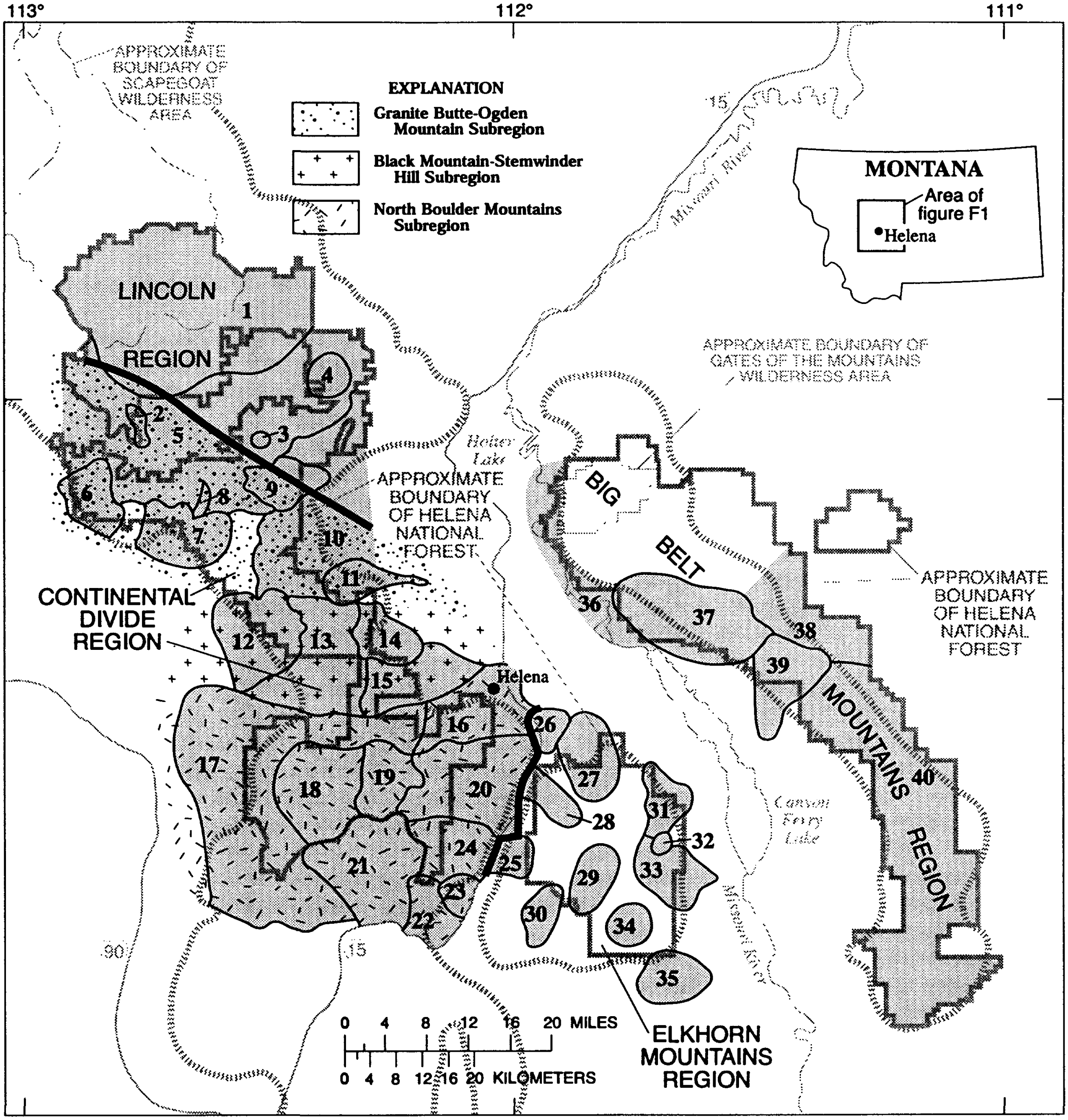
MINERAL RESOURCE GEOLOGY OF MINING DISTRICTS/AREAS

INTRODUCTION

The mineral resource geology of the Helena National Forest (the Forest) is described by mining districts/areas that host, or potentially host, mineral deposits. The districts/areas are grouped by regions, which generally correspond with geographic divisions of the Forest. From northwest to southeast, the regions are Lincoln, Continental Divide, Elkhorn Mountains, and Big Belt Mountains (fig. F1). These regional divisions are used because they generally define contiguous geologic terranes and associated patterns of mineralization, facilitating the description of mining districts/areas and mineral deposits. Because of complex geology and diverse types of mineralization, the Continental Divide region is divided further, into three subregions: Granite Butte-Ogden Mountain, Black Mountain-Stemwinder Hill, and North Boulder Mountains (fig. F1).

Most mineral deposits in the Continental Divide and Elkhorn regions are genetically and spatially related to granitic intrusions and extrusive to intrusive volcanic rocks. The Lincoln and Big Belt Mountains regions contain these same associations, but in addition contain stratabound mineral occurrences. The distribution of these stratabound occurrences, which are areally extensive tabular-shaped bodies, is determined partly by sedimentological properties of the host formations. The stratabound deposits do not fit neatly into the district/area classification scheme generally used in this chapter because the host formations, which are in the Middle Proterozoic Belt Supergroup, extend throughout the Lincoln and Big Belt Mountains regions, well beyond district/area boundaries. Hence, the stratabound occurrences are described by deposit type, and deposits within a district/area are discussed under the appropriate deposit-type heading.

This chapter is arranged to reflect the genetic relationships of the deposits. The geology and mineral deposits of the Lincoln and Big Belt Mountains regions, which contain most of the genetically related stratabound deposits, are described first, followed by the Continental Divide and Elkhorn Mountains regions.



1 Scapegoat area	11 Marysville district	21 Basin district	31 Winston district
2 Lincoln Gulch area	12 Ophir district	22 Boulder district	32 Park district
3 Seven-Up Pete Gulch area	13 Dog Creek area	23 Amazon district	33 Indian Creek district
4 Heddleston district	14 Austin district	24 Wickes district	34 Slim Sam area
5 Blackfoot River area	15 Stemwinder Hill area	25 Golconda area	35 Radersburg area
6 Big Blackfoot area	16 Helena district	26 Montana City district	36 Missouri River area
7 Finn district	17 North Boulder Mountains area	27 McClellan-Mitchell Creek district	37 York district
8 McClellan Gulch district	18 Elliston district	28 Warm Springs district	38 Beaver-Elk Creek district
9 Stemple-Gould district	19 Rimini district	29 Tizer Basin area	39 Confederate Gulch district
10 Little Prickly Pear area	20 Clancy district	30 Elkhorn district	40 Southern Big Belt area

Figure F1. Map showing regions, subregions, and mining districts/areas of Helena National Forest.

LINCOLN REGION

By R.G. Tysdal, J.E. Elliott, E.A. du Bray, and J.W. Whipple

The Lincoln Region lies north of the St. Mary-Helena Valley fault in the northwestern part of the Forest (fig. F1). It mainly includes rocks within the southeastern part of the Choteau 1° x 2° quadrangle (fig. A2). The region hosts the Heddleston mining district and the recently discovered gold deposit at McDonald Meadows.

Blackfoot River Area

Geologic Setting

The Blackfoot River area is adjacent to and includes parts of the Forest in the vicinity of Lincoln (pl. 2, map B), and contains parts of both the Lincoln and Continental Divide regions (fig. F1). The principal rock types are sedimentary rocks of the Middle Proterozoic Belt Supergroup: the Spokane and Empire Formations of the Ravalli Group; the Helena Formation; and the Snowslip, Mount Shields, and Shepard Formations of the Missoula Group (pl. 1, map A). Broad, open folds and steeply dipping normal, reverse, and strike-slip faults are dominant structures. In the eastern part of the area the Proterozoic sedimentary rocks have been intruded and covered by Tertiary andesitic and rhyolitic volcanic rocks. Several granodiorite plutons (Tertiary and Cretaceous) are in the southern part of the area.

Mineral Deposits

Mineral deposits of the Blackfoot River area historically produced metals from gold placers and polymetallic veins that yielded small quantities of gold, silver, copper, and lead. The area is a relatively small producer of metals, mainly gold, and the estimated total value of production for the area is about $27,000 (Elliott and others, 1992). However, the area also contains the undeveloped McDonald Meadows gold deposit (described below), which contains several million ounces of gold.

Mineral deposits of the Blackfoot River area are spatially associated with igneous rocks. The associations are shown by geophysical studies of the Butte 1° x 2° quadrangle (Hanna and others, 1994), which indicate several magnetic and gravity anomalies (figs. C1, C4). A magnetic high in the western part of the Blackfoot River area is associated with a small granodiorite stock near Mineral Hill. The terrace-magnetization pattern (fig. C4, anomaly 4) suggests a much larger subsurface extent than the small surface exposure indicates (Hanna and others, 1994; pl. 1, map A). Two magnetic highs along (figs. C1, C4, anomalies 3 and 6) the south and southeast borders of the Blackfoot River area are associated with the Dalton Mountain and Silver Bell (Stemple Pass) stocks, respectively. The Dalton Mountain stock (figs. C1, C4, anomaly 3) continues into the adjacent Finn and McClellan Gulch districts. The magnetization pattern suggests that the stock extends to the south in the subsurface (Hanna and others, 1994), an interpretation confirmed by McCafferty (Chapter C of this report, fig.

C4). The Silver Bell stock extends into the adjacent Stemple-Gould district. The magnetic pattern for this stock suggests that its subsurface extent is two to three times larger than the surface extent (Hanna and others, 1994). A gravity low may be associated with the subsurface extent of the Silver Bell stock (Hanna and others, 1994). Another magnetic high along the eastern border of the Blackfoot River area may be related to part of the Lincoln volcanic field, composed of andesitic and rhyolitic rocks (Hanna and others, 1994); it may also be due to the presence of relatively thick low-density volcanic and volcaniclastic rocks of the Lincoln volcanic field.

Geochemical anomalies in arsenic, silver (fig. D13), gold (fig. D12), barium, bismuth (fig. D15), copper (fig. D16), iron (fig. D20), molybdenum (fig. D17), manganese (fig. D21), lead (fig. D14), antimony, tin, tungsten, and zinc (fig. D19) are present in the Blackfoot River area. The geochemicalanomalies in these figures (Alminas, Chapter D of this report) are for stream sediments and incorporate only the stream sediment dat of McDanal and others (1985).

McDonald gold deposit

The recently discovered McDonald deposit (pl. 2, no. 53) contains 8.2 million ounces of gold in 414 million tons of rock (Denver Post, 1994). It is within the Blackfoot River area, outside the Forest. It may be genetically related to epithermal veins in the Seven-Up Pete Gulch area to the south. The McDonald deposit, in rocks of the Tertiary Lincoln volcanic field, has many characteristics of a hot-spring gold-silver deposit. As described by Enders and others (1995), the deposit is within the upper part of the volcanic succession and is hosted by a 1,500-ft-thick sequence of rhyolite ash-flow tuffs that are underlain by a sequence of andesitic volcanic and volcaniclastic rocks. Approximately 90 percent of the mineralized rock is in the lower lithic-rich portion of the rhyolite tuffs. This lithic tuff is up to 1,200 ft thick. An overlying crystal-rich tuff, up to 350 ft thick, contains only about 7 percent of the deposit and an underlying sequence of andesitic flows and volcaniclastic rocks contains the remainder of the mineralized rock. Volcaniclastic rocks overlying the deposit contain depositional siliceous sinters with anomalous concentrations of trace elements that are primary indicators of the underlying mineral deposit.

The geometry of the mineralized zone is controlled by permeable zones in tuffaceous rocks and by steeply dipping, intersecting vein sets. The mineralized zone is nearly tabular and stratiform, dips 20° to 25° to the north, and has an average thickness of about 450 ft. Many of the vein sets may have been controlled by pre-mineral faults. The deposit is cut by two high-angle faults that have strikes of N. 60 E. and N. 15 W. Many mineralized veins are parallel to the north-northwest (N. 15 W.) fault and with west-northwest striking faults. The N. 60 E. fault is probably a post-mineral structure.

Gold- and silver-bearing minerals and associated gangue minerals occur in veins and, to a lesser extent, are disseminated into the wall rock. Most of the gold occurs as electrum with a gold:silver ratio of about 56:44. Other ore and gangue minerals are native gold, acanthite, quartz, chalcedony, calcite, adularia, pyrite, marcasite, specular hematite, goethite, jarosite, and cryptomelane. Silicification and quartz-adularia are the main forms of alteration. Argillic alteration forms a halo around the mineralized area.

Seven-Up Pete Gulch Area

Geologic Setting and Mineral Deposits

The Seven-Up Pete Gulch area (fig. F1; pl. 2, map B), 8 miles east of Lincoln, is a mineralized intrusive-extrusive volcanic center that was a probable source of much of the surrounding Tertiary andesitic and rhyolitic volcanic rocks (pl. 1, map A). Sulfide-bearing quartz veins are along shear and breccia zones in andesite. The area has produced moderate quantities of gold and silver. Recent exploration has indicated approximately 10 million short tons of mineralized rock with an average grade of 0.06 ounces of gold per ton, mainly in the vicinity of the Columbia mine (pl. 2, map B; Rocky Mountain Pay Dirt, 1991). The mineralization could be genetically related to that of the McDonald deposit, approximately 3 mi to the north. The andesitic volcanic rocks that host the Seven-Up Pete mineralization are found to correlate with those that underlie the rhyolitic volcanic rocks of the McDonald deposit. Thus, the epithermal veins in the Seven-Up Pete Gulch area probably formed at a lower stratigraphic level than the McDonald deposit. The area is a small producer of metals with an estimated total value of production of about $25,000 (Elliott and others, 1992). The results of a geochemical survey (McDanal and others, 1985) indicate geochemical anomalies for silver and gold in this relatively small area.

Heddleston District

Geologic Setting

The Heddleston district, 14 miles northeast of Lincoln (fig. A2, pl. 2), is largely underlain by quartzite (metasandstone) and siltite of the Middle Proterozoic Spokane and Empire Formations, and hornblende diorite and gabbro sill-like intrusive masses of Late Proterozoic age (pl. 1). Multiple Tertiary felsic igneous bodies intrude the Proterozoic rocks. Miller and others (1973), from whose work the following descriptive material is derived, described the intrusive rocks as a series of feldspar porphyries, related breccia intrusions, and quartz porphyry. The oldest and largest is a steep-sided intrusion that is composed of quartz monzonite porphyry. Numerous dikes of the same rock type extend north and south of the main mass. Large phenocrysts of potassium feldspar, plagioclase, biotite, and rounded quartz in an aplitic groundmass are characteristic of the quartz monzonite porphyry. Miller and others (1973) reported that the intrusion is cut by zones of complex brecciation.

The granitic intrusions were believed by Miller and others (1973) to be younger than those of the Boulder Batholith (emplaced 78-70 Ma); Amax Exploration determined a middle Eocene K-Ar age of 44.5±1.2 Ma for sericite from altered rock.

Two prominent fault systems, an older N. 20-40 E.-striking set and a younger N. 50-70 W. set, offset rocks in the district. Both fault systems contain mineralized rock, but the northeast-striking set seems to have influenced intrusion emplacement, whereas the vein deposits seem to have been controlled by the northwest-striking set (Miller and others, 1973).

Mineral Deposits

The first ore deposits identified in the Heddleston district were large, supergene-enriched mineralized shear zones and veins. These were first exploited for gold and subsequently for their base metals. Known mines in the Heddleston district include the Anaconda (pl. 2, no. 40), Bobby Boy (no. 37), Calliope (no. 31), Carbonate (no. 32), Consolation (no. 35), Midnight (no. 33), Mike Horse (no. 43), Paymaster (no. 38), and Rex Beach (no. 34), all of which are inactive (Earhart and others, 1981). By 1930, lodes had produced about $2,000,000 worth of gold, silver, lead, zinc, and copper. Additional ore was intermittently produced, principally from three major veins in the Mike Horse Mine, between 1930 and 1964, by which time total production from the district was estimated at $25,000,000.

During the period 1962-1970 the Anaconda Company conducted a full-scale exploration and development project that resulted in a fairly complete understanding of the geology and resource potential of the Heddleston district. Exploration and preliminary development work by Anaconda identified several significant porphyry copper-molybdenum prospects that are amenable to open-pit mining, but have not been developed. Early prospecting in the area led to small-scale mining of base and precious metals from vein systems that are probably related to the larger Heddleston copper-molybdenum deposit.

Mineralized rock in the Heddleston district is spatially and genetically associated with the numerous intrusions of quartz monzonite porphyry and quartz porphyry. As a group, the intrusions are responsible for the primary chalcopyrite-molybdenite deposits in the district and for extensive host rock hydrothermal alteration. Some of the most strongly mineralized rock is associated with the zones of complex autobrecciation, described above (Miller and others, 1973).

Several stages of quartz-chalcopyrite-molybdenite cut the main quartz monzonite porphyry of the Heddleston district. Important vein deposits containing galena, sphalerite, chalcopyrite, bornite, and tetrahedrite are spatially and genetically associated with copper-molybdenum deposits. Chalcopyrite and molybdenite are also broadly disseminated throughout the main quartz monzonite porphyry but their distributions are not well understood.

Much of the rock in the Heddleston district, including an area about 9000 ft long and 2000 ft wide, has been affected by sericitic and pyritic alteration that broadly grades out to propylitic alteration. Weak alteration has resulted in zoning patterns that are not particularly well developed in this area. Alteration is widespread and affects the intrusive rocks as well as their host rocks. Supergene enrichment zones contain secondary chalcocite and covellite whose distribution appears to be controlled by steeply-dipping, pre-mineralization structures. Miller and others (1973) stated that no extensive supergene copper enrichment blanket, such as those associated with many other copper-molybdenum deposits, has been identified. Much of the rock affected by supergene processes has been converted to montmorillonite.

The Kleinschmidt breccia pipe, in the southern part of the district, contains angular fragments of quartzite, siltite, quartz monzonite porphyry and highly altered quartz porphyry. The pipe is about 250 ft wide and 400-500 ft long and contains abundant pyrite and minor chalcopyrite. A 600 ft by 300 ft intrusive breccia in the north part of the district, near the Midnight mine (no. 33), is one of the most strongly mineralized areas of the district.

Scapegoat Area

Geologic Setting

The Scapegoat area, north and east of Lincoln (fig. F1, pl. 2), is mainly underlain by strata of the Middle Proterozoic Belt Supergroup. Except for the Newland Formation, all Belt formations present in the Forest are exposed in the Scapegoat area. The sequence is largely composed of clastic rocks that range in grain size from argillite to metasandstone. The Helena Formation, near the middle of the sequence, is comprised of dolomitic limestone, calcareous metasandstone, and siltite. These rocks locally are intruded by sills of Late Proterozoic diorite or gabbro. Paleozoic limestone and dolomite of Cambrian to Mississippian age overlie the Proterozoic strata locally in the northernmost part of the Scapegoat area.

Mineral Deposits

The Lincoln region (and the Big Belt Mountains region) contains mineral deposits that are stratabound. The mineralized rocks are described by deposit type, and deposits within a district/area are discussed under the appropriate deposit-type heading. Stratabound deposits of the Forest are present within some formations of the Middle Proterozoic Belt Supergroup.

Sediment-hosted copper

The main mineral deposits in the Scapegoat area are stratabound sediment-hosted copper-silver deposits within the Belt Supergroup. In Montana and northern Idaho, these deposits have been subdivided into greenbed, quartzite (metasandstone) or Revett, and carbonate deposits (Harrison, 1972, 1974; Lange and Sherry, 1986). Classification of sediment-hosted copper deposits is undergoing change and in this report are classified as follows, per written communication with D.A. Lindsey of the USGS:

Types of sediment-hosted copper-silver deposits (and host lithology). *, present in the Forest
Redbed type
Greenbed subtype* (siltite and argillite)
Reduced-facies type
Carbonate subtype* (limestone and dolomite)
Kuperschiefer subtype (euxinic black shale)
Revett type* (quartzite)
Vein type* (quartz-carbonate veins)

Greenbed subtype, Revett type, and carbonate subtype mineralized zones typically consist of small, disseminated mineral occurrences characterized by low tonnages and grades. The greenbed subtype and Revett type form mainly in localized, chemically reduced (green and gray) beds within sequences of oxidized (red) strata. The carbonate subtype also occurs within a chemically reduced environment but not necessarily within a redbed sequence. Vein type deposits consist of quartz-carbonate veins that are enriched in copper and silver during remobilization of these elements from nearby or contiguous stratabound greenbed, carbonate, and Revett occurrences. Geologic factors that control the distribution of the greenbed, Revett, and carbonate deposits also are directly related to distribution of the vein deposits. Mineralization processes that formed the stratabound copper-silver deposits of the Belt Supergroup are dependent on stratigraphic and sedimentologic properties of the host strata.

Redbed type, greenbed subtype. Green beds that contain copper- and silver-bearing minerals are present in many of the Belt formations in the Forest--upper part of the Greyson, Spokane, Empire, Snowslip, Mount Shields, and McNamara Formations. The Spokane green beds contain most of the mineralized zones, according to Earhart and others (1981), who reported as many as 16 mineralized greenbed argillite and siltite sequences that are as thick as 60 ft in the upper part of the Spokane. The middle part of the Spokane lacks green strata and the lower part contains some green beds that are sparsely mineralized. The copper and silver minerals commonly are near the middle of the greenbed units, within green to olive-gray argillite and siltite that are interbedded with red beds. In siltite, and locally very fine grained quartzite, concentration of minerals is in the coarser laminae at the base of beds. In argillite, the minerals are in discordant structures such as shrinkage cracks or along coarser grained laminae.

Where mineralized siltite or quartzite beds are more than 1-2 in. thick, they generally are assigned to the quartzite subtype of redbed deposit. Beds of quartzite 1-3 ft thick within greenbed sequences were classified as greenbed occurrences by Mudge and others (1974) and Earhart and others (1977, 1981), a time when classification of deposit types was still being determined. Such beds here are considered Revett type occurrences, discussed below.

The Empire Formation, above the Spokane, is mostly a greenbed unit and locally contains zones about 3 ft thick of stratabound copper-silver-bearing zones, mainly in the middle and lower parts of the formation, but locally in the upper part within the Forest (Earhart and others, 1981). Some of these zones consist of mineralized quartzite beds and here are classified as the Revett type. Green beds of argillite and siltite are present throughout the Snowslip Formation, but mineralized zones typically are lenticular and difficult to trace for more than a few feet. Most mineralized zones in green beds of the McNamara Formation are discontinuous and are considered to have a low potential for mineral resources (Earhart and others, 1981).

Revett type. Quartzites of the Spokane Formation within the Scapegoat area are white, buff, gray, or pale-green fine-grained, noncalcareous, vitreous, feldspathic metasandstones (Whipple, 1980). The beds or lenses range up to about 7 ft thick and occur within sequences of both red and green siltite and argillite. The mineralized quartzites of the Spokane have a higher potential for mineral resources than those in the younger formations of the Belt Supergroup because they are the thickest, most laterally extensive, and of the highest grade in copper and silver. Connor and McNeal (1988) reported that quartzites hosting copper- and silver-bearing minerals generally contain low but anonalous concentrations of mercury and barium as well.

On Green Mountain, northeast of Alice Creek (pl. 2, no. 19), quartzite beds occur through as much as 1,000 ft of the middle part of the Spokane Formation (Trammel, 1975; Earhart and others, 1981). Based on outcrop sampling, Connor and McNeal (1988) calculated that these quartzite lenses could contain more than 700,000 oz of silver, mostly in two bodies near the crest of the mountain. Exploratory drilling of mineralized quartzite beds in this area was done in the 1970s by Bear Creek Mining Company (Whipple, 1980).

The Alice Creek mine (pl. 2, no. 19) is a small, high-grade, silver deposit that was mined from quartzite of the Spokane Formation in the late 1970's. Connor and McNeal (1988) stated that it has silver values that range up to 280 ounces per ton, but copper concentrations are no richer than those in other mineralized quartzite lenses. The exceptionally high silver content, along with high values of lead and mercury, led them to suggest that the deposit may reflect a hydrothermal source related to an inferred, concealed intrusive. The aeromagnetic data in this area of low resolution (fig. C2) and cannot be used to determine if hydrothermal alteration exists (A.E. McCafferty, oral commun., 1994). No other evidence of hydrothermal alteration exists, however. Neither the magnetic nor gravity data suggest a concealed intrusion in this area.

The Mount Shields Formation contains mineralized quartzites, in its middle and upper parts, in lenses within green beds of argillite and siltite. Quartzite beds similarly occur within the Empire and Snowslip Formations. Many of the quartzite occurrences were considered greenbed subtype deposits by Mudge and others (1974) and Earhart and others (1981), but here are assigned to the Revett type because the thickness of the quartzite beds exceeds 1-2 in., and commonly are in the 1 ft range. Most of these quartzites are thinner than those at Green Mountain, although Earhart and others (1981) reported one 10-ft-thick mineralized quartzite in the Empire Formation, near the Copper Camp mine (pl. 2, no. 9). They stated that it averages 0.12 percent copper and about 0.25 ounces of silver per ton.

<u>Reduced facies, carbonate subtype</u>. Mineralization in this subtype is present in limestone and in calcareous metasandstone (quartzite) in the Scapegoat area. Limestone-hosted stratabound mineralization is known only from Red Mountain (pl. 2, no. 8), in a clastic limestone of the basal part of the Helena Formation. The occurrence is a 2-7 ft thick mineralized zone that has a strike length of about 525 ft. The main copper-bearing mineral is chalcopyrite (Lange and Eby, 1981; Lange and Sherry, 1986).

Mineralized calcareous metasandstone is widely dispersed in the Scapegoat area, in basal strata of the Helena Formation. The mineralized rock contains disseminated minerals of lead and zinc, and less commonly copper and silver. Earhart and others (1977) reported that mineralized zones are planar to lenticular, as thick as 7 ft and 200 ft long. At Landers Fork (pl. 2, loc. 16), an 11.5 ft wide zone of structurally thickened rock yielded values of 0.5 percent copper and 0.2 ounces per ton silver (Earhart and others, 1981).

<u>Vein type.</u>--Quartz-carbonate veins that are enriched in copper and silver are present at several places in the Scapegoat area of the Forest. The veins occur in the same Belt formations that host stratabound mineral occurrences of the greenbed subtype and Revett type. Such occurrences are believed to be metals of the stratabound Belt deposits that have been remobilized into veins. The veins and vein systems occupy small faults and shear zones and are most common

in the Spokane, Empire, and Helena Formations. They also are present in the Late Proterozoic diorite to gabbro sills that intrude the Belt strata. Copper and silver minerals commonly are disseminated into strata adjacent to the veins and the mafic sills.

Prospecting and mining in the early 1900s in this area was focused mainly on the vein type copper-silver deposits. The Cotter Basin mine (pl. 2, no. 10) actively produced until the mid-1970s. The copper and silver deposits are in sheared dolomitic limestone of the Helena Formation. The principal shear zone is as wide as 5 ft and more than 1,100 ft long. The shear zone and adjacent mineralized wallrock form a zone that is at least 16 ft thick and contains identified resources of 1,000,000 tons of ore, which averages 1.2 percent copper and 0.2 ounces per ton silver (Earhart and others, 1977, p.54).

Little Prickly Pear Area

Geologic Setting

The Little Prickly Pear area of the Forest, southeast of Lincoln (fig. F1), is in the northeast part of the Butte 1° x 2° quadrangle. The area is underlain by clastic strata of the Middle Proterozoic Spokane Formation, and locally the Empire Formation, of the Belt Supergroup. Late Proterozoic diorite to gabbro sills intrude the Spokane.

Mineral Deposits

Sediment-hosted copper, Revett and redbed types

The only reported mineral occurrence in this part of the Forest is of sediment-hosted copper and silver of the redbed type-greenbed subtype and Revett type deposits. (See Scapegoat area discussion of the deposit types, subtypes, and sedimentology pertinent to sediment-hosted copper.) Mineralized quartzite beds (Revett type deposit) of the lower Empire and the upper Spokane crop out in a 1 sq mi area in the vicinity of the Copper Hill (McVay, Canyon Creek) deposit (pl. 2, no. 112). The deposit has been explored by drilling.

A drillhole penetrated basal beds of the Empire and extended into the middle of the Spokane; core from the hole permitted detailed study of ore-forming processes (Trammel, 1975; Braun and Lange, 1984; Lange and others, 1986, 1989). Scattered copper sulfides were encountered in green beds of the Empire and upper part of the Spokane. Copper and silver minerals in the middle part of the Spokane occur through a 130 ft interval comprised of light-gray quartzite beds and interstratified green siltite and argillite (greenbed subtype). Mineralized rock is most abundant and laterally persistent in the quartzites (Braun and Lange, 1984; Lange and others, 1989). Values of 1.52 percent copper, 0.93 ounces per ton silver, and 0.005 ounces per ton gold were reported from this deposit (Brox and Guilbert, 1960; Brox and Potter, 1965).

BIG BELT MOUNTAINS REGION

By R.G. Tysdal, E.A. du Bray, and J.W. Whipple

York Distirct

Geologic Setting

The York district (fig. F1; pl. 2) is on the southwest flank of the Big Belt Mountains, about 20 mi northeast of Helena. Argillite, siltite, and metasandstone of the Middle Proterozoic Newland, Greyson, Spokane, and Empire Formations, and siltite and limestone of the Helena Formation underlie much of central and northern part of the district. The Helena Formation has been thinned by erosion. These formations are intruded by Late Proterozoic dikes and sills of gabbro, diorite, and andesite. On the southwest, adjacent to the Townsend Valley, the Proterozoic units are overlain by limestone and dolomite of Cambrian to Mississippian-age formations. An area of andesite to basalt flows of probable Cretaceous age overlies strata of the Greyson Formation in the eastern part of the district (Mertie and others, 1951; Gualtieri, 1975a).

The Proterozoic and Paleozoic rocks were folded and faulted during the Laramide orogeny, and a thrust fault trends southeast through the middle of the district (Pardee and Schrader, 1933; Mertie and others, 1951). The Helena Valley fault (fig. B1; pl. 1) trends southeast through the southwestern part of the district. It is a Tertiary normal fault with right-lateral offset, separating the mountains from deposits of the Townsend Valley, and is the northern edge of the Lewis and Clark Line (Reynolds, 1979).

Mineral Deposits

The York district has experienced intermittent exploration or production from the late 1800s to the 1990s. Mineralized zones are assigned to four types of mineral deposit models: sediment-hosted copper, redbed; sediment-hosted copper, veins; sedimentary exhalative, gold; and vein, gold-bearing. The first three models are for stratabound deposits; the vein, gold-bearing model is related to granitic intrusions.

Sediment-hosted copper, redbed

Sediment-hosted copper, redbed type, is present in scattered occurrences in the Spokane Formation of the York district. The mineralization is of the greenbed subtype. (See "Scapegoat (Mineral Hill) Area" for discussion of deposit types and subtypes.) Rocks of the Spokane Formation in the Big Belt Mountains contain fewer green interbeds than rocks in the Scapegoat area and are only parsely mineralized. Metasandstone (quartzite) beds in the Spokane of the Big Belt Mountains are very thin, discontinous, and generally not thick enough to host Revett deposits.

Sediment-hosted copper, veins

Most copper in the York district is in veins. The deposits are characterized by chalcopyrite-rich, quartz-ankerite veins that are associated with the transition zone strata of the lower part of the Spokane Formation. The veins, and vein systems, are 1 ft to several feet thick, occupy small faults and shear zones, and occur discontinuously along the length of the district. Although some of the copper deposits are of high grade, they usually are local and restricted. The copper mineralization of the veins generally is believed to have resulted primarily from remobilization, and concentration into veins, of metals from low grade, stratabound occurrences of copper-bearing minerals that are disseminated within green beds of the Belt strata (Baitis and others, 1988; Lange and others, 1992; Whipple and Morrison, in preparation).

The Argo mine (pl. 2, no. 558) was the main producer of copper in the York district. Copper ore was mined from a quartz-carbonate vein system in faulted strata near the contact of the Spokane and Greyson Formations. Pardee and Schrader (1933) described the main vein of the Argo as composed of 4-5 ft thick tabular bodies several hundred feet in length and depth consisting nearly entirely of chalcopyrite. Most of the ore was confined to green argillite--ore grades decreased markedly where red argillite was encountered. The Argo mine produced about 3,000,000 pounds of copper from 1902 to 1918.

Exhalative, gold

A zone of gold-bearing sedimentary rocks is present in the Middle Proterozoic Greyson Formation of the York district. The zone is at least 12 mi long and consists of (1) mineralized orange-weathering siltite that contains abundant, intergranular potassium feldspar and locally iron carbonate; and (2) non-mineralized olive siltite that is thinly laminated (Whipple and Morrison, in preparation). The mineralized strata form resistant outcrops, termed "reefs," which are laterally discontinuous and range up to about 100 ft thick and several thousand feet long (Baitis and others, 1988; Thorson and others, in preparation) (pl. 2, nos. 535, 537, 539).

Potassium feldspar of the reefs is orthoclase (Baitis and others, 1989) and appears to be authigenic; K_2O is as much as 12 percent of the rock. At the base of some of the mineralized reefs is a distinct interval, a few tens of feet thick, of altered and bleached siltite that contains 2.4-4.7 percent K_2O (Whipple and Morrison, in preparation). The map of potassium aeroradioactivity (fig. C6), which shows intensities of potassium detected in rocks, reveals that the potassium-rich rocks define a positive anomaly over Greyson strata in the York district (Pitkin, Chapter C of this report).

The stratabound nature of gold mineralization in the district was first recognized by geologists of Noranda Exploration in the mid-1980s. Drilling by Noranda, and later other companies, showed that veins of quartz-carbonate-potassium feldspar cut all rocks at York but are most common in the reefs. Mineralization is disseminated within the reefs and in veins that are parallel and discordant to bedding within the reefs. The veins contain gold, pyrite, galena, and minor chalcopyrite (Baitis and others, 1988, 1989). Gold is absent from the bleached, altered siltite that occurs at the base of some reefs (Whipple and Morrison, in preparation). Reefs with greater than 0.01 ounces per ton gold were estimated to contain resources of more than 7,000,000 ounces of gold

(Thorson and others, in preparation). Gold values in the reefs are 3-4 times those of background gold values for the Greyson (Baitis and others, 1988). Anomalous concentrations of gold in stream sediments from the York district are shown in figure D12 (Alminas, Chapter D of this report).

The Greyson Formation was examined by Whipple and Morrison (in preparation) to determine the stratigraphy and sedimentological features of the strata that host the gold. They recognized four informal map units. Unit 1, the basal unit, is 500-1,700 ft thick and mainly is carbonate-cemented siltite and argillite. Unit 2, which contains the mineralized gold-bearing reefs, is 3,500-4,000 ft thick. It is mostly very thinly laminated olive siltite that contains discontinuous interlaminae of blackish green siltite and argillite. Several tuffaceous, volcaniclastic beds, a few feet thick, occur in the Avalanche Gulch area of the district (pl. 2) and are stratigraphically above and below the potassium-bearing rocks. Unit 3, about 1,200 ft thick, consists of blocky beds of gray to olive siltite and interbedded, very thinly laminated siltite. Some beds display hummocky crosslamination. Soft-sediment deformation structures occur in basal strata of this unit. Unit 4, about 1,000 ft thick, consists of mixed siliciclastic rocks and limestones that are lenticular and locally fragmental and stromatolitic. Mud-chip breccia, and rarely salt casts, are present in the uppermost beds. The succession of facies in the units 1-4 indicates a depositional environment that shallows upward from oshore basin plain to subtidal.

Sedimentary structures and lamination styles of some beds in unit 2 suggested deposition from turbidity currents, in deep parts of a restricted basin (Whipple and Morrison, in preparation; Thorson and others, in preparation). The volcaniclastic rocks and interbedded siltite of unit 2 suggest deposition in a deep-water environment that experienced periodic submarine volcanism (Whipple and Morrison, in preparation). The turbidites may have been generated by synsedimentary movement along intrabasin faults (Thorson and others, in preparation).

Several hypotheses have been proposed for genesis of the deposits, including granitic-intrusion related, epigenetic, syngenetic, and exhalative (Baitis and others, 1988, 1989; Thorson and others, in preparation; Whipple and Morrison, in preparation). The origin of these deposits is obscure. For this report we classified the gold deposits as exhalative, in the broadest sense. We include deposits that may have formed from metal-rich plumes issuing into the water column above a basin floor, as well as deposits that may have formed within the sedimentary pile beneath the basin floor, thus formed within the entire plumbing (feeder) system.

Vein, gold-bearing

The York mining district produced gold from veins in the early part of the 1900s. The deposits are typified by veins of the Golden Messenger mine (pl. 2, no. 522). The mine is within a Late Proterozoic mafic dike that is 200-400 ft thick, several miles long, and cuts the Greyson and Spokane Formations. The dike contains replacement systems of gold-bearing quartz-carbonate veins, some as much as 30 ft thick and 200-300 ft in other dimensions. Veins are not confined to the dike but extend into the adjacent sedimentary rock. Minerals are native gold, pyrite, and minor galena, sphalerite, and chalcocite; a small amount of silver was recovered from ore. Ore rich in gold also was rich in galena (Pardee and

Schrader, 1933). Lode production from the York district was about 70,000 ounces of gold, mostly from the Golden Messenger mine (Koschmann and Bergendahl, 1968).

Woodward (1992) interpreted the lode-gold deposits of the Greyson and Newland Formations to be localized along basement faults that were active during Proterozoic sedimentation, but he was not certain of the timing of remobilization of elements and concentration into veins. Whipple and Morrison (in preparation) observed that the dike hosting the Golden Messenger mine, and nearby mines and prospects, intruded the northern end of the gold-enriched, potassium feldspar-bearing zone of the Greyson Formation. They suggested that the gold in the dike could have been remobilized from the low-grade stratabound gold occurrences and concentrated into veins of the dike. In contrast, lead-isotope data suggests a Laramide age of mineralization, according to Lange and others (1993).

Confederate Gulch District and Southern Big Belt Area

Geologic Setting

The Confederate Gulch district is on the southwest flank of the Big Belt Mountains, about 30 mi east of Helena, and the southern Big Belt area adjoins it on the southeast (fig. F1; pl. 2). The Confederate Gulch district and the Southern Big Belt area are discussed together because much of the mineralized rock of the two areas is related to one system of plutonic rocks, or is hosted by Proterozoic strata that extend through both areas.

Most of the sedimentary rocks of the Confederate Gulch district and the Southern Big Belt area are argillite, siltite, and metasandstone of the Middle Proterozoic Newland and Greyson Formations. The Spokane and Empire Formations are exposed in a small area in the westernmost part of the Confederate Gulch district. Late Proterozoic dikes and sills of gabbro and diorite are present locally. Limestone and dolomite of Paleozoic and Mesozoic ages constitute most of the strata in the southernmost part of the Big Belt Mountains (pl. 1).

Cretaceous(?) andesitic volcanic rocks are exposed on the west side of the Confederate Gulch district (Mertie and others, 1951; Gualtieri, 1975a) and similar Cretaceous extrusive rocks are present in the southernmost part of the Southern Big Belt area (Skipp and Peterson, 1965; Skipp and McGrew, 1977). Rocks of both areas are probably erosional remnants of the much larger Elkhorn Mountains Volcanics field.

Granitic intrusions crop out extensively in the northern part of the Southern Big Belt area. The Boulder pluton, about six miles in diameter, is centered between Boulder Baldy and Boulder Mountain, and a small satellitic stock lies about 1 mi to the east (pl. 1) (Gualtieri, 1975a). To the south, another pluton crops out in the area of Mount Edith, in the headwaters of Big Birch Creek (du Bray, 1995). West of the Mount Edith pluton, and outside the limit of geology shown on plate 1, plutons mapped by Nelson (1963) yielded radiometric dates of 64.4 ± 2.4 Ma (biotite) and 71.5 ± 3.2 Ma (hornblende) (Daniel and Berg, 1981; ages recalculated by du Bray, 1995). The Boulder and Mount Edith plutons probably are coeval with the plutons mapped by Nelson (1963).

The Boulder pluton was mapped by Gualtieri (1975a), who recognized a concentric zonation, and later by du Bray (1995). The small pluton at Miller Mountain (pl. 1; pl. 2, no. 583) in the Confederate Gulch district was examined by Johnson (1973), who described rocks of differing compositions that comprise at least two stages of intrusion. The petrographic and intrusive relationships he described are similar to those observed in the middle and core zones of the Boulder pluton. The Miller Mountain pluton probably is an apophysis of the Boulder pluton; similarly, the other, very small intrusions in the district also probably are apophyses or are related to the same magma chamber as the Boulder pluton.

The Mount Edith pluton is petrographically similar to the intermediate zone of the Boulder pluton, implying temporal and genetic association of the plutons. The majority of the Mount Edith pluton is covered by a mantle of glacial deposits in the headwaters of Big Birch Creek.

The close spatial association and the petrographic and mineralogic similarities among the plutonic rocks of the central part of the Big Belt Mountains suggests they are genetically related and part of a single intrusive episode. Gravity and aeromagnetic data (McCafferty, Chapter C of this report, figs. C1, C4, anomalies 13, 14) corroborate the interpreted subsurface continuity of the intrusive masses. Thermal metamorphism associated with these intrusions produced aureoles that do not extend more than several hundreds of feet into sedimentary rocks of the Belt Supergroup.

Mineral Deposits

Exhalative(?), gold

Stratabound, sediment-hosted gold-bearing reefs like those in the York district are not known in the Confederate Gulch district and Southern Big Belt area. However, this area contains altered rocks similar to those of the York mineralized reefs and the underlying non-gold-bearing altered rocks of the York district. The altered rocks transgress stratigraphy (Thorson and others, in preparation), cutting downsection southeastward within the district (J.W. Whipple, oral commun., 1994). Light-gray, finely laminated, potassium-rich, altered siltite beds occur within the lower part of the Greyson Formation and upper part of the Newland Formation in the Southern Big Belt area. They crop out along State highway 12 on the west and east flanks of the mountains and were observed locally within the mountains as well. The potassium aeroradioactivity map (fig. C6), which shows a positive anomaly over the potassium-rich rocks of the Greyson Formation in the York district (see York district, "Exhalative, gold"), reveals that the anomaly also overlies lower Greyson and (or) upper Newland strata southward, in the Confederate Gulch district. In the Southern Big Belt area, the anomaly is along the west flank of the mountains; across the southern part of the mountains where the strata cross the range in an anticline; and on the east flank of the mountains (see Pitkin, Chapter C of this report).

The relationship of the altered rocks in the southern part of the range to gold-rich and gold-poor, potassium-rich, altered rocks of the York district is unknown. Analyses of several altered rocks collected in the Southern Big Belt area during this study failed to detect gold. The continuity of the aeroradioactivity over potassium-rich rocks in the York and Confederate districts and the Southern Big Belt area, however, suggests that all of the potassium-rich rocks may be genetically related.

Cretaceous gold-bearing veins

The Confederate Gulch area was a major producer of placer gold during the latter half of the 1800s and sporadically thereafter (Lyden, 1948). Total gold production from the Confederate Gulch district through 1959 was between 550,000 and 600,000 ounces, all but about 10,000 ounces from placers (Kochmann and Bergendahl, 1968). A close spatial association between mineral deposits and intrusive rocks in the district suggests a genetic relationship. The gold in the placer deposits is commonly attributed to lode sources at Miller Mountain on the north side of Confederate Gulch (Pardee and Schrader, 1933).

Lode mining from veins in the vicinity of the pluton at Miller Mountain, and a small pluton to the south at the Satellite claims (pl. 2, no. 586), was conducted intermittently from the late 1800s to the early 1940s (Pardee and Schrader, 1933; Johnson, 1973). The gold vein deposits occur in two settings. In one setting quartz veins are in the contact zone of the granitic rocks with the Newland strata and contain gold, abundant pyrite, and minor sphalerite, digenite, and covellite. In the other setting, quartz veins occur entirely within the granitic rocks and mineralization consists mainly of gold and pyrite. The veins, up to 3 ft thick, have a general north-south trend according to Johnson (1973); subhorizontal veins, up to 6 ft thick, were emphasized by G. Wittman (Pegasus Gold, oral commun., 1993).

Recent gold exploration at Miller Mountain has delineated a resource of at least 11 million short tons of ore containing 310,000 ounces gold (grade, 0.028 ounces/ton) (Pegasus Gold, Inc., 1992). Gold grades are highest near major structural intersections, particularly along low-angle shear zones. Johnson (1973) identified two main phases of intrusion of granitic rock at Miller Mountain; mineralization appears to be related to the second phase (G. Wittman, Pegasus Gold, oral commun., 1993).

Granitoid rock along the outer margin of the Boulder pluton and its satellitic stock to the east is coincident with a prospect (pl. 2, no. 591), the Porcupine Mine (no. 595), and a small mine nearby (no. 594), all observed during reconnaissance fieldwork for this study. Prospects (nos. 597, 598, 588) were observed in Newland strata near the pluton, as were the Snowbank and Bigler mines (both no. 596). Samples from these mines and prospects all contain anomalous abundances of elements (table E1). Fluorite is common at many of these mines and prospects, forming small veins in a shear zone in the core zone of the Boulder pluton (pl. 2, no. 589) and in veinlet-filled fractures near the edge of the pluton at the Normandy prospect (no. 592) (Sahinen, 1962; Ross, 1950; Roby, 1950; du Bray, 1995). Mineralized rock apparently is less common peripheral to the Mount Edith pluton, perhaps partly due to extremely poor exposures in the area.

Geochemical analyses of rocks collected by Gualtieri (1975b) in the Confederate Gulch-Boulder Mountain region show anomalous values mainly in the general area of Miller Mountain. The rocks are anomalous in gold, silver, and molybdenum, some of the same elements found in anomalous abundance in the present study for rocks in and adjacent to the Boulder and Mount Edith plutons. However, the other elements found during this study do not appear to be anomalous in Gualtieri's data, probably because analytical techniques used at the time had considerably higher threshhold values of detection. Anomalous values of gold and silver in stream sediments are shown in figures D12 and D13 (Alminas, Chapter D of this report).

Northern Part of Big Belt Mountains

The area discussed here includes Snedaker basin in the northern part of the Big Belt Mountains and the separate, isolated part of the Forest in the Dry Range, directly east of the hamlet of Lingshire. The area is directly north of the York and Beaver-Elk Creek districts (fig. F1; pl. 2).

Geologic Setting

Paleozoic carbonate strata constitute most of the exposed rocks in the Dry Range area. The Forest area to the west is chiefly underlain by Paleozoic and Mesozoic carbonate strata, Middle Proterozoic Newland and locally Greyson Formations, and Tertiary volcanic rocks (pl. 1). The pre-volcanic rocks were thrust into their present positions and consititute parts of several thrust sheets. Two magnetic anomalies (figs. C1, C4, anomalies 17 and 18) suggest that concealed intrusive bodies may lie beneath the Snedaker-Dry Range area (see Chapter C of this report), as does the occurrence of an apparent polymetallic replacement deposit.

