Geology, Geochemistry, and Mineral Resources of the Lower Part of the Middle Fork Boise River Drainage Basin, Boise and Elmore Counties, Idaho

By Thor H. Kiilsgaard *and* Cole L. Smith

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Metric Conversion Factors

Multiply	By	To obtain
Miles	1.609	Kilometers
Feet	0.3048	Meters
Inches	2.54	Centimeters
Tons	1.016	Metric tons
Short tons	0.907	Metric tons
Troy ounces	31.103	Grams
Ounces	28.35	Grams

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Introduction

Geologic mapping of the western part of the Hailey 1°×2° quadrangle and geochemical sampling of sediments from various streams that drain into the Middle Fork of the Boise River indicate that three areas in the drainage basin contain anomalous amounts of one or more elements, but no mines. The three areas are in the vicinity of Mt. Heinen, south of Grand Mountain, and south and west of Sheep Mountain. A fourth area, in the vicinity of Swanholm Creek, contains anomalous amounts of antimony, and one mine, the Hermada, which has produced significant amounts of antimony. Placer gold has been mined at a number of sites along the Middle Fork Boise River.

The study area covers approximately 385 mi^2 in the lower part of the Middle Fork of the Boise River drainage basin, in Boise and Elmore Counties, Idaho. It extends about 43 mi upstream along the Middle Fork from near the Arrowrock Dam to the junction of the Middle Fork and the Yuba Rivers (Worl and others, 1991). The approximate boundary of the study area is shown on figure 1.

Geology

The oldest plutonic rocks in the study area are principally biotite granodiorite and muscovite-biotite (two-mica) granite (fig. 2, units Kgd, Kg) of the Idaho batholith of Cretaceous age. These rocks are intruded by younger (Eocene) dioritic rocks and biotite granite units (Td, Tg). Intruding these plutonic rocks is a myriad of hypabyssal dikes of Tertiary age that range in composition from basalt to rhyolite. Cutting all of the rocks are steep faults, most of which strike northeast or northwest. Patches of unconsolidated sand, gravel, and cobbles are present locally. Some exposures of these unconsolidated rocks cap ridges, but most are along or near the Middle Fork Boise River and at the mouths of various tributary streams that empty into the Middle Fork. Many of the gravel exposures contain placer gold.

Plutonic and Hypabyssal Rocks

Plutonic Rocks of Cretaceous Age

Light-gray, medium- to coarse-grained, equigranular to porphyritic biotite granodiorite (fig. 2, Kgd) (Worl and others, 1991) is widespread in the study area. Excellent exposures of this rock crop out along the Middle Fork Boise River, from near the mouth of the North Fork Boise River upstream to beyond Atlanta. Mineralogic and chemical characteristics of the biotite granodiorite are presented in Kiilsgaard and others (in press).

Along the ridge that extends southwest from Mt. Heinen are a number of exposures of altered biotite granodiorite that were mapped as silicified granodiorite by Scanlan (1986, unit Ksi) and as altered granodiorite by Worl and others (1991, unit Kai). Feldspar in the rock is altered to sericite and clay minerals. Biotite is altered to chlorite or to various iron oxide minerals that stain the rock a rusty color. Locally, the altered rock is moderately to intensively silicified, either by disseminated silica flooding or by countless veinlets of quartz that commonly are 2 mm or less thick. Exposures of the rock also are present south of Mt. Heinen and to the southeast as far as 2.5 mi southeast of Cottonwood Creek. All mapped exposures of the rock are near younger intrusive rocks of Eocene age. The field relationships and alteration features indicate that the alteration is the result of hydrothermal processes associated with Eocene intrusive activity.

Muscovite-biotite (two-mica) granite (fig. 2, unit Kg) is exposed in the vicinity of Grand Mountain and Swanholm Creek (Worl and others, 1991) (fig. 2). The rock is similar to biotite granodiorite (unit Kgd), the major differences being the presence of laminated plates or books of primary muscovite that are large enough to recognize in hand specimen. Books of primary muscovite are a field criterion that was used both in the Hailey 1°×2° quadrangle and in the Challis 1°×2° quadrangle to the north (Fisher and others, 1992) to differentiate two-mica granite from biotite granodiorite.

Figure 1. Map showing lower part of the Middle Fork Boise River drainage basin, Boise and Elmore Counties, Idaho. Location of placer mine sites (diamonds) and approximate boundary of study area identified.

Plutonic Rocks of Eocene Age

Two categories of Eocene plutonic rocks are recognized in the study area: a dioritic suite of rocks and biotite granite (commonly called pink granite). Both categories of plutonic rocks intrude the more widely exposed Cretaceous rocks (fig. 2). Mineralogic and chemical characteristics of the Eocene rocks are discussed in Kiilsgaard and others (in press).

Dioritic Suite

The dioritic suite of rocks (fig. 2, unit Td) is composed of gabbro, diorite, quartz monzodiorite, and hornblende-biotite granodiorite, all of Eocene age. The large exposure of these rocks in the western part of the study area has a pronounced northeast trend (fig. 2). Three small stocks of gabbro (shown as diorite (unit Td) on Worl and others, 1991) crop out on ridges northeast of Mt. Heinen and north of Cottonwood Creek. Near the western border of the study area, southwest of Mt. Heinen, are a number of exposures of diorite, most of them near or peripheral to larger exposures of quartz monzodiorite or hornblende-biotite granodiorite (Scanlan, 1986). Quartz monzodiorite, a rock containing less than 20 percent quartz, makes up most of the western part of the block shown as dioritic suite in figure 2. From the vicinity of Mt. Heinen and to the northeast, the quartz content of the rock increases to more than 20 percent; this increase in quartz content changes the classification of the rock from quartz monzodiorite to hornblende-biotite granodiorite (Streckeisen, 1973).

Biotite (Pink) Granite

Biotite (pink) granite is the principal rock of the northeast-trending Sheep Creek batholith and the Sawtooth batholith (fig. 2, unit Tg). Coarse crystals of potassium feldspar account for the pink color that is characteristic of the rock, although at some localities finer grained and medium-grained varieties of the rock are not pink but light gray.

Stocks and batholiths of pink Eocene granite are widely exposed in central Idaho, and these rocks have geochemical

Figure 2. Simplified geologic map of the Hailey 1°×2° quadrangle, Idaho, showing location of study area (solid heavy line).

affinities that are typical of A-type (evolved) granite (Lewis and Kiilsgaard, 1991). Relative to other granitic rocks, evolved granite such as that of the Sheep Creek batholith is enriched in F and in incompatible elements including U, Th, Li, Be, Rb, Cs, Nb, and Y and is depleted in compatible elements such as Ca, Mg, Ba, and Sr. Concentrations of incompatible and other elements in the Sheep Creek batholith are discussed in a later section of this report entitled "Sheep Creek area."

A distinctive characteristic of Eocene pink granite in the central part of Idaho is its content of radioactive elements (Swanberg and Blackwell, 1973; Bennett, 1980a, b; Bennett and Knowles, 1985; Kiilsgaard and others, 1970). Commonly, pink granite is two to four times more radioactive than other Eocene or Cretaceous plutonic rocks of the region. Unpublished National Uranium Resource evaluation (NURE) airborne gamma-ray spectrometry surveys for uranium and thorium clearly outline the Sheep Creek batholith (Bennett, 1980b).

Hypabyssal Rocks of Probable Eocene Age

Countless dikes that range from andesite to rhyolite in composition occur in the Cretaceous and Eocene plutonic rocks of the study area (Kiilsgaard and others, in press). The dikes may be classified as a rhyolitic suite of light to red-tinted felsic dikes and a suite of dark-green to grayish intermediate to mafic dikes. Rhyolitic dikes are most numerous in or near Eocene biotite granite. Excellent examples of northeast-trending rhyolite dikes crop out in the Eocene biotite granite along the south-facing canyon wall of the Middle Fork Boise River near Twin Springs and in the canyon wall to the west. The similarity in chemical composition between the rhyolite and the intruded biotite granite suggests a genetic relationship. Intermediate to mafic dikes tend to be concentrated in or near exposures of the Eocene dioritic plutonic rocks, and similarities in chemical composition between the dikes and the dioritic plutonic rocks suggest a similar genetic relationship.

The crosscutting dikes strike in diverse directions, but the majority trend northeast, more or less in the same direction as the Eocene plutonic rocks. Emplacement of the dikes and the Eocene plutonic rocks probably was guided by the northeast-striking pattern of regional faults and associated shears that are widespread throughout central Idaho.

Sedimentary Rocks

Payette Formation

On the divide at the head of Swanholm Creek, at an altitude of 5,640 ft, beginning about 500 ft east of the road to Atlanta and continuing as a ridge cap to the northeast for about 2,000 ft, is an exposure of stratified sandstone and interbedded gravel that is correlated with the Miocene Payette Formation. The sandstone is loosely consolidated, and the grain size ranges from fine to coarse. Some thin beds of very fine grained material are probably volcanic ash.

Bedding of the sandstone strikes N. 40°–50° W. and dips 10° SW. The exposed unit is about 250 ft thick. It is in a down-dropped fault block that is bounded on the east by the Deer Park fault and on the west by the Swanholm Creek fault, and it may be a remnant of a far larger expanse of the formation.

Unconsolidated Sediments

For purposes of field geologic mapping, unconsolidated sediments of the study area were classified as glacial moraine, high gravel, terrace gravel, and alluvium.

