DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

MISCELLANEOUS FIELD STUDIES
MAP MF-1469-B
PAMPHLET

MINERAL RESOURCE POTENTIAL OF THE SAPPHIRE WILDERNESS STUDY AREA AND CONTIGUOUS ROADLESS AREAS, GRANITE AND RAVALLI COUNTIES, MONTANA

By

C. A. Wallace, D. J. Lidke, J. E. Elliott, J. C. Antweiler, W. L. Campbell,
J. H. Hassemer, and W. F. Hanna, U.S. Geological Survey
and
D. P. Banister and T. J. Close, U.S. Bureau of Mines

STUDIES RELATED TO WILDERNESS

Under the provisions of the Wilderness Act (Public Law 88-577, September 3, 1964) and related acts, the U.S. Geological Survey and the U.S. Bureau of Mines have been conducting mineral surveys of wilderness and primitive areas. Areas officially designated as "wilderness," "wild," or "canoe" when the act was passed were incorporated into the National Wilderness Preservation System, and some of them are presently being studied. The act provided that areas under consideration for wilderness designation should be studied for suitability for incorporation into the Wilderness System. The mineral surveys constitute one aspect of the suitability studies. The act directs that the results of such surveys are to be made available to the public and be submitted to the President and the Congress. This report discusses the results of a mineral survey of the Sapphire Wilderness Study Area and contiguous roadless areas, Deerlodge and Bitterroot National Forests, Granite and Ravalli Counties, Mont. The Sapphire Wilderness Study Area was established by Public Law 95-150, November 1977, and contiguous roadless areas (01421) were classified as further planning areas during the Second Roadless Area Review and Evaluation (RARE II) by the U.S. Forest Service, January 1979.

MINERAL RESOURCE POTENTIAL
SUMMARY STATEMENT

Some areas in the Sapphire Wilderness Study Area and contiguous roadless areas, Granite and Ravalli Counties, Mont., hereafter referred to as the "study area," contain identified mineral resources and have a high potential for the occurrence of base- and precious-metal resources in small deposits that contain gold, silver, copper, lead, zinc, and molybdenum. Most areas of high potential are in the southern part of the Sapphire batholith in the Frogpond Basin region, where granodiorite is in contact with metasedimentary rocks of the middle and upper Belt Supergroup. Identified resources occur at the Lutz, Millers, and Kent mines, and at the Log Cabin and O'Brien prospects. Recorded mineral production in the study area is 1,103 oz of gold, 4,352 oz of silver, 2,409 lb of copper, 83,715 lb of lead, and 22,397 lb of zinc. Other areas adjacent to the study area have either a high or moderate potential for the occurrence of base- and precious-metal resources in small deposits; the Banner and Senate mines occur in these areas.

Associated with many vein occurrences are areas having potential for gold placers derived from mineralized veins. One area in Frogpond Basin contains an identified resource of gold in a low-grade placer. Most other areas having potential for gold placers are classified as having high or moderate potential for the occurrence of low-grade gold resources, and most of these areas are in the southern part of the study area. There is a high potential for the occurrence of a small molybdenum resource near the east border of the study area. Small areas that contain sulfide-bearing veins occur locally in the study area, and, in general, geochemical data from these areas show anomalously high amounts of base and precious metals; these areas also have potential for gold resources in small, low-grade placers downstream fom veins. Most of these small, mineralized areas have low to moderate potential for the occurrence of small base- and precious-metal resources.

The potential for the occurrence of resources of disseminated rare-earth and associated elements is low. In the western part of the study area, monzogranite and granodiorite contain allanite, sphene, and epidote as accessory minerals, and the rocks contain high concentrations of lanthanum, yttrium, vanadium, titanium, and scandium. Placers formed in streams that drain this terrane contain concentrations of tin and niobium above background levels.

Porphyry-copper and tin-greisen deposits probably do not occur near the surface because the rocks show little alteration or mineralization, key mineral assemblages are lacking, breccia pipes are absent, multiple intrusive events are lacking, and geochemical data indicate an absence of mineralization patterns suggestive of these types of deposits.

Oil, gas, coal, geothermal, and radioactive mineral resources are unlikely to occur in the study area.

INTRODUCTION

The Sapphire Wilderness Study Area and contiguous roadless areas, Granite and Ravalli Counties, southwestern Montana, will be referred to collectively as the "study area" in this report. The study area straddles the topographic crest of the southern Sapphire Mountains. The eastern part of the study area is in the Deerlodge National Forest, and the western part is in the Bitterroot National Forest. This area of 147 mi^2 is about 21 mi east of Hamilton, Mont., and about 24 mi west of Philipsburg, Mont. (fig. 1).

The western, northwestern, southern, and southwestern parts of the area are dominated by rugged, glacially sculptured topography along the mountain crest, and by deeply incised canyons below the limits of glaciation. The northeastern part of the area typically has a more rolling and knobby topography. The total topographic relief in the study area is about 4,000 ft. Gravel roads provide access to four parts of the study area: (1) seasonally open State Highway 38 between Philipsburg and Hamilton, Mont., provides access to the northern part of the study area along the West Fork of Rock Creek and to the western part between Skalkaho Creek and the East Fork of the Bitterroot River; (2) the road along the East Fork of the Bitterroot River provides access to the southern part of the study area; (3) the road along the Middle Fork of Rock Creek provides access to the southeastern part of the study area; and (4) an unimproved road provides access to the study area along Ross Fork of Rock Creek.

The area was mapped in reconnaissance by C. P. Ross (Ross and others, 1955) for the geologic map of Montana. As part of a master's thesis, R. J. Pederson (1976) produced a geologic map of the eastern part of the study area and studied the mineral resource potential of this area. Geologic mapping for this study was done in 1979 and 1980 by C. A. Wallace and D. J. Lidke, and the geologic map has been published (Wallace and others, 1982). A field geochemical survey was completed in 1980 by J. C. Antweiler, W. L. Campbell, and G. K. Lee, and these data have been published (Campbell and others, 1983); interpretation of the geochemical results are in preparation for publication. Geophysical surveys consisted of an airborne magnetometer survey and a gravity survey; results of the aerial magnetic survey were published in September 1981 (U.S. Geological Survey, 1981), and the gravity survey was completed in August 1981. Interpretation of results of the geophysical surveys are in preparation for publication.

Personnel of the U.S. Bureau of Mines searched the literature, county claims records, U.S. Bureau of Mines mineral-property files and mineral production records, and conducted field investigations during 1978 under T. J. Close and during 1979 under D. P. Banister (Banister and others, 1983). A total of 32 lode mines, prospects, or claim groups were examined during field studies. About 550 chip and grab samples from mines and prospects were analyzed by atomic-absorption, chemical, and fire-assay methods, and about one-third of the samples were analyzed using semiquantitative spectrographic analysis. Six areas of placers were evaluated using 239 samples taken from 165 locations. All sample analyses are on file at the U.S. Bureau of Mines Western Field Operations Center, Spokane, Wash.

GEOLOGY

Regional geologic setting

The bedrock in the study area is composed primarily of Cretaceous plutons of the Sapphire batholith and metamorphosed sedimentary rocks of the Belt Supergroup (Proterozoic Y). The middle and upper parts of the Belt Supergroup are present in the study area. Most original stratigraphic relations of these rocks have been disrupted by later thrust faults that characterize the structural pattern in this region. These Proterozoic rocks were transported from west to east on the regionally extensive Sapphire thrust plate prior to intrusion of the Sapphire batholith. The Sapphire batholith is an irregularly shaped, north-south-oriented mass of plutons that is concentrically zoned from granodiorite along the edges to monzogranite in the interior.[1] These plutons intruded and metamorphosed thrust-faulted rocks of the Wallace Formation and Missoula Group (Proterozoic Y) about 73 m.y. ago. During middle and late Tertiary time the present area of the Sapphire Mountains was uplifted, and sediment was shed to the east and west. Remnants of pediments and mountain-front deposits flank much of the range. Igneous rocks were deeply weathered during this period of uplift. During Pleistocene time, glaciers in the higher parts of the Sapphire Mountains formed arêtes, cols, cirques, and horns along the topographic divide and deposited till and outwash in lower parts of the valleys.

Sedimentary rocks

Sedimentary rocks in the study area consist of the middle Belt carbonate unit (Wallace and Helena Formations) and the Missoula Group (Proterozoic Y) of the Belt Supergroup (fig. 2). Rocks of the Ravalli Group, which elsewhere underlie formations of the middle Belt carbonate unit, are absent from the stratigraphic succession in the study area because thrust faults have displaced parts of the sequence (Wallace and others, 1982).

The oldest rocks exposed in the study area form the middle Belt carbonate, which consists of the laterally equivalent Wallace and Helena Formations. The Helena Formation consists of interbedded calcite-bearing argillite and siltite, argillaceous limestone, and limy quartzite. The Wallace Formation is composed mainly of interbedded dolomitic argillite and siltite, and minor beds of siliceous quartzite and argillaceous dolomite. Zones of distinctive syndepositional breccia occur locally in the middle part of the Wallace Formation.

Overlying the Helena and Wallace Formations in depositional contact is the Missoula Group, the basal unit of which is the Snowslip Formation (formations of the Missoula Group are not separated in figure 2, the generalized geologic map). This unit consists of interbedded argillite, argillaceous siltite, fine-grained quartzite, and some distinctive, well-sorted, coarse-grained quartzite. The upper part of the Snowslip Formation and possibly the overlying Shepard Formation are absent in the study area because of

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[1]Intrusive rocks are classified according to the IUGS system (Streckeisen,1973).

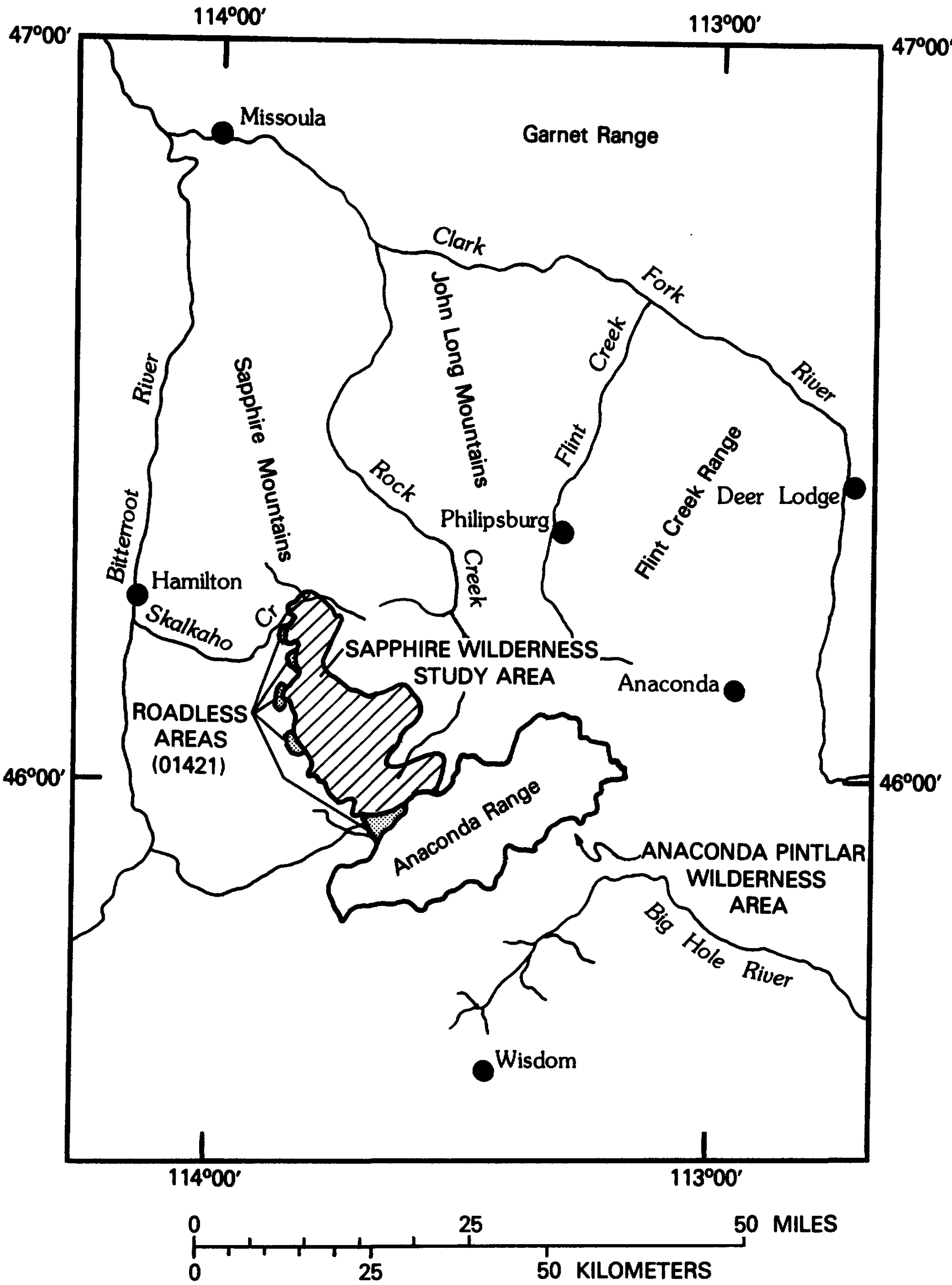


Figure 1.—Index map showing location of the Sapphire Wilderness Study Area and contiguous roadless areas (01421), Granite and Ravalli Counties, Mont.

