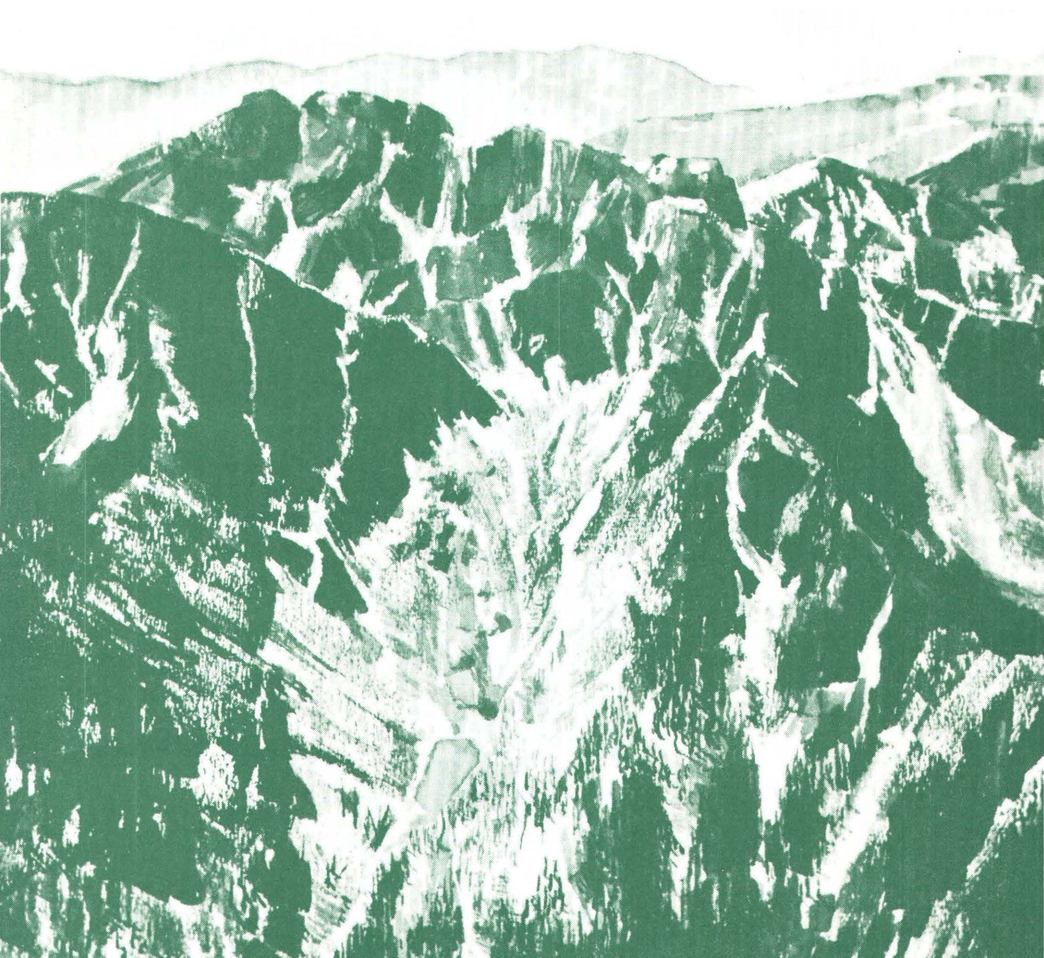
STUDIES RELATED TO WILDERNESS
STUDY AREAS



PROPOSED ADDITIONS TO SCAPEGOAT WILDERNESS, MONTANA

GEOLOGICAL SURVEY BULLETIN 1430

U. S. DEPARTMENT OF THE INTERIOR
March 3, 1849

Mineral Resources of the Proposed Additions to the Scapegoat Wilderness, Powell and Lewis and Clark Counties, Montana

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With a section on GEOPHYSICAL SURVEYS

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STUDIES RELATED TO WILDERNESS — STUDY AREAS

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An evaluation of the mineral potential of the area

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STUDIES RELATED TO WILDERNESS

STUDY AREAS

In accordance with the provisions of the Wilderness Act (Public Law 88–577, Sept. 3, 1964) and the Joint Conference Report on Senate Bill 4, 88th Congress, the U.S. Geological Survey and U.S. Bureau of Mines have been conducting mineral surveys of wilderness and primitive areas. Studies and reports of all primitive areas have been completed. 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 now 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. This report discusses the results of a mineral survey of some national forest lands in the proposed additions to the Scapegoat Wilderness, Montana. The area studied is in Powell and Lewis and Clark Counties in Montana.

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CONVERSION FACTORS

To convert English unit	*Multiply by*	*To obtain Metric unit*
Cubic yard (yd^3)	0.7645	Cubic meters (m^3).
Mile	1.609	Kilometers (km).
Square Mile (mi^2)	2.59	Square kilometers (km^2).
Short ton	.907	Tonnes (t) (metric ton).
Ounce per ton (oz/ton)	34.3	Grams per tonne (g/t).
Troy ounce	.031	Kilogram (kg).
Troy ounce	31.1	Grams (g).

STUDIES RELATED TO WILDERNESS — STUDY AREAS

MINERAL RESOURCES OF THE PROPOSED ADDITIONS TO THE SCAPEGOAT WILDERNESS, POWELL AND LEWIS AND CLARK COUNTIES, MONTANA

By ROBERT L. EARHART, DAVID J. GRIMES, and REINHARD W. LEINZ, U.S. Geological Survey, and by LAWRENCE Y. MARKS, U.S. Bureau of Mines

SUMMARY

The proposed additions to the Scapegoat Wilderness include the Silver King–Falls Creek and Arrastra–Stonewall units. They cover about 84 square miles (218 square kilometers) south and southeast of the wilderness in the Helena and Lewis and Clark National Forests, northwest Montana. Their mineral resources were evaluated as part of a study by the U.S. Forest Service to determine their suitability for addition to the wilderness.

The additions have copper resources, which may also contain some silver, some lead, and possibly zinc and gold. Stone and sand and gravel deposits are present, but deposits of equal or better quality are available closer to major markets. The Silver King–Falls Creek addition may have a potential for the discovery of oil and gas, but detailed studies, including seismic surveys and drilling, would be required to adequately determine the potential. The additions have a low potential for geothermal resources.

The geology is structurally complex and consists of sedimentary rocks that range from Precambrian Y to Holocene in age. Precambrian rocks are locally intruded by sills of intermediate composition.

The mineral resource evaluation is based on geological, geochemical, economic, and geophysical studies. A total of 480 rock samples and 120 stream-sediment samples were collected during geologic mapping; 86 lode samples and two placer samples were collected during the examination of mines and prospects. Results from these samples delineate areas that are anomalously high in base metals, precious metals, and mercury. The geophysical investigations indicate small magnetic and gravity anomalies, which mostly appear to be unrelated to mineralized areas.

More than 60 recorded mining claims have been located in the additions. Except for a small amount of copper shipped from Stonewall Mountain, no record of mineral production exists for the additions. Gold has been mined from placer deposits near the southern boundary of the Arrastra–Stonewall unit, and small amounts of copper have been extracted from deposits near the northern boundary.

A copper deposit in Cotter basin, adjacent to the northern boundary of the Arrastra–Stonewall unit, was being explored and developed by industry during the present investigations, and minor production has resulted. This deposit, a carbonate vein system, is estimated to contain 1 million tons (910,000 tonnes) of paramarginal resource averaging 0.85 percent copper and 0.2 ounce byproduct silver per ton (6.9 grams per tonne) with selected areas of higher grade that may be presently economic. Similar copper deposits may occur in this carbonate vein system in the northern and eastern parts of the Arrastra–Stonewall unit. Smaller and lower grade copper deposits occur near the mouth of Byrnes Creek and near the head of Alice Creek, in the Silver King–Falls Creek unit.

INTRODUCTION

The proposed additions to the Scapegoat Wilderness are roadless areas in the Helena and Lewis and Clark National Forests, northwest Montana, and include the Silver King–Falls Creek addition and the Arrastra–Stonewall addition, which are contiguous to the east and to the south of the Scapegoat Wilderness, respectively (fig. 1). For convenience, these areas are hereinafter referred to as the Silver King addition and the Arrastra addition. The mineral resources of the additions were evaluated as a part of a study by the U.S. Forest Service to determine their suitability for wilderness inclusion.

The Silver King addition covers about 47 mi^2 (122 km^2) and has a total relief of 3,650 feet (1,113 m). The high point, 8,755 feet (2,670 m), is Caribou Peak on the Continental Divide, and the low point, 5,105 feet (1,557 m), is where Falls Creek leaves the addition at the northern boundary. The Continental Divide forms the western boundary in the northern part of the addition, extends through the central part, and forms the southern boundary in the eastern part (pl. 1). The divide is mostly above the elevation of timberline, at about 8,500 feet (2,600 m). The rest of the addition is covered with timber and brush. The area is drained by Falls Creek and its tributaries to the north and east of the divide. Falls Creek is tributary to the Dearborn River. South of the divide, a stream also named Falls Creek drains the addition and flows southwestward into the Landers Fork of the Blackfoot River. The Silver King addition is accessible from the north by a road along the Dearborn River to its confluence with Falls Creek, and then by horsetrail up Falls Creek valley. The southern access to the area is by horsetrail from the Indian Meadows branch of a road along Copper Creek (pl. 1).

The Arrastra addition covers about 37 mi^2 (96 km^2) and has a total relief of 3,317 feet (1,010 m). The high point, 8,677 feet (2,646 m), is on the northern boundary in the western part of the area, and the low point, 5,360 feet (1,635 m), is near Snowbank Creek on the eastern boundary. The area is west of the Continental Divide, and the principal drainages, Arrastra Creek and Stonewall Creek, flow southward

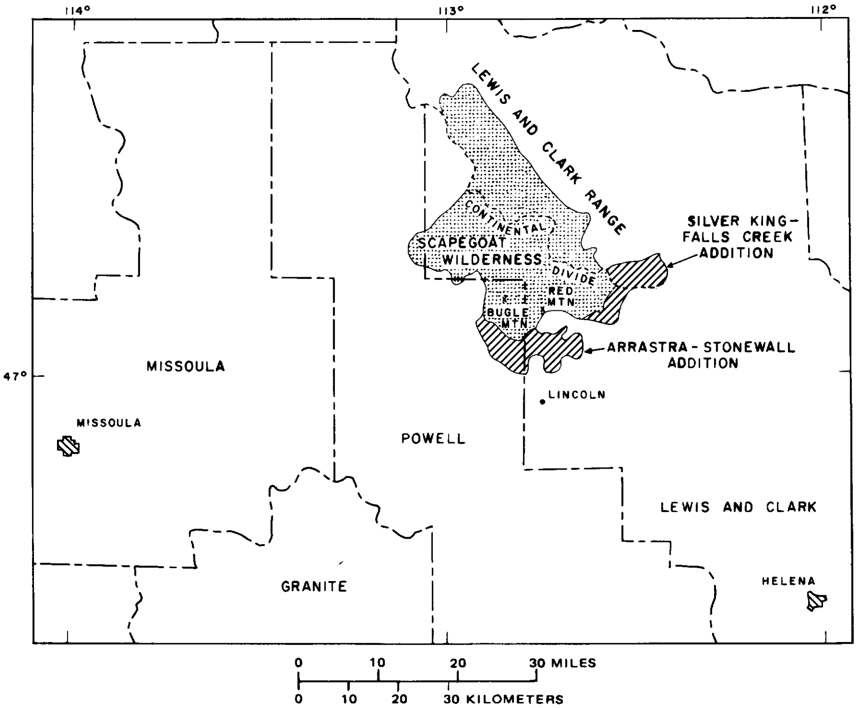


FIGURE 1.—Index map of part of western Montana, showing the location of the proposed additions to the Scapegoat Wilderness.

into the Blackfoot River. Except for the barren highest peaks in the western part, the area is mostly covered with timber and brush. The principal access to the area is by a horsetrail that begins from near the intersection of Beaver Creek road and Arrastra Creek and extends up Arrastra Creek valley. The eastern part of the area is accessible by a horsetrail that begins from Sucker Creek Road.

The U.S. Forest Service planimetric map of the Lincoln Ranger district of the Helena National Forest covers both the Silver King and Arrastra additions at a scale of 1:125,000. Both areas are also in the southern part of the U.S. Geological Survey 1:250,000-scale Choteau topographic sheet. In addition, both areas are covered by U.S. Geological Survey quadrangle maps at 1:24,000 scale. The Bean Lake, Blowout Mountain, Caribou Peak, Heart Lake, and Silver King Mountain quadrangles cover the Silver King addition, and the Arrastra Mountain, Silver King Mountain, and Stonewall Mountain quadrangles cover the Arrastra addition. The base for plate 1 is a reduction of the combined 1:24,000-scale maps to a scale of 1:48,000.

PREVIOUS STUDIES

Walcott (1906, 1908, 1910) made the earliest known geological studies of the Precambrian and Cambrian rocks in and adjacent to the Scapegoat additions. Clapp and Deiss (1931) studied the Belt rocks in and adjacent to the area. Clapp (1932, 1934) published the first geologic map of the area and briefly discussed the stratigraphy and structure. Metalliferous deposits in the Copper Creek area and in the area to the south of the Arrastra addition are briefly described by Pardee and Schrader (1933). The Coopers Lake, Ovando, and Saypo 30-minute quadrangles were mapped by C. F. Deiss in the late thirties and early forties but were never published. The Devonian rocks in the northern part of Silver King addition were studied by Sloss and Laird (1946). The glacial deposits in the drainages of the Blackfoot River are discussed by Alden (1953). The additions were covered in 1964 by a U.S. Geological Survey aeromagnetic survey that used flightline spacings of 2 miles (3.2 km).

Recent studies that pertain to the economic geology of adjacent areas to the north and west of the additions include a reconnaissance study of the geology, geophysics, and geochemistry on the southeastern part of the Lewis and Clark Range (fig. 1; Mudge and others, 1968) and a resource evaluation of the Scapegoat Wilderness (Mudge and others, 1975).

PRESENT STUDIES AND ACKNOWLEDGMENTS

The present studies were conducted in July and August 1974 for the purpose of evaluating the mineral potential of the Silver King and Arrastra additions, which are under consideration for wilderness inclusion. These studies consisted of geological, geochemical, and geophysical investigations by the U.S. Geological Survey, a courthouse search for mining claims, and a field evaluation of mineralized areas by the U.S. Bureau of Mines.

A field party headed by Earhart made foot traverses along the ridges and streams in order to closely examine the rocks, to collect rock and stream-sediment samples, and to map the geology of the area at a scale of 1:48,000. These studies were greatly aided by a helicopter, which shuttled the field party to and from dropoff and pickup points.

The geology of the additions was mapped on U.S. Geological Survey $7^1/_2$-minute topographic quadrangle maps and compiled on a base made from the combined quadrangles reduced to a scale of 1:48,000 (pl. 1). The mapping includes a small part of the Scapegoat Wilderness adjacent to the Silver King addition that was not designated as part of a study area by the U.S. Forest Service prior to wilderness classification of the Lincoln Back Country (Scapegoat area) in 1971. The rocks were subdivided by ages or by formations, in a manner consistent with the subdivisions used in the Scapegoat Wilderness (Mudge and others, 1975).

During the course of studies, the possible presence of warm or hot springs and the deposits around the orifices of springs were investigated in order to determine the potential for geothermal energy. No indications of a geothermal energy resource were found.

A total of 600 samples were collected, of which 480 are rock samples and 120 are stream-sediment samples. Spectrographic analyses for 30 elements were made on all samples, in a mobile laboratory, by D. J. Grimes, using a semiquantitative emission spectrographic method (Grimes and Marranzino, 1968). In addition, all samples were analyzed for copper, lead, zinc, and gold by atomic absorption spectroscopy methods (Ward and others, 1969), and for mercury by a mercury vapor detector method (Vaughn and McCarthy, 1964). Also, all stream-sediment samples were analyzed by a 0.8 N nitric acid leach-atomic absorption method for extractable copper, lead, and zinc. The atomic absorption and mercury vapor analyses were made by R. W. Leinz, D. J. Grimes, and J. D. Sharkey in the Denver laboratories of the U.S. Geological Survey. Analytical data and geological information were entered into a computer storage system and edited from a remote terminal in the field by L. O. Wilch. G. H. Allcott of the U.S. Geological Survey was consulted on the types of data retrieved from the computer.

The geophysical studies were made by D. L. Peterson; they consisted of an interpretation of an aeromagnetic survey, flown in 1964 by the U.S. Geological Survey, and of a gravity survey conducted in 1970 by the U.S. Geological Survey supplemented with gravity stations made by the 1381st Geodetic Survey Squadron, Air Photographic and Charting Service, U.S. Air Force.

U.S. Bureau of Mines investigations were made during 1973 and 1974 by L. Y. Marks, project leader, assisted by D. B. Kennedy in 1973 and by R. W. Cross in 1974. All available information on previous mining or exploration activities in the area was reviewed, and known mines, prospects, and mineralized areas were mapped, sampled, and evaluated. Lode-sample analysis was directed by H. H. Heady, U.S. Bureau of Mines, Reno, Nev. Placer sample processing was directed by D. C. Holt, U.S. Bureau of Mines, Spokane, Wash. Paul McIlroy, U.S. Bureau of Mines, Spokane, Wash., furnished production cost estimates for copper deposits.

Reports of previous studies dealing with mineral resources in or near the study area were used as background information. County records were searched to determine the location of all mineral properties in the area. Data on production, history, reserves, and geology were obtained. U.S. Bureau of Mines personnel visited each place where the description of a mining location was specific enough to warrant a field investigation. Mines, prospects, and mineralized outcrops were examined, sampled, and mapped by tape-and-compass and rangefinder methods. A planetable survey was made in 1974 at the Cotter Basin mine. Samples were taken from outcrops and mine dumps where underground workings were inaccessible. Property owners were contacted, where possible, and some accompanied the author to their property and pointed out exposures of mineralized rock. Deposits were classified according to the probability that they could be mined under present or anticipated economic conditions. Tonnage and grade of deposits were estimated partly from sample analyses and measurements and partly from reasonable geologic projection. Production costs were estimated by comparison to similar operating properties. Oil and gas lease data were obtained from the U.S. Bureau of Land Management to identify areas of interest to petroleum companies.

The close cooperation from personnel of the Helena and the Lewis and Clark National Forests greatly aided the investigations. We especially thank Mr. Neal Peterson, Chief Ranger of the Lincoln District of the Helena National Forest, and Mr. Robert Duncan, Chief Ranger of the Sun River District of the Lewis and Clark National Forest, for their assistance in resolving logistical problems, and Mr. James W. Whipple, zone geologist of the Helena National Forest, for stimulating discussions on the geology of the area and for assistance in the fieldwork. The aid and cooperation of claim owners also greatly assisted the investigation.

GEOLOGY

GEOLOGIC SETTING

The Silver King addition is in the eastern margin of the Belt basin and on the southwestern extension of the northern disturbed belt of Montana. The Belt basin, an epicratonic reentrant onto the North American craton, formed in Precambrian Y time, and was filled with fine-grained clastic rocks and some carbonate rocks (Harrison, 1974). The disturbed belt is a zone of closely spaced thrust faults, normal faults, and folds all related to a Tertiary orogeny (Mudge, 1970). The Arrastra addition is entirely in the Belt basin to the west of the disturbed belt.

Sedimentary rocks that range in age from Precambrian Y to Holocene crop out in the additions. The Precambrian rocks are regionally metamorphosed to the chlorite subfacies. Locally, they are intruded by sills of Precambrian Y and Z ages. Remnants of conglomerate and tuff of Tertiary(?) age and poorly consolidated gravels of Tertiary(?) and Quaternary age are in and near the southern part of the Silver King addition. Most valley sides and floors are mantled with alluvial, glacial, and colluvial deposits. The Silver King addition contains large landslide deposits adjacent to cliffs of carbonate rocks of Cambrian age, and a small landslide deposit occurred in Precambrian rocks in the Arrastra addition.

PRECAMBRIAN ROCKS

Most rocks in the proposed additions are metasedimentary rocks assigned to the Belt Supergroup of Precambrian Y age; their maximum exposed thickness is about 15,400 feet (4,690 m). They are divided into six formations, which are, from oldest to youngest, the Spokane, Empire, Helena, Snowslip, Shepard, and Mount Shields Formations. In addition, the upper part of the Greyson Formation (not shown on pl. 1), which underlies the Spokane, may be exposed in the western part of the Arrastra-Stonewall addition. These formations are regionally metamorphosed to the chlorite subfacies and are contact metamorphosed where they are adjacent to diorite sills of Precambrian Z age. The following descriptions of the formations are, in part, summaries from the Scapegoat Wilderness report (Mudge and others, 1975); they also include formational features that were noted in the additions but were not observed in the wilderness.

SPOKANE FORMATION

The oldest rocks exposed in the Silver King and Arrastra additions belong to the Spokane Formation. In the Silver King addition, the Spokane is exposed along a northwesterly trending belt on the northeast side of the Continental Divide and along the northeast side of the valley formed by Landers Fork (pl. 1). The Spokane is the most widely exposed of all the formations in the Arrastra addition, and in the western part of the area its estimated thickness is about 5,500 feet (1,700 m); however, this thickness may include the upper part of the Greyson Formation (not shown on pl. 1). A precise minimum thickness of the Spokane in the Arrastra area is difficult to determine owing to faulting; the total thickness is unknown. At several localities, the Spokane is intruded by a diorite sill of Precambrian Z age, and the strata are commonly hornfelsed for as much as 400 feet (122 m) from both the upper and lower sill contacts. Thin metaandesite sills of Precambrian Y age locally intrude the Spokane but with no apparent metamorphic effect on the formation.

The Spokane Formation is mostly pale-red to purplish-red beds of siltite, argillitic siltite, and argillite, with very minor thin beds of silty quartzite. Thin sequences of green to greenish-gray siltite and argillite, commonly less than 3 feet (1 m) thick, are locally interbedded with the red beds. Approximately 3,000 feet (900 m) below the upper contact, the Spokane contains an undetermined thickness of continuous beds of green to greenish-gray argillite and argillitic siltite that may belong to the Greyson Formation. A precise thickness of this "green-bed" section was not determined, because where it is best exposed in the vicinity of Arrastra Creek it is repeated at least three times by normal faults. Where the Spokane is hornfelsed by diorite sills, the strata are drab gray and contain fairly abundant epidote and increased amounts of biotite.

A unique feature of the Spokane in the Arrastra addition is the common occurrence of concentric-shaped bleached zones in both the red and green siltites and argillitic siltites. Local residents refer to this feature as "target rock." The "targets" are perfect circles as much as 3 cm in diameter and contain a 2 mm or less dark-brown core; the remainder of the circle area is light gray or light tan. An abrupt change to the color of the host rock occurs at the circumference. The cause of this feature is uncertain; however, it may be due to the radiogenic decay of zircon.