Mineral Deposits

The northern part of the Big Belt Mountains has very few prospects and no known significant mineralization. The two magnetic anomalies in the area, interpreted as indicating concealed plutons (McCafferty, Chapter C of this report, figs. C1, C4, anomaly 18), could have associated mineralization even though little surface evidence of mineralization exists. Detailed examination of the Gates of the Mountains Wilderness, a small part of which lies in the westernmost part of the permissive terrane, yielded no significant evidence of mineralization (Close and Rigby, 1984; Reynolds, and Close, 1984). Mineralization, if present, likely is concealed beneath the surface rocks.

Lower Belt Supergroup Strata in Big Belt Mountains

Sediment-hosted massive sulfide deposits occur in lower strata of the Belt Supergroup in Montana, Idaho, Washington, and Canada. In the Helena structural salient (see Chapter B on geologic setting), copper-cobalt and lead-zinc mineral occurrences are present in the Newland Formation at Sheep Creek about 15 mi east of the Forest. South of Butte, near the southern margin of the Helena salient (fig. B1), Thorson (1984, in preparation) reported massive sulfide occurrences in the Greyson Formation. Newland and lower Greyson strata in the Forest were evaluated for this type of deposit.

Geologic Setting

The lower two-thirds of the Newland Formation of Big Belt Mountains area is mainly noncalcareous to dolomitic and locally calcareous argillite and siltite, with sparse thin interbeds of sandstone. The upper third consists of interbedded dolomite, limestone, siltite, and argillite. The formation is at least 9,500 ft thick in the Big Belt Mountains (Nelson, 1963). Schieber (1985) measured only about 8,150 ft of the Newland along Deep Creek near highway U.S. 12, but stated that a fault may cut out part of the sequence.

The lower member was deposited below wavebase in a basinal environment, punctuated by thin sandstone beds that are microturbidites; the upper member also was deposited below wavebase but in shoaling-upward environments in shallower water than the lower part, according to Zieg (1986). Schieber (1985, p. 160-163) concluded that most of the lower member was deposited towards the center of a basin in water "only a few meters deep." Later, (Schieber, 1989) stated that these strata represent sediments deposited below normal wavebase but above storm wavebase. Schieber (1992) concluded that limestone of the upper member in the Big Belt Mountains was primarily deposited in a distal, starved basin setting.

The Greyson Formation was described generally in the section on the York district. Turbidites are interpreted to make up a significant part of the lower three units of the Greyson, and were probably deposited in the deeper parts of a restricted basin (Whipple and Morrison, in preparation).

Mineral Deposits

Massive sulfide deposits

The massive sulfide deposits of the Belt sedimentary basin are commonly attributed to exhalative processes. Exhalative deposits are stratiform accumulations of sulfide and sulfate minerals that are interbedded with marine sediments. The sediments were deposited below wavebase, generally at depth within a marine basin. Deposits are sheet- or lens-like tabular bodies a few tens of feet to locally a few hundred feet thick. Mineralizing fluids moved upward along intrabasinal faults that were active during deposition of the sediments. During ore formation, the mineral-rich fluids permeated and altered rocks adjacent to the flow path, and emanated onto the sea floor and into the water column, where minerals precipitated to form deposits (Briskey, 1986).

The following description of the Sheep Creek mineralization, north of the Forest, is summarized, for comparative purposes, from Zieg and others (1991) and Zieg and Leitch (1996). The Sheep Creek area lies at the northern edge of the Helena embayment, along the Volcano Valley fault (fig. B1), on the south flank of the Little Belt Mountains. Metal-rich hydrothermal fluids moved upward along the ancestral Volcano Valley fault and were exhaled from vent centers. The fluids were rich in copper, cobalt, nickel, arsenic, and barium, as well as locally rich in lead, zinc, and silver. The minerals precipitated as sulfides that are bedded and interstratified within the Newland Formation. Exhalative activity must have been nearly continuous throughout deposition of the lower member of the Newland Formation and at least intermittent during deposition of the upper member. Drilling showed that the mineralized zones form several lenses along the fault and they extend for as much as 2,000 ft basinward (south) from the fault zone.

No massive sulfide mineral deposits of the Sheep Creek type were found during reconnaissance examination of areas of the Newland in the Big Belt Mountains, and we know of no reported occurrences of the deposit type in the range. However, the possibility of an occurrence cannot be eliminated because the region was active tectonically during deposition of the Newland, as demonstrated in the Sheep Creek and Highland Mountains areas. Syndepositional faults possibly could have been active within the central part of the Helena structural embayment, even though most of the Newland in the Forest is distant from either the basin-margin fault zones at Sheep Creek to the north or the Highland Mountains to the southwest.

Schieber (1991) stated that pyritic shale (argillite and siltite) horizons of the Newland Formation are similar to Proterozoic lead-zinc bearing pyritic shales in Australia (Mt. Isa, McArthur River). However, no lead-zinc orebodies have been found in the Newland of central Montana. Schieber's data from Montana samples show only minute quantities of these two metals and he stated that pyritic shales are not anomalous in their lead-zinc content.

Tourmalinites are commonly associated with a variety of stratabound mineral deposits, including lead-zinc-silver deposits in lower Belt strata in the western part of the Belt sedimentary basin. J.M Leask (personal commun. in Slack, 1993, p. 34) reported a tourmalinite locality in the Newland Formation of Cement Gulch, which is in the headwaters of Confederate Gulch. A thin section of rock collected from this area was examined and revealed no tourmaline; a chemical analysis showed only a few ppm boron.

CONTINENTAL DIVIDE REGION

By J.E. Elliott

The Continental Divide region includes most of the Forest west of Interstate Highway 15 and southwest of the St. Marys-Helena Valley fault, which transects the Forest in the vicinity of Lincoln (fig. F1). Essentially all of this region was recently studied under a Conterminous United States Mineral Assessment Program (CUSMAP) evaluation of the Butte 1° x 2° quadrangle. Reports of the many studies conducted in this quadrangle are described by Elliott and others (1993).

Geologic Setting

The Continental Divide region contains igneous, metamorphic, and sedimentary rocks and surficial deposits that range in age from Middle Proterozoic to Quaternary. The oldest rocks exposed are clastic and carbonate sedimentary rocks of the Middle Proterozoic Belt Supergroup, which are widespread and abundant in the northern and central parts of the region (pl. 1, map A). During the Late Proterozoic, sills and dikes of gabbro and diorite intruded the older sedimentary rocks. Paleozoic carbonate and carbonate-bearing clastic rocks, deposited in near-shore and shallow-water environments, are present in the central part of the region where they unconformably overlie the Belt rocks. Mesozoic sequences of marine and nonmarine clastic rocks, deposited in foreland basins, overlie Paleozoic rocks in the south-central part of the region.

Magmatic activity commenced in the region during the Late Cretaceous and continued intermittently until the middle Tertiary. This magmatism resulted in the formation of several volcanic sequences, a batholith, several stocks, and numerous dikes and sills. Most of the igneous rocks are in the southern part of the region and include part of the Boulder batholith, a large granitic pluton that extends south of the Forest (fig. B1), and three predominantly volcanic sequences, which include andesitic, dacitic, and rhyolitic rocks, of Late Cretaceous, middle Eocene, and late Eocene ages, respectively. Another relatively small volcanic field is in the northern part of the region, southeast and east of Lincoln, and consists of both andesitic and rhyolitic volcanic and volcaniclastic rocks. In the central part of the region, several stocks, mainly of granodioritic composition and Late Cretaceous age, are aligned along a northwesterly trend. Thermal aureoles adjacent to the Boulder batholith and the stocks resulted in contact metamorphism of the sedimentary rocks, converting them to hornfels, marble, and, locally, skarn. Most of the mineral deposits of the region are spatially and genetically associated with the igneous rocks. Hydrothermal activity during and following the waning stages of magmatism formed many of the mineral deposits that have been discovered in the region.

Surficial deposits include widespread lacustrine and fluvial deposits that accumulated in intermontane basins during mid- to late-Tertiary time and glacial, alluvial, colluvial, and landslide deposits formed during Quaternary time. The glacial deposits are most abundant in the northern part of the region where deposits of glacial till, moraine, and glaciofluvial deposits are common and widespread.

The principal structural elements of the region are two major northwest-trending faults, the St. Marys-Helena Valley and Bald Butte faults (fig. B1), that are part of the Lewis and Clark line of western Montana and northern Idaho; a broad syncline including sedimentary rocks ranging from Middle Proterozoic to Late Cretaceous in age; and part of the Sapphire thrust terrane (pl. 1, map A). Although some of the movement along the Lewis and Clark line may have occurred during Proterozoic time (Wallace and others, 1990), most of the faulting and folding probably occurred during the Late Cretaceous when regional compression formed the laterally extensive Sapphire thrust terrane and caused major strike-slip movement along the Lewis and Clark line (Wallace and others, 1990).

Subregions

To facilitate the description of mining districts and mineral deposits, the Continental Divide region is divided into subregions with boundaries that correspond closely to geologic terranes or structural features. From north to south these are the (1) Granite Butte-Ogden Mountain, (2) Black Mountain-Stemwinder Hill, and (3) North Boulder Mountains subregions (fig. F1). The Granite Butte-Ogden Mountain subregion is south of the Lincoln region, described previously; their common boundary is the St. Marys-Helena Valley fault. The Black Mountain-Stemwinder Hill subregion is separated from the Granite Butte-Ogden Mountain subregion by the Bald Butte fault. The North Boulder Mountains subregion is separated from the Black Mountain-Stemwinder Hill subregion by U.S. Highway 12, which parallels and is near the northern boundary of the Boulder batholith.

Granite Butte-Ogden Mountain Subregion

Geologic Setting

Most of subregion is underlain by formations that are part of the Belt Supergroup. Sequences representative of the lower Belt (Spokane Formation) to the upper Belt (Bonner Formation) are present. Several stocks of Late Cretaceous age and one of possible Tertiary age occur along a northwest-trending belt. These include the Tertiary Silver Bell stock near Stemple Pass, and (from northwest to southeast) the Ogden Mountain, Dalton Mountain, Granite Butte, and Marysville stocks of Cretaceous age (pl. 1). For the Silver Bell stock, K-Ar ages from biotite are 50 and 52 Ma, but they may be reset ages due to the proximity of a Tertiary volcanic field (C.A. Wallace, U.S.G.S., written comm., 1989). Most of the stocks are granodiorite, but plutonic rocks range in composition to monzogranite, quartz monzonite, and quartz monzodiorite. The subregion includes most of a Tertiary volcanic field that extends mainly south and east of Lincoln. This volcanic field includes two compositionally distinct sequences: an older sequence of andesitic flows, breccia, air-fall tuff, and volcaniclastic rocks; and a younger sequence of rhyolitic flows, breccia, tuffs, and volcaniclastic sedimentary rocks. These volcanic rocks extend north into the Lincoln region and occur in isolated patches to the southeast and south of the main Lincoln field.

The Belt rocks are folded and cut by several normal faults, one thrust fault of probable small displacement, and two major regional faults, the St. Marys-Helena Valley and Bald Butte faults, both with strike-slip movement. The latter are two of several principal faults that form the Lewis-and-Clark line (Wallace and others, 1990). The St. Marys-Helena Valley fault cuts the northeastern part of the subregion and forms the northern boundary of the Lewis and Clark line. A right slip offset of about 8 mi is indicated in the western segment of the fault (Wallace and others, 1990). The Bald Butte fault forms the southern border of subregion. Based on offset of stratigraphic units, about 17.4 mi of right-lateral separation is indicated for the Bald Butte fault (Wallace and others, 1990).

Mineral Deposits

The Granite Butte-Ogden Mountain subregion encloses all of the following mining districts and areas: Lincoln Gulch area and Big Blackfoot, Finn, McClellan Gulch, Stemple-Gould, and Marysville districts (fig. F1; pl. 2, map B). It also includes parts of the Blackfoot River and Little Prickly Pear areas. The majority of lode deposits are either polymetallic veins or epithermal veins. Placer gold deposits are also numerous and widespread. Other types of known lode deposits include skarn tungsten, porphyry copper-molybdenum, and Climax molybdenum.

Lincoln Gulch Area--The Lincoln Gulch area is approximately four miles west of Lincoln and includes parts of the Forest. Calcareous siltite and argillite, and limestone of Middle Proterozoic Helena Formation have been intruded by thin Late Proterozoic dikes of intermediate to mafic composition. Quaternary till and alluvial and terrace gravels occupy the valley of Lincoln Creek. The area is one of the most famous districts of the region and was a very large producer of gold from placer deposits (approximately $7 million, Pardee and Schrader, 1933; estimated 372,000 ounces, Elliott and others, 1992). An undetermined amount of gold has also been produced from the Blackfoot (Big Blackfoot) mine (pl. 2, no. 23), which is a vein deposit in a shear zone within a diorite dike. Over two million tons of gold ore containing approximately 100,000 ounces of gold are reported to be present at the Blackfoot mine (McCulloch, 1989; Rocky Mountain Pay Dirt, 1987).

The southern end of the Lincoln Gulch area is associated with a magnetic high that extends into the surrounding Blackfoot River area (fig. C1). This high is spatially associated with the Blackfoot mine. The source of this anomaly is probably an intrusive body similar in size and composition to the Ogden Mountain stock, to the southwest (Hanna and others, 1994).

Geochemical anomalies in arsenic, bismuth (fig. D15), copper (fig. D16), iron (fig. D20), molybdenum (fig. D17), lead (fig. D14), antimony, and tungsten are present in the Lincoln Gulch area, based on a geochemical survey of McDanal and others (1985). The geochemical anomalies in these figures (Alminas, Chapter D of this report) are for stream sediments and incorporate only the stream sediment data of McDanal and others (1985).

Little Prickly Peak Area--The Little Prickly Pear area is north and northwest of Helena and east and southeast of Lincoln (fig. F1). It includes parts of the Forest along the upper tributaries to Little Prickly Pear Creek. Most of the area is within the Lincoln Region and is described in the previous section of this chapter.

Big Blackfoot (Ogden Mountain) Distirct--The Big Blackfoot district, approximately 10 mi southwest of Lincoln, is within and adjacent to a granodiorite stock (fig. F1; pl. 2, map B). Much of the district is within the Forest. The Late Cretaceous Ogden Mountain stock, with an age of about 81-85 Ma (Schmidt and others, 1994), intruded sedimentary rocks of the Middle Proterozoic Helena, Snowslip, and Shepard Formations. The sedimentary rocks are offset by normal faults and, in the southwest part of the area, by right-lateral strike-slip faults of the Bald Butte fault zone. Tertiary volcanic and sedimentary rocks cover older rocks in places. Mineral deposits are polymetallic veins, gold placers, and a tungsten skarn. Two of the principal mines of the district are the Hobby Horse and Blackfoot mine (Elliott and others, 1992). The Hobby Horse (pl. 2, no. 73) produced gold, silver, and lead from quartz veins in granodiorite. At the Blackfoot mine (pl. 2, no. 77), weathered parts of quartz veins in granodiorite and limestone of the Helena Formation were mined adjacent to the contact of the Ogden Mountain stock. This was the largest mine in the district and produced gold, silver, copper, and lead (McClernan, 1976). The district has produced moderate quantities of gold (about 4,500 ounces), silver, copper, and lead and has a total value of recorded production of about $134,000 (Elliott and others, 1992).

The aeromagnetic anomaly map (McCafferty, Chapter C of this report, fig. C1, anomaly 2) shows a prominent magnetic high associated with the Ogden Mountain stock. Elements that are geochemically anomalous in the district are silver (fig. D13), gold (fig. D12), copper (fig. D16), iron (fig. D20), and tungsten (McDanal and others, 1985). The geochemical anomalies in these figures (Alminas, Chapter D of this report) are for stream sediments and incorporate only the stream sediment data of McDanal and others (1985).

McClellan Gulch District--The areally small McClellan Gulch district (fig. F1; pl. 2, map B) is approximately six miles south-southeast of Lincoln and within the Forest. The gulch is underlain by argillite, siltite, limestone, and quartzite of the Middle Proterozoic Helena, Snowslip, Shepard, and Mount Shields Formations. At the head of the gulch, granodiorite of Late Cretaceous Dalton Mountain stock, with an age of about 79 Ma (Schmidt and others, 1994), is in contact with Mount Shields and Shepard Formations. The district was a very large producer of gold from placer deposits between 1864 and 1875 (about $7 million, Pardee and Schrader, 1933; estimated 340,000 ounces, Elliott and others, 1992). The sources of the gold are probably vein deposits such as at the Wiggins mine (pl. 2, no. 92) where quartz veins occur within and near the contact of granodioirte of the Dalton Mountain stock. The south end of the district borders a magnetic high that is associated with the Dalton Mountain stock (McCafferty, Chapter C of this report, fig. C1, anomaly 3).

Geochemical anomalies in barium, iron (fig. D20), lead (fig. D14), and tungsten are present in the district (McDanal and others, 1985). The geochemical anomalies in these figures (Alminas, Chapter D of this report) are for stream sediments and incorporate only the stream sediment data of McDanal and others (1985).

Stemple-Gould District--The Stemple-Gould district is approximately 10 mi southeast of Lincoln and is within or enclosed by Forest lands (fig. F1; pl. 2, map B). Sedimentary rocks of Middle Proterozoic Helena, Empire, and Spokane Formations have been intruded by Late Proterozoic diorite sills and dikes, the Cretaceous Granite Butte granodiorite stock, and the Tertiary Silver Bell quartz monzonite porphyry stock (pl. 1, map A). Proterozoic rocks are cut by northwest-trending, steeply dipping normal, reverse, and strike-slip faults. Ore deposits are epithermal gold-silver veins and gold placers. The district also includes a porphyry copper-molybdenum prospect in the western portion of the Silver Bell stock (Brannon, 1981; McKee, 1978). The district has produced gold, silver, copper, lead, and iron and the estimated total value of production is about $5.3 million (Elliott and others, 1992). The largest producer in the district was the Jay Gould mine (pl. 2, no. 105; Pardee and Schrader, 1933), which is classified as an epithermal vein deposit based on its mineralogy and textures. It is largely composed of lamellar calcite and quartz with textures indicative of having filled an open fissure. The Jay Gould vein is west-trending and dips steeply north. The host rocks are argillites of the Empire Formation. Ore minerals are chalcopyrite, argentite, and native gold (Pardee and Schrader, 1933).

The magnetic and gravity anomaly maps (McCafferty, Chapter C of this report, figs. C1, C3) show anomalies associated with intrusive rocks. A prominent magnetic high is associated with the Granite Butte stock (fig. C1, anomaly 6) and a magnetic high combined with a gravity low is associated with the Silver Bell stock (fig. C1, anomaly 6).

Geochemical anomalies for arsenic, silver (fig. D13), gold (fig. D12), barium, bismuth (fig. D15), copper (fig. D16), iron (fig. D20), molybdenum (fig. D17), lead (fig. D14), antimony, tin (fig. D18), and tungsten are present in the district (McDanal and others, 1985). The geochemical anomalies in these figures (Alminas, Chapter D of this report) are for stream sediments and incorporate only the stream sediment data of McDanal and others (1985).

Finn District--The Finn district is located about 10 mi south of Lincoln and is adjacent to and includes parts of the Forest (fig. F1; pl. 2, map B). The district is known principally for gold placers that occur along several southwest-flowing tributaries to Nevada Creek. Thrust-faulted and folded sedimentary rocks of Middle Proterozoic Helena, Mount Shields, Shepard, and Snowslip Formations were intruded by the Late Cretaceous Dalton Mountain granodiorite stock in the mountainous northeastern part of the district (pl. 1, map A). A northwest-trending fault separates the mountainous terrain from the Nevada Creek Valley to the west, which is underlain by Tertiary and Quaternary deposits. The Finn district has produced gold and silver, mostly from placer deposits. The largest producer of placer gold was Washington Creek. The source of the gold was probably polymetallic veins that are near the contact of the stock. Some of these have been mined for gold, silver, and copper north of the Finn district, for example the Wiggins mine (table E1, no. 92). The district produced approximately 95,000 ounces of gold and minor silver with an estimated total value of about $1.8 million (Elliott and others, 1992).

A magnetic anomaly high occurs along the north edge of the district, corresponding to the Dalton Mountain stock (McCafferty, Chapter C of this report, fig. C1, anomaly 3) and a gravity low (fig. C3) in the western part of the district associated with low density sediments of the Avon Valley (Hanna and others, 1994).

Geochemical anomalies for silver (fig. D13), gold (fig. D12), barium, bismuth (fig. D15), iron (fig. D20), molybdenum (fig. D17), manganese (fig. D21), and tungsten are present in the district McDanal and others, 1985). Anomalies in these figures (Alminas, Chapter D of this report) are for stream sediments and incorporate only the stream-sediment data of McDanal and others (1985).

Marysville (Silver Creek) District--Marysville, one of the oldest and most famous mining districts in this region, is located about 16 mi northwest of Helena (fig. F1; pl. 2, map B). The southern and southwestern parts of the district include some Forest lands. Limestone and calcareous argillite and siltite of the Middle Proterozoic Helena and Empire Formations have been folded, cut by faults, and intruded by the Late Cretaceous Marysville granodiorite stock (pl. 1, map A). The age of this stock is 78.5±2.6 Ma, based on K-Ar isotopic-age determination for biotite (Schmidt and others, 1994). The Bald Butte fault cuts the southwestern part of the district. A wide zone of contact metamorphosed rocks is present around the Marysville stock and above an unexposed granite stock (determined by drilling) in the area of Bald Butte. Mineral deposits include polymetallic veins, epithermal veins, a stockwork molybdenum zone, mineralized breccias, skarns, and gold placers. The district was active from about 1876 (Pardee and Schrader, 1933) until the late 1940's (McClernan, 1983) and was a large producer of gold, silver, lead, copper, and zinc with an estimated total value of production of over $40 million (Elliott and others, 1992).

The most famous mine in the district, the Drumlummon (pl. 2, no. 139), produced ore valued at $15 million, of which 60 per cent was in gold, before 1911 (Knopf, 1913). This value of gold ($9 million), at a price of $20.67 per ounce, is equivalent to about 435,000 ounces. The recorded production for the Drumlummon mine during the period of 1901-1948 is 115,694 ounces (McClernan, 1983). The Drumlummon vein is an epithermal gold-silver vein along the contact of the Marysville stock with contact-metamorphosed Helena Formation. The vein has a general N. 15 E. trend and dips steeply to the east (Knopf, 1913). Most of the vein is oxidized; primary sulfide minerals, mainly tetrahedrite and chalcopyrite, are sparse. The gangue is composed of quartz, calcite, and dolomite that commonly has lamellar, vuggy, or drusy textures. The vein has been worked along a strike length of 3,000 ft and to a depth of 1,600 ft (Pardee and Schrader, 1933).

An interesting molybdenum prospect (pl. 2, no. 133) of the Climax type occurs at Bald Butte in the southern part of the Marysville district. On the surface, contact metamorphosed Helena Formation is hydrothermally altered and cut by quartz veinlets that have molybdenite and fluorite. A geochemical survey of the area determined distinct molybdenum anomalies in soil (Rostad, 1969). Later drilling encountered an altered and mineralized porphyritic granite in the subsurface. A sample of this granite obtained from drill core (depth of 1,620 ft) on file at the Montana Bureau of Mines and Geology was analyzed by x-ray fluorescence and found to contain anomalously high concentrations of tin, tungsten, rubidium, niobium, yttrium, thorium, and uranium. These anomalies are similar to those of other granitic rocks associated with Climax molybdenum deposits (Ludington, 1986). An age of 49 Ma was determined by Blackwell and others (1975) on quartz porphyry, probably related to the porphyritic granite in the drill core, from the Bald Butte area.

Aeromagnetic and gravity maps (McCafferty, Chapter C of this report, figs. C1, C3) show prominent anomalies associated with intrusive rocks in the district. A magnetic anomaly high is associated with the Marysville stock (fig. C1, anomaly 11), which extends to the southwest in the subsurface. The subsurface extent of this body is approximately two times the area of the surface exposure. A gravity low (fig. C3) in the west part of the district may indicate subsurface bodies of granitic composition similar to the granite that underlies the Bald Butte molybdenum prospect (Hanna and others, 1994).

Geochemical anomalies for many elements are present in the district. These include arsenic, silver (fig. D13), gold (fig. D12), beryllium, bismuth (fig. D15), copper (fig. D16), molybdenum (fig. D17), manganese (fig. D21), lead (fig. D14), antimony, tin (fig. D18), tungsten, and zinc (fig. D19) (McDanal and others, 1985). The geochemical anomalies in these figures (Alminas, Chapter D of this report) are for stream sediments and incorporate only the stream sediment data of McDanal and others (1985).

Black Mountain-Stemwinder Hill Subregion

Geologic Setting

Much of the subregion is underlain by a sequence of Middle Proterozoic, Paleozoic, and Mesozoic meta-sedimentary and sedimentary rocks that are folded into a broad, south-plunging syncline (pl. 1, map A). The lowermost rocks exposed in this syncline are Middle Proterozoic Missoula Group (Belt Supergroup) and the uppermost are Upper Cretaceous Blackleaf Formation. All of the Paleozoic and nearly all of the Mesozoic rocks, representative of those in the region, are exposed in the syncline.

The southeastern part of the subregion includes plutonic rocks, mainly monzogranite and granodiorite, that are northerly extensions of the Late Cretaceous Boulder batholith. Paleozoic and Mesozoic sedimentary rocks are in contact with these plutonic rocks. In the western part of the subregion, the Blackfoot City granodiorite stock, with an age of 76.6 Ma (Schmidt and others, 1994), was emplaced into the axial portion of the syncline. There are several small exposures of plutonic rocks and moderate-sized areas where Tertiary rhyolitic rocks are exposed. The latter are probably late Eocene and related to the Helena volcanic field (Schmidt and others, 1994).

The major structural features of the subregion are the Bald Butte fault, a broad, south-plunging syncline, and the Sapphire thrust terrane. Imbricate thrust faults along the southwestern margin of this subregion mark the frontal edge of Sapphire thrust plate (Schmidt and others, 1994). This thrust terrane is present throughout much of the Butte 1° x 2° quadrangle to the west of the Forest and has juxtaposed western lithofacies of Paleozoic and Mesozoic formations against eastern lithofacies of equivalent rock units. Therefore, the Sapphire thrust terrane represents a considerable, but undetermined, amount of crustal shortening. The syncline in the lower plate rocks probably formed concurrently with, and as a result of, the same regional compression that formed the Sapphire thrust. The subregion also has high-angle normal and reverse faults, including a range-front fault along the western side of the subregion that marks the eastern edge of Avon Valley.

Mineral Deposits

The Black Mountain-Stemwinder Hill subregion includes the Ophir and Austin mining districts and the Stemwinder Hill and Dog Creek areas (fig. F1). Metallic lode deposits include polymetallic vein, skarn gold, polymetallic replacement, skarn tungsten, epithermal vein, and hot spring gold-silver deposits. Nonmetallic deposits include phosphate, limestone, and clay deposits. Erosion of many pre-existing hydrothermal base- and precious-metal deposits and transportation and deposition of their gold by streams have resulted in the formation of numerous placer gold deposits. Many of the hydrothermal deposits, such as those in the Ophir and Austin districts, are located at or near contact zones between plutonic rocks and Paleozoic carbonate rocks.

Ophir (Snowshoe Creek-Carpenter Creek) District--The Ophir district is approximately 25 mi west-northwest of Helena and 5 mi northwest of Avon (fig. F1). The northeastern part of the district includes parts of the Forest. This part of the district is underlain by the Late Cretaceous Blackfoot City granodiorite stock, other small intrusives, and folded sedimentary rocks of Middle Proterozoic through Cretaceous ages that were intruded by the Blackfoot City stock. The Avon Valley, in the southwestern part of the district and outside of the Forest, occupies a basin formed by northwest-trending faults near the mountain front (pl. 1). Lode deposits of the district, containing mainly gold, copper, silver, and tungsten, include skarns, polymetallic veins, breccia zones, and irregular replacement bodies. These are primarily in Paleozoic limestone near contacts with granodiorite stocks.

The Ajax and Victory mines were two of the most important mines in the district (Pardee and Schrader, 1933). The workings of the Ajax mine (pl. 2, no. 141) exploited a pipe-shaped body of skarn consisting of magnetite and hematite with minor garnet and quartz hosted by Paleozoic limestone. At the Victory mine (pl. 2, no. 142), ore minerals were found in a pipe-shaped replacement (skarn) zone of brecciated carbonate rock (Jefferson Formation) along the contact of the Blackfoot City stock.

Strata-bound phosphate deposits also occur in the district and are discussed in Chapter I on nonmetallic mineral deposits. Gold placers, discussed in Chapter H of this report, are in Quaternary alluvium and in Tertiary gravel. The largest and most productive placers were along Ophir and Carpenter Creeks.

The district has been a producer of gold, silver, copper, lead, tungsten, and phosphate. The district produced approximately 185,000 ounces of gold, mainly from placers, and has an estimated total value of production of about $4 million (Elliott and others, 1992).

The aeromagnetic anomaly map (McCafferty, Chapter C of this report, fig. C1, anomaly 8) shows a magnetic high associated with the Blackfoot City stock. In the subsurface, this intrusive body apparently extends to the southwest and is about two times the size (fig. C4) as indicated in mapped surface extent. A gravity low on the west side of the district is coincident with low-density sediments of the Avon Valley (Hanna and others, 1994).

A geochemical survey revealed anomalies for silver (fig. D13), gold (fig. D12), barium, bismuth (fig. D15), copper (fig. D16), iron (fig. D20), molybdenum (fig. D17), manganese (fig. D21), lead (fig. D14), tin (fig. D18), and tungsten (McDanal and others, 1985). The geochemical anomalies in these figures (Alminas, Chapter D of this report) are for stream sediments and incorporate only the stream sediment data of McDanal and others (1985).

Dog Creek Area--The Dog Creek area is approximately 15 mi west of Helena, south of the Marysville district, and east of the Ophir district (fig. F1). The northern part of the area is within the Forest. Most of central and northern parts of the area are underlain by sedimentary rocks ranging in age from Middle Proterozoic to Cretaceous, which are folded into a southeast-plunging syncline. Several imbricated listric thrust faults of the frontal zone of Sapphire thrust terrane have been mapped in the southwestern part of area. Normal faults are in northern part of area. The southwestern corner of area contains Tertiary and Quaternary sedimentary rocks and Tertiary rhyolite flows. The area includes a few mineral deposits consisting mainly of gold placers and stratified phosphate deposits of the Permian Phosphoria Formation (discussed in Chapter I of this report). Some vein and skarn deposits are also in the area. The area has produced gold, phosphate, limestone, copper, and silver. Metallic production is mostly of gold (estimated 4,500 ounces) from placers (Elliott and others, 1992).

The aeromagnetic anomaly data (McCafferty, Chapter C of this report, fig C1) indicates source rocks with high magnetization near the center of the Dog Creek area (figs. C1, C4). The high is over granitic rock that is mainly in the subsurface, indicated at the surface by small isolated exposures of intrusive rock (pl. 1, map A). The plutonic source rock of this anomaly may be similar in composition to, but somewhat smaller than, other stocks in the region such as the Blackfoot City and Marysville stocks (Hanna and others, 1994).

Although the number and size of metallic mineral deposits in the area is less than some neighboring districts, a large number of elements are geochemically anomalous in the area. A geochemical survey indicated anomalies in arsenic, silver (fig. D13), gold (fig. D12), boron, barium, beryllium, bismuth (fig. D15), copper (fig. D16), molybdenum (fig. D17), manganese (fig. D21), lead (fig. D14), antimony, tin (fig. D18), tungsten, and zinc (fig. D19) (McDanal and others, 1985). The geochemical anomalies in these figures (Alminas, Chapter D of this report) are for stream sediments and incorporate only the stream sediment data of McDanal and others (1985).

<u>Austin District</u>--The Austin district is approximately 10 mi west-northwest of Helena and east of the Dog Creek area (fig. F1). The Forest adjoins the western part of the district, which includes part of the northern border of the Late Cretaceous Boulder batholith and a sequence of Middle Proterozoic, lower Paleozoic, and upper Paleozoic sedimentary rocks. This sedimentary sequence has been cut by numerous normal faults and intruded by several small bodies of Late Cretaceous granodiorite and Tertiary dacite. Mineral deposits include polymetallic vein, copper-gold skarn, and placer deposits. The district produced silver, copper, lead, gold, iron, zinc, and tungsten and has a total estimated value of production of about $340,000 (Elliott and others, 1992).

The north edge of a large regional magnetic high (McCafferty, Chapter C of this report, fig. C1) extends into the south part of the district, coincident with the northern end of the Boulder batholith (Hanna and others, 1994).

Geochemical survey results of McDanal and others (1985) indicate anomalies in arsenic, silver (fig. D13), gold (fig. D12), bismuth (fig. D15), copper (fig. D16), iron (fig. D20), molybdenum (fig. D17), manganese (fig. D21), lead (fig. D14), antimony, tin (fig. D18), and zinc (fig. D19). The geochemical anomalies in these figures (Alminas, Chapter D of this report) are for stream sediments and incorporate only the stream sediment data of McDanal and others (1985).

<u>Stemwinder Hill Area</u>--The Stemwinder Hill area is west of Helena (fig. F1). Its western part is mostly in the Forest and is underlain by granodiorite of the Boulder batholith and by the Elkhorn Mountains Volcanics; the eastern part is underlain by a sequence of metamorphosed sedimentary rocks of Middle Proterozoic through late Paleozoic age. Mineral deposits include skarns and veins that contain silver, lead, gold, tungsten, and molybdenum as well as gold placers.

The Dutro mine (pl. 2, no. 198), although a small producer, is of geologic interest because of the occurrence of tin (as cassiterite) (Knopf, 1913). The mine produced gold ore from irregular masses of oxidized siliceous, iron-oxide rich zones in Paleozoic dolomite. The mine is situated near a diorite intrusive. The deposit has the geologic characteristics of a skarn gold deposit but with the unusual occurrences of tin minerals. The area produced small quantities of silver, lead, and gold and has an estimated total value of production of about $118,000 (Elliott and others, 1992).

The aeromagnetic anomaly map (McCafferty, Chapter C of this report, fig. C1) shows the western two-thirds of the area is coincident with a magnetic anomaly high (within heavy dashed line of fig. C1, C4) that marks the approximate northeastern edge of the Boulder batholith (Hanna and others, 1992).

A complex geochemical environment is indicated by anomalies in silver (fig. D13), gold (fig. D12), bismuth (fig. D15), copper (fig. D16), iron (fig. D20), molybdenum (fig. D17), manganese (fig. D21), lead (fig. D14), tin (fig. D18), tungsten, and zinc (fig. D19) (McDanal and others, 1985). The geochemical anomalies in these figures (Alminas, Chapter D of this report) are for stream sediments and incorporate only the stream sediment data of McDanal and others (1985).

North Boulder Mountains Subregion

Geologic Setting

Most of the rocks in the North Boulder Mountains subregion (fig. F1) are igneous in origin and include both plutonic and volcanic units. The dominant rock types are granodiorite and monzogranite that are major phases of the Boulder batholith, which extends into the Elkhorn Mountains region to the east and beyond the Forest to the southeast (Tilling, 1973). Four predominately volcanic map units of regional extent are the Late Cretaceous Elkhorn Mountains Volcanics, Paleocene or Late Cretaceous basaltic and andesitic volcanic rocks, Eocene Lowland Creek Volcanics, and Tertiary rhyolite (pl. 1). The Elkhorn Mountains Volcanics range in composition from rhyolite to basalt, but consist mostly of andesitic rocks, generally predate the Boulder batholith but plutonism associated with the emplacement of the batholith probably commenced before the volcanism ceased (Tilling, 1973). Basaltic and andesitic volcanic rocks in the northwest part of the subregion may be correlative with the Elkhorn Mountain Volcanics, but this correlation is uncertain due to obscure field relations and lack of geochronometric data. After the youngest plutonic rocks of the Boulder batholith were emplaced, about 68 Ma, and a period of quiescence, igneous activity was renewed during the Eocene when Lowland Creek Volcanics were formed about 50 Ma (Smedes and Thomas, 1965). These rocks are predominantly quartz latite to dacite in composition. The youngest volcanic episode in the North Boulder Mountains subregion is represented by Tertiary rhyolitic rocks. These cover older rocks and are exposed at higher elevations along the Continental Divide. They are part of the Helena volcanic field with ages in the range of 37 to 39.8 Ma (Schmidt and others, 1994).

Paleozoic and Mesozoic sedimentary rocks, older than the Late Cretaceous Elkhorn Mountain Volcanics, are present in the western part of the North Boulder Mountains subregion forming part of the leading edge of the Sapphire thrust terrane, as described in Chapter B of this report.

Mineral Deposits

The Boulder batholith played a major role in the metallogeny of southwestern Montana, including a large part of the Forest. The batholith and older rocks within or adjacent to the batholith host a great number and variety of mineral deposits. Many of the largest and richest mines and districts in Montana, including the famous Butte district, are spatially and genetically related to the batholith. Many of the mineral deposits are probably just slightly younger than the batholith and formed from late-stage hydrothermal emanations of magmas that formed the batholith.

The North Boulder Mountains subregion includes all or parts of the Helena, Elliston, Rimini, Clancy, Basin, Wickes, Boulder, and Amazon districts and the North Boulder Mountains area (fig. F1). The predominant deposit type is this subregion is polymetallic veins. Of the approximately 180 known mines and prospects in the subregion, about 150 (83 percent) are of this type. The next most abundant deposit type is placer gold, which results from secondary processes of erosion of lode deposits and transportation and deposition of their gold by streams. Other secondary metallic deposits in the subregion include bog manganese and bog copper deposits. Other metallic deposits in the subregion include hot-spring gold-silver, breccia pipe polymetallic, porphyry copper-molybdenum, epithermal manganese, and skarn gold deposits. Nonmetallic deposits include limestone and silica.

Helena (Last Chance) District--Most of the Helena district is south and southwest of Helena, where it includes Forest lands, but the district also includes the gold placers along Last Chance Gulch in Helena (fig. F1). Rocks of the Helena district are mainly limestone, shale, and sandstone of Middle Proterozoic, Paleozoic, and Mesozoic ages that have been folded, faulted, and, along the south and west parts of district, intruded by Late Cretaceous monzogranite and granodiorite of the Boulder batholith.

Lode deposits are gold-bearing veins in granodiorite and polymetallic vein and skarn gold deposits in Paleozoic limestone at or near contacts with granodiorite. Last Chance Gulch was a major producer of gold from placers (Koschmann and Bergendahl, 1968). The sources of gold for placers were gold-bearing skarn and polymetallic deposits along the contact of the Boulder batholith with sedimentary rocks. The most important deposits of these types are the Spring Hill mine (pl. 2, no. 204), a skarn deposit; Whitlach-Union mine (no. 205), a polymetallic vein; and Big Indian mine (no. 208), a polymetallic vein deposit. The district was a very large producer of gold (over one million ounces, as estimated by Elliott and others, 1992), mainly from placers. The total value of production is estimated at more than $28 million (Elliott and others, 1992).

The aeromagnetic anomaly map (McCafferty, Chapter C of this report, fig. C1) shows a prominent anomaly high across the southern part of the Helena district. The anomaly coincides with the mapped area of the strongly magnetic Unionville granodiorite (pl.1) that forms the northern rim of the Boulder batholith in this area (Hanna and others, 1994; within heavy dashed line on figs. C1, C4).

A geochemical survey of McDanal and others (1985) showed that numerous elements are present in anomalous concentrations in the district. These elements include arsenic, silver (fig. D13), gold (fig. D12), boron, beryllium, copper (fig. D16), molybdenum (fig. D17), manganese (fig. D21), lead (fig. D14), antimony, tin (fig. D18), and zinc (fig. D19) (McDanal and others, 1985). The geochemical anomalies in these figures (Alminas, Chapter D of this report) are for stream sediments and incorporate only the stream sediment data of McDanal and others (1985).

Elliston District--The Elliston district is approximately 20 mi southwest of Helena and mostly within the Forest (fig. F1). The district is underlain by andesitic tuff, breccia, and flows of the Elkhorn Mountains Volcanics and monzogranite of the Boulder batholith. Mineral deposits are polymetallic veins in volcanic rocks and monzogranite and small gold placers. The Big Dick mine was the largest producer; its workings follow two polymetallic veins in andesite breccia. Ore shoots up to 3.5 ft thick were mined and some ore averaged 5 opt gold (Pardee and Schrader, 1933). The district produced gold, silver, lead, and copper with a total value of recorded production of about $3.1 million.

Several connected magnetic highs in the eastern half of the district (MCafferty, Chapter C of this report, fig. C1) are due mainly to plutonic rocks of the Boulder batholith and, possibly, also in part to the Elkhorn Mountain Volcanics (Hanna and others, 1994). A steep north-trending magnetic gradient through the center of the district marks the approximate western margin of the batholith (heavy dashed line on figs. C1, C4).

Geochemical anomalies in arsenic, silver (fig. D13), gold (fig. D12), barium, beryllium, bismuth (fig. D15), copper (fig. D16), manganese (fig. D21), lead (fig. D14), tin (fig. D18), tungsten, and zinc (fig. D19) are present in the district (McDanal and others, 1985). The geochemical anomalies in these figures (Alminas, Chapter D of this report) are for stream sediments and incorporate only the stream sediment data of McDanal and others (1985).

Rimini (Vaughn) District--The Rimini district is about 12 mi southwest of Helena, mostly within or enclosed by the Forest (fig F1). The principal rocks in the district are Late Cretaceous monzogranite and aplite of the Boulder batholith. Along the northern margin of the district the batholith intruded andesitic rocks of the Elkhorn Mountains Volcanics. Tertiary rhyolitic volcanic and volcaniclastic rocks locally cover the older plutonic rocks of the batholith. The principal mineral deposits are polymetallic veins in granitic rocks that contain silver, lead, gold, and locally, copper and zinc. The district was a very large producer (estimated total value of production of more than $27 million, Elliott and others, 1992) of gold, silver, lead, zinc, and copper.

The recently active Paupers Dream (Basin Creek) mine (pl. 2, map B, no. 278) has characteristics of a hot spring gold-silver deposit. The gold mineralization consists of fracture-controlled quartz veins, zones of silicified stockwork veins, argillized shear zones, and disseminated minerals in Tertiary volcanic and volcaniclastic rocks. In 1989, the mine reportedly had proven reserves of 5 million tons and probable reserves of 7.5 million tons, both with an average grade of 0.042 opt gold (McCulloch, 1989).

Aeromagnetic and gravity maps (McCafferty C of this report, figs. C1, C3) show anomalies associated with mineralized areas. The district is entirely within the batholith and a magnetic anomaly low may coincide either with less magnetic plutonic rocks of the batholith or with areas of hydrothermal alteration, or a combination of both (Hanna and others, 1994). A gravity low in the southeast part of the district (fig. C3) is part of a large low that covers parts of the Clancy, Basin, Wickes, Boulder, and Amazon districts. The gravity low is mainly associated with the batholith (Hanna and others, 1994).

A geochemical survey showed anomalies for arsenic, silver (fig. D13), gold (fig. D12), boron, bismuth (fig. D15), copper (fig. D16), lead (fig. D14), antimony, tungsten, and zinc (fig. D19) (McDanal and others, 1985). The geochemical anomalies in these figures (Alminas, Chapter D of this report) are for stream sediments and incorporate only the stream sediment data of McDanal and others (1985).

Clancy (Lump Gulch) District--The Clancy district is south of the Helena district and its western part extends into the Helena National Forest (fig. F1). The district is entirely within the Boulder batholith and is underlain by Late Cretaceous granodiorite, monzogranite, alaskite, aplite, and pegmatite. Mineral deposits include polymetallic veins and gold placers. The principal lode deposits are veins consisting of chalcedonic quartz with sulfides, mainly galena, sphalerite, and tetrahedrite, in monzogranite of the batholith; the deposits were valuable mainly for silver (Knopf, 1913). The principal lode mines are the Little Nell (pl. 2, no. 305), Free Coinage (no. 301), and King Solomon (no. 306) mines. The largest placers were along Clancy and Prickly Pear Creeks (Lyden, 1948). The district produced gold, silver, and lead with a total value of recorded production of about $2.8 million.

The magnetic anomaly map (McCafferty, Chapter C of this report, fig. C1) shows a magnetic anomaly low on the west side of the district. The anomaly may be associated with less magnetic plutonic phases or with hydrothermal alteration, as in the Rimini district (Hanna and others, 1994).

Geochemical anomalies are present for the following elements: arsenic, silver (fig. D13), gold (fig. D12), bismuth (fig. D15), copper (fig. D16), molybdenum (fig. D17), manganese (fig. D21), lead (fig. D14), antimony, tungsten, and zinc (fig. D19) (McDanal and others, 1985). The geochemical anomalies in these figures (Alminas, Chapter D of this report) are for stream sediments and incorporate only the stream sediment data of McDanal and others (1985).

Basin (Cataract) District--The Basin district is approximately 20 mi southwest of Helena (fig. F1). The northern part of the district is adjacent to, but does not include Forest lands. The district is underlain by monzogranite of Boulder batholith and Tertiary and Cretaceous volcanic and volcaniclastic rocks. Most of the mineral deposits are in the eastern part of the area and hosted by granitic rocks of the batholith. These deposits include polymetallic veins and placer deposits.

Principal mines include the Custer, Josephine, and Crystal mines; these are polymetallic veins in monzogranite. The Crystal vein is along a fault zone that trends about N. 75 W. and dips about 70 N. (Ruppel, 1963). The Crystal vein has been developed along a length of about 6 mi, explored to a depth of 1,500 ft, and has an average width of 30 ft (Pardee and Schrader, 1933). Ore shoots are discontinuous and form separate fissures and overlapping lenses within the zone of altered country rock.

The district was a large producer with an estimated total value of production of about $15.6 million (Elliott and others, 1992). Principal products were gold, silver, copper, lead, and zinc. A geochemical survey (McDanal and others, 1985) indicated anomalies in arsenic, silver (fig. D13), gold (fig. D12),boron, barium, beryllium, bismuth (fig. D15), copper (fig. D16), molybdenum (fig. D17), manganese (fig. D21), lead (fig. D14), antimony, tin (fig. D18), tungsten, and zinc (fig. D19). The geochemical anomalies in these figures

(Alminas, Chapter D of this report) are for stream sediments and incorporate only the stream sediment data of McDanal and others (1985).

Wickes (Corbin) District--The Wickes district is approximately 15 mi south of Helena and its western part includes Forest lands (fig. F1). It lies within the Boulder batholith and includes a large inlier of volcanic and volcaniclastic rocks, which consist of Elkhorn Mountains Volcanics and Lowland Creek Volcanics. Most mines and prospects in the district are in volcanic and plutonic rocks of the Elkhorn Mountains Volcanics and the Boulder batholith, which are of Late Cretaceous age. In contrast, the Montana Tunnels mine (pl. 2, no. 374) is a large-tonnage, low-grade gold-silver-lead-zinc deposit that is in Lowland Creek Volcanics, which is of Eocene age. Most mineral deposits are polymetallic veins in plutonic and volcanic and volcaniclastic rocks.