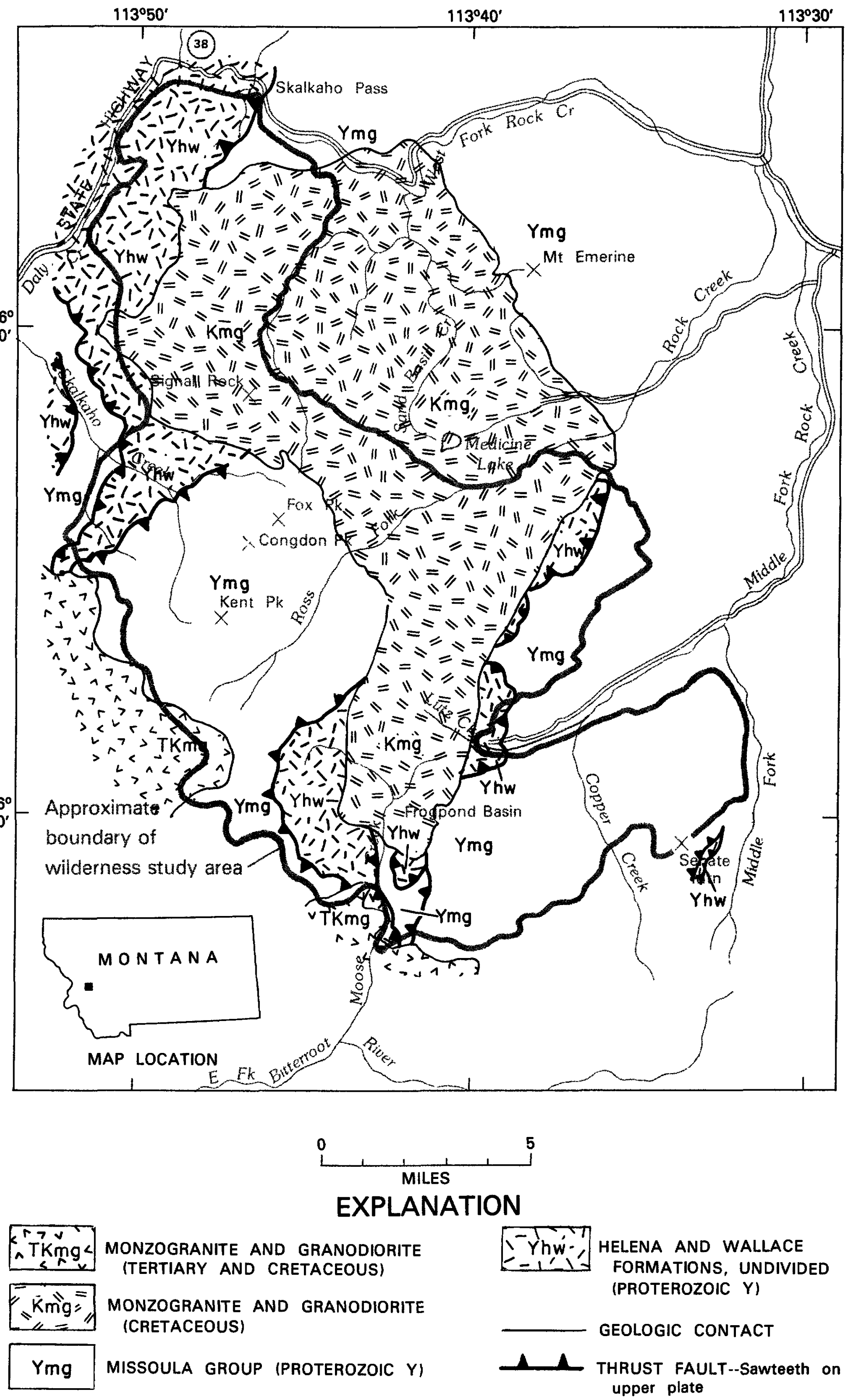


Figure 2.—Generalized geologic map of the Sapphire Wilderness Study Area and contiguous roadless areas, Granite and Ravalli Counties, Mont.

thrust faulting. The overlying Mount Shields Formation is exposed widely over the study area; it contains three members, none of which are completely exposed in the study area. The lower member consists of zones of thinly interbedded argillite, siltite, and fine-grained quartzite that alternate with zones of well-sorted, fine-grained feldspathic quartzite. The middle member is mainly thickly bedded, fine- and medium-grained feldspathic quartzite and minor beds of pebble conglomerate. The upper member consists of interbedded argillite and fine-grained feldspathic quartzite. Thrust faults separate the Mount Shields Formation from the overlying Bonner Quartzite. The Bonner Quartzite is a coarse-grained, feldspathic, conglomeratic quartzite present in the northern part of the study area. Based on recent paleomagnetic data (D. P. Elston, oral commun., 1982), this unit is also present in the northeastern part of the study area, an area that was previously mapped as Mount Shields Formation (Wallace and others, 1982). Overlying the Bonner Quartzite is the McNamara Formation, which is an interbedded sequence of argillite and fine-grained quartzite that is present in the northern part of the study area. Normally, overlying the McNamara Formation would be the Garnet Range Formation, but, possibly because of thrust faulting, this unit is absent in the study area.

Intrusive Rocks

Three main intrusive bodies are in, or adjacent to, the study area. In the central part of the study area is the Sapphire batholith, which is a peraluminous intermediate plutonic rock. Intrusive rocks of intermediate composition intrude Belt rocks along the south, southwest, and west boundaries of the study area, and a stock of intermediate composition occurs along the northwestern edge of the study area, along Daly Creek. Intrusive rocks exposed along the edges of the study area represent margins of larger plutons, the bulk of which occur outside the study area. Scattered through parts of the study area are dikes, sills, and pods of variable composition.

The Sapphire batholith is an epizonal complex of six comagmatic monzogranite and granodiorite bodies that have been intruded by late-stage leucomonzogranite and porphyritic micromonzogranite dikes and sills. The batholith, which underlies the central and northeastern parts of the study area, is elongate north-south. Contacts of the batholith with country rocks are sharp and discordant. The outer rim of the batholith is composed of siliceous, peraluminous hornblende-biotite granodiorite and monzogranite, whereas the small inner core of the batholith is composed of peraluminous muscovite-biotite granodiorite and monzogranite. Late-phase dikes, sills, and pods of porphyritic leucomicromonzogranite, leucomonzogranite, and minor pegmatite and quartz veins represent the final stage of crystallization of a magma that contained a relatively small volume of residual liquid.

Field data suggest that the six plutons of the Sapphire batholith were intruded at about the same time. Radiometric ages obtained by J. D. Obradovich, using the potassium-argon method on mineral pairs from four of the plutons, are all about 73 m.y. (Late Cretaceous).

The rocks of intermediate composition along the south, southwest, and west boundaries of the study area are Cretaceous and possibly Tertiary in age; these rocks form a mesozonal(?) and epizonal assemblage of tonalite, biotite granodiorite, biotite-hornblende granodiorite and monzogranite, rhyodacite, and dacite. The crystalline rocks have a prominent northwest-trending foliation. Extensive zones of migmatite formed within Proterozoic Y rocks at the contact with the plutonic rocks. These plutons are probably related to the Bitterroot lobe of the Idaho batholith.

Along the northwestern edge of the study area, epizonal intrusive rocks of Daly Creek are part of a zoned pluton of quartz diorite, tonalite, and biotite-hornblende granodiorite of probable Cretaceous or Tertiary age; the most mafic rocks are present along the discordant contact with Proterozoic Y Belt rocks. This narrow, long stock trends east-west, and only the east margin of the pluton extends into the study area.

Dikes, sills, and pods of oligoclasite, microgabbro, and gabbro are scattered through parts of the study area, and these small and discontinuous plutons cut metasedimentary rocks of the Belt Supergroup. These intrusive rocks are not metamorphosed, so they postdate the 73-m.y. age of the Sapphire batholith over most of the study area.

Metamorphic rocks

Contact metamorphism occurred during Cretaceous and Tertiary time where plutonic masses intruded the thrust-faulted succession of Belt rocks. The epizonal Sapphire batholith and intrusive rocks of Daly Creek thermally metamorphosed adjacent country rocks. (Metamorphic aureoles are not shown in figure 2, the generalized geologic map.)

The Wallace Formation was metamorphosed to a calc-silicate hornfels that ranges in metamorphic grade from hornblende hornfels facies adjacent to the pluton to albite-epidote hornfels facies several miles from the contact. The highest grade rocks contain mainly quartz, actinolite, scapolite, diopside, biotite, calcite, and dolomite and suggest a probable maximum temperature of metamorphism near 600°C and a probable maximum pressure near 2 kilobars (Pederson, 1976, p. 39).

In most of the study area, metamorphic facies are difficult to distinguish in quartzo-feldspathic rocks of the Missoula Group and in the muscovite-biotite schist formed from some argillaceous parts of the Missoula Group. Conditions of metamorphism were probably similar to those determined for the Wallace Formation.

Dynamothermal metamorphism occurred along the south, southwest, and west border of the study area, where wide zones of migmatite formed in country rock along the margins of large plutonic bodies of probable Cretaceous age. Calc-silicate and quartzo-feldspathic, sillimanite-bearing gneiss and migmatitic gneiss occur adjacent to these plutons and as roof pendants in the plutons. These metamorphic rocks may represent a synkinematic regional metamorphism (N. R. Desmarias, oral commun., 1981), or they could represent contact metamorphism during multiple intrusive events that occurred at mesozonal depth under local directed stress.

Structural geology

All of the Proterozoic rocks in the study area are allochthonous and are part of the much larger Sapphire thrust plate (Hyndman and others, 1975; Ruppel and others, 1981; Wallace and others, 1982). The dominant structural features in the study area are thrust faults in the Proterozoic succession. Most thrust faults dip gently to the west and strike generally north. The strike and dip of some faults change along trace, and in the southern and western parts of the study area thrust faults were folded after the thrusting event.

Interpretation of structural relations and facies relations on a regional scale suggests that the Sapphire thrust plate was transported from west to east. Distance of transport for the Sapphire plate has been estimated variously at a minimum of 40 mi by Hyndman (1980), and a minimum of 60 mi, based on a general palinspastic restoration, by Wallace and others (1976).

Intrusive relations between thrust faults and the Sapphire batholith indicate that thrust faults had ceased movement prior to about 73 m.y. ago. This is a minimum age for cessation of thrust faulting because older ages are obtained from intrusive bodies that truncate thrust faults of the Sapphire plate, such as the 78-74 m.y. ages (ages corrected approximately using the IUGS decay constant) determined for the Philipsburg batholith in the Flint Creek Range (Hyndman and others, 1972).

Pederson (1976, p. 55-56) mapped two large, open folds in Proterozoic rocks in the eastern part of the study area, the Whetstone anticline and the Meyers Creek syncline. However, stratigraphic data suggest that thrust faults may separate oppositely dipping sequences. Because there is some doubt about the regional trends of these large folds, their axial traces are not shown on the geologic map at 1:50,000 scale (Wallace and others, 1982). Small-scale folds related to faults occur throughout the study area, but these folds were not mapped systematically because of poor exposures.

Most steep-angle faults shown as strike-slip, reverse, and normal faults by Pederson (1976), using traces on aerial photographs, were not mapped during this study because they do not offset boundaries of rock units and because our field investigations suggest that the traces on aerial photographs may not represent faults, or they represent small faults that can be traced for only short distances in the field.

Interpretation of geophysical data

Geophysically, the study area is characterized by (1) an areally extensive, elongate, annular magnetic high that separates local magnetic highs to the east and west; and (2) a low-amplitude Bouguer gravity low that is approximately coincident with the inner low region of the annular magnetic high (Hassemer, 1981; U.S. Geological Survey, 1981; and fig. 3 this report). Interpreting the annular magnetic high and gravity low in the context of magnetization and density data suggests that the core of the Sapphire batholith is characterized by relatively low magnetization and density and is surrounded by a thick rim of rocks of relatively high magnetization and density. This interpretation generally corresponds to the mapped zonation in the batholith that ranges from a muscovite-biotite monzogranite core to a biotite-hornblende granodiorite outer rim. Preliminary modeling of magnetic anomaly sources suggests that the contact between the east side of the batholith and Belt rocks may dip steeply to the east, whereas the contact between the west side of the batholith and Belt rocks may dip more gently to the west. The local magnetic highs to the east and west of the annular anomaly are inferred to be associated with plutons at depths of less than about 650 ft.