The contact between the Spokane and the overlying Empire is placed at the top of the first thick sequence of red interbedded siltite and argillite. The siltite in beds above the contact are coarser grained than those below, contain lenses of very fine grained quartzite, and are mostly green. On the basis of color the contact is fairly sharp; on the basis of lithology it is gradational over several tens of feet.

EMPIRE FORMATION

The Empire Formation crops out north of the Spokane at the localities described in the Silver King addition and in the central and eastern parts of the Arrastra addition. It ranges in thickness from about 850 to 1,000 feet (260 to 300 m). In the eastern part of the Silver King addition, a diorite sill inflects upward into the Empire and has altered the strata to hornfels. In the Arrastra addition, metaandesite sills, 2–10 feet (0.6–3 m) thick, locally intrude the Empire with no apparent metamorphic effect.

The lower part of the Empire is mostly green to greenish-gray beds of siltite and argillite, with local red sequences of similar lithologies that are 6.0 feet (2 m) or less thick. Compared to the underlying Spokane, the lower part of the Empire contains more siltite and less argillite. Locally, such as on the Continental Divide in the Silver King addition, the lower part of the Empire contains a few thin lenticular beds of very fine grained gray crossbedded quartzite. The quartzite beds are increasingly abundant upward in the formation to near the Helena contact and are commonly 3–4 feet (1–1.2 m) thick. The upper part of the Empire is mostly green siltite that is locally calcareous and, in addition to quartzite, contains some thin beds, a few inches thick, of silty limestone. The lime content increases towards the top of the formation. The contact at the top of the Empire is sharp where it is overlain by a basal calcareous sandstone unit of the Helena Formation; elsewhere, the contact is gradational over about 20 to 30 feet (6 to 9 m) and is placed at the top of a green siltite unit that separates predominantly carbonate beds above from predominantly siltite beds below.

HELENA FORMATION

The Helena Formation, which is mostly a carbonate unit, is exposed in the vicinity of the Continental Divide and along the ridges to the east and west of Falls Creek in the Silver King addition. In the Arrastra addition the Helena is exposed at several localities in the eastern half of the area. A complete section of the Helena is exposed along the Continental Divide in the central part of the Silver King addition. There, the formation is 4,900 feet (1,490 m) thick. In the Arrastra addition, the top of the Helena is eroded and only the lowermost 2,000 feet (610 m) of the formation remains.

At most localities in the Silver King addition where the base of the Helena is exposed, the basal unit consists of lenticular gray calcareous poorly sorted medium-grained sandstone. The long axes of individual lenses of the sandstone as viewed in outcrop are commonly as much as 200 feet (61 m) long, and the lenses are 2–7 feet (0.6–2 m) thick. They do not appear to occupy the exact same stratigraphic position and, at places, overlapped segments of lenses are separated by a few feet of dolomitic or calcareous siltite. The beds above the lenses are mostly dolomite and dolomitic siltite; below the lenses, siltite and argillitic siltite are predominant. The base of the Helena on Stonewall Mountain in the Arrastra addition also contains the basal sandstone unit, but the unit is not as well developed as in the Silver King addition.

The Helena in the proposed additions contains the same rock types and features as the Helena in the Scapegoat Wilderness, and the reader is referred to that report for a stratigraphic description (Mudge and others, 1975). Stromatolites, oolites, flat-pebble conglomerates, and "molar-tooth" structures are all characteristic features of the Helena in the additions.

The contact between the Helena and Snowslip Formations is gradational through a section 100–200 feet (30–61 m) thick. The amount of limestone or dolomite decreases upward through the gradational zone, and the contact is placed at the base of a coarse-grained feldspathic quartzite or quartzitic gritstone assigned to the Snowslip Formation.

SNOWSLIP FORMATION

The Snowslip Formation crops out only in the Silver King addition, where a few tens of feet of lowermost Snowslip is present on a high point on the Continental Divide near the western boundary. About 500 feet (150 m) of the lower part of the Snowslip crops out outside the boundary near the end of the western arm of the area.

The Snowslip consists of interbedded red and grayish-green siltites, argillites, and very fine grained quartzites. Some beds have limy matrices, and the lime content increases towards the base. A few very thin beds of limestone and stromatolitic limestone occur near the base. The basal unit consists of a feldspathic quartzite and locally a quartzitic gritstone that ranges in thickness from a few inches to about 2 feet (0.6 m). The presence of gritstone suggests that the Snowslip and the Helena are at least locally separated by a minor disconformity.

SHEPARD FORMATION

The Shepard Formation crops out in the eastern part of the Silver King addition and has a minimum thickness of about 600 feet (183 m); the actual thickness is unknown because the base is not exposed. In the northern part of the addition, the upper part of the Shepard is truncated by a paleoerosion surface, and an angular unconformity separates the Shepard from the overlying Cambrian strata. The angular unconformity projects upsection into the Mount Shields Formation in the southeastern part of the addition. There, the Shepard is in normal contact with the overlying Mount Shields.

The Shepard is mostly a carbonate unit and contains all the lithologic types and features described in the Scapegoat Wilderness report (Mudge and others, 1975). The Shepard appears to contain more glauconite beds in the Silver King addition than in the wilderness, which reflects a "closer to shoreline" depositional environment in addition.

The contact between the Shepard and the overlying Mount Shields is gradational through about 100 feet (30 m) of yellowish-gray siltite and some very thin bedded reddish-brown siltite and quartzite; the contact is placed at the top of the uppermost yellowish-gray unit.

MOUNT SHIELDS FORMATION

The Mount Shields is the youngest Precambrian formation exposed in the proposed additions to the Scapegoat Wilderness; only the lower part is present in the southeastern part of the Silver King addition. The Mount Shields ranges in thickness from 0 to about 1,000 feet (305 m). The upper part of the Mount Shields was eroded prior to deposition of the Cambrian rocks.

The Mount Shields consists of reddish-brown thin-bedded siltite, argillite, and very fine grained quartzite containing some beds, mostly less than 1 cm thick, of gray to greenish-gray siltite.

PALEOZOIC ROCKS

The Paleozoic rocks are mostly limestone and dolomite; they crop out in the northern and eastern parts of the Silver King addition. The Paleozoic rocks overlie Precambrian strata to the east in angular unconformity, and, to the southwest, they are overlain in thrust-fault contact by Precambrian strata.

The Paleozoic rocks are divided into Cambrian, Devonian, and Mississippian units in this report. The reader is referred to the Scapegoat Wilderness report for descriptions of these units (Mudge and others, 1975).

The Cambrian rocks are approximately 2,700 feet (823 m) thick and include a basal sandstone formation (Flathead Sandstone), two mudstone units (Gordon and Switchback Shales), and five carbonate units (Damnation, Dearborn, Pagoda, and Steamboat Limestones, and Devils Glen Dolomite). All landslide deposits in the Silver King area are formed from Cambrian carbonate rocks. Cambrian strata in the Silver King addition are similar to those in the wilderness.

Devonian rocks crop out in the northern part of the Silver King addition. At Monitor Mountain, on the northeast boundary, the thickness of the Devonian section is 1,200 feet (366 m; Sloss and Laird, 1946). Elsewhere, the thickness is difficult to determine owing to thrust faulting. The Devonian strata include the Maywood, Jefferson, and Three Forks Formations. These formations contain limy and dolomitic rocks, and the Jefferson and Three Forks also contain evaporite-solution breccias. A minor disconformity separates the Devonian rocks from the overlying Mississippian strata.

Mississippian rocks crop out in the northern part of the Silver King addition and are about 1,300 feet (396 m) thick. The Mississippian strata are overlain by Devonian rocks because of thrust faulting. The top of the Mississippian is absent owing to faulting; however, the section must be nearly complete if the thicknesses of the Mississippian sections in the Silver King addition and the Sun River Canyon area, a few miles to the north of the area shown in figure 1, are comparable (Mudge and others, 1962).

The Mississippian rocks of the Madison Group include the Allan Mountain Limestone and the Castle Reef Dolomite; the formations are of approximately equal thickness.

TERTIARY(?) ROCKS

Conglomerate and tuff, both of probable Tertiary age, crop out in the valley of Landers Fork near the Silver King addition.

Prominent bluffs of conglomerate as much as 100 feet (30 m) high occur locally along the banks of the Landers Fork of the Blackfoot River. The conglomerate is pale reddish orange and consists of angular to subrounded cobbles as much as 6 inches (13 cm) in diameter in a clayey and sandy matrix. The cobbles appear to be derived from the nearby formations of the Belt Supergroup. The conglomerate strikes northward and dips about 10° E.

Crystal tuff of probable Tertiary age caps a low ridge on the west side of Indian Meadows, near the southern part of the Silver King addition. The tuff is the same as that described from the Landers Fork part of the Scapegoat Wilderness (Mudge and others, 1975) and is similar to that described by Melson (1964) from the upper rhyolite series of middle Tertiary volcanic rocks south of Lincoln, Mont. The tuff is light gray, is highly porous, and contains euhedral crystals of smoky quartz and sanidine.

TERTIARY(?) AND QUATERNARY SURFICIAL DEPOSITS

Surficial deposits of Tertiary(?), Pleistocene, and Holocene ages mantle the floors and sides of most valleys (pl. 1). Glacial till is in the upper reaches of the more extensive drainages, and it covers the floor of the larger valleys. The Landers Fork area of the Silver King addition contains glacial sand and gravel. The sand and gravel deposits are overlain by glacial till. Alluvium is along most major streams, and small alluvial fans are common where small streams enter onto broad valley floors. Colluvial deposits mantle most hillsides, and talus deposits are along the bases of cliffs. The north side of Blowout Mountain in the Silver King addition contains large landslide deposits which formed from cliffs of Cambrian carbonate rocks.

PRECAMBRIAN IGNEOUS ROCKS

Igneous sills of Precambrian Z age intrude the Belt rocks in the Silver King addition, and sills of Precambrian Y and Z ages intrude Belt strata in the Arrastra addition.

Sills of metaandesite and metabasaltic andesite, 2–10 feet (0.6–3 m) thick, intrude the Spokane, Empire, and Helena Formations over a stratigraphic range of about 3,000 feet (915 m) at numerous localities in the central and eastern parts of the Arrastra addition (pl. 1). Continuous exposures of the sills are rare; therefore, their lateral continuity cannot be determined. The sills are similar to those investigated in the Red Mountain area of the Scapegoat Wilderness by Earhart (1975), who concluded that they are probably of Precambrian Y age. The metaandesite and metabasaltic andesite are mostly dark-greenish-gray, have an aphanitic groundmass of predominantly plagioclase, and contain chloritized amphibole and biotite phenocrysts. Where the sills are in the hornfelsed zones adjacent to diorite sills of Precambrian Z age, they are bleached and highly kaolinized.

Diorite and quartz diorite sills of Precambrian Z age crop out in the Silver King and Arrastra additions. They range in thickness from 425 to 1,500 feet (130 to 458 m). The thickest sill is in the Silver King addition, where it is in a thrust fault plate. Its thickness may be greatly exaggerated owing to deformation associated with thrusting, but the average thickness is about 500 feet (153 m). The composition of the sills is similar to that of sills from the Wood Creek area, about 15 miles (24 km) north of the map area (pl. 1); these sills were described by Knapp (1963, p. 23–24), who noted that they consist of 45 percent finely to coarsely crystalline plagioclase, 25 percent hornblende, 25 percent clinopyroxene, and 5 percent quartz and orthoclase. Locally, magnetite constituted as much as 14.5 percent of the rock, and the diorite sills in the proposed additions contain variable amounts of magnetite. A diorite sill in the central part of the Arrastra addition was dated as late Precambrian in age (730±30 m.y. (million years)) by potassium–argon methods (R. F. Marvin, oral commun., 1974), and similar sills elsewhere in northwest Montana have been dated at 750±25 m.y. by J. D. Obradovich (oral commun., 1966).

A diorite sill in the Spokane, in the central part of the Silver King addition, inflects upsection into the Empire Formation in the western part of the area. A diorite sill in the Arrastra addition is entirely in the Spokane and is locally repeated as many as three times by normal faulting and folding.

In addition to the igneous rocks described, a small unmapped quartz monzonite dike is exposed in a shear zone a short distance north of the Arrastra addition, and an unmapped granitic dike intrudes a diorite sill on the north side of Snowbank Creek outside the Arrastra addition.

STRUCTURE

The structure of both the Silver King and Arrastra additions is complex, and the areas are situated in two different structural provinces.

The Silver King addition is on the southern extension of the northern Montana disturbed belt (Mudge, 1970). The northern part of the area contains closely spaced thrust faults and associated tight and locally overturned folds. These result in older strata over younger rocks and repeat parts of the Paleozoic sequence. The largest thrust fault transported Spokane strata onto Paleozoic strata (pl. 1).

A normal fault of large but undetermined displacement parallels the Landers Fork of the Blackfoot River in the southern part of the Silver King addition. This fault trends northwestward, is downthrown to the southwest, and appears to be part of a fault system that extends to the southwest into the eastern part of the Arrastra addition.

The Arrastra addition contains a system of westerly trending normal faults which are faulted down to the south. The minimum apparent vertical displacement on these faults ranges from 250 feet (76

m) to 3,300 feet (1,006 m). The largest displacement is in the southern part of the area, where a normal fault has juxtaposed the Helena and Spokane Formations. Displacements along most of these faults appear to increase in a westerly direction. The westerly trending faults may be displaced by the northwesterly trending faults in the eastern part of the area; however, this relationship is uncertain.

The only major fold in the Arrastra addition is an anticline with a westerly trending axis in the southern part of the area. The anticline plunges to the west, and it terminates into nearly flat lying strata in the vicinity of Stonewall Creek to the east. Numerous minor folds are associated with normal faults in the area.

GEOPHYSICAL INVESTIGATIONS

By Donald L. Peterson

MAGNETIC AND GRAVITY SURVEYS

The aeromagnetic data are from a widespread survey flown in 1964 by the U.S. Geological Survey. Total-intensity magnetic measurements were made with a continuously recording ASQ 10 fluxgate magnetometer installed in a Convair aircraft. The survey was flown at a barometric elevation of 9,000 feet (2,743 m) above sea level, with deviations to 10,500 feet (3,200 m) to clear mountain peaks. Flightlines were flown in an east-northeast direction with a spacing of about 2 miles (3.2 km). The total-intensity data were reduced to an arbitrary datum and contoured at an interval of 20 γ (gammas; pl. 1).

Most gravity data are from a regional survey made in 1970 by the U.S. Geological Survey (Mudge and others, 1975). These data are supplemented with 15 gravity stations made available through the courtesy of the 1381st Geodetic Survey Squadron, Air Photographic and Charting Service, U.S. Air Force, in compiling the Bouguer gravity map at a contour interval of 5 mGal (milligals; pl. 2). Vertical and horizontal positions for most gravity stations are from bench marks or other elevations shown on U.S. Geological Survey 1:24,000–scale topographic maps. Vertical positions for a few stations were interpolated from map contours where the contour interval was 40 feet (12.2 m). Vertical positions for these stations may be in error by 20–40 feet (6.1–12.2 m). An error of 40 feet (12.2 m) would change the Bouguer anomaly by 2.4 mGal. Observed gravity values were referenced to the North American Gravity Control Network at Station WA 124, Great Falls, Mont. (Woollard, 1958, p. 533). The gravity stations are corrected for terrain out to a distance of 103.6 miles (166.7 km) on a digital computer by a method described by Plouff (1966). A density of 2.67 g/cm^3 (grams per cubic centimeter) was assumed for the material between sea level and station elevations in reducing the data to the complete Bouguer anomaly.

The gravity data are considered to be of reconnaissance quality and the estimated accuracy of the Bouguer anomalies is about 3 mGal.

Most igneous rocks in the area are expected to produce detectable magnetic anomalies, whereas the sedimentary rocks are considered essentially nonmagnetic (Kleinkopf and Mudge, 1972).

Rock densities for the general area have been reported by Kleinkopf and Mudge (1972) to average 2.7–2.8 g/cm^3 for Paleozoic and Precambrian sedimentary rocks, 2.9 g/cm^3 for Precambrian diorite, and 2.7–2.8 g/cm^3 for Precambrian intrusive granitic rocks. Therefore, when the enclosing rocks are Paleozoic and older sedimentary rocks, diorite or rocks of similar composition are expected to produce positive gravity anomalies, and granitic rocks, little or no anomaly.

Each anomaly discussed is identified by a number on plates 1 and 2.

DISCUSSION

Magnetic and gravity gradients are coincident along the southern edge of the mapped area. The magnetic gradient has about 200 γ and the gravity gradient, about 15–20 mGal of amplitude. These gradients probably reflect a zone of major normal faulting with the downthrown block to the south.

A sharp high-amplitude positive magnetic anomaly (1) is on this gradient zone. About 4 miles (6.4 km) to the west, a closed gravity anomaly (6) is indicated by the southeast nosing of the contours. Small closed positive gravity anomalies (2 and 6, pl. 2) appear to be related to magnetic anomaly 1 on plate 1. These anomalies approximately correspond to surface exposures of Precambrian Z diorite sills, which intruded Belt strata, and are interpreted to reflect these rocks.

To the east a positive magnetic anomaly (3) is indicated by a southward nosing of the contours. A gravity anomaly is not associated with the magnetic anomaly; however, the gravity data may be too widely spaced to detect an anomalous mass. The magnetic nosing is near the Cotter Basin prospects, where a small unmapped exposure of quartz monzonite was observed. The anomaly probably reflects the quartz monzonite but suggests that the mass is small.

A positive magnetic anomaly (4) is indicated by the southeasterly nosing of the contours about 5 miles (8 km) north of Lone Mountain. The anomaly probably reflects a diorite sill of Precambrian age, which is exposed at the surface. The northern part of the gravity anomaly (5), with about 15 mGal of positive closure, coincides with the magnetic anomaly. The source of the gravity anomaly is uncertain; however, it may reflect a small buried stock that is correlative with the exposed diorite sill.

The magnetic and gravity anomalies discussed in this section are interpreted as reflecting the presence of igneous sills and stocks. This interpretation suggests that the geologic and geochemical evidence should be critically evaluated for potential mineralization of economic importance.

For a discussion of geophysical anomalies outside the boundary of this study area, see Mudge, Erickson, and Kleinkopf (1968); Mudge and others (1975); and Kleinkopf and Mudge (1972).

MINERAL RESOURCES

The rocks in the proposed additions to the Scapegoat Wilderness contain deposits of copper, silver, gold, lead, and zinc. Copper deposits with marginal to submarginal economic potential occur at the Cotter Basin mine and at Copper Camp, which are 500–2,000 feet (150–610 m) outside of the Arrastra addition. Geochemical sampling and geological inference suggest that similar deposits may occur within the addition. Silver, lead, zinc, and gold are unlikely to be produced except as a byproduct of copper mining. Other metallic mineral commodities and rare earth elements are highly localized and are of insufficient size and grade to be a potential resource. The Silver King addition may have a potential for fossil fuels. The Silver King addition contains large deposits of stone, sand, and gravel, but these commodities are readily available in more accessible areas nearer to markets. The additions have a low potential for geothermal resources.

Several mineral prospects are located within or near the boundaries of the proposed additions. The Cotter Basin claim group was being explored by industry during the present investigations, and minor exploration activity was noted at the head of Alice Creek and at the placers in Stonewall Creek (pl. 1). The other prospects show no evidence of recent exploration activity.

Nearby mining districts and some outlying mines south of the proposed additions are described by Pardee and Schrader (1933), Lyden (1948), and Sahinen (1959, p. 136). These include the Marysville district, about 28 miles (45 km) southeast of the additions; the Gould–Stemple Pass district, about 15 miles (24 km) south of the Arrastra addition; and the Heddleston district, about 16 miles (26 km) east of the Arrastra addition. Descriptions and summaries of past production from these districts are included in the Scapegoat Wilderness report (Mudge and others, 1975). Mines and prospects northeast of the proposed additions are discussed by Mudge, Erickson, and Kleinkopf (1968). Prospects in the Scapegoat Wilderness to the north and west of the additions are discussed by Tuchek (in Mudge and others, 1975).

Gold and copper have been produced from deposits near the proposed additions to the Scapegoat Wilderness. The most important previously worked deposits include (1) large gold placer deposits in Lincoln Gulch, about 2 miles (3 km) south of the Arrastra addition; (2)

copper deposits in a northwesterly striking vein system adjacent to the northern boundary of the Arrastra addition; and (3) small gold placer deposits in Stonewall, Keep Cool, and Liverpool Creeks, which are adjacent to the southern boundary of the Arrastra addition. About $7 million in gold was obtained from the Lincoln Gulch placer between 1865 and 1871 (Pardee and Schrader, 1933). The copper vein system contains numerous prospects near the northern boundary of the Arrastra addition and in the Scapegoat Wilderness (Mudge and others, 1975). Limited tonnages of copper ore were shipped from the Copper Camp mine during 1917, 1919, and 1920 (Mudge and others, 1975, p. 76), and a minor amount of copper ore was mined from the Cotter Basin Group of prospects as a result of recent exploration activity (G. Kornec, oral commun., 1974). Some of these prospects are discussed in the Scapegoat Wilderness report, and others are discussed and evaluated in this report. Placer deposits in Stonewall, Keep Cool, and Liverpool Creeks are irregular and low grade according to Pardee and Schrader (1933).

METHODS OF EVALUATION

The evaluation of the mineral resource potential of the proposed additions to the Scapegoat Wilderness is based on (1) analyses of rock and stream-sediment samples, (2) geologic mapping, (3) detailed study of prospects and mineral occurrences, and (4) the interpretation of geophysical surveys.

Rock and stream-sediment samples were collected along most ridges and streams during the course of geologic mapping, and the samples were located with respect to an arbitrary metric grid system established for this study (pl. 2). Unbiased rock samples were collected from all rock types in order to determine normal concentrations of the elements critical to the resource evaluation. An unbiased rock sample is one collected randomly from a fresh, unaltered rock that has no visible indication of valuable minerals. The unbiased sample is collected objectively, and it has no basis of selectivity except that it comes from exposed rock. Approximately 70 percent of the rock samples are unbiased. About 30 percent of the samples are biased; they include rocks with visible amounts of economic minerals, pyrite, limonite, or included veinlets, or with any other characteristic that caused the collector to choose the sample in preference to a sample from another rock.

Stream-sediment samples were collected along traverses at intervals of 1 mile (1.6 km) or less and at the confluence with tributary streams. Where possible, the sample was collected from midchannel. Where this was unpractical, the sediment was collected along the side of a stream channel. In the Arrastra addition many samples were collected from dry streams. The sediments were sieved through an

80–mesh screen, and both the coarse and fine fractions were analyzed. The minus-80-mesh fraction consistently contained greater amounts of heavy metals; therefore, the stream-sediment analytical results included in this report are from the analyses of the fine fractions.