One of the most productive mines in the region, the Alta lead-silver mine (pl. 2, map B, no. 381), is located in the Wickes district. This deposit was discovered in 1869 and is thought to have produced more than 1.25 million tons of ore valued at $32 million before 1893 (Pardee and Schrader, 1933). Between 1901 and 1948, about 10,000 tons of ore were produced and nearly 250,000 tons of tailings were reprocessed (Becraft and others, 1963). The ore bodies of the Alta mine apparently consisted of large overlapping lenses, veins, and replacement bodies along a well-defined east-trending shear zone in rocks of the Elkhorn Mountains Volcanics. The ore minerals, consisting of galena, pyrite, tetrahedrite, and minor sphalerite, are in a gangue of mainly altered wallrock. The ore zone is about 1,600 ft along strike and was mined to a depth of about 1,400 ft (Becraft and others, 1963).

The Montana Tunnels deposit (pl. 2, no. 374), presently being mined, contains ore minerals of gold, silver, lead, and zinc as disseminations and veinlets in diatreme and hydrothermal breccias. The host rocks are dacitic lithic and crystal-rich welded ashflow tuffs and a dacite porphyry stock of the Eocene Lowland Creek Volcanics, which forms an inlier in the Boulder batholith (Sillitoe and others, 1985). The year-end 1990 reserves at Montana Tunnels were 32.1 million tons of proven and 2.2 million of probable reserves at a grade of 0.019 opt gold (Engineering and Mining Journal, 1991).

A stockwork copper-molybdenum prospect (pl. 2, no. 384) also occurs in monzogranite in the eastern part of the district. The district is very large producer (estimated total value of more than $125 million, Elliott and others, 1992) and principal products are silver, gold, lead, copper, and zinc.

In the center of the district, a magnetic anomaly low (McCafferty, Chapter C of this report, fig. C1) coincides with the area of exposure of the Lowland Creek and Elkhorn Mountain volcanic and volcaniclastic rocks (pl. 1). Much of the area is hydrothermally altered, and several large mineral deposits, including the Montana Tunnels and Alta mines, are within this magnetic low. The main cause of the low may be the hydrothermal alteration (Hanna and others, 1994).

Geochemical anomalies (McDanal and others, 1985) in arsenic, silver (fig. D13), gold (fig. D12), boron, bismuth (fig. D15), copper (fig. D16), molybdenum (fig. D17), manganese (fig. D21), lead (fig. D14), antimony, tungsten, and zinc (fig. D19) are present in the district (McDanal and others, 1985). The geochemical anomalies in these figures (Alminas, Chapter D of this report) are for stream sediments and incorporate only the stream sediment data of McDanal and others (1985).

Boulder (Comet) District--The Boulder district is adjacent but outside of the Forest (fig. F1). Most of the district is in granitic rocks of the Boulder batholith, but some of the north part of the district is underlain by Elkhorn Mountains Volcanics and Lowland Creek Volcanics. Nearly all of the deposits are polymetallic veins; one deposit is a gold placer. The district is a large producer of silver, gold, lead, copper, and zinc (Elliott and others, 1992).

The most important mine in the district is the Comet mine (pl. 2, no. 340). Discovered in 1874, this mine is reported to have produced silver, lead, zinc, gold, and copper with a total value that exceeded $20 million. The mine is located along a strong and persistent regional structure called the Comet-Gray Eagle shear zone (Becraft and others, 1963). This complex shear zone, which trends N. 80 W., cuts plutonic rocks of the Boulder batholith and volcanic rocks of the Elkhorn Mountain Volcanics. Other mines, including the Morning Glory and Gray Eagle, are located to the west on the same structure. The ore bodies at the Comet mine were mined from three main veins and many smaller veins along a 150 ft wide zone and from near the surface to a depth of about 800 ft. Most of the large ore bodies, however, bottomed out between 400 ft and 600 ft depth. The ore consisted of galena, sphalerite, pyrite, arsenopyrite, chalcopyrite, and tetrahedrite in a gangue of quartz, carbonate minerals, and altered wallrock (Becraft and others, 1963).

A magnetic low anomaly (McCafferty, Chapter C of this report, fig. C1), probably associated with hydrothermal alteration, extends southwest from the adjacent Wickes district (Hanna and others, 1994; figs. C1, C4).

Geochemical anomalies (McDanal and others, 1985) are present for the following elements: silver (fig. D13), gold (fig. D12), boron, barium, bismuth (fig. D15), copper (fig. D16), molybdenum (fig. D17), manganese (fig. D21), lead (fig. D14), antimony, tungsten, and zinc (fig. D19). The geochemical anomalies in these figures (Alminas, Chapter D of this report) are for stream sediments and incorporate only the stream sediment data of McDanal and others (1985).

Amazon District--The Amazon district is located adjacent to the Wickes and Boulder districts and outside of the Forest (fig F1). The northwest part of the district is in Elkhorn Mountains Volcanics and the remainder of the district is in granitic rocks of the Boulder batholith. All of the known mines and prospects, for which information is available, are polymetallic veins. The Australian (pl. 2, no. 344) and Bismarck (no. 345), two of the most productive mines, are both located on the same vein. This vein strikes N. 75 E. and dips 65-89 N. and is about 8 to 15 ft wide. Wall rock along the vein is monzogranite that is intensely altered to clay minerals and sericite (Becraft and others, 1963). The vein consists of sulfide minerals, mainly galena and sphalerite, in quartz and is valuable for gold and silver. The district produced silver, lead, gold, and copper with a total value of recorded production of about $120,000.

A magnetic anomaly low trends southwest along the west side of the district (McCafferty, Chapter C of this report, within heavy dashed line of figs. C1, C4) and is probably related to hydrothermal alteration (Hanna and others, 1994).

Geochemical anomalies in arsenic, boron, barium, lead (fig. D14), and zinc (fig. D19) are present in the district (McDanal and others, 1985). The geochemical anomalies in these figures (Alminas, Chapter D of this report) are for stream sediments and incorporate only the stream sediment data of McDanal and others (1985).

ELKHORN MOUNTAINS REGION

By Steve Ludington, Felix E. Mutschler, and Marta Franchini

Introduction

In this section, we describe geologic attributes of the mining districts and other mineralized areas in the Elkhorn Mountains. A mineralized area is an area whose characteristics are conveniently described together, and, ideally, correspond to regions affected by coherent mineralizing events and to historically defined mining districts. Because of our incomplete knowledge about the Forest and about the genesis of mineral deposits, strict adherence to this guideline is not always possible. In many cases, the groupings do correspond to mining districts, but the boundaries of mining districts are often poorly defined, and, even when known, may be accidents of history. The mineralized areas described here are shown in figure F2. These descriptions are prepared in the context of the geologic summary presented in Chapter B of this report, including the rock-unit descriptions on plate 2, and we assume the reader to be familiar with that summary.

Geologic Setting

The Elkhorn Mountains region of the Helena National Forest is underlain mostly by Elkhorn Mountains Volcanics and related intrusive rocks and by the Boulder batholith and satellitic stocks, all of Late Cretaceous age (fig. F2). A smaller part of the Forest is underlain by sedimentary strata of Paleozoic to Mesozoic age. In addition, sedimentary rocks of the Middle Proterozoic Belt Supergroup crop out directly south of the area, and presumably lie beneath the Paleozoic strata in most parts of the area. All of these rocks were intruded by igneous dikes and stocks and locally are overlain by related middle and late Tertiary volcanic rocks. The Elkhorn Mountains occupy a tectonically uplifted block, bounded on the east and north by major faults. This uplifted block has been eroded to its present form by glaciers and running water. Hydrothermal mineral deposits formed in the Elkhorn Mountains in concert with four distinct magmatic events, as shown in table F1. There are no hydrothermal deposits of unequivocal Tertiary age.

Mineral Deposits

<u>Montana City district</u>

The Montana City district lies directly outside the Forest. The most important metallic deposits are polymetallic veins and replacement deposits south of Helena and west of Interstate 15. The Montana City limestone quarry is in Paleozoic limestones. Similar limestones occur on the eastern margin of the Elkhorn Mountains, mainly outside the Forest, and in the core of the large antiform in the southern part of the region (plate 1). Limestone at Montana City is metamorphosed into marble by heat from the nearby Boulder batholith.

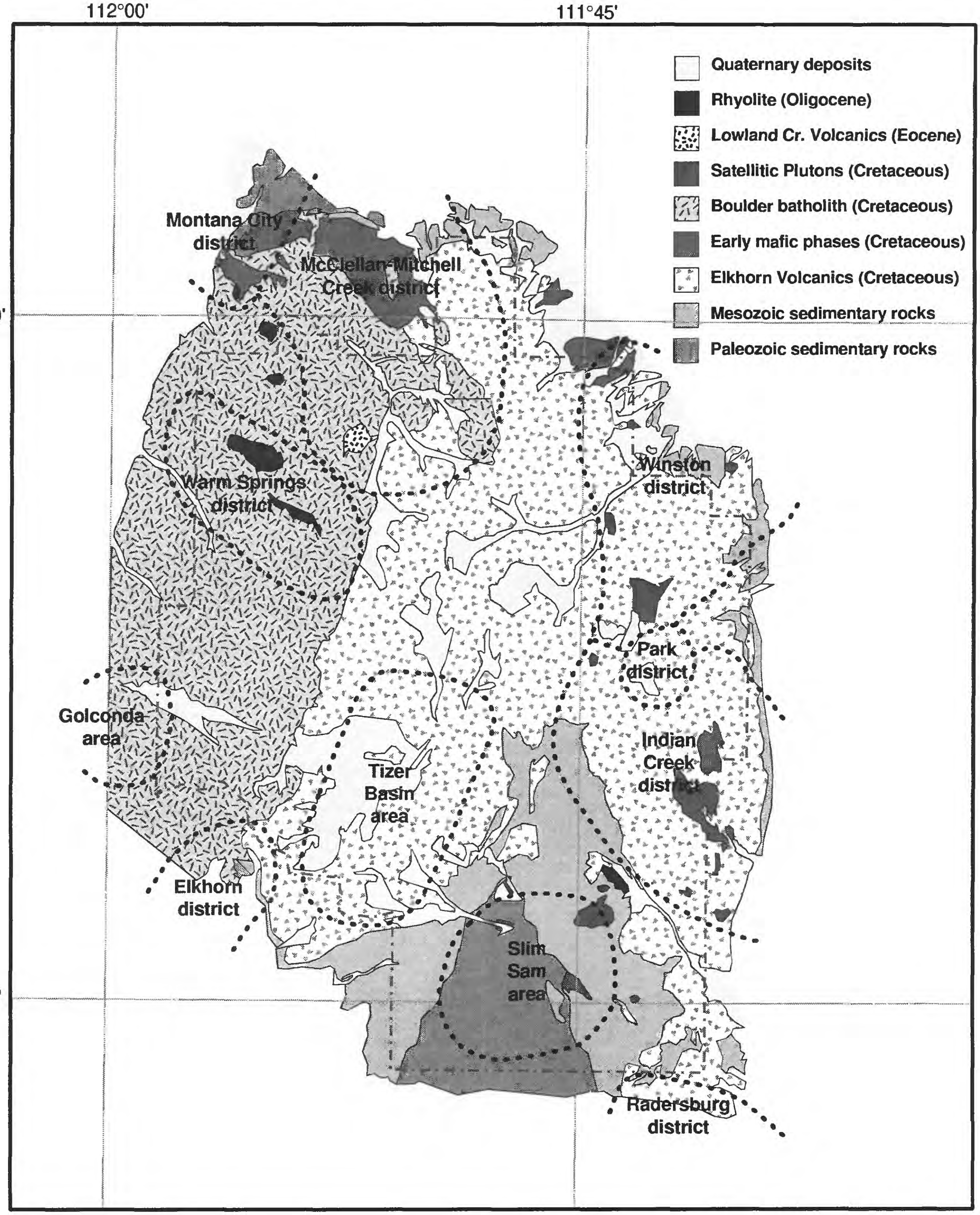


Figure F2. Map of the Elkhorn Mountains region, showing geology, Hele na National Forest boundary, and mining districts and mineralized areas discussed in the text.

Table F1. Mineral deposits and correlative magmatic events in the Elkhorn Mountains region.

Magmatic Event	Age Ma	Type of Mineral Deposit (examples)
Elkhorn Mountains Volcanics	81-79	Gold-bearing breccia pipes (Skyline, Black Jack mines
Satellitic stocks	<80, >75?	Skarn Au deposits (Diamond Hill, Elkhorn) Polymetallic veins (Radersburg, East Pacific mines)
Boulder batholith, main stage	80-75	Polymetallic veins (Warm Springs district, McClellan-Mitchell Creek district)
Boulder batholith, aplites	70-68	Porphyry copper deposits (Golconda deposit)

McClellan-Mitchell Creek district

The remnants of an intriguing hydrothermal system, developed in intrusive rocks of the Boulder batholith, crop out along a tributary to Jackson Creek, in sections 2 and 11 of T.8N., R.2W. (Ludington and Greenwood, 1990) (fig. F3). Rock samples from this area contain up to 1,500 ppm (parts per million) Cu, 50 ppm Mo, and 1,000 ppm Bi. Rock types vary widely in this small area, and it is not clear how much of this apparent variation is due to hydrothermal alteration of the original rocks. Many of the rocks lack potassium feldspar, presumably because of hydrothermal alteration. However, secondary sericite (white mica) is only weakly and sporadically developed. Disseminated pyrite is common, and some samples contain as much as 10 percent sulfide minerals. The area was apparently explored by drilling in the 1960s, but the results are not known. The nature of this hydrothermal system remains enigmatic. Minor placer workings are present north of this area, downstream on Jackson Creek, but nothing is known of their history (Smedes, 1966).

Elsewhere in the McClellan-Mitchell Creek district, mineral deposits are widely scattered polymetallic vein deposits. Most are quite small, and the largest, the Economy mine, produced only about 2,000 oz (troy ounces) of Au and is about a mile outside the Forest. The Economy, Eureka, and Last Hope mines all contain skarn minerals (diopside, hedenbergite, garnet), as well as tourmaline, in the gangue and disseminated in the wall rocks; they appear to be similar to deposits in the Helena district (pl. 2), and suggest the possibility for undiscovered Au skarn deposits. The relationship of the polymetallic vein deposits to the Jackson Creek hydrothermal system is not known. Placer deposits have been worked on the lower reaches of both McClellan and Mitchell Creeks, with the deposit on Mitchell Creek, below the Economy mine, being much the larger.

Warm Springs district

The most important deposits in the Warm Springs district are a series of west-trending polymetallic veins found just south of the Oligocene rhyolitic complex on Lava Mountain, in sections 29, 30, 31, and 32 of T8N, R2W. Some workers have speculated over the years that these veins are related to the Oligocene igneous activity (see Billingsley and Grimes, 1918, p. 337, as well as the discussion about radioactivity in Smedes, 1966, p. 110). However, the presence of unaltered obsidian in the same structures as the base-metal veins indicates that hydrothermal activity ceased before emplacement of the rhyolite. Perhaps uranium related to the rhyolite has subsequently been concentrated in some of the vein structures because of their permeability.

Placer deposits were discovered on Warm Springs Creek as early as 1865, but they were apparently not extensive, and little is known about the history of their exploitation (Smedes, 1966). All these deposits in the Warm Springs district are inside the Forest, and some of the ore produced in the past was very rich, but there has been little activity in recent years. There is little indication of potential in this district for the occurrence of any type of large, low-grade deposit that would be attractive today.

Golconda area

The Golconda porphyry copper-molybdenum deposit (possibly also known as Anderson Gulch) was apparently discovered by geologists of the Exxon Corporation in the early 1970s. The mineralization is primarily in, and closely related to, a large aplite body that intrudes the Boulder batholith. The deposit is in Anderson Gulch and Golconda Creek, directly south of Prickly Pear Creek, immediately adjacent to the Forest boundary, in sections 16, 17, 20, and 21 of T.7N., R.3W. (fig. F3). The area affected by mineralization and hydrothermal alteration is about 4-5 sq. mi.; perhaps 10 percent of that area lies within the Helena National Forest. Geologic details can be found in Ludington and Greenwood (1990). In 1977, exploration was in progress, and at least 4 diamond drill holes of unknown depth were completed at that time. Nothing is known of the subsequent exploration history. Though most of the potential ore lies outside the Forest, any development of this prospect would impact Forest lands.

Pripheral to the Golconda mineral system, but not clearly related to it, are a number of northeast-trending polymetallic veins, notably the Reddings, Big Chief, and Golconda or Golden Assets (fig. F2). These veins are typical of many polymetallic veins in the Boulder batholith, consisting of fault breccias, cemented by quartz and sulfide minerals, chiefly pyrite, galena, and sphalerite (Becraft and others, 1963; Stone, 1911). The Golden Assets property, a little more than a mile west of the Forest, was being developed in 1993 as a small open-pit mine to exploit low-grade Au-mineralized rock that envelops the veins proper.

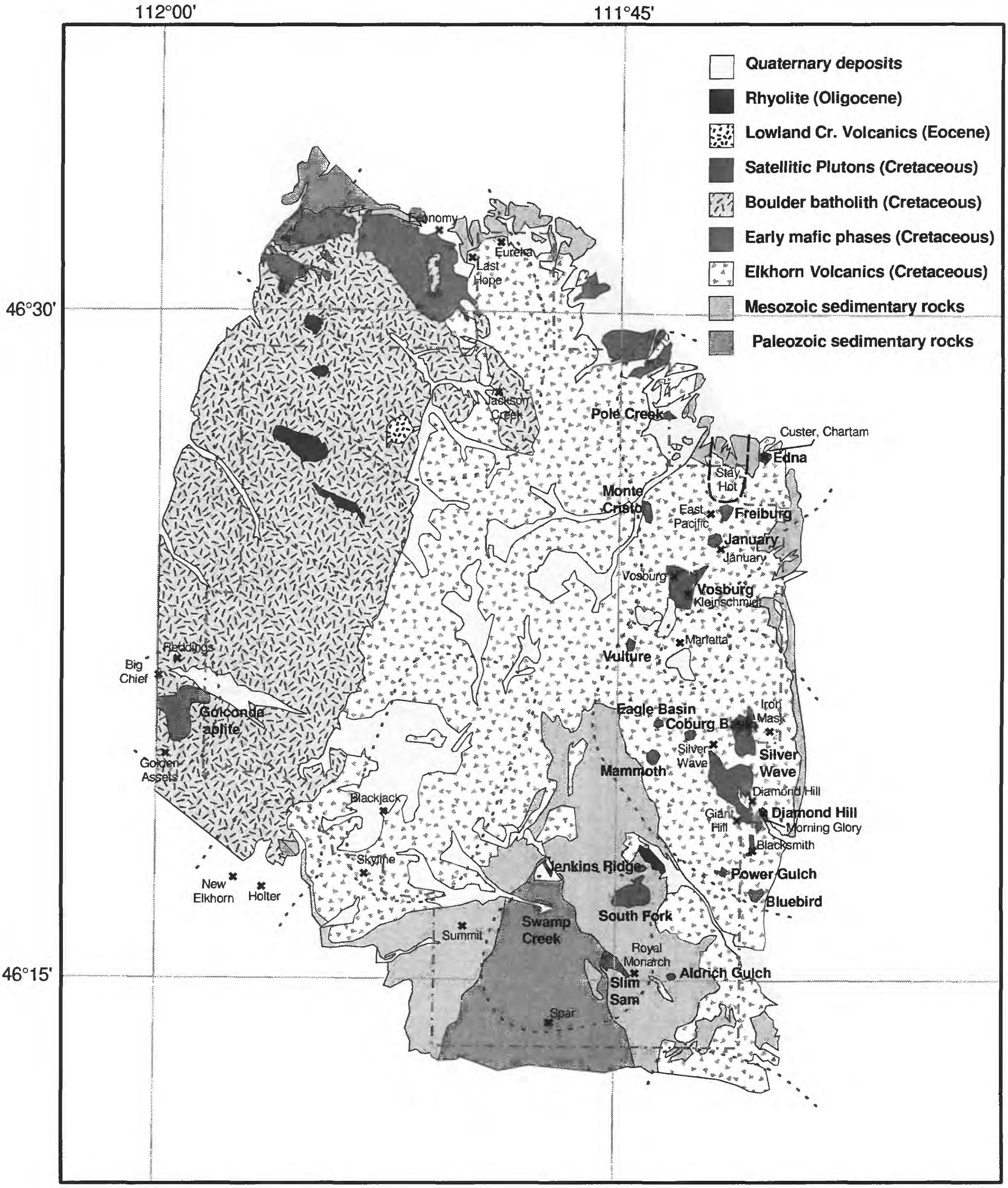


Figure F3. Map of the Elkhorn Mountains region, showing geology, Hele na National Forest boundary, and names of satellitic plutons (larger type) refe rred to in text. Mining districts and areas from fig. F2 are subdued and names are omitted. Sp ecific deposits and prospects referred to in the text are shown by *, with names in small type.

Minor heap-leaching of ore from this deposit has been done in the last decade. Reserves were reported to be about 575,000 st (short tons) at a grade of 0.06 oz/st Au and 8.5 oz/st Ag (Private proprietary report).

Minor placer deposits were exploited on Golconda and Prickly Pear Creeks (Stone, 1911).

Elkhorn district

We describe the Elkhorn district briefly, even though it is in the Deer Lodge National Forest, because it is the site of one of the most significant historic mines in the area, and is also the site of an important modern mineral discovery that is being actively explored. The new discovery also shows some similarities to the Diamond Hill deposit on the east flank of the Elkhorn Mountains.

The most important historic deposit in the Elkhorn district was exploited by the Holter (Elkhorn) mine, immediately adjacent to the historic townsite. In the years between, 1875 and 1952, this mine produced more than 500 st of Ag and about 7,000 st of Pb (Roby and others, 1960). This deposit, which at times was the leading Ag producer in the United States, would have a gross value of more than $100 million at today's prices. It consists of replacement bodies along the contact between the dolomite of the Pilgrim Formation and the overlying Red Lion Formation, both Cambrian in age. The orebody had the form of two steep, stratabound shoots, localized along the crests of minor folds in the limestone, and was mined from the surface to depths of about 1,500 ft. Most of the ore consisted of argentiferous (silver-bearing) galena; it was not demonstrably related to any nearby igneous body.

In 1982, the Gold Fields Mining Corporation began exploration in the district, looking to develop new deposits of silver. Instead, they soon encountered gold-bearing skarn deposits to the north and west of the townsite. After considerable exploration and development during the 1980s, the property passed into the hands of the Santa Fe Pacific Minerals Corporation in 1993, and, as of the middle of 1995, drilling and permitting work was ongoing. The new deposit is reported to contain nearly 900,000 oz of Au (Giancola and Razvi, 1995).

In the southern part of the district is Turnley Ridge, a very low-grade low-fluorine molybdenite system that was drilled in the late 1970s, apparently with discouraging results (Ludington and Greenwood, 1990).

Tizer Basin area

The Tizer Basin mineralized area, within the Forest, is characterized by two kinds of mineral deposit, polymetallic veins and tourmaline-bearing breccia pipes. The veins all strike northeast, similar to others in districts to the west and north, and produced Cu, Pb, Zn, Au, and Ag in small quantities. The total amount of ore produced is little more than 11,000 st, and none of the deposits were developed to a depth as great as 700 ft (Klepper and others, 1957).

One of these deposits was examined during this study, an unnamed prospect in the northeast corner of section 3, T. 6 N., R. 2 W. Much of the exploration of this area appears to have taken place in the decades after World War II.

Numerous trenches and prospect pits are developed in the Elkhorn Mountains Volcanics, near the base of the welded tuff units mapped by Klepper and others (1957). The material examined consisted largely of thin drusy quartz veins that cut the volcanic rocks along an E-W trend that continues for at least 1,000 ft. Galena, sparse pyrite, and copper oxide were the only metallic minerals noted. Two geochemical samples were collected (HL44 and HL45, Table F2) that were anomalous in Ag, Au, Cu, Pb, and Zn, and contained nearly 300 ppm Ag and as much as 1.6 ppm Au.

Breccia pipes at the Blackjack and Skyline mines are both composed of fragments of Elkhorn Mountains Volcanics, cemented by quartz, tourmaline, and sulfide minerals. They were investigated in some detail by Ludington and Greenwood (1990). The Skyline is the larger of the two, shows more base-metal sulfide minerals in outcrop, and contains anomalous amounts of Mo, Sn, and W, whereas the Blackjack exhibits only pyrite at the surface, and contains only anomalous Mo. Both deposits could indicate the presence of a pluton at depth.

Slim Sam area

Production from scattered mines in this area within the southern part of the Forest (fig. F2) has been negligible. However, some exploration has taken place, and several long-abandoned mines yielded interesting geochemical results during the present study.

The most significant modern exploration effort in the area was known as the Royal Monarch. Hecla Mining Company geologists apparently recognized the potential for skarn Au deposits surrounding the Slim Sam stock in 1987, and substantial exploration efforts ensued. In 1989, Molycorp Inc. apparently completed 8 diamond drill holes in the area, of unknown depth, and with unknown results. Our studies added little information, although we can confirm that skarns exist in the area. Three mineralized samples were taken from the surface. One of them (HL36B, Table F2) contained about 300 ppm Mo and nearly 20 ppm Au (> 0.5 oz/t).

At the Summit claim, Klepper and others (1957) reported silicification and limonite in argillaceous siltstone in the lower part of the Jurassic Morrison Formation. A brief visit revealed no more details, but a composite geochemical sample (HL71, Table F2) was surprisingly anomalous in Ag, As, Au, Cd, Mo, Pb, Sb, Sn, and Zn, containing more than 60 ppm Ag and about 1 ppm Au.

At the Spar mine, a small polymetallic replacement deposit in the Devonian Jefferson Dolomite produced a small amount of ore in the first half of this century (Klepper and others, 1957). The material that remains on the dumps consists primarily of brecciated chalcedony and barite that apparently has replaced limestone and dolomite. Two samples from the dumps (HL72, HL73, Table F2) were anomalous in Ag, As, Au, Cu, Pb, Sb, and Zn, and contained as much as 200 ppm Ag, 500 ppm Sb, and about 0.3 ppm Au.

Radersburg district

The Radersburg district is almost entirely outside the Forest, with the richest mines about 4 km distant from the boundary (fig. F2). Historic production for the district is estimated to be about 11.1 st of Au and about 9.2 st of Ag, along with modest amounts of Cu and Pb, and small amounts of Zn (this study; Koschmann and Bergendahl, 1968). This production would have a gross value of more than $130 million at today's prices. Most of this production came from two adjacent mines, the Keating and Ohio-Keating, which exploited veins that consist primarily of auriferous pyrite, along with minor gangue of quartz and calcite. Other sulfide minerals include chalcopyrite, bornite, chalcocite, galena, pyrite, pyrrhotite, and marcasite. At the Keating mine, these veins were developed to depths of >1,300 ft.

A gold-rich porphyry copper system lies at depth beneath the district, apparently in the vicinity of the Keating and Ohio-Keating deposits. Indications of this deposit were known as early as the 1970s, when the prospect was first drilled to depths of several hundred feet. The system, related to a granodiorite with large potassium feldspar phenocrysts, is covered by 300-1,000 ft of alluvium. Hydrothermal alteration is concentrically zoned around a potassium feldspar core zone that is nearly a mile in diameter. Fluid inclusions also display zonation, with filling temperatures of about 460° C. for inclusions with 40-60 percent salinity in the center, indicating fluids typical of porphyry copper deposits. The best drill intercept was an interval of >600 ft with grades of about 0.25 percent Cu and 0.01 oz/st Au. The information presented in this paragraph was presented P.W. Mitchell at the July 1993 meeting of the Tobacco Root Geolocical Society, held near Whitehall, Montana.

Table F2 (facing page). Chemical analyses of mineralized rocks from the Elkhorn Mountains, Helena National Forest, Montana.

[All values in parts per million, except Fe, which is in weight percent. The samples were analyzed by 3 different methods: ICP-AES—40 element, ICP-AES—10 element, with organometallic halide extraction, and gold by Atomic Abosrbtion flame methods, with dissolution in HF, aqua regia, and HBr-Br_2 (see Arbogast, 1996, for details). Detection limits among these methods vary. Where the same sample was analyzed for the same element by more than one method, an average is reported. The samples are listed in order of decreasing north latitude, i.e., from north to south.]

Field No.	Latitude	Longitude	Sample description	Fe %	Ag	As	Au	Bi	Cd	Cu	Mo	Pb	Sb	Sn	Zn
HL53	46.46	111.72	hydrothermal quartz, Pole Cr.	6.8	0.89	37	< 0.05	6	0.30	430	145	87	< 1.0	< 5	110
HL77	46.44	111.71	skarn, Stay Hot prospect	10	1.9	1.1	< 0.05	13	0.44	3,800	0.33	10	2.8	< 5	80
HL56	46.44	111.70	Fe-stained quartz fragments	6.5	0.21	2.3	< 0.05	1	<0.05	230	0.64	9	< 1.0	< 5	14
HL37A	46.44	111.70	mineralized volcanic, Stay Hot	2.7	0.38	8.2	< 0.05	66	0.06	180	2.7	15	< 1.0	< 5	13
HL55	46.43	111.73	vein material	4.0	4.4	2,200	0.42	14	0.41	82	1.1	36	< 1.0	14	72
HL26	46.41	111.70	January quartz monzonite, mineralized	2.1	0.54	31	< 0.05	5	0.13	260	1.3	20	< 1.0	< 10	26
HL27	46.40	111.69	vein material, Stray Horse	15	210	29,000	2.1	<20	26	1,000	9.0	98,000	nd	< 10	1,100
HL35A	46.39	111.72	vein material, Kleinschmidt	2.8	27	7,600	0.20	<1	81	23	1.2	9,300	52	< 5	9,600
HL23	46.39	111.71	vein material Little Olga	5.2	61	17,000	0.95	<15	65	210	6.6	5,100	76	< 10	8,900
HL34	46.39	111.73	veins with Cu Mo, Silverdyke	5.4	280	480	1.5	1,300	8.1	2,600	13	4,600	75	< 5	870
HL33	46.39	111.73	metavolc, mineralized Silverdyke	7.0	24	210	< 0.05	<1	25	74	1.1	3,600	24	< 5	6,400
HL47	46.37	111.74	wall rock to vein	5.0	13	1,500	0.23	<1	16	36	1.5	2,300	16	< 5	770
HL46	46.37	111.74	vein with coarse quartz	1.5	100	2,100	0.44	<1	1.5	25	0.83	7,800	37	< 5	300
HL50	46.37	111.70	vein material (hisulfide)	11	6.0	560	0.49	34	36	66	0.80	170	1.2	< 5	5,300
HL13	46.36	111.71	vein material; Marietta dump	12	45	35,000	3.5	<20	140	240	<4	13,000	nd	< 10	20,000
HL61	46.36	111.73	quartz-pyrite vein in rhyolite	1.6	1.3	120	0.05	<1	0.17	9	1.2	35	< 1.0	< 5	51
HL62	46.36	111.73	quartz-pyrite vein in rhyolite	3.1	33	6,800	0.35	15	27	520	2.1	11,000	32	< 5	3,400
HL63	46.35	111.74	quartz-pyritegal veins	5.2	95	1,300	4.5	4	4.3	73	1.7	61,000	130	16	1,200
HL12	46.35	111.68	vein material from dump	12	280	45,000	2.5	<20	970	2,300	9.0	120,000	nd	< 10	110,000
HL10	46.35	111.68	vein material from dump	10	<4	44,000	0.80	<20	120	160	<4	740	nd	< 10	18,000
HL08	46.35	111.68	carbonate vein, Phoenix	8.9	0.88	170	0.56	<1	0.55	32	0.49	98	< 1.0	< 10	135
HL65	46.35	111.74	Fe-stained rhyolite	12	56	2,600	1.7	<1	97	250	3.6	11,000	44	11	5,900
HL66	46.34	111.73	assorted dump material	6.7	0.83	12	< 0.05	<1	0.85	120	0.30	56	< 1.0	< 5	120
HL68	46.34	111.74	veinlets in gabbro	7.8	0.12	84	0.05	<1	4.4	150	0.36	27	< 1.0	< 5	1,000
HL67	46.34	111.74	Fe-stained rock with quartz veins	4.2	35	1,300	1.5	26	15	180	1.4	2,300	10	32	1,000
HL14	46.34	111.69	altered and mineralized metavolcanic	6.4	0.40	160	< 0.05	<1	1.4	32	0.83	120	< 1.0	< 10	250
HL15A	46.33	111.70	volcanic rock	5.9	0.21	35	< 0.05	<1	0.33	140	0.74	31	< 1.0	< 10	120
HL28	46.32	111.68	white and green rock, dike(?)	12	3.0	820	2.0	<1	37	130	7.1	510	< 1.0	< 10	67,000
HL29	46.32	111.68	typical skarn	8.0	<0.08	28	0.66	3	0.76	53	1.2	2	< 1.0	< 5	150
HL57	46.32	111.68	assorted skarn samples, Diamond Hill	11	5.6	14	0.43	31	3.4	2,600	0.28	33	1.4	< 5	450
HL31	46.32	111.70	Elkhorn intrusive, mineralized	7.7	0.40	30	0.22	2	0.45	20	1.4	23	< 1.0	< 5	77
HL03	46.32	111.68	metavolcanic with sulfide veinlets	5.7	<0.08	2.4	< 0.05	<1	0.09	47	0.26	13	< 1.0	< 10	44
HL04	46.32	111.68	carbonate vein	4.7	0.27	34	< 0.05	<1	0.33	4	0.81	12	< 1.0	< 10	32
HL30	46.32	111.72	metavolcanic, skarn(?)	5.2	<0.08	1.8	< 0.05	<1	0.08	67	0.29	7	< 1.0	< 5	73
HL06	46.31	111.67	mineralized Diamond Hill quartz monzonite	4.2	0.87	<10	1.8	<10	<0.5	1,100	5.4	14	<10	< 10	53
HL44	46.31	111.83	drusy quartz veins	3.9	280	270	0.40	<10	52	240	8.0	82,000	nd	< 5	29,000
HL45	46.31	111.83	vein material	2.1	270	51	1.6	<20	<4	950	13	160,000	nd	< 10	1,200
HL43	46.28	111.79	jasperoid, Swamp Cr	0.60	0.17	6.2	< 0.05	<1	1.4	37	1.6	1	< 1.0	< 5	100
HL02	46.26	111.77	carbonate breccia in Quadrant Fm.	19	1.2	420	0.05	<1	13	17	23	900	7.3	< 10	83
HL71	46.26	111.82	Fe-stained siltstone and sandstone	19	63	950	1.1	15	50	85	34	9,200	36	37	2,400
HL70	46.25	111.78	jasperoid	1.6	0.09	110	< 0.05	<1	0.31	12	1.5	15	14	< 5	41
HL38	46.25	111.74	Fe-stained breccia	7.3	9.9	160	0.10	6	0.08	17	1.0	4,100	6.8	< 5	12
HL36B	46.24	111.74	skarn, Monarch	3.3	3.2	20	18	35	0.20	20	300	12	3.4	< 5	58
HL35B	46.24	111.75	Fe-stained material, Monarch	4.3	0.15	6.8	< 0.05	<1	0.15	92	0.42	6	< 1.0	< 5	34
HL40	46.24	111.72	black shale, Colorado Fm.	5.4	0.19	12	< 0.05	1	0.54	54	2.4	54	< 1.0	< 5	120
HL72	46.23	111.79	brecciated chalcedony and barite	0.27	120	61	0.31	<1	220	150	3.0	1,600	510	< 5	21,000
HL73	46.23	111.79	brecciated chalcedony and barite	0.21	210	100	0.15	<1	22	290	1.0	900	490	< 5	3,700

Indian Creek district

There are a number of important mineral deposits and prospects surrounding both bodies of the dioritic Silver Wave stock, which is one of the satellitic stocks that are marginal to the Boulder batholith along the eastern margin of the Elkhorn Mountains. There are numerous smaller deposits scattered throughout the district as well.

Silver Wave vicinity

Along the north margin of the Silver Wave stock, on the old Silver Wave and Silver Dollar claim groups, an exploration program was conducted within the Forest by Molycorp Incorporated in 1988 and Pathfinder Gold Corporation in 1989 (area marked Silver Wave on fig. F3). Surface rock samples indicated the possibility of good Au and Ag mineralization with strong base metals. Many samples contained more than 1 percent Pb, 0.05-0.1 percent Cu, and 0.1-0.5 percent Zn, along with Au values >0.01 oz/st and Ag >1 oz/st. Drilling results (about 9 shallow holes) suggest that the material between the veins is not strongly mineralized, as composite assays are much lower, seldom exceeding 100 ppb Au. All precious-metal vein intercepts showed significant lead and zinc mineralization. The high base metals suggest that the mineralization in this area is related to the Marietta mine to the north, in the Park district, not to the Diamond Hill orebody to the south. Two rock samples collected from this area (HL14, HL15A, Table F2) yielded equivocal results on this question; they are weakly anomalous in Zn, but do not contain large amounts of Pb, Cu, As, or precious metals. The near-surface potential of this area has probably been adequately tested, but the nature of deeper portions of the hydrothermal system remains unknown.

Giant Hill

At Giant Hill, more than 20 shallow (130-300 ft) holes were drilled by Pegasus Gold Incorporated in 1991. These holes were drilled at a 45° angle to explore a series of gold-bearing veins that are detectable at the surface. We are indebted to Greg Wittman and Mike Maslowski of Pegasus for information about this project. The rocks exposed at the surface are andesites of the lower member of the Elkhorn Mountains Volcanics, intruded by diorite of the Silver Wave stock. Much of the rock is affected by argillic alteration and contains moderate amounts (as much as 3 percent) of disseminated pyrite. The rocks are cut by as many as 20 to 25 parallel faults that trend about N. 80W. Many of these faults host thin, high-grade precious-metal veins that were, in the past, mined to shallow depths. The drilling results were less favorable than expected. Typical 5 to 10 ft intervals assayed 0.01-0.04 (rarely to 0.1) oz/st Au, and generally even lower amounts of Ag, with intervening intervals characterized by much lower values. Again, deeper portions of this system remain untested.

The adjacent Blacksmith prospect (not shown), has similar oxidized sulfide veins, probably related to a north-trending dike(?) of Silver Wave diorite, but has not been explored. Surface occurrences of skarn have also been reported from the Blacksmith prospect. No geochemical samples were collected from either area.

Diamond Hill

The major target in the Indian Creek district, presently being explored by Pegasus Gold Inc., is called Diamond Hill, after the old Diamond Hill mine. It is a skarn deposit that contains a minimum of about 1,173,000 short tons of mineralized material with an average grade of 0.271 oz/st Au (Giancola and Razvi, 1995). This is a resource of 318,000 oz of Au. The deposit is incompletely explored, and there is a good chance that more reserves will be found if exploration is continued. The deposit is located about 1,000 ft east of the Helena National Forest boundary. Much of the information in this section was provided by Mike Maslowski, Senior Geologist with Pegasus Gold.

Lode gold was first discovered at Diamond Hill in 1870. From then until about 1940, small- to medium-scale underground mining of high-grade gold ore, termed "quartz-poor pyrite veins" by Klepper and others (1971), yielded as much as 2.9 st of Au. From 1940 until 1971, there was only sporadic mining, principally in small open pits. First Amax Inc., in 1971-72, and then Kerr McGee Corporation, in 1973, drilled in the immediate area, searching for a porphyry copper deposit related to the adjacent Diamond Hill quartz monzonite stock. In 1974, Utah International explored the Diamond Hill skarns in search of tungsten, and, from 1978 to 1981, Diamond Hill was again explored for porphyry copper deposits, this time by Exxon Minerals Company. In 1982-83, gold became the focus of exploration again, as Utah International drilled nearly 30 holes on the property in search of gold in the skarns, followed by gold exploration conducted by Nord Resources Corporation in 1983-84. Finally, in 1988, Pegasus Gold signed a joint venture development agreement with Broadwater Developments Inc., who had acquired the property in 1984. Pegasus' initial exploration efforts were aimed at development of a low-grade open-pit mine, but, since 1992, exploration has been focused on delineation of underground mineable reserves. As of February 1995, a 4,000-foot-long exploration decline had been completed that will permit detailed evaluation of grade distribution in the deposit; a decision regarding development of the property should follow soon.

The skarn is developed in the lower member of the Elkhorn Mountains Volcanics, along the southern margin of the dioritic Silver Wave stock (fig. F3). This skarn occurs in near-vertical pipe-like bodies, oval in cross-section, that are known from drilling to extend to at least 1,500 ft below the surface. The skarn bodies appear to be formed along north-south trending, nearly vertical fractures and faults (See Klepper and others (1971) for possible relation with "Diamond Hill Fault Zone"). The protolith of the skarn is not known with certainty. A distinctive feldspar porphyry, known to the project staff as diorite porphyry, appears to envelop the skarns; this rock may be either a fine-grained facies of the Silver Wave diorite, or recrystallized, contact-metamorphosed andesite of the Elkhorn Mountains Volcanics. The skarn consists of medium-grained, inequigranular masses of quartz, calcite, actinolite, chlorite, epidote, and(or) garnet, along with minor pyrite, pyrrhotite, and chalcopyrite.

Four phases of high-temperature skarn formation and alteration are discernible at Diamond Hill. First is formation of a prograde skarn assemblage of garnet + diopside + calcite. This is followed by a retrograde event in which garnet and diopside are replaced by epidote and actinolite, respectively. The principal sulfide and gold mineralization accompanies this assemblage. This event appears to be followed by a potassic overprint that results in patchy development of orthoclase in the groundmass. In the fourth and final stage, many rocks show a late replacement of garnet by chlorite. These metamorphic assemblages are followed by development of two distinct episodes of quartz + calcite, which generally fill low-angle veins and other voids. Carbonate in the last phase is commonly iron-rich and accompanied by galena + sphalerite; this may be a distal manifestation of the silver and base-metal veins to the north (Marietta mine area).

Surrounding these skarns is an envelope of rock, termed endoskarn by the project staff, that is perhaps better referred to as skarnoid. It's igneous parentage is generally evident, and it may well be external to the Silver Wave stock. In this rock, an initial phase is represented by the development of fine-grained granoblastic diopside in the groundmass. This is again followed by a potassic alteration event, represented either by orthoclase flooding or by the development of secondary biotite that replaces ferromagnesian minerals. Finally, many of these rocks show evidence of subsequent propylitization, signaled by the development of actinolite, chlorite, epidote, and calcite.

Opaque minerals found in the skarn include gold, pyrite, chalcopyrite, sphalerite, galena, rare pyrrhotite, minor silver, and microscopic tellurobismutite, which, along with gold, is spatially and temporally associated with pyrite. The gold occurs as free grains from 10 microns to 2 mm in size, and as thin films on pyrite.

Surface composite samples collected during the present study (HL29, 31, 57; table F2) of typical mineralized rock are anomalous only in Au, Cu, and Zn, containing as much as 0.66 ppm Au, 2,600 ppm Cu, and 450 ppm Zn. These results contrast sharply with those from the polymetallic vein systems immediately to the north, in the Park and Winston districts. There, mineralized samples are commonly characterized by large amounts of Ag, As, Cd, Pb, and Sb, in addition to Au, Cu, and Zn. The contrast is perhaps best demonstrated by As. Arsenic contents in the samples from Diamond Hill are hundreds to thousands of times lower than in the mineralized rock to the north.

Morning Glory

On the Morning Glory claims, the Diamond Hill stock, just to the south of the Silver Wave stock, was drilled as a porphyry copper prospect in the 1970s by AMAX. The Diamond Hill stock is a quartz monzonite porphyry, apparently younger than the Silver Wave stock, that is pervaded by a quartz-pyrite stockwork. It lies just outside the Forest.

Five diamond drill holes were completed by AMAX in 1971 to explore this system, with results as follows (unpublished reports, Amax Incorporated and Pegasus Gold Incorporated):

AMAX-1: Total depth, 700 ft; begun in quartz monzonite, passed out of intrusive into metamorphosed Elkhorn Mountains Volcanics at about 260 ft. No assay results available.

AMAX-2; Total depth 495 ft; quartz monzonite from collar to 115 ft, then Elkhorn Mountains Volcanics; most Cu assays 0.03 to 0.1 percent. The entire hole showed Au >0.02 ppm, with values as high as 0.06 in 10 ft composites.

AMAX-3; Total depth 1,090 ft; collared in quartz monzonite and remained in it; most Cu assays 0.03 to 0.16 percent. Six of eleven 10 ft composites showed detectable Au, with values to 0.18 ppm (at top of hole).

AMAX-4; Total depth 865 ft; collared in Elkhorn Mountains Volcanics, and encountered only some dikes of quartz monzonite; most Cu assays 0.02 to 0.09 percent. Three of eight 10 ft composites showed detectable Au, with values to 0.1 ppm at bottom of hole.

AMAX-5; Total depth 300 ft; entire hole in quartz monzonite.

AMAX-6; Total depth 985 ft; collared in quartz monzonite; Elkhorn Mountains Volcanics from 450-790 ft, then quartz monzonite to bottom of hole.

Surface rock geochemistry yielded values of about 0.05 to 0.18 percent Cu, with Pb, Zn, and Mo almost all <100 ppm, Ag mostly 0.1-1 ppm, with one sample of 18 ppm, and Au mostly less than 200 ppb, but one sample as high as 4.7 ppm. A single geochemical sample (HL06, table F2) collected during this study contained 1.8 ppm Au and 1,100 ppm Cu. It is reported that drill core here shows the quartz monzonite to be younger than the Silver Wave stock, but older than the rhyolite porphyry. It is also reported that AMAX obtained a K-Ar date on the Diamond Hill stock, but the results are not known to us. The prospect was later held by Heather Resources, but they relinquished in 1983. There has been no known activity since then.

Indian Creek placers

Beginning just downstream from the Diamond Hill target, at the townsite of Hassel, Indian Creek has been worked repeatedly since as early as 1870 (Reed, 1951) for placer Au over a length of several miles. The source of this gold was probably outcropping portions of the Diamond Hill deposit, as well as the Au-bearing polymetallic veins in the drainage area. Reed (1951) reports that there were significant amounts of scheelite (calcium tungstate) in the black sand residue from placer mining.

Other deposits

Other known deposits in the Indian Creek district are apparently quite small. Except for the Iron Mask, which produced more than 22,000 st of ore, production from them has been negligible. Study of their mineralogy and geochemistry, however, could prove valuable as exploration guides by allowing delineation of metallogenic zoning patterns in the district.

A series of geochemical samples were collected at unnamed prospects from the drainages of Eureka Creek (HL 61, 62, 63, 65; Table F2) and Eagle Creek (HL 66, 67, 68; Table F2) in the far western part of the district. All four samples from Eureka Creek contained anomalous values of Ag, As, Au, Pb, and Zn, with Au values as high as 4.5 ppm. Most of these samples were also anomalous in Sb, and two of them contained detectable Sn in amounts of 16 and 11 ppm. One of the three samples from Eagle Creek was anomalous in the polymetallic suite (Ag, As, Au, Pb, Cu, Sb, Sn, and Zn), with a Au content of 1.5 ppm.

Park district

The Park district, entirely within the Forest, encompasses an important system of polymetallic veins that have been exploited by a number of mines, chief among them being the Marietta. Lode deposits in the district were discovered in the 1870s, with the highest level of activity occuring between 1880 and 1906 (Reed, 1951). Information about the Marietta mine comes primarily from Sanguinetti (1986).