The geophysical data indicate that Belt rocks surrounding the Sapphire batholith are relatively nonmagnetic and have densities similar to those of granodiorite at the rim of the batholith.

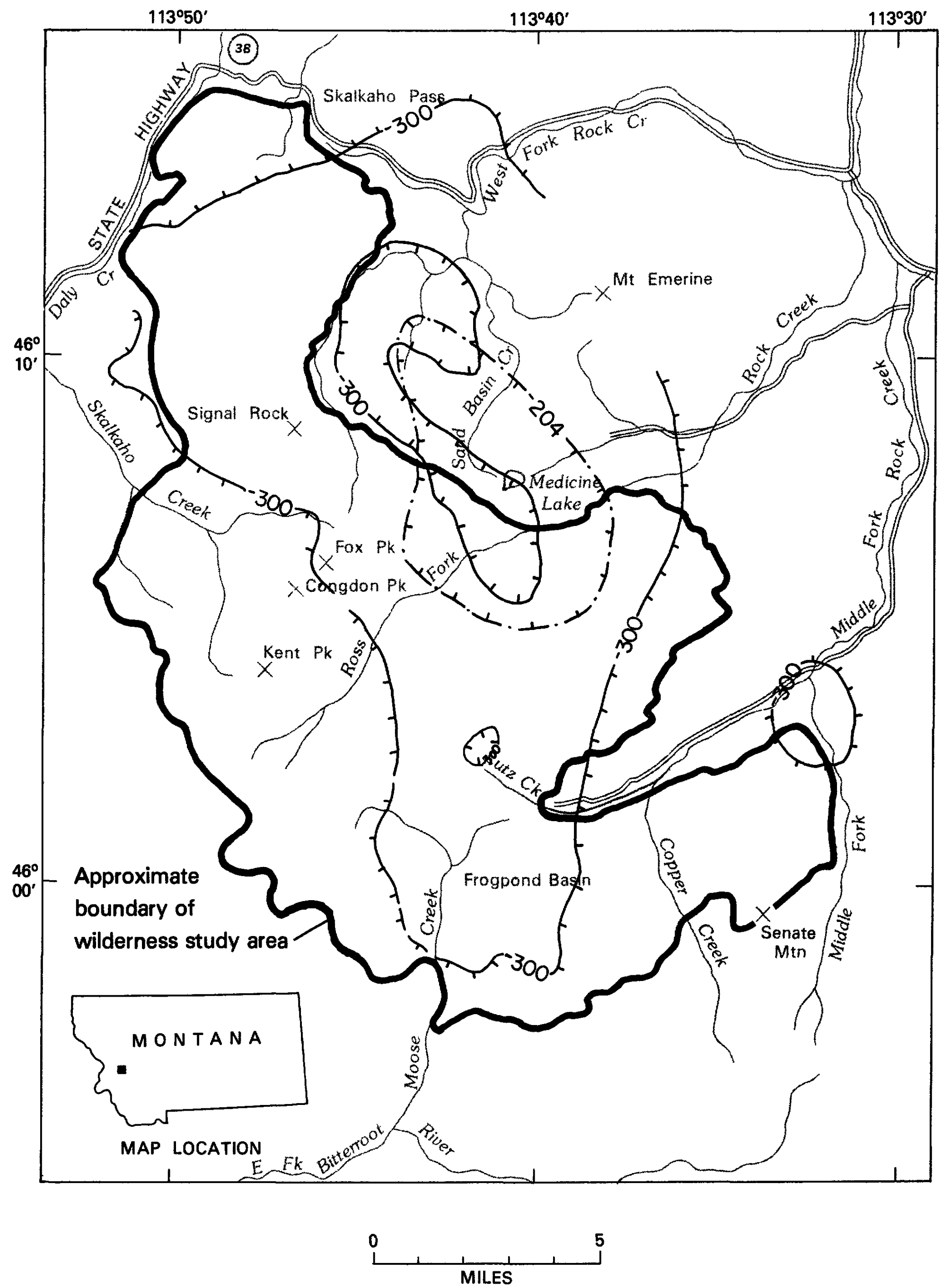
Geochemical methods and interpretations

A total of 322 minus-80-mesh stream-sediment, 263 nonmagnetic panned-concentrate, and 295 rock samples were collected in the study area (Campbell and others, 1983). Stream-sediment samples were collected from most active first-order streams and from all second-order and larger streams. A composite of fine-grained material from several localities within the stream was collected at each sample site. Panned concentrates of stream sediments were collected from streams that were large enough to deposit gravel and coarser sediment, generally from near the stream-sediment sample localities.

Rock samples collected at mineralized locations consisted of the most altered and mineralized material present. Nonmineralized composite chip samples were taken from outcrops to obtain background data representative of rock units in the study area. At mines and prospects mineralized and nonmineralized samples were collected for comparison.

Stream-sediment samples were dried and sieved through an 80-mesh (177 micrometer) screen, and the fraction finer than 80-mesh was split and analyzed by spectroscopy. Panned-concentrate samples were dried, and a small split of each sample was separated for spectrographic analysis. The remainder of each concentrate was weighed and chemically analyzed for gold content. All rock samples were crushed, ground, and split for analysis. Six-step, semiquantitative emission-spectrographic analyses for 31 elements were made of all the samples by R. T. Hopkins, Jr., using the method of Grimes and Marranzino (1968). Atomic-absorption analysis for gold was performed by W. L. Campbell, using the method described by Ward and others (1969). Atomic-absorption determinations of copper, lead, zinc, silver, antimony, bismuth, and cadmium were made on selected samples by W. L. Campbell, T. A. Roemer, and A. L. Gruzensky, using the partial-solution method described by Viets and others (1979). Concentrations of elements cited in the following text are designated "spec" for determinations made by six-step, semiquantitative emission-spectrographic methods, and "AA" for determinations made by atomic-absorption methods.

Thresholds for geochemical anomalies were chosen by one of several criteria for commodity elements and trace elements: (1) sharp changes in slope or discontinuities in graphs of the data; (2) taking multiples of two or three times the geometric mean as a lower limit for an anomaly; (3) the lower limit of analytical detection; and (4) crustal abundance of the element. Threshold concentrations used for this report



EXPLANATION

RESIDUAL MAGNETIC INTENSITY IN GAMMAS--
Hachures point to lower intensity

COMPLETE BOUGUER GRAVITY ANOMALY--
Hachures point to lower values

Figure 3.—Generalized map showing aeromagnetic and gravity features, Sapphire Wilderness Study Area and contiguous roadless areas, Granite and Ravalli Counties, Mont.

are listed in table 1. Analysis of geochemical data resulted in identification of 20 areas that contain anomalously high concentrations of elements that have potential use (commodity elements) or of pathfinder elements. Anomalously high concentrations of some elements that occur as single-element, isolated anomalies are not considered as significant criteria upon which resource potential can be based.

MINING DISTRICTS AND PROSPECTS

Under the supervision of D. P. Banister and T. J. Close, personnel from the U.S. Bureau of Mines investigated pertinent data and literature from the U.S. Bureau of Mines, U.S. Forest Service, and the U.S. Bureau of Land Management, and searched county claim records in Granite and Ravalli Counties to locate mines, prospects, or claim groups in and adjacent to the study area (fig. 4). Field investigations included examination of 32 lode mines, prospects, and reported mineral occurrences, and examination of six areas of placers. About 125 lode claims were located or relocated in the study area; most of these were in the Frogpond Basin mining district. Not all claims were found during this study because of incorrect or vague descriptions of locations in county records.

Mapping, sampling, and analysis by the U.S. Bureau of Mines included all accessible underground mines, surface prospects, and mine and prospect dumps. About 550 chip and grab samples from accessible mines and surface prospects and from mine and prospect dumps were analyzed by atomic-absorption, chemical, fire-assay, and semiquantitative spectrographic methods. Studies of placers yielded 239 samples from pits, auger holes, and panned concentrates, which were treated using gravity-concentration methods to determine the amount of recoverable gold. Some samples were analyzed for radioactive minerals and fluorescent minerals. Placer samples were analyzed by petrographic, semiquantitative spectrographic, and fire-assay methods.

Investigations by the U.S. Bureau of Mines identified two mining districts that occur within the boundary of the Sapphire Wilderness Study Area and contiguous roadless areas, and several districts close to the study area, but outside it. The two mining districts in the study area are (1) the Frogpond Basin district at the head of Moose Creek, in the area of Lutz Creek, which contains the most mines and prospects (fig. 4); and (2) the loosely defined Moose Lake district, near the junction of Copper Creek and the Middle Fork of Rock Creek, which contains the Banner Mine (location 35, fig. 4). The Medicine Lake mining district (locations 2 and 3, fig. 4), the Sand Basin area (4 mi east of location 1, fig. 4) (U.S. Bureau of Mines, 1954), the Skalkaho mining district (3 mi northwest of the north boundary of the study area), and the Crystal Point fluorspar mine, 3 mi southwest of the southwest boundary of the study area, all are outside the study area.

All recorded production within the study area was from the Frogpond Basin mining district. The first claims were located in this district in 1898; the most intense exploration and mining activity took place during the period 1907-37. About 1,400 tons of ore was produced from three mines in the Frogpond Basin district, and 1,103 oz of gold, 4,352 oz of silver, 2,409 lb of copper, 83,715 lb of lead, and 22,397 lb of zinc were recovered from the ore. The Banner mine (location 35, fig. 4), which is in the Moose Lake district and is adjacent to the east boundary of the study area, may have been sporadically active during the late 1890's. Production records through 1936, and records of production from mine dumps through 1973, show that 1,979 oz of gold, 5,896 oz of silver, and 20,935 lb of copper were produced from the Banner mine. The Senate mine (location 38, fig. 4), adjacent to the southeast boundary of the study area, was staked in 1896 and may have had brief production in the late 1890's, but no records are available. Bear Creek Mining Co. explored the Senate mine area from 1958 to 1962, using core drilling and induced-polarization surveys to assess the property. Prospects are scattered through the study area; these have had different amounts of development but no recorded production. Data obtained by the U.S. Bureau of Mines on mines and prospects are summarized in table 2.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

Mineral resource potential, as used in this report, is a geologic evaluation of the potential for occurrences of metallic and energy resources that is based on criteria developed from geological, geophysical, geochemical, and mine and prospect investigations. A mineral resource is defined as "a concentration of elements in a particular location * * * in such a form that a useable mineral commodity * * * can be extracted from it" (Brobst and Pratt, 1973, p. 3). Identified resources, as used in this report, are "specific bodies of mineral-bearing rock whose existence and location are known. They may or may not be evaluated as to extent and grade" (Brobst and Pratt, 1973, p. 3). The criteria by which the study area was evaluated for potential for occurrences of resources are given in table 3. Areas that lack sufficient diagnostic features to determine whether or not resources occur are considered to have some potential, however low, for the occurrence of resources. A summary of the evaluation and rating assigned to parts of the study area is given in table 4. Figure 5 shows the areas that have low, moderate, or high potential for the occurrence of resources. Numbered areas listed in the text correspond to areas described in table 4 and shown in figure 5.

Possibility of porphyry-copper and tin-greisen deposits in the Sapphire batholith

Some geological, geochemical, and geophysical characteristics of the Sapphire batholith are similar to those associated with porphyry-copper and tin-greisen deposits known elsewhere (Cox and others, 1982; Reed, 1982), but the Sapphire batholith lacks critical characteristics that would suggest the occurrence of either type of deposit near the present surface. Magma differentiation formed late-crystallizing porphyritic peraluminous granodiorite and monzogranite and leucomicromonzogranite porphyry in the core of the batholith, which would provide a proper setting for the occurrence of a porphyry-copper or tin-greisen deposit. Fluorite, which is rare in rocks of the core of the batholith in the study area, is in places associated with late alteration of some porphyry

TABLE 1.--Threshold concentrations for geochemical anomalies, Sapphire Wilderness Study Area and contiguous roadless areas, Granite and Ravalli Counties, Mont.