All samples were analyzed for 30 elements by a semiquantitative emission spectrographic method. They were analyzed by D. J. Grimes in a mobile laboratory in the field. The precision of the analytical method has been documented by Harrison and Grimes (1970). The samples were also analyzed for copper, lead, zinc, gold, and mercury by atomic absorption methods, in the Denver laboratories of the U.S. Geological Survey, by R. W. Leinz, D. J. Grimes, and J. D. Sharkey. In addition, stream-sediment samples were analyzed for copper, lead, and zinc extracted in a 0.8 N nitric acid solution in the Denver laboratories, also by Leinz and Grimes. This analytical method, hereinafter referred to as "extractable copper, lead, or zinc," measures only the most soluble part of the metal present in the sample. This part is most likely to be related to base-metal dispersion patterns; therefore, it is more significant in the determination and evaluation of anomalies than is the total value of the metal. The total value includes values for both the metal that is tightly bound in the crystal lattice of common rock–forming minerals and the metal in the more soluble, "loosely bound" form. The latter is redistributed in solution (hydromorphic) in ground and surface waters and is finally absorbed or precipitated on clay or silt-size particles included in the sediments.

All analytical data were entered into the RASS II computer storage system by L. O. Wilch and are available on tape (Grimes and others, 1976). The analytical results for selected elements critical to the mineral evaluation are given in tables 1 and 2.

The background value for each selected element in stream sediments and for the major rock types sampled was chosen as that concentration found at the fiftieth percentile cumulative frequency.

The threshold value, which is defined as the upper limit of background, above which the values are considered to be anomalous, was arbitrarily chosen as twice the background value. Thresholds for the elements in stream sediments and different rock types are given in table 3.

Threshold values for some elements in table 3, such as copper, vary considerably with rock type. For example, carbonate rocks have a copper threshold of 10 ppm (parts per million), whereas Precambrian diorite sills have a copper threshold of 480 ppm. Hence a carbonate rock containing 200 ppm copper is highly anomalous, but a diorite rock containing the same concentration of copper—200 ppm— is sub-

TABLE 1.— *Partial list of the analyses of stream-sediment samples*

[All values in parts per million. Lower limits of detection; xCu, xPb, and xZn = 1; Cu, Pb, and Zn = 5; Hg = 0.05. N, not detected; L, present but less than limit of determination; G, greater than value shown. Leaders (. . .) indicate no data. Analytical methods: xCu, xPb, and xZn by 0.8 *N* nitric acid leach–atomic absorption; Cu, Pb, and Zn by concentrated nitric acid digestion–atomic absorption; Hg by mercury vapor detector; others by emission spectroscopy. Analysts: D. J. Grimes, R. W. Leinz, and J. D. Sharkey]

Sample No.	xCu	xPb	xZn	Cu	Pb	Zn	Hg	Other
S-1	7	3	24	35	10	130	0.06	Mo-L(5)
S-2	6	6	38	35	25	160	.08	
S-3	5	6	24	25	15	120	.04	Mo-L(5)
S-4	5	4	24	40	20	130	.06	
S-10	6	5	22	25	10	70	.04	
S-11	7	3	16	40	10	85	.04	
S-13	3	3	14	35	10	75	.04	
S-15	3	3	12	15	5	60	.02	
S-16	3	1	20	20	L	70	.04	
S-17	5	3	110	20	10	170	.02	
S-18	5	1	14	25	5	70	.04	
S-22	5	2	16	20	10	65	.04	
S-23	7	11	16	25	35	85	.02	
S-24	6	4	18	30	15	90	.04	
S-25	3	2	8	15	5	50	.04	
S-30	5	2	10	20	5	55	.02	
S-31	3	N	12	15	5	50	.02	
S-32	5	4	44	25	15	100	.02	
S-33	18	6	24	100	20	110	.04	
S-34	17	9	54	95	25	170	.04	
S-35	15	5	24	95	20	110	.02	
S-36	10	9	40	35	20	100	.02	
S-37	13	5	26	95	20	110	.04	
S-38	5	5	24	25	20	110	.02	
S-39	6	5	28	20	15	90	.02	
S-40	3	2	20	15	15	65	.02	
S-41	15	3	18	95	20	110	.02	
S-42	5	6	18	25	20	100	.18	
S-43	4	4	18	25	20	100	---	
S-44	5	5	20	25	20	110	.06	
S-45	6	7	40	45	15	220	.08	
S-47	4	3	14	20	15	95	.12	
S-51	5	5	34	20	20	120	.10	
S-53	5	6	15	30	25	120	---	
S-54	8	8	44	35	20	110	.04	
S-55	G(100)	4	12	G(200)	15	60	.08	Ag-1.5
S-56	6	3	10	40	10	60	.02	
S-57	4	4	8	30	10	55	---	
S-58	15	4	26	130	15	120	.04	
S-59	38	62	69	115	140	300	.12	
S-60	40	56	90	135	110	520	.22	
S-61	28	40	44	130	80	270	.22	
S-62	9	8	13	70	30	130	0.16	
S-63	8	7	26	30	20	90	.14	
S-64	9	3	8	120	10	65	.04	
S-65	5	3	12	80	10	65	.04	
S-66	7	5	10	95	10	80	.04	
S-67	5	15	12	70	40	120	.04	
S-68	4	3	6	110	5	65	N	
S-69	9	4	12	120	10	50	.08	
S-70	6	39	6	110	75	65	.02	
S-71	6	3	8	95	5	70	.04	
S-72	7	8	12	35	20	90	.06	
S-74	2	4	12	10	10	45	.02	
S-75	4	6	22	15	15	100	.06	
S-76	4	4	16	15	10	70	.04	
S-77	42	12	36	130	35	120	.20	
S-78	26	9	48	100	30	160	.06	
S-79	47	14	12	160	45	95	.08	Ag-.5
S-80	54	20	16	160	70	70	.06	
S-81	16	13	16	45	30	90	.06	
S-82	17	11	12	75	30	85	.08	
S-83	6	3	12	85	10	65	.02	
S-84	33	5	22	160	15	120	.08	
S-85	12	4	12	190	5	75	.06	
S-86	8	2	4	150	5	60	.02	
S-87	5	2	4	110	5	50	.02	
S-88	5	4	10	40	10	75	.04	
CH-26	17	6	5	50	15	75	---	Ag-L(.5), Mo-L(5)
CH-27	7	6	6	20	10	65	---	Ag-L(.5), Mo-L(5)
33	1	4	4	5	10	55	.14	
34	10	5	5	40	10	60	.12	
35	48	12	13	110	35	70	.22	
36	62	12	12	320	30	85	.06	
37	9	11	13	35	25	80	.14	
449	9	11	19	60	25	79	.11	
482	3	13	6	20	40	70	.20	
483	4	10	16	20	40	140	.08	
500	4	8	17	20	30	95	1.20	
509	2	4	9	15	20	60	.18	
528	2	10	4	15	20	60	.45	
531	3	5	5	35	10	40	.55	
542	2	6	4	10	10	50	.14	

normal and considered unimportant in the mineral-resource evaluation of the area. By including only samples containing elements with concentrations above the threshold values, the anomalous metal occurrences of possible economic significance are more readily apparent (figs. 2–5).

The distribution of total copper values in stream sediments presents an interpretive problem. The variation of total copper in stream sediments draining rock types having a wide range of background values from nonmineralized parts of the area is about the same as the varia-

TABLE 2.— *Partial list of the analyses of rock samples*

[All values in parts per million. Lower limits of detection: Cu, Pb, and Zn = 5; Ag = 0.5; Hg = 0.05. N, not detected; L, present but less than limit of determination; G, greater than value shown. Analytical methods: Cu, Pb, Zn, and Au by atomic absorption; Hg by mercury vapor detector; Ag and others by emission spectroscopy. Analysts: D. J. Grimes, R. W. Leinz, and J. D. Sharkey]

Sample No.	Cu	Pb	Zn	Ag	Hg	Other	Sample No.	Cu	Pb	Zn	Ag	Hg	Other
L-17	260	15	55	N	L		R-1a	10	10	10	N	0.1	
L-20	150	5	85	N	L		R-3	10	20	110	N	.06	
L-23	640	890	65	N	L		R-4	30	100	35	N	.26	Mo-5
L-24	L	10	5	N	L		R-4a	25	85	5	N	.45	
L-27	50	15	60	N	0.06		R-4b	30	230	45	N	2.0	Mo-50
L-28	25	10	50	N	L		R-5	15	10	65	N	.14	
L-29	32,000	40	140	3	.06		R-5a	N	5	60	N	.06	
L-30	160,000	10	130	1.5	.08		R-6	65	10	75	N	L	
L-64	5	L	85	N	L		R-13	N	5	5	N	L	
L-65	1,000	N	60	N	L		R-25	N	5	10	N	.1	
L-67	470	30	250	3	L	Mo-30	R-28	N	5	5	N	L	
L-85	540	30	570	N	L		R-33	10	15	15	N	.1	
L-88	5	L	15	N	.06		R-35	1,100	1,300	20	2	.3	Mo-15
L-89	7,000	10	75	3	.06		R-35a	620	1,400	15	1.5	.55	Mo-150
L-90	8,400	N	130	15	.32		R-35b	610	920	15	1	.45	Mo-100
L-91	4,600	L	140	10	.12	Mo-5	R-35c	10	40	15	N	L	
L-92	25	10	95	N	L	Mo-5	R-36	15	25	60	N	.06	
L-383	L	10	15	N	L		R-37c	250	45	95	N	L	
L-386	10	20	55	N	L		R-37d	10	N	70	N	.1	
CC-2	560	L	85	1.5	.14	Mo-15	R-37e	240	5	60	N	L	
CC-3	230,000	650	200	300	1.1	Mo-100	R-39	5	N	15	N	.06	
CC-5	100,000	3,300	1,300	300	G(10)	Mo-500, Sb-500	R-39b	5	5	55	N	L	
CC-6	7,500	850	90	3	L		R-39c	400	N	40	N	L	
CC-7	520	4,300	60	N	L		R-40a	640	1,100	50	1	L	Au-0.2
CC-8	1,600	35	30	N	L		R-47	N	5	5	N	.08	
CM-1	40	50	45	N	L		R-50	N	5	25	N	.06	
B-64	430	160	120	N	L		R-55	N	10	85	N	L	
B-67	520	10	45	N	L		R-56	340	N	35	N	L	
B-73	L	L	80	N	L		R-57	N	5	5	N	.06	
B-77	5	N	85	N	L		R-62	5	15	10	N	L	
B-380	5	L	10	N	L		R-63	L	N	10	N	.08	
B-397	35	430	440	.5	.5	Mo-7	R-65	80	40	85	N	L	
B-400	10	25	110	N	L		R-66	10	120	130	N	L	
B-401	L	5	30	N	.06		R-67	5	5	110	N	.14	
B-406	5	5	20	N	L		R-68	L	N	10	N	L	
B-450	5	5	25	N	.06		R-74	N	N	10	N	L	
B-451	L	20	100	N	.06		R-76	95	5	10	N	.06	
B-453	20	100	70	N	.14		R-77	L	5	10	N	.08	
B-455	5	15	30	N	L		R-78	N	5	5	N	L	
B-458	L	10	15	N	L		R-80	10	70	40	N	.08	
B-462	L	10	35	N	L		R-81	95	5	30	N	L	
B-463	L	10	15	N	L		R-82	10	10	35	N	L	
B-468	L	5	60	N	L		R-82a	20	40	30	N	L	
B-494	140	15	25	L	.4		R-83	65	5	70	N	L	
R-1	10	10	20	N	.06		R-84	5	N	20	N	.06	
R-84a	65	5	75	N	0.06		R-214	85	L	95	N	L	
R-85	5	10	30	N	.06		R-216	30	5	40	N	L	
R-86	45	55	30	N	L		R-217a	L	10	60	N	0.2	
R-88	5	10	640	N	.2		R-220	5	5	25	N	.08	
R-114	15	60	35	N	L		R-221	10	10	15	N	.06	
R-118	L	70	35	N	N		R-223	10	10	35	N	L	
R-118a	40	100	45	1	L		R-224	10	15	840	N	.2	
R-119b	N	5	110	N	N	Y-700	R-225	5	15	90	N	.06	
R-123a	55	15	60	N	N		R-226	25	25	25	N	L	Nb-50
R-124	110	L	85	N	L		R-227	5	20	35	N	L	Nb-50
R-125	5	5	20	N	L		R-228	5	30	60	N	N	Nb-70
R-130	45	10	30	N	L		R-229	20	N	35	N	.8	

TABLE 2.— *Partial list of the analyses of rock samples*—Continued

Sample No.	Cu	Pb	Zn	Ag	Hg	Other
R-132	25	20	60	N	.24	
R-133	N	5	60	N	L	
R-134	5	10	20	N	L	
R-138	210	25	75	N	L	
R-138a	520	120	50	1	.16	
R-146	5,600	L	5	7	.22	
R-146a	2,500	N	10	5	.3	
R-147	20	5	35	N	L	
R-148	5	L	35	N	L	
R-151	10	5	25	N	.1	
R-152a	5	20	20	N	L	
R-156	150	420	55	N	N	Mo-20
R-158	470	30	100	5	L	Au-9.5, W-70
R-158a	390	15	110	2	L	Au-14
R-158b	75	10	80	.5	L	Au-1.5
R-158c	21,000	N	55	N	N	
R-159	160	L	35	N	N	
R-164	20	10	30	N	L	
R-166	55	5	35	N	N	
R-167	L	5	140	N	L	
R-189a	50	3,000	70	.5	L	
R-189b	330	110	70	N	L	
R-194	1,100	10	45	N	L	
R-199a	160	240	210	N	N	
R-200	L	15	25	N	N	
R-200a	10	470	70	5	N	
R-207	N	N	55	N	.12	
R-208	5	5	25	N	.12	
R-209	L	15	30	N	L	
R-210	35	10	120	N	L	
R-230	20	20	20	N	.2	
R-231	10	20	20	N	.06	
R-233	120	500	200	N	L	Mo-15
R-239	35	L	10	N	L	
R-242	130	5	95	N	L	
R-245	200	N	20	N	L	
R-261a	20	60	60	N	L	Mo-10
R-261b	20	15	75	N	N	Mo-5
R-265	30	110	65	.7	N	Mo-30
R-267	50	250	35	1	N	
R-268	250	N	15	N	N	
R-268a	20	5	10	N	N	
R-270	80	5	L	N	N	
R-272	5	N	35	N	N	
R-275	N	5	20	N	N	
R-276a	25	280	35	N	N	
R-280	5	10	40	N	N	
R-281	700	10	25	1.5	.3	Mo-L(5)
R-282	5	10	50	N	L	
R-283	N	5	50	N	L	
R-284	20	20	20	N	.06	
R-285	30	250	20	N	.08	
R-286	5	55	50	N	.08	
R-286a	5	65	190	N	.45	
R-289	5,400	10	70	1.5	.08	
R-289a	16,000	45	95	10	2.0	Mo-10
R-289b	53,000	480	1,100	70	G(10)	Mo-30, Au-.6
R-290	160	10	25	N	.08	
R-291	20	10	35	N	L	

tion of total copper in sediments draining mineralized and nonmineralized rocks. Therefore, the map showing the distribution of total copper (fig. 3) was evaluated in the context of the geologic map (pl. 1) and of the maps showing the distribution in stream sediments of extractable copper (fig. 4) and the ratio of extractable copper to total copper (fig. 5).

COPPER

Copper minerals were observed in a variety of rock types within and near the boundaries of the proposed additions to the Scapegoat Wilderness. The distribution of anomalous copper values in rocks is shown in figure 2. Copper minerals are in (1) carbonate veins and adjacent rocks in the lower part of the Helena Formation, (2) the basal calcareous sandstone of the Helena Formation, (3) quartzite units in the Empire Formation, (4) green siltite units in the Empire and Snowslip Formations, (5) stromatolitic and oolitic carbonate rocks in the Helena and Shepard Formations, and (6) gold-bearing shear zones in diorite sills. The potential for economic deposits of copper is moderate in the carbonate veins and adjacent rocks, moderate to low in the basal calcareous sandstone unit of the Helena, and low in the other occurrences.

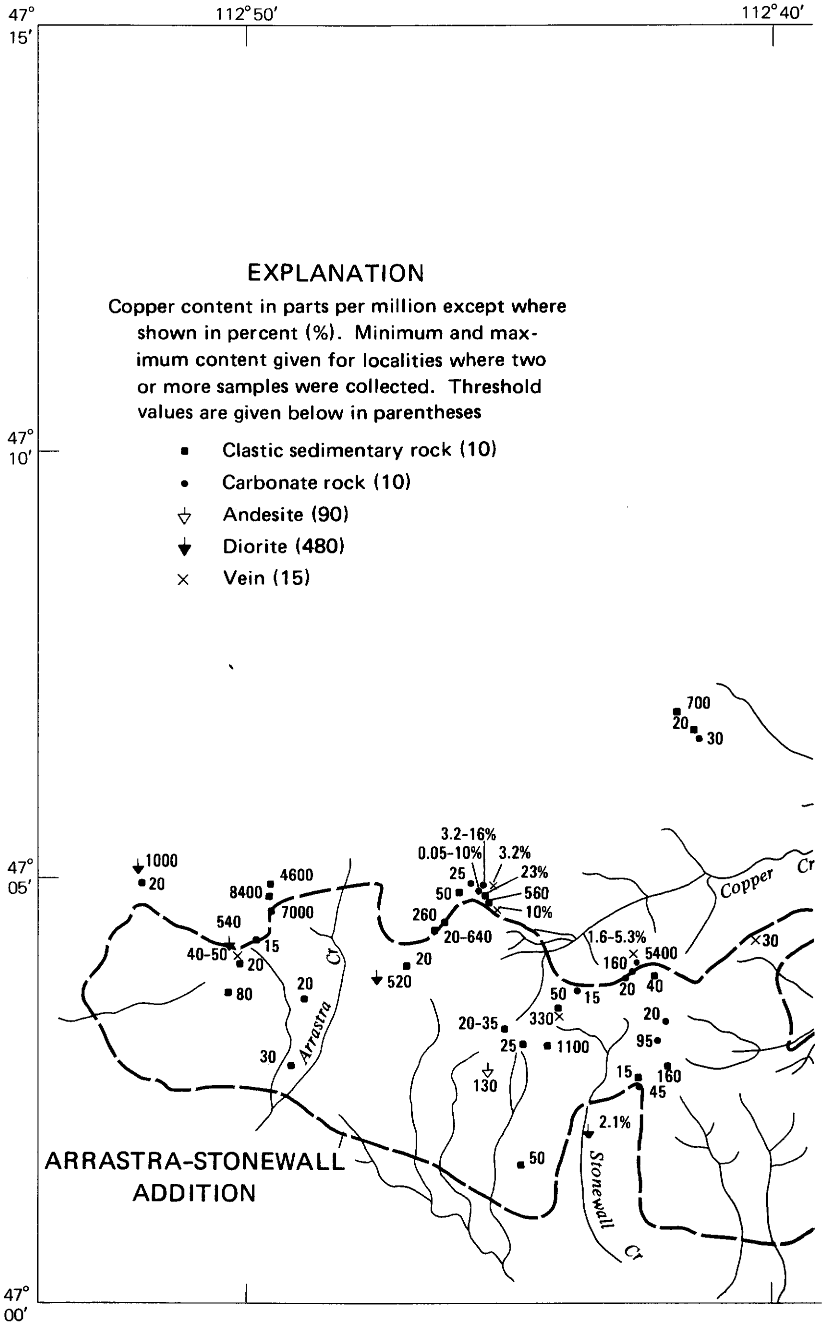
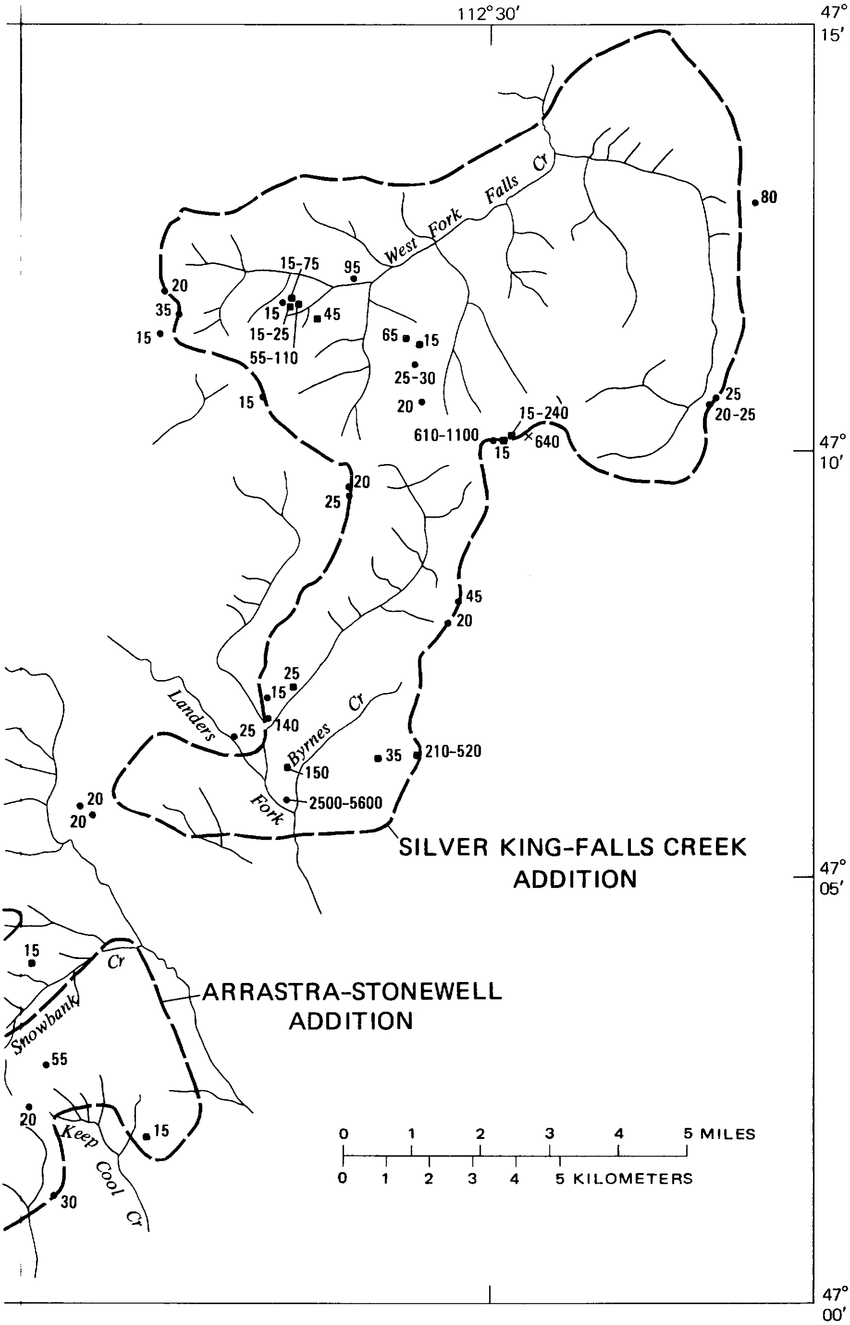


FIGURE 2.— Rock samples containing copper



in amounts greater than the threshold value.