The Marietta mine exploits three important vein systems, the Marietta, Blue, and Gold Dust. The Marietta vein has been mined along a strike length of >1600 ft. The vein strikes nearly north-south, and dips west at a low angle (25°-40°), so that, although it has been worked down dip for over 600 ft, it is only about 300 ft below the surface at that point. The vein varies from about 6 in to nearly 10 ft wide at depth. Mineralized material consists chiefly of pyrite and arsenopyrite, with minor amounts of galena, sphalerite, chalcopyrite, and native Au, in a gangue of quartz and manganiferous carbonate. The wall rock, tuff of the Elkhorn Mountains Volcanics, is pyritized, silicified, and argillized for 3-6 ft on either side of the veins.

Drilling of 6 holes, designed to sample the Marietta vein down dip (west) from existing workings, found the vein to be 3-10 ft wide and to contain grades of 0.1-0.4 oz/st Au and 0.1-0.8 oz/st Ag. Resources remaining in surface waste dumps were estimated to contain 0.2 st Au and 1.3 st Ag. Activity subsequent to 1986 is unknown.

Two samples were collected from waste dumps in the Park district (HL 13, 50; table F2). Both contained anomalous amounts of Ag, As, and Au. HL 50, the more strongly mineralized of the two samples, contained 3.5 ppm Au and 3.5 percent As, along with anomalous amounts of Pb, Zn, Cu, and Cd.

It is difficult to assess ore controls in the Marietta vein system, because there are no intrusive rocks known to crop out nearby, and none are indicated by aeromagnetic or gravity data. Nevertheless, much of the system is unexplored, and it is likely that substantial reserves remain underground.

Winston district

Evidence of mineralization in the Winston district clusters around at least six quartz monzonite porphyry stocks, four of which appear to be aligned along the Weasel Creek fault. These are, from north to south, the Pole Creek, Edna, Monte Cristo, Freiburg, January, and Vosburg stocks (Klepper and others, 1971). Four of the stocks are associated with mines that had significant production from polymetallic vein deposits, Custer with the Edna stock, East Pacific with the Freiburg stock, January with the January Stock, and Vosburg and Little Olga-Kleinschmidt with the Vosburg stock. Earll (1964) estimated total production from these deposits to be about 3.57 st Au, 51 st Ag, and >6,000 st of Cu, Pb, and Zn. There was additional production of about 0.3 st of placer gold.

A series of samples from waste dumps in the vicinity of these mines (HL 23, 26, 27, 33, 34, 35A, 46, 47, and 55; table F2) are generally anomalous in the polymetallic suite of metals (Ag, As, Au, Cu, Pb, and Zn), along with some instances of high values of Bi, Cd, or Sb. Gold values are as high as 2.1 ppm, and the Ag:Au ratio is commonly about 100, distinctly higher than for the samples from the Diamond Hill area.

Stay Hot

The most promising area in the Winston district may be the Stay Hot prospect, located in sections 14, 15, 22, 23, 26, and 27 of T. 8 N., R. 1 W. This area includes the historic Sunshine and Maine-Sullivan deposits, which yielded only minor production. The area was explored by FMC Gold Company in 1988 and 1989. Most information comes from Hawksworth (1989).

A target called Scott's Ridge was developed, a zone 2,300 ft long that trends about N.70W., and contains both skarn Au and stockwork Au mineralization in the Slim Sam Formation. This area is mostly within the Forest, in the northwest quarter of section 23. Surface rock and soil sampling revealed a large area of 0.03 to 0.5 ppm Au, with some samples as high as 3 ppm, along with sporadic anomalies in Ag, Bi, Te, Cu, and As. Drilling in 1989 on BLM land to the north encountered zones of mineralized skarn and stockwork mineralization, but Au values were not as high as expected. The best intercept was 33 ft at about 0.06 oz/st Au. The most promising ground, which is within the Forest, has not been tested.

Our field examination revealed two additional areas of interest. Directly west of the Scott's Ridge target, on the west bank of Weasel Creek (section 22), a large area of disseminated pyrite and pyrrhotite in Elkhorn Mountains Volcanics suggests a large hydrothermal system. North of there, on BLM land on the south bank of Beaver Creek (section 15), an area of unknown size contains strong skarn mineralization with disseminated sulfide minerals.

Three surface rock samples were collected from the Stay Hot area during this study (HL 37A, 56, 77; table F2). None of them contained important amounts of precious metals, but one contained as much as 3,800 ppm Cu.

Chartam

A mineralized body called Chartam has been delineated at the Edna stock. Chartam is a group of low-angle quartz-pyrite veins in quartz monzonite porphyry that are closely enough spaced to be bulk-mined. The prospect is located in section 13, T. 8 N., R. 1 W., on BLM land, less than a mile from the Forest boundary, and was not visited during this study. The resource is reported to be 9.1 million st at 0.033 opt Au and 0.065 opt Ag by Giancola and Razvi (1993), who report that Chartam was originally explored by Montana Power, but became a Canyon Resources Corporation property in 1992, and was explored by Phelps Dodge Corporation, who did more than 2,000 ft of new drilling in 1992. There has been about 15,000 ft of drilling by previous workers. The area was reportedly being restored in the summer of 1994.

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CHAPTER G

MINERAL RESOURCE ASSESSMENT FOR LOCATABLE MINERALS

By Steve Ludington, J.E. Elliott, Christopher Osterman, and J.W. Whipple

INTRODUCTION

Resource assessments are of use to strategic planners, who plan for a nation's economic and military security; to economic planners, who estimate current and future mineral supplies and plan development; to mineral production companies, that use it to guide and help plan exploration; to governmental planning agencies, that help make decisions between competing land uses; and to public agencies that lease, trade, or sell publicly owned mineral resources. Our goal in the present study is to assess the undiscovered metallic and nonmetallic mineral resources in the Helena National Forest, Montana. An assessment of mineral resources (materials that are in such form that economic extraction of a commodity is currently or potentially feasible) can take many forms. The simplest might be a statement such as, "Yes, this is a good place to look for minerals." Another type of assessment might consist of an exhaustive inventory of the location, nature, and amount of known resources, which, in principle, is much like a shepherd counting sheep. An assessment of this sort would only be possible if the area were completely explored and no undiscovered deposits remained.

Qualitative estimates of the mineral content of specific areas have been with us for decades, if not centuries. All systematic mineral exploration requires decisions about the relative favorability of alternative tracts of ground. The assessment of undiscovered mineral resources in the Helena National Forest carries the evaluation process further, into the quantitative realm. A quantified assessment includes a numerical estimate of the amount and quality of mineralized rock and metal present within a tract (a specific area) to a specified depth. Because of the uncertainty inherent in assessment of the unknown, the results obtained are presented probabilistically. That is, the likelihood of the existence of undiscovered mineral deposits is expressed by a number. Because the resources being assessed are undiscovered, the assessment is necessarily subjective; it's quality is dependent on the collective knowledge and experience of the assessors. An assessment may be well done or poorly done, but because of the probabilistic nature of the result, it cannot be right or wrong. Likewise, it cannot be verified within the lifetimes of the assessors. Only with the passage of time, and with exhaustive exploration, will the accuracy of the assessment be known. Thus, *resource assessment is clearly an estimate and not a precise measurement.*

The quantitative assessment methods used in this study have been described by Singer (1993), Menzie and Singer (1990), Singer and Cox (1988), Drew and others (1986), and Singer and Ovenshine (1979). A thorough discussion of issues related to mineral resource assessment can be found in Barton and others (1995), along with an extensive bibliography on the subject.

Delineation of Permissive Tracts

The first part of the assessment process defines areas where mineral deposits are, or could be, present. These areas are said to be permissive for the deposit type being evaluated. They are different from areas where deposits are most likely to occur, because, by definition, the permissive tract will contain all undiscovered deposits that are postulated in the assessment process. In other words, the permissive tract is the land that remains after excluding those areas where there is no reasonable chance that the deposit type could occur. The definition of a reasonable chance is critical; if it is defined to be too small, the maps of permissive tracts would commonly be all-inclusive and therefore, of limited value. Singer (1993) has stated that the boundaries should be defined such that the probability of deposits occurring outside the boundary is "negligible, that is, less than 1 in 100,000 to 1,000,000." Unfortunately, there are very few types of mineral deposits whose genesis we understand well enough that we can eliminate the last vestige of probability that they might occur in any particular place.

For this study, within some of the permissive tracts, we have outlined subareas that are particularly favorable for the occurrence of deposits. These favorable tracts were designated because the geologic environment contains a coincidence of a large number of important features that are characteristic of a particular deposit type. In these favorable tracts, we believe that the spatial density of undiscovered deposits is higher than throughout the permissive area in general, although we are, in general, unable to specify how much higher.

Boundaries of the permissive tracts may not correspond exactly to the outcrops of permissive rocks on the geologic map. This is because we considered undiscovered deposits at some depth below the surface, and permissive conditions may extend beneath the cover of younger rocks. This subsurface extension of permissive areas is largely subjective because we did not apply detailed geophysical information to estimate depths to basement rocks.

GRADE AND TONNAGE MODELS

The size of mineral deposits is commonly referred to as the tonnage, meaning the amount of ore that has been or might be mined in order to extract the valuable materials in the deposit. The grade of a mineral deposit refers to its quality. Deposits with higher grades contain more valuable material per unit mass of ore. Grade and tonnage models are used as part of the resource assessment to help classify the deposits, thus aiding in tract delineation, and to provide information about the potential value of undiscovered deposits. They are created using measured grades and tonnages of well explored or mined deposits. When estimates of undiscovered deposits are made, the grade and tonnage models define the deposits being estimated. Combined with estimates of the number of undiscovered deposits, they are instrumental in translating geologic expertise into statements that economists can use. Grade and tonnage are expressed in metric units because they are the worldwide standard for expressing size and mass.

Frequency distributions of tonnage and grade of well explored or mined deposits are now available for many deposit types (Cox and Singer, 1986; Bliss, 1992; Orris and Bliss, 1991). For this study, we use some of those models, and have created some new ones. Table G1 provides a brief description of the deposit

Table G1. Mineral deposit models used in the mineral resource assessment.

Index	Model Name	No.	Descriptive model reference	Grade/tonnage model reference	Description	Selected references	comments
81	Porphyry Cu (North America)	17	Hammarstrom and others (1993)	Hammarstrom and others (1993)	Generalized model includes various subtypes, all of which contain chalcopyrite in stockwork veinlets in hydrothermally altered porphyry and adjacent country rock.	Titley (1982)	North American subset of Mark3 index 4
105	Skarn Au, truncated	n.a.	Theodore and others (1991)	Ludington and Cox (1996)	Gold in skarns near intrusive igneous contacts. Includes Cu, Zn-Pb, and Fe skarns with gold as a major commodity.	Meinert (1989)	Deposits from Mark3 index 82 that are larger than 15,000 metric tons
n.a.	Skarn W	14a	Cox (1986a)	n.a.	Tungsten in skarns within the thermal aureoles of apical zones of plutons that intrude carbonate rocks	Einaudi and others (1981)	
47	Polymetallic replacement	19a	Morris (1986)	Mosier and others (1986)	Hydrothermal, epigenetic, Ag, Pb, Zn, Cu minerals in massive lenses, pipes, and veins in limestone, dolomite, or other soluble rock near igneous intrusive contacts.	Graybeal and others (1986), Megaw and others (1988)	
n.a.	Polymetallic vein	22c	Cox (1986b)	n.a.	Quartz or quartz-carbonate veins with Au, Ag, and base-metal sulfides related to hypabyssal intrusions in sedimentary and metamorphic terranes.		Existing grade and tonnage models not appropriate to Forest
5	Climax molybdenite	16	Ludington (1986)	Singer, Theodore, and Mosier (1986)	Stockwork of quartz and molybdenite associated with fluorite in granite porphyry	Carten and others (1993)	
45	Hot Spring Au-Ag	25a	Berger (1986)	Berger and Singer (1992)	Fine-grained silica and quartz in silicified breccia with gold, pyrite, and Sb and As sulfides.	Berger (1985)	Revised grade and tonnage model in Bulletin 2004 (1992)
25	Epithermal vein, quartz-adularia	25c +25d	Mosier and others (1986),	Ludington and Cox (1996)	Gold, electrum, silver sulfosalts, and argentite in vuggy quartz-adularia veins hosted by felsic to intermediate volcanic rocks that overlie unspecified basement.	Heald and others (1987)	Combination of grades and tonnages of Comstock (index 16) and Sado (ndex 28)
13	Sedimentary exhalative Zn-Pb	31a	Briskey (1986)	Menzie and Mosier (1986)	Stratiform basinal accumulations of sulfides and barite interbedded with euxinic marine sediments form sheet- or lens-like ore bodies tens of meters thick, distributed through a stratigraphic interval of more than 1,000 m.	Large (1981)	
97	Sediment-hosted Cu, redbed	n.a.	Ludington and Cox (1996)	Ludington and Cox (1996)	Redbed copper deposits are stratabound mineralized bodies of disseminated copper and copper sulfides, with or without silver, uranium, and vanadium, occuring in reduced zones of red-bed sequences.	Kirkham (1989), Eugster (1989)	Subset of worldwide sediment-hosted Cu model (index 63)

Index refers to the number which uniquely identifies the grade and tonnage model used for estimation and simulation. See Root and others (1996).
No. refers to the number used for classification of deposit types in Cox and Singer (1986) and subsequent publications.
n.a. means not applicable.

types used in this assessment, and provides a cross-reference to the original descriptions of the various descriptive and grade and tonnage models.

Estimation of Number of Undiscovered Deposits

The method used to estimate the number of undiscovered mineral deposits in this study was subjective and used the expert judgment of a number of geologists familiar with the geology and mineral deposits present in the Forest. The assessment team gathered available pertinent information about the various types of mineral deposits that might occur in the study area. After reviewing the geologic, geochemical, and geophysical information, and after delineating the boundaries of the permissive tracts, each member of the assessment team made estimates of the number of undiscovered deposits at five probability levels (0.9, 0.5, 0.1, 0.05, and 0.01). The estimates were shared among team members, and those with extreme estimates, both high and low, were asked to justify their responses. The estimates were discussed until consensus on a single set of five values was attained.

The deposits are estimated consistent with the appropriate grade and tonnage model. That is, if 10 deposits are estimated, 5 of them are visualized to be larger than the median tonnage, and 5 of them are visualized to have a higher grade than the median grade of the distributions that constitute the models. Most of them will fall within the range of values in the models, also.

Although a large number of mineral-deposit types were considered in this study, many were excluded from our final analysis because of limited importance or inadequate information on which to base an estimate. Table G2 summarizes information for those deposit types formally analyzed and provides a synopsis of the estimates of numbers of deposits. The team that made the estimates reported in this chapter consisted of Steve Ludington, J.E. Elliott, C. Osterman, and J.W. Whipple. Some members of the team participated in the estimation of only specific deposit types. Not all members of the team that studied the Forest participated in the quantitative estimation process, although they provided geologic, geochemical, or geophysical input and discussion that aided those who made the estimates. The team that made the estimates includes geologists who have spent an extensive period of time (years) working in and adjacent to the Forest and (or) with the types of deposits that were evaluated.

Simulation

A computer program, the Mark3 simulator, is used to combine information about grade, tonnage, and estimated number of deposits into information about amounts of metal that may be present and about the quantity of ore, or mineralized rock that would be mined in order to recover the metal. Probabilities for the existence of undiscovered deposits are stated as inequalities because mineral deposits occur only as discrete numbers of deposits. A simulator must be used because the probability distributions used to describe grade, tonnage, and number of deposits are empirical (i.e., not mathematical functions) and cannot be combined mathematically. The quantiles of the grade and tonnage distributions cannot be multiplied to generate the quantiles of contained metal. Multiplying quantiles could be successful only if the ordinal lists of grades and tonnages were identical, a very unlikely event. The result of the simulation is a probability distribution of contained metal and ore, or mineralized rock.

The results of the simulations can be presented in various ways. Class-interval histograms emphasize, and make it easy to highlight, those amounts of metal that are estimated to be most likely to exist. Cumulative histograms are especially useful because all the information generated by the simulation can be read from a single plot. Various quantiles and the means are best used for comparisons between and among estimates for different deposit types or different permissive tracts. No single number can adequately represent the magnitude of an estimate, because no single number can represent the uncertainty in judgment that is inherent in the estimation process or the range of values that make up the grade and tonnage models.

UNDISCOVERED DEPOSITS IN THE FOREST

Below, we describe the particular estimates for undiscovered deposits in the Helena National Forest, along with the most important information that affected the estimates. The maps that portray the permissive and favorable tracts to which the estimates pertain are on plates 5 and 6, maps K through R. table G2 summarizes the estimates.

PORPHYRY COPPER DEPOSITS

Porphyry copper deposits are the most valuable type of metallic mineral deposit commonly found in North America. They commonly consist of hundreds of millions of tons of mineralized rock, and are usually mined by open-pit methods. They are genetically associated with epizonal igneous porphyry intrusions, and contain chalcopyrite in stockwork veinlets in hydrothermally altered porphyry and adjacent country rock. They are commonly associated with polymetallic vein, skarn, and replacement deposits.

Choice of Model

In this assessment, we used a grade and tonnage model for porphyry copper deposits that is made up of 107 examples from North America (Mark3 index 81) extracted from the worldwide model (Mark3 index 4) of Singer, Mosier, and Cox (1986). Mark3 index is a numerical identifier that refers to which grade and tonnage model the Mark3 simulator uses in any particular case (see table G1). The North American model was created for, and first used, in the Custer-Gallatin National Forest assessment (Hammarstrom and others, 1993). The 107-deposit North American model contains an average of 6 percent less mineralized rock, 20 percent less copper, 45 percent less molybdenum, 31 percent less gold, and 8 percent more silver than the worldwide model. The team judged that the slightly smaller size and lower copper grades of the North American model are more representative of the population of undiscovered porphyry copper deposits that might exist in central Montana.

Table G2. Summary of mineral deposit types analyzed, with numerical estimates of numbers of undiscovered mineral deposits (locatable minerals) in Helena National Forest. The columns labeled 0.9, 0.5, 0.1, 0.05, and 0.01 list the least number of deposits estimated to exist at the specified probability or more (Root and others, 1992). The Mark3 index identifies the specific grade and tonnage model used for the estimates (see Table G1).

	Probability					Mark3	
Deposit Type	0.9	0.5	0.1	0.05	0.01	Index	Comments
Porphyry Cu (North America)	0	0	1	2	3	81	There are 5 important prospects in or near the Forest; both permissive and favorable tracts were delineated.
Skarn Au	1	1	5	7	8	105	Au-poor, Cu-, Fe-, and Zn-bearing skarns were not analyzed separately, but the area is also permissive for them.
Skarn Au in Elkhorn Mountains	0	1	2	3	4	105	Separate estimate made because of different geologic environment.
Skarn W(Mo)	—	—	—	—	—	—	No formal estimate made because deposits in the Forest are very small.
Polymetallic Replacement	0	0	0	1	3	47	none
Polymetallic Vein	—	—	—	—	—	—	No appropriate grade and tonnage models; deposits may occur in entire Forest.
Polymetallic Vein (U-bearing)	—	—	—	—	—	—	No appropriate grade and tonnage models.
Climax molybdenite	0	0	1	1	2	5	none
York-type exhalative (?) Au	—	—	—	—	—	—	No numerical estimate; permissive tract only.
Cretaceous Au-bearing vein	—	—	—	—	—	—	No numerical estimate; permissive tract only.
Hot-spring Au-Ag	1	1	2	2	2	45	Hot-spring and epithermal vein deposits share the same permissive tract.
Epithermal vein, quartz-adularia	0	1	2	3	4	25	Hot-spring and epithermal vein deposits share the same permissive tract.
Sedimentary exhalative Zn-Pb	—	—	—	—	—	—	Area is permissive for deposits like Sheep Creek; no estimate made.
Sediment-hosted Cu, redbed	—	—	—	—	—	—	Deposits and prospects in the Forest are generally small; no estimate made.

Known Examples

There are several known examples of porphyry copper deposits and prospects within or near the Helena National Forest. Probably the best known deposit is at Heddleston (plate 2, map B; table E1, no. 42), which is related to a group of Eocene quartz monzonite plutons. This deposit was extensively explored by the Anaconda Company before 1973, but has never been mined.

In addition, a prospect known informally as Golconda (plate 2, map B; table E1, no. 392), is situated immediately adjacent to the Forest boundary, along the west flank of the Elkhorn Range, just east of Jefferson City. Some exploratory drilling was done here in the late 1970s, but its tonnage and grade are not known, nor is it known why the exploration effort was abandoned. The area is described in Ludington and others (1990).

Just outside the Forest, immediately west of Interstate 15, and to the south of Corbin, is another small porphyry copper deposit, known as Beaverton. It was explored extensively by several companies also in the late 1970s, although the present status of the prospect is not known. Much of the possible ore consisted of oxidized protore, and is probably enriched above the original tenor.

Directly outside the eastern boundary of the Elkhorn part of the Forest, the Morning Glory claims, on the Diamond Hill stock, were explored as a porphyry copper target from 1971 until 1983. Limited exploration yielded equivocal results. At Radersburg, about 3 mi southeast of the Forest boundary, exploration was conducted in the 1970s and two deep (>1,000 ft) holes were reportedly drilled. Details results of this exploration are not known, although anomalous copper was reportedly encountered.

On Jackson Creek (plate 2, map B; table E1, no. 405), southeast of Helena, an area with anomalous copper, molybdenum, and bismuth in bedrock samples, shows some similarities to a porphyry copper system, although its nature is very poorly understood (Greenwood and others, 1990).

Rochester (plate 2, map B; table E1, no. 62), which is about 7 mi. southeast of Lincoln, was explored in the 1980s (Brannon, 1981), but little is known about the results. Near Chessman Reservoir (plate 2, map B; table E1, no. 295), mineralized and altered rock typical of porphyry copper deposits was encountered during exploration of the Montana Tunnels deposit (Whiteley, 1982).

Tract Delineation

The permissive tract for porphyry copper deposits was delineated using the procedure outlined below, and is depicted on plate 5, map K. First, areas of exposed plutonic rocks of the Boulder batholith were delineated, including an approximately 2 mi-wide buffer to capture areas underlain by concealed plutons and subsurface extensions. This area was extended to include areas where aeromagnetic data suggested the possibility for other buried plutonic rocks, and also to include known polymetallic vein and polymetallic replacement districts, which are often spatially associated with porphyry copper deposits. All the known porphyry copper prospects fall within the resulting permissive tract. The tract was found to be generally coincident with the areas where high values of Cu occur in stream-sediment samples (see Chapter D).

In addition, two areas north and south of Helena were delineated to constitute a favorable tract. These are areas where all the characteristics listed above are present. The northerly area contains the Heddleston deposit; the southern one is centered on the northern end of the Boulder batholith, and includes most of the Elkhorn Mountains.

Estimate of Undiscovered Deposits

For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 1, 2, and 3 undiscovered porphyry copper deposits consistent with the North American subset (Mark3 index 81) of the porphyry copper grade and tonnage model of Singer, Mosier, and Cox (1986). The estimates were strongly influenced by the fact that there has been substantive exploration on at least five prospects within the permissive tract, and within, or very near to, the Forest boundaries. All of these prospects have been explored extensively, many by diamond drilling. The team considered that Golconda and Rochester were the prospects most likely, if fully evaluated, to qualify as deposits in terms of size and grade. In addition, there is already one known deposit (Heddleston) within the Forest, and another (Beaverton) very near the Forest boundary.

GOLD SKARN DEPOSITS

Skarn deposits are mineral deposits wherein the ore consists primarily of carbonate and calc-silicate minerals, formed by metasomatic replacement of the original rocks, adjacent to, and sometimes, in, plutons. Valuable metals are found in and in association with sulfide minerals distributed throughout the skarn. Gold skarns are often attractive targets for mineral exploration. They tend to have higher grades and are smaller than many other important types of gold-bearing deposits. Hence, they may be mined less-expensively and with smaller excavations and infrastructure investments.

Choice of Model

The abundance of various metals in skarn deposits may well form a continuum; their categorization is based on the materials present that have the greatest value. Thus, gold skarns are those skarn deposits in which gold is the most valuable metal in the deposit. Exploration for skarn deposits in Montana has focused closely on gold during the last decade. Thus, although there are a few examples of copper- and (or) zinc-lead- bearing skarns in the region that did not contain significant gold, we chose not to evaluate them separately, as they are unlikely to be a target for mineral development during the lifespan of this assessment.

Theodore and others (1991) presented a grade and tonnage model for gold skarns, and included data for 90 deposits. They restricted deposits in the model to those that had gold grades greater than 1 g/ metric ton. This model has since been used for quantitative assessment in a number of instances. However, this team believes that many of the deposits that make up that model are inappropriate, in that they are too small to be significant attractions for development today. Therefore, we created a truncated model (Mark3 index 105), discarding the 27 deposits that contained less than 15,000 metric tons of mineralized rock. The remaining 63 deposits contain more than 99 percent of the metal present in the deposits that make up the original model.

Known Examples

The Spring Hill mine (plate 2, map B; table E1, no. 476) is one of several good examples of small gold skarn deposits; in addition, there are others in the Helena district. In the Ophir district, a number of mines have produced small amounts of gold from skarn deposits in the past.

More significantly, the Diamond Hill deposit in the Elkhorn Mountains (plate 2, map B; table E1, no. 477), is presently undergoing active exploration by Pegasus Gold. Diamond Hill is located immediately adjacent to the eastern boundary of the Elkhorn region of the Forest, and contains a known resource of greater than 10 metric tons of gold, with opportunities to discover more. The deposit is found in the lower member of the Elkhorn Mountain Volcanics, along the southern margin of the Silver Wave stock, and occurs in near-vertical pipe-like bodies that extend to at least 500 m below the surface. The skarn bodies consist of medium-grained, inequigranular masses of quartz, calcite, actinolite, chlorite, epidote, and(or) garnet, along with minor pyrite, pyhrrotite, and chalcopyrite that replace the enclosing volcanic rocks. Gold is temporally associated with pyrite and occurs as free grains and as thin films on pyrite.

Nine other areas in the Elkhorn Mountains were judged to have a specific probability of occurrence for gold skarn deposits. They include areas near the Antelope, Vosburg-January-Freiburg, Monte Cristo, Vulture, Silver Wave, South Fork, Slim Sam, and Swamp Creek stocks, and the Marietta Mine area (plate 2, map B; table E1, no. 460).

Gold skarn deposits in the Elkhorn district (plate 2, map B; table E1) are about 3 mi. southwest of the Forest boundary, near the townsite of Elkhorn, in the Deer Lodge National Forest. A silver-rich replacement deposit was exploited here in the 19th and early part of the 20th centuries. Exploration in the 1980s encountered gold skarn deposits nearby that are currently undergoing continued exploration and evaluation. Deposits here could contain 1 million troy oz. of gold.

Tract Delineation

In deciding which areas to include within the permissive tract for this deposit type, we used the basic criteria that a skarn deposit requires a reactive host rock and an intrusion to provide heat, fluids, and metals. Accordingly, we began by outlining those areas that are near plutons, both exposed and inferred, and that are underlain by carbonate-bearing strata. Formations included in the permissive tract are the Helena, Empire, Shepard, Red Lion, and Hasmark Formations; the Park Shale, Meagher Limestone, Wolsey Shale, and Flathead Sandstone; the Three Forks, Jefferson, and Maywood Formations, and members of the Madison Group; and the Amsden, Phosphoria, and Kootenai Formations. We excluded rocks of the Colorado Group, the Blackleaf, Mount Shields, and Bonner Formations, all intrusive rocks, and volcanic rocks outside of the Elkhorn Mountains. An area underlain by the Elkhorn Mountains Volcanics was included in the permissive tract because of the occurrence of the Diamond Hill deposit, which proves that subaerial andesites can be reactive in some cases. We then ensured that this area included all the known gold skarn deposits and prospects. The resulting permissive tract is depicted on plate 5, map L.

We then delineated a smaller area, designated as favorable. To qualify as favorable, areas had to meet the above criteria, including being near important deposits or prospects, and, in addition, they had to exhibit anomalous gold geochemical values, as shown by the NURE stream-sediment data (Chapter D). The resulting favorable tract consists of three small areas west and south of Helena, and a large area composed of volcanic rocks that form the roof of the Boulder batholith along the east flank of the Elkhorn Mountains (plate 5, map L).

Estimate of Undiscovered Deposits

Two discrete estimates were made of numbers of undiscovered deposits, both consistent with the gold skarn grade and tonnage model of Theodore and others (1991), modified as described above (Mark3 index 105). For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 1, 1, 5, 7, and 8 undiscovered gold skarn deposits for the part of the permissive tract exclusive of the Elkhorn Mountains, and 0, 1, 2, 3, and 4 or more undiscovered gold skarn deposits for the part of the permissive tract in the Elkhorn Mountains. The presence of important representatives of this deposit type in the immediate vicinity of the Forest weighed heavily in our estimate. In the Elkhorn Mountains, many of the mafic alkaline satellitic stocks on the east flank of the range are petrochemically similar to source plutons for gold skarns elsewhere.

TUNGSTEN-(MOLYBDENUM) SKARN DEPOSITS

Skarn deposits are mineral deposits wherein the ore consists primarily of carbonate and calc-silicate minerals, and that formed by metasomatic replacement of the original rocks, adjacent to, and sometimes, in, plutons. Very few tungsten skarn deposits are polymetallic, and most are exploited only for tungsten, although many contain trace amounts of molybdenum (including some of the prospects in the Forest) which is sometimes produced as a byproduct. Meinert and others (1990) showed that tungsten skarn deposits are associated with intrusive rocks that are somewhat richer in silica than the intrusive rocks that are characteristic of gold, copper, or zinc-lead skarns. The Butte Quartz Monzonite (plate 1) and many other rocks of the Boulder batholith are of the appropriate composition to generate tungsten skarn deposits.

Choice of Model

Tungsten skarn deposits are an important source of tungsten worldwide, but known deposits and occurrences in Montana, and those in and near the Forest are small, and the available grade and tonnage model was judged to be inappropriate to this area. Exploration for this deposit type in the United States is limited. Worldwide tungsten production is dominated by low-cost operations in Asia, and deposits like those that might be found in the Forest are unlikely to be exploited without a significant increase in the price of tungsten.

Known Examples

Skarn deposits in the Ophir district (plate 2, map B; table E1), 7-10 mi northwest of Elliston, have produced a small amount of tungsten, certainly less than 100 tons. Recent exploration in the Ophir district, however, has been directed toward gold-bearing deposits. Other possible historic tungsten skarn deposits and prospects are in the Big Blackfoot and Stemwinder Hill districts, and in the Dog Creek area.

Tract Delineation

For the permissive tract for tungsten skarn deposits, we delineated the same area as for gold skarns, with one important exception; areas underlain by the Elkhorn Mountains Volcanics were also excluded from the permissive tract because tungsten skarns are not known to occur in volcanic rocks. We then ensured that this area included all the known tungsten skarn deposits and prospects; the result is depicted on plate 5, map L.

Again, we designated three small areas to constitute a favorable tract (plate 5, map L). These three areas had to meet all of the above criteria, including being near important deposits or prospects; they are west and south of Helena and are apparently related to outlying granodiorite plutons at the north end of the Boulder batholith.

Estimate of Undiscovered Deposits

Because the team believed that Montana tungsten skarn deposits are likely to be small, compared to others found worldwide, the existing grade and tonnage model was judged to be inappropriate to this area, and no numerical estimates were made.

POLYMETALLIC REPLACEMENT DEPOSITS

Polymetallic replacement deposits typically form tabular, pod-, and pipe-like ore bodies that may be localized by faults or favorable sedimentary strata. The deposits are found in sedimentary rocks, chiefly carbonates (limestone and dolomite), which are intruded by porphyritic plutons. Massive carbonate beds that may fracture readily during intrusion and deformation are the preferred host rock. Mineral zoning is common, with inner zones rich in chalcopyrite or enargite and outer zones containing only sphalerite and rhodochrosite. Jasperoid is commonly found near ore bodies.

Choice of Model

Polymetallic replacement ores have been important sources of lead, zinc, and silver throughout history. However, Helena Forest examples are smaller than the majority of the districts that make up the worldwide grade and tonnage model (Mosier and others, 1986); most important U.S. districts are in Nevada and Utah. The Elkhorn mine, nearby in the Deer Lodge Forest, was a significant deposit, however, and we determined that the worldwide model is appropriate to the Forest.

Known Examples

Polymetallic replacement-type mineralization is found in the Austin and Ophir districts within the Forest (plate 2, map B; table E1). In addition, the Elkhorn mine (plate 2, map B; table E1), nearby in the Deer Lodge National Forest is representative of this type of deposit.

Tract Delineation

In a particular mineral system, polymetallic replacement deposits are usually found farther from intrusive rocks than related skarn deposits. However, at the small scale of this assessment, this distinction becomes trivial, and we considered the criteria for delineation of the permissive tract to be the same for polymetallic replacement as for skarn deposits. We used the criteria that a polymetallic replacement deposit requires a reactive host rock and an intrusion to provide heat, fluids, and metals. Accordingly, we outlined areas near plutonic rocks, both exposed and inferred, that are underlain by carbonate-bearing strata. Formations included in the permissive tract are the Helena, Empire, Shepard, Red Lion, and Hasmark Formations; the Park Shale, Meagher Limestone, Wolsey Shale, and Flathead Sandstone; the Three Forks, Jefferson, and Maywood Formations, and members of the Madison Group; and the Amsden, Phosphoria, and Kootenai Formations. We excluded rocks of the Colorado Group, the Blackleaf, Mount Shields, and Bonner Formations, all intrusive rocks, and all volcanic rocks. We then ensured that the resulting area included all the known polymetallic replacement deposits and prospects; the result is depicted on plate 5, map M. No favorable area was delineated.

Estimate of Undiscovered Deposits

Polymetallic replacement deposits rarely form in isolation, and examples in the grade and tonnage model are districts, which commonly cover tens of square miles. Thus, the team reasoned that, because of their size, undiscovered districts are unlikely to be concealed beneath alluvial cover, and are unlikely to have been overlooked by past exploration. Thus, a relatively small estimated number of deposits seemed appropriate. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 1, and 3 or more polymetallic replacement deposits, consistent with the grade and tonnage model of Mosier and others (1986) (Mark3 index 47).

POLYMETALLIC VEIN DEPOSITS

Polymetallic vein deposits are the most common type of metallic mineral deposit in the Helena National Forest, and possibly, in the world. They appear to be a product of the emplacement of intrusive rocks into shallow to moderate levels of the crust. Thus, areas permissive for the occurrence of polymetallic vein deposits are the same as those for porphyry copper deposits. Indeed, polymetallic vein deposits are commonly used in prospecting, as an indicator of porphyry copper deposits. These vein deposits are associated with a wide spectrum of compositions of igneous rocks. Quartz is commonly the most important gangue mineral, whereas the most important metallic minerals are pyrite, sphalerite, galena, and various silver-bearing minerals, along with electrum.

Although polymetallic vein deposits have provided a large part of the past production of mineral wealth in Montana, and in the entire western United States, there is, at present, no suitable grade and tonnage model for these deposits. The existing model (Bliss and Cox, 1986) is not representative of deposits in the Rocky Mountains. The known deposits, like polymetallic replacement deposits, occur in districts, often consisting of dozens of individual veins and(or) mines. In contrast, many of the deposits used in the Bliss and Cox (1986) model are individual mining entities, and consist of only a very small part of the district in which they occur. The sizes of deposits in the model are too small to be used reliably in Montana, and no quantitative estimates were made, even though we believe the remaining resource in these known districts is substantial.

Districts within the scope of this study that incorporate many polymetallic vein deposits include Basin, Big Blackfoot, Clancy, Corbin-Wickes, Elliston, Heddleston, Indian Creek, Marysville, Park, Radersburg, Rimini, and Winston.

Because of the large size of polymetallic vein districts, the team believes that there are few undiscovered districts in exposed areas. Any that might exist would be in areas covered by surficial sediments. Perhaps of more significance is the resource remaining in known districts. Mining halted in nearly all these districts for economic or political reasons, not because mineralized rock was exhausted. The remaining resource in these areas is probably as large or larger than the resource that may exist in undiscovered districts. However, we presently lack a technology for estimating this resource.

URANIUM-BEARING POLYMETALLIC VEIN DEPOSITS

Some polymetallic vein deposits in the Forest contain trace amounts of uranium, and a few produced small amounts of uranium ore. Most of these veins are in a northeast-trending band that extends from southwest of Clancy to the vicinity of Lava Mountain. It is probable that the uranium in the veins is related to the intrusion of the rhyolites, because of the veins' spatial distribution and coincidence with an area of northeast-trending, highly-evolved, rhyolitic dikes and minor intrusions of Oligocene age. Wenrich and others (1990, their plate 5) demonstrated that aerial gamma ray spectroscopic data outline an area of anomalous radioactivity coincident with these veins. Some of these deposits have also been exploited as "health mines" for some years. The amount of uranium in these deposits is not known, but must be very small. We do not believe these veins are likely to be a significant source of uranium, nor will they be an attractive exploration target during the lifetime of this assessment.

CLIMAX MOLYBDENITE DEPOSITS

Climax molybdenite deposits are invariably associated with high-silica granite or rhyolite. These high-silica rocks display a characteristic geochemical signature and are strongly enriched in Rb, Y, Nb, Th, Sn, and W (Ludington, 1986). They exhibit higher molybdenite grade, and higher fluorine contents than other large, porphyry-type molybdenite deposits. Climax deposits included in the grade-tonnage model (Singer, Theodore, and Mosier, 1986) all have three or more ore bodies, formed by repeated porphyry intrusion, but included together as one deposit in each case. Considering this fact and the restricted permissive environment, the occurrence of a Climax deposit should be considered an uncommon event. Topaz-bearing rhyolites, like those at Lava Mountain in the Elkhorn Mountains, have been suggested (Burt and others, 1982) to mark the tops of deeply buried deposits.

Known Examples

There is one important Climax deposit in Montana, at Big Ben (376 million metric tons at 0.098 percent Mo; Carten and others, 1993), in the Little Belt Mountains, about 50 mi northeast of the Forest. The Bald Butte deposit (plate 2, map B; table E1, no. 133), a few thousand feet outside the Forest southwest of Marysville, appears to have most of the characteristics of a Climax deposit. A sample of drill core from the deposit analyzed for this study showed elevated contents of Rb (>350 ppm), Nb (>70 ppm), Y (>150 ppm), Sn (>100 ppm), and W (>100 ppm). These are all important components in the geochemical signature of Climax deposits. The presently known resource at Bald Butte is smaller (14 million metric tons at 0.1 percent Mo; Carten and others, 1993) than any of the deposits in the grade and tonnage model and is unlikely to be exploited within the lifespan of this assessment.

Tract Delineation

The following criteria were used to delineate the permissive tract for Climax deposits: 1) stream-sediment anomalies for Mo, sometimes accompanied by Bi, Sn, and W; 2) the presence or suspected presence of high-silica rhyolite flows, dikes, and small stocks; 3) trace-element geochemistry of rhyolites that exhibits elevated Rb, Y, Nb, W, Sn, or Th. To meet any one of these criteria was deemed sufficient evidence to make an area permissive.

We delineated a permissive tract that consists of three discrete areas in the western part of the Forest (plate 5, map N). In the north, an area that encompasses the McDonald Meadows area and the Stemple-Gould district was delineated. Some of the rhyolites at McDonald Meadows display elevated Y, Nb, and Th, even though hydrothermal alteration may have altered their Rb, Sr, and Ba contents. The Stemple-Gould district is the site of a pronounced Mo anomaly in stream-sediment data, but no rhyolitic rocks are known in the area. Farther south, a nearly circular area was delineated north of MacDonald Pass on U.S. 12. The basis for delineation of the northern part of this area is the deposit at Bald Butte, which is apparently responsible for another large Mo anomaly in stream-sediment data. The southern part of this area contains a cluster of rhyolite intrusions west of Mullan Pass that can be inferred to be the source of the Avon volcanics, part of which are high-silica rhyolites. Farther south, a third permissive area stretches from near Basin, north-northeast to the vicinity of Lava Mountain in the Elkhorn Mountains. This area was delineated primarily because of the occurrence of a series of high-silica flows and intrusions, and it also displays a moderately-strong Mo anomaly in stream-sediment data, centered just northeast of Chessman Reservoir. The tract is delineated on plate 5, map N.

Estimate of Undiscovered Deposits

We envisioned a number of possible sites for undiscovered Climax deposits within the permissive tract: McDonald Meadows, the Stemple-Gould district, the Bald Butte area, west of Mullan Pass, the vicinity of Buffalo Gulch (near Chessman Reservoir), the Basin area, and the vicinity of Lava Mountain. We evaluated the possibility that each of these might be the site of an undiscovered deposit. The area west of Mullan Pass is probably the most highly favorable target, and we estimated that there is about one chance in 20 that it contains an undiscovered deposit. Stemple-Gould is difficult to evaluate because no rhyolites are known from the area. We doubt that there is room in the Bald Butte area for a new undiscovered deposit, though Mo resource there could likely be increased with further exploration. McDonald Meadows, Basin, Buffalo Gulch, and Lava Mountain were judged to be much less interesting, with estimated probabilities of occurrence between 1 in 10,000 and 1 in 1,000. Our final estimate was, for the 90th, 50th, 10th, 5th, and 1st percentiles, 0, 0, 1, 1, and 2 or more Climax deposits (Singer, Theodore, and Mosier, 1986) (Mark3 index 5).

YORK-TYPE EXHALATIVE(?) GOLD DEPOSITS (AND AU-BEARING VEINS

The York district, on the southwest flank of the Big Belt Mountains, contains a unique combination of geologic characteristics that suggest the possible presence of a heretofore unknown mineral deposit type (see Chapter F, York district). An extensive zone in the Middle Proterozoic Greyson Formation is characterized by uncommon amounts of potassium, with as much as 12 weight percent K_2O. These zones, termed reefs, are also characterized in part by elevated gold contents. Very little of this rock apparently contains enough gold to be classified as ore, but there is a large low-grade resource. Thorson and others (in preparation) quote a resource of more than 7 million oz., using a cutoff grade of 0.01 opt. Within this zone, some gold-bearing vein deposits are known, most notably the Golden Messenger mine (Pardee and Schrader, 1933). The Late Proterozoic mafic dike that hosts the Golden Messenger and associated prospects intrudes the northwest end of the gold- and potassium-enriched zone described above; thus these vein deposits may contain gold that has been remobilized from the potassic reefs.

Tract Delineation

The gold- and potassium-enriched reefs can be difficult to recognize in the field, especially in areas of poor outcrop. However, the map of aeroradioactivity due to potassium (fig. C6) delineates the known anomalous zones (reefs) quite well. For this reason, we relied primarily on this map to delineate a permissive tract where similar chemically anomalous zones and possible associated mineral deposits may be found. This area extends the length of the Big Belt Mountains (plate 6, map O).

Estimate of Undiscovered Deposits

In the absence of a grade and tonnage models (even the descriptive model is very preliminary), no estimates of undiscovered resources could be made. However, we expect the permissive area to continue to be the site of prospecting for possible gold deposits.

CRETACEOUS GOLD-BEARING VEIN DEPOSITS

The gold-bearing vein deposit at Miller Mountain, in the Confederate Gulch district in the Big Belt Mountains (see Chapter F, Confederate Gulch district), is difficult to classify. Polymetallic vein deposits can be quite variable in their mineralogy, and deposits that are gold-rich and those that show an almost complete lack of gold can both be so classified. There are several gold-rich prospects and occurrences of this type around the margin of the Boulder pluton, south of Miller Mountain. But the deposits at Miller Mountain are notably poor in base metals and contain almost no sulfide minerals except pyrite and arsenopyrite. Veins with mineralogy similar to that at Miller Mountain are usually classified as low-sulfide gold-quartz veins, but the tectonic setting at Miller Mountain is not indicative of that deposit type, which is normally associated with deep-seated shear zones, and low- to medium-grade metamorphic terranes. The polymetallic veins around the Boulder pluton and the deposits at Miller Mountain are all apparently Late Cretaceous in age, however, and, largely for this reason, we have classified them together. In the Big Belt Mountains, we have delineated a permissive tract for these vein deposits, based largely on proximity to pluton margins, and to the location of known prospects (plate 6, map O). In essence, this tract describes the area where we predict that exploration for deposits like Miller Mountain will continue. As with the York-type occurrences, there is no grade and tonnage model, and we made no estimate of undiscovered resources.

QUARTZ-ADULARIA AND HOT-SPRING GOLD-SILVER DEPOSITS

Quartz-adularia deposits consist of epithermal veins or groups of veins that typically have a sulfide assemblage that includes argentite, tetrahedrite, tennantite, and variable amounts of galena and sphalerite. Gold, as electrum, is usually present. Hydrothermal alteration associated with these deposits is characterized by sericitic and argillic alteration assemblages, along with adularia and carbonate; primary alunite is not associated with the main stage of mineralization. The mineralized area is often elongate, and some of the deposits and districts are very large, with vein systems many miles long. Structural controls for intrusion and mineralization are complex; caldera ring and radial fracture settings are not uncommon, yet some deposits occur remote from any caldera. Most deposits formed at paleodepths of less than a few thousand feet, with many forming within a few hundred feet of the paleosurface.

Hot-spring gold-silver deposits, defined by Berger (1985, 1986), represent the uppermost parts of epithermal systems, and formed within a few tens to hundreds of feet from the surface. They appear to form above quartz-adularia deposits, thus will be found in the same regions and geologic environments. We estimated numbers of undiscovered deposits for both types independently.

Choice of Model

Epithermal quartz-adularia gold deposits have been divided into three subtypes—Creede, Comstock, and Sado (Mosier and others, 1986). Because of difficulties in distinguishing among the environments likely to contain these subtypes, we evaluated the possible occurrence of epithermal quartz-adularia vein districts using a combination of the Comstock and Sado grade and tonnage models (Mark3 index 25). The grade and tonnage model of Berger and Singer (1992) (Mark3 index 45) was used to evaluate hot-spring gold-silver deposits.

Known Examples

Important deposits in the Forest that were classified as quartz-adularia deposits include Drumlummon, Jay Gould, and Piegan-Gloster (plate 2, map B; table E1, nos. 139, 105, and 119). The most significant hot-spring deposit, which lies outside the Forest, is clearly McDonald Meadows (plate 2, map B; table E1, no. 53), one of the largest gold deposits in the United States (see Chapter F, Blackfoot River area).

Tract Delineation

The following criteria were used to delineate the permissive tract for quartz-adularia and hot-spring gold-silver deposits: 1) presence of Tertiary volcanic rocks and 2) presence of epithermal prospects or deposits in or near the Forest. The Elkhorn Mountains Volcanics were not included because there is minimal evidence that this type of mineralization is associated with the Cretaceous volcanic rocks. We also excluded areas that appear to be too deeply eroded to preserve epithermal deposits. The resulting permissive tract is depicted on plate 6, map P.

