Geology and Geochemical Exploration of the Vienna District Blaine and Camas Counties, Idaho

Spencer S. Shannon Jr.

Idaho Bureau of Mines and Geology
Moscow, Idaho
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GEOLOGY AND GEOCHEMICAL EXPLORATION OF THE VIENNA
DISTRICT, BLAINE AND CAMAS COUNTIES, IDAHO

by

Spencer S. Shannon, Jr.

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GEOLOGY AND GEOCHEMICAL EXPLORATION OF THE VIENNA DISTRICT BLAINE AND CAMAS COUNTIES, IDAHO

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Spencer S. Shannon, Jr.

ABSTRACT

A geologic and geochemical study of the Vienna district in the Sawtooth Mountains of south-central Idaho was made to determine the usefulness of geochemical exploration techniques in the reevaluation of a dormant metal-mining district.

Marine calcareous sandstone and siliceous limestone of the Wood River Formation, deposited during Desmoinesian to Wolfcampian time, were deformed during the Nevadan orogeny in late Jurassic time. Silicic magmas of the Idaho batholith intruded the folded strata during middle Cretaceous time; in the contact zone, carbonate rocks are metamorphosed to wollastonite-diopside granofels and siliceous rocks are transformed to metaquartzite. The Paleozoic rocks are deformed by cataclasis and were refolded, in turn along northeasterly and northwesterly axes; the deformations tentatively have been assigned to the Laramide orogeny.

Flows, flow breccias, and tuffs of hornblende latite, trachyte, and andesite composing the basal member of the Challis Volcanics were deposited on a surface of much relief in Eocene time. Probably during the same epoch, hornblende latite porphyry and andesite breccia dikes were emplaced in the quartz monzonite pluton.

Epithermal quartz veins containing tetrahedrite, ruby silver, and subordinate stibnite, galena, and sphalerite formed along shear zones in quartz monzonite. The seemingly consanguineous dikes, flows, tuffs, and mineral deposits may have had a common source in the upper mantle.

In late Tertiary time, movements along steep normal and reverse faults tilted the Challis Volcanics. During Pinedale time, alpine glaciers scoured the major stream valleys and deposited moraines and outwash near their mouths.

Silver ore was discovered in the Vienna district in 1879. In the ensuing decade, ore valued at nearly $2 million was shipped from the district. Since 1889, small shipments have been made occasionally from various properties.

Active stream-bed and floodplain sediments were sampled near the mouths of first- and second-order tributaries. Cold-extraction tests for ammonium citrate-soluble heavy metals were run on all samples. Background for the Vienna district is 2 ppm zinc equivalent of cold-extractable heavy metals; the threshold value is 8 ppm.

Two cold-extraction copper tests were compared on selected samples; the test using dithizone in petroleum ether as a collector was slightly more sensitive than the test using 2,2'-biquinoline in isoamyl alcohol. Specific total-extraction tests for copper and zinc were made on selected samples.

Field tests with cold ammonium citrate were conducted upstream from sample sites. Anomalous sources found include limonite-stained quartz veinlets and organic sediments.
Contamination from old workings masks natural anomalies. Anomalies in Pleistocene drift may indicate ore deposits in glaciated terrane. The anomalies seem to be independent of post-Challis faults, but may have some relation to fracture-controlled valleys.

The probability is moderate of finding new ore deposits in the Vienna district; most are likely to be small and to have no surface expression.
INTRODUCTION

PURPOSE AND SCOPE OF THE INVESTIGATION

The chief purpose of this investigation was the revaluation of the dormant Vienna mining district. Geochemical sampling and geologic mapping were used to select favorable areas for exploration.

The relative reliability and effectiveness of several types of field and laboratory sampling procedures and geochemical tests were compared. The information obtained may facilitate selection of satisfactory procedures and tests for use in mining districts that have similar lithology, mineralogy, climate, and vegetation.

LOCATION AND ACCESSIBILITY

The Vienna district is in the southern Sawtooth Mountains in northwestern Blaine County and northern Camas County, Idaho (fig. 1). The county line follows the drainage divide between the headwaters of the Salmon River and the headwaters of the South Fork of the Boise River. The district has an area of approximately 67 square miles.

United States Highway 93 parallels the northeastern border of the district. The nearest towns are Stanley, 20 miles north of the Vienna district, and Ketchum, 40 miles southeast of it. The nearest railhead is at Ketchum on a branch of the Union Pacific Railroad.

CLIMATE AND VEGETATION

The Vienna district has a subarctic climate with short, cool, dry summers. At Obsidian, elevation 6,900 feet, 7 miles north of Vienna, the mean annual temperature is 35°F; the mean annual precipitation is 15 inches, most of which falls as snow (U. S. Weather Bureau, 1937, 1958, 1953-62). Near the Solace Mine, elevation 8,800 feet, at the head of the west fork of Smiley Creek, average recorded precipitation is 50 inches a year (U. S. Weather Bureau, 1949-58). Because the mean annual snowfall at Obsidian is 85 inches, the yearly average at the Solace Mine is estimated to be more than 500 inches.

Sagebrush and bunch grasses grow upon alluvial deposits and also partially cover many south- and west-facing mountain slopes. Lodgepole pine is the dominant species on the north- and east-facing mountain slopes and on the moraines.

PREVIOUS INVESTIGATIONS

J. B. Umpleby (1914, p. 247-249) made a brief reconnaissance of the Vienna district in 1913. S. M. Ballard (1922, p. 5-33) conducted a more detailed survey of the geology of the mines in August 1921. C. P. Ross (1927a, p. 1-17) mapped the areal and underground geology of the central part of the Vienna district in August, 1926 and examined portions of the surrounding area during 1924-1930 (Ross, 1937, p. 4). In his report on the Bayhorse region, Ross (1937, pl. 1) included a geologic map of the

METHODS OF INVESTIGATION

Field work was undertaken in the Vienna district during the summer of 1962. The geology of the part of the district west of long. 114°50' W. was mapped on a scale of 1:31,680 (pl. 1). The geology of the part of the district east of long. 114°50' W. is a revised compilation of the work of Barnes (1962, pl. 1).

Field measurements were made by Brunton and pace traverses. Short distances were measured with a cloth metallic tape.

Sediment samples were taken from stream beds and floodplains. A field laboratory was set up in a ranch house near Obsidian and geochemical tests on stream-sediment samples were performed. Detailed field geochemical surveys were conducted in stream valleys that appeared from preliminary, base-camp laboratory tests to be areas of possible mineralization.

Petrographic studies of thin sections and additional geochemical tests were made in the laboratories of the College of Mines.

Igneous rocks are named according to the descriptive modal classification proposed by Peterson (1960, p. 30-36). Colors of rocks are described according to the Rock Color Chart (Geological Society of America, 1951).

ACKNOWLEDGMENTS

The Idaho Bureau of Mines and Geology underwrote field expenses and provided chemicals and air photographs. Mrs. Isabel C. Miller of Twin Falls, Idaho, kindly permitted the use of one room of her ranch house near Obsidian, Idaho, as a geochemical laboratory. Mr. Spencer S. Shannon provided major financial assistance. Mr. Jose R. Bollar drafted many of the maps.

The faculty of the College of Mines, University of Idaho, especially Dr. Rolland R. Reid, gave able guidance to the doctoral thesis (Shannon, 1964) of which this report is a summary. Dr. Peter L. Siems and Dr. John M. Hills criticized and improved the manuscript.

Mrs. Mackenzie G. Shannon was a constant source of encouragement and inspiration for its completion.
FIGURE 1
INDEX MAP OF
VIENNA DISTRICT, IDAHO
GENERAL GEOLOGY

STRATIGRAPHY AND PETROLOGY

Wood River Formation

Metaquartzites and calc-silicate granofelses of the Wood River Formation crop out in a narrow belt extending from Vienna northwestward to the lower reach of Beaver Creek.

The base of the Wood River Formation is not exposed in the Vienna district. Within the map area, the Wood River rocks are overlain unconformably by volcanic rocks of Tertiary age and are in fault contact with quartz monzonite of Cretaceous age.