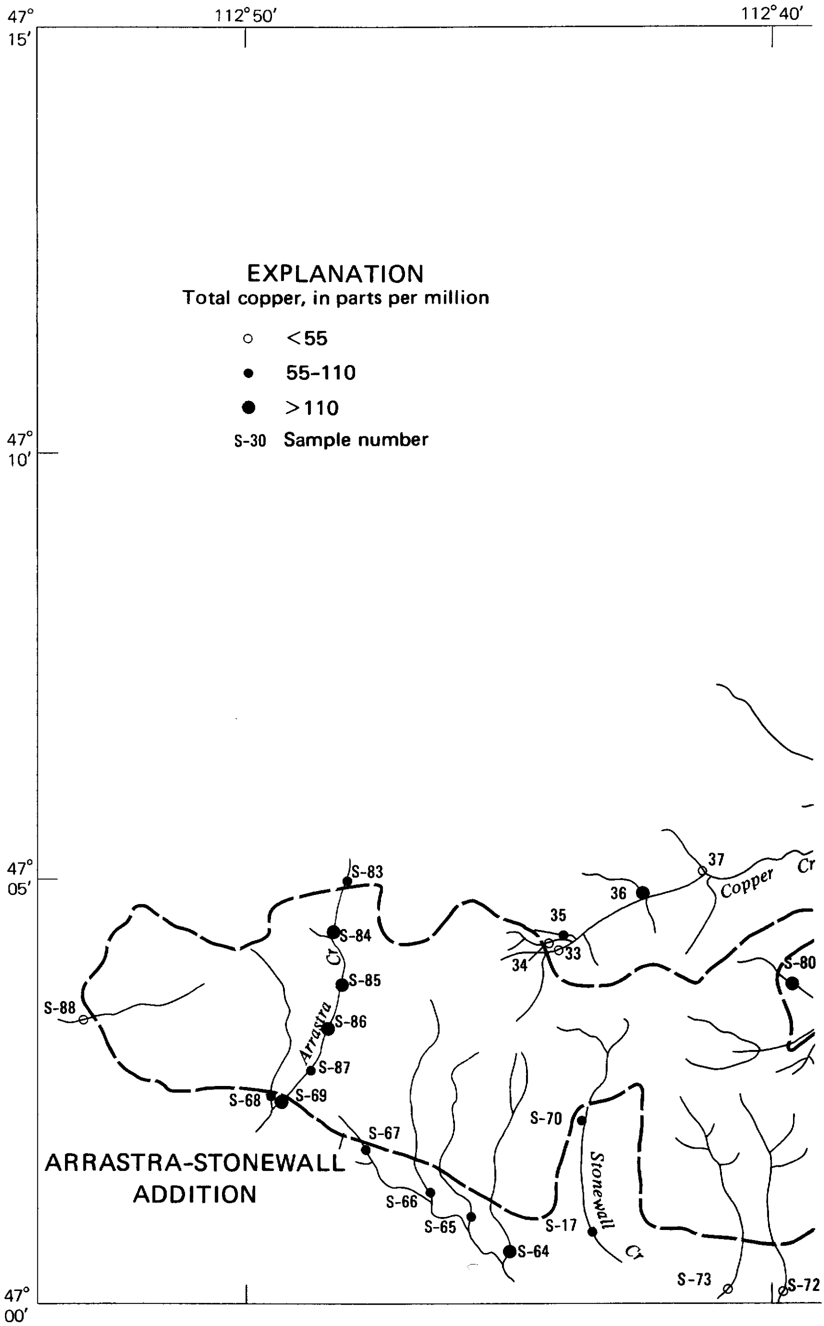
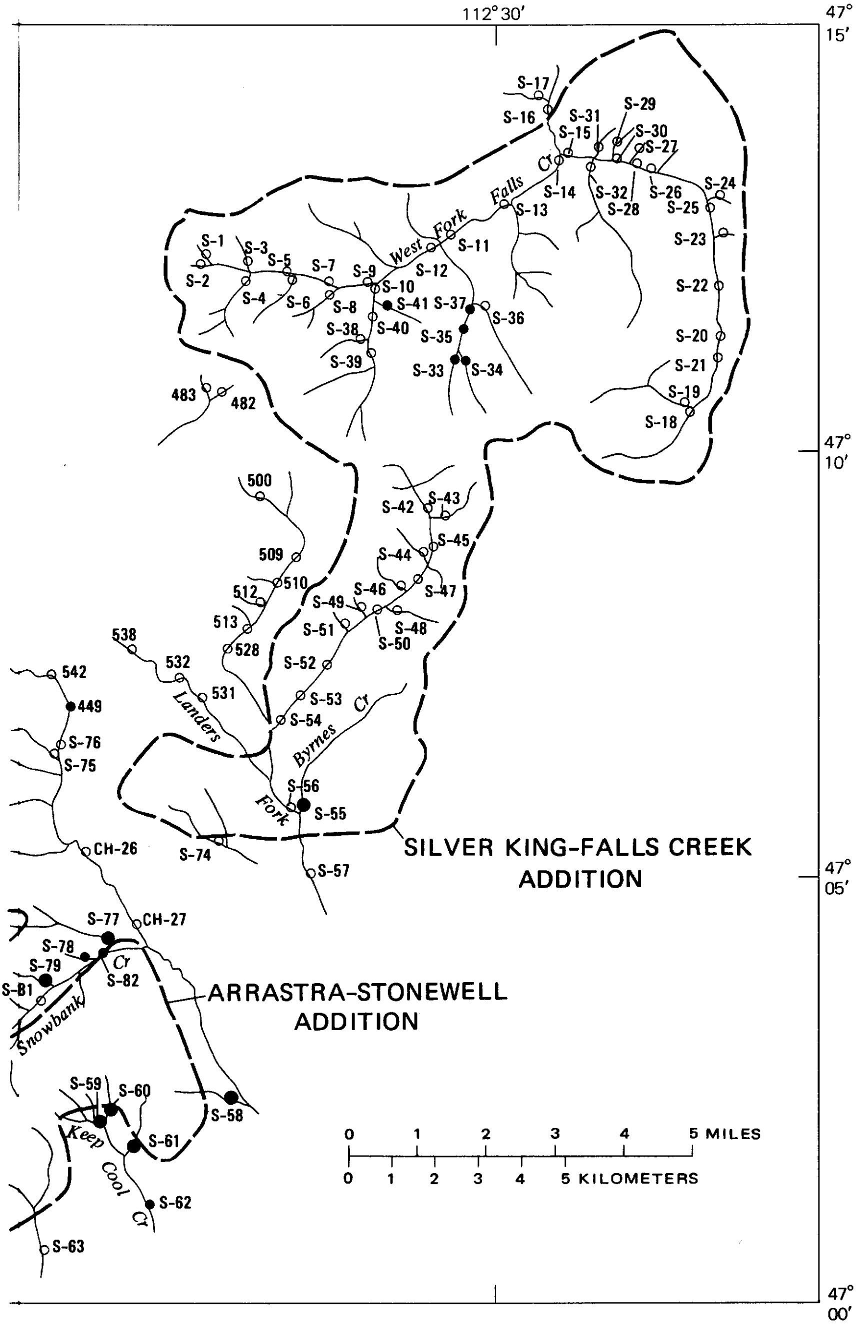


FIGURE 3.—Distribution of total



copper in stream sediments.

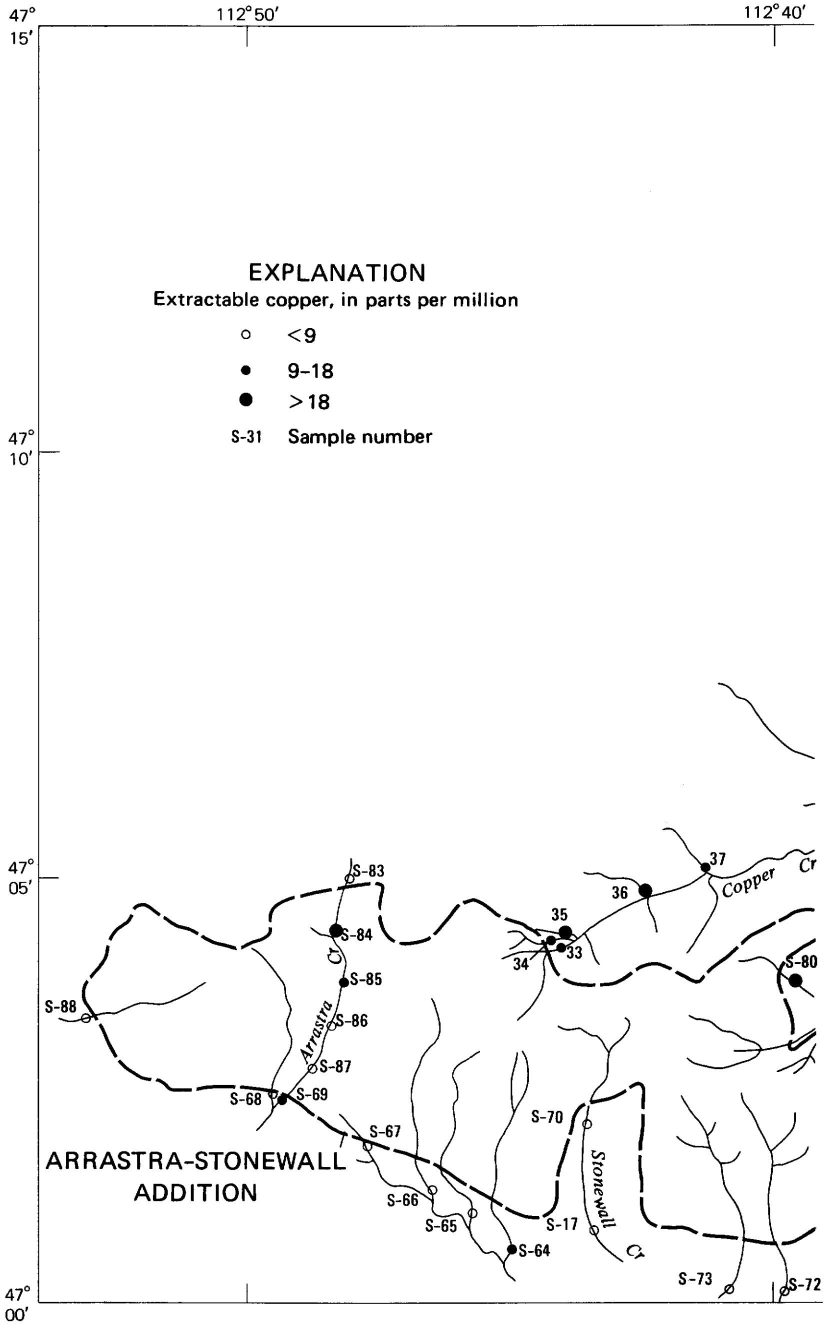
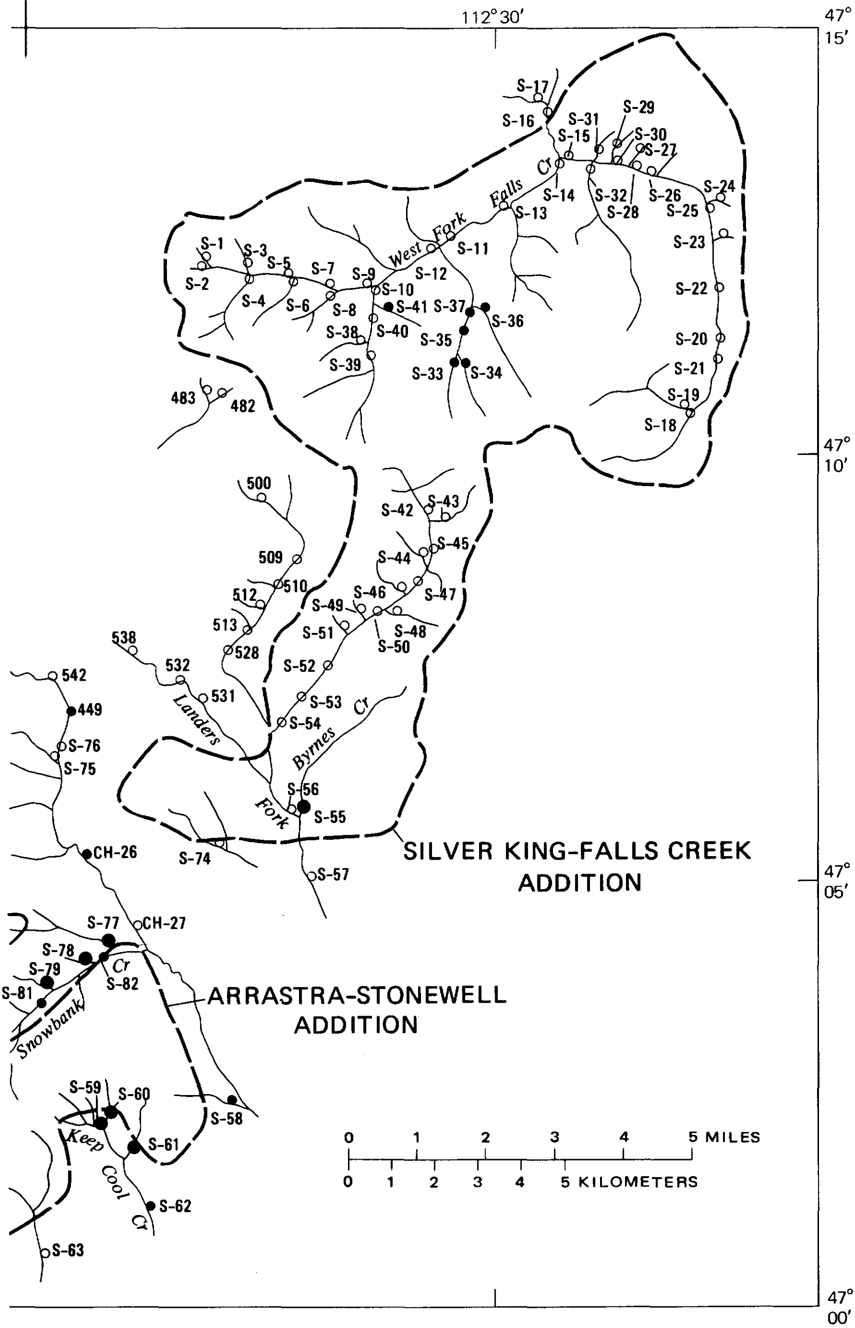


FIGURE 4.— Distribution of extractable



copper in stream sediments.

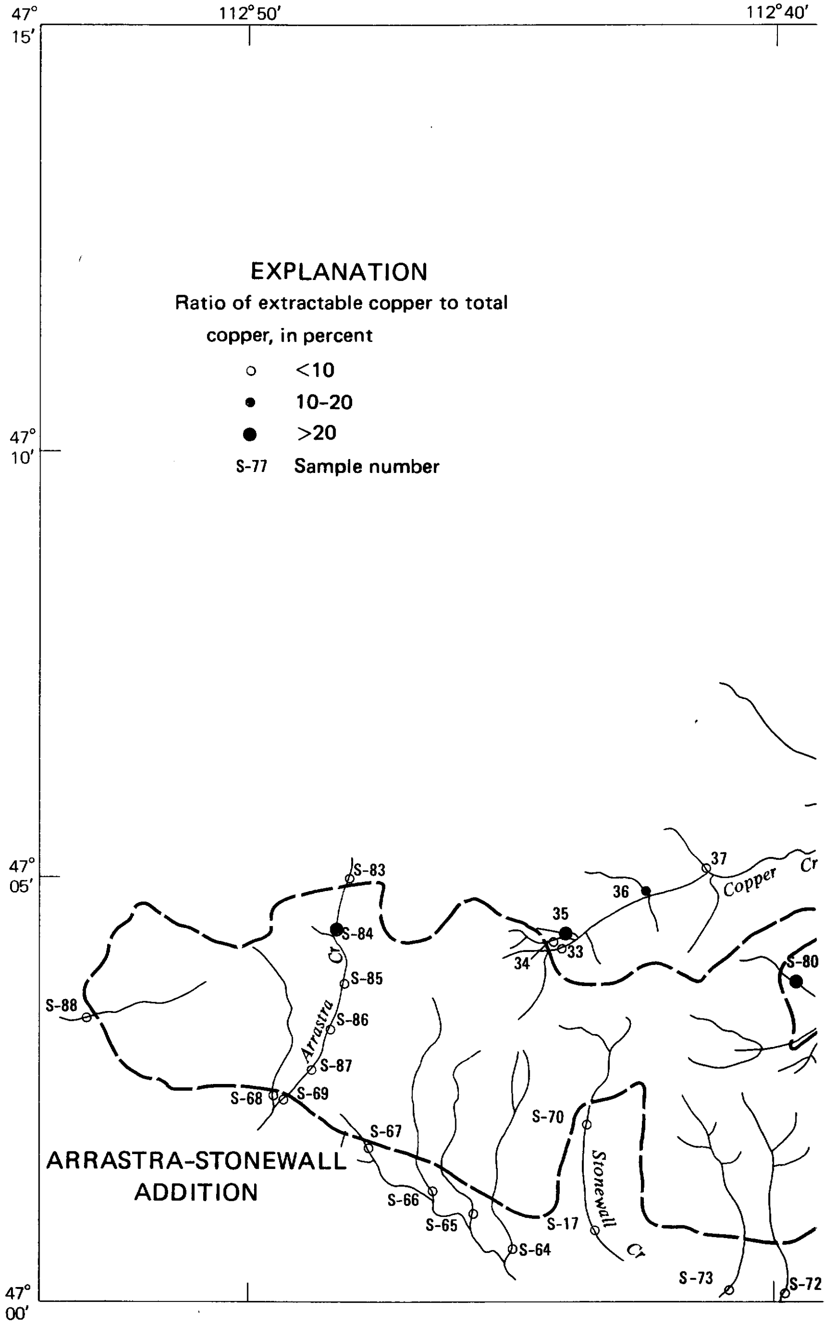
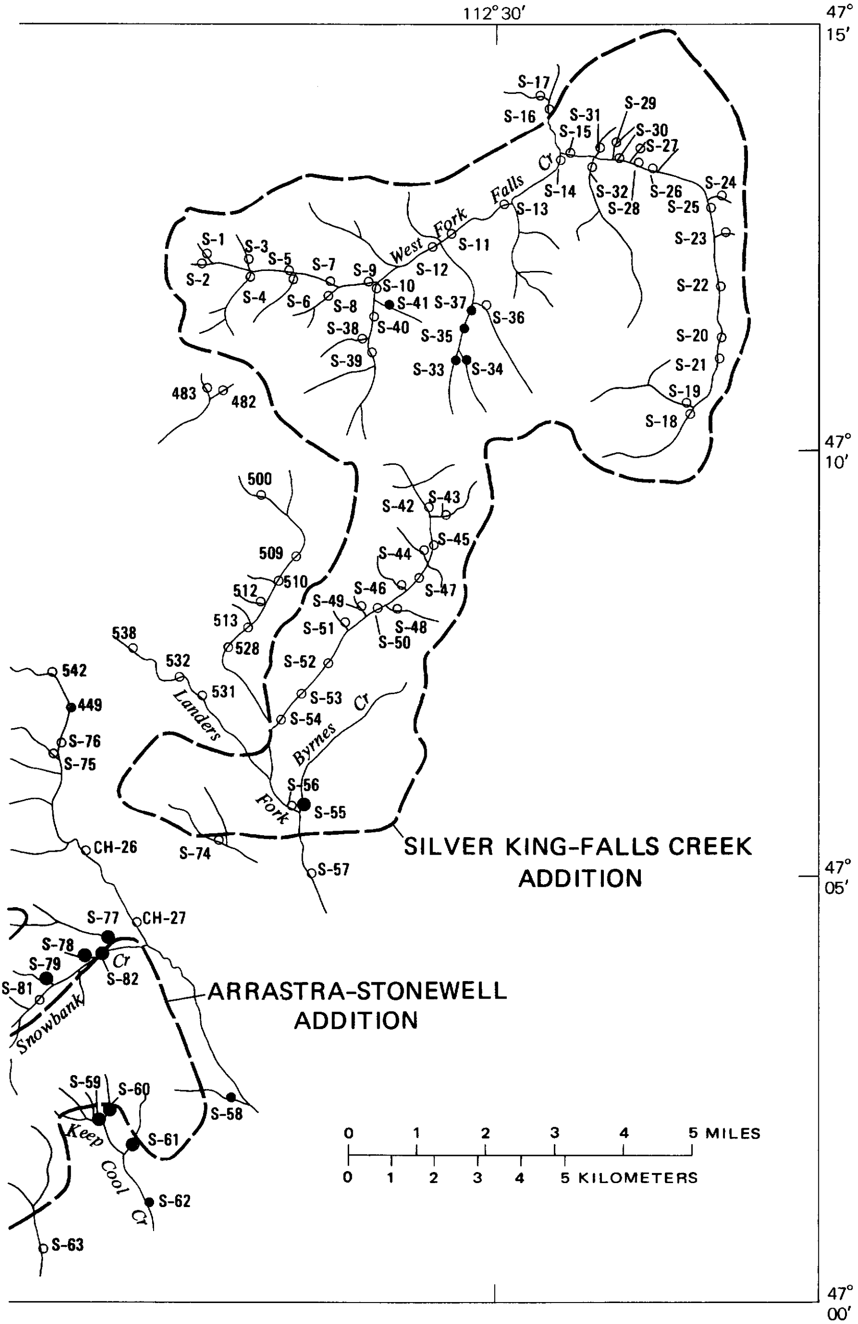


FIGURE 5.— Distribution of the ratio of extractable copper to total



copper in stream sediments (for samples containing >54 ppm copper).