Glacial Moraine

Glacial moraine consisting of unsorted boulders, some 5 ft or more in long dimension, cobbles, pebbles, and sand extends along the upper reaches of Hot Creek, which drains the northern side of Steel Mountain. Morainal debris is scattered along Hot Creek for a distance of about 3 mi, extending from an altitude of about 5,800 ft at its lower point to 7,600 ft at its upper end. The moraine was formed by Pleistocene alpine glaciation that scoured the northern and northeastern sides of Steel Mountain.

High Gravel

High gravel of probable Pleistocene age is present as isolated patches of boulders, cobbles, gravel, and sand high on the valley walls of the Middle Fork Boise River. Deposits of high gravel also are present at the heads of tributaries leading to the river and as caps on some ridges. The well-rounded nature of the boulders and cobbles indicates that they were deposited by rapidly eroding, high-energy streams, such as were active during Pleistocene time when abundant water was derived from melted glacial ice.

A patch of ridge-capping high gravel about 800 ft long is on the divide at the head of Swanholm Creek, near the foot of Swanholm Peak. The base of this patch is at an altitude of 6,200 ft, which is 1,840 ft above the Middle Fork Boise River at the mouth of Swanholm Creek. Some of the high gravel deposits along the Middle Fork Boise River, and north of the study area in the vicinity of Idaho City, are gold bearing and have been placer mined at localities where miners could get water to the deposit. At some high-gravel deposits, old ditches indicate that the water for placer mining was derived from melting snow.

Terrace Gravel

Terrace gravel is present in terraces along the Middle Fork Boise River. Some terraces are as much as 60 ft above river level. The terraces consist of boulders, coarse to medium gravel, and sand. Most of the boulders are of resistant rhyolite or fine-grained aplite.

Much of the terrace gravel probably is reworked high gravel, the tops of the terraces marking the former valley floor. Erosion into the old valley floor by the river removed most of the old gravel but left behind the present remnant terraces. Terrace gravel along the river walls is gold bearing and has been placer mined at many locations.

Alluvium

Alluvial sand, gravel, and boulders cover most of the Middle Fork valley floor. At the mouths of some of the larger tributary streams, the alluvium forms fans that extend out onto the valley floor of the river. Locally, the alluvium is only a few feet thick, but at some places it extends to unknown depths. Valley alluvium along the Middle Fork is gold bearing, particularly at its contact with underlying bedrock.

Structure

Major faults in the study area strike either northeast or northwest (Worl and others, 1991). Northeast-striking faults probably are part of the Trans-Challis fault system (Bennett and Knowles, 1985; Kiilsgaard and Lewis, 1985; Kiilsgaard and others, 1989; Fisher and others, 1992). The age of faulting is unknown but could be as old as Precambrian (Lopez, 1981). Field evidence both in the Hailey 1°×2° quadrangle and in the Challis 1°×2° quadrangle to the north (Worl and others, 1991; Fisher and others, 1992) indicates that northeast-trending faults guided emplacement of most Eocene plutonic rocks and dikes. Subsequent left-lateral movement along some northeast-trending faults in the Challis quadrangle has displaced some Eocene plutonic rocks.

The most conspicuous northeast-striking fault in the study area is marked by a number of sheared and altered rock exposures along a 19-mi stretch of the Middle Fork Boise River. The exposures extend from near the mouth of Cottonwood Creek to a localities about 1.5 mi west of the mouth of Browns Creek, where surface traces of the fault are lost on the weathered, south-facing slopes of the ridge that forms the north wall of the Middle Fork canyon (fig. 1) (Worl and others, 1991). The best exposure of the fault zone is in the north bank of the Middle Fork road about 1 mi northeast of the mouth of Willow Creek; here, the Eocene biotite granite host rock has been sheared and altered in a zone more than 400 ft wide. Parts of the sheared zone consist, essentially, of white, altered material that is so pulverized that the original rock type cannot be identified. Elongation of northeast-trending Eocene plutonic rocks along the fault zone and alignment of swarms of Tertiary dikes with the fault zone suggest that initial fault movement was pre-Eocene; however, the above-described exposure of sheared Eocene biotite granite denotes definite post-Eocene fault adjustment. Eocene biotite granite in apparent fault contact with Cretaceous biotite granodiorite, east of the mouth of Big Five Creek, also indicates post-Eocene adjustment along the northeast-striking fault. The direction of movement along the fault could not be determined. A number of hot springs, including those at Twin Springs, at the mouth of Sheep Creek, and at other locations along the Middle Fork Boise River from above the mouth of the North Fork Boise River to the area west of the mouth of Browns Creek, are along or near the fault.

Several major northwest-striking faults cross the study area (Worl and others, 1991). Of these, the Deer Park fault may be the longest. It has been mapped for a strike length of about 50 mi. A splay of this fault follows Swanholm Creek (fig. 9) and is referred to as the Swanholm fault. The northeast end of the study are is crossed by the Montezuma fault, another major northwest-striking fault (Anderson, 1939; Reid, 1963; Kiilsgaard and others, 1970; Kiilsgaard and Lewis, 1985; Kiilsgaard and Bacon, in press). The Deer Park and Montezuma faults are similar in that rocks on the southwest side of each are downdropped and both display prominent scarps that are conspicuous topographic features.

Geochemical Studies

The following three areas (fig. 3) within the study area are anomalous in one or more of the suites of elements that were used to interpret the geochemistry of the Hailey 1°×2° quadrangle (Smith, 1995): the Mt. Heinen vicinity; south of Grand Mountain; and south and west of Sheep Mountain. There is no mining activity in any of these areas and little evidence of extensive mineral exploration. Geochemical anomalies extend well beyond any of the known prospects. These three areas are referred to herein as the “geochemical study areas.” A fourth area, the Swanholm antimony district (figs. 3, 9), contains the Hermada antimony mine and several antimony prospects. Many stream-sediment samples from this area were anomalous in antimony.

Figure 3. Map showing location of geochemical study areas, Swanholm antimony district, and outcrops of Eocene granite.

Each of the geochemical study areas is dominated by different groups of elements. To better characterize the geochemistry of these areas, samples of both stream sediments and the heavy-mineral fraction of stream sediments (panned concentrates) were collected, but little attempt was made to find the sources that contributed anomalous concentrations of elements to the stream sediments. Gold, tungsten, and tin tend to be concentrated in the heavy-mineral fraction of stream sediments; thus, panned concentrates were collected to check for these elements. The samples were analyzed at U.S. Geological Survey laboratories in Denver, Colorado. Methods of sample handling and analysis and the geochemical data are given in Malcolm and Smith (1992).

As used in this report, the terms “anomalous concentration” or “anomalous sample” refer to exceptionally high concentrations of elements of interest in stream-sediment or panned-concentrate samples. Generally, an analytical value that is two standard deviations above the regional mean for that element in stream sediments is considered anomalous. For some elements that are rarely detected in stream sediments, such as gold, silver, tin, or bismuth, the mere detection of the element in the sample is sufficient to consider the sample anomalous.

Data Handling

To characterize the geochemistry of the geochemical study areas, two data sets were formed. Panned concentrate data for each area were combined into one data set, and stream-sediment sample data from each area were combined with stream-sediment data for the western part of the Hailey 1°×2°quadrangle to form the other data set. Because elements have different concentration ranges in different geologic environments, a ranking system was designed that display, on a common scale, elemental concentrations for geologically different areas. The rank of a particular element was determined as described in the following example: If a sample set consisting of concentrations of silver contains 20 samples, the sample that has the highest silver concentration is assigned a rank of 20, the sample that has the next highest concentration of silver is assigned a rank of 19, and so forth. The average rank of each element in each geochemical study area was calculated for each data set. The average ranks of selected elements in each of the areas are shown in figures 4 and 5. This ranking procedure is explained in more detail in Smith (1995).

Evolved Granites

Evolved igneous rocks can be associated with economic deposits of some elements, and it is important to recognize these rocks for the purposes of resource assessment. Lewis and Kiilsgaard (1991) indicated that Eocene biotite granite in the study area has geochemical affinities of A-type (evolved) granite. As summarized by Hannah and Stein (1990), evolved granite and rhyolite have characteristics related to their tectonic setting, the chemistry and mineralogy of their source, timing and mechanism of fluid release, and differentiation processes. These rocks also are distinguished by their distinctive chemical composition. Relative to other granite and rhyolite, these rocks are enriched in F and in incompatible elements such as U, Th, Li, Be, Rb, Cs, Nb, and Y and are depleted in compatible elements such as Ca, Mg, Ba, and Sr. In the Hailey 1°×2° quadrangle, study of the enrichment and depletion of these elements in stream sediments, soils, and concentrates helps to identify associated granite and rhyolite as evolved rocks. As shown in figure 4, relative to samples collected for the regional geochemical survey, samples from the three study areas are enriched in some of the elements that characterize evolved rocks.

Figure 4. Bar graphs showing average rank of selected elements in stream-sediment samples from three geochemical study areas and from the regional geochemical survey of the Hailey 1°×2° quadrangle, excluding areas that might contain Paleozoic rocks.

Figure 5. Bar graph showing average rank of selected elements in panned concentrate samples from the three geochemical study areas.