Estimate of Undiscovered Deposits

Our resource estimates were based primarily on the number of known and suspected eruptive centers and very shallow plutons, combined with the occurrence of known deposits and prospects. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 1, 1, 2, 2, and 2 or more hot spring deposits and 0, 1, 2, 3, and 4 or more quartz-adularia districts.

SEDIMENTARY EXHALATIVE ZINC-LEAD DEPOSITS

Sedimentary exhalative (sedex) deposits are large deposits of zinc, lead, and silver; their shape is generally similar to that of the host sedimentary strata. They are an important worldwide source of zinc and lead, and some of the largest deposits in the world are in North America (Menzie and Mosier, 1986). They are formed during, or shortly after, deposition of clastic rocks in the deep part of ocean basins, apparently due to expulsion of metal-bearing hydrothermal fluids from the basins along faults that are active during deposition. Individual deposits are commonly not directly associated with igneous rocks.

Known Examples

The Sullivan deposit, in British Columbia, Canada, is an important example of sedex deposits. It is one of the largest in the world, and is found in a tectonic and stratigraphic setting that is similar to parts of the Belt Supergroup in the Forest. The Sheep Creek deposit (see Chapter F, Big Belt Mountains region), east of the Forest on the south flank of the Little Belt Mountains, contains many similarities to sedex deposits, especially style of alteration and tectonic setting. Its metallogeny is, however, quite distinct; Sheep Creek is rich in copper, cobalt, and nickel. Nevertheless, we believe that Sheep Creek and any other deposits like it formed in a similar environment to that in which zinc- and lead-rich sedex deposits developed.

Tract Delineation

A permissive tract for sedex deposits, including those similar to the Sheep Creek deposit was defined by inclusion of Proterozoic rocks that were deposited in deep water environments (below wave base). This restriction indicates that most of the Newland Formation and the lower two-thirds of the Greyson Formation are permissive. The tract was delineated using the presence of these stratigraphic units, and their possible subsurface extensions within about 1,000 feet from the surface. Syndepositional faults may be present in other nearby parts of the Belt Basin, but this feature has not been clearly demonstrated in the Forest. The resulting permissive tract is depicted on plate 6, map Q.

Estimate of Undiscovered Deposits

Although the tectonic and stratigraphic environment supports the delineation of a permissive tract for sedex deposits, the absence of demonstrable syndepositional faulting argues against their presence. Our assessment team estimated that there is a chance of approximately 1 in 1,000 that an undiscovered sedex deposit exists in the Helena National Forest.

SEDIMENT-HOSTED COPPER DEPOSITS, REDBED TYPE

Sediment-hosted copper deposits are layered, stratabound, and locally stratiform mineralized bodies of disseminated copper and copper sulfides, with or without silver, uranium and vanadium. Their formation is associated with acidic, reducing environments, and they often form at the boundary between oxidized and reduced sedimentary rocks.

Choice of Model

Sediment-hosted copper deposits and prospects in the Helena Forest are in Proterozoic shallow-water clastic and mixed clastic and carbonate rocks, and appear to be of the redbed type. Three subtypes were recognized locally (see Chapter F), deposits that occur in (1) quartzite, 2) greenbeds (siltite and argillite), and 3) carbonate (limestone and dolomite). In addition, some small copper-bearing vein deposits appear to have formed by remobilization of the sediment-hosted deposits. These vein occurrences are not assessed separately, as they are generally small and of little significance.

Known Examples

Known examples of prospects and occurrences in the Forest include the Hayworth claims (Alice) (quartzite subtype), Copper Hill (greenbed subtype), and Klondike (carbonate subtype) (plate 2, map B; table E1, nos. 19, 112, and 2). All are small, and the total amount of production from deposits of this type in the Forest is negligible. A few deposits have small to moderate identified resources.

Tract Delineation

A permissive tract in the Forest was defined by inclusion of Proterozoic rocks that were deposited in shallow water. This restriction indicates that the Spokane and Empire Formations, the upper third of the Greyson Formation, the Missoula Group, the lower 2 m of the Helena Formation, and the Bonner and McNamara Formations are permissive. That is, of the Proterozoic section, only the Helena and Newland Formations and the lower two-thirds of the Greyson Formation are excluded. The tract was delineated using these stratigraphic units, and their possible subsurface extensions, to a depth of about 500 feet.

A favorable tract was delineated within the permissive tract. It was restricted to the Spokane and Empire Formations, and used the additional criteria that prospects must be present, and that stream-sediment samples contain anomalous amounts of copper. The resulting permissive tract is depicted on plate 6, map R.

Estimate of Undiscovered Deposits

Deposits and prospects in the Forest are small, and the team judged that there is less than a 1 in 100 chance that any deposits are present that are representative of any applicable grade and tonnage models.

SIMULATION RESULTS AND ESTIMATED CONTAINED METAL

The results of the Mark3 simulations are reported in table G3, and figures G1 through G7.

A summary of the results of this assessment is presented in table G4. It shows the amount of undiscovered contained metal predicted to exist in the 6 deposit types that were evaluated. Although the table is a convenient summary, it does not convey a complete answer to the question, "What is the magnitude of undiscovered resources in the study area?" The *mean* and *median* values in the table are statistical characteristics of populations, which are products of simulation, using the computer program called MARK3, described in Root and others (1992). The amount of undiscovered resource, for any given metal, cannot be properly represented by any single number.

Nature of Distributions

The probability distributions that result from the computer simulations are different from those with which many users are familiar, due primarily to the marked asymmetry of most known tonnage distributions. In all the deposit types considered in the study area, a few large deposits in the grade and tonnage models account for a large proportion of the contained metal. Logarithmic standard deviations representing nearly an order of magnitude or more are common among the tonnage models compiled by Cox and Singer (1986). This is one reason why the *mean* amounts of metal are commonly significantly larger than the *medians*, and why amounts as large as the mean are unlikely to exist. For example, with reference to figure G3, the *median* (50th percentile) copper estimate is 780 metric tons, whereas the *mean* estimate is 42,000 metric tons, nearly two orders of magnitude larger. For this copper estimate, there is less than a 16 percent probability of occurrence of an amount as large as the *mean*.

In addition, the proportion of this undiscovered metal that can be recovered at a profit is not determined here. The estimated undiscovered metal is that present *in deposits like those in the associated grade and tonnage models* (see table G1). Some deposits in the models are economic, and some are not. The economic viability of any individual mineral deposit is a function of current metal prices and mining and recovery costs. Also, of course, new resources may well be discovered in the form of deposit types not considered in this study, or not yet conceived of.

Meaning of the Estimates

Whatever form is used to communicate the results of these estimates, it is well to remember that they reflect a large uncertainty in the number and sizes of undiscovered deposits of the types evaluated. Undiscovered deposits are, by their very nature, not known with a high degree of certainty. Furthermore, not all types of deposits known to be present in the study area could be evaluated.

The most important conclusion that can be drawn from the probability distributions represented in tables G3 and G4, and figures G1 through G7, is the dominant role that copper and gold play in the Forest. These two commodities constitute approximately 90 percent of the potential value of the undiscovered

Table G3. Summaries of simulated metal and mineralized rock in undiscovered deposits in the Helena National Forest at 5 probability levels, and at the mean (all amounts are in metric tons). Each subtable describes predicted resources in one type of mineral deposit, A) Porphyry Cu deposits, North American subset, B) Skarn Au deposits for all areas except Elkhorn Mountains, model truncated to those with >15,000 t of ore, C) Skarn Au deposits for Elkhorn Mountains, model truncated to those with >15,000 t of ore, D) Polymetallic replacement deposits, E) Climax Mo deposits, F) Hot-spring Au-Ag deposits, and G) Epithermal quartz-adularia vein deposits. Index refers to the number which uniquely identifies the grade and tonnage model used for estimation and simulation. See Root and others (1996). Estimated numbers of deposits are in Table G2.

A. Mark3 Index 81: Porphyry Cu (North America)

quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	2,000,000	21,000	10	300	420,000,000
0.05	4,300,000	78,000	37	1,100	840,000,000
mean	920,000	20,000	9	260	170,000,000
Probability of mean	0.15	0.10	0.10	0.10	0.16
Probability of zero	0.70	0.81	0.86	0.84	0.70

B. Mark3 Index 105: Skarn Au, truncated (except Elkhorn Mts.)

quantile	Cu	Au	Fe	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	53,000
0.50	12,000	9	0	18	0	2,800,000
0.10	240,000	70	665,000	290	11,000	29,000,000
0.05	470,000	110	1,600,000	570	33,000	44,000,000
mean	85,000	25	390,000	130	32,000	9,800,000
Probability of mean	0.19	0.28	0.12	0.20	0.05	0.29
Probability of zero	0.20	0.07	0.86	0.19	0.80	0.07

C. Mark3 Index 105: Skarn Au, truncated (Elkhorn Mts.)

quantile	Cu	Au	Fe	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	780	2	0	2	0	510,000
0.10	80,000	33	0	110	0	16,000,000
0.05	230,000	54	460,000	250	9,300	25,000,000
mean	42,000	12	150,000	59	11,000	4,600,000
Probability of mean	0.16	0.25	0.06	0.16	0.05	0.22
Probability of zero	0.43	0.32	0.94	0.42	0.91	0.32

Table G3. (continued)

D. Mark3 Index 47: Polymetallic replacement

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	1,700	1	99,000	290	110,000	2,800,000
mean	2,000	1	49,000	170	47,000	880,000
Probability of mean	0.05	0.05	0.06	0.06	0.06	0.06
Probability of zero	0.93	0.94	0.92	0.93	0.92	0.92

E. Mark3 Index 5: Climax Mo

quantile	Mo	rock
0.95	0	0
0.90	0	0
0.50	0	0
0.10	710,000	420,000,000
0.05	1,200,000	630,000,000
mean	200,000	100,000,000
Probability of mean	0.23	0.24
Probability of zero	0.70	0.70

F. Mark3 Index 45: Hot spring Au-Ag

quantile	Au	Ag	rock
0.95	0	0	0
0.90	1	0	510,000
0.50	28	45	20,000,000
0.10	140	670	94,500,000
0.05	230	1,000	200,000,000
mean	58	240	41,000,000
Probability of mean	0.28	0.27	0.27
Probability of zero	0.07	0.38	0.07

G. Mark3 Index 25: Epithermal vein, quartz-adularia

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	2	0	22	0	400,000
0.10	300	52	0	2,000	0	8,700,000
0.05	1,100	100	0	4,600	0	15,000,000
mean	380	21	18	1,400	2	3,700,000
Probability of mean	0.09	0.20	0.02	0.12	0.03	0.18
Probability of zero	0.87	0.31	0.98	0.31	0.96	0.31

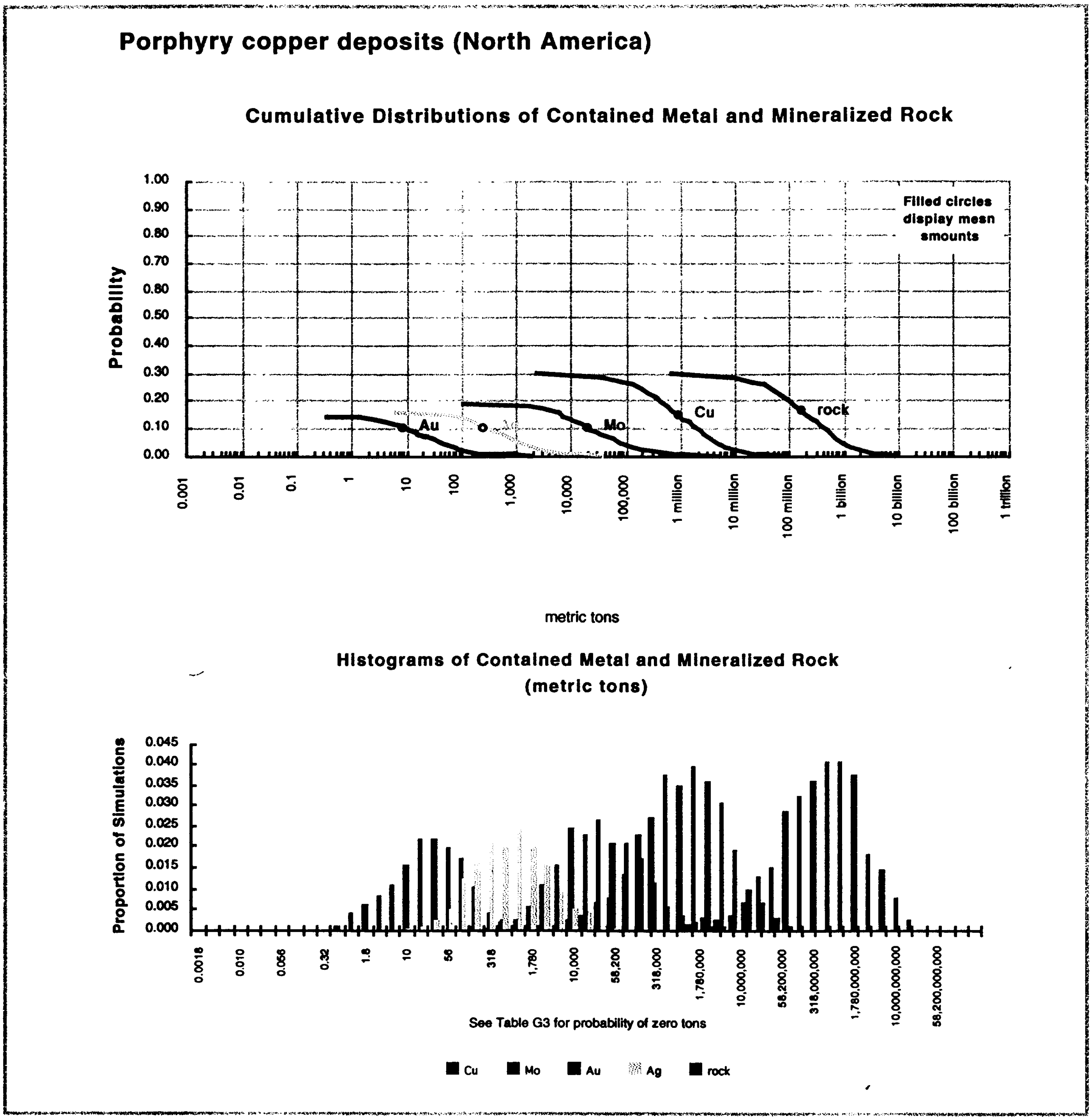

Figure G1. Simulated metal content in undiscovered porphyry copper deposits in the Helena National Forest (all amounts in metric tons).

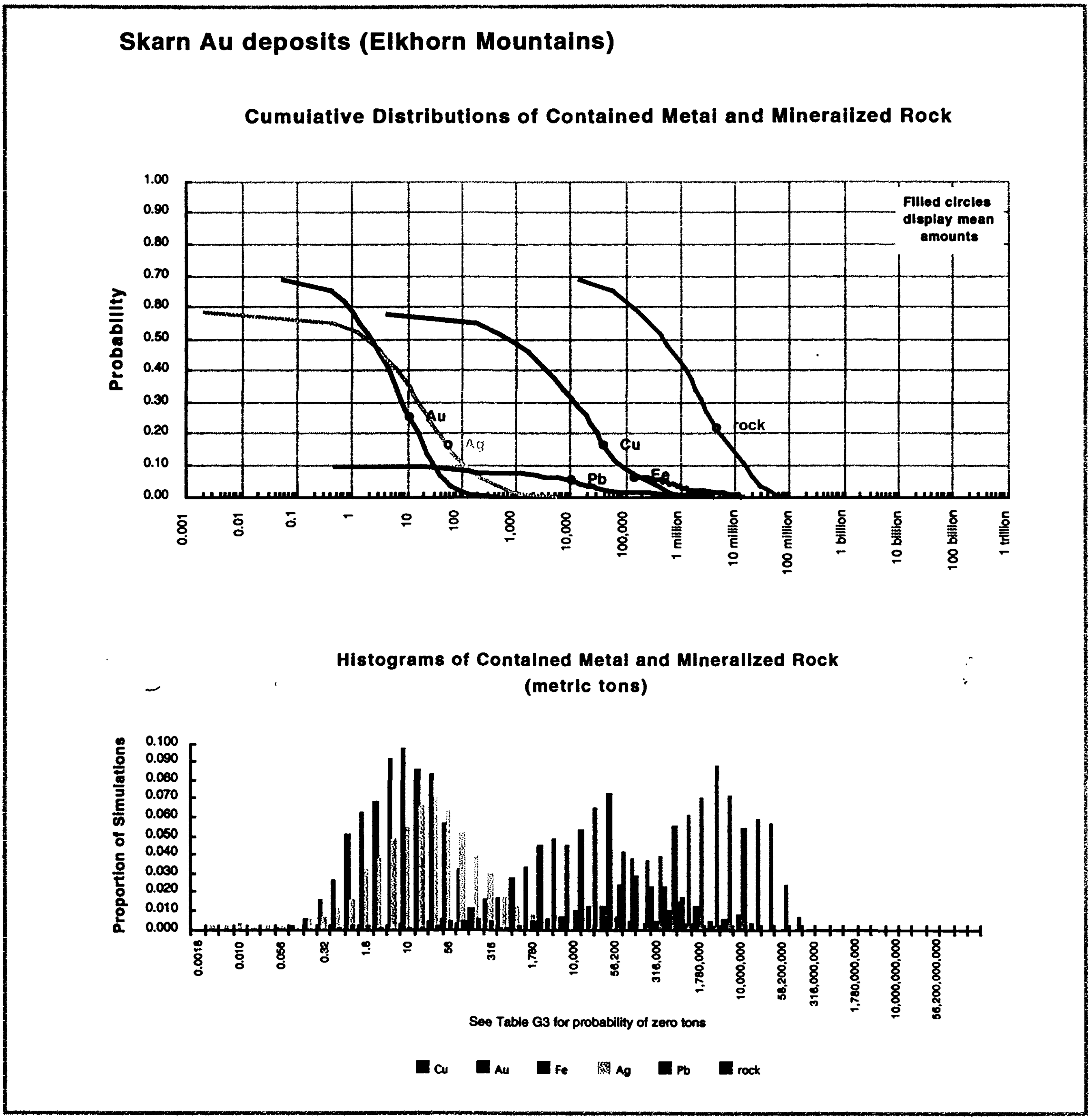

Figure G2. Simulated metal content in undiscovered skarn gold deposits in the Helena National Forest (exclusive of the Elkhorn Mountains). All amounts in metric tons.

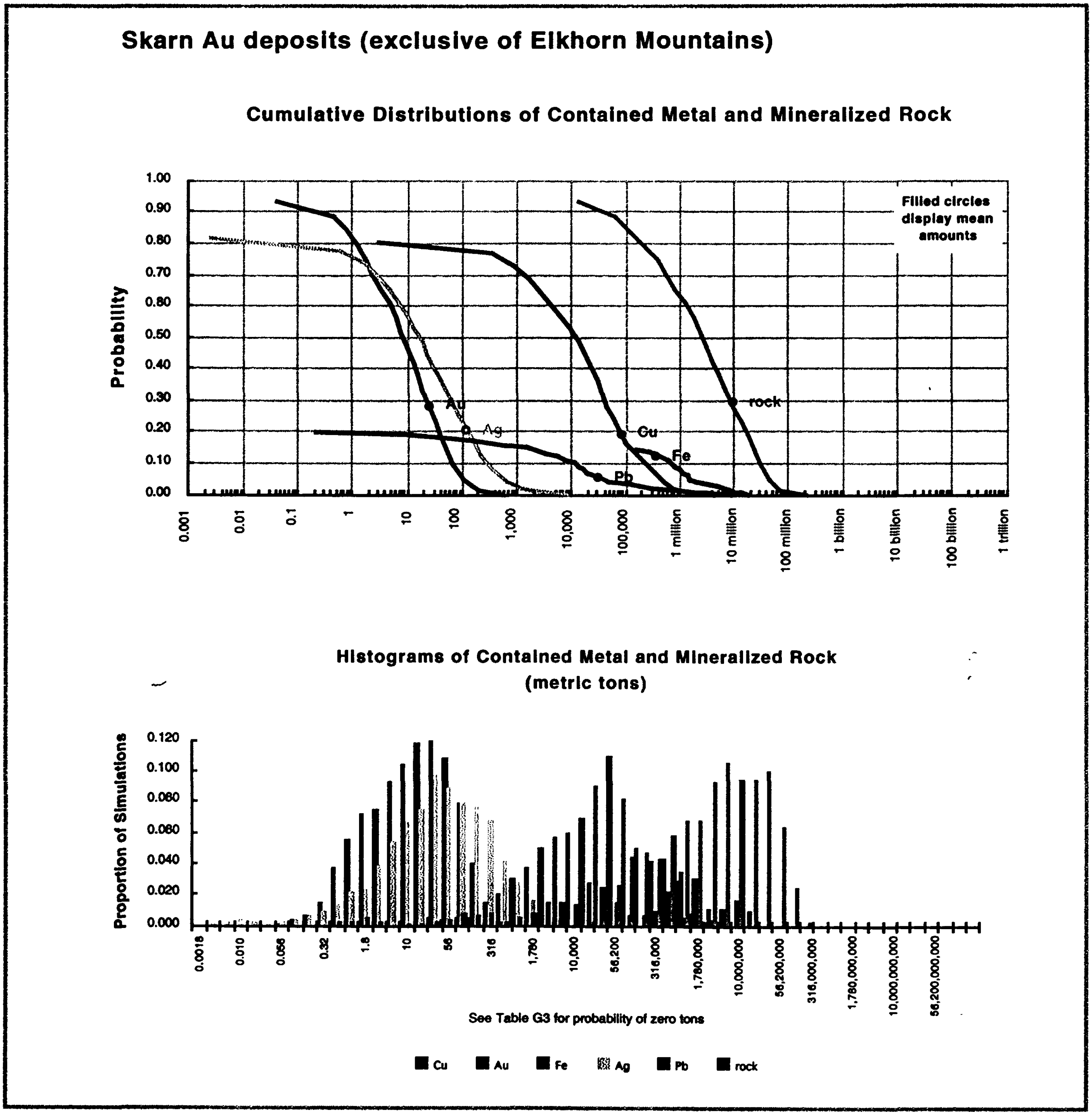

Figure G3. Simulated metal content in undiscovered skarn gold deposits in the Helena National Forest (Elkhorn Mountains only). All amounts in metric tons.

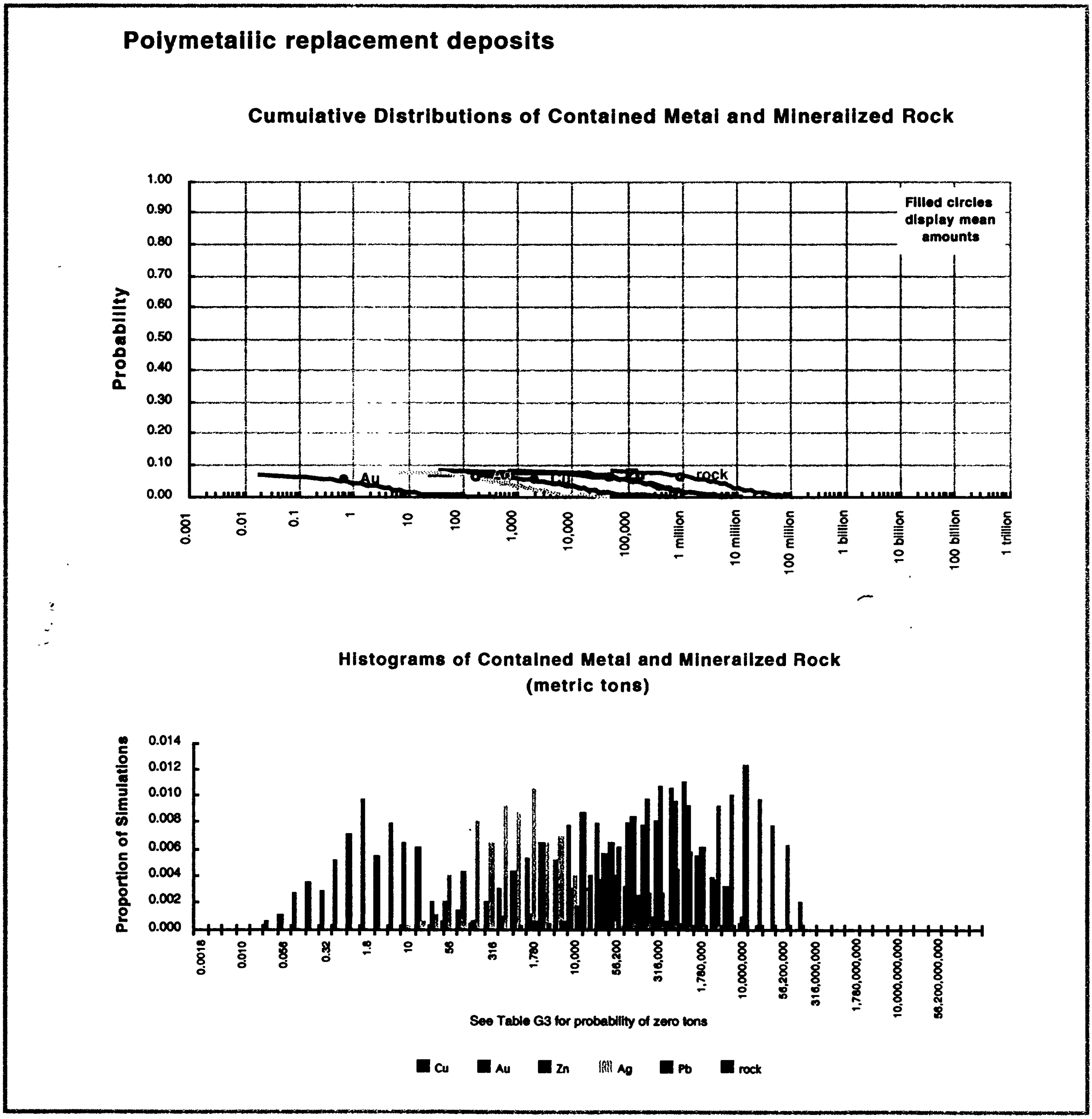

Figure G4. Simulated metal content in undiscovered polymetal contentlic replacement deposits in the Helena National Forest (all amounts in metric tons).

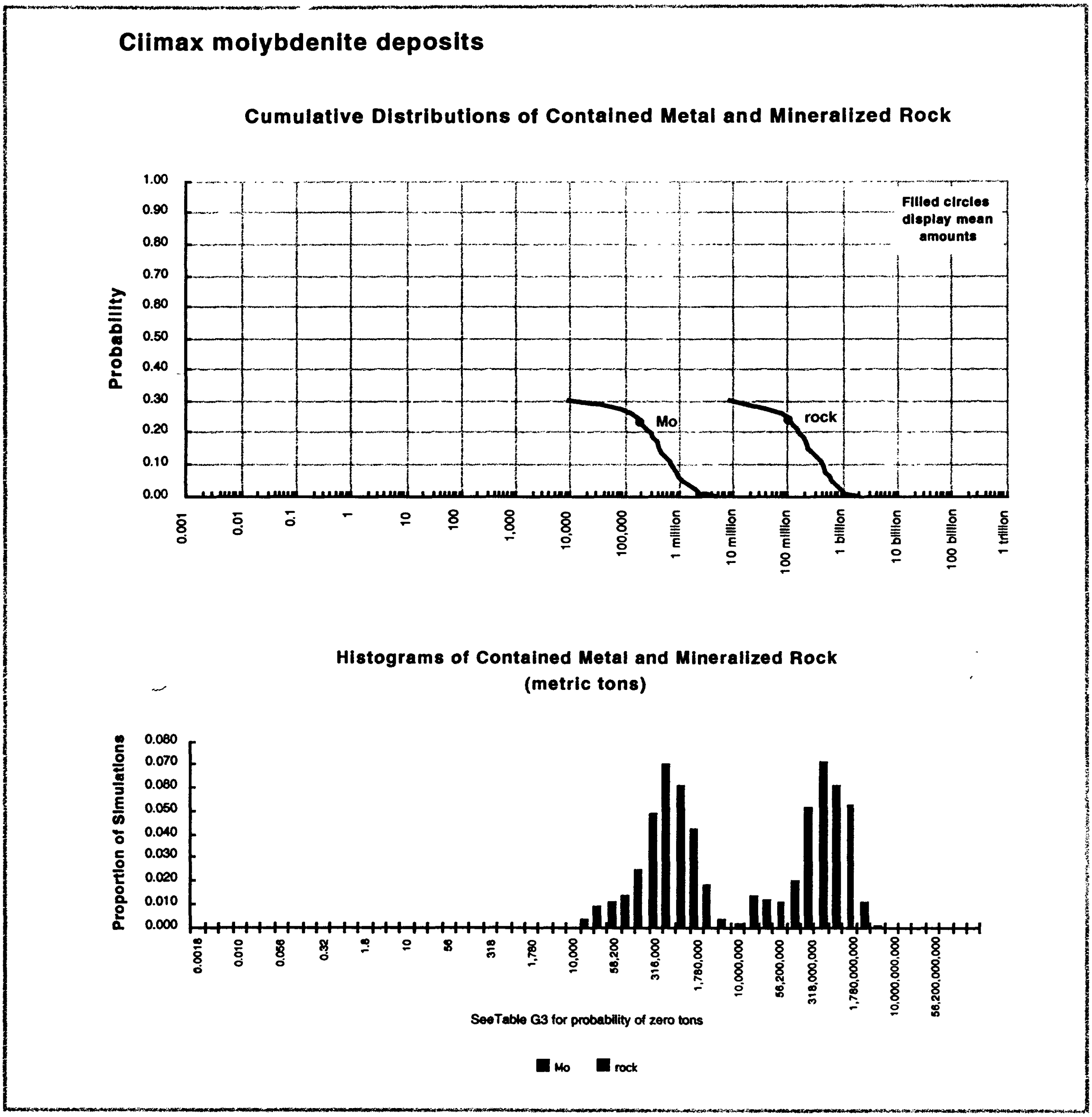

Figure G5. Simulated metal content in undiscovered Climax molybdenite deposits in the Helena National Forest (all amounts in metric tons).

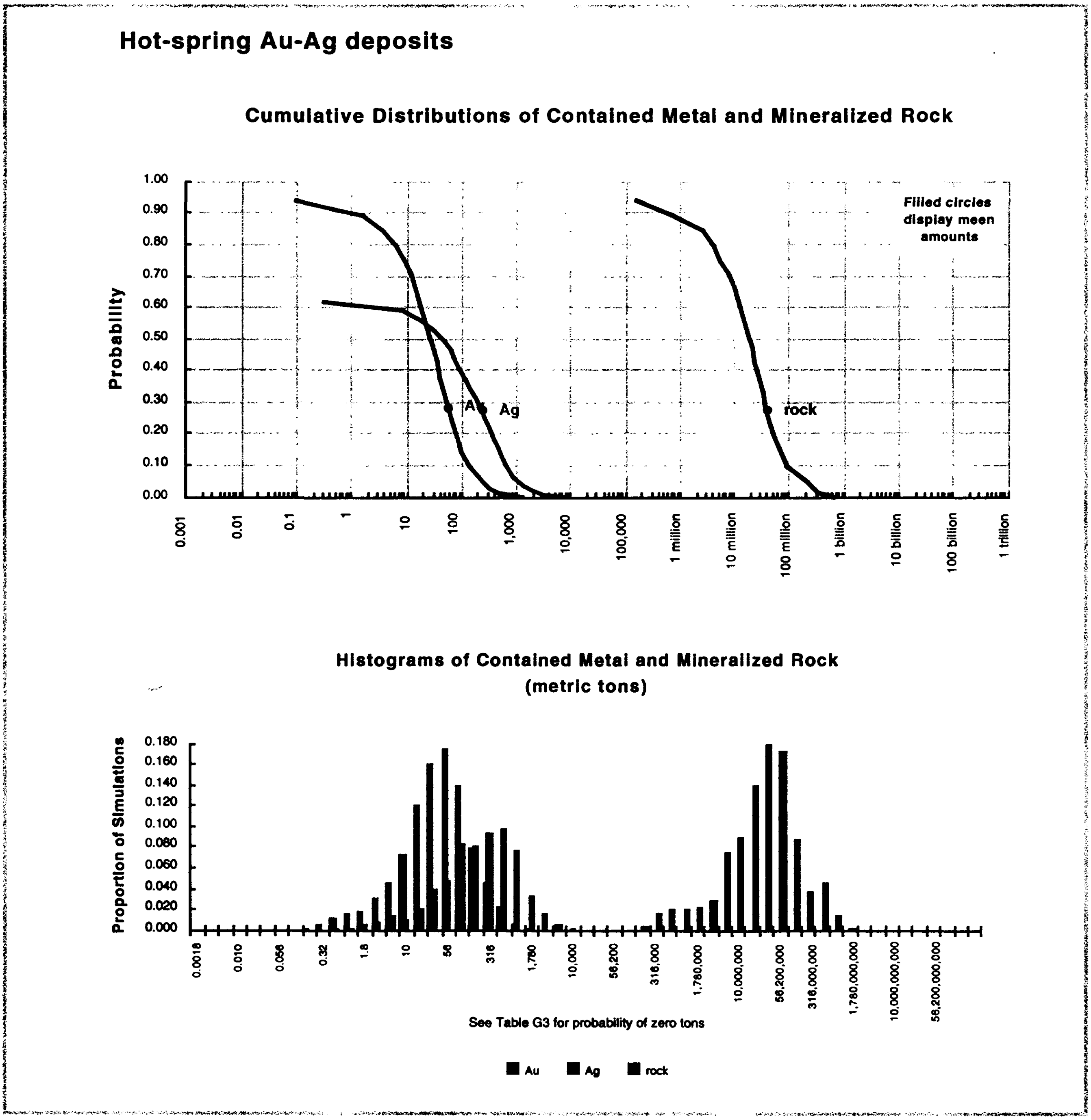

Figure G6. Simulated metal content in undiscovered hot-spring Au-Ag deposits in the Helena National Forest (all amounts in metric tons).

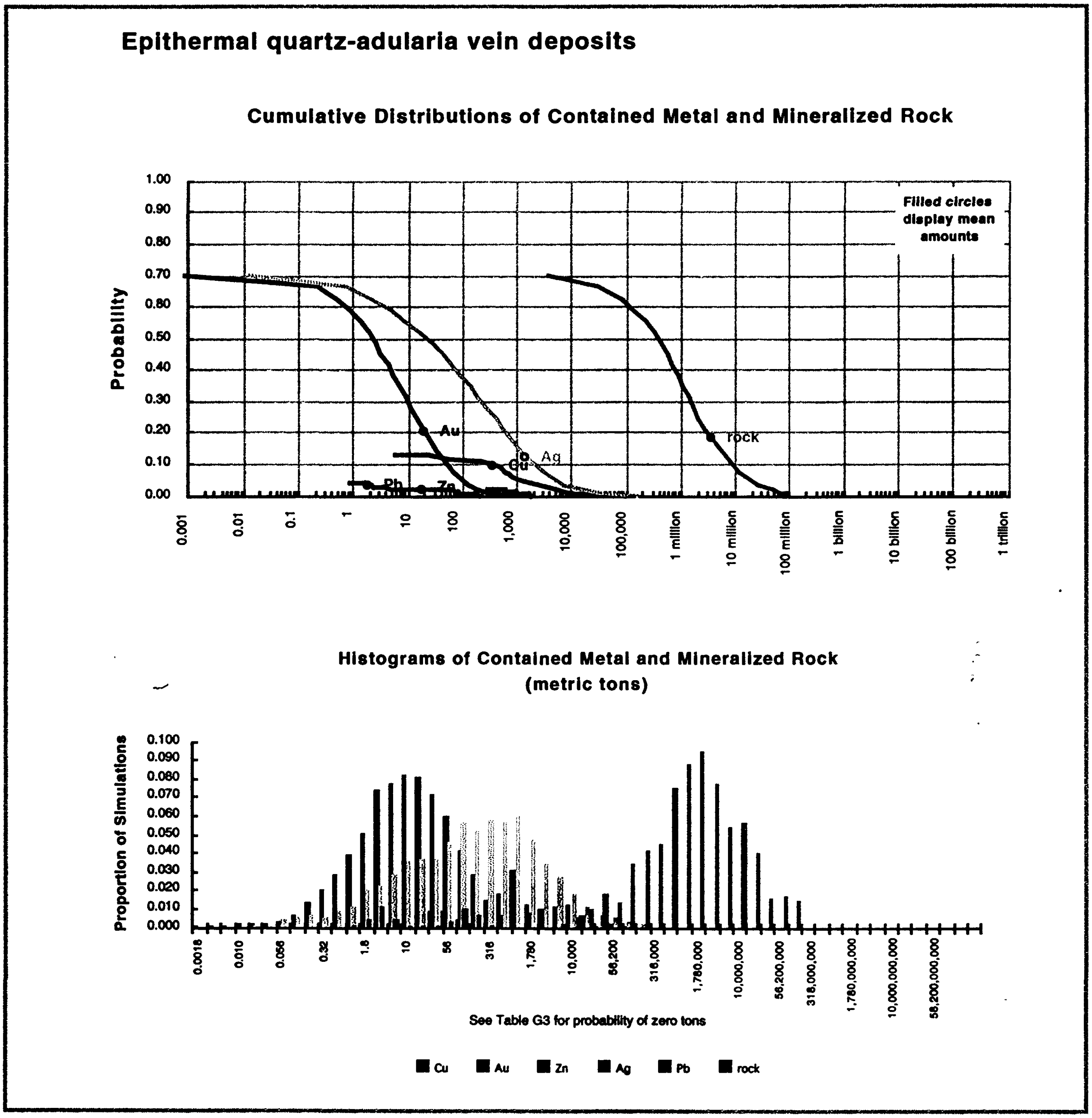

Figure G7. Simulated metal content in undiscovered epithermal quartz-adularia deposits in the Helena National Forest (all amounts in metric tons).

Table G4. Mean and median estimated metal endowment for undiscovered metallic deposits evaluated in the Helena National Forest, Montana.

[All amounts are in metric tons. See Figures G1 through G7 for mean and median values for individual deposit types that were evaluated. Note that estimates are not made for all of the deposit types that might be found in the area; see text for explanation. Values for Butte, taken from Meyer and others (1968), are for production during the period 1880-1964, from the underground mines only, and are provided for perspective only.]

Commodity	Median	Mean	Butte
Gold	85	130	78
Silver	590	2,200	20,000
Copper	83,000	1,000,000	7,300,000
Lead	0	90,000	380,000
Zinc	0	49,000	2,200,000
Molybdenum	0	220,000	-
Iron	0	540,000	-
mineralized rock	100,000	330,000,000	-

resources predicted in this study. Most of the copper would come from porphyry copper deposits; most of the gold from hot-spring, quartz-adularia, and skarn gold deposits. Lead and zinc are minor constituents of the deposits predicted to exist. Silver and molybdenum are byproducts in deposits that are primarily exploited for gold and copper at present. Iron is generally recovered from sources other than the skarn deposits predicted to occur here.

It is also important to remember that not all of the possible resources known to be present, or that might be present, in the Forest were quantified in this study. We did not quantitatively evaluate the non-metallic deposits, as well as a few metallic deposit types, such as polymetallic veins. Until sufficient information is available regarding these other types of deposits, the resource estimates presented herein should be considered incomplete.

Finally, the spatial distribution of the predicted deposits is not addressed by the quantitative part of this assessment. That information is presented on the maps on plate 5. The maps of permissive and favorable tracts depict where exploration activity will take place in the future.

SOME ENVIRONMENTAL CONSIDERATIONS

The abundance of metal sulfide minerals is a major factor that affects the ability of a body of rock to generate acid when in contact with natural waters. Acidic water generated in this way is an important environmental concern in land management. Unfortunately, we have virtually no direct information about the sulfide mineral content of various mineralized areas in the Forest, because much of the sulfur in metallic mineral deposits is in

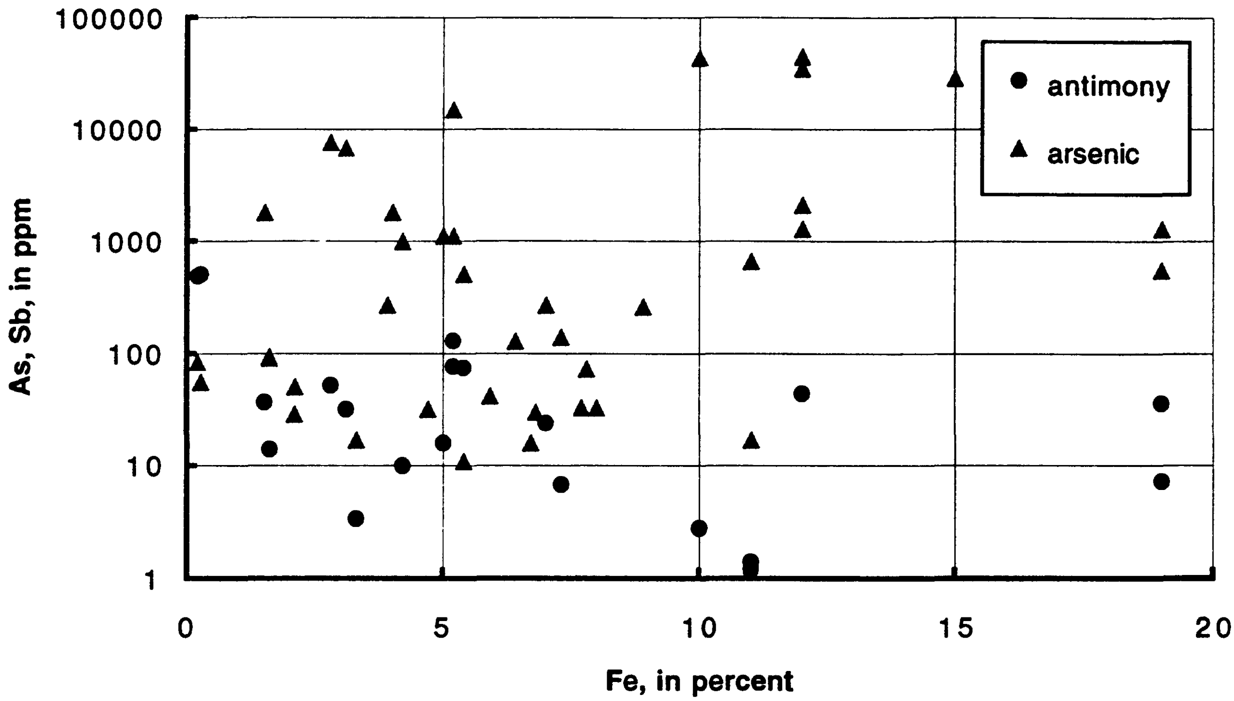

Figure G8. Arsenic and antimony content of mineralized samples from the Elkhorn Mountains. Arsenic and antimony units are parts per million, iron is in weight percent.

samples from the Elkhorn Mountains do not directly imply high toxicity to plant and animal life. Studies to determine levels of *bio-available* toxic metals would be necessary to establish toxicity.

iron-bearing sulfides that contribute nothing to the value of the deposit, and are not commonly measured. However, it is possible that geochemical maps can serve as a proxy for the abundance of sulfides. In an earlier chapter (Alminas, this volume, Chapter D), two important geochemical associations (lead and gold) were developed and mapped. Both the lead and gold associations are associated with the common sulfide-bearing polymetallic vein and skarn gold deposits found over wide areas of the Forest.

Those districts that have especially high values for the lead- and gold-association models are: Heddleston (Pb, Au), Finn (Au), Stemple-Gould (Pb, Au), Marysville (Pb, Au), north part of Dog Creek (Au), Austin (Au), Elliston (Pb, Au), Rimini (Au), McClellan-Mitchell (Au), Warm Springs (Pb, Au), Elkhorn (Au), Winston (Pb, Au), Park (Pb, Au), and Indian Creek (Pb, Au). If high values of these element-association models are good proxies for sulfide content, those areas are more likely than average to be the sites of acid drainage, associated with both natural outcrops and historic mining operations.

Hot-spring gold, porphyry copper, and Climax molybdenite deposits are the largest deposits expected to occur in the Forest. Any development of these would create the most significant potential source of surface disturbance and generation of large amounts of tailings and waste rock.

A survey of data recently compiled on the geoenvironmental character of a number of mineral deposit types (du Bray, 1995) reveals a paucity of information about toxic metal concentrations in materials from mineralized systems like those in the Helena National Forest. Perhaps the most interesting and relevant data are some that relate to gold skarn deposits. Hammarstrom and others (1995) reported on the Fortitude skarn gold deposit in Nevada. In the border zone, lower ore zone, and upper ore zone, respectively, mean values are as follows: As—96, 1,732, 633; Sb—11, 7, 7. Figure G8 shows arsenic and antimony values for a suite of mineralized rock and ore samples collected during this study from the Winston, Park, and Indian Creek mineralized areas. Mineralized areas in the Elkhorn Mountains appear to be generally comparable to the data from Nevada. It should be emphasized that the high arsenic and antimony contents noted in mineralized samples from the Elkhorn Mountains do not directly imply high toxicity to plant and animal life. Studies to determine levels of *bio-available* toxic metals would be necessary to establish toxicity.

SUMMARY

The general location and number of selected undiscovered metallic mineral deposits, and the quantity of metal that might be contained in them, are predicted in this section.

To assess location, we defined *permissive tracts* to be those areas where mineral deposits are, or could be, present. These permissive tracts are defined by important geologic, geochemical, and geophysical features that are characteristic of a particular deposit type. Within some of the permissive tracts, we outlined subareas that are particularly favorable for the occurrence of deposits. These *favorable tracts* were designated because the geologic environment contains a coincidence of a large number of important features that are characteristic of a particular deposit type. In these favorable tracts, we believe that the areal density of undiscovered deposits is higher than throughout the permissive tract in general, although we have made no attempt to specify how much higher. The permissive and favorable tracts are shown on a series of maps on plates 5 and 6.

The quantity of contained metal in predicted undiscovered deposits was subjectively estimated by a team of earth scientists, using the Mark3 computer program to simulate amounts by extrapolation from the grade and tonnage models, and from probabilistic estimates of the number of undiscovered deposits present. Those amounts are shown in Figures G1 through G7 and in tables G2, G3, and G4.

The broad range of values in the estimates reflects an inherent large uncertainty in the number and sizes of undiscovered deposits of the types evaluated. Copper and gold together constitute approximately 90 percent of the potential value of the undiscovered resources predicted in this study. Most of the copper would come from porphyry copper deposits; most of the gold from hot-spring, quartz-adularia, and skarn gold deposits.

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CHAPTER H

PLACER GOLD OF THE HELENA NATIONAL FOREST

GEOLOGY OF PLACER GOLD DEPOSITS

By R.G. Tysdal

Introduction

Placer gold deposits consist of elemental gold in grains and rarely nuggets in gravel, sand, silt, and clay, and their consolidated equivalents, in alluvial, beach, eolian, and rarely glacial deposits. Descriptive models for gold placer deposits are given by Yeend (1986) and Yeend and Shawe (1989), which is the basis for the following discussion.