TABLE 3.— *Threshold values for element sample-type pairs*

[Values in parts per million. xCu, xPb, and xZn determined by 0.8 *N* nitric acid extraction. Analyzed by D. J. Grimes and R. W. Leinz. Leaders (...) indicate no data]

Sample Type	xCu	xPb	xZn	Cu	Pb	Zn	Hg
Stream sediments	9	7	28	55	25	140	0.08
Clastic sedimentary rocks	---	---	---	10	10	10	.04
Carbonate rocks	---	---	---	10	15	15	.06
Andesite	---	---	---	90	10	10	.04
Diorite	---	---	---	480	10	10	.04
Vein	---	---	---	15	10	10	.04

VEIN-TYPE DEPOSITS

Cupriferous carbonate veins as much as 3 feet (0.9 m) thick are exposed in prospects of the Cotter Basin claim group and at Copper Camp, which is less than 0.5 mile (1 km) north of the Arrastra addition (pl. 1). The veins occupy northwesterly striking shear zones, dip about 85° N. at Copper Camp, and dip 25° to 55° SW. at the Cotter Basin mine. Thus, a downdip extension of the veins is probably present at moderate depth within the Arrastra addition adjacent to the Cotter Basin mine (fig. 6). The exposed veins are within the Helena and Empire Formations at Copper Camp and within the Helena Formation in the Cotter Basin mine area. Locally, the sheared wallrocks contain significant amounts of copper and associated economic minerals over a zone as much as 10 feet (3 m) wide.

The most abundant copper mineral is bornite, followed by chalcocite, azurite, malachite, and chalcopyrite. An unidentified silver mineral, galena, minor sphalerite and molybdenite, and traces of gold are locally associated with the copper minerals. One sample (CC–5) from the Copper Camp area contained an anomalous amount of antimony. In addition, the veins contain anomalous amounts of mercury. The copper and associated metallic minerals in the veins occur as vugs and large, irregular sulfide masses in a matrix of calcite and minor quartz. Adjacent to the veins the metallic minerals are commonly richly disseminated in the sheared host rocks. The grade of the material and an economic evaluation are included in the section on the Cotter Basin mine (p. 50). The geochemistry of the soils overlying the veins is included in an open-file report (Grimes and Earhart, 1975).

The veins near the Arrastra addition are a part of a closely spaced vein system that very likely extends over a strike length of about 15

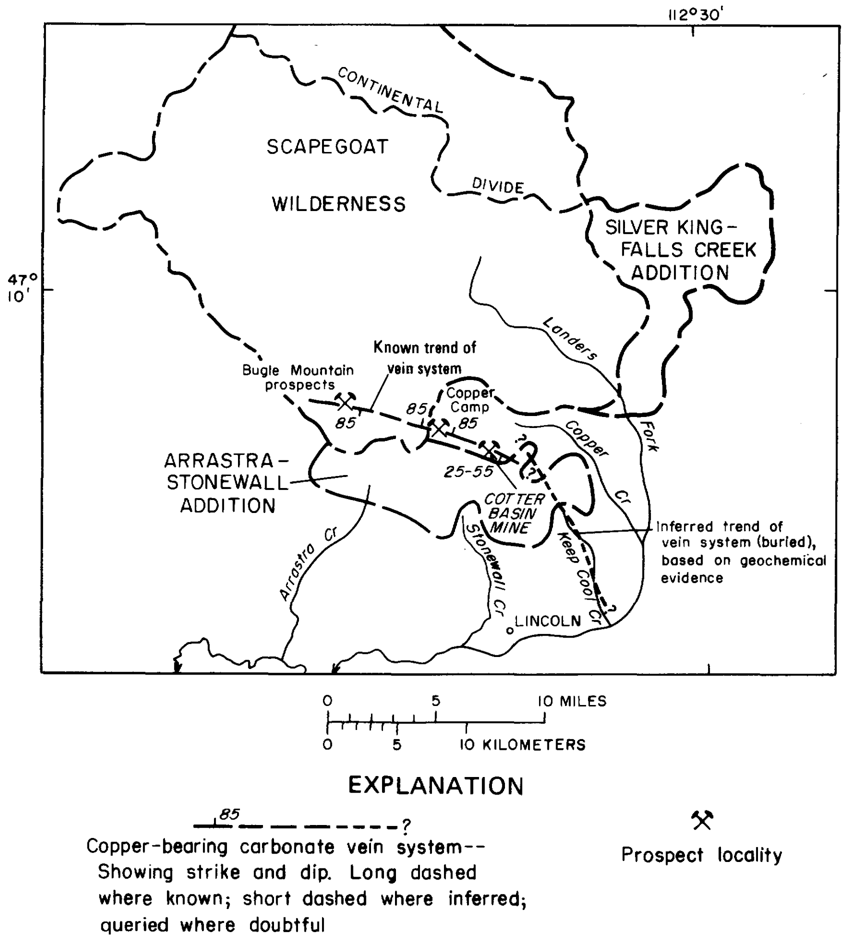


FIGURE 6.— Map of part of the Scapegoat Wilderness and proposed additions, showing the known and inferred trends of the copper-bearing carbonate vein system.

miles (24 km) from near the western boundary of the Scapegoat Wilderness (Mudge and others, 1975) southeast to the Cotter Basin area, then through the eastern part of the Arrastra addition near Keep Cool Creek (fig. 6). A continuance of the vein system to the southeast of the Cotter Basin area has not been observed, but the geochemical data presented in a following discussion indicated that the vein system persists to the southeast and is very likely present at a shallow depth in the eastern part of the Arrastra addition. At most localities, the vein system is too poorly exposed to determine the number of veins included or the width of the mineralized zone in the wallrock; however, at a prospect on Bugle Mountain in the Scapegoat Wilderness, the width, including disseminated copper minerals in the wallrock, is 110 feet (33.5 m; Mudge and others, 1975). The distribution of copper is erratic over this width, and it appears to be highly discontinuous over the entire length of the vein system.

The distribution of total copper in stream sediments (fig. 3) indicates widespread anomalous values in the Arrastra addition. Anomalous values that may indicate the presence of copper deposits are shown by the distributions of total copper (fig. 3) and extractable copper (fig. 4) and by the ratio of extractable copper to total copper (fig. 5) in stream sediments. Figures 4 and 5 show the amount of extractable copper and the ratio of extractable copper to total copper and indicate that the high total copper values (fig. 3) from streams in south-central and western parts of the Arrastra addition reflect the diorite sill exposed in the drainage catchment area. Sediment sample S–86 (figs. 3, 4), for example, contains 150 ppm total copper but only 8 ppm extractable copper, suggesting that most of the copper is probably in the lattice of the mafic minerals of the diorite.

Sediment samples from the north-central and the eastern parts of the Arrastra addition contain anomalous amounts of both total and extractable copper (figs 3, 4) and relatively high ratios of extractable copper to total copper (fig. 5). Sediment sample S–80 (figs. 3, 4), for example, contains 160 ppm total copper and 54 ppm extractable copper, which indicate that a relatively high proportion of the copper is derived from sulfide minerals. Other stream-sediment analyses show anomalies of total copper and extractable copper along Copper, Snowbank, and Keep Cool Creeks (figs. 3–5). These anomalies support the conclusion that the southeastern extension of a vein system containing copper sulfide minerals continues through the eastern part of the Arrastra addition. The vein system probably occupies the approximate position of the fault that parallels Keep Cool Creek (pl. 1). The change from a westerly to northwesterly trend of the vein system, as reflected by stream-sediment anomalies in the eastern part of the Arrastra addition, is coincident with a change of fault trends. Structural controls are also evident at the Cotter Basin and Copper Camp occurrences. Alternatively, the vein system inferred to occupy the northwesterly trending fault along Keep Cool Creek (pl. 1) may be a separate, but related, system.

Although the copper-bearing carbonate veins are likely present in the Arrastra addition both on a downdip extension of the exposures at the Cotter Basin mine and along a southeasterly strike extension of the vein system, existing evidence is not sufficient to indicate whether the veins contain minable concentrations of copper ore. Such data can be obtained only by subsurface exploration, which is beyond the scope of this study. Where the veins are exposed in prospects outside the addition, the occurrences of high-grade copper ore are erratic and, judged on the basis of these data, the copper deposits appear to have submarginal to paramarginal potential. Therefore, the potential for economic deposits of copper in unexposed parts of the vein system within the Arrastra addition is considered to be moderate. The potential may be greatest where the carbonate veins intersect copper-bearing sedimentary rocks, such as the basal sandstone unit of the Helena Formation or the quartzite units of the Empire Formation. Copper from the vein system may enrich the deposits inherent in the sedimentary rocks, and remobilization associated with the hydrothermal activity that produced the veins could result in higher concentrations and greater continuity of ore-grade material. This possibility is suggested by the copper occurrences at Bugle Mountain in the Scapegoat Wilderness (Mudge and others, 1975), where the most significant copper deposits are concentrated near the intersection of the vein system and cupriferous Belt strata.

The magnetic anomaly (3) on plate 1 and the small unmapped exposure of quartz monzonite at the Cotter Basin mine suggest that a stock may be present at depth. Detailed geophysical studies followed by drilling would be required to determine the presence, depth, size, and composition of the stock. The present data are insufficient to evaluate the economic potential for copper in this hypothetical intrusive rock.

DEPOSITS IN CALCAREOUS SANDSTONE

In the Silver King addition the basal calcareous unit of the Helena Formation commonly contains anomalous amounts of copper, lead, zinc, and silver. At some places, such as sample locality R–146 (pl. 2; fig. 2), copper is the most abundant valuable element, 5,600 ppm; at others, such as sample locality R–35 (pl. 2), lead is the most abundant, 1,400 ppm. This unit contains disseminated copper minerals in the Scapegoat Wilderness to the west of the Silver King addition (Mudge and others, 1975), and it is the principal host to lead-zinc occurrences in a northwesterly trending belt about 18 miles (29 km) long, north of the Silver King addition (Mudge and others, 1968).

The basal sandstone is medium grained, is poorly sorted, and has a calcareous matrix that locally contains disseminations of bornite, malachite, galena, and sphalerite. At most localities the combined grade of the chalcophile elements is submarginal. The sandstone commonly occurs as lenses as much as 200 feet (61 m) long and 2–7 feet (0.6–2.1 m) thick. These occurrences have low resource potential because of their small size and low grade.

The calcareous sandstone unit may be as much as 12 feet (3.7 m) thick where it is exposed near the confluence of Byrnes Creek and Landers Fork (pl. 1). Here the above-normal thickness of the unit may be a result of deformation associated with the normal fault that parallels Landers Fork. A rock sample from this locality (R−146) contained 5,600 ppm copper and 7 ppm silver, and the stream sediment (S−55) collected near the confluence of the streams contained more than 200 ppm copper and 1.5 ppm silver (figs. 2, 3). Widely scattered exposures of copper-bearing basal sandstone are near the fault located about 2 miles (3 km) to the north and near the boundary between the Scapegoat Wilderness and the Silver King addition (Mudge and others, 1975). Outcrops are too sparse between these localities to determine continuity, thickness, and grade of the basal unit; however, the indicated thickness and grade near Byrnes Creek and the possible continuation of copper mineralization for about 2 miles (3 km) to the north suggest that this occurrence may have moderate resource potential.

OTHER COPPER DEPOSITS

The potential for discovering minable copper deposits in other rock units within the Silver King and Arrastra additions is low. Quartzite units in the Empire Formation commonly contain disseminated bornite and malachite, but they are thin and the copper is too low grade to be of economic interest. The quartzite units may have greater potential where they are intruded by copper-bearing carbonate veins.

Green quartzites, siltites, and argillites of the Belt Supergroup commonly contain disseminated occurrences of bornite, chalcocite, and chalcopyrite and anomalous amounts of silver (Mudge and others, 1975; Harrison, 1974), but they are not known to contain economic deposits. The green siltites of the Snowslip, Empire, and Spokane Formations in the Arrastra and Silver King additions contain copper occurrences at several localities, such as those represented by samples R−194 and R−281 (pl. 2), which have copper values of 1,100 ppm and 700 ppm, respectively. The resource potential of these occurrences is low because they are highly localized and low grade. Like quartzites of the Empire Formation, the potential for economic deposits in the cupriferous green beds should be higher where they are intruded by the carbonate veins.

Small amounts of chalcopyrite are in some stromatolitic and oolitic limestone samples from the Helena and Shepard Formations. In most samples, galena or sphalerite is the most abundant economic sulfide mineral. The deposits are highly localized and low grade and, thus, have a very low potential for production.

A gold-bearing shear zone at the Giant prospect by Stonewall Creek, south of the Arrastra addition, contains localized occurrences of chalcocite and malachite. Sample R−158 c (pl. 2) has more than 2 percent copper, but other samples from this locality contain normal copper values for the diorite host rock. The prospect is of interest because of the gold content of the rocks, but it has a low copper potential.

LEAD AND ZINC

The proposed additions to the Scapegoat Wilderness have a low potential for lead and (or) zinc deposits. Galena and minor amounts of sphalerite are associated with copper sulfide minerals in the carbonate vein system. Lead and possibly zinc might be recovered if any of the vein deposits were mined for their copper content.

Galena is locally the most abundant sulfide in the basal calcareous sandstone of the Helena Formation; however, its occurrences are too small to be of economic interest.

Green siltites of the Snowslip, Empire, and Spokane Formations locally contain anomalous amounts of lead associated with copper minerals (B−64, pl. 2; figs. 2, 7) and, rarely, galena is more abundant than the copper minerals (R−189, pl. 2; figs. 2, 7). At some localities in the Spokane Formation, the green beds contain anomalous amounts of lead and only normal amounts of copper (R−256, pl. 2; fig. 7).

The distribution of total lead in stream sediments (fig. 8) indicates anomalous values in the eastern part of the Arrastra addition. These values reflect the association of galena with the copper sulfide minerals in the carbonate vein system and are supporting evidence indicating an extension of the vein system through the eastern part of the addition. The extractable lead values are not shown on a distribution map, because the anomalous values show the same pattern as the anomalous values of total lead; however, the extractable lead values are included in table 2.

Most anomalous lead values in the northwestern part of the Silver King addition (fig. 7) are from carbonate rocks that contain stromatolitic or oolitic debris. Locally, such as at sample locality B−397 (pl. 2; table 2), the carbonate rocks also contain weakly anomalous amounts of zinc and silver. The anomalous zinc values are not shown on a distribution map because relatively few values were obtained; however, zinc values are included in table 2. The occurrences described above are not of economic importance because of their small size and low grade.

SILVER

The proposed additions to the Scapegoat Wilderness do not contain potential deposits in which silver is of chief economic value. Silver was analyzed in all samples by a spectrographic method for which the lower limit of detection is 0.5 ppm. Silver is in amounts of as much as 300 ppm in samples of the carbonate veins to the north of the Arrastra addition and in amounts of as much as 7 ppm in samples of the basal calcareous sandstone of the Helena Formation in the Silver King addition (CC−3, CC−5, R−146, table 2; pl. 2; fig. 9). These modes of occurrence are the apparent source of the silver in the two stream-sediment samples (S−55, S−79, pl. 2; fig. 9) that contained detectable amounts

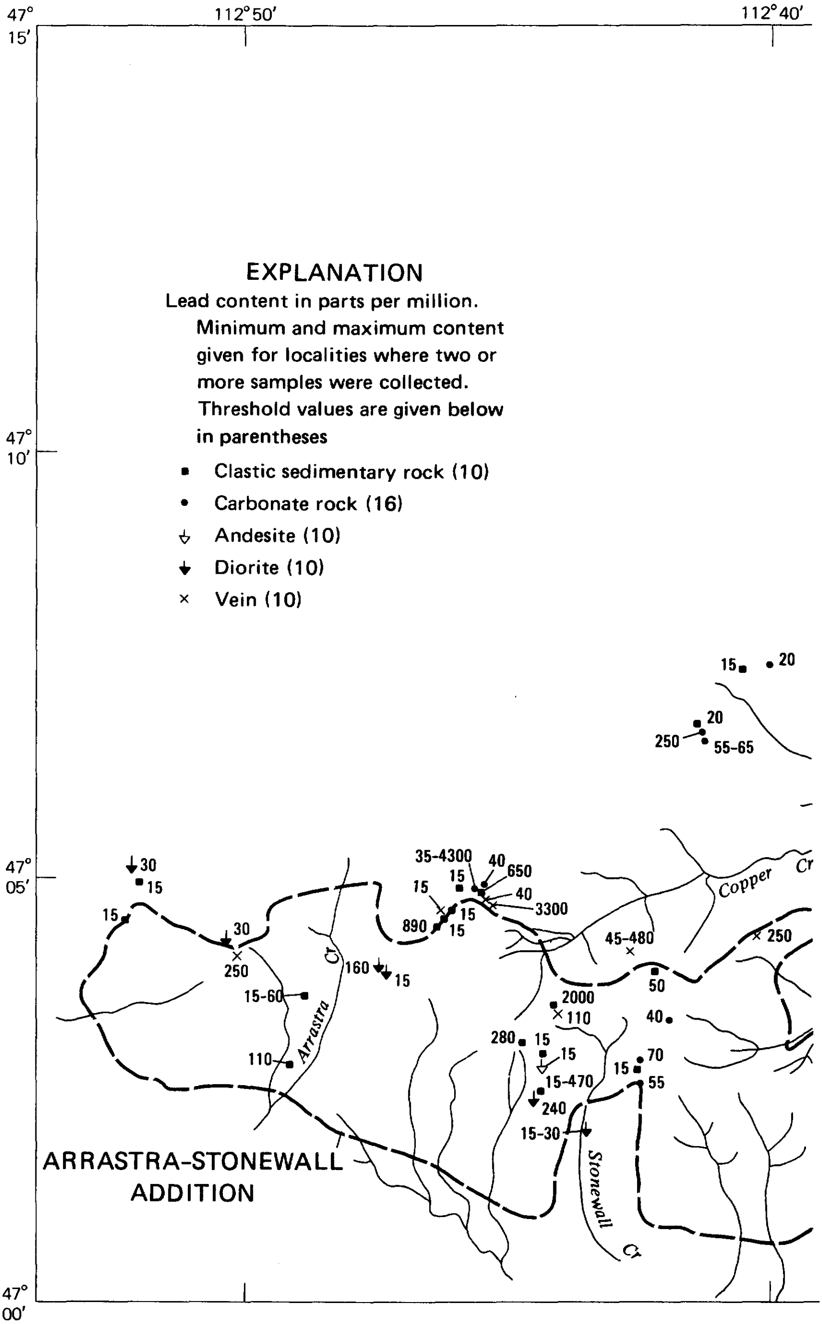
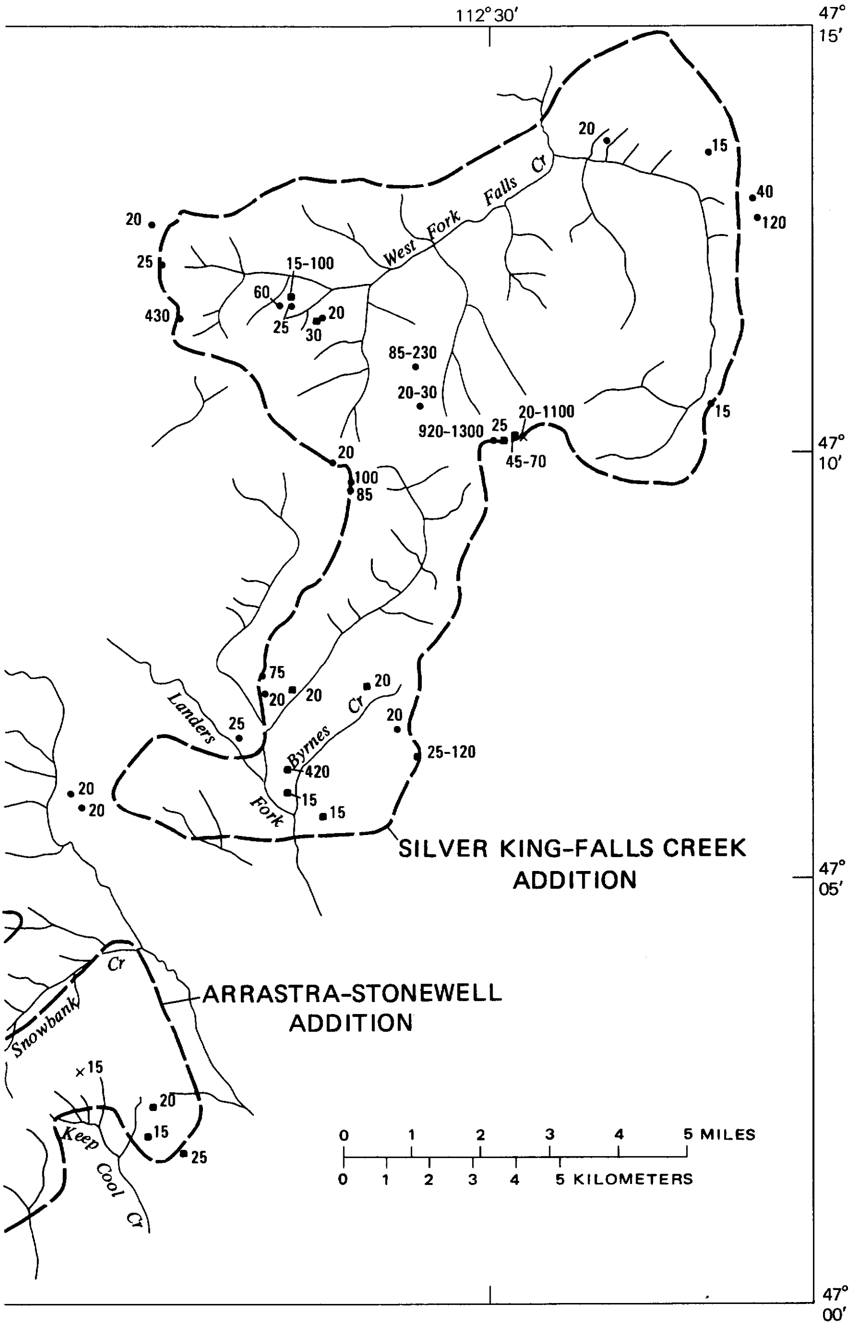


FIGURE 7.— Rock samples containing lead



in amounts greater than the threshold value.