During the intrusion of the Idaho batholith, the metaquartzites were formed by contact metamorphism from preexisting quartzites, and the granofelses were formed by contact metamorphism from limestones and dolomites.

The metasedimentary rocks of the Wood River Formation are white to medium gray, massive to bedded, graphite or muscovite metaquartzite, and orthoclase-diopside or epidote-wollastonite-quartz granofels. Weathered specimens range from pinkish gray to moderate brown or moderate yellowish orange. The metaquartzites are fine grained and have granoblastic texture. The muscovite metaquartzite has a weak schistosity parallel to the bedding. The metaquartzites contain 75 to 90 percent xenoblastic quartz grains. Muscovite, graphite, pyrite, and magnetite are the most abundant accessory minerals.

Granofels have a granoblastic to nematoblastic texture. Some wollastonite porphyroblasts have sieve texture and contain xenoblastic quartz grains.

Quartz is the most abundant mineral in the granofels. Wollastonite, epidote, diopside, orthoclase, and garnet are prominent mineral constituents that locally comprise 10 to 25 percent of the granofels.

Unmetamorphosed lower Wood River strata in the Hailey quadrangle were dated as Middle Pennsylvanian (Desmoinesian) by Moore and others (1944, p. 701). Bostwick (1955, p. 944) concluded from paleontological evidence that the upper two-thirds of the Wood River Formation near Bellevue is of Early Permian (Wolfcampian) age. Ross (1962, p. 56) suggested that the minimum thickness of the Wood River Formation in the adjoining Hailey quadrangle is 8,000 feet.

Biotite quartz monzonite

Biotite quartz monzonite is the dominant rock type in the Vienna district, cropping out in 80 percent of the area. The pluton was intruded into Paleozoic strata during one of the later episodes in the emplacement of the Idaho batholith. A lead–alpha age determination on zircon from a granodiorite east of Stanley gave an absolute age of 94 million years (Jaffé and others, 1959, p. 94). In most places, the eastern edge of the quartz monzonite is in fault contact with metasedimentary rocks of the Wood River Formation and volcanic rocks of Tertiary age.

Fresh specimens of biotite quartz monzonite range in color from very light gray to
light olive gray; weathered surfaces range from yellowish gray to moderate brown. Near hydrothermal veins, the rock is altered and is greenish gray. The rocks are cut by one or more sets of closely spaced joints.

The quartz monzonite is medium grained and has hypidiomorphic granular texture. In a few specimens, a moderate cataclastic fabric is superposed.

The biotite quartz monzonite has the following average mode: quartz, 40 percent; plagioclase (An$_{31}$), 30 percent; potassic feldspar, 20 percent; biotite, 8 percent; and minor amounts of magnetite, ilmenite, sphene, apatite, zircon, and allanite.

The quartz formed late; interstitial, anhedral to round grains of quartz occur singly and in clusters between feldspar crystals. Plagioclase occurs in somewhat altered, euhedral crystals ranging from 0.5 to 2 mm in length.

Microcline is the most abundant potassic feldspar; orthoclase is present in some samples. Both microcline and orthoclase are perthitic in part. Microcline in-set crystals, as much as 15 mm in length, contain unoriented relict crystals of plagioclase and biotite and probably formed as the result of late deuteric reactions.

The biotite is pleochroic in yellow and brown. It forms ragged and broken, un-oriented flakes that average 1 mm in length. Cataclastic microfolks are present in a few flakes.

Magnetite is the second most abundant accessory mineral. Some specimens contain as much as 1 percent magnetite. Ilmenite occurs with magnetite and separately. In places, leucoxene forms after ilmenite. Sphene locally makes up as much as 1 percent of the quartz monzonite. Apatite is present as inclusions in magnetite and as discrete crystals. Zircon and allanite form euhedral crystals and inclusions in biotite that are surrounded by pleochroic halos.

Adjacent to hydrothermal veins, the rock is altered and its mafic mineral is lower. Near the cross-cutting veins, some of the mafic constituents seem to have been removed from the country rock.

On the divide between Mill Guich and Vienna Creek, quartz monzonite along fractures has been transformed to quartz biotite schist by mechanical metamorphic differentiation caused by shearing stress.

**Challis Volcanics**

Flows, flow breccias, and tuffs of the Latite-andesite Member (Ross, 1937, p. 49) of the Challis Volcanics (Ross, 1930, p. 2) crop out in the northeastern part of the Vienna district. These volcanic rocks range in composition from hornblende latite to biotite-hornblende quartz latite. In the Vienna district, the Challis Volcanics unconformably overlie metasedimentary rocks of the Wood River Formation and quartz monzonite of the Idaho batholith. In one part of the district, volcanic rocks are in fault contact with the quartz monzonite.

Ross (1962, p. 77) estimated that the total thickness of the Challis Volcanics
varies from 2,500 feet to more than 5,000 feet. In the Vienna district, the Latite-
andesite Member is more than 1,200 feet thick.

Fresh samples of Challis Volcanics from the Vienna district are predominantly
olive gray, but range from brownish gray to dusky yellow green. The color of wea-
thered specimens is chiefly light olive gray, but may be light brownish gray or
dusky yellow green because of propylitization.

The tuff and flow-breccia as well as most of the flows studied are hornblende
latite. Two flows are biotite-hornblende quartz latite.

The hornblende latite has the following average mode: potassic feldspar, 40 per-
cent; plagioclase (An₃₂), 40 percent; green hornblende, 10 percent; biotite, 5 percent;
quartz, 5 percent; and minor amounts of apatite, zircon, magnetite, and augite.

The hornblende latite flows have a felty, hialtal porphyritic texture. They contain
phenocrysts of andesine, sanidine, green hornblende, biotite, and quartz. The holo-
crystalline to hypohyaline groundmasses are composed of potassic feldspar and
plagioclase.

The hornblende latite flow breccias also have hialtal porphyritic textures, but con-
tain angular irregular xenoliths of andesite, latite, and trachyte as much as 35 mm in
length. Most of the xenoliths have a more mafic composition than the groundmass of
the breccia.

The hornblende latite tuff contains hypohyaline and mafic lithic fragments as well
as smaller shards of volcanic glass. Flow and compaction structures are absent.
Because sorting is fair to moderately good, the hornblende latite tuff is probably an
airfall tuff.

The biotite-hornblende quartz latite has the following average mode: plagioclase
(An₃₂), 30 percent; potassic feldspar, 30 percent; quartz, 20 percent; brown horn-
blende, 10 percent; biotite, 10 percent; and minor amounts of magnetite and zircon.

The quartz latite flows contain phenocrysts of andesine, biotite, hornblende,
quartz, and magnetite. The rocks have hialtal porphyritic textures and holocrystalline
to hypohyaline groundmasses, composed chiefly of potassic feldspar.

Basal clastic beds of the Latite-andesite Member exposed at a uranium prospect
near Stanley contain spores and pollen of Eocene age (Ross, 1962, p. 98). In the
Mackay quadrangle, granitic rocks that have intruded the lower part of the Challis
Volcanics are 40 to 50 million years old, based on lead-alpha age determinations.
Similar rocks in the Middle Fork of the Salmon River area are 59 million years old.
Ross inferred from these data the "... volcanism began in the Eocene, conceivably
in the Paleocene" (Ross, 1962, p. 101). From this evidence, I conclude that the
Latite-andesite Member of the Challis Volcanics was deposited in the Vienna dis-
trict during Eocene and perhaps, in part, early Oligocene time.
Quartz-microcline pegmatite

A 4-inch thick quartz-microcline pegmatite intrudes quartz monzonite in the upper part of Sawmill Canyon.

Andesite breccia

Two parallel andesite breccia dikes, 30 and 75 feet thick, which strike 060° and dip 60° NW were seen near the headwaters of the principal unnamed stream between Sawmill Canyon and Mill Gulch. Plagioclase, amphibole, and pyroxene phenocrysts are set in a feathery groundmass of plagioclase and potassic feldspar microlites. Magnetite is a minor accessory mineral as well as an alteration product.

Inclusions of quartz monzonite more than 2 feet in diameter may be evidence for forceful injection of the dikes, perhaps by shattering or magmatic stoping. The andesite breccia dikes in the Vienna district probably were intruded at almost the same time that the consanguineous Latite-andesite Member of the Challis Volcanics was extruded.