[spec , six-step semiquantitative spectrographic analysis; AA, atomic-absorption analysis; ppm, parts per million; L, lower limit of detection in ppm taken as threshold concentration; leaders (--), not applicable; pct, percent]

Element	Threshold for anomaly	
	Spec	AA
Stream-sediment samples		
Ag	1 ppm	1 ppm
Cu	30 ppm	10 ppm
Pb	100 ppm	50 ppm
Sb	--	1 ppm
Zn	200 ppm (L)	30 ppm
Cd	--	0.5 ppm
Panned-concentrate samples		
Ag	1 ppm	--
Au	10 ppm (L)	0.2 ppm
Co	30 ppm	--
Cu	50 ppm	--
Mo	10 ppm (L)	--
Ni	150 ppm	--
Pb	100 ppm	--
Sn	20 ppm	--
W	100 ppm (L)	--
Th	1,000 ppm	--
Rock samples		
Ag	10 ppm	10 ppm
Au	10 ppm (L)	1 ppm
Co	30 ppm	--
Cu	100 ppm	50 ppm
Mo	5 ppm	--
Ni	100 ppm	--
Pb	100 ppm	30 ppm
Sb	100 ppm (L)	5 ppm
Sn	10 ppm (L)	--
W	50 ppm (L)	--
Zn	200 ppm (L)	20 ppm
Ti	0.5 pct	--
As	200 ppm (L)	--
Cd	20 ppm (L)	0.5 ppm
Bi	10 ppm (L)	3 ppm
La	70 ppm	--
Nb	20 ppm (L)	--
Sc	20 ppm	--
Sr	700 ppm	--
V	150 ppm	--
Y	70 ppm	--

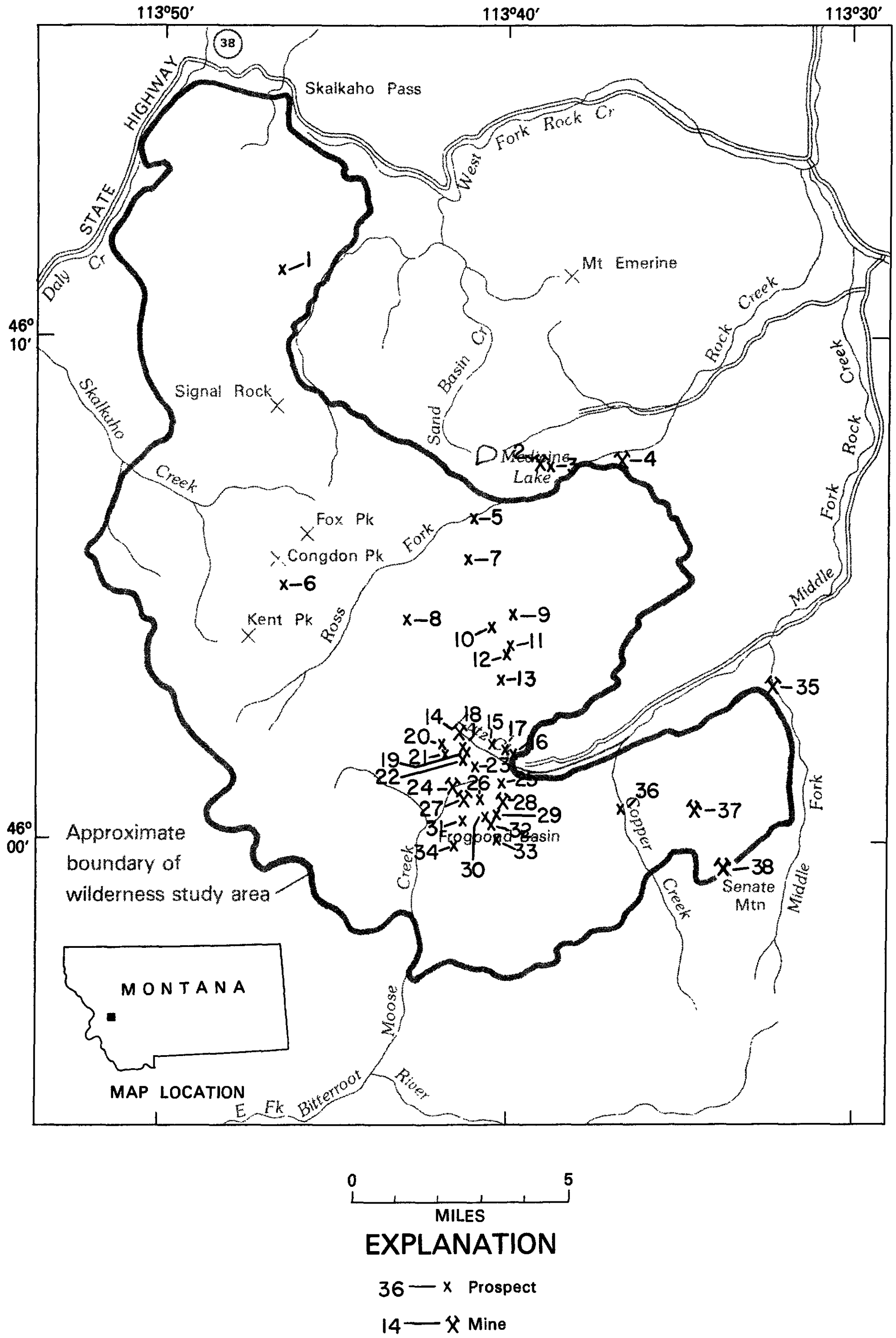


Figure 4.--Map showing location of mines and prospects in and adjacent to the Sapphire Wilderness Study Area and contiguous roadless areas, Granite and Ravalli Counties, Mont. Numbers refer to mines and prospects described and named in table 2.

systems. Geochemical data show a concentration of copper, molybdenum, silver, gold, lead, and zinc in the southern part of the batholith, which could correspond to outer aureoles of a porphyry copper system. Geochemical data also show enrichment of rocks in tin, tungsten, niobium, thorium, and rare-earth elements in the northern part of the batholith; such enrichment is characteristic of tin-greisen deposits. Geophysical data show a prominent annular high magnetic anomaly that rims the batholith and a less intense magnetic low over the core of the batholith, which might suggest the presence of an altered zone near the interior of the batholith, a zone that is not exposed at the surface. At the north end of the batholith a gravity low is centered over the late-phase, two-mica core, which could reflect alteration of core rocks at depth.

Despite superficial similarities to porphyry-copper deposit models, the Sapphire batholith lacks key features of alteration commonly associated with porphyry-copper systems, such as abundant quartz veins and pyrite, as well as propylitic, argillic, phyllic, or potassic alteration (Cox and others, 1982, p. 27-32). Multiple intrusive phases and breccia pipes associated with some porphyry-copper deposits (Cox and others, 1982, p. 28) are also absent from the Sapphire batholith. Similarly, key features of a tin-greisen deposit are lacking in the Sapphire batholith: (1) replacement of granitic rock by quartz, muscovite, topaz, and tourmaline is absent, and albitization and sericitization of potassium feldspar are lacking; (2) characteristic ore minerals, such as cassiterite, molybdenite, arsenopyrite, beryl, or wolframite, are lacking; and (3) geochemical data suggest lack of enrichment in fluorine, rubidium, lithium, beryllium, boron, cesium, and tantalum (Reed, 1982, p. 55-61). Evaluation of geological and geochemical data suggests that there is little likelihood for the occurrence of large, low-grade porphyry-copper and tin-greisen deposits near the surface in the Sapphire batholith.

Potential for the occurrence of gold resources

Mesothermal veins and replacement bodies

Identified gold resources occur in sulfide-bearing quartz veins in several places, and several areas have moderate and high potential for occurrence of gold resources. Five mines in the study area have produced gold. The Frogpond Basin region (area 1) has the greatest potential for the occurrence of gold resources in small deposits of moderate or high grade. Gold concentrations in samples from numerous mines, prospects, and streams in Frogpond Basin range between 0.2 ppm (AA) and 70 ppm (AA). Interpretation of data from mines in area 1 suggests values of 0.18 oz of gold per ton for the main vein of the Miller mine, 0.11 oz of gold per ton for higher grade zones in the south vein of the Lutz mine, and 0.01-0.05 oz of gold per ton for the main vein of the O'Brien prospects.

Areas 3 and 4 have high potential for the occurrence of gold resources in small deposits. These areas have gold concentrations that range between 0.2 ppm (AA) and 50 ppm (AA). Data collected by the U.S. Bureau of Mines suggest values of 0.09 oz of gold per ton from the 17-in.-wide vein at the Rainbow prospect, and historical records suggest 0.4 oz of gold per ton from the Banner mine.

The area around Point Lookout (area 7) has a high potential for the occurrence of gold resources in small deposits; gold concentrations range between 0.2 ppm (AA) and 10 ppm (AA). Data obtained by the U.S. Bureau of Mines indicate that a vein at the Kent mine contains 0.34-1.06 oz of gold per ton.

Area 6, along the South Fork of Rock Creek, and area 15, near Table Mountain, have a moderate potential for the occurrence of gold resources in small, low grade, veins. Gold concentrations in samples from these areas range between 0.2 ppm (AA) and 70 ppm (AA). Data from sulfide-bearing quartz veins in area 6, interpreted by the U.S. Bureau of Mines, suggest concentrations between 0.1 and 0.14 oz of gold per ton, and veins near Table Mountain (area 15) contain 0.1-0.26 oz of gold per ton.

The area southwest of Congdon Peak (area 9), has a low potential for the occurrence of a gold resource in small, low-grade veins and possible replacement zones. Veins in prospects in area 9 and in streams that drain this area contain gold in concentrations that range between 0.2 ppm (AA) and 70 ppm (AA). Gold-bearing veins or breccia zones that may occur above Green Canyon Creek (area 8) and in Daly Creek (area 11) suggest a low potential for occurrence of gold resources in small veins of probable low grade. Although vein sources were not found in areas 9 and 11, occurrence of gold slightly above and below threshold values suggests possible small gold sources upstream.

Veins and replacement bodies at the Senate mine (area 2) contain only a trace of gold, based on geochemical data from the U.S. Geological Survey and the U.S. Bureau of Mines, and there is probably a low potential for occurrence of gold resources in this area.

Placers

Identified and potential gold resources in placers occur in several areas, but few areas contain prospects for placer gold. The Frogpond Basin region (area 1) is the largest of these areas and has the greatest potential for the occurrence of gold resources in low-grade deposits or in small zones of moderate grade. Lutz Creek, tributaries to Moose Creek, and small streams in Frogpond Basin have gold concentrations that range between 0.2 ppm (AA) and 150 ppm (AA), based on sampling by the U.S. Geological Survey. (Moose Creek, as used in this report, refers to the Moose Creek that flows south to the East Fork of the Bitterroot River from the southwestern part of Frogpond Basin.) The area of Lutz Creek, near prospect 17, has a high potential for the occurrence of gold resources in low-grade placers; sampling by the U.S. Bureau of Mines indicated an average gold content of about 0.005 oz of gold per yd^3 of gravel, and local high concentrations of about 0.10 oz of gold per yd^3 of gravel.

The geochemical survey conducted by the U.S. Geological Survey detected gold in several streams in the Frogpond Basin area. Visible gold occurs in Moose and Cuba Creeks and in an unnamed tributary north of Cuba Creek; all of these streams are assigned a moderate potential for the occurrence of a gold resource, but the concentration is not known. An unnamed tributary to Copper Creek, southwest of

TABLE 2.--Summary of mines and prospects in the Sapphire Wilderness Study Area and contiguous roadless areas, Granite and Ravalli Counties, Mont.

No. in fig. 4	Name (commodity)	Geologic or Geomorphic setting	Workings and production	Sample data and resources of mines and prospects
1	Bowles Creek placer (rare-earth elements).	Narrow valleys; streams drain granodiorite.	None----------------------------	Seventeen samples from 10 pits in Bowles Creek; 13 panned samples from tributaries. Allanite averaged 0.015 percent.
2	Kent mine[1] (gold, silver, copper, and lead).	Sulfide-bearing quartz veins and lenses in shear zone that may extend for 1,700 ft. Shear zone is as much as 10 ft wide.	Caved adit and shaft estimated to have 2,000 ft of workings; 3 small pits. Production 1933-35: 341 tons of ore, which yielded 88 oz of gold, 5,932 oz of silver, 197 lb of copper, and 2,162 lb of lead.	Thirteen samples: two chip samples across 2.5-ft-wide shear zone contain 0.34-1.06 oz of gold per ton and 53.9-242.1 oz of silver per ton. Samples from dumps contain 0.04-0.22 oz of gold per ton and 4.8-12.9 oz of silver per ton, as well as some copper, lead, and zinc.
3	Unnamed[1] prospect (silver).	Quartz vein 0.8 ft wide and about 220 ft long, in granodiorite.	Three prospect pits------------	One chip sample across vein contains 3 oz of silver per ton. Two grab samples contain 0.1 and 1.7 oz of silver per ton.
4	Bentz mine[1] (molybdenum and silver).	Molybdenite-bearing quartz veins in widely separated shear zones and fractures; veins as much as 1.5 ft wide and 40 ft long within 370-ft-wide zone.	Two adits, 40 ft and 80 ft long	Thirteen samples: six samples contain 0.01-0.23 percent molybdenum; five samples contain 0.9-1.7 oz of silver per ton.
5	Ross Fork Rock Creek placer (gold).	Stream gravel, sand, silt, and reworked glacial deposits.	None----------------------------	Twenty-two panned samples from along Ross Fork and its tributaries. One sample shows a trace of gold.
6	Green Goose-Moly Hogan prospect (copper).	Sulfide-bearing quartz vein 12 in. wide beneath a gabbroic sill 18 in. wide in upper member of Mount Shields Formation. Some mineralized rock may be stratabound.	A 35-ft-long adit and two pits	Six chip and two grab samples: copper content from 0.04 to 0.09 percent, except one chip sample that contains 0.38 percent copper.
7	Mosquito Basin placer (gold).	Sand and silt in remnant glacial bogs which formed behind lateral moraine.	Three shallow pits-------------	Three panned samples: no gold detected.