Geochemical Study Areas

Mt. Heinen Area

Mt. Heinen is near the center of the Mt. Heinen geochemical area (fig. 3). The eastern side of the area is drained by Cottonwood Creek and its various tributaries (fig. 6), whereas the western side is drained by Smith, Dunnigan, and Volquelin Creeks. Geologically, the area is underlain chiefly by Eocene dioritic rocks that include diorite, quartz monzodiorite, and hornblende-biotite granodiorite. Eocene biotite granite crops out on the southeast side of Mt. Heinen. All of the Eocene rocks are components of the large, northeast-trending block of plutonic rocks that forms a striking geologic feature of the area (fig. 2) (Worl and others, 1991). The Eocene rocks intrude Cretaceous biotite granodiorite of the Idaho batholith, and west and south of Mt. Heinen the intrusive action of the younger Eocene rocks has had a profound alteration affect on the intruded Cretaceous rocks (Kiilsgaard and others, in press). There are a few prospect pits in the area, but no evidence of mineral production.

Stream-sediment samples from the Mt. Heinen area contain anomalous concentrations of bismuth, molybdenum, silver, and lead, as shown in the regional set of stream-sediment sample data (Smith, 1995). Panned-concentrate samples from

Figure 6. Map showing Mt. Heinen geochemical study area and stream-sediment and panned concentrate sample localities (solid circles).

the area are enriched in silver, bismuth, lead, molybdenum, tungsten and to a lesser degree, tin (fig. 5, table 1).

Some stream-sediment samples, from streams flowing west from Mt. Heinen, contain anomalous concentrations of one or more of the elements silver, molybdenum, copper, lead, cadmium, and bismuth (Scanlan, 1986). Some of the anomalous values in stream-sediment samples from Voquelin Gulch may have been derived from northwest-striking veins that crop out on the ridge at the head of Voquelin Gulch, a ridge that extends southwest from Mt. Heinen. In the headwaters of Smith Creek, a stream that flows northwest from Mt. Heinen, no vein exposures were found that could account for anomalous samples collected along that stream. A stream-sediment sample collected by Scanlan (1986) in the upper stretches of Deer Creek, southwest of Mt. Heinen, contained 2 parts per million (ppm) Bi. Steam-sediment samples collected east of Mt. Heinen, in the upper stretch of North Fork Cottonwood Creek, and from the mouths of Wood, Garden, and Toms Gulches, contain anomalous concentrations of one or more of the elements silver, molybdenum, cadmium, and bismuth.

The initial collection of stream-sediment samples was followed by a more intensive effort to collect panned-concentrate samples (fig. 6, table 1). Of particular significance in the panned-concentrate samples are the high concentrations of tungsten (table 1). Scheelite was recognized in the panned-concentrate samples but was not identified in any outcrops. No mineralized exposure extensive enough to account for the anomalous metal content in stream sediments from Virgil, Wood, Garden, and Toms Gulches and from Ranger and Boren Creeks were found.

Grand Mountain Area

The Grand Mountain geochemical study area (fig. 3) extends from Grand Mountain south to the Middle Fork Boise River and east to beyond the East Fork of Swanholm Creek. It is underlain by biotite granodiorite and muscovite-biotite (two-mica) granite of Cretaceous age. These rocks are intruded by many porphyritic dikes of Tertiary age, most of which strike northeast (Worl and others, 1991). Principal streams of the area are Browns, Swanholm, Granite, and Dutch Creeks. Comparison of stream-sediment sample data from the Grand Mountain area (table 2) with data obtained from the regional study of the Hailey 1°×2° quadrangle shows that the Grand Mountain samples are enriched in beryllium and lithium (fig. 4), elements that are associated with the margins of evolved plutons. Eocene granite does not, however, crop out in the Grand Mountain area, and the source of the beryllium and lithium could be pegmatites associated with near-surface Eocene intrusive rocks. Initial stream sediment sampling in the Grand Mountain area also indicated anomalous concentrations of arsenic and antimony. Because the elements arsenic and antimony can serve as pathfinders to precious-metal deposits, the Grand Mountain area and the nearby Swanholm Creek antimony area were sampled in more detail. Stream-sediment and panned-concentrate sample localities are shown on figure 7, and analytical results are shown in table 2.

A number of gold-bearing panned-concentrate and stream-sediment samples were collected in the Grand Mountain area (fig. 7). Placer gold has been mined extensively in nearby areas, along the Middle Fork Boise River and near Phifer and Swanholm Creeks (see section on Middle Fork Boise River placers, this report), and some placer gravels extend hundreds of feet above river level. The high gravel deposits that have been mined are remnants of extensive high gravel deposits that probably extended up lower reaches of the various nearby Middle Fork tributary streams. The highest elevation of nearby placer deposits is 5,000 ft; thus, it is reasonable to assume that ancestral high gravel did not exceed that elevation in any stream valleys in the Grand Mountain study area.

At present, there is no evidence of high gravel in any of the Middle Fork tributaries in the Grand Mountain area. All such gravel has been removed by erosion. Placer gold that formerly

Table 1. Analytical determinations of nonmagnetic fraction of panned concentrate samples from Mt. Heinen geochemical study area.

[Concentrations shown in parts per million. Sample localities shown on fig. 6]

Field No.	Location	Ag	Bi	Cu	Mo	Pb	Sn	Th	W
1CB	South Fork, Garden Gulch	2	700	10	30	150	500	2,000	1,000
2CB	North fork, Garden Gulch	5	300	100	150	1,000	500	>5,000	1,000
3CB	Mouth, Garden Gulch	<1	100	10	150	500	500	>5,000	300
4CB	North fork, Wood Gulch	2	300	100	300	1,000	500	>5,000	1,000
5CB	Mouth Wood Gulch	5	700	15	1,500	5,000	300	>5,000	1,000
6CB	Mouth, Virgil gulch	<1	<20	15	300	2,000	200	2,000	100
3CS	West part, Boren Creek	2	500	<10	10	100	150	>5,000	500
4CS	North fork, Ranger Creek	<1	700	10	50	700	200	>5,000	150
5CS	South fork, Ranger Creek	5	1,500	70	200	700	200	5,000	15,000
6CS	Ranger Creek	<1	500	<10	200	150	200	>5,000	1,000
7CS	North fork near mouth, Ranger Creek	<1	200	<10	<10	100	150	>5,000	<50
8CS	Mouth, Boren Creek	<1	200	<10	10	500	200	>5,000	500
9CS	Mouth, Ranger Creek	<1	300	15	10	150	300	>5,000	1,000
1KS	North fork, Garden Gulch	10	1,500	100	300	1,000	200	>5,000	700
2KS	South fork, Garden Gulch	10	2,000	20	30	500	700	>5,000	10,000
3KS	Garden Gulch	<1	500	10	150	700	300	>5,000	1,000
4KS	Mouth, Toms Gulch	2	1,500	15	30	200	500	>5,000	300
5KS	South fork, Wood Gulch	7	<20	10	100	300	200	>5,000	300
6KS	North fork, Wood Gulch	<1	<20	<10	10	30	500	2,000	<50
7KS	Wood Gulch	5	700	<10	100	500	300	>5,000	2,000

was in the high gravel conceivably could have lagged behind during the course of erosion and thereby account for the gold in stream gravel, but this is unlikely along upper reaches of the streams because the tributary streams have steep gradients and are undergoing rapid erosion. Stream-bed gravel along the tributary streams is shallow to nonexistent and is the product of recent or current erosion. If placer gold in the panned-concentrate samples is lag gold derived from erosion of high gravel, it would be reasonable to expect placer gold to be present in all tributaries because all tributaries, to an elevation of 5,000 ft, likely once contained high gravel. Samples from some tributaries do not, however, contain placer gold (fig. 7), and thus most of the gold in the panned-concentrate samples probably was derived from local sources.

Of particular interest are panned-concentrate sample nos. 12KS and 13KS, from upper reaches of Browns Creek (fig. 7), (sec. 19, T. 6 N., R. 9 E.), sample no. 09CB, from the left fork of Granite Creek (sec. 20, T. 6 N., R. 9 E.), sample no. 25KS, from the northeast fork of Dutch Frank Creek (W1/2, sec. 32, T. 6 N., R. 9 E.), and sample no. 36KS, from the mouth of the left fork of Dutch Creek, at an altitude of 5,000 ft. The first four samples were collected above the altitude of 5,000 ft; thus the gold content in each (table 2) could not have been derived from ancestral high gravel. Sample no. 36KS was collected at an altitude of 5,000 ft, and it is possible that the contained gold originated in the high gravel, although for reasons given above, it is unlikely. Sample nos. 12KS and 13KS were collected on the west side of a long ridge that extends south from Granite Mountain and the gold in the samples presumably was derived from one or more deposits that crop out on the ridge. Sample no. 09CB was collected near the headwaters of the west fork of Granite Creek, within half a mile of the ridge crest. The source of the gold presumably is on the east side of the ridge, within the small drainage area above the sample site. The high gold value (300 ppm), for sample no. 25KS, is of special interest because, although the sample site is less than a quarter of a mile from the crest of the ridge, no contributing source was observed upstream in that short interval. Sample no. 36KS (700 ppm Au) from the mouth of the left fork of Dutch Creek is also interesting. The gold in the sample probably originated from erosion of an unknown deposit somewhere above the sample site, in the drainage area of the headwaters of that stream.