Hornblende latite porphyry

Most of the dikes in the Vienna district are hornblende latite porphyry; all dikes of this composition intrude quartz monzonite.

The largest hornblende latite porphyry dike is south of the Solace Mine and crops out along the drainage divide between Emma Creek and the western fork of Smiley Creek. The 50-foot thick dike strikes 065° to 075° and dips from 75° SE to vertically. It can be traced continuously along strike for 0.6 mile; discontinuous exposures of similar rocks can be traced 0.7 mile farther along the same trend to the southwest.

Two parallel hornblende porphyry dikes, approximately 800 feet apart, were noted at the foot of the north face of Marshall Peak. These dikes strike 290° and dip vertically. Each has an average thickness of 15 feet.

A hornblende latite dike crops out 800 feet southeast of Johnson Creek along the main unnamed stream that drains the north side of Marshall Peak. The 12-foot dike strikes 050° and dips 75° SE.

The dike rocks contain plagioclase (An29) phenocrysts as much as 7 mm in length. Inset crystals of brown hornblende are also common and in places make up 40 percent of the total rock. Some specimens contain a few small phenocrysts of biotite. Zircon and magnetite are less abundant accessory minerals. The groundmass is composed of microlites of potassic feldspar and plagioclase.

Chilled contacts and thin apophyses of very fine-grained minerals are evidence that the dike-forming magma was intruded into cold, completely solidified quartz monzonite. The biotite and potassic feldspar content of the hornblende latite porphyry decreased toward the margins of the dikes. Xenoliths as much as 4 inches in diameter were noted along the margin of the largest dike.
Diabase

A diabase dike cuts quartz monzonite at the extreme western edge of the Vienna district, near the head of Johnson Creek. The olive-gray dike has a thickness of 2 feet, strikes 335°, and dips 70°SW. Labradorite laths partly enclose grains of pigeonite, magnetite, ilmenite (?), and olivine.

Quaternary sediments

Introduction

Alluvial clastic sediments are exposed in all principal stream valleys in the Vienna district. Part of the detritus is made up of glacial debris.

Pinedale sediments

Terrace deposits are common in glaciated valleys in the Vienna district. Williams (1961, p. 19) concluded that such deposits are of Pinedale age.

Morainal ridges bound the valleys of West Beaver Creek and the two major forks of Little Beaver Creek (Williams, 1961, pl. 1). A lateral moraine separates Alturas Lake from West Beaver Creek. Williams (1961, p. 9) concluded that this moraine is of Pinedale age. A belt of hummocky terminal moraines extends from West Beaver Creek to the mouth of Frenchman Creek. Below the mouth of Vienna Creek, Johnson Creek crosses an end moraine.

A narrow, pitted, outwash plain with prominent kettles extends along the south side of the Salmon River valley from the mouth of Smiley Creek to the Alturas Lake moraine. The outwash sediments are also of Pinedale age.

Recent sediments

Small rock glaciers of post-Pinedale age are present at the heads of north-facing cirques. Alluvial fans containing poorly sorted post-Pinedale (?) sediments are well developed at the termini of lateral tributary streams that enter the main U-shaped valleys. Fine-grained alluvium of post-Pinedale age is present on the floodplains of some streams.

STRUCTURAL GEOLOGY

Vienna faults

Two steep faults, here named the West Vienna and South Vienna faults, separate the eastern edge of the Idaho batholith from downthrown rocks of the Wood River Formation and Challis Volcanics.

The West Vienna fault between Little Beaver Creek and the county line has an average strike of 010° and dips approximately 80°SE. The exposed thickness of the Latite-andesite Member of the Challis Volcanics is 1,200 feet; therefore, the probable minimum vertical displacement along the West Vienna fault is 1,200 feet.
The South Vienna fault between the county line and Smiley Creek has an average strike of 080°. At one point along this segment, the fault strikes 060° and dips 80° SE. In two places, the trace of the steep reverse fault is offset to the southeast 20 and 100 feet, respectively, along cross faults that strike 340°.

The South Vienna fault segment projected westward coincides with a saddle in the Sawtooth Range and the valley of Vienna Creek. The West Vienna fault segment continued southward follows the upper course of Vienna Creek. On the basis of this topographic evidence and stained reddish brown quartz monzonite near the inflection point of contact, it is concluded that two steep faults intersect near the head of the unnamed east fork of Vienna Creek.

Between Smiley Creek and Frenchman Creek, the contact between the Challis Volcanics and the quartz monzonite strikes 070°. Along tributary F13 of Frenchman Creek (pl. 2), the contact is approximately vertical and is probably a continuation of the South Vienna fault.

Other faults

From the outcrop pattern, the northeast-trending Smiley Creek lineament may be inferred to represent a left-lateral fault. An alternative interpretation is that the outcrops of the Wood River Formation west of Smiley Creek may be inliers exposed beneath an exhumed unconformity.

Joints

Poles to joints in the Vienna district were plotted on a stereonet. The dominant joint set trends 295° and has northeasterly dips ranging from 20° to 70°. A second strong joint set strikes 040° and dips 80° NW to 80° SE.

Shear zones in the quartz monzonite are essentially parallel to the major joint sets. Ross (1927a, p. 9) noted that such shear zones dip less steeply than the joints. The principal veins follow shear zones.

Intraformational contacts

Bedding in the metaquartzites of the Wood River Formation has varied attitudes. A $\pi$-diagram of poles to the bedding has a diffuse girdle trending 060°; therefore, the folds in the Wood River Formation probably strike approximately 330°. The absence of marker beds in the metaquartzite members precludes detailed structural interpretations. Bedding in the Wood River rocks is largely masked by cataclasis.

In the Vienna district, flows and tuffs of the Challis Volcanics form a homocline that has an average strike of 010° and dips 10° to 18° SE. The Challis rocks and the Vienna fault have nearly parallel strikes, so the flows and tuffs may have been tilted during formation of the Vienna faults.

Regional structure

Paleozoic strata along the present eastern margin of the Idaho batholith were folded
during the Nevadan orogeny (Anderson, 1948, p. 98). Ross (1936, p. 377-380) con-
cluded that these beds were deformed further into a broad anticline during the intru-
sion of the batholith; in response to this intrusion, overturned folds and thrust faults
formed in the Bayhorse quadrangle northeast of the Vienna district (Ross, 1937, p. 73).
However, Anderson (1948, p. 98) attributed the intensive folding and fracturing of the
Paleozoic strata to the later transmission of forces through the solid batholith during
one or more episodes of the Laramide orogeny.

The stages of Late Cretaceous and Early Tertiary deformation of Paleozoic strata
were described by Anderson (1961, p. 64) in the Lemhi quadrangle, approximately 80
miles northeast of the Vienna district.

A later cataclastic deformation is reflected in thin sections of quartz monzonite from
the Vienna district. This took place after the consolidation of the Idaho batholith and
is assigned a Laramide age.

The age of faults cutting the volcanic rocks of the Vienna district can be stated only
as younger than the basal Andesite-latite Member, because the upper members of the
Challis Volcanics are absent.

Reid (1963, p. 11) mapped a high-angle normal fault, named the Sawtooth fault by
Hamilton (1962, p. 612), paralleling the eastern flank of the Sawtooth Range. The
West Vienna fault may be a southward extension of the Sawtooth fault. The high-
angle normal Montezuma fault bounds the western flank of the Sawtooth Range (Anderson,
1939, p. 17). The Sawtooth Range therefore appears to be a horst bounded by two steep
normal faults. Livingston (1918, p. 491) suggested that the structural basins in south-
central Idaho were formed by block faulting of Basin and Range type.

GEOMORPHOLOGY

Pre-Challis surface

The Challis Volcanics were deposited on a surface of more than 4,500 feet of relief
(Ross, 1937, p. 87). In the Vienna district, the elevation of the base of the Challis
Volcanics varies from 7,500 feet near Vienna to 8,500 feet in Sawmill Canyon. Post-
Challis block faulting may account for some of the difference.