8	Todd prospect (gold).	Sulfide-bearing quartz vein, 1-12 in. wide, in upper Mount Shields Formation. Gold may be associated with pyrite in the vein.	A 23-ft-long adit, a 40-ft-long trench, and a pit.	Three chip samples across vein contain 0.01-0.05 oz of gold per ton. One sample from stockpile contains 0.26 oz of gold per ton.
9	Last Chance prospect (gold).	Dump and workings indicate several quartz veins at least 7 in. wide. Veins not exposed.	Two caved adits and six trenches.	Ten samples from dumps and stockpiles contain as much as 0.01 oz of gold per ton and 0.05 oz of silver per ton.
10	South Fork Rock Creek placer (gold).	Stream gravel, sand, silt, and reworked glacial deposits.	Two prospect pits--------------	Seven channel samples from four test pits. Eight panned samples from creeks. Gold present in one test pit.
11	Little Wonder prospect (gold).	Thin, sulfide-bearing quartz veins in granodiorite in east-trending shear zone as much as 22 ft wide and 300 ft long.	Caved adit about 50 ft long, a 15-ft-long adit, and two trenches.	Nine samples: two chip samples across vein contain 0.04-0.14 oz of gold per ton. One select sample contains 0.17 oz of gold per ton.
12	Unnamed prospect.	Thin quartz vein in granodiorite.	Two prospect pits--------------	Four grab samples from dumps and stockpiles. Only traces of metals.
13	T. M. T. prospect (gold, silver, and lead).	Two quartz veins 1-10 in. wide.	Two prospect pits--------------	Three chip and five grab samples contain as much as 0.04 oz of gold per ton, 1.2 oz of silver per ton, and 0.43 percent lead.
14	Millers mine (gold, silver, copper, lead, and zinc).	Sulfide-bearing quartz veins in shear zones in granodiorite. Veins vary from a fraction of an inch to, reportedly, 9 ft wide. Veins explored for 400 ft.	Workings flooded or caved. Extensive main workings on Miller vein. Numerous other small workings adjacent to claim group. Production from veins between 1929-37 and 80 tons of dump material in 1968: 817 oz of gold, 4,145 oz of silver, 2,177 lb of copper, 76,436 lb of lead, and 22,397 lb of zinc.	Resources not determined for main Miller vein. Fifty-three samples collected from dumps, stockpiles, and other veins. One dump contains about 6,200 tons that average 0.05 oz of gold per ton and 0.37 oz of silver per ton, and other dump contains 490 tons that average 0.03 oz of gold per ton and 0.26 oz of silver per ton. Dumps also contain 0.5-1.0 percent lead and zinc combined.

TABLE 2.--Summary of mines and prospects in the Sapphire Wilderness Study Area and contiguous roadless areas, Granite and Ravalli Counties, Mont.--Continued

No. in fig. 4	Name (commodity)	Geologic or Geomorphic setting	Workings and production	Sample data and resources of mines and prospects
15	Townsend prospect (gold).	One or more thin sulfide-bearing quartz veins in granodiorite. Veins not exposed.	Two flooded shafts, 20 pits and trenches.	Nine grab samples and two select samples: select samples contain 0.02-0.03 oz of gold per ton, and minor silver, lead, and copper; and one grab sample of dump material contains 0.01 oz of gold per ton.
16	Log Cabin prospect (silver).	Sulfide-bearing quartz veins in shear zone in granodiorite and Wallace Formation. Veins not exposed.	Five caved shafts having about 580 ft of workings and 11 pits or trenches occur along quartz veins and shear zones.	Sixteen samples of dump and stockpile material: four samples of quartz veins from stockpiles along main vein in granitic rock average 15 oz of silver per ton.
17	Lutz Creek (a.k.a. Gold Bar/Agnes/Townsend) placer (gold).	Northeastern part Frogpond Basin.	Two trenches, 15 ft and 50 ft long; possibly site of former small-scale mining.	Samples outline gold-bearing placer 6-10 ft deep, about 1,000 ft long, and 50-300 ft wide. Weighted average gold content (from surface to bottom of excavation) is about 0.005 oz of gold per cubic yard.
18	Nancy Lee prospect (gold).	Sulfide-bearing quartz vein at least 750 ft long and as much as 16 in. wide. Vein not exposed.	Three shafts 6-12 ft deep, and five small pits and trenches.	Ten samples from dumps contain as much as 0.02 oz of gold per ton. One select sample from easternmost pit contains 0.05 oz of gold per ton.
19	Ohio prospect (unknown).	East-trending quartz veins and lenses in shear zone in granodiorite.	Thirteen pits and trenches-----	Eleven samples: only traces of metals.
20	Mayflower prospect (unknown).	Weathered, sheared, limonite-stained granodiorite.	One shallow pit----------------	One sample: only traces of metals.
21	Airedale prospect (unknown).	Two parallel, sulfide-bearing shear zones 10 ft apart and 0.9-3 ft wide. Contain quartz blebs, limonite-stained gouge, and disseminated limonite.	One adit 30 ft long and a 10-ft-deep shaft.	Four samples: only traces of metals.
22	Indiana prospect (unknown).	Altered granodiorite---------	Two trenches 13 ft and 20 ft long.	Two grab samples: only traces of metals.

23	Heaney mine (a.k.a. Frog-pond lode) (Gold).	Sulfide-bearing quartz vein 1 ft wide and 500 ft long. Vein not exposed.	Caved shaft, a 25-ft-long cut and three trenches. Five tons of ore shipped in 1937 yielded 2 oz of gold, 9 oz of silver, and 367 lb of lead.	Ten samples: two select samples of stockpiles range from 0.10 to 0.14 oz of gold per ton and 0.10 to 1.5 oz of silver per ton. Select sample of quartz from cut contains 0.03 oz of gold per ton.
24	Montana Prince claim group (gold, silver, lead, and zinc).	Several parallel sulfide-bearing quartz veins in shear zones in granodiorite. Veins vary from a few inches to 9 ft wide, and one may extend 1,000 ft in length.	Main adit reported to have 1,500 ft of workings that crosscut five veins. Also a caved shaft reported to be 62 ft deep and a 32-ft-long crosscut; a caved shaft reported to be 75 ft deep and a caved adit about 35 ft long. Thirty-two other pits and trenches scattered in claim group.	Thirty-four samples from dumps, but high values of metals from only two claims: (1) Thor claim contains 0.37 oz of gold per ton; and (2) Montana Prince claim contains 0.15 oz of gold per ton. Assays reported in 1925 from veins in the main adit average 0.19 oz of gold per ton, 2.0-20 oz of silver per ton, 1.0-2.0 percent lead, and 2.0-6.0 percent zinc.
25	J. P. prospect (gold, silver).	Several 1.0-in.-wide quartz veins in 2.0-ft-wide shear zone in middle of Mount Shields Formation.	Ten-foot-long shaft and two trenches.	Three samples: only traces of metals.
26	Tuscarora prospect (gold, silver).	Small zones of altered granodiorite cut by two limonite-stained shear zones 1-12 in. wide.	Two shafts, 10 and 18 ft long; a vertical shaft 10 ft deep; seven trenches and six pits.	Nine samples: a select sample and grab sample contain 0.06 and 0.02 oz of gold per ton, and 1.8 and 0.1 oz of silver per ton.
27	Lutz mine (a.k.a. Gold Leaf mine) (gold, silver, and lead).	Two main sulfide-bearing quartz veins; south vein 0.2-0.3 ft wide and may extend 920 ft; north vein not exposed.	South vein exposed by two adits, 12 pits and trenches. Lower adit caved at 700 ft; upper adit 875 ft long. North vein has five shafts 15-30 ft deep, 14 pits and trenches, and 1 adit. Ore shipments from 1910-40 totaled 34 tons of ore that yielded 50 oz of gold, 197.5 oz of silver, 232 lb of copper, and 6,912 lb of lead.	The south vein contains identified resources of 92,000 tons containing 0.06 oz of gold per ton, 0.43 oz of silver per ton, and 0.31 percent lead. The ore minerals occur in shoots of 350-10,000 tons with moderate continuity downdip but only several feet along strike. Likelihood is high for similar tonnage and grade for north vein. Stockpiles total approximately 10 tons containing 0.13 oz of gold per ton and 0.58 oz of silver per ton.

TABLE 2.--Summary of mines and prospects in the Sapphire Wilderness Study Area and contiguous roadless areas, Granite and Ravalli Counties, Mont.--Continued

No. in fig. 4	Name (commodity)	Geologic or Geomorphic setting	Workings and production	Sample data and resources of mines and prospects
28	O'Brien prospects (silver and gold).	Several sulfide-bearing quartz veins in shear zones in Mount Shields Formation near contact with granodiorite. Exposed shear zone is 2.7 ft wide and contains a 0.5-ft-wide quartz vein.	Numerous small workings in area of about 2,400 ft long and 1,200 ft wide.	One chip sample across vein in adit contains 5.2 oz of silver per ton and 0.1 oz of gold per ton. A sample from a 1-ton stockpile contains 0.05 oz gold per ton and 48.9 oz silver per ton. Many samples contain lead, copper, and zinc.
29	Joker prospect (silver?).	Quartz veins and stringers in altered granodiorite and Mount Shields Formation. No veins exposed.	Three trenches and five pits--	Five samples: one sample of quartz vein in stockpile contains 0.7 oz of silver per ton.
30	Unnamed prospect (unknown).	Dumps contain altered granodiorite and vein-quartz fragments. No veins exposed.	Six trenches and three pits---	Twelve grab and select samples: only traces of metals.
31	Unnamed prospect (gold and silver?).	Workings along 280-ft zone. Fragments of quartz and altered granodiorite contain pyrite and galena. No veins exposed.	Three trenches and four pits--	Four select samples from dumps: one sample contains 0.02 oz of gold per ton and 0.4 oz silver per ton.
32	Unnamed prospect (gold and silver?).	Thin quartz veins in altered Mount Shields Formation. No veins exposed.	Caved shaft estimated to be 40 ft deep, 1 trench, and 11 pits.	Fifteen grab and select samples of dumps and stockpiles: two grab samples contain 0.4 and 2.2 oz of silver per ton. A select sample contains 0.01 oz of gold per ton, 2.8 oz of silver per ton, and 0.05 percent molybdenum.
33	Unnamed prospect (unknown).	Mount Shields Formation------	One trench on top of ridge----	One sample: only a trace of metals.
34	Unnamed prospect (gold and silver).	Sulfide-bearing quartz vein 3.5 ft wide in granodiorite.	Two caved adits 100 ft apart. Upper adit at least 80 ft long; lower adit may be 200-300 ft long.	Four samples: one select sample contains as much as 0.01 oz of gold per ton, 1.7 oz of silver per ton, and 0.09 percent copper.

35	Banner mine[1] (gold, silver, and copper).	Sulfide-bearing quartz veins 4-9 ft wide.	Flooded and caved shaft at least 240 ft deep with lateral workings at 138-ft and 225-ft levels. Production records from 1921 to 1936 and 1962 to 1975 show total recorded production of 1,979 oz of gold, 5,896 oz of silver, and 20,935 lb of copper.	No samples taken. All workings inaccessible.
36	Copper Creek placer (gold).	Reworked glacial deposits in streambed and terraces.	None--------------------------	Twelve channel samples from six pits and twenty panned samples contain traces of gold.
37	Rainbow prospect (gold).	Two prospects: (1) gold prospect in quartz vein about 17 in. wide, in quartzite; (2) gold and quartz-crystal prospect is 600 ft north of first prospect.	Gold prospect has caved adit 30 ft long. Gold and quartz-crystal prospect has trenches.	Two chip samples across vein average 0.09 oz of gold per ton. A select sample from stockpile contains 0.01 oz of gold per ton.
38	Senate mine[1] (copper and silver).	Sulfide-bearing veins along common shear zones; disseminated sulfide minerals occur in carbonate-bearing replacement zones in Mount Shields Formation quartzite.	Workings total about 900 ft of drifts, crosscuts, and winzes. About 3,500 ft of diamond core drilling. Production of small tonnages in the 1890's.	Stentz (1975, p. 14) reported that "mineralization may have been peripheral to a series of small deep-seated 5-20 million ton ore bodies." Drill intercepts gave the highest values of 0.44 percent copper.

[1]Mines or prospects located outside of study area.

TABLE 3.--Criteria and rating of potential for occurrence of resources in the Sapphire Wilderness Study Area and contiguous roadless areas, Granite and Ravalli Counties, Mont.