The gold values of panned-concentrate samples listed in table 2 should be viewed with caution. Sample handling in the field and laboratory can greatly enrich gold in the concentrate (Nash, 1988). In addition, the small size of the sample used for analysis (about 15 mg), coupled with the tendency of gold to be present as coarse grains or small nuggets, can have a profound effect on sample evaluation. A single grain of gold in a small sample gives a distorted value, which, if applied to a large

Figure 7. Map showing Grand Mountain geochemical study area and the Swanholm antimony district and stream sediment and panned concentrate sample localities. Circles indicate sample localities; solid circles indicate localities where anomalous amounts of gold was detected.

volume of gravel yields highly erroneous values. Nevertheless, the fact that placer gold was present in all of the streams that drain south from Grand Mountain raises speculation as to the source of the gold because no gold-bearing veins or mineralized zones were seen in the drainage area.

Sheep Creek Area

The Sheep Creek geochemical study area (fig. 3) is southwest of Sheep Mountain. It includes the upper part of Sheep Creek, the East Fork of Sheep Creek, the lower part of Devils Creek, and various tributaries of these streams and ridges between the streams (fig. 8). Sheep Creek is a major tributary to the Middle Fork Boise River. The entire Sheep Creek drainage basin is within the Sheep Creek batholith, which consists of Eocene biotite (pink) granite (Worl and others, 1991; Kiilsgaard and others, in press). Many northeast-striking rhyolitic dikes cut the Eocene granite.

Anomalous concentrations of various incompatible elements such as beryllium, lithium, thorium, niobium, and yttrium are characteristic of an evolved granite such as the Sheep Creek batholith. Anomalous concentrations of other elements such as fluorine, uranium, tin, and molybdenum have been reported from various exposures of Eocene granite in central Idaho (Kiilsgaard and others, 1970; Bennett, 1980b; Kiilsgaard, 1983). Because the entire Sheep Creek drainage is underlain by Eocene granite, it was decided to test for these elements by collecting a number of panned-concentrate samples from the principal streams and their tributaries (fig. 8) and by reviewing published and unpublished literature on the area.

The Blue Cloud beryl deposit is the only mineralized deposit in the area that has been explored in any way; the exploration consists of a few surface pits and bulldozer cuts. The deposit is west of the mouth of Devils Creek and south of Sheep Creek, in the NW1/4 sec. 14, T. 4 N., R. 7 E. In two mineralized zones, about 88 ft apart, are narrow 1-2 inch-wide northeast-striking quartz veinlets that contain small blue-green crystals of beryl, the maximum size of which is 0.2 by 0.75 in.

Table 2. Analytical determinations of stream-sediment samples and nonmagnetic fractions of panned concentrate samples from Grand Mountain geochemical study area and the Swanholm antimony area.

[Concentrations in parts per million. Sample localities shown on figure 7]

Field No.	Au (AA)	Ag	Au	Be	Bi	La	Mo	Nb	Pb	Sb	Sn	Th	W	Y
07CB	<0.05	<1	<20	<2	<20	>2,000	<10	2,000	100	<200	100	>5,000	<50	>5,000
08CB	<0.05	<1	<20	3	100	>2,000	<10	3,000	150	<200	100	>5,000	<50	5,000
09CB	<0.05	20	20	3	<20	>2,000	<10	2,000	100	<200	<20	>5,000	<50	3,000
10CB	<0.05	5	20	<2	100	>2,000	50	300	300	<200	<20	2,000	<50	1,500
12CB	<0.05	200	100	<2	150	1,500	<10	300	50	<200	30	500	<50	700
13CB	<0.05	<1	<20	<2	30	1,000	<10	300	150	500	300	200	<50	700
14CB	<0.05	2	<20	2	<20	>2,000	<10	700	100	<200	<20	>5,000	<50	>5,000
15CB	<0.05	5	<20	<2	150	2,000	<10	200	150	700	50	500	<50	700
16CB	<0.05	<1	<20	<2	500	>2,000	<10	500	70	<200	50	1,500	<50	1,000
17CB	<0.05	<1	<20	2	<20	>2,000	<10	500	100	<200	20	2,000	<50	3,000
18CB	<0.05	<1	<20	<2	<20	2,000	<10	70	30	<200	<20	300	<50	700
19CB	<0.05	<1	<20	<2	<20	>2,000	<10	150	50	<200	<20	1,000	<50	1,500
20CB	1.8	<1	<20	<2	<20	>2,000	50	1,000	300	<200	30	5,000	<50	3,000
21CB	<0.05	<1	<20	<2	<20	>2,000	<10	200	70	<200	<20	1,500	<50	2,000
22CB	<0.05	<1	<20	<2	50	1,500	<10	300	100	<200	100	500	70	1,000
23CB	<0.05	50	50	<2	<20	>2,000	<10	1,000	700	<200	<20	1,500	<50	2,000
24CB	0.05	<1	<20	<2	50	>2,000	<10	500	200	<200	70	700	<50	1,500
25CB	0.30	<1	<20	<2	<20	1,500	30	300	50	<200	30	700	50	700
12KS	0.06	<1	<20	<2	<20	>2,000	<10	700	30	<200	30	5,000	<50	2,000
13KS	<0.05	150	200	2	500	>2,000	<10	3,000	200	<200	<20	>5,000	<50	3,000
14KS	<0.05	<1	<20	3	150	>2,000	<10	2,000	150	<200	20	5,000	150	2,000
15KS	<0.05	<1	<20	3	<20	>2,000	20	5,000	150	<200	<20	>5,000	<50	5,000
16KS	<0.05	20	<20	5	100	>2,000	<10	1,500	100	<200	70	2,000	<50	1,500
17KS	<0.05	<1	<20	2	<20	>2,000	<10	2,000	100	<200	<20	>5,000	<50	5,000
18KS	<0.05	<1	<20	3	700	>2,000	<10	3,000	700	<200	70	>5,000	<50	5,000
19KS	<0.05	15	<20	3	1,000	>2,000	<10	1,500	300	<200	<20	>5,000	150	3,000
20KS	<0.05	<1	<20	3	<20	>2,000	<10	2,000	200	<200	20	>5,000	<50	3,000

Table 2—Continued. Analytical determinations of stream-sediment samples and nonmagnetic fractions of panned concentrate samples from Grand Mountain geochemical study area and the Swanholm antimony area.

[Concentrations in parts per million. Sample localities shown on figure 7]

Field No.	Au (AA)	Ag	Au	Be	Bi	La	Mo	Nb	Pb	Sb	Sn	Th	W	Y
21KS	<0.05	2	<20	2	300	>2,000	<10	1,500	200	<200	<20	>5,000	<50	>5,000
22KS	<0.05	<1	<20	2	200	>2,000	<10	1,500	150	500	<20	>5,000	<50	>5,000
23KS	<0.05	5	<20	2	500	>2,000	<10	3,000	70	<200	<20	>5,000	<50	3,000
24KS	<0.05	<1	<20	15	150	1,500	<10	200	100	<200	30	200	70	700
25KS	0.13	100	300	2	300	>2,000	<10	150	50	<200	70	>5,000	<50	5,000
26KS	<0.05	<1	<20	<2	<20	700	<10	100	30	<200	<20	200	<50	1,000
27KS	<0.05	<1	<20	<2	<20	2,000	<10	500	100	<200	50	700	<50	1,500
28KS	<0.05	15	<20	<2	300	2,000	<10	150	70	<200	<20	300	<50	700
29KS	0.15	2	<20	<2	100	>2,000	30	1,000	50	<200	30	5,000	<50	3,000
30KS	<0.05	<1	<20	<2	<20	>2,000	<10	200	30	<200	<20	2,000	<50	2,000
31KS	<0.05	2	<20	<2	200	700	<10	70	20	<200	<20	500	<50	700
32KS	0.05	2	<20	<2	<20	>2,000	<10	200	200	<200	<20	700	<50	1,000
33KS	<0.05	<1	<20	2	100	>2,000	<10	1,000	150	<200	20	>5,000	<50	3,000
34KS	<0.05	<1	<20	<2	150	>2,000	<10	500	150	<200	20	1,000	<50	700
35KS	<0.05	2	<20	<2	<20	2,000	<10	70	30	<200	<20	700	<50	700
36KS	<0.05	300	700	<2	100	2,000	<10	200	50	<200	<20	1,000	<50	1,500
37KS	<0.05	70	100	<2	<20	>2,000	<10	200	70	<200	70	1,000	<50	1,500
38KS	<0.05	<1	<20	<2	150	1,500	<10	100	30	<200	<20	500	<50	700

Figure 8. Map showing Sheep Creek geochemical study area and stream sediment and panned concentrate sample localities.

(Pattee and others, 1968). Random chip samples of the veins contain less than 650 ppm Be. Thirteen chip and grab samples taken from the deposit by the Inspiration Development Company in 1981 also contained low beryllium values; the highest value was 239 ppm Be (Patrick DeWilliams, written commun., 1991).

An airborne gamma-ray and magnetic survey of the Hailey 1°×2° quadrangle by EG&G Geometrics (1979), as part of the National Uranium Resource Evaluation (NURE) program, shows that the Sheep Creek batholith is unusually radioactive (Bennett, 1980b). In an extensive stream-sediment sampling program in Trinity Mountain-Steel Mountain area undertaken by the Idaho Bureau of Mines and Geology in 1976-77, several stream-sediment samples collected from Sheep Creek, Devils Creek, and some of their tributaries were anomalous in one or more of the metals molybdenum, copper, and silver (Bennett, 1980a).