Post-Challis surface

Ross (Ross and others, 1930, p. 645) noted "... remnants of an old peneplain in
the post-Challis topography" at an elevation of approximately 9,500 feet. Within the
Vienna district, fifteen prominences above 9,500 feet have an aggregate area of
approximately 1.5 square miles. Because these lack broad-topped remnants or many
accordant summits a major post-Challis erosion surface at 9,500 feet is questionable.

Glaciation

The post-Challis landscape of the Sawtooth Range was modified by alpine glacia-
tion during the Pleistocene Epoch. The paths of the glaciers were controlled by the
preglacial drainage systems. During Pinedale time (Williams, 1961, p. 10) the valleys of the principal streams were filled with moving ice.

Cirques formed at the heads of major valleys. The V-shaped transverse profiles of these valleys were altered to U-shaped troughs.

Till and moraines were deposited in the lower parts of the valleys. All major valleys in the Blaine County portion of the Vienna district have U-shaped profiles, but glaciation was less extensive in valleys south of the Sawtooth Range.

**Drainage**

Only the unglaciated V-shaped valleys contain streams that are graded. The glaciated valleys have irregular longitudinal profiles and contain nongraded streams.

The tributaries of the South Fork of the Boise River have steeper profiles than their Salmon River counterparts. Many tributary streams have a linear drainage pattern that suggests structural control by joint sets.
ECONOMIC GEOLOGY

MINES

History

Silver ore was discovered in the Vienna district in 1878 (Idaho Historical Society, no date, p. 19). The first claims staked were the Pilgrim on Beaver Creek (Campbell, 1921, p. 23) and the Emma near the head of Smiley Creek (Burchard, 1883, p. 218). The locations of all patented claims are shown in Plate 3. Word of the new strikes spread rapidly and prospectors hurried to the district. More veins were discovered in 1880; by 1885, most of the veins now known in the district were found.

Town sprang up at Vienna on Smiley Creek and at Sawtooth on Beaver Creek to house the miners; in its heyday, each town claimed a population of 1,000.

Small shipments of hand-cobbled ore were packed to the Buffalo mill in Atlanta (d'Easum, 1962, p. 4) and to a smelter in Salt Lake City, Utah, (Strahorn, 1881, p. 59) in 1880. A $15,000 wagon road was constructed from the Wood River across Galena Summit to the Vienna district in 1881 (Burchard, 1882, p. 177). Supplies were freighted more than 300 miles from Corrine, Utah, and Kelton, Utah, on the Union Pacific Railroad, and ore was hauled back to these points for transshipment to the smelters (Bell, 1912, p. 86; Ballard, 1922, p. 32).

Three mills operated in the Vienna district during the silver boom. The Columbia and Beaver Co. constructed a 20-stamp, chlorination mill near Sawtooth (Burchard, 1883, p. 212); silver bullion valued at $60,000 was produced in the autumn of 1883 (Umpleby, 1914, p. 249). Most of the ore for the mill was supplied by the Silver King and Pilgrim Mines. In 1883, a 30-ton stamp and chlorination mill was built 0.5 mile south of Vienna (Burchard, 1884, p. 448), and bullion valued at $103,600 was produced from ore from the Mountain King Mine (Umpleby, 1915, p. 247). In 1884, bullion valued at $200,000 was produced from ore from the Vienna Mine (Burchard, 1885, p. 263). A 30-ton concentrator was erected at the Silver King Mine in 1884 (Burchard, 1885, p. 263).

The mines in the Vienna district shut down prior to the silver panic of 1893. Umpleby (1914, p. 247) reported that Vienna was an active mining camp until 1885. The Silver King Mine operated until 1888 (Umpleby, 1914, p. 249); when it closed most of the inhabitants of Sawtooth moved away.

The Vienna, Silver King, and Pilgrim Mines have been reopened several times since 1890. Several carloads of ore were shipped from mines of the Vienna group between 1915 and 1917 (Bell, 1915, p. 57; Bell 1917, p. 56). Ore was produced from mines of the Vienna group during 1933 to 1943 (Minerals Yearbook, 1933-1943). A 75-ton flotation mill was built in 1934 to treat the Vienna ores (Simons, 1934, p. 93). The Silver King Mine was operated from 1937 to 1941 (Minerals Yearbook, 1937-1941); ore from this property was concentrated in a 40-ton ball mill and flotation plant (Campbell, 1942, p. 93). Small lots of high-grade silver ore were shipped from the Pilgrim Mine in 1940 (Minerals Yearbook, 1940, p. 340).

Excluding one lot of ore shipped in 1949 from an unspecified mine (Minerals Yearbook, 1949, p. 1470), the mines of the Vienna district have been idle for 20 years. Efforts were made to dewater the Silver King Mine during the summers of 1961 and 1962.
Most of the output of silver ore from the Vienna district was during the period from 1880 to 1889; production data for the decade are meager and fragmentary. Ump-leybo (1914, p. 247 and 249) estimated that, prior to 1912, ore and bullion valued at about $1 million were shipped from the mines near Vienna and ore and bullion valued at nearly $1 million were shipped from the mines in the Sawtooth district (Beaver Creek, Eureka Gulch, and Jakes Gulch). Most of the ore was produced from the Vienna, Mountain King or Webfoot, Silver King, and Pilgrim Mines. Virtually all the ore produced since 1912 has come from these properties. Production from the district from 1912 to 1932 was small and discontinuous. Since 1933, 4,569 tons of ore valued at $63,149 have been shipped from the Vienna district (Table I).
<table>
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<th>Year</th>
<th>Mines</th>
<th>Ore sold (short tons)</th>
<th>Gold (oz)</th>
<th>Silver (oz)</th>
<th>Lead (lb)</th>
<th>Copper (lb)</th>
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<td>59,921</td>
<td>88,618</td>
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Source: Minerals Yearbook
ORE DEPOSITS

Mineralogy

The chief hypogene ore minerals in the deposits of the Vienna district are tetrahedrite and ruby silver. The tetrahedrite contains some arsenic and is, at least in part, argentian, Pyrargyrite and proustite are isostructural, and form a continuous solid solution series above 300°C.

Stibnite, galena, and sphalerite, are locally abundant in the Vienna ores. The antimony, lead, and zinc sulfides in the Vienna ores are reported to be silver-bearing. Minor amounts of argentite, chalcopyrite, and stephanite, are also reported from the Vienna district. Much of the "black metal" mentioned in the old reports is probably argentite.

The zone of supergene enrichment in the Vienna ore bodies was very shallow, but some ore from it contained as much as 4,000 oz. of silver per ton (Burchard, 1883, p. 212). Native silver, and cerargyrite, were found in the outcrops of some veins. Much of the argentite in the upper parts of the veins may have been of supergene origin.

Two stages of wallrock alteration took place in the Vienna district; (1) early widespread sericitization with accompanying transformation of biotite to chlorite and the formation of epidote, and (2) later, less extensive but more intensive silicification. The silicic alteration zone, containing minor microcline, grades imperceptibly into gangue quartz that fills fractures. Other nonmetallic gangue minerals in lesser amounts include siderite, sericite, and chlorite. The principal metallic gangue minerals are pyrite, and arsenopyrite; reportedly, both in part are gold-bearing.

Structure

Ore deposition in the Vienna district was controlled by the distribution and intensity of fracturing. Ross (1926a, p. 9) concluded that some of the fractures are contraction joints that formed as the quartz monzonite cooled, whereas other fractures are shears that formed in response to later stresses.

Repeated shearing accompanied and followed vein infilling. Quartz veins were brecciated and recemented. Shearing was also common in both the hanging walls and footwalls of the veins (Ballard, 1922, p. 28). Other minerals were deposited from fluids passing through the newly formed fractures. As a result, bands of quartz and sulfide minerals are aligned parallel to the shear zones (Ross, 1927a, p. 11).

Ross (1927a, p. 9) reported mineralization chiefly along major shears, but also along joint planes and cross-cutting minor fractures. He stressed the irregular shape and discontinuous nature of the mineralized zones (Ross, 1927a, p. 9). Maximum ore deposition and wall rock alteration were localized in and near zones of maximum shearing (Ballard, 1922, p. 16 and 28).