I. Mesothermal veins and replacement zones

Criteria	Rating
a. Presence of an identified resource that contains commodity elements such as gold, silver, lead, copper, zinc, molybdenum, or tungsten. Metal-bearing veins and replacement bodies are known to occur in mines and prospects, and production from mines may be recorded.	
b. Presence of zones of alteration, shear, or replacement of original rock, which commonly contain sulfide-bearing quartz veins or disseminated sulfide minerals; or known occurrence of metal-bearing veins.	High potential: Must satisfy criteria a and b, and usually satisfies criteria c, d, e, and f.
c. Presence of host rocks favorable for fracturing that would permit access by mineralizing solutions or favorable for replacement by mineralizing solutions.	
d. Geochemical identification of anomalously high amounts of commodity elements, as well as pathfinder elements, such as arsenic, tin, antimony, bismuth, cadmium, nickel, or cobalt, in veins, replacement bodies, or in samples from streams that drain a mineralized area.	
e. Presence of a contact zone between plutonic rocks and sedimentary rocks.	Moderate potential: Must satisfy criteria b, d, and g, and usually satisfies criteria c, e, and f.
f. Favorable setting for mineralization suggested by interpretation of geophysical data. Such a setting could include areas of relatively lower gravity that may be related to areas of alteration in plutonic rocks, or areas of relatively high magnetic intensity that may be related to exposed or buried intrusive rocks.	
g. Possible occurrence of small bodies of resources. Scattered prospects may be present, but mines and prospects showing extensive development are absent.	
h. Possible occurrence of prospects in area, but resources not known to occur.	Low potential: Must satisfy criteria h, i, and j, and usually satisfies criteria e and f.
i. Possible occurrence of zones of alteration, brecciation, or replacement of original rock, which may contain metalliferous veins or possible occurrence of small veins.	
j. Geochemical identification of low, but anomalous, amounts of some commodity elements and of a few pathfinder elements, such as arsenic, tin, antimony, bismuth, tungsten, cadmium, nickel, and cobalt, in rocks or in stream sediments.	

II. Placers

Criteria	Rating
a. Presence of identified resource in surficial deposits. Placer mines or prospects may have recorded production of gold, and may contain concentrations of silver, lead, copper, zinc, tungsten, tin, or rare-earth elements.	High potential: Must satisfy criteria a, b, c, and e, and may satisfy criteria d and f.
b. Geochemical identification of gold and some other elements, such as silver, lead, copper, zinc, or tungsten, above threshold values, as well as pathfinder elements such as arsenic, tin, thorium, antimony, bismuth, cadmium, nickel, or cobalt in surficial deposits, which may be related to metalliferous veins or disseminated deposits upstream.	
c. Probable or known occurrence of metalliferous veins, replacement bodies, or disseminated mineral occurrences upstream from area.	Moderate potential: Must satisfy criteria b and c, and may satisfy criteria d, e, and f.
d. Possible presence of scattered prospects in area, but no identified resources in most of area.	
e. Presence of visible gold and heavy minerals in panned-concentrate samples from surficial deposits.	Low potential: Must satisfy criteria d and f, and may satisfy criterion c.
f. Geochemical identification of low concentrations of gold or a few pathfinder elements near, or slightly below, threshold values in panned-concentrate or stream-sediment samples, which may suggest the presence of metalliferous veins upstream from area.	

III. Disseminated rare-earth elements in plutonic rocks	
Criteria	**Rating**
a. Presence of rocks known to contain rare-earth-bearing minerals such as allanite. b. Geochemical identification of anomalously high amounts of elements such as vanadium, scandium, cobalt, yttrium, lanthanum, thorium, tin, zirconium, titanium, or niobium in rock samples or in deposits of streams that drain the rock body. c. Presence of a contact zone between plutonic rocks and sedimentary rocks in or close to area. d. Favorable setting for plutonic rocks suggested by interpretation of aeromagnetic data, such as a relatively high magnetic intensity that may be related to intrusive rocks.	Low potential: Must satisfy criteria a, b, c, and d.

IV. Miscellaneous possible replacement, vein, and disseminated resources	
Criteria	**Rating**
a. Presence of favorable rocks, such as gabbro or pegmatite, that may contain disseminated metals such as gold, silver, copper, zinc, or titanium in low concentration. b. Geochemical identification of anomalous, but low, amounts of gold, silver, copper, zinc, titanium, or rare-earth elements in rock samples. c. Presence of host rocks favorable for fracturing that would permit access by mineralizing solutions or favorable for replacement by mineralizing solutions. d. Favorable setting for plutonic rocks suggested by interpretation of aeromagnetic data, such as a relatively high magnetic intensity.	Low potential: Must satisfy criteria b and c, and may satisfy criteria a and d.

TABLE 4.--Summary and rating of areas of potential resource occurrence, Sapphire Wilderness Study Area and contiguous roadless areas, Granite and Ravalli Counties, Mont.

[Au, gold; Ag, silver, Cd, cadmium; Co, cobalt; Cu, copper; La, lanthanum; Mo, molybdenum; Nb, niobium; Pb, lead; Sb, antimony; Sn, tin; Th, thorium; Ti, titanium; V, vanadium; W, tungsten; Y, yttrium; Zn, zinc]

Area No. in fig. 5	Location	Commodity elements	Type of occurrence	Criteria for rating	Estimate of size and grade of deposits	Mineral resource potential
				Mesothermal veins		
1	Frogpond Basin, T. 3 N., R. 16 and 17 W.	Au, Ag, Cu, Pb, Zn, W.	Sulfide-bearing quartz veins and lenses along fractures, joints, and shear zones in granodiorite and in sheared rocks of the Missoula Group. Sulfide minerals are disseminated in altered host rock.	In area of Millers, Montana Prince, and Lutz mines: I. a, b, c, d, e, f.	Small deposits of probable moderate or high grade.	High
				In area peripheral to above mines that contains numerous prospects: I. b, c, d, e, f, g.	Small deposits, grade not estimated.	Moderate
				Headwaters of Sign Creek and on ridges west and east of Sign Creek: I. e, f, h, i, j.	Possible small deposits, probable low grade.	Low
				Placers		
		Au-------	Stream deposits in Moose, Cuba, Sign, and Lutz Creeks, an unnamed tributary north of Cuba Creek, and an unnamed tributary to Copper Creek may contain placers. Because streams drain glacial deposits that may contain gold; till, outwash, and modern stream channels are considered possible placers. Frogpond Basin has similar deposits that may contain gold.	Lutz Creek and part of Frogpond Basin: II. a, b, c, d, e.	Extent of deposit not known, probable low grade with some zones of moderate grade.	High
				Other surficial deposits in Frogpond Basin: II. b, c, d, e.	Extent of deposits not known, grade not estimated.	Moderate
				Moose Creek: II. b, c, d, e, f.	---------------do.------------	Do.
				Cuba Creek: II. b, c, d, e.	---------------do.------------	Do.
				Unnamed tributary north of Cuba Creek: II. b, c, d, e.	---------------do.------------	Do.
				Sign Creek: II. d, f.	Extent of deposit not known, probable low grade.	Low
				Unnamed tributary to Copper Creek: II. d, f.	Extent of deposit not known, grade not estimated.	Low
				Mesothermal veins and replacement bodies		
2	Senate Mountain area and Middle Fork of Rock Creek, secs. 12, 13, 14, 23, and 24, T. 3 N., R. 6 W.	Cu, Au, Ag, Pb.	Sulfide-bearing quartz veins and lenses in fracture zones in Mount Shields quartzite. Replacement of quartzite by sulfide and carbonate minerals in lenses and pods in quartzite. Mineralization in veins localized by many shear zones, which may also have controlled location of replacement zones.	In area of Senate mine and Ivanhoe Lake: I. a, b, c, d.	Extent of deposits not known. Probable low grade.	High
				On ridges west and north of Senate mine and south to Ivanhoe Lake: I. b, c, d, g.	Extent of deposits not known; grade not known.	Moderate

				Placers		
		Au-------	Stream deposits in two unnamed tributaries to Middle Fork of Rock Creek that drain east from Senate mine area and from cirque north of the mine area contain possible placers, as does the Middle Fork of Rock Creek below confluence of these tributaries.	In two unnamed tributaries that drain east from Senate mine and from cirque directly north of Senate mine area, and in Middle Fork of Rock Creek below confluence of tributaries: II. b, c, d.	Possible small deposits of probable low grade.	Moderate
				Mesothermal veins		
3	Meyers Creek, sec. 15, T. 3 N., R. 16 W.	Au, Ag, Cu, Mo.	Sulfide-bearing vein along bedding plane parallel to shear zones in quartzite. Effects of alteration or replacement of host rock absent.	In area of developed Rainbow prospect along Meyers Creek: I. a, b, c, d.	Possible small deposit, grade not estimated.	High
				Placers		
		Au-------	Stream deposits in Meyers Creek and an unnamed tributary to Meyers Creek below Rainbow prospect contain visible gold in panned concentrates. Because gold may be present in some till, parts of glacial deposits are considered possible placers. Vein at Rainbow prospect probable source of gold in placers.	In upper Meyers Creek and in unnamed tributary below developed prospect: II. b, c, d, e.	Possible small deposit. of probable low grade.	Moderate
				In lower Meyers Creek downstream from area of moderate potential: II. d, e, f.	Possible small deposit of probable low grade.	Low
				Mesothermal veins		
4	Middle Fork of Rock Creek, sec. 36, T. 4 N., R. 16 W.	Au, Ag, Cu.	Sulfide- and limonite-bearing quartz veins in quartzite.	At Banner mine and area surrounding mine: I. a, b, c, d, f.	Possible small deposit, grade not estimated.	High

TABLE 4.--Summary and rating of areas of potential resource occurrence, Sapphire Wilderness Study Area and contiguous roadless areas, Granite and Ravalli Counties, Mont.--Continued

[Au, gold; Ag, silver, Cd, cadmium; Co, cobalt; Cu, copper; La, lanthanum; Mo, molybdenum; Nb, niobium; Pb, lead; Sb, antimony; Sn, tin; Th, thorium; Ti, titanium; V, vanadium; W, tungsten; Y, yttrium; Zn, zinc]

Area No. in fig. 5	Location	Commodity elements	Type of occurrence	Criteria for rating	Estimate of size and grade of deposits	Mineral resource potential
				Mesothermal veins		
5	Ross Fork of Rock Creek, sec. 5, T. 4 N., R. 16 W.	Mo, W, Ag.	Sulfide-bearing quartz veins cut granodiorite near contact with sedimentary rocks. Veins occur along shear zones but do not extend into sedimentary rocks.	In area of Bentz mine: I. a, b, c, d, e, f.	Small vein deposit, full extent of veins not known; grade not known.	High
				Mesothermal veins		
6	South Fork of Rock Creek (land grid absent).	Au, Ag, Pb, Zn.	Sulfide-bearing quartz veins along shear zones(?) and fractures in granodiorite. Extent of alteration of intrusive rock not known.	In area of prospects along South Fork of Rock Creek: I. b, c, d, f, g.	Small vein deposits. Extent of veins not known, grade not estimated.	Moderate
				Placers		
		Au--------	Several panned-concentrate samples of stream deposits contain gold. Glacial deposits considered as possible placers because modern streams drain till and because till may have been transported north into the South Fork of Rock Creek from Frogpond Basin. Source of gold may be local veins in South Fork drainage basin or in Frogpond Basin.	In drainage basin of South Fork of Rock Creek: II. b, c, d.	Possible small deposits of low grade.	Moderate
				Mesothermal veins		
7	Point Lookout area, about 0.5 mi east of Medicine Lake (land grid absent).	Au, Ag, Pb, Zn.	Sulfide-bearing quartz veins. Main vein at Kent mine occurs along a shear in granodiorite.	In area of Kent mine: I. a, b, c, d, f. East of Kent mine near prospect 3 (fig. 4 and table 3): I. f, h, i, j.	Small deposits of probable moderate to high grade. Possible small deposits, probable low grade.	High Low

			Mesothermal veins			
8	Green Canyon Creek, Green Canyon Lake, and ridge to southwest above Green Canyon Lake, secs. 31, 32, and 33, T. 4 N., R. 16 W.	Au, Zn---	No sulfide-bearing quartz veins known. Presence of zinc and cadmium suggests genetic relation to mesothermal veins in Frogpond Basin.	On ridge above Green Canyon Lake: I. f, h, i, j.	Possible small vein deposits, grade probably low.	Low
			Placers			
		Au--------	Stream deposits contain anomalous concentrations of gold and cobalt. Glacial deposits considered as possible placers because modern streams drain till and because glacial deposits may have been transported from the Frogpond Basin into Green Canyon drainage basin.	In Green Canyon downstream from cirque basin: II. d, f.	Possible small deposits, grade not estimated.	Low
			Miscellaneous occurrences			
9	In saddle about 0.5 mi southwest of Congdon Peak, and along Skalkaho Creek and Ross Creek (land grid absent).	Au, Co, Mo.	Sulfide minerals occur near contact of gabbro dike and possibly as disseminated sulfide in Mount Shields quartzite. Veins rare.	In area southwest of Congdon Peak: IV. a, b, c.	Probable small vein or stratiform body; grade probably low.	Low