In 1981, Inspiration Development Company staked 135 lode claims on the ridge between Devils Creek and Sheep Creek, in secs. 13 and 14, T. 4 N., R. 7 E., and secs. 18, 19, and 20, T. 4 N., R. 8 E.; the claims were quitclaimed to Pat DeWilliams in 1983. The geology of the ridge area was mapped by geologists from Inspiration Development and several hundred rock and soil samples collected. Silicified, brecciated, and mineralized zones were observed on the northeast-trending ridge top in the SW1/4 sec. 19, T. 4 N., R. 8 E., and on the northwest-trending ridge top in secs. 13 and 14, T. 4, R. 7 E. Molybdenite, fluorite, and some beryl were seen in some of the stockwork quartz veins in the silicified zones. A suite of 105 soil samples taken on a grid across the ridge averaged 405 ppm F. Chip samples of the silicified and mineralized zones contained as much as 465 ppm MoS_2, 25 ppm Ag, 570 ppm Sn, and >2,000 ppm WO_3. Two hundred and five chip samples of pink granite averaged 829 ppm F, 24 ppm Sn, and 17 ppm Mo (Patrick DeWilliams, written commun., 1991). The elemental average of these elements is much greater than that in reported for unaltered Eocene or Cretaceous granitic rocks in central Idaho. For example, in 17 samples of unaltered granitic rock from the Sawtooth Mountains (presumably Eocene in age), two samples contained 30 and 100 ppm Sn but the others less than 10 ppm, and one sample contained 5 ppm Mo but the others less than 5 ppm (Kiilsgaard and others, 1970, p. D158).

Sample localities of the panned concentrates collected as part of the present study are shown on figure 8, and analytical values for the samples are given in table 3. The values obtained for tin are particularly high for panned concentrates. Ten of the 29 panned-concentrate samples contained more than 2,000 ppm Sn. Unusually high values also were obtained for niobium, thorium, yttrium, and lanthanum (table 3). The average ranks for the incompatible elements beryllium, thorium, and yttrium are higher in the Sheep Creek are than in any of the other terranes that were sampled (fig. 4).

Swanholm Antimony District

The Swanholm antimony district contains the only mine in the Hailey 1°×2° quadrangle that has produced a significant amount of antimony. It also contains several prospects that have been explored for antimony. None of the properties are known to contain significant quantities of other metals.

The Swanholm antimony district is located between Swanholm Creek and the East Fork of Swanholm Creek (fig. 9), in T. 6 N., R. 9 E., Elmore County, Idaho. The district is about 70 mi northeast of Boise, Idaho, via the road along the Middle Fork of the Boise River leading to Atlanta. From Idaho City, the district can be reached by following State Highway 21 northeast to the Edna Creek turnoff and then by various well-marked U.S. Forest Service roads leading to Atlanta.

The Swanholm antimony district is in a downdropped fault blocked that is bounded on the east by the Deer Park fault and on the west by the Swanholm Creek fault (fig. 9). The northeast part of the district is underlain by Cretaceous biotite granodiorite (fig. 9, unit Kgd), and the rest of the district is underlain by Cretaceous muscovite-biotite granite (unit Kg). Crosscutting these Cretaceous intrusive rocks are numerous dikes, most of andesitic to dacitic composition. Most of the dikes strike northeast, more or less aligned with the regional strike of widespread Tertiary dikes in this part of Idaho (Worl and others, 1991). Some small, discontinuous andesitic dikes in the area trend north to northwest. These north-trending andesitic dikes probably are older than the northeast-trending dikes because in at last three locations they are cut by the northeast-striking Tertiary dikes.

An unusual feature of the Swanholm district is the occurrence of several separate exposures of gravel and one exposure of sandstone. The exposures are all at or near the tops of ridges and are considered to be remnants of much more extensive exposures of sedimentary rocks that formerly covered parts of the region. The sandstone is correlated with the Payette Formation (fig. 9), the nearest known exposure of which is near the mouth of Thorn Creek, about 5 mi south of Idaho City (fig. 2) and about 28 mi southwest of the Swanholm area. The gravel exposures are remnants of more extensive Quaternary gravel that formerly covered much of this part of Idaho. In the Swanholm area, the sedimentary rock exposures probably were preserved because they are in a downdropped block west of the Deer Park fault (fig. 9). Judging from changes in elevation of ridge tops on opposite sides of the Deer Park fault, there could be as much as 2,600 ft of vertical displacement on the fault. The sedimentary rocks have been eroded from nearby ridges that are higher in altitude and outside of the fault block.

Figure 9. Simplified geologic map of the Swanholm antimony district. Mines and properties described in the Swanholm antimony district are as follows: 1, Svensson antimony prospect; 2, Weatherby antimony prospect; 3, Anderson-Bida property; 4, North pit of the Hermada antimony mine; and 5, Hermada antimony mine.

Stibnite, the principal antimony-bearing mineral of the district, is present in quartz veins as scattered crystals, as small discontinuous aggregates of crystals, and as masses and ore shoots. The quartz veins are small; they range from a fraction of an inch to 5 ft in thickness and are as long as 115 ft. Mineralized parts of the veins rarely are more than 30 ft in strike length, and most range from a few inches to 2 ft in thickness. Granitic rock near the veins commonly has undergone intense hydrothermal alteration and now contains sericite, clay minerals, and, locally, silica. Most of the veins strike north-northwest and are located near or contiguous with the strike of the northerly striking andesitic dikes. Small inclusions of stibnite and native antimony are present sporadically in the northerly striking andesitic dikes, which could be of Cretaceous age. Some antimony-bearing veins, however, strike northeast, more or less parallel with the northeast-striking dikes, and stibnite and native antimony are present in northeast-striking dacite dikes, which are believed to

Table 3. Analytical determinations of nonmagnetic fraction of panned-concentrate samples of the Sheep Creek geochemical study area.

[Concentrations shown in parts per million]

Field No.	Location	Ag	Au	Be	Bi	La	Mo	Nb	Pb	Sn	Th	W	Y
26CB	West tributary, Sheep Creek	<1	<20	7	150	>2,000	20	2,000	150	700	>5,000	<50	2,000
27CB	Sheep Creek	5	<20	7	<20	500	20	500	100	700	>5,000	200	3,000
28CB	East Fork Sheep Creek	<1	<20	20	<20	>2,000	<10	5,000	100	1,500	>5,000	<50	>5,000
29CB	North tributary, Sheep Creek	<1	<20	100	500	>2,000	<10	5,000	150	>2,000	>5,000	<50	>5,000
30CB	North tributary, Sheep Creek	<1	<20	30	<20	500	50	500	300	700	>5,000	<50	2,000
31CB	Devils Creek	<1	<20	7	500	>2,000	<10	2,000	50	700	>5,000	<50	2,000
34CB	North Sheep Creek	<1	<20	300	<20	2,000	<10	1,500	150	700	>5,000	<50	2,000
39KS	Sheep Creek	<1	<20	7	<20	>2,000	<10	3,000	500	700	>5,000	<50	3,000
40KS	West tributary, Sheep Creek	<1	<20	10	100	1,500	<10	1,500	50	700	>5,000	<50	2,000
41KS	East tributary, Sheep Creek	<1	<20	5	200	1,500	15	3,000	30	700	>5,000	<50	3,000
42KS	Sheep Creek	<1	<20	7	100	2,000	<10	1,500	70	700	>5,000	<50	3,000
43KS	East tributary, Sheep Creek	<1	<20	20	700	2,000	100	3,000	300	>2,000	>5,000	<50	3,000
44KS	South tributary, Sheep Creek	<1	<20	200	<20	1,500	20	2,000	100	>2,000	5,000	200	5,000
45KS	North tributary, East Fork Sheep Creek	2	<20	70	<20	2,000	10	2,000	500	>2,000	5,000	2,000	5,000
46KS	East Fork, Sheep Creek	<1	<20	15	300	700	<10	700	50	>2,000	>5,000	500	3,000
47KS	North tributary, East Fork Sheep Creek	<1	<20	100	500	2,000	<10	1,500	100	>2,000	>5,000	500	3,000
48KS	East Fork Sheep Creek	<1	<20	50	300	500	<10	700	100	>2,000	>5,000	300	1,500
49KS	North tributary, East Fork Sheep Creek	<1	<20	150	100	>2,000	<10	>5,000	100	>2,000	>5,000	<50	>5,000
50KS	South tributary, East Fork Sheep Creek	<1	<20	15	<20	>2,000	<10	>5,000	200	700	>5,000	200	>5,000
51KS	North tributary, East Fork Sheep Creek	10	20	50	700	1,000	10	500	100	>2,000	>5,000	100	>5,000
52KS	South tributary, Sheep Creek	20	<20	200	1,000	>2,000	300	5,000	1,000	>2,000	>5,000	<50	5,000
01SJ	South tributary, Sheep Creek	<1	<20	5	<20	1,500	<10	1,500	100	700	>5,000	<50	1,500
02SJ	South tributary, Sheep Creek	<1	<20	7	150	1,500	<10	700	100	700	>5,000	<50	1,500
03SJ	South tributary, Sheep Creek	<1	<20	5	<20	2,000	100	1,000	30	150	>5,000	<50	1,000
04SJ	South tributary, Sheep Creek	<1	<20	10	150	500	20	1,000	50	70	>5,000	<50	700
05SJ	Devils Creek	<1	<20	7	<20	2,000	<10	1,500	70	200	>5,000	<50	3,000
06SJ	East tributary, Devils Creek	<1	<20	7	<20	1,500	<10	1,000	30	100	>5,000	<50	1,000
07SJ	Devils Creek	<1	<20	7	<20	1,000	<10	700	30	150	>5,000	<50	1,500
08SJ	East tributary, Devils Creek	<1	<20	7	<20	2,000	<10	700	100	200	>5,000	<50	1,500

be of Tertiary age. The presence of primary antimony minerals in the Tertiary dikes indicates that the antimony minerals are of Tertiary, not Cretaceous, age.