The joints and shear zones have subparallel strikes, but the joints dip more steeply than the shear zones (Ross, 1927a, p. 9). The long axes of the ore bodies are aligned parallel to the shear zones; the dips of the ore bodies and the shear zones
are subparallel (Ross, 1927a, p. 9). Ballard (1922, p. 11) concluded that the lodes are independent of the joints and formed at a later time. His conclusion favors the argument that ore-bearing fractures formed by shearing prior to and during ore deposition.

Two major vein systems are prominent in the Vienna district. One system strikes 295° and includes the Webfoot vein; the other set strikes due east (Ballard, 1922, p. 16; Ross, 1927a, p. 16-17). Shearing and mineralization are more intense along the easterly veins than along the northwesterly one (Ballard, 1922, p. 16). Ore shoots form at the intersection of the two vein systems (Ballard, 1922, p. 16).

Data to supplement previous observations are scanty, because the mines are now inaccessible. Attitudes of veinlets and the trends of the adits support the existence of two major vein systems.

Origin

Most previous workers in the Vienna district have stated that the ores were derived from the magma that formed the Idaho batholith (Lindgren, 1900, p. 104; Umpleby, 1914, p. 233; Ross, 1931, p. 170 and 184; Anderson, 1951, p. 592) and that both were derived from the deep-seated basic magma.

Ross (1927a, p. 7) considered that the lamprophyre dikes are "... late products of granitic intrusions". Because a lamprophyre dike cuts a vein in the Webfoot Mine, Ross (1927a, p. 7) concluded that the magmatic intrusion and the introduction of ore-bearing solutions into the fractures were closely related in time.

Anderson (1951, p. 600), however, questioned that the lamprophyre dikes and the quartz monzonite are related genetically. He suggested instead that the dikes and the ore-bearing solutions have a common deep-seated source related to Laramide igneous activity.

I question Anderson's inference that the lamprophyre dikes are of pre-Challis age. The similarity in the composition of the hornblende latite porphyry dikes and the hornblende latite flows, flow breccias, and tuffs of the Latice-andesite Member of the Challis Volcanics and the presence of inclusions of volcanic rocks in the dikes suggest to me that the dikes and the volcanic rocks are consanguineous. If so, Ross' evidence cited above may be used equally well to relate the epithermal silver deposits to the Challis Volcanics in space, time, and genesis.

Sulfosalts commonly tend to be deposited along the periphery of mineralized areas. Ross (1931, p. 181) considered the presence of such minerals within the batholith, in the Vienna district, anomalous. If the ore solutions and the volcanic rocks had a common parentage, the sulfosalts should be expected within the quartz monzonite marginal to the volcanic rocks.

Schneiderhohn viewed epithermal ores and mesothermal to epithermal copper-arsenic ores as subvolcanic (Noble, 1955, p. 163-164). Furthermore, he also considered some tetrahedrite-tennantite ores as subvolcanic. Schmitt (1950, p. 198) attributed epithermal deposits to volcanic emanations and suggested that silica in such deposits need not be derived from a magma.
Wisser (1960, p. 104) concluded that epithermal ores are derived from deep-seated uniform ore sources during periods of major uplift. He postulated that during broad shield-like uplifts tension fractures of great length and depth extended into the upper part of the mantle and tapped the deep-seated ore sources.

The ore deposits of the Vienna district seem to be related genetically to the Latite-andesite Member of the Challis Volcanics; perhaps both were derived from a common source in the upper mantle.

POTENTIAL

No major discoveries have been made in the Vienna district since 1885. The known ore bodies are small, shallow, high-grade deposits. Most, if not all, of the outcrops of metalliferous veins have been examined and tested by prospectors. If new ore bodies are found, they are likely to be blind veins of similar size and composition to the known occurrences. Because the Silver King ore body does not crop out, a search for similar deposits is warranted. Other rich blind lodes may lie undiscovered in the Vienna district. Favorable areas for exploration are discussed in the geochemistry chapter of this report.

The chances are slim of finding unmined parts of known ore bodies left in place by previous operators because of metallurgical problems, decreased metal prices, or poor working conditions. The mines of the Vienna district closed down before the silver panic, probably because they ran out of ore. Much of the recoverable low-grade sulfide ore, including galena deposits that were not amenable to the chlorination process, were mined and concentrated by flotation in the decade before and during World War II. The principal mine dumps also were reworked for rejected sulfides during the same period.

MINE DESCRIPTIONS

Smiley Creek

Webfoot

The Webfoot Mine on the east side of the unnamed west fork of Smiley Creek has been the largest source of production in the Vienna district. This property was referred to as the Mountain King Mine in the early literature (Strahorn, 1881; Burchard, 1881-1885; Umpleby, 1914). The mine is on the Webfoot claim, one of a group of 32 patented claims controlled by Lewis A. Hippach of Chicago, Illinois, collectively referred to as the Vienna group or Vienna "mine". The Vienna group includes the old Vienna Mine across Smiley Creek canyon from the Webfoot Mine; since 1912 (Bell, 1912, p. 86), virtually all output of the Vienna group has been from the Webfoot Mine.

The Webfoot vein was discovered in June 1881 (Burchard, 1882, p. 187). Strahorn (1881, p. 59) described the early status of the Webfoot Mine as follows:
The vein has been located for a mile. It projects above the surface two to seven feet, and is from eight to sixteen feet wide, five feet of which is ruby silver and sulfuret ore, worth $200 to $800 silver and $8 to $12 gold per ton. Nearly 800 tons of rich ore are on the Mountain King dump, with hundreds of thousands of dollars worth in sight in the various openings. About 100 tons shipped to Salt Lake this year yielded $240 per ton. Excepting the Custer, this is the largest outcrop of very high-grade ore I have seen, and its granite walls are so well defined it seems almost certain that it will maintain its present proportions and probably its richness.

The Webfoot vein strikes 295° to 300° and dips 50° to 80° NE. (Umpleby, 1914, p. 248; Ross, 1927a, p. 16). It contains tetrahedrite, proustite, argentian galena, and sphalerite (Umpleby, 1914, p. 231).

As shown by the old stopes, the ore body was about 700 feet long and ranged in width from a few inches to 15 feet, probably averaging about 4 feet (Umpleby, 1914, p. 248).

A small vein striking 040° and containing galena, sphalerite, and pyrite was noted by Umpleby (1914, p. 248).

The property was developed by four adits separated by vertical distances of 100 feet. Umpleby (1914, p. 248) reported 6,000 feet of workings in the Webfoot Mine.

In 1883, a total of 74 bars of bullion, having a value of $103,600, were produced from ore from the Webfoot Mine (Burchard, 1884, p. 458). At that time the average toner of the ore was 20 ounces of silver per ton. Three carloads of ore, valued at $50 per ton, were shipped from the Webfoot Mine in 1912, presumably from the small vein. The total output of the Webfoot Mine prior to 1917 was several million ounces of silver (Bell, 1917, p. 86).

Since 1917, the property has been worked on a small scale several times. In 1934, a 35-man crew produced 2,600 tons of ore which were treated in a 75-ton flotation plant (Simons, 1934, p. 93). The dumps were reworked by screening and flotation during the second World War (Ellis Merritt, oral communication, 1962). The mine has been idle since 1944.

Vienna

The Vienna Mine is on the west side of the unnamed west fork of Smiley Creek nearly opposite the Webfoot Mine. Strahorn (1881, p. 59) reported that 600 tons of ore, valued at $100 to $500 per ton, were mined during the development of three adits and that 2,000 tons of similar ore were blocked out. A 20-ton shipment to Salt Lake City, Utah, in 1880 (?), was valued at $400 per ton. The upper part of the vein was 2 to 7 feet thick and contained some ore worth $1 a pound.

Burchard (1883, p. 218) reported that the Vienna Mine was one of the best developed mines in the district and that a new raise and adit had opened additional ore bodies. He noted that the monthly output of the mine was valued at $25,000 and that for
"... some years it has been the mainstay and largest producer in Smiley Gulch ..." (Burchard, 1884, p. 458). In 1884, the mine was operated all year and 120 miners were employed; bullion, valued at $200,000 was produced from ores from the Vienna Mine (Burchard, 1885, p. 263).