Placers form by weathering of gold from bedrock sources and mechanical concentration of the particles by running water in streams, rivers, and locally slopewash. The richness (concentration) of gold in placer deposits depends on the supply of gold in source rock and on conditions favorable for its concentration and preservation. Gold has a high specific gravity and works its way into joints, fractures, or irregular rock surfaces in stream beds. In some deposits, however, gold is dispersed throughout a gravel mass and lacks significant concentration. Most alluvial placers are of Cenozoic age, but "fossil" placers may be preserved within sediments protected beneath younger rocks. Placer deposits are subject to destruction and the gold may be recycled by the same processes that led to their formation. The most prospective areas for placer deposits are in, or near, known lode gold districts.

Placers in and adjacent to the Forest

Placer deposits of the Forest include those in unconsolidated sediments of streams, terraces adjacent to streams, eluvium (residum of weathered rock), glacial debris, and Quaternary-Tertiary deposits in consolidated materials of alluvial fans and benches, chiefly along mountain flanks. Placer locations are shown on plate 2, along with other mines, prospects, and mineral occurrences in and adjacent to the Forest. Placers also are shown on map D (pl. 3), which depicts streams and stream-segments where publications indicate placer operations yielded gold in the past. The placer-bearing streams primarily were compiled from Lyden (1948), but also include data from publications cited in the "Sources of Data" column of table E1, including field observations for this report. Coordinates for each placer deposit represent only one point along a stream, generally at the lower end, whether inside or outside the Forest. However, in some cases tributary streams also are represented by coordinates (table H1), which corresponds to a data entry in table H1.

Production records of gold recovery from the various streams within and adjacent to the Forest are incomplete. Nevertheless, data show that most of the gold was produced from only a few streams, primarily in the 1880's to first third of the 1900's. Recovery of gold included the use of dredges on some drainages. Koschmann and Bergendahl (1968) reported the following cumulative production of placer gold, through 1959: Helena (Last Chance) district--at least 940,000 ounces; Confederate Gulch--550,000-600,000 ounces; Lincoln Gulch--342,000 ounces; McClellan Gulch district (near Lincoln)--340,000 ounces; Ophir district--minimum of 180,000 ounces (Loen [1989] estimated 300,000 ounces for this district); western part of the York district (York, Oregon, Clark, Cave, and Magpie Creeks)--minimum of about 160,000 ounces; Missouri River terraces--minimum of about 105,000 ounces; and Finn district--81,000 ounces.

Almost certainly every stream within and adjacent to the Forest has been prospected for placer gold. Some streams never contained gold and others contained placers that have been exhausted of their gold. The following streams within the Forest had placering operations that were producing or developing in 1992 (McCulloch, 1993a). In the Big Belt Mountains: Avalanche Creek (York district) and Vermont Gulch (Beaver-Elk Creek district). In the western part of the Forest: Lincoln Gulch area, and Washington Gulch (Finn district); and outside but directly adjacent to the Forest--Sauerkraut Creek (Finn district).

Exploration (testing) of permissive placer ground was ongoing at the following locations in or adjacent to the Forest in 1992 (McCulloch, 1993b). In the Big Belt Mountains: Confederate and Cement Gulches (Confederate Gulch district); Benton, Thompson, and Vermont Gulches, and Beaver and Elk Creeks (Beaver-Elk Creek district). In the western part of the Forest: Mike Reinig Creek (Elliston district), Greenhorn Creek (Austin district), and Hope Creek (Dog Creek area).

Fossil stream-laid deposits ("bars") are present locally along the Missouri River, on terraces as much as 200-250 ft above water level. These terrace deposits yielded gold, and locally sapphires, in past and some present placer operations. Gold in the bars probably came from lodes in the York district; the amount of gold decreased rapidly downstream from the district (Pardee and Schrader, 1933). The richest deposits were in French Bar (pl. 3, map D, no. 510), close to the district. Eldorado Bar (no. 505) is partly within the Forest and lies below the mouth of Trout Creek, which is the probable source of its gold (Pardee and Schrader, 1933); dredging ground was reportedly exhausted by 1942 (Lyden, 1948). American Bar (no. 503) also is partly within the Forest. It is composed of bedrock that is overlain by about 3 ft of river gravel and cobbles, which in turn is overlain by as much as 11 ft of alluvium. About 13 acres of the bar was hydraulically mined for placer gold in the late 1800's and is believed to have yielded only a small amount of gold (Close and Rigby, 1984).

The only modern study of placer deposits within or adjacent to the Forest is that of Loen (1989) for the Ophir district (pl. 2). Loen reported that placering has taken place in terrace gravel, alluvium, lag deposits (old stream deposits that have undergone prolonged in-place weathering), and eluvium (gold concentrated in-place from prolonged weathering of bedrock). Gold was freed from the Blackfoot City stock (plate 1) and the surrounding mineralized rocks that lie at the head of streams of the district.

Alluvium of the present-day streams was extensively placered for their gold, but the richest deposits of the Ophir district were found in consolidated (cemented by calcium carbonate) stream gravels of Pleistocene(?) and Pliocene age (Loen, 1989). These strata deposits the present streams and underlie terraces a few feet above stream level. The terrace gravels lie almost wholly outside the Forest, contained within map unit QTg (pl. 1).

Three placer deposits of the Ophir district lie within the Forest: at the head of Nugget Gulch (pl. 3, map D, no. 143), Mexican Gulch (no. 158), and

Table H1. Placer Au deposits and production, grouped by district, Helena National Forest, Montana

[*, mine or prospect on or just outside Forest boundary; (r), reserves; oz, ounces; data corresponds to that of table E1, plate 2, and map D of plate 3. [1] Alternate name(s) in parentheses; [2] Value given only when recorded in data source, as cited in table E1.]

No.	Site name	District/ Area [1]	Au Production/ Reserves (oz) [2]
24	Lincoln Gulch (Lincoln Creek) placer	Lincoln Gulch Area	350000
48	Moose Creek placer	Blackfoot River Area	
49	Sauerkraut Creek placer	Blackfoot River Area	
50	Stonewall Creek placer	Blackfoot River Area	703
51	Liverpool Creek placer	Blackfoot River Area	
52	Keep Cool Creek placer	Blackfoot River Area	
54	Seven-Up Pete Creek Placer	Blackfoot River Area	
60	Poorman Creek placer	Blackfoot River Area	36
65	Wasson Creek placer	Big Blackfoot (Ogden Mtn)	
66	Wilson Creek (Kilburn, Raleigh) placer	Big Blackfoot (Ogden Mtn)	
68	C.D. Hurd placer*	Big Blackfoot (Ogden Mtn)	
78	Canarway Gulch Placer	Big Blackfoot (Ogden Mtn)	
79	Chimney Creek placer	Big Blackfoot (Ogden Mtn)	
80	Deer Creek placer	Big Blackfoot (Ogden Mtn)	Minor
81	Chicken Creek placer	Big Blackfoot (Ogden Mtn)	Minor
86	All Placer	Finn	
87	Buffalo Gulch placer*	Finn	230
88	Jefferson Creek placer	Finn	15
89	Madison Gulch placer	Finn	75
90	Washington Creek placer	Finn	5300
91	American Gulch placer	Finn	Minor
93	McClellan Gulch (Creek) placer	McClellan Gulch	350000
97	Gold Creek placer (Blue Jay)	Stemple-Gould	
103	Rooster Bill Creek placer, Margaret	Stemple-Gould	
106	Fool Hen Creek placer	Stemple-Gould	
111	Gould Creek placer	Stemple-Gould	
113	Specimen Creek placer	Little Prickly Pear Area	
114	Tarhead Creek placer	Little Prickly Pear Area	
115	Virginia Creek placer	Little Prickly Pear Area	
120	Empire Creek placer (Lost Horse Creek)*	Marysville (Silver Creek)	
140	Three Mile Creek placer	Ophir	250
143	Nugget Gulch placer	Ophir	250
155	Tiger Gulch placer*	Ophir	200
158	Mexican Gulch placer	Ophir	500
161	Deadwood Gulch placer	Ophir	500
169	Illinois Gulch placer*	Ophir	500
170	Eureka Gulch placer*	Ophir	3000
171	Ophir Creek placer (Tributary of Carpenter Creek)	Ophir	100000
172	Snowshoe Creek placer	Ophir	25000
173	Carpenter Creek placer*	Ophir	150000
174	Gold Canyon Creek placer*	Dog Creek Area	4700
176	Dog Creek placer	Dog Creek Area	Minor
181	Little Blackfoot River placer	Dog Creek Area	
194	Skelly Gulch (Greenhorn Creek) placer	Austin	
200	Blue Cloud Mining Co. placer*	Stemwinder Hill Area	
201	Nelson Gulch placer	Helena (Last Chance)	
202	Orofino, Dry, Grizzly, and Last Chance Gulch placers*	Helena (Last Chance)	800000

No.	Site name	District/ Area [1]	Au Production/ Reserves (oz) [2]
209	Pretty Girl placer*	Helena (Last Chance)	
211	Mike Relnig Gulch placer	North Boulder Mountains Area	180
226	Telegraph Creek placer	Elliston	12
231	Ontario Creek placer	Elliston	184
246	Tenmile Creek (Gould, Monitor, Tucker, and Minnehaha) placer	Rimini (Vaughn)	
275	Travis placer	Rimini (Vaughn)	
298	Lump Gulch placer	Clancy (Lump Gulch)	27
299	Buffalo Creek (Weber) placer	Clancy (Lump Gulch)	Minor
308	Clancy Creek placer*	Clancy (Lump Gulch)	8600
329	Basin Creek placer*	Basin (Cataract, Comet)	1300
330	Cataract Creek placer*	Basin (Cataract, Comet)	
332	High Ore Creek placer*	Boulder (Comet)	
385	Comet Creek (Spring Creek) placer*	Wickes (Colorado, Corbin)	Minor
395	Holmes Gulch placer*	Montana City	
396	Prickly Pear Creek placer	Montana City	59000
399	Mitchell Creek placer*	McClellan-Mitchell Creek	14000
400	McClellan Creek placer*	McClellan-Mitchell Creek	Minor
408	Warm Springs Creek placer	Warm Springs	Minor
412	Wilson Creek placer	Tizer Basin Area	
415	Tizer Creek placer	Tizer Basin Area	
440	Beaver Creek placer	Winston	10000
463	Unnamed placer	Indian Creek	
482	Indian Creek placer*	Indian Creek	22000
501	Crow Creek placer*	Radersburg	25000
502	Ming's Bar placer*	Missouri River Area	Minor
503	American Bar placer	Missouri River Area	Minor
504	Dana's Bar placer*	Missouri River Area	Minor
505	El Dorado Bar placer	Missouri River Area	41000
506	McCune Bar placer*	Missouri River Area	
507	Spokane Bar placer*	Missouri River Area	27500
506	Gruel Bar (Gruel's Bar, Metropolitan Bar) placer*	Missouri River Area	2050
509	Lovestone*	Missouri River Area	
510	French Bar placer*	Missouri River Area	75000
516	Trout Creek, York Gulch, Rattlesnake Gulch, Kelly Gulch,	York	250000
542	Garnet placer	York	
544	Bar Gulch placer	York	
545	Linda Jo placer	York	
546	Ruth placer	York	
547	Oregon Gulch placer	York	25000
546	Clark Gulch placer	York	15000
549	Cave Gulch, Cooper Gulch placers	York	20000
550	Magpie Creek placer	York	14000
550	Hellgate Gulch placer	York	
562	Avalanche Creek placer	York	5000
564	Sheep Creek placer	Beaver (Elk Creek)	
567	Fig Springs placer	Beaver (Elk Creek)	
568	Beaver Creek placer	Beaver (Elk Creek)	Minor
571	Vermont Gulch placer	Beaver (Elk Creek)	
572	Benton Creek placer	Beaver (Elk Creek)	Minor
573	Thomas Creek placer	Beaver (Elk Creek)	1100

No.	Site name	District/ Area[1]	Au Production/ Reserves (oz)[2]
576	Elk Creek placer	Beaver (Elk Creek)	5
577	Camas placer*	Beaver (Elk Creek)	Minor
579	White Creek placer	Confederate Gulch	75000
587	Confederate Gulch placer	Confederate Gulch	600000; 181400 (r)
590	Atlanta Gulch placer	Southern Big Belt Area	422
593	Little Camas Creek placer	Southern Big Belt Area	
599	Thompson Creek placer	Southern Big Belt Area	2500
603	Deep Creek placer*	Southern Big Belt Area	Minor

Deadwood Gulch (no. 161). All are eluvial deposits that had an estimated total production of only 1,250 ounces. These deposits lie above the level of modern streams, along hill slopes that have been exposed to weathering, possibly for as much as several million years (Loen, 1989).

Permissive Tracts

Map D (pl. 3) shows extensive shaded areas that are a composite of all geologic terranes containing, or are permissive for, gold-bearing rocks, as explained in Chapter G of this report. Streams on map D are shown in a "drainage net" of differing line weights. The fine-line weight represents the following: (1) streams within the Forest, and within the areas of geologic mapping directly adjacent to the Forest, for which we found no record of placer gold recovery, and for which the streams do not flow across geologic terrane considered permissive for gold-bearing mineralization; and (2) all streams that lie outside the Forest and outside the limit of geologic mapping, whether or not the streams yielded placer gold, flow across geologic terrane permissive for gold, or flow across terrane considered permissive for placer gold.

The bold and intermediate weight lines of the drainage net are shown only within the Forest and within the areas of geologic mapping directly adjacent to the Forest. Bold lines represent streams or stream-segments that yielded gold from placer operations, as determined from a cited geologic publication (table E1). An asterisk is placed after the name of each placer deposit for which the publication(s) indicates the gold-bearing stream or stream-segment lies entirely outside the Forest. In many cases, a bold line clearly represents a stream within (or partly within) the Forest. In other cases, however, the actual occurrence of placer mining within the Forest is uncertain (*whether or not a bold line lies entirely outside the Forest*), due to the unclarified nature of statements in some publications.

Intermediate weight lines show streams for which cited publication(s) did not definitively indicate placer production. The streams flow across geologic terrane that is considered permissive for gold-bearing mineral deposits, thus these streams could yield gold to form placers. Such streams (or stream-segments) are considered prospective for placer deposits. However, because it is almost certain that every stream within and adjacent to the Forest has been prospected for placer gold, streams most likely to yield gold probably will be those from which gold has been recovered in the past.

Occurrences of placer gold have led to discoveries of many lode gold deposits by tracing the placer anomalies to bedrocks sources upstream. In the Confederate Gulch district, the gold in the streams of Confederate and White Gulches has long been considered to come from quartz veins in the vicinity of Miller Mountain (Pardee and Schrader, 1933). Pegasus Gold (1992) reported reserves of 310,000 ounces of lode gold in the Miller Mountain area.

A placer prospect at Sheep Creek (Scapegoat area), north of Lincoln, was reported by Earhart and others (1977), but not included in a later compilation of mines, prospect, and mineral occurrences of Earhart and others (1981). They found no record of gold recovery and their sampling yielded no gold. Similarly, Willow Creek (southern part of Blackfoot River area) was reported by Lyden (1948) as having placer activity, but Elliott and others (1992) found no evidence or record of placering and did not include the stream as productive.

In the northwestern part of the Forest, Stonewall, Liverpool, and Keep Cool Creeks flow south from the Scapegoat area of the Forest into the Blackfoot River area (pl. 2; map D of pl. 3). Placering operations were reported along each of these streams within the Forest (Earhart and others, 1977, 1981), and along the southern parts of the streams, which are outside the Forest. These reports led us to classify the headwaters of these streams as prospective for placer gold (pl. 3, map D). However, Earhart and others (1977, 1981) cited no record of production and Lyden (1948) stated that the lower parts of the Liverpool and Keep Cool Creeks yielded only minor gold from irregular and low-grade concentrations. Lyden (1948) reported that the lower end of Stonewall Creek was dredged but yielded less than 1,000 ounces of gold. The source of this gold may not be from rocks in the headwaters of the three creeks, within the Forest, but may be from gold-bearing rocks in the vicinity of the McDonald Meadows gold property (pl. 2, no. 53) about 7 mi east of Lincoln.

Three Mile Creek (pl. 3, map D, no. 140) heads in terrane not considered prospective for gold. Gold in the placers may have come from the Quaternary-Tertiary conglomeratic terrace gravels of rock unit (QTg) that directly underlies the southern placered stream segment or from glacial till that underlies the northern placered segment. Such gold would be considered recycled from a previously formed sedimentary placer concentration.

COMPOSITION OF GOLD GRAINS FROM PLACERS

by W.H. Raymond and G.A. Desborough

Introduction

Gold in stream sediments reported here is from two separate studies. Data collected in 1970 (table H2, nos. M001-M027) are from a study of placer deposits of Montana by Raymond. The study was designed to sample coarse-grained gold of placer deposits and use gold composition as an aide in determining the sources of the gold. Data collected in the 1990-94 period (table H2, nos. M050-M148) are from an extensive, ongoing stream-sediment sampling program of Raymond and Desborough. The study focused on Idaho and Montana and is designed to determine the feasibility of mechanical panning techniques for recovery of, and tracing sources of, very fine grained gold and other metals.

Data from the two studies are not directly comparable because the sampled gold is from two different size fractions, collected by different techniques, and likely represents different histories of transport and origin. The two sets of data are distinguished by different symbols on map E (pl. 3), which shows only general, qualitative abundance: no gold recovered, some gold recovered, and a significant amount of gold recovered. Only data for samples collected within and adjacent to the Forest during the two studies are presented here. None of the data have been published previously.

Placer Gold Collected in 1970

Each sample of the 1970 data set (table H2, nos. M001-M027) was collected and processed by a standard procedure. A set of portable riffles was placed in the stream and about 30 shovelfuls (about 300 lbs) of gravel were worked and reduced to a concentrate. The goal was to recover at least 20 usable colors ("The specks of gold seen after successful operation of a gold pan ...", Thrush, 1968) for a statistical analysis of the composition of gold grains. Field panning of the concentrates indicated when sufficient colors had been obtained. In a few cases, additional gravel was processed to obtain sufficient colors. In the laboratory, some loss of gold grains occurred during mounting and polishing, reducing the number of gold grains to insufficient levels for statistically significant analysis. The existing data for these samples are included in the table, however, along with notes on other minerals observed in the concentrates.

Gold grains were mounted in epoxy, ground to expose the cores of grains, and polished in preparation for analysis by electron microprobe. Readings on the microprobe were taken at a minimum of four sites in the core of each grain, avoiding measurement of leached rims. Grains suspected of having been ground to the leached rims on the underside were discarded. Analyses were made for gold, silver, and copper. The mounts later were repolished and examined by energy dispersive analysis for platinum group elements (PGE), but none were detected.

The resulting data set shows that the gold is remarkably consistent in composition, almost without regard to the number of grains analyzed. The samples from the Ophir district (table H2, nos. M001, M002, M004) and the one sample from Grizzly Gulch (no. M008) are the only grains that contain gold of significantly higher-than-average fineness. Copper was detected in small amounts only, near the southwesternmost part of the Elkhorn Mountains (pl. 3, map E, no. M020), and in Tenmile Creek (no. M007) west of Helena. PGE's were not found in these fairly coarse-grained gold samples, although copper and palladium were detected in the much finer grained gold of the 1990-94 data set from some of the same areas. These samples are thought to have been derived directly from the Middle Proterozoic host rocks of the Big Belt Mountains and nearby localities, as described below with the 1990-94 data set.

Repeat collection of samples at sites on the west slope of the Big Belt Mountains yielded a startling decrease in gold population between 1970 and 1993. Local inquiry indicated that a large, catastrophic flood in the late 1970's removed much of the sediment in the lower reaches of many of the streams. Some sites along Confederate Gulch that yielded abundant gold in 1970 yielded little or none in 1993 (table H2), suggesting that gold was flushed downstream and redeposited in alluvium outside the Forest.

Placer Gold Collected in 1990-94

The 1990-94 placer samples were collected in a manner to recover very fine grained gold. At each sample site, two one-kilogram (2.2 lbs) bags of sediment were collected from the stream bed near the thread of maximum water velocity. In the laboratory, each sample was weighed and screened to five size fractions, and each fraction was panned mechanically according to the procedure described in English and others (1987). The concentrate was examined under a microscope, the colors inventoried and reported in colors per kilogram of sample. Compositional variations in the gold grains were determined for selected sites by using energy dispresive techniques on a scanning electron microscope (SEM).

The very fine-grained gold (<0.2 mm) has less silver and more detectable copper and palldium than the coarse-grained gold of the 1970 data set, which is of the type known and recovered by miners throughout the region. The very fine-grained gold generally is not recovered in commonly used panning techniques. Gold grains in particles large enough to be recovered in most commercial operations are from faults, veins, and dikes that have consolidated and enriched the very fine-grained gold into larger, localized particles. These larger and younger grains generally have lost copper, palladium, and some other elements.

Native arsenic is associated with the fine-grained gold in Sulphur Bar Creek and tributaries in the southern part of the Big Belt Mountains (pl. 3, map E, nos. M127, M128, and M129). Its presence is anomalous and is not understood.

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Table H2. Composition of gold in placer samples. Table corresponds with map E of plate 3.

[[1]Column also shows calculation of number of colors per kilogram of sample. [2]Au grains were lost during sample preparation. —, no data]

No.	Drainage	District/Area	Latitude North	Longitude West	Number of colors analyzed (1970 data)	Number of colors recovered (1990-94 data)[1]	Au (percent)	Ag (percent)	Comments
Collected in 1970									
M001	Carpenter Creek	Ophir	46-37-00	112-32-40	8 Au	—	94.10	5.90	25 Au recovered.
M002	Carpenter Bar	Ophir	46-38-17	112-31-45	29 Au	—	91.00	9.00	121 Au recovered, many amalgam.
M003	Snowshoe Creek	Ophir	46-39-28	112-28-40	NONE	—	—	—	Substantial coarse scheelite, no Au recovered.
M004	Ophir Creek	Ophir	46-41-27	112-31-39	10 Au	—	93.60	6.40	Substantial scheelite, 42 Au recovered.
M005	Silver Creek	Marysville	46-45-05	112-13-51	7 Au	—	78.50	21.50	Hematite after pyrite, coarse scheelite, 40 Au recovered.
M006	Silver Creek	Marysville	46-44-44	112-11-50	10 Au	—	80.90	19.10	Scheelite, 67 large Au recovered.
M007	Tenmile Creek	Rimini	46-28-50	112-14-39	37 Au	—	70.00	30.00	101 Au recovered, 5 percent of grains (2) have 0.1-0.2 percent Cu.
M008	Grizzly Gulch	Helena	46-32-49	112-06-04	28 Au	—	92.09	7.91	Mercury, substantial scheelite, 170 Au recovered.
M009	Orofino Gulch	Helena	46-32-47	112-04-35	3 Au (lost)[2]	—	—	—	Scheelite, 14 Au recovered.
M010	Dry Gulch	Helena	46-33-32	112-02-55	2 Au (lost)[2]	—	—	—	Scheelite, 23 Au recovered.
M011	Clancy Creek	Clancy	46-25-17	112-05-26	2 Au (lost)[2]	—	—	—	Scheelite, 15 Au recovered.
M012	Prickly Pear Creek	Clancy	46-22-43	112-01-47	8 Au	—	75.90	24.10	Scheelite, amalgam, abundant magnetite, 43 Au recovered.
M013	Beaver Creek	Winston	46-26-44	111-42-40	3 Au	—	84.34	15.66	Scheelite, 7 Au recovered.
M014	Weasel Creek	Winston	46-26-23	111-42-19	45 Au	—	76.75	23.25	Scheelite, gold frothy and variable in color, 82 Au recovered.
M015	Kimber Gulch	Winston	46-24-52	111-25-00	NONE	—	—	—	Probable scheelite, no Au recovered.
M016	Whitehorse Gulch	None	46-23-49	111-38-04	1 Au (lost)[2]	—	—	—	Abundant fine-grained scheelite, 3 Au recovered.
M017	Indian Creek	Indian Creek	46-18-41	111-40-02	3 Au	—	85.30	14.70	Abundant sulfides, scheelite, 10 Au recovered.
M018	Indian Creek	Indian Creek	46-19-52	111-35-59	21 Au	—	84.70	15.30	39 Au recovered, varying size and color.
M019	Crow Creek	None	46-15-01	111-39-44	14 Au	—	81.20	17.90	31 Au recovered, wide size range, mostly small.
M020	Trib. to Crow Creek	Radersburg	46-11-43	111-38-35	23 Au	—	84.70	15.30	140 Au recovered, some coarse, trace Cu in some grains.
M021	Trout Creek	York	46-42-34	111-47-52	NONE	—	—	—	Some scheelite, no Au recovered.
M022	Trout Creek	York	46-42-43	111-46-08	NONE	—	—	—	Several Au recovered, probable inclusions of magnetite.
M023	Magpie Gulch	York	46-41-38	111-37-27	13 Au	—	86.40	13.60	Some scheelite, 25 Au recovered.

No.	Drainage	District/Area	Latitude North	Longitude West	Number of colors analyzed (1970 data)	Number of colors recovered (1990-94 data)[1]	Au (percent)	Ag (percent)	Comments
M024	Avalanche Creek	York	46-37-59	111-33-55	NONE	—	—	—	Probable scheelite, no Au recovered.
M025	White Gulch	Confederate Gulch	46-36-42	111-35-49	NONE	—	—	—	Abundant scheelite, 1 Au recovered.
M026	Confederate Gulch	Confederate Gulch	46-34-14	111-27-58	35 Au	—	80.30	19.70	Very abundant scheelite, 80 Au recovered.
M027	Duck Creek	S. Big Belt Area	46-28-37	111-24-21	One large (lost)[2]	—	—	—	Abundant magnetite and scheelite, 11 Au recovered.
Collected in 1990-1994									
M050	Ophir Creek	Ophir	46-37-56	112-32-38	—	4 Au-3/kg	—	—	Magnetite.
M051	Carpenter Creek	Ophir	46-37-56	112-32-30	—	3 Au-3/kg	—	—	
M052	Carpenter Creek	Ophir	46-37-50	112-32-34	—	5 Au-4/kg	—	—	Magnetite, trace of monazite?
M053	Ophir Creek	Ophir	46-41-38	112-31-20	—	NONE	—	—	Magnetite
M054	Snowshoe Creek	Ophir	46-40-16	112-28-28	—	1 Au-1/kg	—	—	Magnetite.
M055	Crow Creek	Radersburg	46-11-37	111-41-55	—	1 Au-<<1/kg	—	—	Almost no fines.
M056	Keating Gulch	None	46-13-58	111-38-01	—	15 Au-3/kg	89.90	10.10	Pyrite cubes, Cu in 60 percent of gold, Pd in 7 percent of gold.
M057	Eldorado Bar	Missouri River Area	46-43-37	111-51-10	—	95 Au	—	—	
M058	Spokane Bar	Missouri River Area	46-40-04	111-49-00	—	48 Au	—	—	
M059	Lovestone Mine	Missouri River Area	46-40-19	111-46-15	—	278Au-204/kg	—	—	278 Au recovered from 1358 grams of concentrate.
M060	Cave Gulch	York	46-40-31	111-41-08	—	2 Au-3/kg	—	—	
M061	Kingsberry Gulch	York	46-42-47	111-43-51	—	NONE	—	—	
M062	York Creek	York	46-42-51	111-43-48	—	3 Au-3/kg	—	—	
M063	Brown's Gulch	York	46-43-54	111-43-58	—	7 Au-4/kg	—	—	
M064	Kelly Gulch	York	46-44-05	111-43-37	—	NONE	—	—	
M065	Trout Creek	York	46-44-18	111-41-41	—	4 Au-2/kg	—	—	4 tiny Au recovered, pyrite framboids.
M066	Blacksmith Gulch	York	46-44-57	111-40-51	—	2 Au-1/kg	—	—	2 tiny Au recovered, fine-grained pyrite and chalcopyrite.
M067	Trout Creek	None	46-46-02	111-38-50	—	5 Au-2/kg	—	—	
M068	Sheriff Gulch	None	46-44-56	111-35-50	—	3 Au-3/kg	—	—	
M069	Magpie Gulch	None	46-44-38	111-35-57	—	NONE	—	—	
M070	Magpie Gulch	York	46-41-39	111-37-26	—	2 Au->1/kg	—	—	
M071	Avalanche Creek	York	46-38-04	111-33-40	—	NONE	—	—	

No.	Drainage	District/Area	Latitude North	Longitude West	Number of colors analyzed (1970 data)	Number of colors recovered (1990-94 data)[1]	Au (percent)	Ag (percent)	Comments
M072	Avalanche Creek	York	46-39-49	111-32-17	—	NONE	—	—	
M073	Cayuse Gulch	Beaver-Elk Creek	46-41-36	111-30-29	—	1 Au-<1/kg	—	—	
M074	Avalanche Creek	Beaver-Elk Creek	46-42-25	111-29-35	—	3 Au-2/kg	—	—	
M075	Avalanche Creek	Beaver-Elk Creek	46-42-53	111-29-18	—	4 Au-2/kg	—	—	
M076	Thompson Creek	Beaver-Elk Creek	46-43-39	111-30-00	—	11 Au-5/kg	88.80	11.20	1.1 percent Pd in one gold grain.
M077	Avalanche Creek	Beaver-Elk Creek	46-43-41	111-29-56	—	2 Au-2/kg	—	—	Goethite after pyrite.
M078	Thompson Creek	Beaver-Elk Creek	46-43-34	111-30-14	—	6 Au-<1/kg	—	—	About 6 Au from large sample, goethite after pyrite.
M079	Avalanche Creek	Beaver-Elk Creek	46-44-03	111-30-07	—	108 Au	86.60	13.40	Sample from placer operator, 0.9 percent Cu in one gold grain, 0.8 percent Pd in one gold grain.
M080	Rock Creek	None	46-50-30	111-24-17	—	NONE	—	—	
M081	Beaver Creek	None	46-44-43	111-22-01	—	4 Au-2/kg	—	—	4 tiny Au recovered.
M082	Beaver Creek	Beaver-Elk Creek	46-41-43	111-25-30	—	1 Au-<1/kg	—	—	1 small Au recovered.
M083	Horse Gulch	Beaver-Elk Creek	46-41-50	111-21-47	—	2 Au-1/kg	—	—	2 tiny Au, not saved.
M084	Benton Gulch	Beaver-Elk Creek	46-41-05	111-20-55	—	NONE	—	—	
M085	Beaver Dam Gulch	Beaver-Elk Creek	46-41-14	111-24-05	—	1 Au-<1/kg	—	—	1 very small Au recovered.
M086	Long Gulch	Beaver-Elk Creek	46-40-34	111-23-31	—	NONE	—	—	
M087	Vermont Gulch	Beaver-Elk Creek	46-40-27	111-23-20	—	NONE	—	—	
M088	Priest Gulch	Beaver-Elk Creek	46-40-12	111-23-32	—	NONE	—	—	
M089	Benton Gulch	Beaver-Elk Creek	46-39-38	111-22-56	—	2 Au-<1/kg	—	—	2 Au recovered from a large sample.
M090	Ohio Gulch	Beaver-Elk Creek	46-39-37	111-22-52	—	3 Au-<2/kg	—	—	
M091	Hour Gulch	Confederate Gulch	46-38-51	111-24-08	—	1 Au-<1/kg	—	—	1 nice Au recovered.
M092	Cement Gulch	Confederate Gulch	46-37-51	111-23-28	—	NONE	—	—	Abundant cinnabar, abundant pyrite.
M093	White Gulch	Beaver-Elk Creek	46-39-27	111-25-25	—	NONE	—	—	
M094	Johnny's Gulch	Confederate Gulch	46-38-04	111-26-30	—	2 Au-3/kg	—	—	Trace of cinnabar.
M095	White Gulch	Confederate Gulch	46-37-39	111-27-20	—	1 Au-<1/kg	—	—	1 large Au in a large sample.
M096	White Gulch	Confederate Gulch	46-36-54	111-30-02	—	NONE	—	—	
M097	Confederate Gulch	Confederate Gulch	46-32-49	111-28-29	—	14 Au-1/kg	95.60	4.40	6.2 percent Cu in one, 0.6 and 0.8 percent Pd in 2.
M098	Lower Confederate Gulch	None	46-29-28	111-30-38	—	>6 Au-<1/kg	—	—	2 very large and 4 or 5 small Au recovered from large sample.
M099	Duck Creek	S. Big Belt Area	46-28-34	111-24-21	—	2 Au-<1/kg	—	—	2 Au recovered from large sample.
M100	Middle Fk. Duck Creek	S. Big Belt Area	46-29-13	111-22-31	—	2 Au-<1/kg	—	—	2 Au recovered from large sample.

No.	Drainage	District/Area	Latitude North	Longitude West	Number of colors analyzed (1970 data)	Number of colors recovered (1990-94 data)[1]	Au (percent)	Ag (percent)	Comments
M101	Duck Creek	S. Big Belt Area	46-29-04	111-20-45	—	NONE	—	—	
M102	Gurnett Creek	S. Big Belt Area	46-27-50	111-20-05	—	NONE	—	—	
M103	Ray Creek	S. Big Belt Area	46-23-21	111-16-59	—	NONE	—	—	
M104	North Fk. Deep Creek	S. Big Belt Area	46-22-37	111-14-52	—	1 Au-<1/kg	—	—	1 very small Au recovered.
M105	West Fk. Cabin Gulch	S. Big Belt Area	46-22-07	111-13-26	—	NONE	—	—	
M106	Black Butte Gulch	S. Big Belt Area	46-19-55	111-15-34	—	NONE	—	—	
M107	West Fk. Cabin Gulch	S. Big Belt Area	46-20-49	111-13-10	—	NONE	—	—	
M108	Deep Creek	S. Big Belt Area	46-19-51	111-12-29	—	NONE	—	—	
M109	Deep Creek	S. Big Belt Area	46-13-35	111-11-32	—	NONE	—	—	
M110	Cedar Bar Creek	S. Big Belt Area	46-19-58	111-10-24	—	NONE	—	—	
M111	East Fk. Cabin Gulch	S. Big Belt Area	46-21-13	111-11-00	—	NONE	—	—	
M112	West Tr. Cabin Gulch	S. Big Belt Area	46-21-41	111-10-57	—	1 Au	—	—	
M113	East Fk. Cabin Gulch	S. Big Belt Area	46-22-08	111-10-09	—	NONE	—	—	
M114	Deep Creek	S. Big Belt Area	46-21-56	111-06-56	—	NONE	—	—	
M115	Carl Creek	S. Big Belt Area	46-20-55	111-07-16	—	NONE	—	—	
M116	Unnamed Creek	S. Big Belt Area	46-19-55	111-05-16	—	NONE	—	—	
M117	Sulfur Bar Creek	S. Big Belt Area	46-19-18	111-12-25	—	7 Au-6/kg	—	—	6 pyrite, 6 cinnabar, barite.
M118	Trib. Sulfur Bar Cr	S. Big Belt Area	46-19-19	111-12-29	—	NONE	—	—	
M119	Blacktail Creek	S. Big Belt Area	46-19-13	111-10-12	—	8 Au-11/kg	—	—	Cinnabar.
M120	West Fk. Blacktail Cr	S. Big Belt Area	46-18-53	111-10-21	—	5 Au-9/kg	—	—	
M121	Sulfur Bar Creek	S. Big Belt Area	46-18-36	111-11-21	—	6 Au-4/kg	—	—	
M122	Trib. Sulfur Bar Cr	S. Big Belt Area	46-18-25	111-11-30	—	1 Au-1/kg	—	—	
M123	Sulfur Bar Cr. Drain	S. Big Belt Area	46-18-27	111-12-01	—	NONE	—	—	
M124	Sulfur Bar Cr. Drain	S. Big Belt Area	46-18-10	111-12-23	—	1 Au-2/kg	—	—	1 Au recovered (acicular).
M125	Black Butte Gulch	S. Big Belt Area	46-17-55	111-12-37	—	NONE	—	—	
M126	Sulfur Bar Creek	S. Big Belt Area	46-18-01	111-10-19	—	6 Au-5/kg	—	—	1 cinnabar, one pyrite.
M127	E. Trib. Sulfur Bar	S. Big Belt Area	46-17-49	111-09-50	—	>1000 recovered	89.90	10.10	Cinnabar, native As, F mineral, 0.8-1.0 percent Cu in 3, 0.7-2.0 percent Pd in 2.
M128	W. Fk. Sulfur Bar Cr	S. Big Belt Area	46-17-43	111-09-50	—	>9 Au-12/kg	—	—	Arsenic with one gold grain.
M129	Sulfur Bar Creek	S. Big Belt Area	46-17-47	111-09-52	—	>1000 recovered	94.00	6.00	Native As, cinnabar, F mineral, 0.9-1.6 percent Cu in 3, 1.2 percent Pd in 1.

No.	Drainage	District/Area	Latitude North	Longitude West	Number of colors analyzed (1970 data)	Number of colors recovered (1990-94 data)[1]	Au (percent)	Ag (percent)	Comments
M130	E. Trib. Sulfur Bar	S. Big Belt Area	46-17-42	111-08-55	—	13 Au-11/kg	—	—	13 large Au recovered, one cinnabar.
M131	E. Trib. Sulfur Bar	S. Big Belt Area	46-17-38	111-08-53	—	13 Au-15/kg	—	—	2 cinnabar, abundant silver-colored mineral.
M132	W. Trib. Sulfur Bar	S. Big Belt Area	46-17-36	111-10-33	—	NONE	—	—	
M133	W. Trib. Sulfur Bar	S. Big Belt Area	46-17-29	111-10-46	—	NONE	—	—	
M134	W. Trib. Sulfur Bar	S. Big Belt Area	46-17-32	111-11-22	—	NONE	—	—	
M135	Greyson Creek	S. Big Belt Area	46-16-02	111-08-43	—	NONE	—	—	
M136	Greyson Creek	S. Big Belt Area	46-16-08	111-09-14	—	NONE	—	—	
M137	S. Trib. Greyson Cr	S. Big Belt Area	46-16-08	111-09-18	—	NONE	—	—	
M138	S. Trib. Greyson Cr	S. Big Belt Area	46-16-15	111-09-56	—	NONE	—	—	
M139	Greyson Creek	S. Big Belt Area	46-16-55	111-10-15	—	NONE	—	—	
M140	S. Trib. Greyson Cr	S. Big Belt Area	46-16-50	111-12-08	—	1 Au	—	—	
M141	Greyson Creek	S. Big Belt Area	46-16-44	111-12-48	—	NONE	—	—	
M142	Greyson Creek	S. Big Belt Area	46-17-15	111-15-39	—	NONE	—	—	
M143	Greyson Creek	S. Big Belt Area	46-15-39	111-20-50	—	NONE	—	—	
M144	Dry Creek	S. Big Belt Area	46-15-02	111-16-23	—	NONE	—	—	
M145	N. Trib. Dry Creek	S. Big Belt Area	46-15-06	111-16-23	—	NONE	—	—	
M146	Miners Gulch	S. Big Belt Area	46-14-43	111-15-28	—	NONE	—	—	
M147	Dry Creek	S. Big Belt Area	46-14-08	111-13-43	—	NONE	—	—	
M148	North Fk. Dry Creek	S. Big Belt Area	46-13-29	111-10-08	—	NONE	—	—	

CHAPTER I

NONMETALLIC MINERAL DEPOSITS OF THE HELENA NATIONAL FOREST

By R.G. Tysdal

BARITE

Barite forms veins and pods in the Middle Proterozoic Spokane Formation at a few widely separated localities along the southwest flank of the Big Belt Mountains (Berg, 1988) in the York mining district (fig. A2, pl. 2). The veins and pods belong to a class of barite vein deposits that occur within metasedimentary rocks of the Middle Proterozoic Belt Supergroup and generally occur along faults (Berg, 1986). Barium in the veins probably was derived from the host Belt strata: (1) the veins are most abundant in the Belt rather than younger strata; (2) the veins generally are not associated with igneous intrusives; and (3) the Belt rocks are known to contain fairly high values of disseminated barium that locally could be concentrated into veins and pods (Berg, 1986).

The barite veins and pods in the Big Belt Mountains are too small and localized to be considered of economic significance (pl. 2 and table E1, nos. 513, 514, 520, 561). Further, some of the veins contain quartz that would need to be separated before the barite could be used for industrial purposes.

BUILDING STONE

Building (dimension) stone is naturally occurring rock that is selected, shaped, or cut into blocks, slabs, or other specified shape for use in structures such as pavements, walkways, fireplaces, or walls of buildings. Building stone is not known to have been quarried from within the Forest. Near State highway 12 in Deep Creek Canyon, a thick granitic dike has been quarried for road metal (pl. 2, no. 602). This appears to be the same locality that Berg (1974, p. 16) applied the term andesite, stating that when polished, the rock would produce a decorative stone. Rhyolite has been obtained from a large accumulation of talus west of the Josephine mine in an area north of Basin (pl. 2, no. 604). This stone has been termed "rubble" by Berg (1974, p. 11 and 25), which he defined as a variety of stone that has at least one relatively flat surface produced by splitting or rough sawing.

CLAY

Clay used in bricks and paving stones was produced from the Blossburg mine (pl. 2, no. 177), in the Mullan Pass area west of Helena, from the late 1800's (Rowe, 1908) to about 1950. Clay was mined from a Tertiary unit (Ts, pl. 1), possibly Oligocene in age, comprised of nonmarine claystone, siltstone, sandstone, and volcanic ash (Schmidt and others, 1994). The Blossburg mine is on private land that lies inside the Forest boundary, but the clay-bearing stratigraphic unit extends westward onto Forest land.

LIMESTONE

The distribution of limestone, dolomite, and calcareous and dolomitc strata in the Forest is shown on map C (pl. 3). Limestone of quality that is adequate for use in cement or as a smelting flux is present locally in the Gates of the Mountains Wilderness (Reynolds and Close, 1984) and nearby strata in the northern part of the Big Belt Mountains. Analyses by the U.S. Bureau of Mines indicate that most of this limestone is suitable for cement and for other construction uses (Close and Rigby, 1984).

On the east flank of the Elkhorn Mountains, outside the Forest, limestone is produced from the Indian Creek mine (pl. 2, no. 481) in the Mississippian Mission Canyon Formation. The operation produces about 1 million tons of raw limestone per year (McCulloch, 1992, 1993). The host formation also is present in the southeastern part of the Forest in the Elkhorn Mountains, but we have conducted no analyses of composition to determine suitability for industrial use. Limestone for cement is produced from the Montana City quarry (pl. 2, no. 397) south of Helena, from altered limestone (McCulloch, 1992). A small amount of limestone is quarried from Cambrian limestone at the Helena limestone quarry (pl. 2, no. 203) (Chelini, 1965). The adjacent Forest contains an extensive area of limestone of Cambrian to Mississipian age. Similarly, limestone has been quarried near the Forest about 3 mi east of Elliston, and an extensive area of Cambrian to Mississippian limestone is present in the Forest north of Elliston, in the Ophir district--Dog Creek area.

The Forest contains Cambrian to Mississippian-age limestones that could be utilized for industrial purposes, but large areas of limestone also lie outside the Forest and generally are closer to major transportation routes.

PHOSPHATE

In western Montana, the Lower Permian Phosphoria Formation is the host for minable phosphate. The phosphate is of the upwelling type. Deep, cold ocean water rich in phosphorous welled upward to replace near surface water, and phosphate precipitated due chiefly to a decrease in pressure and an increase in temperature (Sheldon, 1964; Mosier, 1986).

The Phosphoria Formation is present only locally in the northern part of the Big Belt Mountains, where it was generally removed by erosion prior to deposition of younger strata. No phosphatic rocks were reported to occur within the Gates of the Mountains Wilderness, or proposed additions thereto, in the northern part of the Forest (Reynolds and Close, 1984; Close and Rigby, 1984). Robinson and others (1969) stated that as much as 40 ft of the formation is present locally near American Bar (pl. 2, vicinity of no. 503) (along the Missouri River directly east of Holter Lake); at the northwesternmost edge of the Forest, west of the Missouri River; and near Hauser Dam. They reported none of the phosphatic strata that produces phosphate in western Montana, noting only phosphatic sandstone in the isolated remnants of the formation. The Big Belt Mountains area lies east of the phosphate producing region, where the formation is thin and sandy and does not have minable grade, thickness, or extent.

In the southeastern part of the Elkhorn Mountains, the Phosphoria Formation has limited exposures. It consists mainly of chert and quartzitic sandstone, but in places includes one or two thin beds of phosphate-bearing rock. A lower phosphatic bed, only 9 in. thick, and chips of phosphatic material in a quartzite bed at the top of the Phosphoria, occur east of the Forest; none of the phosphate rock in the Forest is of minable grade or thickness (Klepper and others, 1971, p. 6).

In the westernmost part of the Forest, in the Ophir district-Dog Creek area north of Elliston (pl. 2), most of the phosphate occurs in a 2.5-7.5 ft thick single zone (the Retort Phosphatic Shale Member) of the Phosphoria Formation. Swanson (1973, p. 827) stated that the phosphate varies widely in quality, with some beds containing too little phosphate to mine whereas other beds are thick enough to mine by themselves. The irregular distribution was attributed to the strata representing landward deposits of the Phosphoria sea. A small tonnage has been produced from each of several small underground exposures, mostly before World War II. In the area where the Phosphoria is contiguous in and adjacent to the Forest, Swanson (1973, p. 829) calculated resources of the Phosphatic Shale Member to be about 200 million short tons of rock containing greater than 18 percent P_2O_5. About half of the area of distribution of the member lies within the Forest.

SAPPHIRES IN PLACER DEPOSITS

Sapphires have been recovered from terrace deposits of gravel ("bars") near the Missouri River along the west side of the Big Belt Mountains (Pardee and Schrader, 1933). The sapphires originally were recovered as a byproduct of placer gold operations, and later for gems, but their pale colorations failed to find a significant market. Most seem to have been used for industrial purposes (Clabaugh, 1952). The bars presently produce small-scale concentrates for commercial use and fee digging for recreational recovery (Ziehen, 1987; Voynick, 1988; McCulloch, 1993). Parts of only two of the bars, American and Eldorado (pl. 2, nos. 503 and 505), lie partly inside the Forest. Washed commercial concentrates of sapphires were being recovered from the Eldorado and some of the other bars as recently as 1992 (McCulloch, 1993).

The source of the sapphires has not been satisfactorally determined. A few sapphires have been found in an igneous dike about 1 mi down stream from Canyon Ferry Dam, on the west bank of the Missouri River. Kunz (1893) and Pardee and Schrader (1933) believed this dike and perhaps others to be the source of the placer sapphires. Baker (1992) attributed a sapphire-bearing dike of the Little Belt Mountains (east of the Forest study area) to emplacement from a deep-seated crustal magma during Eocene regional magmatic activity, which is in accord with modern concepts of the origin of sapphires. Several decades earlier, Mertie and others (1951) hypothesized that the sapphires were derived from contact-metamorphic rocks formed in the roof zone of a granitic intrusive that crops out directly south of Canyon Ferry Dam, along the west side of the reservoir; they speculated that the lode deposits were entirely removed by erosion.

No sapphire-bearing dikes, or sapphire-bearing contact-metamorphic rocks, are known to be present within the Forest in this vicinity.

SILICA

Deposits of high silica content are of both igneous and sedimentary origin. The only sedimentary unit of very high silica content is the Pennsylvanian Quadrant Formation, which is known to be of high purity locally in western Montana (Chelini, 1966). No evaluations were made of the purity of the Quadrant in the Forest. Only one deposit type, of igneous origin, is considered here.