Thirty-three sediment samples were collected from streams that drain the Swanholm antimony district during three different sampling programs. In 1986, five stream-sediment samples were collected and analyzed by the standard U.S. Geological Survey semiquantitative spectrographic method. No detectable antimony, or anomalous concentrations of any other metals, was determined in these samples even though one sample was collected only 500 ft downstream from the North pit of the Hermada antimony mine. These disappointing findings probably resulted from the way in which the samples were collected or from the analytical method used. Semiquantitative spectrographic analysis has a lower limit of detection of 100 ppm for antimony and is not recommended for analysis of antimony in stream sediments.

As part of the second sampling program, stream-sediment and panned-concentrate samples were collected at 8 different sites in 1988. The stream-sediment samples were analyzed by an inductively coupled plasma spectrometry (ICP) method, which has a lower detection limit of 1 ppm for antimony. The panned-concentrate samples were analyzed by the semiquantitative spectrographic method, using an analytical procedure that has a detection limit of 200 ppm Sb for this type of concentrated sample (Malcolm and Smith, 1992). To check the analytical results obtained for these eight samples, a third set of twelve panned-concentrate and stream-sediment samples was collected in 1989 and analyzed by the same methods as the samples collected in 1988.

The sampling programs show clearly that analyzing panned-concentrate samples by semiquantitative spectrographic analysis and stream-sediment samples by an ICP analytical method are both successful ways to detect antimony in stream sediments. In the Swanholm antimony district, panned-concentrate samples yielded anomalous concentrations of antimony at most sites that were downstream from the Hermada mine or below other known antimony prospects.

Hermada Antimony Mine

The Hermada antimony mine (fig. 9, loc. 5) is in the western half of sec. 13, T. 6 N., R. 9 E. Mine workings consist chiefly of the Hermada pit and the North pit, which is about 2,500 ft north of the Hermada pit. Both workings are along the west side of the East Fork of Swanholm Creek, about 3 mi northeast of the junction of Swanholm Creek and the Middle Fork Boise River. In addition to the Hermada and North pits (fig. 9, loc. 4), several thousand feet of bulldozer trenches, many of them more like roads than trenches, extend along hillsides west of the Hermada pit. In 1992, the Hermada property consisted of 13 unpatented mining claims and 5 patented claims (Hermada and Hermada Nos. 1, 2, 4, and 6).

The Hermada claims were staked in 1947. The most active period of mining operations at the property was from 1947 to 1950. Original exploration was by adits, but these were obliterated by subsequent development of the Hermada open pit, which is about 250 ft long and as wide as 125 ft. Mining in the Hermada pit was by bulldozer and handsorting of selected pieces of ore. According to Popoff (1953), in 1947–48 the Hermada Mining Company mined and shipped 207.65 tons of crude ore that averaged 32.05 percent Sb. A high-grade ore sample collected in 1948 contained 35.3 percent Sb, 12.4 percent S, 0.05 percent As, 0.11 percent Pb, 46.0 percent SiO_2, 0.30 percent CaO, 1.30 percent FeO, 4.7 percent Al_2O_3, and nil gold and silver (Popoff, 1953). From 1947 to 1950, 4,600 tons of ore averaging 11.7 percent Sb was produced from the mine and trucked to the Talache mill at Atlanta, Idaho. From these shipments, the mill produced 776 tons of concentrate that averaged 59.92 percent Sb. Antimony ore also was produced from the Hermada mine in 1951 and 1952 and concentrated at the Atlanta mill. As of 1992, total output from the mine was about 1,502,000 pounds of antimony according to unpublished U.S. Bureau of Mines records. Almost all of this antimony was mined from the Hermada pit.

The Hermada deposit is in biotite granodiorite (fig. 10, unit Kgd), and consists of a broad zone of north-northwest-striking faults and narrow andesitic dikes along which are quartz-stibnite veins that are irregular in strike length and thickness. The

Figure 10. Geologic map of the northern part of the upper bench of the Hermada pit. Mapped by T.H. Kiilsgaard in 1951.

longest vein explored to 1950 was 115 ft (Popoff, 1953); it commonly was only a few inches thick, but some shoots were as thick as about 5 ft. The overall width of the mineralized zone was about 100 ft. Stibnite was the principal ore mineral, although other antimony minerals, including kermesite, stibiconite, cervantite, and valentinite, were also present. At the Hermada pit, the northerly trending Hermada zone is intersected and crosscut in at least three locations by younger northeast-striking dacitic dikes.

Biotite granodiorite along dikes in the Hermada zone is hydrothermally altered to sericite and clay minerals. Locally, the alteration is so intense that identification of the original rock is difficult. The andesitic dikes also are altered and decomposed locally to a brownish, earthy material. The quartz-stibnite veins are in the granodiorite, contiguous with or near the northerly trending dikes (fig. 10). Mineralized lenses in the veins are in granodiorite that has undergone sericitic and silicic alteration. Near mineralized shoots, the granodiorite has been mostly replaced by quartz, much of which has been broken and granulated by postmineral faulting.

The Hermada deposit was explored under a Defense Minerals Administration (DMA) contract in 1951 and 1952. The exploration work consisted of extensive bulldozer trenching in the North pit, several thousand feet of bulldozer trenching west of the Hermada pit and driven west to intersect north-striking veins projected south from the Hermada pit (Kiilsgaard and Zoldak, 1955, unpublished DMA report available in Spokane field office). Exploration in the North pit exposed a north-striking quartz-stibnite vein a few inches thick that was cut by a large, northeast-striking shear zone that postdates quartz-stibnite mineralization. Pulverized stibnite was found in the shear zone. A quartz-stibnite vein about 10 in. thick was exposed in a bulldozed cut about 2,400 ft S. 60° W. from the Hermada pit. Native antimony was found in a northeast-trending dacite dike, about 1,100 ft south of the Hermada pit. Sparse pyrite and flecks of stibnite also were found in altered biotite granodiorite intruded by a northeast-striking dacite dike that was intersected in the adit about 260 ft from the portal. The final 60 ft of adit intersected highly altered biotite granodiorite in which there was numerous north-striking quartz stringers as thick as 5 in. and much pyrite but no stibnite.

Svensson Antimony Prospect

The Svensson antimony prospect (fig. 9, loc. 1) is along the eastern side of sec. 10, T. 6 N., R. 9 E., about 0.5 mi east of Swanholm Creek and about 4 mi north of the intersection of Swanholm Creek and the Middle Fork Boise River. Mine workings at this prospect explore several small, discontinuous stibnite-bearing quartz veins that cut Cretaceous biotite granodiorite.

Mineral exploration at the prospect has been concentrated at two locations (1) a caved adit, the portal of which is at an altitude of 5,800 ft, and that, according to Bill Weatherby (oral commun., 1992) extended about 120 ft southeast into the hillside, and (2) a large bulldozed pit about 140 ft long, 70 ft wide, and 20 ft deep, the bottom of which is at an altitude of 5,930 ft and 400 ft southeast of the portal of the adit. Several other bulldozed cuts are northeast and east of the principal workings. All of the workings are on the Hope Nos. 1 and 2 unpatented claims.

The large bulldozed pit was excavated in 1952 as part of a Defense Minerals Exploration Administration (DMEA) contract let to Oscar V. Svensson, Boise, Idaho, for the purpose of exploring three parallel stibnite-bearing quartz veins that strike N. 15° W. and dip 50°–60° NE. The veins range from 2 to 12 in. in thickness, are about 5 ft apart, and consist chiefly of a hanging-wall gouge zone along which are quartz veins that contain disseminated, fine-grained pyrite and minor amounts of stibnite. Biotite granodiorite within the vein zone is strongly altered to sericite and clay minerals and, locally, stained by limonite derived from oxidized pyrite. Samples of the veins collected in 1952 ranged from nil to 7.5 percent Sb. Atomic absorption analysis of two samples of the vein material collected in 1986 showed 0.08 and 0.09 ounces of gold per ton. Semiquantitative spectrographic analysis of the two samples showed 200 and more than 1,000 ppm As and 100 and more than 1,000 ppm Sb. Svensson reported that prior to 1951, several tons of quartz, some of it containing 6–8 percent Sb, was mined from the pit, production that was a justifying reason for the subsequent DMEA contract. No significant amount of stibnite, however, was discovered by the DMEA exploration program.

The lower, caved adit was driven by the Weatherby family during the 1960's to test the veins explored by the large open pit. A few tons of quartz and stibnite are reported to have been mined from the adit, but the work did not find a significant amount of antimony (Bill Weatherby, oral commun., 1992).

About 570 ft N. 20° E. of the large open pit is a veinlet of quartz containing disseminated stibnite. The vein strikes N. 25° W., dips 50° NE., is about 4 in. thick, and was explored in 1952 over a strike length of 70 ft by bulldozer trenching. Two samples collected from the vein in 1952 contained 0.30 and 0.06 percent Sb. One of the samples contained 0.44 percent As and 0.10 percent Pb (Popoff, 1953).