The property has been idle for many years and now is one of the Vienna group of claims owned by Lewis A. Hippach of Chicago, Illinois.

Emma

The Emma Mine is the oldest in Smiley Canyon. It was discovered and located by Levi Smiley in 1878 (Idaho Historical Society, no date, p. 19). A vein 2 to 3 feet in thickness containing ore "... worth $100 to $1,000 a ton ..." (Strahorn, 1881, p. 59) was worked to a depth of 300 feet by an adit and two inclined shafts. Burchard (1885, p. 263) reported that in the autumn of 1884 an ore "... chute ..." was struck, but work had to be halted because of lack of storage space for the ore. Title to the Emma claim is held by the Twin Falls Title and Trust Co. and J. P. Swisher of Twin Falls, Idaho.

Solace

The Solace Mine is on the same vein as the Emma Mine and is near the head of the west fork of Smiley Creek. It was discovered in 1881 and was sold two months later for $40,000 (Strahorn, 1881, p. 60). Workings include an adit, an inclined winze, and four lower levels (Ross, 1927a, pl. 3). Near the surface, the vein was 4 feet thick and contained argentite and tetrahedrite (Strahorn, 1881, p. 60). In the lower workings, the vein is 2 to 6 inches thick and contains pyrite and sphalerite (Ross, 1927a, p. 12 and 17). The vein strikes 270° to 280° and dips 20° to 55° N. Although a sizeable tonnage of high-grade ore was reported by Burchard (1885, p. 263) and enough argentian galena was found in the bottom level to initiate plans for the erection of a smelter (Bell, 1915, p. 57), the output from the Solace Mine did not approach its anticipated potential. The property is part of the Vienna group and is owned by Lewis A. Hippach of Chicago, Illinois.

Nellie group

The Nellie group includes the Nellie, Champion, Sawtooth, and Nellie Extension claims on the west side of Smiley Creek canyon northwest of the Webfoot Mine. Strahorn (1881, p. 60) reported veins, 6 inches to 2 feet thick, of "... wonderfully rich chloride ores ..." on claims in this group. Burchard (1883, p. 213) reported two adits on the Nellie claim. The lower one was driven 350 feet along a quartz vein 4 to 6 feet thick; the upper adit was 250 feet long. Select ore from a crosscut assayed $70 to $3,000 per ton. These patented claims are held by Eunice B. Leichliter, Thomas J. Mizer, and Nellie B. Vancil of Hailey, Idaho.
Silver King

The Silver King Mine is on the east side of Beaver Creek near the southern limit of the strath. Fifteen tons of ore from the top of the main blind vein were valued at $500 per ton (Burchard, 1883, p. 212).

Burchard described three classes of ore in the Silver King vein: (1) black sulfurets (argentite) in quartz, containing as much as 4,000 ounces of silver per ton; (2) antimonial silver (pyrargyrite) containing as much as 770 ounces of silver per ton; and (3) "... carbonate ores in great abundance..." (Burchard, 1883, p. 212) averaging 93 ounces of silver per ton. He also mentioned "... seams of high-grade antimonial silver..." (Burchard, 1883, p. 212) with thicknesses of 3 to 6 inches on both sides of the same vein. Ballard (1922, p. 22-23) listed pyrargyrite, proustite, argentian stibnite, and "black metal" (argentite?) as the chief ore minerals. He noted that the vein strikes 090° and dips 60° N.

Workings include a 600-foot inclined shaft with three intermediate levels. The developments total 5,100 feet (Campbell, 1942, p. 93). The Silver King Mine probably had the largest production in the Beaver Creek area prior to 1900. Its ores were treated in a 30-ton concentrator and shipped to the Columbia and Beaver mill near Sawtooth (Burchard, 1884, p. 458; Burchard, 1885, p. 263).

The Silver King shaft and headframe burned in 1893. The shaft has been dewatered several times since in search of a 10-inch vein reportedly containing 600 ounces of Silver per ton (Bell, 1919, p. 86). In 1926, a large amount of high-grade ore was reported in the dewatered shaft, but no ore was mined and the workings were again flooded (Campbell, 1927, p. 78). The mine was operated between 1937 and 1941. A 25-ton flotation mill treated silver ores containing gold and antimony (Minerals Yearbook, 1938, p. 320). Later, the mill was described as a "... 40-ton ball mill and flotation plant..." (Campbell, 1942, p. 93). In 1961 and 1962, Viking Exploration Company of Salt Lake City, Utah, endeavored to dewater the Silver King shaft to reexamine the ore exposures. The patented claim is owned by R. E. Campbell of Carey, Idaho.

Pilgrim

The Pilgrim Mine, located in 1879, was the first discovery in the Beaver Creek drainage. The property is on the west side of Beaver Creek 0.6 mile southwest of the Silver King shaft. The Pilgrim vein has an average thickness of 10 feet and in part follows a fault which strikes 295° and dips 70° NE. Three smaller veins that strike 080° and dip 60° NW are dragged to the southeast at the point at which they intersect the Pilgrim vein. "Drag ore was found along the Pilgrim fault... for about 75 feet southeast of the first vein and about 15 feet northwest of the third vein" (Ballard, 1922, p. 27). The chief ore minerals are pyrargyrite and proustite with subordinate sphalerite, galena, and stibnite (?); the gangue is pyrite, arsenopyrite, siderite and sericite (Ballard, 1922, p. 18-20 and 29). Near the surface, the vein was 12 to 20 feet thick (Stahorn, 1881, p. 60) and contained argentite and proustite. The grade varied from 60 to 5,000 ounces of silver per ton (Burchard, 1882, p. 187).
Burchard (1883, p. 211) mentioned 2,000 tons of dump ore and 10,000 tons of measured ore averaging 100 ounces of silver per ton. Ballard (1922, p. 30) reported that approximately $300,000 worth of ore had been extracted from the Pilgrim Mine. Workings include three adits with a total length of 1,800 feet and 275 feet of shafts and raises (Campbell, 1921, p. 23). High-grade silver ore was shipped from the Pilgrim Mine in 1940 (Minerals Yearbook, 1940, p. 340). No work has been done on the property since; the underground workings are now inaccessible. The claim is owned by M. W. Pollock of Santa Fe, New Mexico.

Beaver Extension and Bidwell

The Beaver Extension and Bidwell claims are on the west side of Beaver Creek between the Silver King Mine and the Pilgrim Mine. The main vein is 1 to 4 feet thick. It strikes 090° and dips 45° N. (Ballard, 1922, p. 33). Burchard (1883, p. 212) noted that the ore was ruby silver and native silver. The workings include three adits and an inclined winze whose collar is at the portal of the lowest adit. From the bottom of the winze a 120-foot drift was driven along a branch vein (Ballard, 1922, p. 33). The properties are owned by Eunice B. Leichliter, Thomas J. Mizer, and Nellie B. Vancil, all of Hailey, Idaho.

Sunbeam and Pride of the West

The Sunbeam and Pride of the West claims are in the bottom of Beaver Creek canyon west of the Silver King Mine. In 1927, 300 feet of development of silver-antimony ores was undertaken (Campbell, 1927, p. 80). Title to the idle patented claims is held by Sherman F. Purey, Jr., of May, Idaho.

Columbia and Beaver

The Columbia and Beaver claims are on the west side of Beaver Creek 0.5 mile northwest of the Silver King Mine. Veins on both claims were 1 to 4 feet thick near the surface (Strahorn, 1881, p. 60) and contained ruby silver, argentite, stephanite, and native silver (Burchard, 1882, p. 177). Output in 1880 (?) from the Beaver mine was 400 tons of ore valued at $200 to $400 per ton (Strahorn, 1881, p. 60). Production waned after the high-grade shallow ores were extracted. In 1883, the Columbia & Beaver Co. constructed a 20-stamp, chlorination mill near Sawtooth and treated custom ores from the Beaver Creek Mines. F. M. Mizer of Hailey, Idaho, now owns the Beaver claim. Title to the Columbia claim is shared by Mrs. V. M. Daw of Salt Lake City, Utah, and Herbert Duffy of San Jose, California.