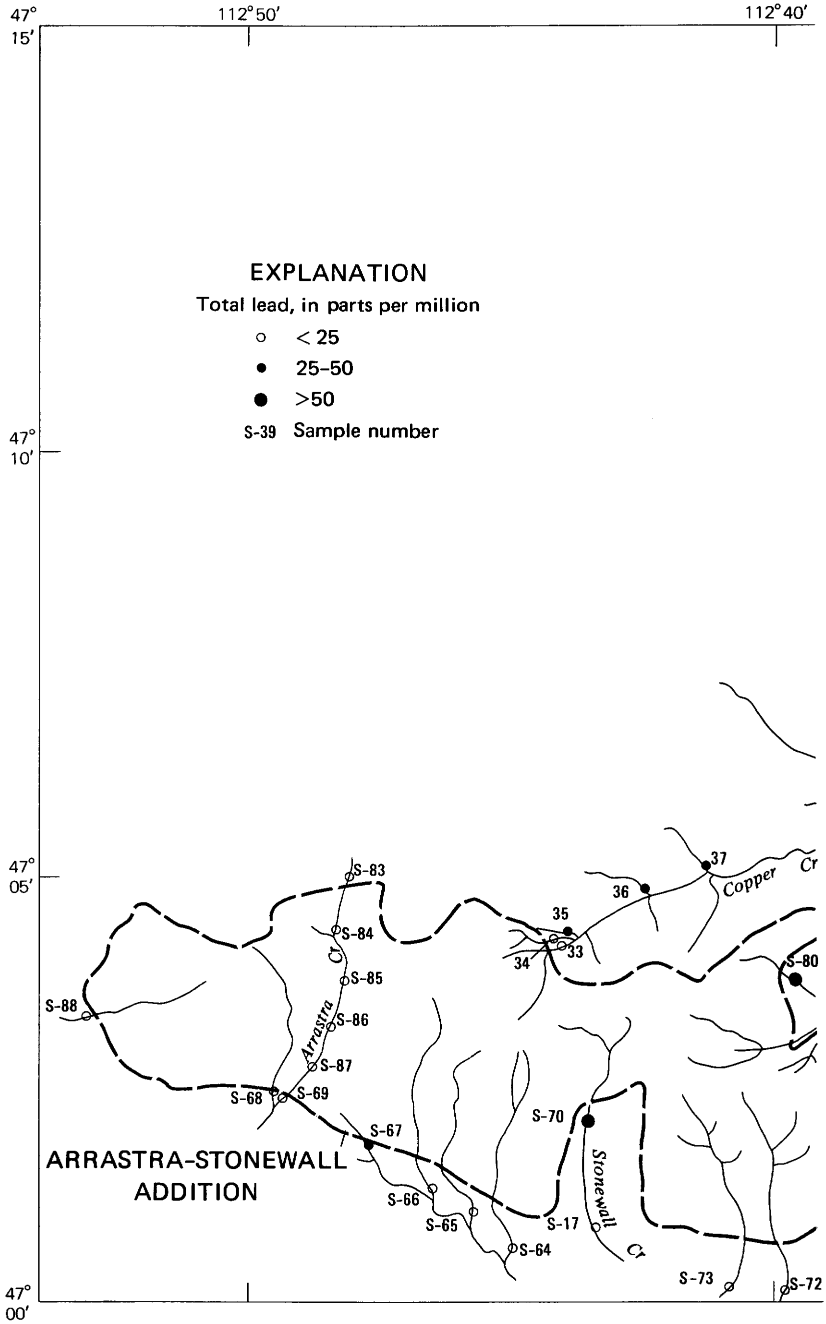
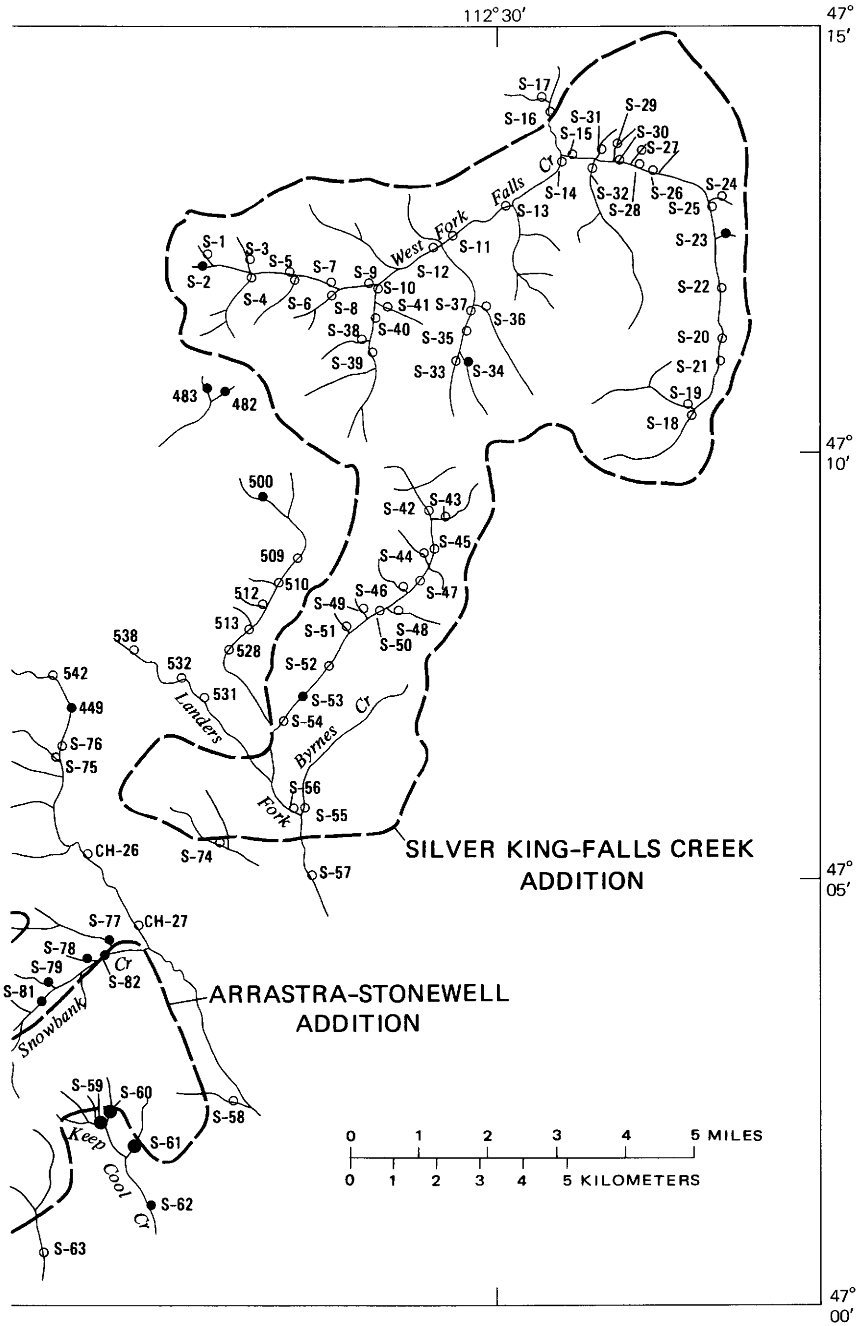


FIGURE 8.— Distribution of



total lead in stream sediments.

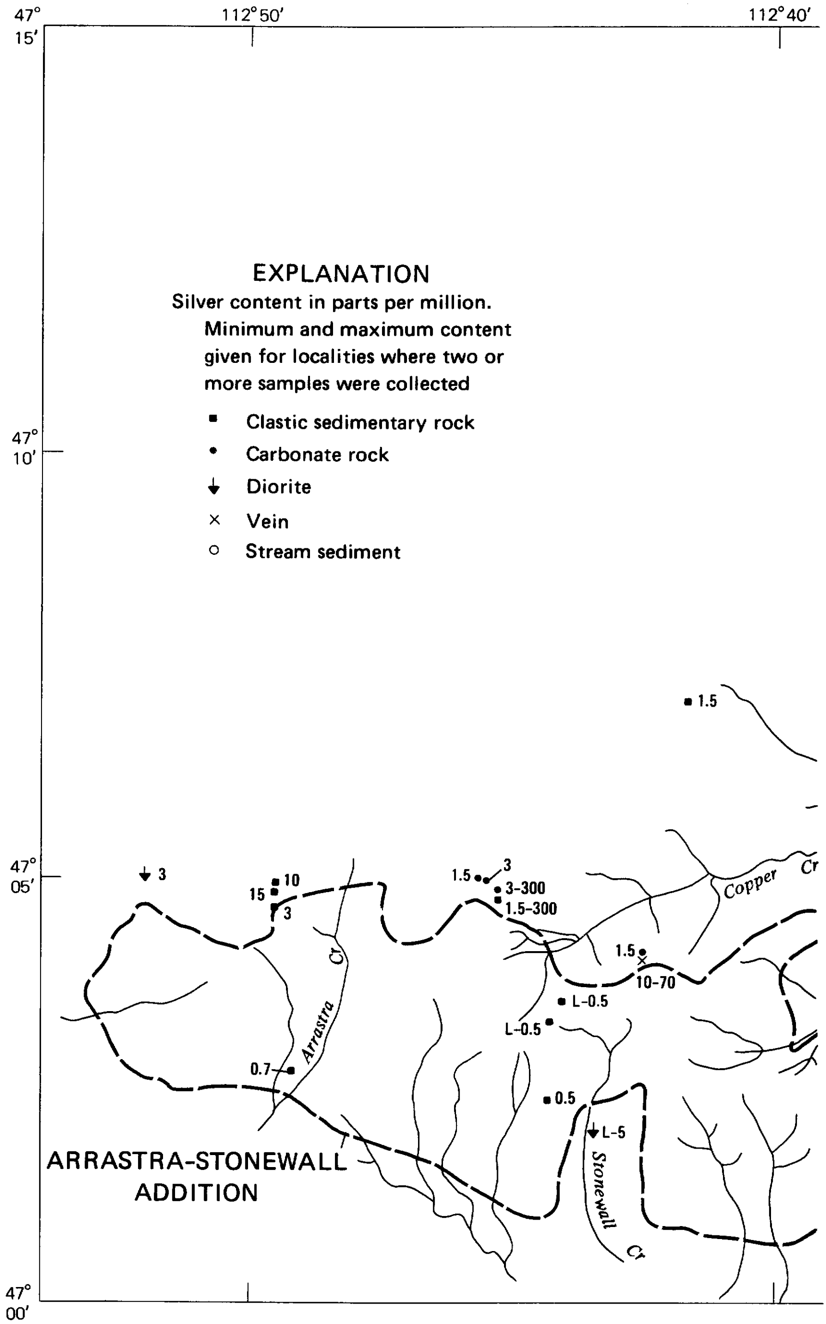
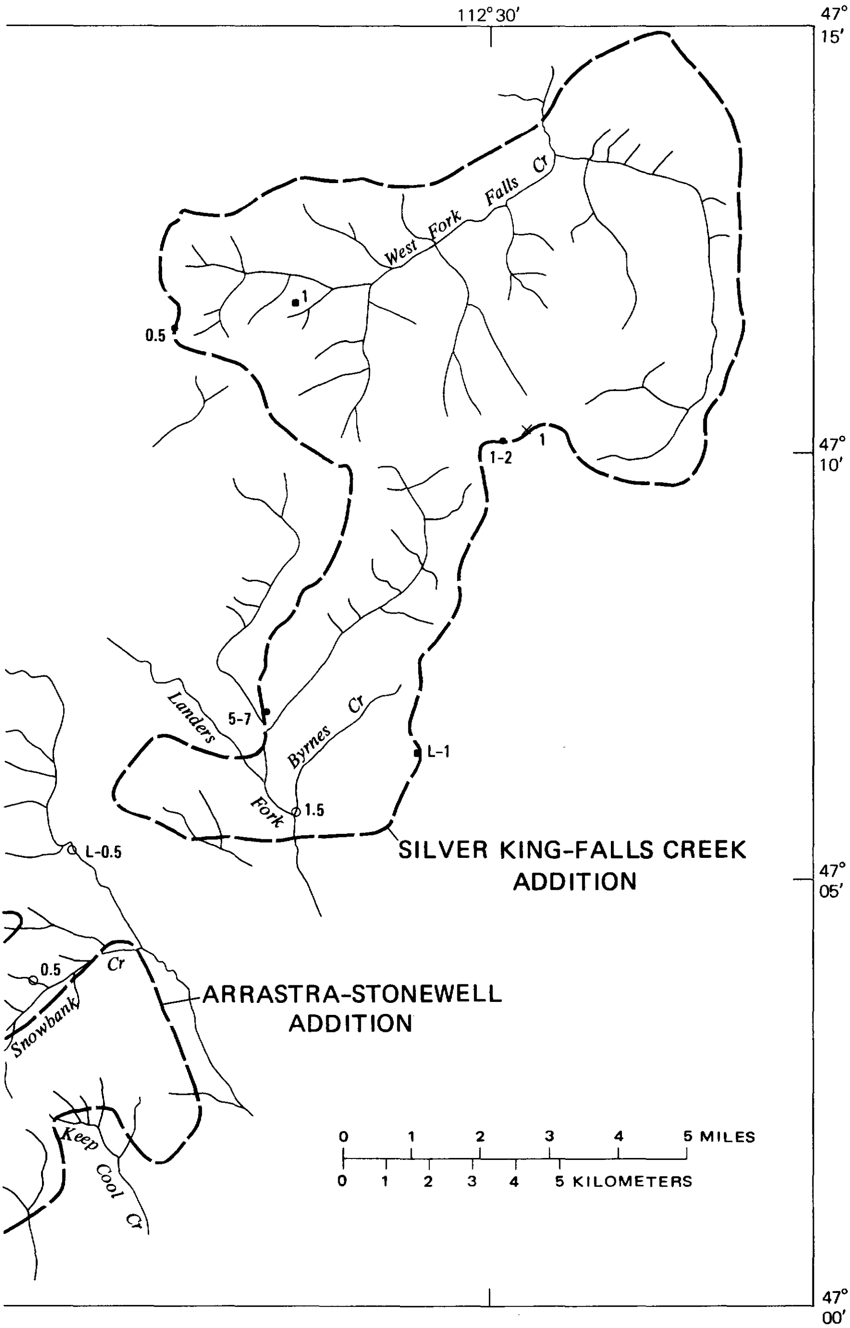


FIGURE 9.— Rock and stream-sediment samples



containing detectable amounts of silver (0.5 ppm).

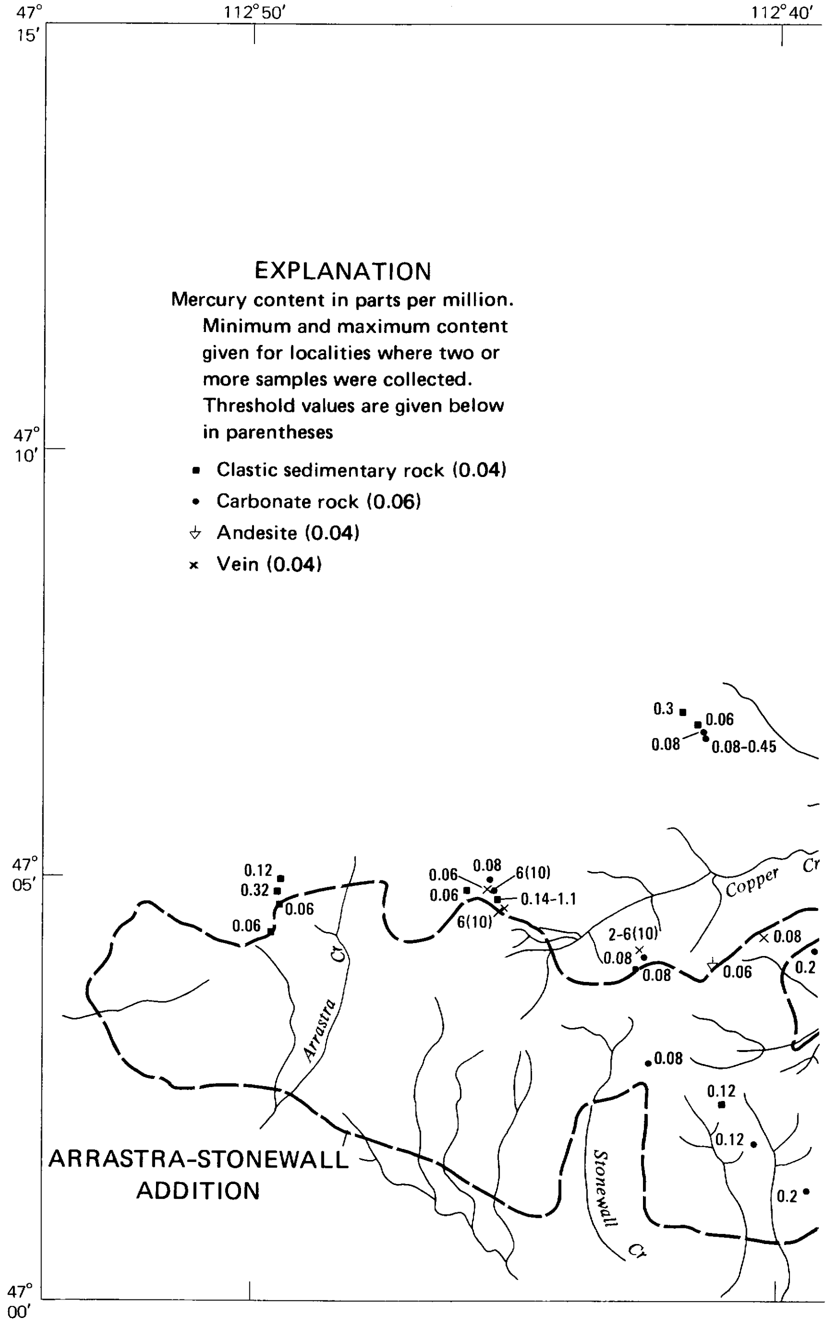
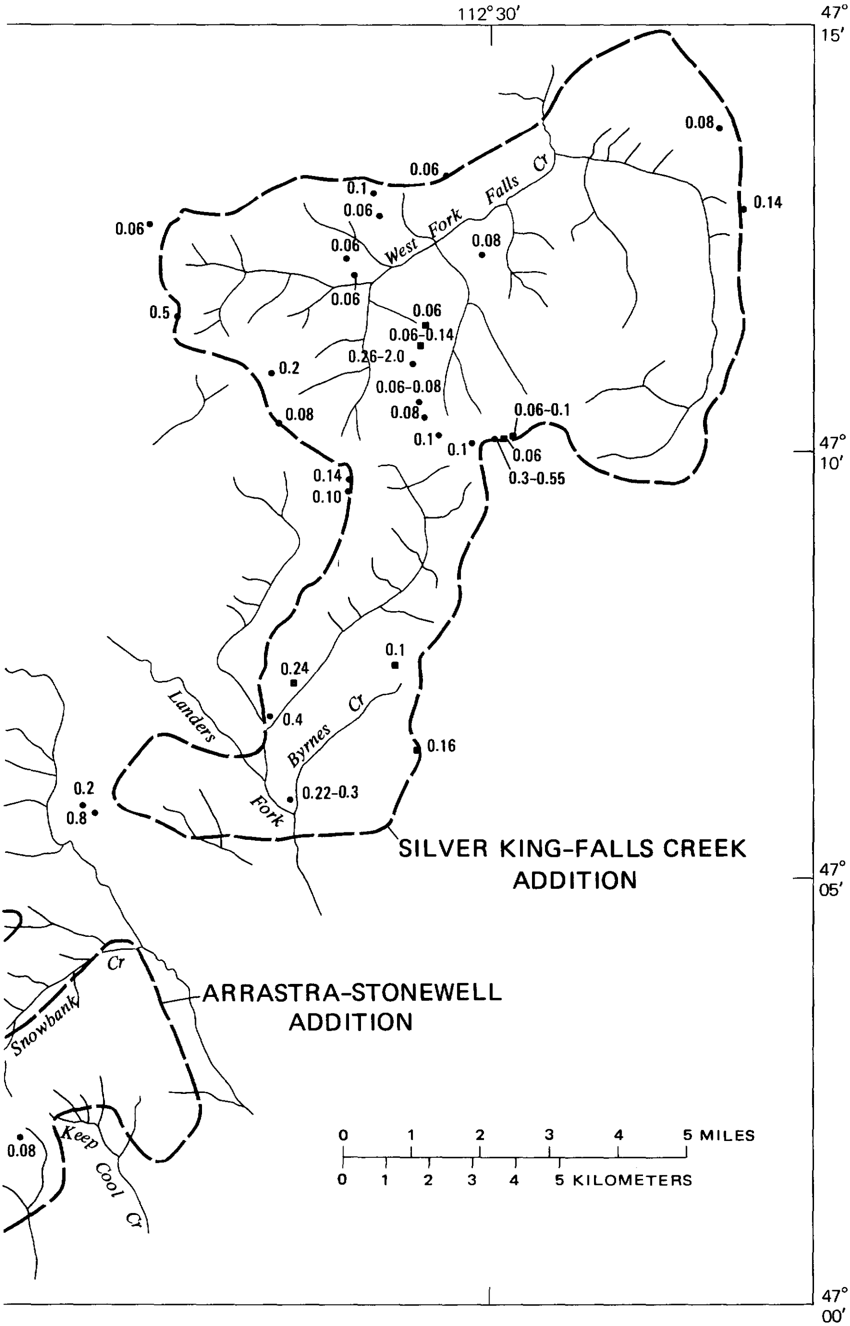


FIGURE 10.—Rock samples containing mercury



in amounts greater than the threshold value.