About 850 ft east of the large open pit, on top of the hill, two parallel quartz veins about 5 ft apart strike N. 19° W., dip 60° NE., and range from 2 to 12 in. in thickness. The veins were explored by bulldozer trenching over a strike length of 140 ft in 1952. Stibnite was found in the veins but not in an amount sufficient to warrant additional exploration.

Another quartz vein tested in 1952 is 950 ft N. 50° E. of the large open pit. The vein strikes N. 12° W., is as thick as 12 in., contains trace quantities of stibnite, and was explored by a crosscutting bulldozer trench.

Stibnite-bearing quartz veins at the Svensson prospect are in a northwest-striking zone about 850 ft wide. The veins are small and discontinuous. Locally, they contain concentrations of stibnite, but the overall antimony grade is low.

Weatherby Prospect

The Weatherby antimony prospect (fig. 9, loc. 2) is in the north-central part of sec. 14, T. 6 N., R. 9 E., along a southwest-flowing tributary of Swanholm Creek, about 3.25 mi north of the junction of Swanholm Creek and the Middle Fork Boise River.

The prospect consists of a sloughed bulldozed cut and a caved adit a few feet below, which is reported to be about 150 ft long and to have been driven in the 1960's (Bill Weatherby, oral commun., 1992). Both the bulldozed cut and the adit trend S. 20° E. Several tens of tons of hand sorted quartz, stibnite, and altered biotite granodiorite were observed on the adit dump in 1986. The handsorted material probably was stockpiled in anticipation of acquiring a volume large enough to warrant shipping, but apparently that volume was not collected. Some of the pieces of ore are too large to have come from the adit and probably are from the bulldozed cut. Quartz of the hand sorted material contains fine-grained pyrite and stibnite. Many pieces of ore have slickensides and are coated with gouge; they may have been mined from a fault zone. Atomic absorption analysis of a selected sample of the dump ore yielded 0.35 ounces of gold per ton. Semiquantitative spectrographic analysis of the same sample yielded more than 10,000 ppm (1 percent) Sb, 1,000 ppm As, and 5 ppm Ag. No vein or fault was seen in the sloughed workings, but the trend of the workings suggests that the workings were driven on a vein that strikes about N. 20° W.

Anderson-Bida Property

The Anderson-Bida property (fig. 9, loc. 3) is in SW1/4 sec. 14. T. 6 N., R. 9 E., about 1 mi southwest of the Hermada mine, and about 2.25 mi north of the junction of Swanholm Creek and the Middle Fork Boise River. The property was staked in 1948 as the Reno Nos. 1–5 claims.

According to Popoff (1953), a number of pits and trenches on the property expose a north-northwest trending zone of dacitic dikes and hydrothermally altered and erratically mineralized granitic rocks that more or less parallels the trend of the Hermada mineralized zone. The hydrothermally altered granitic rocks are in two parallel bands that range from 2 to 10 ft in thickness, strike north-northwest, and were traced by Popoff on strike for about 700 ft. A quartz-stibnite vein that ranges from 1 to 14 in. in thickness is at the northern end of the hydrothermally altered rocks. About 30 tons of low-grade mineralized material was mined from the vein prior to 1949 but was not shipped. At the southern end of the 700-foot-long belt of hydrothermally altered rocks, north-striking quartz-stibnite veinlets as thick as 2 in. were observed in the silicified granitic rock (Popoff, 1953).

In 1986, surface workings at the property were sloughed to the point where no trace of the veins or altered bands could be seen. Fragments of quartz on a northern dump contained fine-grained but sparse stibnite. The property is in rough alignment with the Weatherby and Svensson properties and probably is part of the mineralized trend that extends through the three properties.

Discussion

In epithermal gold-silver-bearing veins, concentrations of antimony and arsenic minerals commonly are highest in the upper parts of the veins, gold and silver values are highest in the middle parts, and base-metal contents are highest at deeper levels. The Swanholm district is in a downdropped fault block, the structural location of which has protected the block from erosion. The presence of stibnite as the primary antimony ore mineral and the concentration of arsenic in the quartz-stibnite veins suggest that only the upper parts of the veins may have been eroded. Gold has not been recovered from Swanholm district ore, but the two samples of vein material from the Svensson property that contained 0.08 and 0.09 ounces of gold per ton, the dump sample from the Weatherby property that contained 0.35 ounces of Au per ton and 5 ppm Ag, and panned sample nos. 10 and 12CB (fig. 7) that contained 20 and 100 ppm Au (table 2) indicate the presence of gold in the district. Known veins are small in size, and vein samples indicate low gold values, but the mineralized zone in which the veins are present is large. The possibility of higher gold and silver contents at depth can be determined only through further exploration.

Middle Fork Boise River Placers

Placer gold was discovered at Atlanta (fig. 1) in August 1863 (Wells, 1983) and in the vicinity of Phifer and Swanholm Creeks in the spring of 1864. River placers in the vicinity of Lucky Peak dam (west of the study area) were being worked in 1864, and placer mining near Twin Springs (fig. 1) was underway by 1877. Little is known about the history or early production of placer gold at various sites along the Middle Fork Boise River because production records were kept only by the County and State, and there is little or no information on individual mine sites. There is, however, considerable evidence of early placer mining, including large evergreen trees growing from piles of placered boulders at different sites along the river. Examples of early placer mining are near the mouths of Phifer and Swanholm Creeks. South of the mouth of Phifer Creek, extending into the NW1/4, sec. 2, T. 5 N., R. 9 E. (fig. 9), is a placered area that is unique in that it is as much as 640 ft above the Middle Fork Boise River. The placer is in high gravel deposits of Pleistocene age. In upper parts of the placered area, spring runoff of melted snow apparently was the source of water for mining. Similar evidence of early placer mining is on the north side of Middle Fork Boise River, east of the mouth of Swanholm Creek, in NW1/4 sec. 36 and SW1/4 sec. 25, T. 6 N., R. 9 E. (fig. 9). Placer mining at this location extended more than 500 ft above the Middle Fork Boise River and, similar to placer mining on the south side of the river, was confined to high gravel deposits.

Piles of boulders and other evidence of early placer mining are present at many locations along the Middle Fork Boise River, but examination of U.S. Geological Survey and U.S. Bureau of Mines placer production records dating back to 1901 indicates five areas have been the principal producers (table 4). Of these, a stretch of river-valley alluvium along the Middle Fork Boise River, above the mouth of Phifer Creek, has been, by far, the most productive. Worked on a small scale in 1908 and 1909, the alluvial deposit was brought into major production by Boise King Placers in 1941 when 7.5-ft^3 bucket-line dredge was placed in operation. During the years 1941, 1942, and 1946, the dredge processed 2,801,894 yd^3 of alluvium from which was recovered 15,278 ounces of gold.

Table 4. Gold and silver production from placers along or near Middle Fork Boise River from 1901 to 1947.

[Concentrations shown in ounces. Data compiled from the U.S. Geological Survey Mineral Resources of the United States, volumes 1908–1916, U.S. Bureau of Mines Yearbooks, 1941–1946, and unpublished U.S. Bureau of Mines reports]

Placer locality	Gold	Silver
Boise King placers—Alluvium along 2.65 mi of Middle Fork Boise River, from 0.3 mi east of mouth of Phifer Creek to 0.35 mi east of mouth of Smith Creek	15,361	5,202
Twin Springs district— Terrace and high gravel deposits near Middle Fork Boise River, from Ada County line northeast to mouth of North Fork Boise River	1,496	409
Terrace gravel along Middle Fork Boise River near the mouth of Phifer Creek	268	91
Terrace gravel along Middle Fork Boise River, near the mouth of Eagle Creek	118	36
Terrace gravel, Queens River, at and near junction with Middle Fork Boise River	141	42
Various small placers of terrace gravel and alluvium at or near the mouths of different streams and their junctions with Middle Fork Boise River	313	90
Total…………………………………………………………………………………………..	17,697	5,870

The Twin Springs mining district was the most consistent producer of placer gold from 1901 to 1940. The gold was mined primarily by hydraulic operations. Water for hydraulic mining came from Sheep Creek, was siphoned across the Middle Fork Boise River (fig. 11*A*), and then flowed chiefly by flume (fig. 11*B*) about 2.5 mi to a placer site in high gravel near Twin Springs (fig. 11*C*). Smaller scale hydraulic placer mining was conducted in terrace gravel on the east side of Middle Fork Boise River, across the river from Twin Springs, using water brought by ditch from nearby Alder Creek.

Gold values varied at different placer sites (table 5). Deposition of placer gold is affected by many conditions, including changes in stream gradient, obstacles in the stream bed such as large boulders or protruding outcrops of bedrock, size of gold particles, and so on. Different gold-bearing channels of gravel usually represent deposition at different times and under different conditions. As would be expected, such channels commonly contain different amounts of gold. The range of gold values shown in table 5, however, may be in part because of incorrect estimates of the cubic yards of gravel mined or because of the recovery procedures. The most reliable gold values of mined placer material probably are those from the Boise King placers, where the bucket-line dredge provided a means of accurately measuring the cubic yards mined. Gold in alluvium mined at the Boise King placers location averaged 0.0054 oz per cubic yard (table 5).