Eureka Gulch

Atlanta

The Atlanta Mine is on the east wall of Eureka Gulch north of the cirque. Burchard (1883, p. 211) reported a vein 4 to 6 feet thick and rich ore in a vein 200 feet beneath the surface. Ballard (1922, p. 33) mentioned workings to a depth of 500 feet including three adits each 500 to 1,000 feet in length. He reported that considerable ore has been shipped from the property. The Atlanta claim is owned by the Thomas Realty Co. of New York, New York. In 1962, Paul Park and Corney Sullivan of Clayton, Idaho, operated the property under lease. They drove a 492-foot adit trending 078° in quartz
monzonite to intercept the Atlanta vein at a lower level, but encountered no ore showings.

**Lucky Boy**

The Lucky Boy property is on the divide between Jakes Gulch and Eureka Gulch. According to Ballard (1922, p. 32) the vein strikes 090° and dips 45° N. The long axis of the claim, however, trends 330°. Within 200 feet of the surface, the vein had an average thickness of 5 feet (Burchard, 1882, p. 177). Later, Burchard (1884, p. 457) reported a vein thickness of 14 inches which suggests that the vein was pinching out with depth. "Hundreds of tons of silver ore worth $100 to $2,000 a ton . . ." (Strahorn, 1881, p. 60) were mined. High-grade ore was shipped in 1882 (Burchard, 1883, p. 211), but no production has been reported since then. Ownership of the patented claim is divided between Mrs. Alice G. Eggleston of Renssalaer, Indiana; R. E. Campbell of Carey, Idaho; and the Silver Spar Mining Co. of Idaho Falls, Idaho.

**Scotia**

The Scotia property adjoins the Lucky Boy claim on the east. The vein is an extension of the Lucky Boy vein. Token shipments of sorted silver ores worth as much as $700 per ton were made in 1881 (Burchard, 1882, p. 177). The Scotia claim is owned by Bessie Stanford of Carey, Idaho.
GEOCHEMICAL EXPLORATION

INTRODUCTION

The Vienna mining district was selected as a project area to determine the usefulness of geochemical exploration techniques in the reevaluation of a dormant metal mining district in which almost all of the old workings are inaccessible.

Geochemical prospecting techniques involve the systematic qualitative or semi-quantitative measurement of small amounts of one or more elements in naturally occurring substances such as gas, water, vegetation, soil, gossan, sediment, glacial drift, or rock (Ginzburg, 1960, p. 1; Hawkes and Webb, 1962, p. 1). Geochemical anomalies are sought in which the amount of one or more elements differs markedly from typical normal background concentrations in barren materials. The background is the abundance of an element in areas in which it is uniformly distributed and is unassociated with mineral deposits. A geochemical anomaly is a deviation from the background abundance of a particular element or chemical property associated with a substance.

In glaciated terrain, the determination of extractable metals in stream sediments has proved to be a successful geochemical exploration method. Stream sediment surveys have been used to good purpose in glaciated areas in Washington (Crosby and Cavin, 1961), New Brunswick (Hawkes and Bloom, 1956), Nova Scotia (Boyle and others, 1958), and Russia (Ginzburg, 1960, p. 150). Ginzburg (1960, p. 150) cited the conclusions of Krasnevskaia that stream sediments in mountainous regions, particularly in seasonally dry stream beds, are favorable matter for geochemical prospecting.

Sampling of stream water is an effective geochemical exploration technique only if the volume of surface flow of streams tested is approximately constant throughout the period of the sampling program. During the summer field season, the surface flow of streams in the Vienna district varies greatly. Therefore, meaningful comparisons could be effected only if all samples were collected during a short interval.

Soil sampling is not a good prospecting technique in alpine glaciated areas, because since the Wisconsin glaciation there has been insufficient time for the formation of soils having well developed profiles. Soils in the Vienna district are thin and are poorly differentiated into layers. It is difficult consistently to obtain soil samples having a low organic content in such azonal soils.

Because of these considerations, detailed sampling of stream sediments was selected as the best method for a geochemical study of the Vienna district.

SAMPLING PROCEDURES

The stream-sediment sampling program was designed to provide thorough coverage of the Vienna mining district. Samples were taken near the mouths of virtually all the mapped first-order and second-order tributaries that flow into named streams. Samples were obtained also from first-order tributaries that debouch into several of the larger unnamed second-order streams. The areas of the sectors drained by the streams along which the samples were taken are small enough that the probability of a major ore body not being intersected by one or more lesser tributaries of such streams is relatively small.
Sediment samples were not taken from the named major streams for three reasons. First, the provenance of samples taken from the channels of the closely spaced first-order tributaries is more easily determined than the provenance of samples taken at 2-mile intervals along major streams. Second, the distance between first-order tributaries in bedrock terrain is sufficiently short that the chances of a major ore body being missed by one or more minor affluents is relatively small. Finally, tailings from mills formerly situated near the banks of Beaver and Smiley Creeks and sediments derived from old workings and mine dumps tend to increase the extractable heavy metal content of the sediments of the major streams.

Tributaries are designated by a letter-number code on Plate 2. The letter or letters are abbreviations of the names of the major streams. All tributaries shown on the planimetric base map are numbered in sequence from the mouths of the major streams headward. For example, SL2 is the twelfth mapped tributary upstream from the mouth of Smiley Creek.

Specific tributaries were identified in the field by traverses from known points of reference. For alluvial fans having several distributaries, the largest distributary or the one most nearly aligned with the course of the main stream was selected.

Sites on tributary streams were selected near their mouths, but upstream from sources of possible contamination such as road culverts and the floodplains of the major streams. Samples were cut with a bricklayer's pick and placed in prelabelled 4.5 inch-by-6 inch tightly woven cloth bags.

Pairs of stream sediment samples were taken at each site. One sample was cut from active stream sediments below the water line; the other was taken from adjacent floodplain sediments. Both samples were taken from places where most of the sediment was of fine sand and silt and contained a minimum of organic matter. However, along some streams it was impossible to avoid cutting samples having a high organic content.

On-site testing was conducted in areas deemed favorable because of relatively high amount of extractable heavy metals in initial sediment samples from specific streams. Samples were taken upstream at 100-yard intervals and at stream forks. Tests were continued at least 100 yards above the last site from which sediments yielding a high heavy-metal content were cut.

LABORATORY FACILITIES

Base-camp laboratory

To avoid costly 1,000-mile round trips to Moscow, it was necessary to improvise a base-camp laboratory. Water for mixing solutions and cleaning equipment was obtained from nearby Yellow Belly Creek and treated with an ion-exchange resin demineralizer. In mid-July a sample of water from Yellow Belly Creek analyzed according to the test devised by Huff (1948, p. 675) was found to contain less than 0.01 ppm of heavy metals.

All solutions for base-camp laboratory and on-site tests were prepared in the base-camp laboratory.
Base-camp laboratory test results were checked and additional tests were made on many other samples in the College of Mines laboratory.

For the cold extraction of ammonium citrate-soluble heavy metals tests, metal-free water was prepared by transmitting tap water in succession through two Illco-Way research model deionizers and an American Sterilizer Co. (Amsco) deionizer. For the other geochemical tests, softened tap water was distilled in a 2 gallons-per-hour copper still and stored in a fiberglass-lined 25-gallon storage tank. As required, the distilled water was drawn from the tank through an Amsco deionizer.

GEOCHEMICAL TESTS USED

Cold extraction of ammonium citrate-soluble heavy metals

Bloom (1955, p. 533) proposed a rapid geochemical test for the determination of the amount of heavy metals that could be extracted from stream sediment or soil samples in a solution of cold ammonium citrate. This test has a sensitivity of 100 ppm of combined copper, lead, and zinc.

The detailed procedures outlined by Ward and others (1963, p. 27-29) for the preparation of reagents were followed in the base-camp laboratory, except that thymol blue was used instead of pH paper to measure the pH of the extractant and toluene was substituted for xylene as an organic solvent for the dithizone.