A 150 ft wide dike that is nearly pure quartz, the Corral Gulch deposit (pl. 2, no. 297), cuts granitic rocks of the Boulder batholith west of Clancy (West, 1959; Chelini, 1966). The quartz is of hydrothermal origin, likely formed from fluids that crystallized during waning stages of formation of the Boulder batholith. The deposit has a measured reserve of 275,000 tons of quartz (Chelini, 1966, p. 20). No production is known to have occurred from the deposit (Elliott and others, 1992).

SHORELINE PLACER DEPOSITS

Shoreline placer deposits are composed of heavy minerals that have been concentrated by wave processes. The concentrations form beds and lenses which, over a large area, constitute elongate "shoestring" deposits indicatve of a strandline. Most such placer deposits formed in a marine beach environment and, to a lesser extent, associated dune and inlet environments. The heavy minerals typically are dark gray to black, well sorted sands of fine to medium grain size. Some minerals that may be present in the placers, and of economic value, include ilmenite (titanium), rutile (titanium), zircon (zirconium), and monazite (rare earths and thorium). Magnetite also commonly is present, although by itself generally is not likely to be of economic value. Quartz, resistant to weathering, also generally is abundant. Present-day production from shoreline placer deposits generally is from late Tertiary-Quaternary deposits, most of which have not been lithified (Force, 1986; E.R. Force, oral commun., 1994).

In the vicinity of the Forest, heavy minerals in fossil (ancient) shoreline placer deposits form black sandstones that were deposited along the margin of the Late Cretaceous Western Interior seaway (Houston and Murphy, 1977). A black sand-bearing zone yielded magnetite and ilmenite from a 7-15 ft thick sandstone at the Iron Cross mine (pl. 2, no. 494), about 1 mi southeast of the southeast corner of the Forest in the Radersburg district of the Elkhorn Mountains (Reed, 1951, p. 60; Klepper and others, 1957, 1971; Freeman and others, 1958). Heavy mineral-bearing sandstone also is present in the southeasternnmost part of the Forest (pl. 2, no. 486). These deposits are within the basal part of the Cretaceous Eagle Sandstone (plate 1), which Tysdal (unpub. data) separated from the Slim Sam Formation as originally defined by Klepper and others (1957, 1971). The host Eagle Sandstone (pl. 1) is discontinuous within the Forest of the Elkhorn Mountains and adjacent area, due to erosion during the Cretaceous, and the black sand-bearing zone is thin and discontinuous within the preserved strata of the formation (Klepper and others, 1971, p. 12; Tysdal, unpub. data).

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CHAPTER J

PETROLEUM POTENTIAL OF THE HELENA NATIONAL FOREST

By William J. Perry, Jr., Mark J. Pawlewicz, Ted A. Daws, Thaddeus S. Dyman and George Desborough

INTRODUCTION

The Helena National Forest (the Forest) lies primarily within southern Lewis and Clark, northeastern Powell, northern Jefferson, northeastern and western Broadwater and northwestern Meagher Counties, and extends into the southern edge of Cascade and the northern edge of Gallatin Counties, Montana. It spans four geologic provinces (fig. B1), from north to south - (1) the Montana disturbed belt (Mudge, 1983; Perry, 1989) or simply the disturbed belt (fig. B1); (2) the Montana transverse zone (Lewis and Clark line of Reynolds, 1979, and Sears, 1995); (3) the Helena salient of the Cordilleran thrust belt; and (4) the Boulder batholith, its satellite bodies and fringing volcanic rocks along the western edge of the Helena salient. To date, only one of these provinces has produced hydrocarbons in commercial quantities, the shut-in two-well Knowlton gas field and adjacent three-well Blackleaf Canyon gas field in T. 26 N., R. 8 W. of the disturbed belt, more than 50 miles north of the northern edge of the Forest. These two small gas accumulations have produced a total of 7 BCF (billion cubic feet) of natural gas and 0.03 million barrels of condensate (J.W. Halvorson, Montana Oil and Gas Conservation Division, 1993, written communication).

The purpose of this chapter is to qualitatively evaluate the petroleum potential of the Forest. First, the oil and gas plays recognized in the vicinity of the Forest are discussed. Second, we summarize the available drillhole data, and third, the available hydrocarbon source-rock data. Structural geology is a recurring theme throughout the chapter. The districts mentioned in this chapter are the Forest Service districts named on the Helena National Forest, Forest Visitor Map (Anonymous, 1991). This chapter discusses the geology of a region greater than the Helena National Forest because regional geologic features, hydrocarbon-bearing rocks, and structures cross National Forest boundaries.

OIL AND GAS PLAYS

Oil and gas plays are sets of known or postulated oil and gas "accumulations sharing similar geologic, geographic, and temporal properties such as source rock, migration pathway, timing, trapping mechanism, and hydrocarbon type" (Gautier, 1996). Play areas are regions over which specific play concepts are considered to be valid.

The Lincoln District of the Forest, north of T. 13 N. (~46°55'N) lies within the disturbed belt and the confirmed Imbricate Thrust Gas Play (2701) of Perry (1996, fig. J1). This gas play is based on the likelihood of undiscovered gas-bearing reservoir rocks, primarily carbonate rocks of the Mississippian Madison Group, in structural traps for hydrocarbons in antiformal stacks of thrust-bounded imbricate zones and related anticlines in the footwall of the

Eldorado-Lewis thrust system (Perry, 1996). Such likely structural traps are inferred to be sourced by gas generated from the Upper Devonian to Lower Mississippian marine rocks and (or) Cretaceous marine shales. The northeastern margin of the Lincoln District lies within the southwestern part of the hypothetical Cone Member, Marias River Shale Oil Play (2703) of Perry (1996, fig. J1). This unconventional, continuous-type play is based on the oil-prone character and above average organic carbon content of the Cone Member and its proven ability to yield oil from fractures, apparently irrespective of structural relief. Source and reservoir are the same; the oil has not been expelled from its source, and conventional oil-water contacts are not anticipated (Perry, 1996).

The northeastern part of the Helena District (Hogback Mountain and Gates of the Mountains Wilderness areas) lies along the southeastern edge of the disturbed belt, abutting the Helena salient and disrupted by Tertiary dextral, oblique-slip and normal faults of the Montana transverse zone (Lorenz, 1984, and Sears, 1995). This area also lies within the southeastern margin of Play 2701 as well as Play 2707, the hypothetical Imbricate Thrust Oil Play of Perry (1996, play areas shown in fig. J1). Play 2707 is defined on the basis of both anticipated source rocks (chiefly Upper Devonian and Lower Mississippian) and reservoirs (in carbonate rocks of the Madison Group), in inferred structural traps similar to those of Play 2701 but within the oil window. Examination of potential reservoir rocks in the southern part of the area of Play 2707 revealed no residual oil in pores or fractures (Reynolds and Close, 1984). Analyses of potential hydrocarbon source rocks they collected suggest that, regardless of the structural position of the samples, these "rocks have passed through temperatures of oil and wet gas generation and have been in the temperature range of dry gas generation" (Reynolds and Close, 1984).

To the west, the main part of the Helena District lies within the batholithic province of McMannis (1965), specifically the northeastern part of the Boulder batholith and related rocks (fig. B1). This area is considered unfavorable for hydrocarbons because of the intense thermal activity associated with emplacement of these igneous rocks and because of expected, related, vertical fractures that would permit the escape of hydrocarbons. To the east, the Big Belt Mountains in the eastern Helena and Townsend Districts expose primarily Middle Proterozoic formations of the lower Belt Supergroup. Based on results from the American Petrofina #1 Manger-Skyline drillhole (no. 32 of table J1 and fig. J1), as well as unpublished seismic data obtained from farther south across the Big Belt Mountains, we interpret these mountains to overlie a major thrust-imbricate-cored structural culmination of Proterozoic Belt strata that have been thrust over other Belt rocks. Shepard and Precht (1989) reported values as high as 3 to 5 percent organic carbon in exposures of Proterozoic Newland Formation in Swimming Woman Canyon in the Big Snowy Mountains about 85 miles east of the northeastern boundary of the Forest. Aram (1993) suspected a Proterozoic source for some oils farther to the northeast (Cat Creek field oils of Aram, 1993). For these reasons and because of the organic-rich appearance of some of these rocks, a source-rock evaluation of these rocks was undertaken by Pawlewicz (1994, see table J3).

All but the westernmost part of the Townsend District of the Forest lies in the area of the Helena Salient Gas Play (2704) of Perry (1996). Anticlinal and thrust imbricate closures within the salient and presence of Mississippian Heath-equivalent and Lower Cretaceous source rocks, plus favorable migration pathways and timing, define the play. The central part of the play area contains

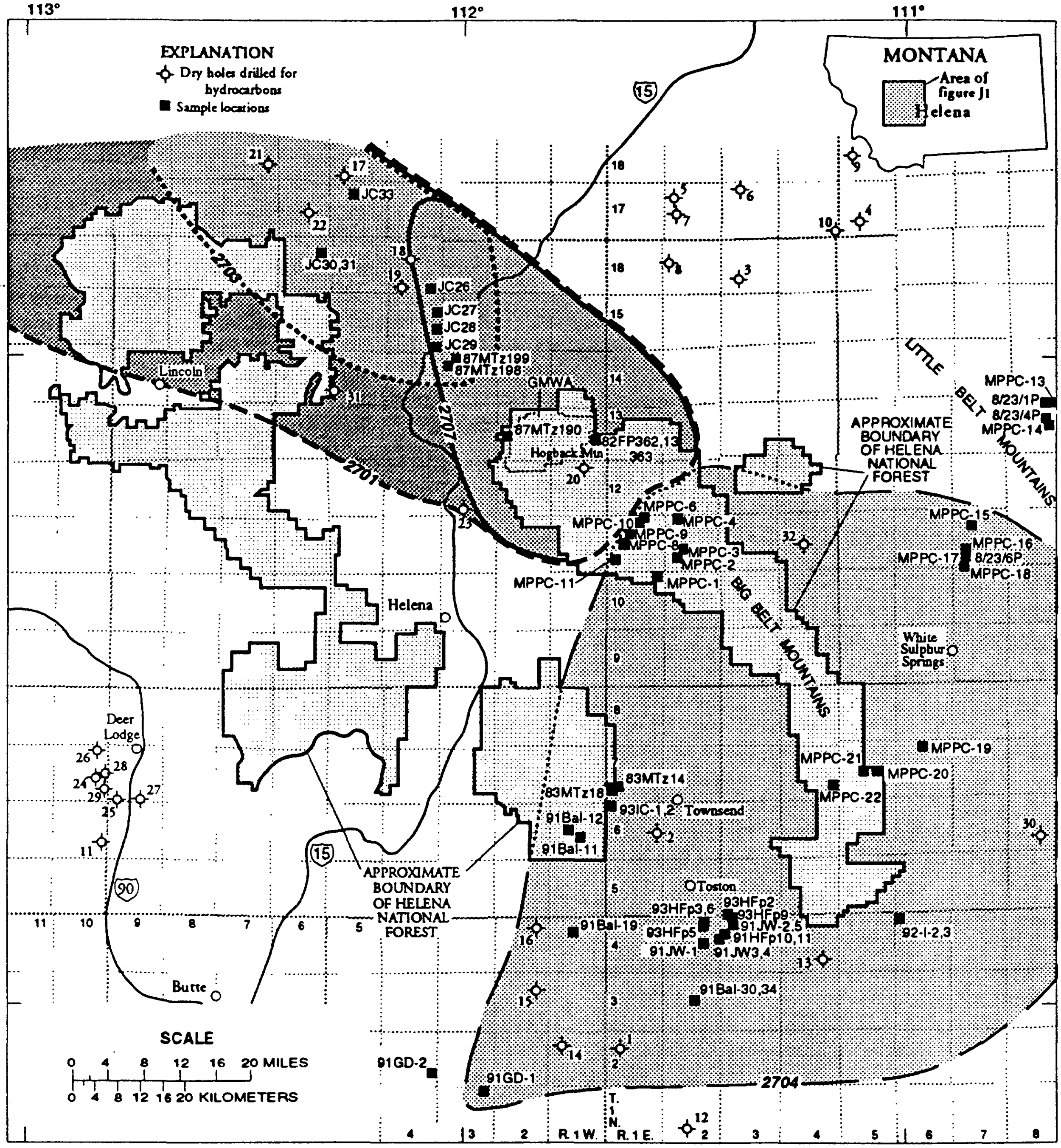

Figure J1. Index map showing Helena National Forest (light shaded areas), outlines of hydrocarbon plays (darker shaded areas) assessed by Perry (1996), dry holes drilled for hydrocarbons in the vicinity of the Forest (Table J1), sample localities (Tables J2 - J6), township-range grid, and geographic features mentioned in the text. GMWA - Gates of the Mountains Wilderness Area. Numbers (i. e., 2704) associated with each hydrocarbon play are the play numbers from Perry (1996).

12,000 to 25,000 ft of Middle Proterozoic sedimentary rocks unconformably overlain by about 9,000 ft of Phanerozoic sedimentary rocks, with nearly half of this sequence composed of Cretaceous strata. No exploratory holes for hydrocarbons (table J1) drilled in this play have proved productive nor have significant shows of oil or gas been reported. A deep exploratory hole (no. 16, table J1 and fig. J1) drilled through the Lombard thrust plate (fig. B1). in Jefferson County about 7 miles south of the western area of the Townsend District (Elkhorn Mountains region of fig. F1) was interpreted by Ballard and others (1993) to have significant hydrocarbon potential. Their interpretation of formations encountered below the Lombard thrust in this drillhole is not supported by our data, summarized in tables J3, J4, J6, figure J2 and discussed below.

DRILLHOLE DATA

Data from 32 exploratory holes drilled in the search for hydrocarbon accumulations in or near the Forest, for which encountered formation tops have been reported, are summarized in table J1. The tops given are those reported by the operators, except for the upper and lower lithic equivalents of the Lower Mississippian and Upper Devonian Bakken Formation (Macqueen and Sandberg, 1970), which are, respectively, the Cottonwood Canyon Member of the Lodgepole Formation and the basal black shale (unit 1) of the underlying Sappington Member of the Upper Devonian (Poole and others, 1992, fig. 2) Three Forks Formation. The depths and apparent thickness of these two units were picked by Perry from geophysical borehole logs. Of the 32 exploratory holes listed in table J1, seven were drilled west of the Forest in the Tertiary basin south and west of Deer Lodge (fig. J1, T. 6-7 N., R. 9-10 W.); these holes targeted Eocene to Oligocene lake deposits with inferred adjacent source and reservoir rocks. Prospective parts of this basin do not underlie the Forest, nor was this exploration effort successful.

Eight of the holes were drilled in the southern part of the Helena salient (T. 1-6 N., R. 2 W. to R. 8 E.) during exploration for hydrocarbons in structural traps in Paleozoic and Mesozoic rocks. No shows of oil were reported from these eight holes in information at hand. Gas shows were reported in the Phillips Petroleum 1 Brainard-B and Amoco Production 1-R Kiff Ranch holes (respectively, nos. 13 and 30, table J1). The former is located 3.4 miles south, and the latter is 16 miles east-northeast of the southeast margin of the Townsend District (fig. J1). Lithologies shown on the hydrocarbon well log (includes drilling time and description of well cuttings) of the former hole indicate a very different drilled sequence of units from that predicted by the operator (see columns 2 and 3, no. 13, table J1, for Perry's preliminary interpretation of formations encountered in this hole). Perhaps the most controversial of these eight holes drilled in the southern part of the Helena salient, the Norcen Explorer 1-11 Kimpton Ranch (no. 16, table J1 and fig. J1), was completed most recently (4/01/91), controversial because the Cretaceous Colorado Group, reported to have been encountered below 7,824 ft in this hole, requires major revisions in the interpretation of Cordilleran structure and Cretaceous stratigraphy of the area. Nine large samples from this hole, kindly provided by Norcen Energy Resources Ltd., spaced roughly 1,000 ft apart, were analyzed in detail (tables J3, J4 and J6), as discussed below.

Three of the 32 holes were drilled along the northern margin of the Helena salient (T. 11-12 N., R. 3 W. to R. 4 E.). One of these, the Getty Oil 3-10 Federal (no. 20, table J1 and fig. J1) reveals great structural complexity and minor gas shows as well as traces of oil staining. The many lost circulation zones reported are consistent with intense fracturing inferred from the various logs available from this hole.

Six of the 32 holes were drilled in the southern part of the disturbed belt (T. 14-18 N., R. 4-7 W.), of which the Unocal 1-B30 Federal (no. 31, table J1), completed 9/26/89 to a total depth (TD) of 17,818 ft, through the Eldorado thrust, revealed an extensive Mesozoic and Paleozoic footwall section within the oil window (table J1, Peterson and Nims, 1992). The report of low-salinity formation water in the Mississippian Madison Group in the Unocal drillhole by Peterson and Nims (1992; data on file at Montana Oil and Gas Conservation Division) is summarized in table J1. Eight additional holes were drilled within the map area outside of the Forest in the foreland northwest of the Little Belt Mountains (T. 16-18 N., R. 2-5 E., fig. J1).

POTENTIAL SOURCE ROCKS FOR HYDROCARBONS

Potential source rocks for hydrocarbons in the vicinity of the Helena National Forest include marine shales and (or) organic mudstones of Devonian, Mississippian, and Cretaceous age. Organic-rich mudstones of the Permian Phosphoria Formation are not present in the disturbed belt or in the Helena salient east of the Boulder batholith (Peterson, 1986, fig. 13). Tertiary oil shales have been identified and analyzed for lithium by Brenner-Tourtelot and others (1978) in T. 15 N., R. 9 W., 6-8 miles northwest of Lincoln, along the northwestern edge of the Forest, but their organic matter was not analyzed. Based on analogy with a study (Curiale and others, 1988) of similar rocks in the Kishenehn basin along the western margin of Glacier Park, 40-50 miles northwest of the Forest, these Oligocene oil shales in the Lincoln area are inferred to be thermally immature with respect to oil generation. Post-Oligocene burial has apparently been regionally insufficient for thermogenic hydrocarbon generation. Proterozoic lower Belt rocks of the Helena salient and Belt embayment farther east have also been considered potential hydrocarbon source rocks (Shepard and Precht, 1989; Aram, 1993). A preliminary evaluation of these Proterozoic rocks by Pawlewicz (1994) did not support this contention. A more extensive discussion of the potential source rocks mentioned in this paragraph follows, but first we provide a brief explanation of methods and terminology.

Methods and terminology

We use the term **kerogen** to designate insoluble organic material in sedimentary rocks; in contrast, **bitumen** is soluble in organic solvents (Tissot and Welte, 1978, p. 123). Kerogen is composed of many different types of organic matter. We use Types I, II, and III as defined by Tissott and Welte (1978, p. 147). Type I kerogen has a high H/C (hydrogen/carbon) ratio, is primarily "derived from algal lipids or from organic matter enriched in lipids [fats], and has a high potential for oil and gas generation". Type II kerogen has a lower H/C ratio and oil and gas potential than Type I, "is usually related to marine organic matter deposited in a reducing environment, with medium to high sulfur content." Type III kerogen is mainly derived from terrestrial higher plants; H/C ratio is low, and oil-generating capacity is moderate to low; it is primarily capable of generating gas. **Rock-Eval pyrolysis** is the controlled heating of a rock sample under dry conditions. It is presently the most common laboratory screening technique in hydrocarbon source rock evaluation (Bordenave and others, 1993) and was conducted on 56 samples in conjunction with the present study (results summarized in Tables J2 and J4). **Tmax** is the temperature in °C (degrees Celsius) recorded for the maximum generation of hydrocarbons from kerogen during the artificial maturation caused by dry pyrolysis. It is a measure of thermal maturity. The high-temperature end of the oil window in source rocks occurs at a Tmax of about 460°C (Tissot and Welte, 1978, p. 454, fig. V.1.16). More recently, Bordenave and others (1993, fig. 2-17) showed that the oil and gas window varies slightly for different types of organic matter. Total organic carbon (**TOC**) is measured by combustion of the organic material of a sample at 600°C after Rock-Eval pyrolysis is complete. Highly mature Type III organic matter can give Rock-Eval TOC values as much as 48 percent lower than actual (Bordenave and others, 1993, table 2-4), because 600° combustion does not completely oxidize such material. The S_1 peak is a measure of hydrocarbons that exist in a rock sample and "can be used as a tool to detect migrated hydrocarbons" (Bordenave and others, 1993, p. 241). The S_2 peak represents hydrocarbons produced by heating of kerogen (Types I, II III). It "gives a reasonable evaluation of the current [hydrocarbon generation] potential of a rock sample"; 70-80 percent of Type I, 45-50 percent of Type II, and only 10-25 percent of Type III kerogen are transformed into hydrocarbons during pyrolysis (Bordenave and others, 1993, p. 242). Rocks with $S_2 < 4$ mg/g of sample have low or no potential; S_2 between 4 and 8 indicates fair potential (Bordenave and others, 1993, p. 260). None of our samples had S_2 values as high as 2 (tables J2, J4). The S_3 peak is a measure of carbon dioxide generated in the sample during pyrolysis of oxygen-bearing organic compounds. It is recorded below 400°C because of thermal decomposition of some carbonates (especially siderite, see table J6) and other poorly crystallized inorganic crystalline materials. The accuracy of this peak is low for rocks with low organic content (TOC < 0.5 percent, especially those containing a large amount of siderite), affecting the oxygen index [OI], computed from S_3/TOC. The hydrogen index [HI], computed from S_2/TOC, correlates well with H/C [atomic] ratios of kerogen. HI vs OI diagrams are used in classifying Types I, II, and III kerogen (Bordenave and others, 1993, p. 251). Obviously, false values of OI, primarily caused by low TOC, will affect such analyses. **Vitrinite reflectance** (table J3), is the standard reflected light technique for measurement of the thermal maturity of organic material (Tissot and Welte, 1978). It is a better measure of thermal maturity than Tmax: oil generation begins at R_o (mean random reflectance in oil) of about 0.7 percent for Type I kerogen and about 0.6 percent for Types II and III. Cracking is sudden for type I and primary hydrocarbon generation is ended by R_o about 1 percent; most type II kerogen is also transformed by the time R_o = 1.0 percent (Bordenave and others, 1993, p. 247). For Type III organic matter, transition to gas condensate generation corresponds to an R_o of 1.3 percent, and dry gas generation continues above an R_o of 1.6 percent.

Mineralogy of the samples (table J6 and figure J2) was determined using nickel-filtered Cu-K_α radiation at an X-ray diffractometer scale of 2°/minute. The same equipment and operating conditions were used for all analyses. Powdered samples were packed into 2 -mm-thick mounts. X-ray peak intensities reported were corrected for background. For each mineral, the x-ray diffraction maximum was used (table J6 and figure J2).

Precambrian

The Middle Proterozoic Newland Formation is 7,000 to 10,600 ft thick in the Big Belt Mountains (Mitchell W. Reynolds, U.S. Geological Survey, 1987, written communication), at the south end of which Robinson (1967) described the upper part as a gray to yellow-brown [weathered] limy siltite, limestone, and fine quartzite. The lower member consists of medium gray siltite and limy siltite (Tysdal, Chapter B and plate 1, this report, description of map units). Outcrops sampled by Pawlewicz and Perry in the Little Belt and Big Belt Mountains consisted of dark gray to black, thin to very thin-bedded, often laminated siltite and limestone, yielding 0.06-0.63 percent TOC (table J2). Reliable Tmax values of these Newland samples ranged from 473 to 545°C. The fine-grained facies of the possibly equivalent LaHood Formation was sampled by Desborough (samples 91GD-1 and 91GD-2, table J2) near the southern edge of the Helena salient, about 25 miles south of the Forest. These samples yielded 0.75 and 1.09 percent TOC respectively, with a reliable Tmax only on the latter of 485°C. All Proterozoic samples obtained (table J2), except one from the LaHood, were remarkably low in TOC, in spite of their general dark gray to black color and our care in collecting only unweathered surface samples. XRD (X-Ray diffraction) analyses by Desborough (table J6) showed a relatively high chlorite content in many of the Newland samples. The chlorite peaks were characteristic of clinochlore IIB, indicating that these rocks had been exposed to temperatures of more than 200°C. Dolomite to calcite peak height ratios indicated that dolomite generally predominated over calcite in the 10 Newland samples analyzed (three from the southwestern edge of the Little Belt Mountains and seven from the Big Belt Mountains).

The dolomite/calcite and chlorite/illite ratios for the Newland Formation and Cretaceous(?) samples from the Kimpton Ranch well (no. 16, table J1, fig. J1) are nearly identical (table J6) and very different from well-documented Cretaceous samples obtained from both hanging wall and footwall rocks of the Lombard thrust. D.J. Nichols (U.S. Geological Survey, 1993, written communication) examined unoxidized palynologic preparations derived from carefully washed drill cuttings from four depths (8,000, 10,000, 11,000, and 13,000 ft) from the Kimpton Ranch drillhole. He found amorphous organic matter, but no palynomorphs. A sample of the bentonite used in the drilling mud, kindly furnished by Jack Warne (Consultant, Billings, Montana), yielded a "sparse but diverse assemblage of fossil and modern palynomorphs including (among fossils) marine forms; none of these were observed in the drill cuttings samples" (D.J. Nichols, U.S. Geological Survey, 1993, written communication). E.I. Robbins (1993, U.S. Geological Survey, written communication) examined the same four preparations and found only very dark brown pellet-shaped microfossils, algal balls, and algal filaments (Robbins and others, 1985) that she considered indigenous. Modern and/or Cretaceous organic matter, probably derived from drilling mud or subsequent contamination, is much lighter in color than the organic matter deemed indigenous. Neither specialist found any trace of vascular plant remains (of the appropriate color to be indigenous), common in Cretaceous samples from this region. The samples from the Kimpton Ranch well are, therefore, all tentatively considered Middle Proterozoic. Reliable Tmax data (table J4) of these samples ranges from 510-592°C, and TOC from 0.26-1.31? percent, both ranges slightly higher than the surface Newland samples to which they bear a remarkable resemblance (color, texture, dolomite/calcite and chlorite/illite peak height ratios - table J6, fig. J2). The abundance of chlorite and pyrite is similar to samples collected by Desborough from the fine-grained facies of the LaHood near the southern edge of the Helena salient; the chlorite (clinochlore IIB) is another link to the Middle Proterozoic suite of samples. We conclude that Proterozoic rocks in the Forest area are generally low in TOC and overmature with respect to liquid hydrocarbons and marginal with respect to gas. Organic material appears to be primarily algal, and some solid pyrobitumen is present, such that these rocks may have generated liquid hydrocarbons long ago, probably prior to Cambrian time.

Upper Devonian - Lower Mississippian

The source of most liquid hydrocarbons on the Sweetgrass arch to the north of the Helena salient is considered to be the Upper Devonian to Lower Mississippian Bakken Formation of southern Alberta (Dolson and others, 1993), termed Exshaw Formation by Macqueen and Sandberg (1970). Typically, the Bakken Formation consists of an upper organic-rich shale member, a medial siltstone member, and a lower organic-rich shale member. The upper Bakken-equivalent unit in the area of the Forest is the Cottonwood Canyon Member of the basal Lodgepole Formation (Sandberg and Klapper, 1967). The lower Bakken-equivalent is the basal black shale (unit 1) of the underlying Sappington Member of the Three Forks Formation (Macqueen and Sandberg (1970, fig. 4). The upper unit is 2 to 3 ft thick where encountered (drillholes 20 and 30, table J1) in the Helena salient but pinches out against a basal Mississippian unconformity to the north (in T. 27-28 N., Dolson and others, 1993, fig. 10). The black shale of the basal Sappington Member is not present in drillhole 30 (Table J1; fig. J1) in the southern Helena salient and is only locally preserved beneath an intraformational unconformity within the Sappington Member farther south (Gutschick and others, 1976). In the Getty Oil 3-10 Federal drillhole (no. 20, table J1) a major thrust encountered at a depth of 7,166 ft separates two Devonian source rock sequences: (1) The upper sequence contains a drilled interval of 15 ft of the lower black shale (carbonaceous mudstone), 58 ft of upper Sappington Member, and 3 ft of Cottonwood Canyon Member. (2) The lower sequence contains a drilled interval of 6 ft of the lower black shale, 44 ft of upper Sappington Member, and 2 ft of Cottonwood Canyon Member. Because the upper sequence (4,351-4,354 ft) probably dips more steeply than the parautochthonous sequence at 12,416-12,468 ft, only the relative proportion of black shale (20 percent in the upper section of Sappington Member, 12 percent in the lower) is deemed significant. Because the upper sequence is displaced eastward with respect to the lower, the carbonaceous mudstone of the basal Sappington Member appears to have originally thickened westward with respect to the entire Sappington interval. Mitchell W. Reynolds (1995, written communication) reports 5.97-15.01 percent TOC from carbonaceous mudstone of the basal Sappington Member and 5.0 percent TOC from the Cottonwood Canyon Member in surface samples collected nearby. To the north, Dolson and others (1993) report 12.9 percent TOC from the Bakken(?) Formation in the Pan American G-1 State drillhole (sec. 36, T. 20 N., R. 3 W.). The upper and lower shales/mudstones of the Bakken-equivalent Cottonwood Canyon-Sappington sequence are considered excellent petroleum source rocks and are oil-prone.

Upper Mississippian

The Heath Formation of the Upper Mississippian Big Snowy Group is a major source for oil on the Central Montana platform northeast of the Forest (Aram, 1993). Samples of the Heath-equivalent Lombard Formation, primarily shale, provided by Jack Warne (samples 91JW-2 to 91-JW5, table J2) and others collected by Perry (93HFp10 and 93HFp11, table J2) ranged from 0.16 to 2.89 percent TOC with reliable Tmax values generally within the oil window. These Heath-equivalent carbonaceous shale/mudstone samples were all collected at or near the type section of the Lombard Formation of the Big Snowy Group (Blake, 1959, SW 1/4 section 7, T. 4 N., R. 4 E.) in the footwall of the Lombard thrust plate, about 5 miles south of the Forest area of the Big Belt Mountains. These rocks are gas-prone (Perry, 1996, discussion of play 2704) and are absent farther west, on the hanging wall of the Lombard thrust as well as northwest of the Gates of the Mountains Wilderness area. Source-rock evaluation of the Heath Formation in the northeastern part of the Helena salient is discussed by Longden and others (1988), who concluded that only dry gas would be present in the subsurface near their sampling locality, consistent with their reported R_o values of 3.7-4.7. Forrest G. Poole (U.S. Geological Survey, 1986, written communication) collected two Heath samples in T. 13 N., R. 01 W. (table J6) which had the highest (4.80-4.86 percent) TOC reported from the Heath in the vicinity of the Forest. These samples yielded Tmax values of 504 to 519°C (approximately equivalent to an R_o of 1.7 to 2.0 percent) in the gas generating range and were not exposed to the intense heating illustrated by the very high R_o of the samples of Longden and others (1988) collected farther east.

If the Lombard thrust was encountered in the Kimpton Ranch drillhole (no. 16, table J1) discussed above, then the footwall cutoff (western limit in the footwall) of these Mississippian rocks is east of this drillhole. The "black shales" encountered in this drillhole (Kimpton Ranch samples discussed above, generally highly pyritic and dolomitic) are clearly not Heath equivalents (see table J6 and fig. J2). Therefore, the likelihood of the Heath-equivalent rocks sourcing liquid hydrocarbons in the close vicinity of the central and southern Forest is considered unlikely; although gas generation is likely to have occurred. The Heath Formation may have also yielded dry gas in the subsurface in the vicinity of T. 13 N., R. 01 W. in the northeastern segment of the Helena District.

Cretaceous

The Cretaceous sequence is the thickest and most complex body of rocks in the vicinity of the Forest. The nature of the primarily siliciclastic Cretaceous sequence has been recently summarized by Dyman and others (1994). Marine tongues, principally represented by the Thermopolis Shale (Flood Member of the Blackleaf Formation), Mowry Shale, Belle Fourche Shale, Carlile Shale, Cody Shale, Marias River Shale, and Bearpaw Shale extend westward and interfinger with the Cretaceous nonmarine sequence. The total thickness of the Blackleaf Formation through Cody Shale in the hanging wall block west of Townsend (fig. J1) is about 2,000 ft (Dyman and others, 1996). This interval contains about 600-700 cumulative ft of black shale intervals (R.G. Tysdal and T.S. Dyman, U.S. Geological Survey, unpub. data, 1995). The Thermopolis Shale is the most organic rich of these shales sampled to date in the footwall of the Lombard thrust (0.79-1.25 percent TOC, samples 92-I-2 and 92-I-3, table J2), where it is about 160 ft thick. These rocks are lean in organic carbon and the organic matter is considered gas-prone. The correlative Flood Member of the Blackleaf Formation on the hanging wall of the Lombard thrust (0.11-0.71 percent TOC, samples 93IC1 and 93IC2, table J2) is very lean where sampled on the eastern flank of the Boulder batholith complex. The R_o values obtained from these samples, ranging from 4.2-4.4 (table J3), indicate exposure to high paleotemperatures.

The source rock potential of Cretaceous rocks in the Sleeping Giant Wilderness area (directly north of the Gates of the Mountains Wilderness) has recently been discussed by Tysdal and others (1991). This area appears to be close to the southern limit of the Upper Cretaceous Marias River Shale of the disturbed belt. Sample 87MTz198 (table J5) yielded 1.38 percent TOC with a Tmax within the oil window. The other two Cretaceous samples from the Sleeping Giant area (87MTz190 and 87MTz199, table J5) were from the Flood Member of the Blackleaf and yielded 1.01 and 1.44 percent TOC respectively; the latter yielded a reliable Tmax well within the oil window.

North of the Forest, Clayton and others (1983) provided organic geochemical analyses of a number of Cretaceous samples; those relevant to the present study are summarized in table J5. The Cone Member of the Marias River Formation, the only oil-prone Cretaceous source rock discovered to date in western Montana, apparently is not found south of T. 16 N. (Clayton and others, 1983; also W.A. Cobban, U.S. Geological Survey, 1988, oral communication). Both the Blackleaf and Marias River Shales are considered source rocks for natural gas in play 2701 (Perry, 1996), which includes the northern part of the Forest as shown on figure J1. Cretaceous shales are also considered a source for biogenic gas and for oil in Cretaceous reservoirs in the adjacent central Montana Province of Dyman (1996).

CONCLUSIONS

In conclusion, only the Lincoln District, northeastern (Gates of the Mountains Wilderness) part of the Helena District, and southern edge of the Townsend District of the Forest are considered to have economically recoverable hydrocarbon potential. The first area lies within the southwestern part of the Imbricate Thrust Gas Play (2701) of Perry (1996). The second area lies within both Play 2701 and the hypothetical Imbricate Thrust Oil Play (2707) of Perry (1996). The presence in or near both areas of normal faults, oblique slip faults, and extensive vertical fracturing associated with the Montana transverse zone reduce the probability of hydrocarbon retention in thrust-related reservoirs. The report of low-salinity formation water in the Mississippian Madison Group in the Unocal 1-B30 Federal drillhole (no. 31, table J1) by Peterson and Nims (1992) also appears to reduce the likelihood of undiscovered economically recoverable hydrocarbons beneath the northern part of the Forest, as the Madison Group is the principal potential reservoir rock for hydrocarbons in this part of the Montana thrust belt.

The third area, the southern edge of the Townsend District, east of Toston (Fig. J1), lies within the Helena Salient Gas Play (2704) of Perry (1996). Drillholes to the south and east have abundant gas shows. However, virtually the entire rock sequence plunges south along the southern edge of Townsend District, and all prospective reservoir rocks are exposed just to the north, along the southern margin of the Big Belt Mountains. Therefore, this must be considered an area of low gas potential within the play. Remaining portions of the Forest within the Helena Salient Gas Play are considered to have no to very low hydrocarbon potential based on our interpretation of the available source rock, paleogeothermal regime, drillhole, and structural data.

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Table J1. Drillholes in vicinity of Helena National Forest - all dry holes (nonproductive of hydrocarbons)

Well no.	Operator	No.	Leasename	Completion date	Twp	Rng	QR QR QR	Sec	Elevation	TD (ft)	Operator's formation tops:	Depth to top (ft)
1	DUNBAR OIL	1	DUNBAR	11/4/50	2 N	1 E	SE SW SE	8	4,065	2,124	Livingston (Cretaceous)	321
											Ellis (Jurassic)	1,557
											Amsden (Miss.-Penn.)	1,640
											Madison (Mississippian)	1,945
											Sappington (Devonian)	2,050
											Three Forks (Devonian)	2,100
2	BUCKHORN PETROLEUM	2-24	FEDERAL	4/5/81	6 N	1 E	NW NW NE	24	4,484	7,340	Belt Supergroup (Proterozoic)	0
3	PETROLEUM PRODUCTION	1	COLBY	8/19/55	16 N	3 E	SE SE NE	29	4,251	860	Madison (Mississippian)	750
	COUCH DRILLING	1	COLBY		16 N	3 E	SE SE NE	29	4,251	2,875	Devonian	1,995
4	KNEES PRODUCTION	1	THRASHER	3/24/54	17 N	5 E	SW SW NW	28	4,562	1,000	Madison (Mississippian)	250
											Lodgepole (Mississippian)	1,225
											Three Forks (Devonian)	1,669
											Jefferson (Devonian)	1,680
5	RIVERDALE OIL	1	MURPHY	12-0-56	17 N	2 E	NW SW NW	8	3,746	2,535	Skull Creek (Cretaceous)	250
											Dakota (Cretaceous)	425
											Kootenai (Cretaceous)	444
											Morrison (Jurassic)	892
											Madison (Mississippian)	1,010
											Devonian	2,403
											Jefferson (Devonian)	2,430
6	AMERICAN CLIMAX -BA	1	NP	5/12/60	17 N	3 E	SE SE	5	3,853	1,002	Morrison (Jurassic)	273
											Swift (Jurassic)	454
											Sawtooth (Jurassic)	521
											Madison (Mississippian)	571
7	MAPCO INC	1-18	GOLLAHER	6/29/76	17 N	2 E	SE NW NW	18	3,806	3,250	Flood (Cretaceous)	390
											Kootenai (Cretaceous)	530
											Morrison (Jurassic)	976
											Swift (Jurassic)	1,004
											Madison (Mississippian)	1,146
											Bakken (Miss.-Devonian)	2,500
											Three Forks (Devonian)	2,504
											Potlatch (Devonian)	2,550
											Nisku (Devonian)	2,730
											Jefferson (Devonian)	2,829
											Souris River (Devonian)	3,222
8	MAPCO INC	1	MORTAG	7/28/78	16 N	2 E	NW SE NW	18	4,328	2,788	Kootenai (Cretaceous)	0
											Cutbank	270
											Morrison (Jurassic)	330
											Swift (Jurassic)	356
											fault	522
											Taft Hill (Cretaceous)	523
											Flood (Cretaceous)	720
											Kibbey (Mississippian)	1,920
											Madison (Mississippian)	2,128

Table J1. Drillholes in vicinity of Helena National Forest - all dry holes (nonproductive of hydrocarbons)

Well no.	Operator	No. Leasename	Completion date	Twp	Rng	QR QR QR	Sec	Elevation	TD (ft)	Operator's formation tops:	Depth to top (ft)
9	GRIZZLEY DRLG	1 MARY GOETTE-DUT	5/16/80	18 N	5 E	SE SE NW	20	4,303	950	Kootenai (Cretaceous)	50
										Cat Creek 2	200
										Cat Creek 3	480
										Madison (Mississippian)	650
10	PARK LANE EXPLORATION	1-36 STATE	---	17 N	4 E	C NE SE	36	4,570	1,353	Madison (Mississippian)	0
										Kibbey (Mississippian)	114
	VIRGIL CHAMBERLAIN	9-36 STATE-GREUL							2,222	Sun River (Mississippian)	186
										Mission Canyon (Mississippian)	600
										Lodgepole (Mississippian)	1,070
										Exshaw (Devonian-Miss.)	1,706
										Nisku (Devonian)	1,788
										Duperow (Devonian)	1,838
11	AMOCO PRODUCTION	1 JACOBSON	3/18/84	6 N	10 W	S2 NW NE	25	4,812	11,774	Renova	4,433
										Lowland Creek	5,232
12	BEN W. RYAN	1 TICE		1 N	2 E	NE NE NE	28	4,260	2,572	Dakota (Cretaceous)	1,800
										Lakota	1,927
13	PHILLIPS PETROLEUM	1 BRAINARD-B	6/8/85	4 N	4 E	SE NE SW	26	5,412	11,586	Kootenai (Cretaceous)	1,275*
	From Hydrocarbon well log:	Depths in ft:								Morrison (Jurassic)	1,725*
	Blackleaf Fm. (Cretaceous)	surface - 890								Ellis (Jurassic)	2,075*
	Kootenai Fm.(Cretaceous)	~890								Phosphoria (Permian)	2,410*
	Pryor Conglomerate Member	~1,220								Quadrant (Pennsylvanian)	2,480*
	Morrison Fm. (Jurassic)	~1,370								Amsden (Miss.-Penn.)	2,620*
	Ellis Fm. (Jurassic)	~1,810								Big Snowy (Mississippian)	2,950*
	Phosphoria Fm.? (Permian)	~2,030?								Mission Canyon (Mississippian)	3,350*
	Quadrant Fm.? (Pennsylvanian)	~2,710?								Lodgepole (Mississippian)	4,300*
	Amsden Fm. (Miss.-Penn.)	~2,720?								Sappington (Devonian)	5,110*
	Madison Fm. (Mississippian)	~2,800?								Three Forks (Devonian)	5,170*
	Thrust fault? (into Quadrant?)	~3,150								Jefferson (Devonian)	5,325*
	Igneous sills & (or) dikes	3,206-3,248								Maywood (Devonian)	5,845*
	Amsden Fm. (Miss.-Penn.)	~3,280								Cambrian	5,915*
	Igneous rocks ("qtz. monzonite")	3,450-3,490								thrust fault	6.565*
	Igneous rocks ("granodiorite")	3,790-3,810								Phosphoria (Permian)	6,565*
	Igneous rocks ("qtz. monzonite")	3,910-4,050								Quadrant (Pennsylvanian)	6,600*
	Thrust fault? (into Blackleaf?)	~4,210?								Amsden (Miss.-Penn.)	6,740*
	Kootenai Fm. (Cretaceous)	~4,800								Big Snowy (Mississippian)	7,070*
	Pryor Conglomerate Member	~5,022								Mission Canyon (Mississippian)	7,470*
	Morrison Fm. (Jurassic)	~5,120								Lodgepole (Mississippian)	8,420*
	Ellis Fm.? (Jurassic)	~5,570								Sappington (Devonian)	9,230*
	Phosphoria Fm.? (Permian)	~5,600? (then lost to ~7,400)								Three Forks (Devonian)	9,290*
	Mission Canyon Ls.. (Mississippian)	~7,400								Jefferson (Devonian)	9,445*
	Lodgepole Ls.(Mississippian)	~8,750 (gas shows below 9,424)								Maywood (Devonian)	9,965*
	Three Forks Fm (Devonian)	~11,150 (Sappington Member)								Cambrian	10,035*
	Trident Shale Member	~11,230								Precambrian	11,435*
	Logan Gulch Member	~11,250-11,580+ (anh.& dol.)									
14	LUHMAN, ET AL	1 DUNBAR	10/3/47	2 N	1 W	NE SW	8	4,750	1,260	conglomerate	0
										Ellis (Jurassic)	776
										Igneous	1,214
15	IOWA MID-WEST EXPL.	1 FEE	12/15/69	3 N	2 W	SE SW SW	11	5,400	1,005	Three Forks (Devonian)	0
										Jefferson (Devonian)	140
										Maywood (Devonian)	840
										Red Lion (Cambrian)	925

*Objective (expected) formation tops reported by operator, derived from seismic data; not in agreement with lithologies shown on hydrocarbon well log (mud log).

Table J1. Drillholes in vicinity of Helena National Forest - all dry holes (nonproductive of hydrocarbons)

Well no.	Operator	No. Leasename	Completion date	Twp	Rng	QR QR QR	Sec	Elevation	TD (ft)	Operator's formation tops:	Depth to top (ft)
16	NORCEN EXPLORER	1-11 KIMPTON RANCH	4/1/91	4 N	2 W	SE NW NE	11	5,409	14,846	Belt (Middle Proterozoic)	Surface
										"Colorado (Cretaceous)"*	7,824
17	SHELL OIL	31-32 KRONE	9/23/62	18 N	5 W	C NW NE	32	4,249	7,800	Kootenai (Cretaceous)	4,680
										Swift (Jurassic)	5,562
										Madison (Mississippian)	5,592
										Three Forks (Devonian)	6,929
										Nisku (Devonian)	7,231
										Duperow (Devonian)	7,284
18	KILROY CO OF TEXAS	1 STATE	9/6/69	16 N	4 W	SE NW NW	16	4,158	3,728	Greenhorn (Cretaceous)	2,186
										Blackleaf (Cretaceous)	2,314
										fault	2,499
										Greenhorn (Cretaceous)	2,499
										fault	2,676
										Blackleaf (Cretaceous)	2,676
19	FRANK BAUMGARTNER	1 BERTHA THOMPSON	8/19/74	16 N	4 W	N2 SE SW	32	4,280	5,834	Virgelle (Cretaceous)	2,712
										Telegraph Creek (Cretaceous)	2,812
										fault	2,876
										Telegraph Creek (Cretaceous)	2,891
										Colorado (Cretaceous)	3,100
										fault	3,807
										Colorado (Cretaceous)	4,210
										Greenhorn (Cretaceous)	4,426
										Blackleaf (Cretaceous)	4,558
										fault	4,598
										Greenhorn (Cretaceous)	4,622
										Blackleaf (Cretaceous)	4,698
										fault	4,982
										Colorado (Cretaceous)	5,007
										fault	5,208
										Colorado (Cretaceous)	5,221
										Greenhorn (Cretaceous)	5,390
										Blackleaf (Cretaceous)	5,532
										Igneous	5,656
										Blackleaf (Cretaceous)	5,780
20	GETTY OIL	3-10 FEDERAL	8/21/82	12 N	1 W	NE NE SW	3	7,752	13,731	Lodgepole (Mississippian)	0
										Sappington (Devonian)	366
										Three Forks (Devonian)	390
										fault	504
										Lodgepole (Mississippian)	1,256
										Sappington (Devonian)	1,912
										Three Forks (Devonian)	1,927
										Potlatch (Devonian)	2,044
										Jefferson (Devonian)	2,108
										Pilgrim (Cambrian)	2,649
										Park (Cambrian)	2,868
										fault	2,872

*Top reported by operator; not in agreement with our analyses.