Most of the placer gold in high gravel, terrace gravel, and alluvium along the Middle Fork Boise River originated from erosion of lode deposits that crop out near Atlanta. This conclusion is supported by the fact that there are no significant gold placer deposits along the Middle Fork upstream from Atlanta. Considerable placer gold, however, has been transported by the Queens and Little Queens Rivers, (Worl and others, 1991); the gold probably was derived from lode deposits that crop out upstream along the Little Queens River. Another source of placer gold has been Black Warrior Creek, where known lode deposits have been eroded both by Black Warrior Creek and its principal tributary, West Warrior Creek (Worl and others, 1991).

The high gravel deposits along the valley walls of the Middle Fork Boise River are the oldest gold-bearing gravel deposits in the area. These deposits formed from Pleistocene erosion by the ancestral Middle Fork Boise River. A larger volume of water, derived from melting glaciers in the Sawtooth Mountains, probably flowed in the river at that time. Uplift of the region increased the stream gradient and the rate of erosion. Erosion exposed the lode deposits in the vicinity of Atlanta and at other locations, and the gold eroded from the lodes was transported downstream by the flowing water and deposited in the gravel. Continued uplift of the mountainous region caused deeper stream erosion, thereby transporting most of the high gravel deposits and the gold to lower elevations and forming what are now referred to as the terrace gravels. Further uplift of the region and erosional deepening of the stream valleys transported most of the terrace gravels downstream, leaving heavier materials in the present stream alluvium.

Placer gold in the transported gravel was subjected to stream-transport abrasion, to the forces of "nature's ball mill." The milling action dislodged adhering and contaminating mineral and rock particles from the gold grains and flakes. It also resulted in smaller gold particles; gold is coarser nearer the eroded source. Stream-transport abrasion also probably affected the fineness (degree of purity) of the transported gold. A sampling of placer gold mined along the Middle Fork supports the conclusion that placer gold mined farther from its originating source, as in the Twin Springs district, tends to be of higher purity (table 6). Pure gold (1000 fine) rarely is found in placer deposits.

Mineral Resources

Placer Resources

A large but unmeasured yardage of unmined auriferous gravel remains along the Middle Fork Boise River, most of it in high and terrace gravel of the Twin Springs district (fig. 1) (Worl and others, 1991). Other areas that contain substantial amounts

Table 5. Gold values of placers mined along Middle Fork Boise River.

[From unpublished U.S. Bureau of Mines sources. Values calculated from a gold price of $35.00 per ounce]

Placer locality	Year	Cubic yards of gravel mined	Ounces of gold produced	Ounces of gold per yd^3	Values per yd^3
Near mouth of Eagle Creek	1935	500	13	0.0260	$0.91
Near mouth of Eagle Creek	1937	300	6.5	0.0218	0.76
Mouth of Buck Creek	1939	5,000	13	0.0026	0.09
Mouth of Yuba River	1939	1,400	8	0.0057	0.20
Mouth of James Creek	1940	8,000	27	0.0033	0.12
Mouth of Queens River	1940	500	4	0.0080	0.28
Boise King Placers, along Middle Fork Boise River	1941 1942 1946	2,801,894[1]	15,278[2]	0.0054[3]	0.19
Near mouth Phifer Creek	1938	7,524	68	0.0090	0.32
Twin Springs district	1934	1,000	15.4	0.0150	0.53
Twin Springs district	1938	1,000	18	0.0180	0.63
Twin Springs district	1938	1,500	19	0.0063	0.22
Mouth of Birch Creek, Twin Springs district	1940	2,000	11	0.0055	0.19
Twin Springs district, mouth of Birch Creek	1947	1,000	5	0.0050	0.18
Twin Springs district	1939	1,800	13	0.0072	0.25
Twin Springs district, near Slide Gulch bridge	1940	500	3	0.0060	0.21

[1] Total yardage mined in 3-year period.
[2] Total ounces of gold produced in 3-year period.
[3] Average grade.

Table 6. Fineness of placer gold mined along Middle Fork Boise River.

[Compiled from U.S. Geological Survey Mineral Resources of the United States, volumes 1908–1916, U.S. Bureau of Mines Yearbooks, and unpublished U.S. Bureau of Mines report]

Placer location	Ounces of mined gold	Fineness of gold (weighted average)
Junction, Yuba and Middle Fork Boise Rivers	17	743
Mouth, Queens River	86	734
Near mouth of Eagle Creek	93	753
Twin Springs district	273	789

of auriferous gravel are terrace gravels along the north side of the Middle Fork Boise River between the mouths of Phifer and Smith Creeks and terrace gravels near the mouth of Eagle Creek. The Black Warrior Creek valley, beginning about 1.7 mi from the mouth of the stream and continuing upstream for about 1.8 mi is a placer resource, as is a tributary, West Warrior Creek, from the stream mouth upstream for about 0.5 mi. From the Black Warrior-West Warrior stream junction, about 1.3 mi upstream along Black Warrior Creek and 0.6 mi downstream, the alluvium-floored valley of the creek ranges from 200 to 500 ft in width and the alluvium is as deep as 10–15 ft (Ballard, 1928). In 1925 attempts were made to mine the alluvium using hydraulic methods. Coarse gold was recovered, but apparently the low stream gradient created a tailings-dump problem that hampered mining. Little evidence of extensive placer mining was seen at the site in 1987.

Placer mining probably occurred at Alexander Flats, along the Middle Fork about 7 mi upstream from the junction of the North Fork Boise River and the Middle Fork. A small placered area in river-valley alluvium at the upstream end of the flats and another small placered area of terrace gravel on the northeast side of Big Five Creek, near the mouth of the stream, at the down-stream end of the flats attest to previous placer efforts in the area. Alexander Flats consists of about 315 acres of alluvium, most of which extends along the southeast side of the Middle Fork. Part of the flats was explored in 1951 by the U.S. Bureau of Mines as part of a project designed to search for radioactive materials. Ten holes were churn drilled through the

Figure 11. Former placer operations in the Twin Springs placer district. *A*, Siphon used to transport water across the Middle Fork Boise River. Water was brought from Sheep Creek by ditch and flume to a point on the southeast side of the river, across the river and discharged into a flume that extended from the ridge crest on the south side of Logging Gulch, through a ridge saddle that is about 2,200 ft southwest of the mouth of Logging Gulch, and southwest to the placer site near Twin Springs. Copyrighted photograph from Idaho State Historical Society #74-165.17, used with permission. *B*, Long wooden river built to carry water from Sheep Creek to a placer site near Twin Springs. Copyrighted photograph from Idaho State Historical Society #76-81.48, used with permission. *C*, Placer mine 1,500 ft north of Twin Springs and about 400 ft above river level in a deposit of high gravel. Note the hydraulic giant that washed the north bank of the pit and the horizontal riffles below the pit that trapped the gold. Beneath the riffles, the water was recaptured and passed through a flume to a point about 2,100 ft upstream from Twin Springs and about 100 ft above river level, where it was reused to mine placer gold from a deposit of terrace gravel. Photograph, probably taken in the early 1900's, courtesy of George C. Castle, Twin Springs, Idaho.

alluvium to depths ranging from 10 to 23 ft before bedrock was reached (Storch and Holt, 1963). Material from the holes averaged 1.1 pounds of ilmenite, 0.08 pounds of monazite, and a few cents in gold values per cubic yard, low metal values for a placer deposit. A significant yardage of alluvium is present at Alexander Flats, but the low metal contents in the drill-hole samples indicate that the alluvium could not be profitably mined at 1992 costs and metal prices.

A commodity in the alluvial gravels that has received little attention but which warrants testing is tin. Biotite granite of the Sheep Creek batholith contains unusually high concentrations of tin, most if not all in the mineral cassiterite. Cassiterite is a heavy mineral, which, as it was eroded from the biotite granite by the tributaries of the Middle Fork Boise River, has become concentrated in the black-sand or heavy mineral fraction of the stream sediments. Cassiterite, by itself, probably would not be minable, but it and concentrations of heavy rare-earth minerals that are likely to be associated with it might be recovered as byproducts from a gold-placer operation.

As of April 1992, most of the Federal land along the Middle Fork, upstream from the Arrowrock Dam to the junction of the North Fork and Middle Fork Boise River, had been withdrawn from the mineral entry. From the river junction, most of the Federal land along the Middle Fork to the vicinity of the Middle Fork-Roaring River junction also has been withdrawn from mineral entry, as had Federal land along the North Fork from the river junction to the vicinity of the North Fork-Lost Owl Creek junction. In March 1993, information on the withdrawn status of these Federal lands could be obtained from the U.S. Bureau of Land Management, Idaho State Office, Boise, Idaho.

Potential Lode-Deposit Resources

Stibnite is present at several separate localities in the Swanholm antimony district, although estimates of the amount of antimony that might be present cannot be made without more exploration. Unknown but probably minor amounts of low-grade gold- and silver-bearing minerals are likely to be associated with stibnite at the mineralized localities.

There are no known mineral deposits in any of the three geochemical study areas that could be considered minable in March 1993. Several brecciated and silicified exposures of Eocene granite in the Sheep Creek area contain molybdenite, but additional exploration is needed. Possible byproduct minerals, including beryl, fluorite, scheelite, cassiterite, and, possibly, unidentified tin-bearing minerals and rare-earth-element minerals, also are present at the molybdenite-bearing localities.

Geologic and geochemical studies of this project have identified the possibility of presently unknown gold deposits in the Granite Mountain area. Deposits containing bismuth, silver, and tungsten, and other metals probably are present in the Mt. Heinen area, but additional exploration is needed.

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