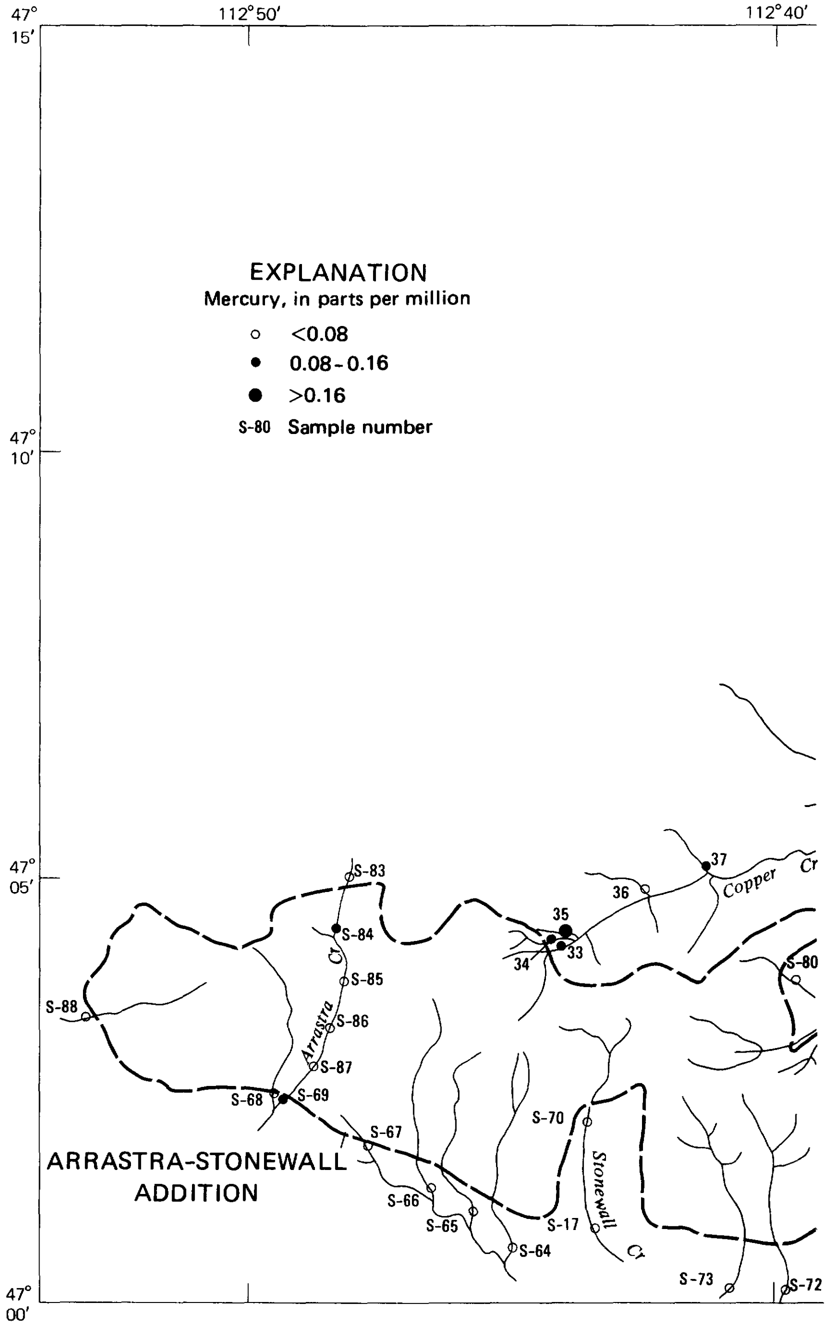
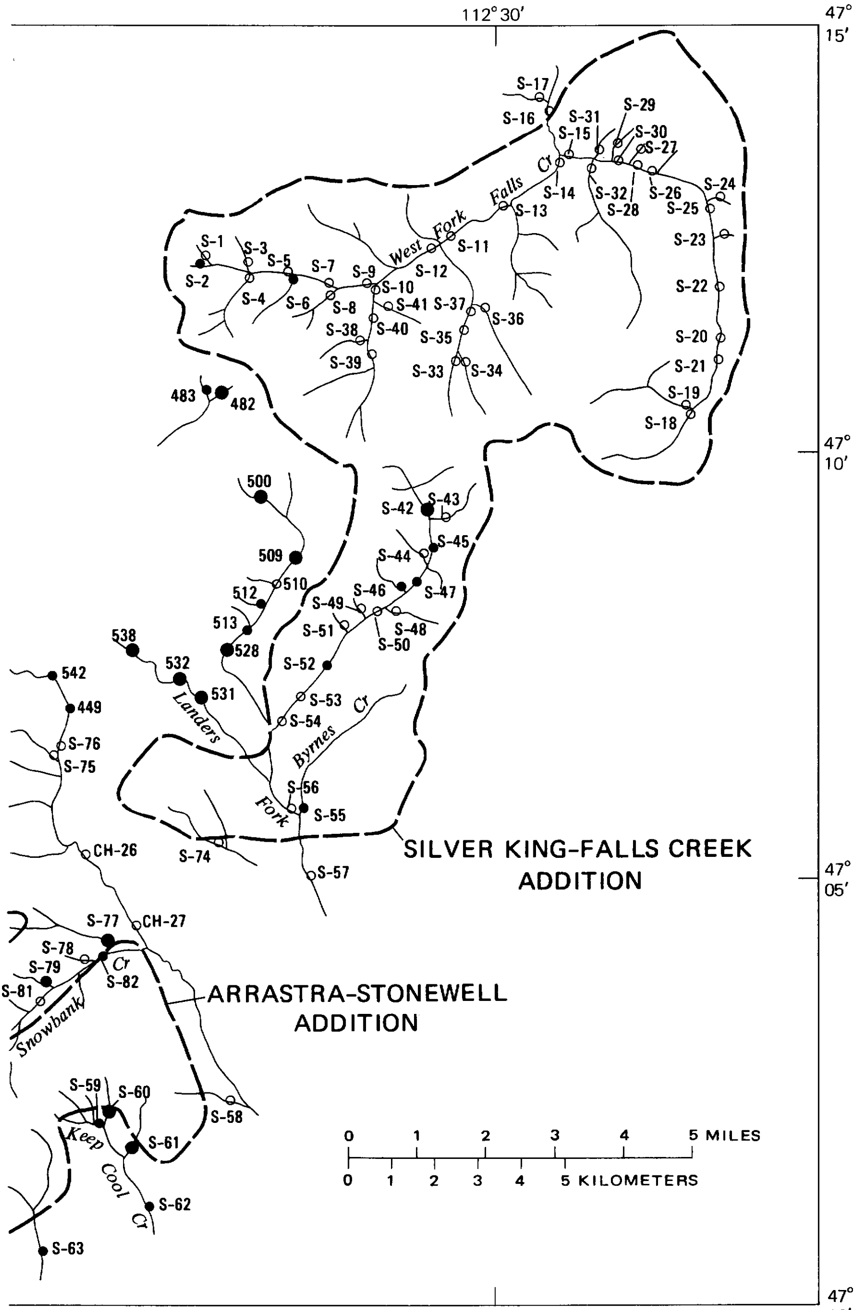


FIGURE 11.— Distribution of



mercury in stream sediments.

of silver. Silver would be an important recoverable element if these deposits were mined for their copper content.

All other types of base-metal deposits also contain anomalous amounts of silver, but the values are too low to enhance the economic potential of the deposits.

GOLD

The proposed additions to the Scapegoat Wilderness have a low potential for economic deposits of gold. All rock and stream-sediment samples were analyzed for gold by an atomic absorption method that has a 0.05 ppm lower detection limit.

Rock samples from three localities, R–158, R–289, and R–40 (pl. 2), contained detectable amounts of gold; however, no measurable gold was found in the stream sediments.

The highest gold values are from samples collected in and near the Giant prospect by Stonewall Creek (fig. 12), just outside the southern boundary of the Arrastra addition (R–158, pl. 2; table 2). The prospect is in sheared diorite near the eastern terminus of an anticlinal axis where the sill intruded nearly flat lying beds of the Spokane Formation (pl. 1). A shear zone a few inches wide is included in a moderately fractured zone about 25 feet (7.5 m) wide. The shear zone and wallrock fractures are lined with abundant epidote, and they locally contain a few quartz stringers and veinlets with minor amounts of limonite and pyrite and with sparse bornite, malachite, and azurite. Gold is associated with the quartz stringers and veinlets and with limonitic zones in the diorite. The highest gold value obtained is 14.0 ppm (R–158a, table 2), and it is from diorite with included quartz stringers that contain abundant limonite and pyrite. The sample was collected from the wallrock adjacent to the shear zone. The analytical results (table 2) suggest that the minor amounts of silver in the mineralized zone are more closely related to copper sulfides than to gold. Mineralization at this prospect appears to be highly localized and the gold values are erratic.

Gold is associated with the sulfide minerals in the cupriferous carbonate veins in the Cotter Basin area, but the distribution is erratic. Sample R–289b (table 2) contained 0.60 ppm gold, and soil samples from the area contained measurable amounts (Grimes and Earhart, 1975). Gold might be recoverable from parts of the veins if they were mined for their copper content.

On the Continental Divide in the Silver King addition, a sample (R–40a) of a 4-mm-wide calcite veinlet with chalcopyrite, malachite, and galena contained 0.20 ppm gold (table 2). A few other small veinlets are exposed in the area; however, samples of them and of the diorite host rock did not contain measurable amounts of gold.

Traces of gold were detected in a sample (E–13) collected by Tuchek from the Nellie Miles claim near the northwest corner of the Silver King addition (Mudge and others, 1975, p. 77). The gold occurs in a weakly mineralized quartz vein along the thrust fault contact between Precambrian and Paleozoic rocks. Tuchek concluded that the occurrence has very low potential, and no mineralized zones were observed along the thrust fault contact within the Silver King addition during the present studies.

In summary, gold might be recoverable as a byproduct if the carbonate veins in or near the Arrastra addition were mined for their copper content. Occurrences of gold in and near the Silver King addition are low grade and highly localized; thus, they have a very low potential.

MERCURY

The proposed additions to the Scapegoat Wilderness have a low potential for economic deposits of mercury; however, anomalous amounts of mercury are associated with base and precious metal occurrences, and, in some cases, the distribution of mercury is of value as an indicator of these deposits. Anomalous amounts of mercury also occur in the sediments of streams that drain the Helena Formation, particularly to the west of the Silver King addition, and weakly anomalous values were detected in some rocks and stream sediments in the thrust-faulted northern part of the Silver King addition (figs. 10, 11). These anomalies do not have any apparent association with base or precious metal deposits.

Mercury was analyzed in all samples by a flameless atomic absorption method that has a 0.02-ppm lower detection limit, and the distribution of anomalous values is shown in figures 10 and 11. The highest mercury values (more than 10 ppm) are associated with the copper-bearing carbonate vein system. Although the veins are not exposed within the area, stream sediments from the upper part of Snowbank and Keep Cool Creeks contain anomalous mercury values (fig. 11), which are associated with the anomalous copper values in these drainages (figs. 3–5).

A few rock samples of the Helena Formation from the western boundary of the Silver King addition contain anomalous amounts of mercury (fig. 10). Most of these high values are associated with base metals in stromatolitic or oolitic carbonate rocks. The widespread stream-sediment anomaly (fig. 11) in the drainage to the west of the boundary probably reflects numerous highly localized and low-grade base-metal occurrences in the Helena.

ECONOMIC APPRAISAL

SETTING

The additions are outside any major mining district. Small production, possibly from within the additions, includes (1) a shipment of oxidized copper ore from a lode claim on Stonewall Mountain (Pardee and Schrader, 1933, p. 119) and (2) placer gold produced from Stonewall Creek between 1937 and 1939 (Lyden, 1948, p. 66). Placer tailings occur inside the study area on Stonewall Creek.

Significant mineral deposits have been discovered within 20 miles (32 km) of the Arrastra addition. Approximately $7 million in gold was produced from placer gravel about 5 miles (8 km) south of the Arrastra addition in Lincoln Gulch, principally between 1865 and about 1875 (Pardee and Schrader, 1933, p. 115 and 116). Considerable development of copper deposits occurred on Copper Creek less than 1 mile (1.6 km) outside the study area (Pardee and Schrader, 1933, p. 119; fig. 12). The Anaconda Co. discovered a large copper-molybdenum deposit about 19 miles (31 km) east of Lincoln, Mont. (Miller, 1973), in the Heddleston mining district, which produced lead, zinc, copper, silver, and gold ores valued at about $25 million between 1889 and 1958 principally from the Mike Horse mine. K & W Mines, Inc., was producing copper-silver ore from the Cotter Basin mine about 500 feet (150 m) north of the Arrastra-Stonewall addition near Cotter Creek, a tributary of Copper Creek (fig. 12), at the time of this investigation.

MINING CLAIMS

Lewis and Clark and Powell County records show that 64 unpatented claims may have been staked in the additions; descriptions of some are vague. Eight are placer claims.

SAMPLING AND ANALYTICAL METHODS

Eighty-six chip samples and two placer pan samples were collected by U.S. Bureau of Mines personnel during the study of the additions. Rock samples were fire assayed for gold and silver and analyzed by atomic absorption methods for copper; a few selected samples were analyzed for lead and zinc by atomic absorption methods. Some selected samples were analyzed spectrographically for other valuable elements. Gravel deposits on Stonewall Creek were tested by reconnaissance panning and subsequent tabling of concentrates for gold and other heavy detrital minerals. All samples were checked for radioactive and fluorescent minerals.

MINERAL COMMODITIES AND ECONOMIC CONSIDERATIONS

Mineral commodities most likely to be produced in the additions are, in order of decreasing importance, copper, silver, and gold. Sand and

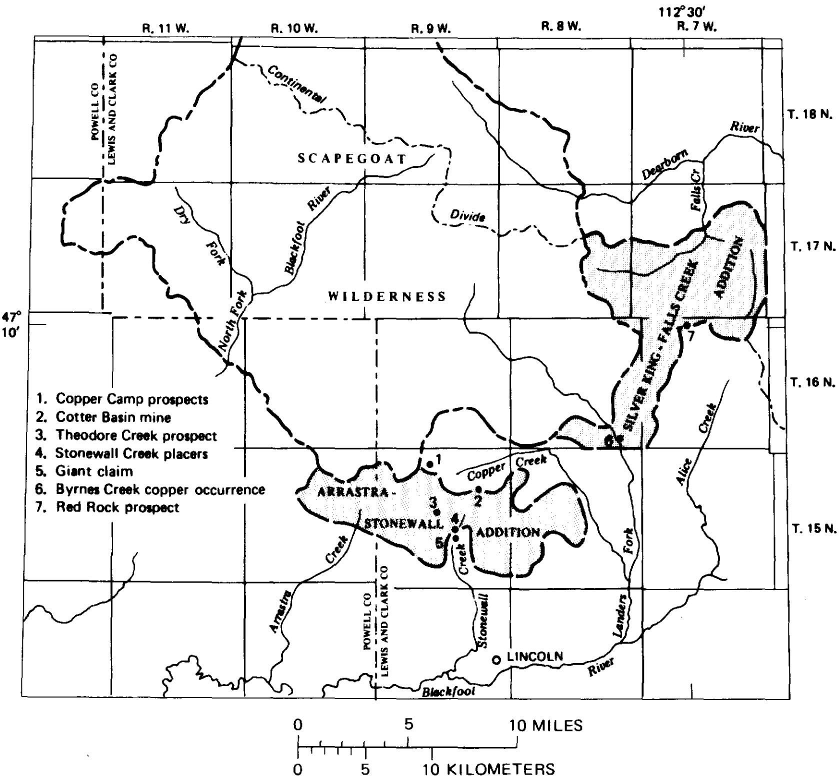


FIGURE 12.— Mines, prospects, and mineralized areas in and adjacent to the proposed additions to the Scapegoat Wilderness.

gravel and stone occur in the additions, but other sources of them are available closer to areas of use. Potential for copper and byproduct silver production is greatest in the northern part of the Arrastra addition.

The following sections contain some generalizations for familiarization with ore values, production costs, and market conditions. Production costs have a wide range and may differ twofold or threefold for different deposits. Where large high-grade ore bodies are encountered near the surface, unit production costs are relatively low.

COPPER

The average price of copper was 76 cents per pound ($1.68/kg) in November 1974 (Engineering and Mining Journal, 1974, p. 48). In 1973 U.S. mine production was about 1.7 million tons of copper (1.5 million t) and domestic consumption was about 2.35 million tons (2.13 million t). Domestic copper demand is forecast to increase an average of 4 percent annually through 1980. New mine projects and expansion plans are expected to maintain the present high degree of self-sufficiency (U.S. Bureau of Mines, 1974, p. 44–45).

SILVER

The price of silver averaged $4.69 per troy ounce ($0.15/g) in November 1974 (Engineering and Mining Journal, 1974, p. 48). U.S. mine production was about 37.4 million troy ounces (1.16 million kg) of silver in 1973 and domestic consumption was about 187 million troy ounces (5.82 million kg). Demand for silver is expected to increase 3 to 4 percent annually through 1980, with resulting increased reliance on imports and stock withdrawals (U.S. Bureau of Mines, 1974, p. 152–153). Silver could be produced in the additions only as a byproduct of copper mining. At November 1974 prices, each 0.1 ounce silver per ton (3.4 g/t) could substitute for about 0.03 percent copper to maintain minable grade.

GOLD

The average price of gold on the world market was $182 per troy ounce ($5.85/g) in November 1974 (Engineering and Mining Journal, December, 1974, p. 48). Costs for producing gold are similar to those for copper. A 1-million-ton (910,000-t) lode deposit should average 0.06–0.08 ounce per ton (2–3 g/t) gold to be mined profitably by open pit or underground methods, respectively. Placer gold deposits of 100,000 to 20 million cubic yards (76,000 to 15 million m^3) probably could be mined for between 50 cents and $1 per cubic yard. Deposits containing less than 100,000 cubic yards (76,000 m^3) of gravel are not minable, except in rare cases of good access, short distance to bedrock, and gold content averaging $1.50 or more per cubic yard.

SAND AND GRAVEL AND STONE

Sand and gravel, quartzite, limestone, and dolomite occur in the additions. Although some of these nonmetallic deposits are suitable for use as construction materials, deposits of equal or better quality are available elsewhere closer to major markets. Transportation cost is significant in determining minability of these high bulk–low value commodities.

MINES, PROSPECTS, AND MINERALIZED AREAS

COTTER BASIN MINE

K & W Mines and Gemco International, Inc., were developing and shipping ore from the Cotter Basin mine, about 7.5 miles (12 km) north of Lincoln, Mont., during 1973 and 1974 (fig. 12, No. 2). The active workings are on the Cotter Basin claim group and are about 500 feet (150 m) north of the boundary of the Arrastra addition (fig. 13). Contiguous claims of this group extend southward into the addition.

Copper and silver minerals are conspicuous in shear zones on the claims in thin-bedded dolomitic limestone of the Helena Formation.

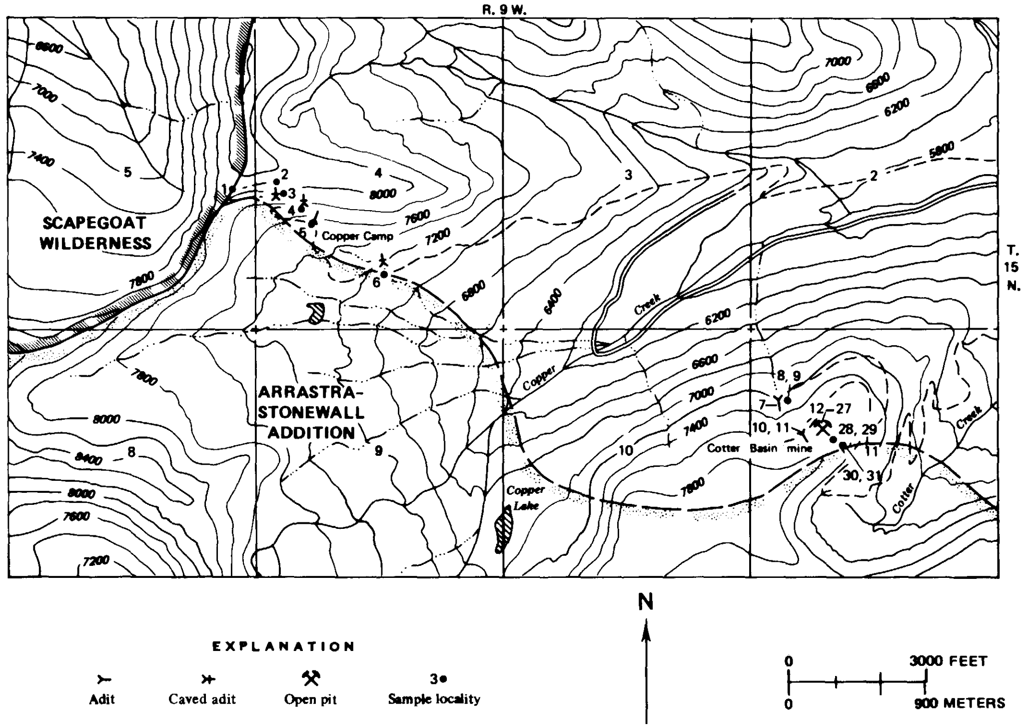


FIGURE 13.—Index map of the northern part of the Arrastra-Stonewall addition, showing the location of the Cotter Basin mine and Copper Camp prospects.

The limestone beds strike about N. 45° W. and dip 32° to 35° NE. Shear zones strike between N. 25° E. and N. 75° W. and dip southward. The principal copper-bearing shear zone strikes N. 75° W. and dips 25° SW. In many places, the zone contains calcite veins with subordinate bornite, chalcocite, azurite, and malachite. The shear zone averages 5.1 feet (1.55 m) thick; intermittent exposures, apparently on the same zone, occur along a distance of 1,100 feet (335 m) across the crest of a ridge. The projected outcrop of the principal shear zone corresponds closely with a treeless area where Grimes and Earhart (1975) identified *Eriogonum* plant cover on copper-rich soil (fig. 14).

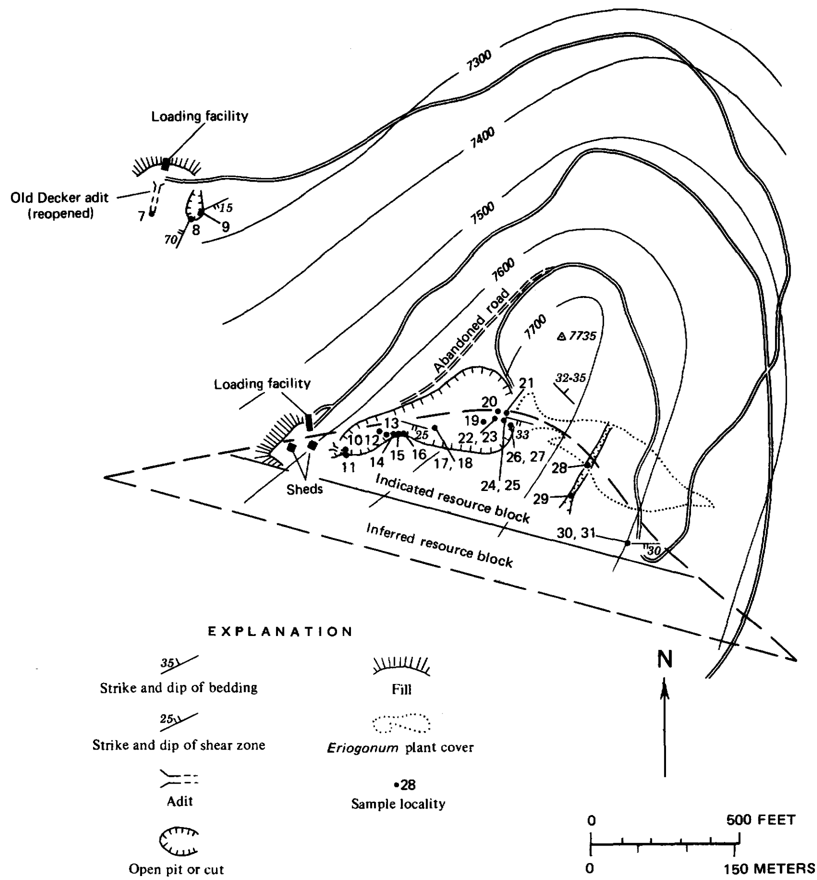


FIGURE 14.—Map of the Cotter Basin mine, showing sample localities and resource blocks.