TABLE 4.--Summary and rating of areas of potential resource occurrence, Sapphire Wilderness Study Area and contiguous roadless areas, Granite and Ravalli Counties, Mont.--Continued

[Au, gold; Ag, silver, Cd, cadmium; Co, cobalt; Cu, copper; La, lanthanum; Mo, molybdenum; Nb, niobium; Pb, lead; Sb, antimony; Sn, tin; Th, thorium; Ti, titanium; V, vanadium; W, tungsten; Y, yttrium; Zn, zinc]

Area No. in fig. 5	Location	Commodity elements	Type of occurrence	Criteria for rating	Estimate of size and grade of deposits	Mineral resource potential
				Placers		
9	In saddle about 0.5 mi southwest of Congdon Peak, and along Skalkaho Creek and Ross Creek (land grid absent).	Au--------	Stream deposits of upper Skalkaho Creek and Ross Fork contain visible gold or contain gold above threshold concentration at several localities. Glacial deposits considered as possible placers because modern streams drain till. Several sources of gold possible: (1) vein or disseminated minerals southwest of Congdon Peak (prospect 6, fig. 4 and table 3); (2) Kent mine (area 7); and (3) mesothermal veins in South Fork of Rock Creek (area 6).	In upper drainage basin of Skalkaho Creek: II. c, d, f. Along Ross Fork of Rock Creek: II. b, c, d, e, f.	Possible small deposits, probable low grade. Possible small deposits, probable low grade.	Low Moderate
				Disseminated rare-earth and related elements		
10	West side of north part of Sapphire batholith along topographic divide from Ross Fork on the south to headwaters of Bowles Creek. Includes tributaries to West Fork of Rock Creek.	Au, La, Nb, Y, V, Sn, Th.	Allanite, sphene, epidote, and zircon accessory minerals in granodiorite on west border of the Sapphire batholith. Allanite is most likely origin of rare-earth and associated elements. Late-crystallizing melt may have penetrated sedimentary rocks along the border of pluton.	West side of northern part of Sapphite batholith: III. a, b, c, d.	Possible large disseminated deposit of very low grade.	Low

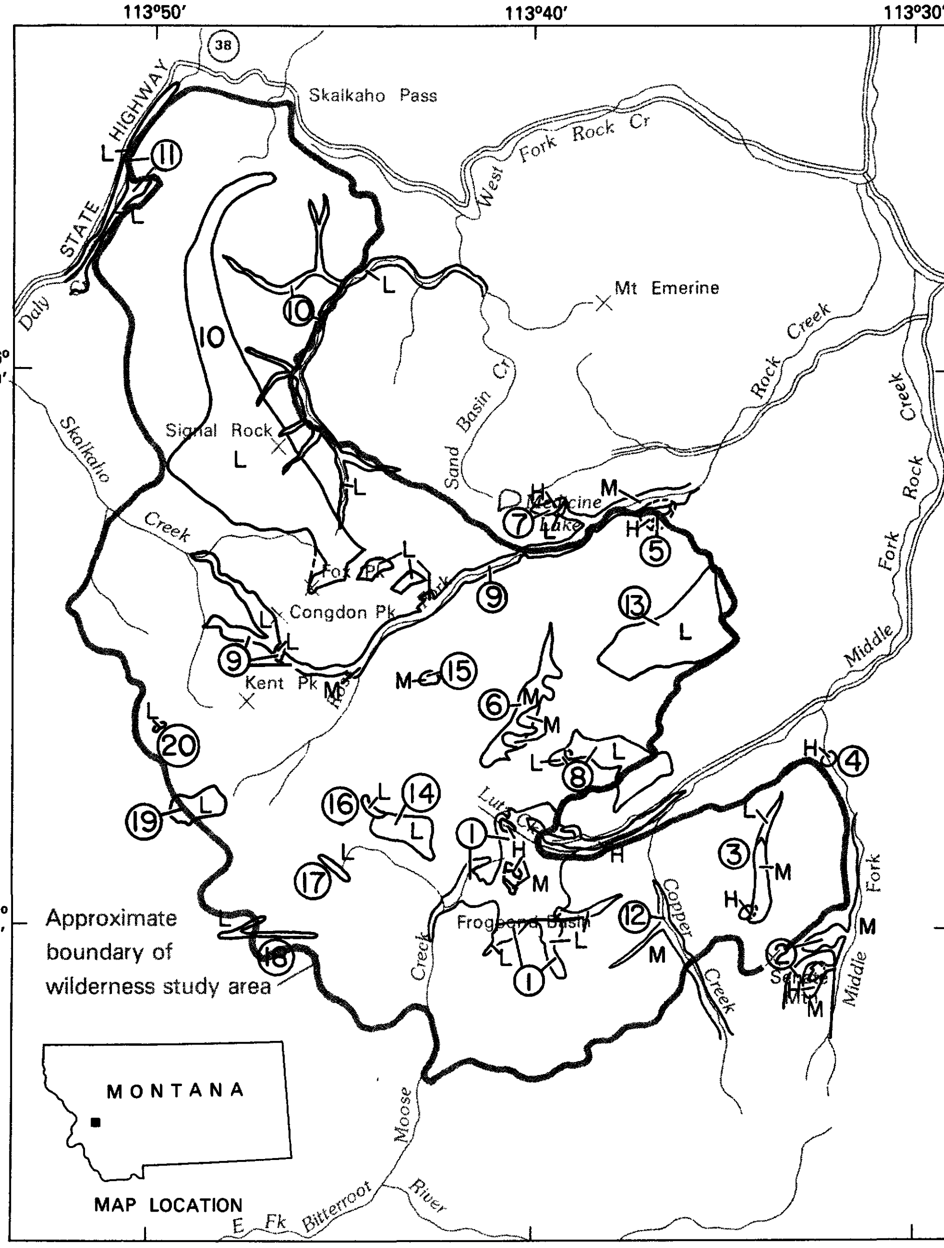
				Placers		
		Au, Sn, Th.	Streams that drain rare-earth-bearing rocks contain anomalous concentrations of tin, thorium, and gold. Tin, thorium, and gold probably derived from accessory minerals or small veins in granodiorite.	West Fork of Rock Creek, Bowles Creek, and unnamed tributaries west of West Fork of Rock Creek: II. c, d, f.	Possible small deposits of probable low grade.	Low
				Mesothermal(?) veins		
11	Daly Creek between Falls Creek on east and Skalkaho Creek on south.	Au, Ag, Pb, W.	No mesothermal sulfide-bearing veins located, but geochemical signature in placers and in rock samples suggests their presence. Zones of shear and alteration occur in canyon of Daly Creek.	In rocks exposed in Daly Creek: I. h, i, j.	No known deposits; possible low-grade veins.	Low
				Placers		
		Au, Cu, Ni, Co.	Stream deposits of Daly Creek contain slightly anomalous concentrations of gold, copper, nickel, and cobalt, which may originate from gabbro dikes and plugs. Slightly anomalous concentrations of gold, silver, lead, tungsten, antimony, and zinc may originate from unknown mesothermal veins.	In stream sediment in Daly Creek: II. c, d, f.	Possible small deposit of probable low-grade.	Low
				Placers		
12	Copper Creek, secs. 17, 21, 28, and 34, T. 3 N., R. 16 W.	Au, Ag, Pb.	Stream sediments contain anomalous concentrations of commodity elements and some pathfinder elements. Glacial deposits are considered as possible placers because modern streams drain till. Mesothermal veins and replacement bodies occur upstream.	In stream sediments of Copper Creek: II. b, c, d.	Possible small deposits of probable low-grade.	Moderate

TABLE 4.--Summary and rating of areas of potential resource occurrence, Sapphire Wilderness Study Area and contiguous roadless areas, Granite and Ravalli Counties, Mont.--Continued

[Au, gold; Ag, silver, Cd, cadmium; Co, cobalt; Cu, copper; La, lanthanum; Mo, molybdenum; Nb, niobium; Pb, lead; Sb, antimony; Sn, tin; Th, thorium; Ti, titanium; V, vanadium; W, tungsten; Y, yttrium; Zn, zinc]

Area No. in fig. 5	Location	Commodity elements	Type of occurrence	Criteria for rating	Estimate of size and grade of deposits	Mineral resource potential
				Mesothermal veins		
13	Area upstream from Zekes Meadows along tributary to Ross Fork, secs. 9 and 14, T. 4 N., R. 16 W.	Cu, Zn, Sb.	Stream sediments contain small, but anomalously high, concentrations of copper, zinc, and antimony that may be related to sulfide-bearing veins in rocks upstream. Veins were not found.	In rocks in drainage basin upstream from stream sediments in Zekes Meadows area: I. h, i, j.	Possible small veins, grade not known.	Low
				Mesothermal(?) veins		
14	Area upstream from unnamed tributary to Moose Creek about 1.5 mi west of Frogpond Basin, T. 3 N., R. 17 W.	Ag, Cu, Co, Cd.	Stream sediments contain small, but anomalously high, concentrations of silver, copper, cobalt, and cadmium that may be related to sulfide-bearing veins in rocks upstream. Veins were not found.	In rock in drainage basin upstream from stream sediments of Moose Creek near Frogpond Basin: I. h, i, j.	Possible small veins of low grade.	Low
				Mesothermal(?) veins		
15	East side of Table Mountain (land grid absent).	Au, Ag, W.	Sparse sulfide-bearing veins exposed in prospects in quartzite of Mount Shields Formation near contact with porphyritic granodiorite. Veins show brecciation and country rock sheared at some places.	Area of prospects on east side of Table Mountain: I. b, c, d, e, f, g.	Probable small deposits, grade not estimated.	Moderate
				Miscellaneous occurrence		
16	On ridge about 0.75 mi southeast of Bare Hill, sec. 4, T. 3 N., R. 17 W.	Y, La----	Rock samples of metamorphosed Mount Shield and Wallace Formations had low, but anomalous, concentrations of yttrium, lanthanum, and strontium. Source of high anomaly not known.	Rock samples from metamorphosed Mount Shields and Wallace Formations: IV. b, c.	No known deposit. Grade not known.	Low

		Miscellaneous occurrence				
17	On ridge above Snow, Legend, and Spud Lakes, secs. 17 and 18, T. 3 N., R. 17 W.	Pb, Mo---	Rock samples of metamorphosed Wallace Formation contain slightly anomalous concentrations of lead and molybdenum. Source of anomaly not known.	Rock samples from metamorphosed Wallace Formation: IV. b, c	Probable low grade -----------	Low
		Miscellaneous occurrence				
18	North of Martin Creek, sec. 19, T. 3 N., R. 17 W., and sec. 24, T. 3 N., R. 18 W.	Ag, Cu---	Pegmatite dike and gabbro dikes. No sulfide-quartz veins known.	In area of dikes: IV. a, b, c	Probable low grade-----------	Low
		Possible mesothermal veins				
19	Head of Sleeping Child Creek, secs. 3 and 10, T. 3 N., R. 18 W.	Zn-------	Origin of high anomaly from rock samples not known. May result from sulfide-bearing quartz veins.	In headwaters of Sleeping Child Creek: IV. b, c.	Possible small veins ---------	Low
		Miscellaneous occurrence				
20	On ridge about 1.3 mi west of Kent Lake.	Cu, Ti---	Dike about 3 ft wide cuts quartzite of Mount Shields Formation. No altered or mineralized rock at surface.	On ridge: IV. a, b, c --------	Possible small disseminated deposit, probable low grade.	Low



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MILES

EXPLANATION

H High potential for the occurrence of a resource

M Moderate potential for the occurrence of a resource

L Low potential for the occurrence of a resource

(8) Area of resource potential described in table 5 and in text. Boundaries are approximate; dashed where inferred to exist below surficial deposits

Figure 5.--Map showing areas having potential for the occurrence of resources, Sapphire Wilderness Study Area and contiguous roadless areas, Granite and Ravalli Counties, Mont. Summary and ratings of potential for resource occurrence given in table 4.

Frogpond Basin, yielded gold at 2.18 ppm (AA) from a single panned-concentrate sample. Although an isolated high concentration such as this is not significant by itself, gold may have been transported with till from Frogpond Basin into this tributary to Copper Creek; this tributary has a low potential for the occurrence of gold resources in placers for which the extent and grade are not known.

Meyers Creek (area 3) has a moderate potential for occurrence of gold resources in small, and possibly low-grade, placers near the Rainbow prospect and a low potential for the occurrence of a gold resource in small, low-grade placers in lower Meyers Creek. Gold concentrations range between 0.2 ppm (AA) and 2.91 ppm (AA); visible gold is present in concentrates collected from the stream below the Rainbow prospect. The source of the gold appears to be veins of the Rainbow prospect.