Table J1. Drillholes in vicinity of Helena National Forest - all dry holes (nonproductive of hydrocarbons)

Well no.	Operator	No. Leasename / notes	Completion date	Twp	Rng	QR QR QR	Sec	Elevation	TD (ft)	Operator's formation tops:	Depth to top (ft)	Depth to base (ft)
20	GETTY OIL	3-10 FEDERAL	8/21/82	12 N	1 W	NE NE SW	3	7,752	13,731	Mission Canyon (Mississippian)	2,872	
		Circulation problems began								Lodgepole (Mississippian)	3,504	
		at 1,980 ft. Many lost cir-								**Cottonwood Canyon (Miss.)***	**4,351**	**4,354**
		culation zones. Set 9 5/8"								Three Forks (Devonian)	4,354	
		casing @ 4,999 in attempt								**Sappington (unit 1) (Devon.)***	**4,412**	**4,427**
		to solve this problem. Ran								Potlatch (Devonian)	4,486	
		into major lost circulation								Jefferson (Devonian)	4,572	
		again at 7,614 - pipe stuck.								Pilgrim (Cambrian)	5,086	
		Sidetracked and again lost								thrust fault/Jefferson (Devonian)	5,324	
		circulation at 8,561-10,080.								Pilgrim (Cambrian)	5,902	
		No returns 10,450-13,699.								Park (Cambrian)	6,086	
										thrust fault/Park (Cambrian)	6,170	
		Minor gas entry suspected								Meagher (Cambrian)	6,264	
		at 6,378, 6,410, 6,430 ft								Wolsey (Cambrian)	6,563	
		Minor gas entry 6,390-6,560.								**primary thrust fault**	7,166	
		Traces of ethane & propane								Lodgepole (Mississippian)	7,690	
		below 7,440 ft. Traces of								'thrust fault/Mission Canyon	8,540	
		ethane 12,566-72, 12,590-								Mission Canyon (Mississippian)	8,540	
		-96, 12,608-118, 12,696-730.								' thrust fault/Mission Canyon	10,880	
										Lodgepole (Mississippian)	11,784	
										normal fault	11,920	
										Lodgepole (Mississippian)	11,920	
										thrust fault/Lodgepole	12,048	
										thrust fault/Lodgepole	12,194	12,416
										Cottonwood Canyon (Miss.)*	**12,416**	**12,418**
										Sappington (unit 1) (Devon.)*	**12,462**	**12,468**
										Three Forks (Devonian)	12,415	
										Potlatch (Devonian)	12,496	
										Jefferson (Devonian)	12,551	
										thrust fault	12,718	
										Potlatch (Devonian)	12,718	
										Jefferson (Devonian)	12,722	
										Pilgrim (Cambrian)	13,302	
										Park (Cambrian)	13,452	
21	AMOCO PROD	1 NICHOLS H B-FEE	11/13/83	18 N	7 W	SE NW NW	25	4,605	9,034	Blackleaf (Cretaceous)	312	
										Kootenai (Cretaceous)	900	
										Marias River (Cretaceous)	2,230	
										Blackleaf (Cretaceous)	3,158	
										Kootenai (Cretaceous)	4,685	
										Morrison (Jurassic)	5,815	
										Morrison (Jurassic)	6,248	
										Rierdon (Jurassic)	6,555	
										Marias River (Cretaceous)	6,760	

*Intervals picked by Perry from geophysical borehole logs.

Table J1. Drillholes in vicinity of Helena National Forest - all dry holes (nonproductive of hydrocarbons)

Well #	operator	No. Leasename	Completion date	Twp	Rng	QR QR QR	Sec	Elevation (ft)	TD (ft)	Operator's formation tops:	Depth to top (ft)	Depth to base (ft)
22	ATLANTIC RICHFIELD	1 ARCO-STEINBACH	10/6/84	17 N	6 W	SE SE NE	22	4,516	11,916	Virgelle (Cretaceous)	2,580	
										Telegraph Creek (Cretaceous)	2,720	
										Marias River (Cretaceous)	3,027	
										Blackleaf (Cretaceous)	5,200	7,792
										Sill	7,607	
										Sill	7,772	7,842
										Kootenai (Cretaceous)	7,792	8,428
										Morrison (Jurassic)	8,458	
										Swift (Jurassic)	8,688	
										Sawtooth (Jurassic)	8,816	
										Mission Canyon (Mississippian)	8,897	
										Lodgepole (Mississippian)	9,640	
										Three Forks (Devonian)	10,124	
										Sappington (Devonian)	10,124	
										Logan Gulch (Devonian)	10,147	
										'Potlatch' anhydrite (Devonian)	10,181	
										Jefferson (Devonian)	10,354	11,307
										Sill	10,647	10,677
										Souris River (Devonian)	11,307	
										Sill	11,568	11,608
23	ATLANTIC RICHFIELD	1 SILVER CREEK	9/24/84	12 N	3 W	SW NW SE	33	4,242	5,002	Madison (Mississippian)	2,400	
										Three Forks (Devonian)	3,110	
										Madison (Mississippian)	3,240	
24	MONTANA POWER	-1-22 STATE	11/17/61	7 N	10 W		22	5,042	2,536	Pliocene	1,175	
										Miocene	1,800	
										Oligocene	2,495	
25	AMOCO PRODUCTION	1 JOHNSON CARL	6/1/82	7 N	9 W	NE SW SW	31	4,743	10,334	Sixmile Canyon	2,600	
										Red Marker	6,185	
26	AMOCO PRODUCTION	1 STATE	8/20/82	7 N	10 W	N2 SW	2	4,996	6,411	igneous rocks	5,634	
27	AMOCO PRODUCTION	1 FEE-CLIFFORD BENSON	8/31/84	7 N	9 W	C SE SW	34	4,820	7,134	Renova	3,750	
										Lowland Creek	5,650	
										volcanics	7,040	
28	MEDALLION OIL	1-13 STATE-PRISON	9/7/87	7 N	10 W	SE SW SE	13	4,785	7,648	Pliocene	200	
										Eocene	6,000	
29	MEDALLION OIL	1-25 MONT STATE PRISON	12/4/87	7 N	10 W	S2 NE NE	25	4,793	9,372	Eocene	9,028	
30	AMOCO PRODUCTION	1-R KIFF RANCH	12/7/82	6 N	8 E	SE SW	27	5,610	12,495	Frontier1 (Cretaceous)	4920	
										Frontier2 (Cretaceous)	5,240	
										Frontier3 (Cretaceous)	5,560	
										Mowry (Cretaceous)	5,726	
										Muddy (Cretaceous)	6,157	
										Skull Creek (Cretaceous)	6,299	
										Dakota (Cretaceous)	6,424	
										Kootenai (Cretaceous)	6,682	
										Morrison (Jurassic)	7,181	
										Swift (Jurassic)	7,552	
										Amsden (Miss. - Penn.)	7,640	
										Mission Canyon (Mississippian)	8,130	10,150
										Lodgepole (Mississippian)	10,150	11,112
										Cottonwood Canyon (Miss.)*	**11,110**	**11,112**
										Three Forks (Devonian)	11,112	
										'Sappington (Devonian)*	**11,112**	**11,172**
										'Trident (Devonian)*	**11,172**	**11,190**
										'Logan Gulch (Devonian)*	**11,190**	**11,424**
										Jefferson (Devonian)	11,424	

*Intervals picked by Perry from geophysical borehole logs.

Table J1. Drillholes in vicinity of Helena National Forest - all dry holes (nonproductive of hydrocarbons)

Well #	operator / notes	No. Leasename / notes	Completion date	Twp	Rng	QR QR QR	Sec	Elevation (ft)	TD (ft)	Operator's formation tops:	Depth to top (ft)	Depth to base (ft)
31	UNOCAL	1-B30 FEDERAL	9/26/89	14 N	5 W	NE NW NE	30	6,833	17,818	Belt Supergroup (Proterozoic)	Surface	12,209
	Vitrinite reflectance(1)	Oil and gas shows:								Eldorado thrust	12,209	
	Depth % Ro	12,242-265' gas increase; dead								Kootenai (Cretaceous)	12,209	
	10,610 4.86	dead oil stain in Kootenai.								Blackleaf (Cretaceous)	13,914	
	11,410 5.34	12,435-478' gas increase.								Taft Hill (Cretaceous) (Cretaceous)	14,344	
	12,010 3.46	12,708-714' gas increase.								Flood (Cretaceous) (Cretaceous)	14,456	
										fault		
	12,210 3.47	12,798-804' gas increase.								Taft Hill (Cretaceous) (Cretaceous)	14,505	
										fault		
	12,610 1.29	12,976-981' gas increase.								Taft Hill (Cretaceous) (Cretaceous)	15,091	
	12,810 1.27	13,058-060' heavily oil-stained								Flood (Cretaceous) (Cretaceous)	15,210	
	12,980 1.26	fractures.								Kootenai (Cretaceous)	15,607	
	13,000 1.36	13,538-540' Gas increase.								Morrison (Jurassic)	16,094	
	13,210 1.45	13,678-682' Gas increase.								Swift (Jurassic)	16,420	
	13,240 1.29	13,768-774' Gas increase.								Rierdon (Jurassic)	16,526	
	13,410 1.42	13,820-821' Gas increase.								Sawtooth (Jurassic)	16,533	
	13,480 1.31	14,889-891' Gas increase, trace								Madison (Mississippian)	16,878	
	13,610 1.46	oil-stained fractures in Blackleaf.										
	13,770 1.32	14,906-14908' Gas increase.										
	13,810 1.45	16,950-953' Trace deade oil-										
	14,010 1.28	stained fractures in Madison.										
	14,190 0.83	17,268-17,340' Gas increase,										
	14,210 1.01	numerous dead-oil-stained fracs.										
	14,210 0.79	17,406-17,444' Gas increase,										
	14,410 1.02	trace dead oil stain.										
	14,470 1.10	17,611-17,628' Gas increase,										
	14,478 0.79	trace dead-oil-stained fractures.										
	14,610 1.14	17,724-768' Gas increase, trace										
	14,820 1.28	oil stain in Madison.										
	15,010 1.31	Production tests of more fractured										
	15,200 0.94	intervals yielded low salinity water(2):										
	15,210 1.24	16,887-999' 288 bbls.										
	15,410 1.32	17,164-379' 141 bbls. ~1,480 ppm										
	15,670 1.18	17,604-333' 171 bbls. ~273 ppm										
	16,410 2.47	total chlorides										
	16,610 2.05	Rw ranged from 2.55 to 3.75 in 3 tests.										
	16,810 2.19											
	17,200 2.12											
	17,810 2.05											
32	AMERICAN PETROFINA	1 MANGER-SKYLINE	6/21/82	11 N	4 E	SE NE NW	21	4,695	12,039	lower Greyson (Proterozoic)	surface	
		No tests run; no shows reported.								upper Newland (Proterozoic)	4,730	
										lower Newland (Proterozoic)	6,208	
										thrust into lower Greyson	6,700	
										upper Newland	8,460	
										lower Newland	9,080	
										Chamberlain Shale (Proterozoic)	10,420	
										Neihart Quartzite (Proterozoic)	11,820	

(1) Vitrinite results published by Peterson and Nims (1992).

(2) On file with Montana Oil and Gas Conservation Division; salinities calculated from Rw values.

Table J2. Rock-Eval analyses by Ted A. Daws - principal sample localities shown on figure J1.

Sample ID	Age	Formation and/or lithology	TWP	RGE	SEC	QTR QTR	LAT ° N	LONG ° W	Tmax ° C	TOC wt %	S1[1]	S2[1]	S3[2]	PI[3]	S2/S3	HI**	OI*1
MPPC-1	Proterozoic	Empire	10 N.	1 E.	1	ctr W1/2 W1/	46.6570	111.5570	602*	0.02	0	0.18	0.06	0	3.00	900	300
MPPC-2	Proterozoic	Greyson	11 N.	2 E.	30	ctr W1/2 SE	46.6810	111.5250	540	0.16	0.02	0.32	0.09	0.06	3.56	200	56
MPPC-3	Proterozoic	Newland	11 N.	2 E.	21	SW SW	46.7000	111.5000	528	0.11	0.01	0.16	0.18	0.06	0.89	145	163
MPPC-4	Proterozoic	Newland	11 N.	2 E.	5	NW SE	46.7420	111.5130	541	0.11	0	0.05	0.17	0	0.29	45	154
MPPC-8	Proterozoic	Newland	11 N.	1 E.	16	NE NW	46.7010	111.6130	473	0.18	0	0.08	0.56	0	0.14	44	311
MPPC-9	Proterozoic	Newland	11 N.	1 E.	9	NW SE	46.7250	111.6080	526	0.14	0	0.07	0.31	0	0.23	50	221
MPPC-10	Proterozoic	Newland	11 N.	1 E.	3	ctr S edge SE	46.7290	111.6000	448*	0.06	0	0.07	0.77	0	0.09	116	1283
MPPC-11	Proterozoic	Greyson	11 N.	1 E.	29	NW NW	46.6880	111.6420	599*	0.05	0.01	0.32	0.27	0.03	1.19	640	540
MPPC-12	Proterozoic	Empire	10 N.	1 W.	3	SW SW	46.6500	111.7250	428*	0.01	0.01	0.1	0.55	0.1	0.18	1000	5500
MPPC-15	Proterozoic	Newland	11 N.	7 E.	8	ctr E edge	46.7470	110.9100	505	0.18	0	0.04	0.68	0	0.06	22	3.77
MPPC-16	Proterozoic	Newland	11 N.	7 E.	29	SE NW	46.6940	110.9220	343?	0.63	0	0	0.31	0	0.00	0	49
MPPC-17	Proterozoic	Newland	11 N.	7 E.	32	NW NW	46.6750	110.9230	500	0.18	0	0.22	1.04	0	0.21	122	577
MPPC-18	Proterozoic	Greyson	11 N.	7 E.	32	SW SW	46.6630	110.9250	514*	0.03	0	0.05	0.1	0	0.50	166	333
MPPC-19	Proterozoic	upper Greyson	7 N.	6 E.	4	NE SE	46.4150	110.9750	584*	0	0	0.04	0.07	0	0.57	0	0
MPPC-20	Proterozoic	upper Greyson	7 N.	5 E.	23	SW NW	46.3580	111.0750	590*	0	0	0.05	0.03	0	1.67	0	0
MPPC-21	Proterozoic	lower Greyson	7 N.	5 E.	21	ctr N edge NE	46.3630	111.1060	474	0.18	0	0.02	0.18	0	0.11	11	100
MPPC-22	Proterozoic	Newland	7 N.	4 E.	25	NE NE	46.3420	111.1630	484	0.18	0	0.07	0.12	0	0.58	38	66
8/23/6P	Proterozoic	Newland	11 N.	7 E.	32	NE NW	46.6750	110.9225	416?	0.19	0.01	0.04	0.12	0.20	0.33	21	63
91GD-1	Proterozoic	La Hood	1 N.	3 W.	2	NE NE	45.8725	111.9308	0	0.75	0	0.04	0.58	0	0.07	5	77
91GD-2	Proterozoic	La Hood	2 N.	4 W.	25	NW NE	45.9008	112.0417	485	1.09	0.02	0.52	0.21	0.04	2.48	48	19
91-JW2	Mississippian	"Heath"	4 N.	3 E.	5	SW	46.1223	111.3858	445	2.89	0.02	1.14	1.98	0.02	0.58	39	68
91-JW2r									434	2.48	0.04	1.37	1.33	0.03	1.03	55	53
91-JW3	Mississippian	"Heath"	4 N.	2 E.	13	NE NE	46.1025	111.4117	503	0.85	0	0.22	0.4	0	0.55	25	47
91-JW3r									488	0.63	0.07	0.34	0.35	0.17	0.97	53	55
91-JW4	Mississippian	"Heath"	4 N.	2 E.	13	NE NE	46.1025	111.4117	470	2.7	0.04	1.47	0.76	0.03	1.93	54	28
91-JW4r									440	2.2	0.09	1.84	0.63	0.05	2.92	83	20
91-JW5	Mississippian	"Heath"	4 N.	3 E.	5	SW	46.1233	111.3858	463	2.8	0.01	0.85	1.71	0.01	0.50	30	61
91-JW5r									444	2.25	0.04	1.32	1.19	0.03	1.11	58	52
91-JW1	Cretaceous	"Colorado Grp."	1 N.	2 W.	22	NE SW	45.8258	111.8358	445	0.82	0	0.11	0.88	0	0.13	13	107

r = replicate samples
* Tmax unreliable for very low TOC values.
1. mg hydrocarbon/g sample
2. mg carbon dioxide/g sample
3. PI = S1/(S1 + S2)
** HI = S2/TOC in mg HC/g TOC
*1. OI = S3/TOC in mg CO2/g TOC

Table J2. Rock-Eval analyses by Ted A. Daws - principal sample localities shown on figure J1.

Sample ID	Age	Formation and/or lithology	TWP	RGE	SEC	QTR QTR	LAT ° N	LONG ° W	Tmax ° C	TOC wt %	S1[1]	S2[1]	S3[2]	PI[3]	S2/S3	HI**	OI*1
91Bal-11	Cretaceous	"Slim Sam Fm."	6 N.	1 W.	22	NE SW	46.2590	111.7160	552	1.1	0.03	0.59	0.52	0.05	1.13	53	47
91Bal-12	Cretaceous	"Slim Sam Fm."	6 N.	1 W.	16	SW	46.2710	111.7330	465	0.85	0	0.33	0.2	0	1.65	38	23
91Bal-19	Cretaceous	"Colorado Grp."	4 N.	1 W.	9	NE SW	46.1140	111.7350	0	1.19	0	0.09	0.66	0	0.14	7	55
91Bal-30	Cretaceous	"Colorado Grp."	3 N.	2 E.	15	ctr W1/2 SW	46.0110	111.4690	489*	0.06	0	0.1	0.15	0	0.67	166	250
91Bal-34	Cretaceous	"Colorado Grp."	3 N.	2 E.	15	NE SW	46.0140	111.4620	450	0.66	0	0.17	0.54	0	0.31	25	81
91Bal-34r									448	0.49	0.15	0.31	0.54	0.33	0.57	63	110
83MTZ14	Cretaceous	Blackleaf/Vaughn	7 N.	1 E.	29	NW SW	46.3330	111.6375	458*	0.04?	0	0.04	0.16	0	0.25	100	400
83MTZ18	Cretaceous	Blackleaf/Vaughn	7 N.	1 E.	30	ctr E edge SE	46.3305	111.6394	0	0.22	0	0.04	0.17	0	0.24	18	77
92-I-2	Cretaceous	Thermopolis	4 N.	6 E.	6	SW	46.1250	111.0310	461	0.79	0.02	0.73	0.84	0.03	0.87	92	106
92-I-3	Cretaceous	Thermopolis	4 N.	6 E.	6	SW	46.1250	111.0637	464	1.25	0	0.46	0.83	0	0.55	36	66
93HFp2	Cretaceous	Kootenai mudston	5 N.	3 E.	31	SW SW SE	46.1375	111.3997	387*	0	0	0.02	0.15	0	0.13	0	0
93HFp3	Proterozoic	fissile shale	4 N.	2 E.	2	NE SW SE	46.1253	111.4383	0	0.48	0	0.18	0	0	inf. lge.	0	37
93HFp5	Proterozoic	mod dk gy shale	4 N.	2 E.	11	ctr N N N1/2	46.1211	111.4417	505*	0	0	0.02	0.09	0	0.22	0	0
93HFp6	Proterozoic	mod dk gy shale	4 N.	2 E.	2	NW SW SE	46.1261	111.4375	0*	0	0	0.04	0	0	inf. lge.	0	0
93HFp9	Mississippian	Lombard limeston	4 N.	3 E.	5	NE SW SW	46.1253	111.3861	348*	0	0	0.02	0	0	inf. lge.	0	0
93HFp10	Mississippian	Lombard shale	4 N.	3 E.	7	SE SW SW	46.1075	111.4050	596	0.16	0	0.31	0.06	0	5.17	193	37
93HFp10r									537	0.16	0	0.05	0.08	0	0.63	31	50
93HFp11	Mississippian	Lombard shale	4 N.	3 E.	7	SW SE SW	46.1078	111.4047	438	0.92	0.04	0.86	0.3	0.04	2.87	93	32
93HFp11r									439	1.55	0.06	1.38	0.41	0.04	3.37	89	26
93IC1	Cretaceous	Blackleaf/Flood	6 N.	1 E.	6	SW NE	46.5625	111.6450	471	0.71	0	0.09	0.18	0	0.50	12	25
93IC1r									471	0.11	0	0.07	0.39	0	0.18	63	354
93IC2	Cretaceous	Blackleaf/Flood	6 N.	1 E.	6	SW NE	46.5625	111.6450	463	0.69	0	0.21	0	0	inf. lge.	10	30
93IC2r									0	0.49	0	0.34	0	0	inf. lge.	0	69

r = replicate samples
* Tmax unreliable for very low TOC values.
1. mg hydrocarbon/g sample
2. mg carbon dioxide/g sample
3. PI = S1/(S1 + S2)
** HI = S2/TOC in mg HC/g TOC
*1. OI = S3/TOC in mg CO2/g TOC

Table J3. Vitrinite reflectance measured by Mark Pawlewicz for samples collected from the Helena National Forest and vicinity and drillhole no. 16, fig. J1 and table J1.

Sample	Age	Depth	County	Min. Ro	Max. Ro	Mean	St. Dev	Remarks
91Bal-11	Cretaceous	surface	Broadwater	3.54	4.97	**4.13**	0.35	All very high rank; mostly Type III organic matter (OM).
91Bal-12	Cretaceous	surface	Broadwater	NA	---	---	---	No organic matter.
91Bal-19	Cretaceous	surface	Broadwater	2.32	2.94	**2.60**	0.16	Types III and IV OM; all very high rank.
91Bal-30	Cretaceous	surface	Broadwater	0.72	0.85	**0.79**	0.09	Organic matter sparse, but consistent.
91Bal-34	Cretaceous	surface	Broadwater	0.81	1.06	**0.91**	0.09	Two populations; lower Rm OM considered indigenous.
91JW-1	Cretaceous	surface	Jefferson	0.74	1.00	**0.87**	0.07	Abundant and diverse organic matter.
91JW-2	Mississippian	surface	Broadwater	0.64	1.00	**0.82**	0.14	75% recycled Type IV OM, not measured (nm), very high rank.
91JW-3	Mississippian	surface	Broadwater	0.72	1.31	**1.01**	---	90% recycled OM, nm. Two measurements indigenous.
91JW-4	Mississippian	surface	Broadwater	0.52	1.29	**0.85**	0.24	Organic matter about 90% recycled.
91JW-5	Mississippian	surface	Broadwater	0.56	0.79	**0.69**	0.07	Organic matter about 75% recycled.
92-I-2	Cretaceous	surface	Gallatin	0.48	0.6	**0.53**	0.03	Two populations; most Type III OM[1].
92-I-3	Cretaceous	surface	Gallatin	0.5	0.62	**0.56**	0.03	Two populations; all Type III OM[1].
93IC-1	Cretaceous	surface	Broadwater	2.71	5.04	**4.20**	0.78	All very high rank; chiefly humic (Type III) OM[2].
93IC-2	Cretaceous	surface	Broadwater	3.95	4.95	**4.38**	0.35	All very high rank; chiefly humic (Type III) OM[2].
93010015	Proterozoic?	8,000 ft	Jefferson	0.32	0.39	**0.37**	0.03	A few very good pieces of Cretaceous OM (contamination?)
93010018	Proterozoic?	9,000 ft	Jefferson	3.01	3.47	**3.29**	0.25	All high rank; appearance suggests Type IV OM.
93010021	Proterozoic?	10,000 ft	Jefferson	2.41	5.17	**3.58**	0.79	Abundant OM; all very high rank. Most appears to be inertinite.
93010022	Proterozoic?	11,000 ft	Jefferson	0.28	4.26	**2.39**	1.6	Two populations. Low Rm OM appears to be contamination.
93010022	Proterozoic?	11,000 ft	Jefferson	2.35	4.26	**3.24**	0.84	Low values (suspected contamination) removed.
93010023	Proterozoic?	12,300 ft	Jefferson	3.97	3.97	---	---	All very high rank in very small pieces. 1 measurement.
93010024	Proterozoic?	13,100 ft	Jefferson	2.65	4.65	**3.49**	0.92	All very high rank, in very small pieces.
93010025	Proterozoic?	14,100 ft	Jefferson	2.26	3.28	**2.7**	0.45	Few OM particles measurable. All but one high rank[3].
93010016	Proterozoic?	14,750 ft	Jefferson	NA	---	---	---	No organic matter.

1. Higher Rm population (nm) is about in range of 0.70 to 0.9.
2. Isolated pieces show signs of rapid heating and/or transport. Inertinite common overall.
3. One trimaceral particle (Rm 0.35) considered contamination and omitted from statistics.

Samples 93010015-25 from Norcen Energy Resources UTP-Kimpton 1-11 drillhole (no. 16, Fig. J1 and Table J1).
See table J2 for location and RockEval results of surface samples. See table J4 for Rock-Eval results from drillhole.

Table J4. Rock-Eval analyses by Ted A. Daws of samples from drillhole no. 16 (table J1 and fig. J1) south of Helena National Forest.

From Norcen Energy Resources UTP-Kimpton 1-11, sec. 11, T.04 N., R.02 W. (drillhole no. 16)

Sample ID	Depth	Sample wt (mg)	Tmax ° C	TOC wt %	S1[1]	S2[1]	S3[2]	PI[3]	S2/S3	HI	OI
93010015	8,000 ft	200.5	537	0.31	0	0.13	0.11	0	1.18	41	35
93010016	14,750 ft	178.1	539	0.39	0	0.27	0.24	0	1.12	69	61
93010017	13,100 ft	153.1	592	0.51	0.01	0.25	0.14	0.04	1.78	49	27
93010018	9,000 ft	196.4	0	0.26	0.02	0.06	0.1	0.25	0.6	23	38
93010021*	10,000 ft	168.4	545	1.31**	0.07	.66**	0.08	0.1	8.25	50	6
93010022*	11,000 ft	137.9	0	0.4	0.03	0.1	0.27	0.25	0.37	25	67
93010023*	12,300 ft	135.0	0	0.67	0.02	0.08	1.09	0.2	0.07	11	162
93010024*	13,100 ft	154.4	510	0.42	0.01	0.16	0.12	0.06	1.33	38	28
93010025*	14,100 ft	195.9	0	0.47	0.02	0.2	0.35	0.09	0.57	42	74

* Samples triple washed to remove contamination, second wash in ultrasonic bath. All samples wet sieved in purified water, using fine-mesh sieve, to remove drilling-mud coatings and particles.

** Probably in part due to hydrolysed salts (T.A. Daws, 1993, oral communication).

1. mg hydrocarbons/g sample.
2. mg carbon dioxide /g sample.
3. PI = S1/(S1 + S2).

HI and OI are respectively S2/TOC in mg HC/g TOC and S3/TOC in mg CO2/g TOC.

Table J5. Summary of previously published or available source-rock data. Sample locations shown in figure J1.

Sample ID	Source	Age	Formation	Member	SEC	TWP	RGE	TOC	Tmax	Ro
JC26	1	Cretaceous	Marias River	Cone	35	16 N.	04 W.	2.3	447	---
JC27	1	Cretaceous	Blackleaf	Flood	12	15 N.	04 W.	0.78	---	---
JC28	1	Cretaceous	Marias River	Kevin	24	15 N.	04 W.	0.76	---	---
JC29	1	Cretaceous	Marias River	Ferdig	36	15 N.	04 W.	1.15	---	---
JC30	1	Cretaceous	Blackleaf	Flood	11	16 N.	06 W.	1.07	531	2.03
JC31	1	Cretaceous	Blackleaf	Flood	11	16 N.	06 W.	0.96	449	0.71
JC33	1	Cretaceous	Marias River	Kevin	9	17 N.	05 W.	1.18	476	---
87MTz190	2	Cretaceous	Blackleaf	Flood	21	13 N.	03 W.	1.01	0	1.40
87MTz198	2	Cretaceous	Marias River	---	7	14 N.	03 W.	1.38	443	0.88
87MTz199	2	Cretaceous	Blackleaf	Flood	5	13 N.	03 W.	1.44	446	1.20
82FP-362S	3	Mississippian	Heath	---	23	13 N.	01 W.	4.80	504	---
82FP-362S	3	Mississippian	Heath	---	23	13 N.	01 W.	4.86	519	---

1. From Clayton and others (1983).
2. From Tysdal and others (1991, p. E27).
3. From Forrest G. Poole (1986, written commun.)

Table J6. XRD relative peak heights (analyses by George Desborough) from samples collected in the Helena National Forest and vicinity. Sample locations shown on figure J1.

Cretaceous samples from Helena Salient

Sample	chlorite	illite	pyrite	siderite	calcite	dolomite	plag-spar	K-spar	Dol/Cal	chlor/illite
83MTz14	9	4	0	0	27	0	30	0	0	2.25
83MTz18	6	3	0	0	0	0	60	0	0	2.00
92-1-3	0	0	0	0	0	0	0	12	0	0
92-I-2	0	0	0	0	0	0	0	8	0	0
91Bal-11	5	7	0	0	0	0	4	0	0	0.71
91Bal-12	9	51	0	10	0	0	14	7	0	0.18
91Bal-19	0	0	0	0	0	0	0	0	0	0
91Bal-30	tr	tr	0	0	0	0	9	0	0	0
91Bal-34	0	0	0	0	0	32	7	0	inf large	0
93IC-1	3	4	0	3	0	0	5	0	0	0.75
93IC-2	0	4	0	2	4	0	9	0	0	0
Average	2.91	6.64	0	1.36	2.82	2.91	12.55	2.45	1.03	0.44
									Ratio of averages	

Cretaceous samples from Lombard thrust plate (vitrinite where obtained yielded > 1.5 mean Ro)

Sample	chlorite	illite	pyrite	siderite	calcite	dolomite	plag-spar	K-spar	Dol/Cal	chlor/illite
83MTz14	9	4	0	0	27	0	30	0	0	2.25
83MTz18	6	3	0	0	0	0	60	0	0	2.00
91Bal-11	5	7	0	0	0	0	4	0	0	0.71
91Bal-12	9	51	0	10	0	0	14	7	0	0.18
91Bal-19	0	0	0	0	0	0	0	0	0	0
93IC-1	3	4	0	3	0	0	5	0	0	0.75
93IC-2	0	4	0	2	4	0	9	0	0	0
Average	4.57	10.43	0	2.14	4.43	0	17.43	1.00	0	0.44
									Ratio of averages	

Mississippian samples from Helena Salient

Sample	chlorite	illite	pyrite	siderite	calcite	dolomite	plag-spar	K-spar	Dol/Cal	chlor/illite
91JW-2	0	0	0	0	110	0	0	4	0	0
91JW-3	0	9	9	9	4	0	0	0	0	0
91JW-5	0	0	0	0	110	0	0	5	0	0
Average	0	3	3	3	74.67	0	0	3	0	0
									Ratio of averages	

Greyson Formation (Proterozoic) samples from Lombard thrust plate

Sample	chlorite	illite	pyrite	siderite	calcite	dolomite	plag-spar	K-spar	Dol/Cal	chlor/illite
93HFp3	4	12	0	0	0	0	12	0	0	0.33
93HFp6	0	10	0	0	0	0	17	0	0	0
Average	2	11	0	0	0	0	14.5	0	0	0.18
									Ratio of averages	

Newland Formation (Proterozoic) samples from Helena salient

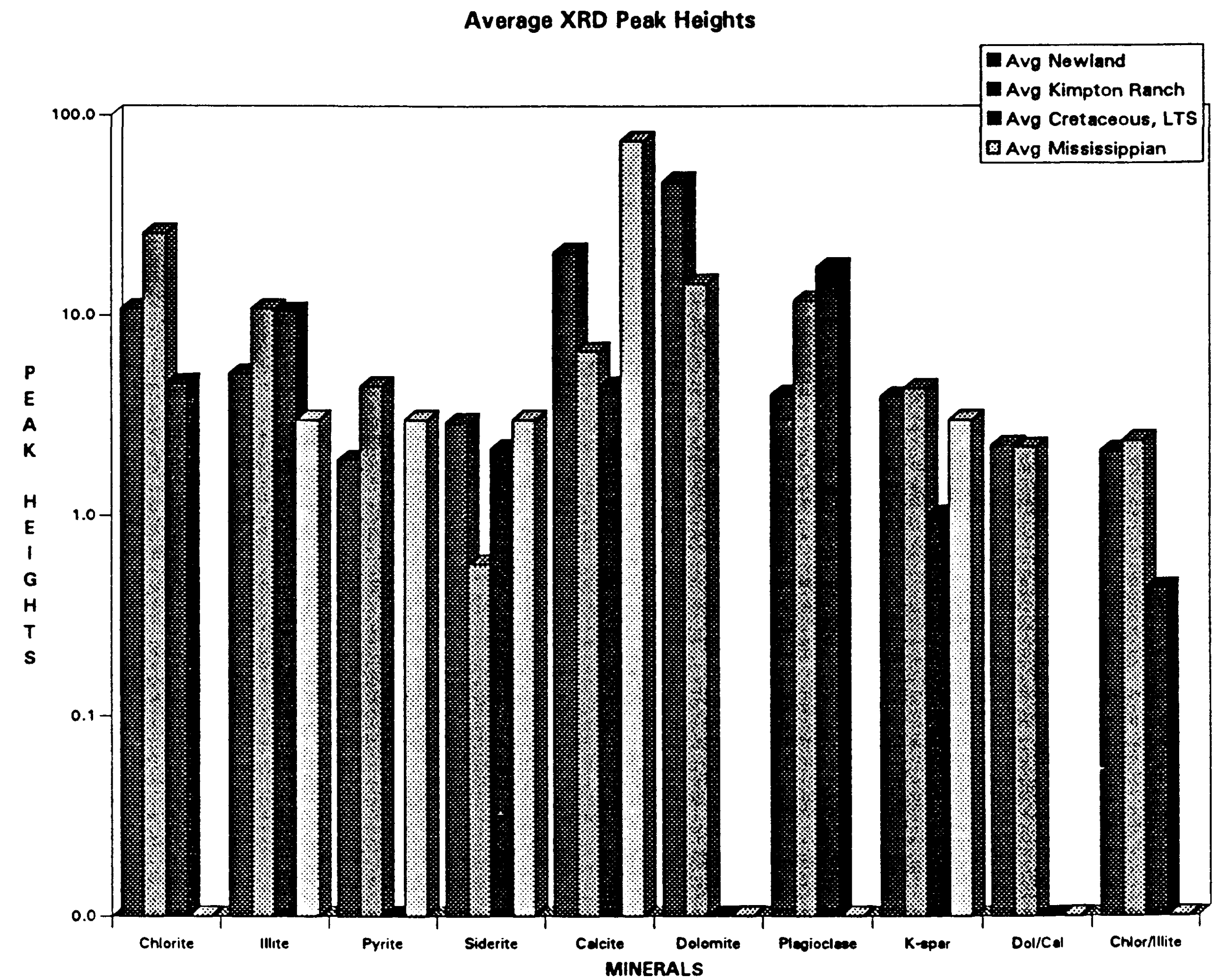
Sample	chlorite	illite	pyrite	siderite	calcite	dolomite	plag-spar	K-spar	Dol/Cal	chlor/illite
MPPC-3	9	4	0	5	11	57	5	7	5.18	2.25
MPPC-4	12	5	0	0	0	72	5	0	inf large	2.40
MPPC-6	22	8	3	6	0	14	7	7	inf large	2.75
MPPC-8	8	3	0	0	7	100	3	4	14.29	2.67
MPPC-9	19	8	0	4	0	54	6	5	inf large	2.38
MPPC-10	6	0	0	0	100	13	0	0	0.13	inf large
MPPC-16	7	4	6	0	0	83	0	0	inf large	1.75
MPPC-17	7	6	5	5	74	14	0	0	0.19	1.17
MPPC-22	10	6	5	5	0	51	6	8	inf large	1.67
Perry-6P	8	7	0	4	16	7	8	8	0.44	1.14
Average	10.8	5.1	1.9	2.9	20.8	46.5	4	3.9	2.24	2.12
									Ratio of averages	

Samples from Norcen Energy Resources UTP-Kimpton 1-11 borehole #16, table J1 and Figure J1

Lithology is predominately very dark gray dolomitic siltite and argillite.

Sample	chlorite	illite	pyrite	siderite	calcite	dolomite	plag-spar	K-spar	Dol/Cal	chlor/illite
8000KR	10	14	9	4	15	43	5	4	2.87	0.71
9000KR	12	5	9	0	4	37	12	0	9.25	2.40
10000KR	29	13	13	0	0	9	12	0	inf large	2.23
11000KR	33	9	0	0	6	8	22	4	1.33	3.67
12300KR	35	12	0	0	21	0	10	7	0	2.92
13100KR	27	11	0	0	0	4	12	8	inf large	2.45
14100KR	35	12	0	0	0	0	10	7	0	2.92
14750KR	20	7	0	0	0	6	9	7	inf large	2.86
Average	25.86	10.86	4.43	0.57	6.57	14.43	11.86	4.29	2.20	2.38
									Ratio of averages	

Age	Chlorite	Illite	Pyrite	Siderite	Calcite	Dolomite	Plagioclase	K-spar	Dol/Cal	Chlor/Illite
Avg Newland	10.8	5.1	1.8	2.9	20.8	46.5	4	3.9	2.24	2.12
Avg Kimpton Ranch*	25.86	10.86	4.43	0.57	6.57	14.43	11.86	4.29	2.20	2.38
Avg Cretaceous, LTS	4.57	10.43	0	2.14	4.43	0	17.43	1.00	0	0.44
Avg Mississippian	0	3	3	3	74.7	0	0	3	0	0



*Kimpton Ranch borehole samples are predominately very dark gray dolomitic siltite and argillite, probably Newland Fm.

Figure J2. Graphic representation of data shown in table J6. XRD relative peak heights were analysed and measured by George Desborough. "Avg Kimpton Ranch" represents average values of samples from Norcen Energy Resources UTP-Kimpton 1-11 borehole #16, table J1 and figure J1; "Avg Cretaceous, LTS" represents average values of Cretaceous samples from the Lombard thrust sheet.

C H A P T E R   K

COAL RESOURCES OF THE HELENA NATIONAL FOREST

By C.W. Holmes

GEOLOGY

An examination was made for coal within the Helena National Forest because significant coal deposits are present to the northeast in the Great Falls-Lewistown coal field and to the south in the Lombard coal field (fig. K1). In addition, "coal" was reported (Whipple and others, 1987) in Tertiary lake deposits in area enclosed by the northwestern part of the Forest. Because rocks similar in age and character to those of the coal-bearing strata of the coal fields are present within the Forest, a two week survey was made over the most likely host areas in the Forest.

The Great Falls-Lewistown coal field, northeast of the Big Belt Mountains, contains discontinuous coal beds 3-6 ft thick that commonly grade into carbonaceous shales. The workable seams have relatively low ash content (<10 percent) with an average of 4.4 percent sulfur. A bed analyzed for sulfur and sulfur isotopes revealed a chemistry of a typical Lower Cretaceous/Upper Jurassic coal ($\delta^{34}S$ -10 to -20).

The Lombard coal field, south of the Big Belt Mountains, is only about 6 square miles in area (fig. K1) and contains bituminous coal that has a high cooking capacity. The field has been neglected because its coal has a high ash and sulfur content--ash = 30 percent, sulfur 8.2 percent. Coal seams 6 ft thick were previously mined but are tectonically distorted.

Observed rocks that are nearest in composition to coal include a carbonaceous shale northwest of Radersburg, in the southwestern part of the Elkhorn Mountains (fig. K1). This high-carbon shale (more than 2 percent total organic carbon) is similar to the carbonaceous shale in the Great Falls-Lewistown coal field and there is a possibility that extensive drilling and exploration could reveal some coal. However, this carbonaceous shale is associated with volcanic rocks and any coal present should be similar in character to the Lombard coal. No Tertiary coal was found during this survey. Near the northwestern part of the Forest, lake "deposits" that have a high carbonaceous appearance were found to be a soil horizon. The landowners in the region were surveyed and no one had ever seen rock resembling coal in the area.

In conclusion, concealed coal may lie beneath parts of the Forest and extensive drilling would be required to find it. Such deposits would be discontinuous and, for the most part, uneconomical.

REFERENCE CITED

Whipple, J.W., Mudge, M.R., and Earhart, R.L., 1987, Geologic map of the Rogers Pass area, Lewis and Clark County, Montana: U.S. Geological Survey Miscellaneous Investigations Series Map I-1642, scale 1:48,000.

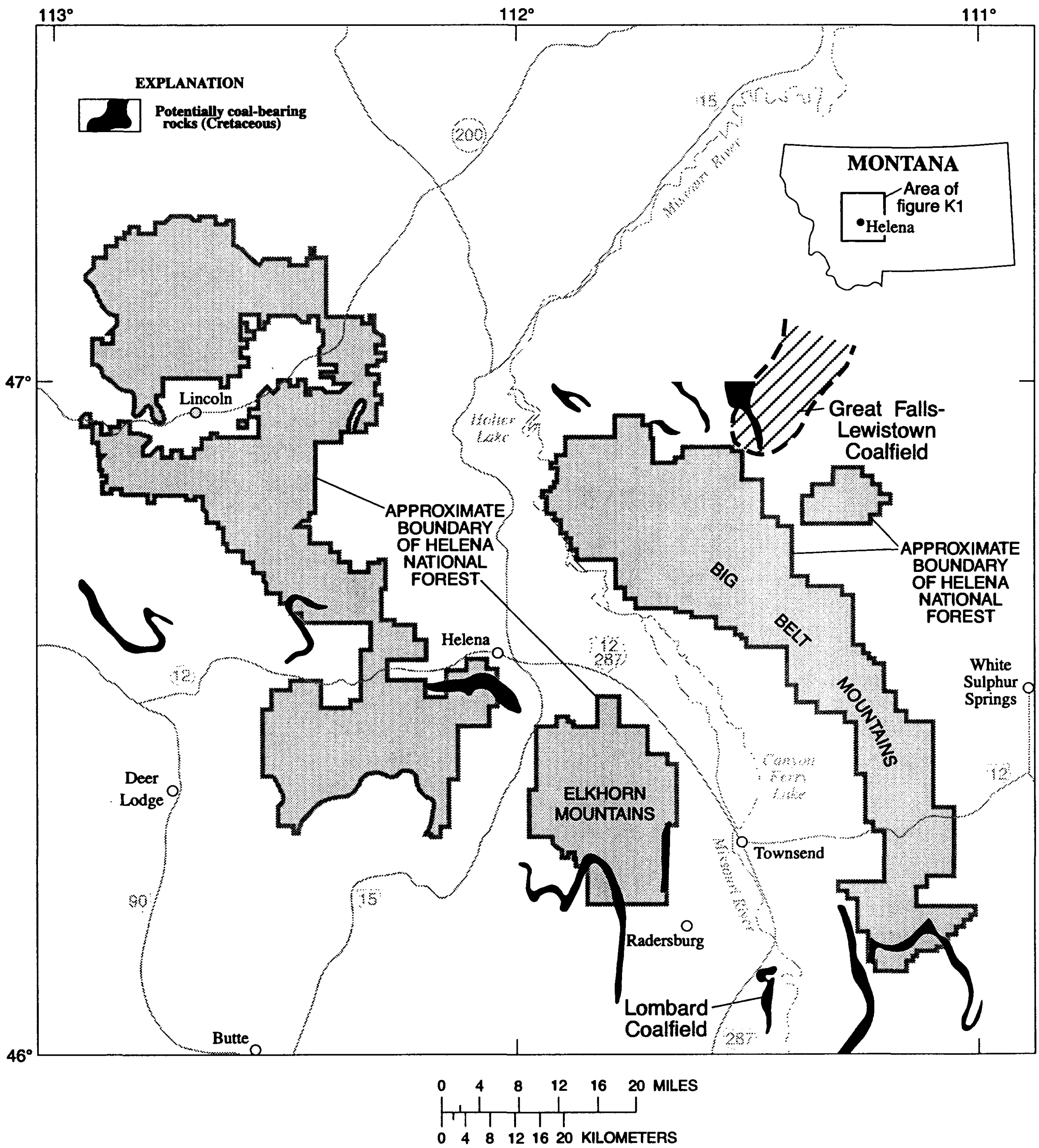


Figure K1. Map showing coal fields and potentially coal-bearing rocks in vicinity of the Helena National Forest.

A P P E N D I X

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DIGITAL DATA PRODUCTS

Many of the maps that appear on the plates of this report, and many of the figures that appear in the text, are available in digital form (CD-ROM disk) in the companion U.S. Geological Survey Open-File Report 96-683-B (Green and Tysdal, 1996). This appendix provides a listing of the digital products and programs[1] that were used in their compilation. The data contained on the CD-ROM are designed to augment and enhance this hard copy Open-File Report by improving clarity of maps and figures through the use of color, and by providing finer detail to some of the black-and-white maps and figures. Some figures, particularly those of Chapter C in which computer-generated pixels depict gradients of changing geophysical characteristics, are poorly displayed by the shades of gray on the paper version. On the computer, these gradations are shown more clearly and in greater detail when presented in color.

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EARTHVISION
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Programs[1]

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GSMAP and GSPOST are programs written by Selner and Taylor (1993), published by the U.S. Geological Survey

REFERENCES CITED

Green, G.R., and Tysdal, R.G., 1996, Digital maps and figures on CD-ROM for mineral and energy resource assessment of the Helena National Forest, west-central Montana: U.S. Geological Survey Open-File Report 96-683-B, 1 CD-ROM disk.

Selner, G.I., and Taylor, R.B., 1993, System 9. GSMAP, and other programs for the IBM PC and compatible microcomputers, to assist workers in the earth sciences: U.S. Geological Survey Open-File Report 93-511, 363 p., 2 disks.

[1]Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the USGS. Although these data have been used by the USGS and have been successfully imported into data base programs, no warranty, expressed or implied, is made by the USGS as to how successfully or accurately the data can be imported into any specific application software running on any specific hardware platform.

RESOURCE / RESERVE CLASSIFICATION

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

Major elements of mineral resource classification, excluding reserve base and inferred reserve base. Modified from U. S. Bureau of Mines and U. S. Geological Survey, 1980, Principles of a resource/reserve classification for minerals: U. S. Geological Survey Circular 831, p. 5.

GEOLOGIC TIME CHART

Terms and boundary ages used by the U. S. Geological Survey, 1986

EON	ERA	PERIOD		EPOCH	BOUNDARY AGE IN MILLION YEARS
Phanerozoic	Cenozoic	Quaternary		Holocene	0 010
				Pleistocene	1 7
		Tertiary	Neogene Subperiod	Pliocene	5
				Miocene	24
			Paleogene Subperiod	Oligocene	38
				Eocene	55
				Paleocene	66
	Mesozoic	Cretaceous		Late	96
				Early	138
		Jurassic		Late Middle Early	205
		Triassic		Late Middle Early	~ 240
	Paleozoic	Permian		Late Early	290
		Carboniferous Periods	Pennsylvanian	Late Middle Early	~ 330
			Mississippian	Late Early	360
		Devonian		Late Middle Early	410
		Silurian		Late Middle Early	435
		Ordovician		Late Middle Early	500
		Cambrian		Late Middle Early	~ 570[1]
Proterozoic	Late Proterozoic				900
	Middle Proterozoic				1600
	Early Proterozoic				2500
Archean	Late Archean				3000
	Middle Archean				3400
	Early Archean				3800?
pre-Archean[2]					4550

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

[2] Informal time term without specific rank.

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