Most development work is along the principal calcite-bearing shear zone. An adit driven southeastward at about 7,600 feet (2,320 m) in elevation reached the copper-bearing zone about 50 feet (15 m) from

TABLE 4.— *Descriptions and analytical results of chip samples from the Copper Camp prospects and the Cotter Basin mine*

[Sample localities shown on figures 13 and 14. Tr, trace; N, not detected]

Sample			Gold (ounce per ton)	Silver (ounce per ton)	Copper (percent)
No.	Length (feet)	Description			
1	Grab	Andesite porphyry----------------------	Tr	0.1	0.016
2	5	Calcareous argillite-------------------	Tr	N	.012
3	2	Calcareous argillite and quartzite-----	Tr	.1	1.62
4	Select	Vein calcite on dump-------------------	Tr	1.0	3.16
5	--do--	-----------------do-------------------	Tr	.9	4.00
6	Grab	Argillite and quartzite on dump--------	Tr	Tr	.78
7	1/ 4.0	Shear zone-----------------------------	Tr	.6	3.39
8	2.0	-----------------do-------------------	N	.2	2.48
9	2.0	-----------------do-------------------	N	1.3	3.99
10	7.0	Principal shear zone(?)----------------	N	N	.51
11	6.0	-----------------do-------------------	N	N	.58
12	10.0	Mineralized limestone below principal shear zone-----------------------------	Tr	.2	.36
13	4.5	Principal shear zone-------------------	N	Tr	.90
14	5.0	-----------------do-------------------	N	.3	2.27
15	5.5	-----------------do-------------------	.01	.8	3.29
16	8.0	-----------------do-------------------	N	.4	1.56
17	4.0	-----------------do-------------------	Tr	.1	.60
18	3.5	Mineralized limestone above principal shear zone-----------------------------	N	N	.76
19	4.0	Principal shear zone-------------------	N	Tr	.91
20	3.0	Mineralized limestone below principal shear zone-----------------------------	Tr	.2	.77
21	4.0	-----------------do-------------------	N	.4	1.08
22	4.0	Principal shear zone-------------------	Tr	Tr	.68
23	5.0	Mineralized limestone above principal shear zone-----------------------------	N	N	.35
24	6.0	Principal shear zone-------------------	.01	.4	1.27
25	5.0	Mineralized limestone above principal shear zone-----------------------------	N	.1	.24
26	5.0	Principal shear zone-------------------	N	Tr	.92
27	5.0	Mineralized limestone above principal shear zone-----------------------------	N	.1	.63
28	6.0	Principal shear zone(?)----------------	N	N	.57
29	6.0	Mineralized limestone above principal shear zone(?)--------------------------	N	Tr	.73
30	1.5	Principal shear zone-------------------	Tr	.2	1.35
31	8.0	Mineralized limestone above principal shear zone-----------------------------	N	Tr	1.33

1/ At this point 7.0 feet (11.2 m) of similar copper-bearing rock was exposed at the face; however, a cave-in prevented sampling the lower 3.0 feet (4.8 m).

the portal. An irregular open pit exposing the shear zone extends from near this upper adit eastward about 600 feet (180 m). The probable extension of the zone is exposed in a bulldozed trench about 300 feet (91 m) southeast (sample 28, fig. 14) of the pit. A copper-bearing exposure 9.5 feet (3 m) thick, in a roadcut (sample 31, fig. 14) 300 feet (91 m) east of the trench, contains a 1.5-foot-thick (0.46-m-thick) calcite vein and probably is another extension of the zone.

A lower adit, driven southerly to reopen the caved Decker adit (sample 7, fig. 14) at about 7,200 feet (2,190 m) in elevation, exposes a copper-bearing zone as much as 7 feet (2.1 m) thick, which may be a faulted extension of the principal westerly trending shear zone. A fault exposed in a cut near the Decker adit (sample 9, fig. 14) strikes N. 25° E., appears to displace rocks to the west downward and intersects a lower angle fault striking N. 65° E. (sample 10, fig. 14). Copper minerals are concentrated at this fault intersection.

The principal shear zone (fig. 15) averages 5.1 feet (1.55 m) thick and contains abundant calcite between samples 10 and 31 (figs. 14, 15). Samples across the zone contain weighted averages of 1.2 percent copper and 0.2 ounce silver per ton (6.9 g/t). Samples of sheared dolomitic limestone wallrock of the Helena Formation, in the interval averaging 5.5 feet (1.68 m) above and 5.5 feet (1.68 m) below the principal zone, contained weighted averages of 0.69 percent copper and 0.2 ounce silver per ton (6.9 g/t). Total mineralized thickness, therefore, averages 16.1 feet.

Samples from both the principal shear zone and adjacent mineralized Helena Formation contained weighted averages of 0.85 percent copper and 0.2 ounce silver per ton (6.9 g/t) over an average thickness of 16.1 feet (4.9 m). This identified resource[1] contains an estimated 1 million tons (910,000 t) to 570 feet (174 m) downdip (fig. 12). Of this, about 490,000 tons (440,000 t) is indicated[2] and 530,000 tons (480,000 t) is inferred.[3] An operation to recover the total resource block by a combination of open pit and underground methods would be paramarginal[4] at the average November 1974 copper price of 76 cents per pound ($1.68/kg). The shear zone alone contains about 320,000 tons (290,000 t) of resources estimated to average about 1.2 percent copper and 0.2 ounce silver per ton (6.9 g/t). This higher grade part of the deposit may also be paramarginal at November 1974 copper price because unit costs for the smaller body would be higher. However, under conditions where a producer is given an added value for the flux

[1]Specific body of mineral-bearing material, the location, quality, and quantity of which is known from geologic evidence supported by engineering measurements related to the classified category.

[2]Tonnage and grade are computed partly from specific measurements and samples and partly from projection for a reasonable distance on geologic evidence.

[3]Estimate is based largely on assumed continuity, for which there is geologic evidence.

[4]The portion of Subeconomic Resources that borders on being economically producible.

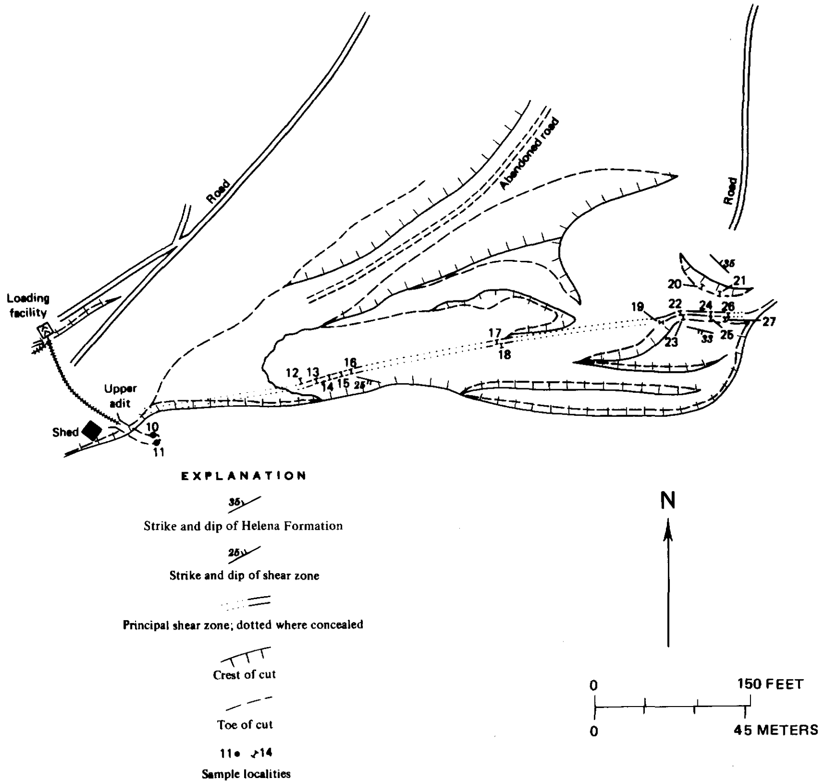


FIGURE 15.— Open pit, Cotter Basin mine.

content of the ore, the body could be mined profitably. Additional copper-silver resources probably occur farther down the projected dip of the shear zone southwest of the inferred block. The development of additional tonnage would reduce overall unit production costs and improve the economic outlook.

Another inferred resource body near the old Decker adit (fig. 14) yielded samples with higher copper and silver values than in the main open pit area. More exploration is necessary before making a quantitative estimate of the size and grade of this body; however, it contains more than 6,000 tons of resources. The deposit may be a downfaulted extension of the principal zone exposed in the open pit.

COPPER CAMP PROSPECTS

Prospects near Copper Camp (fig. 12, No. 1) are 200–500 feet (60–150 m) north of the study area (fig. 13). Mineralized outcrops are outside the area, but the mineralized zone dips under the study area. Old workings consist of a flooded adit trending N. 15° E. and three caved adits of similar trend.

Thin-bedded argillaceous dolomite beds of the Helena Formation overlie argillite and quartzite beds of the Empire and Spokane Formations in the vicinity of the workings. These rocks strike eastward and dip about 30° N. Andesite porphyry crops out about 500 feet (150 m) west of the westernmost adit (sample 1, fig. 13). Vein calcite with abundant copper minerals was found on adit dumps (samples 4, 5, fig. 13). Material on the dumps indicates that some calcite veins are at least 15 inches (38 cm) wide.

Copper minerals are locally abundant in the Empire and Spokane Formations in calcite veins, argillite, and quartzite beds. The mode of occurrence is similar to copper-bearing zones at the Cotter Basin mine 2 miles (3 km) to the southeast in sec. 11 (fig. 13) and to other vein deposits near Mineral Hill and Bugle Mountain, which are on westerly trending shear zones (Mudge and others, 1975, p. B46–B48). These deposits appear to be on the same series of calcareous, copper-bearing shear zones, and other similar deposits may occur along the same series of shear zones in secs. 8, 9, and 10 (fig. 13). Northerly trending faults appear to offset the shear zone near the Cotter Basin mine. Copper-bearing veins in the westerly trending shear zones lack continuity and are narrow (Mudge and others, 1975, p. B48). Distribution of observed copper-bearing quartzite and argillite was erratic. Copper resources could not be estimated, but they probably are submarginal.[5]

BYRNES CREEK COPPER OCCURRENCE

An outcrop north of the confluence of Byrnes Creek and Landers Fork (No. 6, fig. 12) and within the Silver King addition contains malachite. The malachite is visible in weathered calcareous sandstone at the base of the Helena Formation, southwest of a fault. The normal fault, striking about N. 20° W. and dipping southwest, separates argillite and quartzite of the Spokane Formation on the northeast from calcareous sandstone, the basal unit of the Helena Formation. The fault trace extends about N. 45° W. across the steep and unstable east face of a south-trending ridge but is concealed on the moderate west slope.

A 10-foot-long (3-m-long) sample of argillite and quartzite northeast of, but adjacent and parallel to, the fault contained 0.02 percent copper but no detectable silver. Five contiguous 10-foot-long (3-m-long) samples of calcareous sandstone, taken in a line extending from the fault south along the ridge, represented about 35 feet (11 m) of sandstone length parallel to the fault and, as the line diverges 45° from the fault trace, the same distance perpendicular to the fault. These samples contained 0.10 to 0.37 percent copper and 0 to 0.3

[5]Subeconomic resources that would require more than 1.5 times the price at the time of determination or a major cost-reducing advance in technology to be mined profitably.

ounce silver per ton (10 g/t). Copper content was highest in the two samples nearest the fault. Gold was not detected in any sample.

The basal calcareous sandstone of the Helena typically is 2–7 feet (0.6–2.1 m) thick and occurs in lenses as much as 200 feet (61 m) long. Assuming a thickness of 5 feet (1.5 m) at this outcrop, a few hundred tons of sandstone averaging 0.25 percent copper and 0.16 ounce silver per ton (5.5 g/t) is probably present in the sampled area. Similar lenses of calcareous sandstone with low-grade copper and silver mineralization probably occur at other places along this fault but cannot be considered to be a resource. The lenses of calcareous sandstone appear to be erratically distributed. Mudge and others (1975, p. B50) found that the basal calcareous sandstone of the Helena Formation is discontinuous near Landers Fork in the Scapegoat Wilderness.

RED ROCK PROSPECT

J. S. Hinkle, C. N. Huston, and A. B. Morris of Missoula, Mont., located the Red Rock lode claims at the head of Alice Creek (No. 7, fig. 12). The north end of the claim group extends a few hundred feet into the study area, north of the Continental Divide.

The argillite and quartzite country rock of the Empire Formation strikes N. 25° W. to N. 35° E., dips 20° to 40° westward, and is intruded by a diorite sill about 800 feet (240 m) thick. Calcite veins as much as 4 inches (10 cm) wide occur in the diorite, and they locally contain visible amounts of galena, chalcopyrite, and malachite.

A bulldozer trench 40 feet (12 m) long and about 5 feet (1.5 m) deep (samples 4–6, fig. 16) was dug on the Continental Divide at the end of a bulldozed access road extending from the U.S. Forest Service road on upper Alice Creek. Traces of lead and copper minerals are in the trench, and road construction locally exposed malachite-stained argillite and quartzite.

Samples of mineralized calcite veins and diorite (samples 2–6, 9) contained 0.01 to 0.08 percent copper, but this is far below the grade required for mining under present economic conditions. A few samples contained low silver or lead values.

STONEWALL CREEK PLACERS

Big Slide, Little OM, Nancy, and Big George placer claims on Stonewall Creek are inside the Arrastra addition (No. 4, fig. 12) in sec. 22, T. 15 N., R. 9 W., north of the patented Giant lode (M.S. 1547). The creek in the study area is in a narrow canyon, and gravel volume is small. Prospectors have occasionally tested gravels near placer tailings sites, the possible location of gold production between 1937 and 1939 (Lyden, 1948, p. 66). Two placer samples from Stonewall Creek contained no gold. The prospectors also have located the Jock,

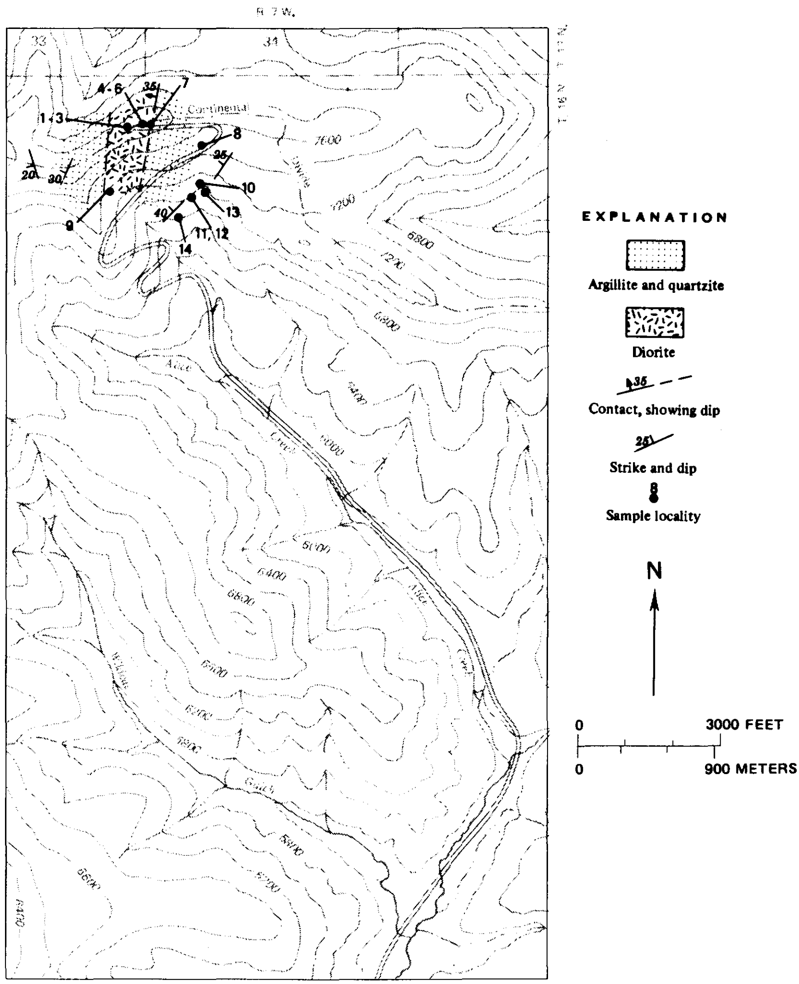


FIGURE 16.— Map of the Red Rock prospect, showing sample localities.

Skookum, Big Slide, and Cabin Site lode claims in the same area. No prospect workings or mineralized outcrops were found during this study.

GIANT CLAIM

The Giant patented claim (M.S. 1547) is in sec. 22, T. 15 N., R. 9 W., outside and adjacent to the south boundary of the Arrastra addition (No. 5, fig. 12). The country rock is diorite, which intruded argillites and quartzites of the Spokane Formation. Underground workings consist of an adit driven 55 feet (16.8 m) S. 45° E. and a 25-foot (7.6-m) winze inclined 60°, N. 70° E. from the end of the adit. Discontinuous

TABLE 5— *Descriptions and analytical results of chip samples from the Red Rock prospect*

[Sample localities shown in figure 16. Tr, trace; N, not detected; N.d., not determined; <, less than]

Sample No.	Sample Length (feet)	Sample Description	Gold (ounce per ton)	Silver (ounce per ton)	Copper (percent)	Lead (percent)
1	3	Calcite vein in diorite outcrop--------	Tr	Tr	0.058	N.d.
2	Select	-----------------do------------------	N	Tr	.05	0.41
3	Grab	Diorite outcrop-----------------------	N	.1	.015	.033
4	--do--	Diorite in pit------------------------	Tr	.1	.031	N.d.
5	2	Diorite outcrop-----------------------	Tr	N	.087	N.d.
6	Select	Calcite vein outcrop	N	N	.027	.011
7	20	Quartzite, from diorite sill contact downward in outcrop-----------	Tr	N	.008	.006
8	Grab	Quartzite outcrop---------------------	N	N	.006	< .005
9	--do--	Diorite outcrop-----------------------	N	N	.028	< .003
10	2	Argillite and siltite outcrop---------	N	N	.002	< .005
11	3	-----------------do------------------	N	N	.007	N.d.
12	3	Argillite outcrop---------------------	N	Tr	.004	.005
13	5	Argillite and quartzite outcrop--------	N	N	.003	N.d.
14	5	Dolomite outcrop----------------------	Tr	Tr	.003	N.d.

quartz veins in the diorite contain gold, silver, and copper minerals. A chip sample across a 1-foot-thick (0.30-m-thick) remnant of a quartz vein less than 2 feet (0.61 m) long in the adit contained 0.59 ounce gold per ton (20 g/t), 0.4 ounce silver per ton (14 g/t), 0.063 percent copper, and 0.002 percent lead.

THEODORE CREEK PROSPECT

An old prospect at the head of Theodore Creek is in the Arrastra addition in sec. 16, T. 15 N., R. 9 W. (No. 3, fig. 12). The country rock, which is argillite with some quartzite of the Spokane Formation, strikes N. 35° W. and dips 26° NE. Workings consist of a caved shaft with a waste dump, indicating as much as 100 feet (30 m) of former depth and about 75 feet (23 m) of combined open cut, adit, and winze north and west of the main shaft. Above average metal content was not indicated in two samples from this property.

OIL AND GAS

The disturbed belt of Montana is a zone of northward-striking thrust faults which dip westward along the eastern flank of the Rocky Mountains. Petroleum companies have been interested in the area since about 1892. Sporadic wildcat drilling, which was most intense between 1950 and 1960, has not resulted in commercial production (Cannon, 1971). The northern part of the Silver King addition is in the disturbed belt, but the potential for oil and gas production in the addition is unknown. Previous drilling results in the area have been generally disappointing although shows of gas and oil have been recorded in several wells, two of which are about 25 miles (40 km) north of the Silver King addition (Cannon, 1971, Fig. 12).

Cannon believed that potential for future oil and gas production in the disturbed belt could not be rated as very good, but large volumes of oil and gas have been discovered in similar structures in Canada; and large untested areas in northwestern Montana contain marine strata beneath overthrust Precambrian strata.

Oil and gas leases have been obtained from the U.S. Bureau of Land Management for part of T. 17 N., R. 7 W., inside the Silver King addition, but no petroleum exploration has been conducted. Some seismic surveys have been made east and possibly north of the area by one or more petroleum companies. The results of these surveys are unknown to us.

The nearest test well, a dry hole, was drilled about 9 miles (14.6 km) northeast of the east boundary of the Silver King addition. Kleinkopf and Mudge (1972, pl. 1) showed it to be drilled to a depth of 7,800 feet (2,379 m) into Devonian rocks. It is Shell Oil 31−32 Krone located in the NW 1/4 NE 1/4 sec. 32, T. 18 N., R. 5 W. The well topped in Upper Cretaceous rocks and penetrated many sills in the Cretaceous sequence. It penetrated the top of the Mississippian, the producing horizon on the Sweetgrass arch, at 5,590 feet (1,075 m) below ground surface.

The eastern part of the Silver King addition and the area to the east contain two thrust plates; Paleozoic rocks and thin sequences of Precambrian rocks are thrust on Paleozoic and Cretaceous rocks (Kleinkopf and Mudge, 1972, pl. 1). Additional small faults and folds are in the Cretaceous rocks (Viele and Harris, 1965, fig. 2). The thicknesses of these rocks can be estimated from data in the above references, including Mudge (1972, fig. 13). An intrusive, the High Bridge stock, is exposed about 4 miles (6.5 km) northeast of the addition (Viele and Harris, 1965; Kleinkopf and Mudge, 1972). Kleinkopf and Mudge inferred a much larger intrusive southeast of the area from aeromagnetic data. The presence of intrusives in the general area would reduce the petroleum potential of the area.

A well would probably be drilled to a depth of more than 12,000 feet (3,660 m) to reach the top of the Mississippian sequence in the eastern part of the Silver King addition. The actual depth would depend on the number and thickness of sills encountered and the extent of repetition of stratigraphic section by thrust faulting.

The disturbed belt in northwest Montana has been sparsely explored, and only three(?) wells southeast of Glacier National Park have tapped gas. All exploration has been east of the mountains.

Large oil and gas fields in Canada are in the eastern part of the disturbed belt. No wells have been drilled in the mountainous part of the disturbed belt in northwestern Montana, which is the setting of the eastern part of the Silver King addition.

The petroleum potential of the eastern part of the addition cannot be adequately evaluated without further detailed stratigraphic and structural studies, regional synthesis, seismic studies, and possibly drilling.

Oil shale of Tertiary age was discovered approximately 1 mile (1.6 km) south of the Arrastra addition near Arrastra Creek by Mr. Sherman Cook of Lincoln, Mont. Six samples collected by him contained from 3.8 to 23.1 gallons per ton (13.1 to 79.3 l/t) of recoverable oil. Oil shale was not found within the proposed additions to the Wilderness.

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