The Middle Fork of Rock Creek (area 2) and Copper Creek (area 12, prospect 36) may have a moderate potential for gold resources in small, and possibly low-grade, placers. Both streams yielded gold from panned concentrates; in the Middle Fork gold concentrations range between 0.2 ppm (AA) and 5.03 ppm (AA), whereas in Copper Creek gold concentrations range between 0.2 ppm (AA) and 2.76 ppm (AA). Presumably, the gold in these streams was derived from the area of the Senate mine.

Gold concentrations in panned concentrates from the South Fork of Rock Creek (area 6) range between 0.2 ppm (AA) and 0.45 ppm (AA); the area has a moderate potential for the occurrence of small, low-grade, gold resources in stream deposits. One placer prospect (prospect 10) is present in this drainage basin; the source of the gold may be nearby veins or Frogpond Basin, from which gold could have been transported with till.

Green Canyon Creek (area 8) has a low potential for the occurrence of gold resources in small deposits for which no grade is determined, based on a single gold anomaly of 0.75 ppm (AA). A vein source above Green Canyon Lake could have produced the gold anomaly, or gold could have been transported from Frogpond Basin with till.

Skalkaho Creek (area 9) has a low potential for the occurrence of low-grade gold resources in placers, based on a single anomalous value of gold of 0.23 ppm (AA). The upper part of Ross Fork (area 9) has a moderate potential for occurrence of gold resources in small, low-grade placers; gold concentrations range between 0.2 ppm (AA) and 6.7 ppm (AA). A trace of gold in prospect 5 may have been derived from sulfide-bearing veins that occur southwest of Congdon Peak. In the lower part of Ross Fork (area 9), gold detected in panned concentrates may have been derived from veins in area 7 near the Kent mine.

In the West Fork of Rock Creek and in Bowles Creek (area 10), gold concentrations range between 0.11 ppm (AA) and 0.74 ppm (AA). Daly Creek (area 11) contains isolated, anomalously high concentrations of gold that range from 0.1 ppm (AA) to 2.02 ppm (AA). Areas 10 and 11 have a low potential for the occurrence of gold resources in small, low-grade placers.

Potential for the occurrence of copper resources in mesothermal veins and replacement bodies

Identified and potential copper resources occur in veins and in replacement zones at several places, and several mines have produced small amounts of copper. The Senate mine (area 2) has mineralized zones, samples from which yielded copper concentrations as high as 26,000 ppm (AA). Estimates by the U.S. Bureau of Mines suggest that mineralized rock from the upper adit of the Senate mine averages 2 percent copper, and mineralized rock from the lower adit averages 1 percent copper. The Bear Creek Mining Co. studied the Senate mine from 1958 to 1962 to determine its potential as a large, low-grade copper deposit, and the company apparently located a small body of rock that had 0.44 percent copper (Stentz, 1975, p. 14). Area 2 has a high potential for the occurrence of low-grade copper resources in one or more zones.

Highly anomalous concentrations of copper are present on the divide southwest of Congdon Peak (area 9, prospect 6); the copper concentration in a rock sample from this area is 15,000 ppm (spec). Data for area 9 from the U.S. Bureau of Mines shows 0.04–0.38 percent copper. High copper concentrations appear to be restricted to a small area, in small and discontinuous veins and stratiform zones, and this area has a low potential for occurrence of a low-grade copper resource.

High copper anomalies occur in the Frogpond Basin region (area 1) and in the Middle Fork of Rock Creek (area 4); these anomalies range from 200 ppm (spec) to 2,000 ppm (spec). Copper concentrations and mine production records suggest that copper resources are small and of low grade in areas 1 and 4. Anomalous copper concentrations of 50–90 ppm (AA), which are at, or slightly above, threshold values, were determined for rock and stream-sediment samples from the South Fork of Rock Creek (area 6), from Daly Creek (area 11), from the West Fork of Rock Creek (area 10), and from the areas west of Kent Lake (area 20). These low concentrations signal a low potential for the occurrence of a small copper resource in these areas.

Potential for the occurrence of lead, zinc, and silver resources in mesothermal veins

Identified resources of lead, zinc, and silver are present in sulfide-bearing veins, and several areas have high and moderate potential for occurrence of lead, zinc, and silver resources. Silver has been produced from five mines, lead from four mines, and zinc from one mine. Veins in the Frogpond Basin region (area 1) contain the highest concentrations of lead (15,000 ppm, spec), zinc (>10,000 ppm, spec), and silver (300 ppm, spec). Estimates by the U.S. Bureau of Mines indicate that ore from the Millers mine may contain 1 percent lead, 1 percent zinc, and 0.66 oz of silver per ton. Similarly, estimates of averages of samples from two veins in the Lutz mine (area 1) suggest that the ore contains 1.1 percent lead, 0.14 percent zinc, and 1.5 oz of silver per ton. The areas of Millers, Montana Prince, and Lutz mines have a high potential for the occurrence of resources of moderate-grade lead, zinc, and silver in small deposits.

Many small prospects in Frogpond Basin

examined by the U.S. Bureau of Mines (prospects 16, 23, 24, 26, 28, 30, 31, 32, and 34) contain concentrations of silver that range between 0.1 and 49 oz per ton and contain traces of lead and zinc. These numerous prospects are peripheral to the above mines and outline an area of moderate potential for the occurrence of lead, zinc, and silver resources of unknown grade in small deposits.

Veins along the South Fork of Rock Creek (area 6) show high concentrations of lead (10,000 ppm, spec), but relatively lower concentrations of zinc (30 ppm, AA) and silver (30 ppm, spec). Sampling by the U.S. Bureau of Mines shows that area 6 (prospects 9, 11, 12, and 13) has silver concentrations of 0.4-2.8 oz per ton. This area probably has a low potential for resources of lead, zinc, and silver in small, low-grade deposits.

In the area of the Kent mine near Point Lookout (area 7), veins contain lead (5,000 ppm, spec), zinc (7,000 ppm, spec), and silver (1,000 ppm, spec). Limited sampling by the U.S. Bureau of Mines of a 2.5-ft-wide quartz vein at the Kent mine yielded high concentrations of 242 oz and 54 oz of silver per ton. This area probably has a high potential for the occurrence of silver resources in small deposits. Prospect 3 contains as much as 15 oz of silver per ton. Areas peripheral to the Kent mine probably have a low potential for occurrence of silver resources in small deposits.

The Senate mine region (area 2) and the Banner mine region (area 4) contain sulfide-bearing rock that has relatively low concentrations of lead, zinc, and silver. Rocks sampled in and near the Senate mine contain the following concentrations: lead, 70 ppm (spec); zinc, 45 ppm (AA); and silver, 70 ppm (spec). Samples from the mine dump at the Banner mine contain the following: lead, 700 ppm (spec); zinc, 200 ppm (spec); and silver, 100 ppm (spec). Area 2 has a low potential for the occurrence of lead, zinc, and silver resources in low-grade deposits. Production records from the U.S. Bureau of Mines indicate that about 1.2 oz of silver per ton of ore was recovered from the Banner mine (area 4). Area 4 has a high potential for the occurrence of silver resources in small deposits and a low potential for the occurrence of lead and zinc resources in small deposits.

Areas 3 (Rainbow prospect) and 5 (Bentz mine) have a low potential for the occurrence of small lead and silver resources. At the Rainbow prospect near Meyers Creek (area 3), high concentrations of lead (15,000 ppm, spec) and silver (50 ppm, spec) were determined for samples from a quartz vein. Samples collected by the U.S. Bureau of Mines from the Bentz mine (area 5) contain as much as 1.7 oz of silver per ton. The Rainbow prospect and the Bentz mine contain small identified resources of lead and silver in sulfide-bearing veins. Because concentrations of lead and silver are relatively low, because sulfide-bearing veins are small and may be discontinuous, and because lead- and silver-bearing veins have not been located elsewhere, these areas have a low potential for the occurrence of lead and silver resources in small deposits.

Many anomalously high concentrations of lead, zinc, or silver occur elsewhere in the study area. Area 17 contains low, but anomalous, concentrations of lead at 100 ppm (spec). Area 19 contains low, but anomalous, amounts of zinc at 47 ppm (spec). Areas 8, 11, 12, 14, 15, and 18 contain low, but anomalous, concentrations of silver that range from 1 ppm (spec) to 30 ppm (spec). These areas probably have low potential for the occurrence of lead, zinc, or silver resources in small, low-grade deposits.

Potential for the occurrence of resources of miscellaneous commodity elements

Miscellaneous commodities, such as molybdenum, tungsten, tin, thorium, titanium, cadmium, scandium, and rare-earth elements, have been detected in several parts of the study area.

Molybdenum occurs in area 5, at the Bentz mine, where concentrations of 2,000 ppm (spec) have been detected. Molybdenite is a major component of some quartz veins at the Bentz mine; sampling by the U.S. Bureau of Mines shows 0.1-0.23 percent molybdenum. Area 5 has a high potential for the occurrence of molybdenum resources in small, possibly discontinuous deposits. In area 3 at the Rainbow prospect molybdenum ranges from 150 to 1,000 ppm (spec). Area 3 is assigned a low potential for the occurrence of molybdenum resources in small, low-grade deposits because additional veins have not been found in the area. Small, but anomalous, amounts of molybdenum were detected in area 9 (70 ppm, spec) and in area 17 (5 ppm, spec). Both of these areas have a low potential for the occurrence of molybdenum resources in low-grade deposits.

Tungsten occurs at three places in the study area: area 5, Bentz mine (300 ppm, spec); area 11, Daly Creek (700 ppm, spec); and area 15, Table Mountain (100 ppm, spec). Tungsten minerals were not identified at the Bentz mine, but tungsten probably is associated with molybdenite and silver in quartz veins. Similarly, tungsten minerals probably occur in sulfide-bearing quartz veins in area 15. The source of tungsten in Daly Creek is not known. Areas 5, 11, and 15 have a low potential for the occurrence of tungsten resources in small, low-grade veins.

Rare-earth elements and associated elements such as tin and thorium were detected in anomalous amounts in area 10 along the west side of the Sapphire batholith, where allanite is a common accessory mineral. Rock samples contain lanthanum (100-200 ppm, spec), vanadium (150 ppm, spec), yttrium (70-150 ppm, spec), and thorium (1,000-1,500 ppm, spec). Tin (30-50 ppm, spec) and niobium (trace) were detected in sediment from streams that drain allanite-bearing granodiorite and monzogranite. Concentrations of rare-earth and associated elements in rock samples and in stream deposits are at, or slightly above, threshold limits. Presumably, concentrations of tin and niobium are too low in rock samples for detection, but stream transport may have concentrated heavy minerals that contain tin and niobium enough so these elements are above detection limits in stream deposits. Area 10 has a low potential for the occurrence of low-grade resources of disseminated rare-earth and related elements along the west side of the Sapphire batholith and in placers.

Anomalously high concentrations of yttrium (100 ppm) and lanthanum (200 ppm) were detected in rock samples near the head of Moose Creek drainage (area 16), but the source of the anomalies is not known. This area has a low potential for the occurrence of yttrium and lanthanum resources.

ASSESSMENT OF ENERGY RESOURCE POTENTIAL

The study area is unlikely to contain energy resources, such as oil, gas, coal, geothermal energy, and radioactive minerals, based on geologic, geochemical, and geophysical data collected for this study.

The study area probably does not contain oil and gas resources because temperatures generated during intrusion of the Sapphire batholith heated host rocks to temperatures of at least 400°-600°C, according to Pederson (1976, p. 39); long-term exposure to temperatures in this range probably would have destroyed volatile components of oil or gas. Rocks exposed at the surface are Proterozoic in age, and, based on maturity trends of hydrocarbon generation, Proterozoic rocks are unlikely to contain oil or gas of Proterozoic origin. If Paleozoic or Mesozoic rocks are present beneath the Sapphire thrust plate in this region, any original oil or gas in them would probably have been destroyed by heating during intrusion of magma and by metamorphism. Geophysical interpretation suggests that the Sapphire batholith is a plug-shaped body rather than a sheet-shaped body, and because intrusion postdated thrust faulting, temperatures were probably higher at greater depth.

Coal resources are not known to occur in the study area. The Proterozoic and plutonic rocks do not contain coal, and Tertiary deposits exposed in the eastern part of the study area are mainly gravel deposits, which are unlikely to contain coal deposits.

The study area is unlikely to contain a geothermal energy resource because no hot-spring or fumarolic activity is known. Young volcanic fields, which are commonly associated with known sources of geothermal energy, are absent in the study area.

The presence of some anomalously high values of thorium in the northern part of the Sapphire batholith is not diagnostic evidence for the occurrence of significant amounts of radioactive minerals. Thorium apparently is associated with accessory minerals that occur in the western part of the batholith, but the concentration of these minerals is generally less than 1 percent. A reconnaissance survey of main intrusive bodies, using a scintillometer, showed that most plutons have abnormally low background radioactivity. Consequently, the occurrence of radioactive energy resources is considered unlikely in the study area.

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