Two revisions in the preparation of the extractant suggested by Hawkes (1963, p. 581) also were used in the College of Mines laboratory tests. The careful adjustment of the pH of the ammonium citrate solution to 8.5 before the removal of heavy metallic ions by use of a solution of dithizone in carbon tetrachloride produced a buffered solution having a lower background metal content than the previous procedure of readjustment of the pH of the solution after removal of the heavy metal ions by the addition of metal-free ammonium hydroxide. Hydroxylamine hydrochloride was not used in the extractant prepared in the College of Mines laboratory because Hawkes (1963, p. 584) concluded that the chemical does not retard appreciably the oxidation of dithizone.

An 0.001 solution (weight/volume) of dithizone in toluene is used as the collector and a dilute alkaline (pH 8.5) aqueous solution of ammonium citrate, ambient in temperature, is used as the extractant. Hydroxylamine hydrochloride was added to the extractant in the base-camp tests to retard the rate of oxidation of the dithizone.

The term "cold extraction" refers to the easy separation of a portion of the heavy metal content of a sample by dilute aqueous reagents such as ammonium citrate. Hawkes (1963, p. 585) noted that only about 5 percent of the total heavy metal content of samples is extracted by dilute cold aqueous solutions.

The metals in the Vienna ores that react with dithizone are iron (II), copper, zinc, silver, lead, and possibly antimony (III). The sensitivity of dithizone varies with various metal cations. Because dithizone is especially sensitive to zinc, the results of heavy metal tests are in terms of the content of equivalent zinc, which is a summation of the total zinc content plus a half of the total copper content and a
fourth of the total lead content. The high silver content of the Vienna ores may affect the validity of this reporting technique. Hawkes (1963, p. 581) reported that for a 0.2-cc sample \"1 ml of dithizone solution at blue endpoint is about equivalent to 1 ppm \" of cold-extractable metal. Unless otherwise stated, all data in this paper are reported in equivalent parts per million of cold-extractable metal.

**Cold-acid extraction of copper**

**2,2'-Biquinoline technique**

Canney and Hawkins (1958, p. 877) proposed a 2-minute field test for determining the amount of copper that can be extracted readily from stream sediment or soil samples. The detailed analytical procedures for the Canney-Hawkins test outlined by Ward and others (1963, p. 25-27) were followed in both the base-camp and the College of Mines laboratories. Two modifications were made: The amount of 2,2'-biquinoline used in each test was halved to 1 ml, and the shaking time was increased to 45 seconds.

This test has a limit of 1 ppm of copper and utilizes 2,2'-biquinoline, a stable organic reagent which is specific under the conditions of the test for copper (I), as chelating agent. An 0.02 percent solution (weight/volume) of 2,2'-biquinoline in isomyl alcohol is used as a collector. A dilute acid (pH 6.3) aqueous solution of sodium acetate and sodium tartrate is combine with 6N hydrochloric acid to form an extractant, ambient in temperature, having a pH of 5.2. Sandell (1959, p. 452) suggested that tartrate is used to inhibit the precipitation of other metals. Hydroxy-lamine hydrochloride is added to the extractant, presumably as a reducing agent.

Copper (I) reacts with 2,2'-biquinoline to form a pink cuprous chelate that is stable for several months. Because the pink color increases with the concentration of copper, a series of stable standard solutions can be prepared. One disadvantage of the test is the fact that the chelations form slowly and require much vigorous shaking.

**Dithizone technique**

Holman (1956, p. 7) first proposed a rapid field test for readily extractable copper in soil and alluvium. The simplified modifications by Hawkes (1963, p. 580-581) were followed explicitly in tests in the College of Mines laboratory.

A 0.001 percent solution (weight/volume) of dithizone in petroleum ether is used as a collector. An acid (pH 2.0), dilute, aqueous solution of ammonium citrate and hydrochloric acid, ambient in temperature, is the extractant.

The heat, light, and oxidation problems involved in the use of weak dithizone solutions are major disadvantages of the copper test of Hawkes. Also the petroleum ether tends to give a yellowish brown tone to the colors. If these problems can be surmounted, Hawkes’ test may be more effective for on-site studies because field readings using the familiar dithizionate-dithizone mixture colors can be made without having to refer to seven shades of pink standards.
Total-extraction tests

Total-extraction tests for copper and zinc were made on stream sediment samples in the base camp and College of Mines laboratories following the procedures described by Ward and others (1963, p. 19-25). In the copper test, only 1 ml of the collector was used.

Each sample was fused with a flux of potassium pyrosulfate and leached in warmed 6N hydrochloric acid. After dilution with metal-free water to a standard volume, a suitable aliquot was transferred to other test tubes containing appropriate buffer solutions and collectors.

Copper

The buffer is a dilute acid aqueous solution of sodium acetate and sodium tartrate. Hydroxylamine hydrochloride is added as a reducing agent. The collector is a 0.02 percent solution (weight/volume) of 2,2'-biquinoline in isoamyl alcohol.

Zinc

The buffer is a solution of sodium thiosulfate and sodium acetate in dilute acetic acid. The sodium thiosulfate is a complexing agent to prevent the formation of other metal dithizonates during the test. The collector is a 0.001 percent solution (weight/volume) of dithizone in carbon tetrachloride.

RESULTS AND INTERPRETATION OF GEOCHEMICAL TESTS

Introduction

Geochemical tests were made on 754 samples of stream sediment from the Vienna district. The locations of sample sites are shown in Plate 2. The results of all tests are given in Table II and are shown graphically in Plate 4.

Ammonium citrate tests on the minus-80-mesh (less than 0.175 mm) fraction of stream sediment samples in the base camp laboratory yielded two to six times as much cold extractable heavy metals as on-site ammonium citrate tests on similar volumes of unsieved sediments from the same valley trains. Therefore, less intensive anomalies can be detected using the fine-grained fraction of stream sediment samples.

Cold-extraction dithizone tests remove about 5 percent of the total metal content of stream sediment samples. However, if the metal has been precipitated from metal-rich waters, a greater percentage of the total metal content of the sample may be detected. Conversely, a smaller proportion of the metal content of detritus may be detected.

The amount of dithizone solution required to reach a blue endpoint in the ammonium-citrate test has also been compared with the amount of heavy metals recovered by hot extraction. By the general heavy-metal test of Huff (1951, p. 524), 42 0.01-cc samples analyzed by Bloom (1955, p. 537-538) had a median value of 57 ppm of heavy metals per milliliter of 0.003 percent dithizone in xylene. With the same linear relation as
above, the corresponding value for a 0.001 percent solution of dithizone would be 19 ppm of heavy metals.

On-site values obtained from unsieved wet samples were considerably lower than the values previously obtained from the dry minus-80-mesh fraction in the base-camp laboratory. This result is in accord with the conclusions of Hawkes and Webb (1962, p. 257) that "Most of the anomalous metal in stream sediments is usually concentrated in the finer size fractions." The lower on-site values made it more difficult to follow the anomalous sediments to their point of origin. Furthermore, it was difficult in many places to find fine sand and silt along streams descending the steep walls of the gla-
ciated canyons.

Background and threshold determinations

For samples of sediment from active stream beds and floodplains in the Vienna district, the volume of a solution of 0.001 percent dithizone in toluene required to reach a blue endpoint in the cold ammonium-citrate geochemical test for heavy metals was plotted on normal and semilogarithmic graph paper against the number of samples for each particular volume. Neither the stream-bed sediment samples, nor the floodplain sediment samples, nor the combined population of sediment samples have normal or lognormal distribution.

With small bodies of single-population background data, or where the statistical distribution is irregular, probably the best approximation is to take the median value as background and to estimate threshold as that value which is exceeded by no more than 2 1/2 percent of the total number of observations, excluding markedly high erratic values . . .

(Hawkes and Webb, 1962, p. 31).

The limitation of the values over threshold to 2.5 percent of the total population is analogous to that set by Hawkes and Webb (1962, p. 30) for symmetrically distributed data, where the threshold was taken as the arithmetic mean plus two standard deviations.

The arithmetic mean for sediment samples from active stream beds in the Vienna district is 1.98 ml of 0.001 percent dithizone in toluene; for colluvial samples, the arithmetic mean is 1.61 ml. Therefore, background for stream sediments in the Vienna district is taken as 2 ml, which is approximately equivalent to 2 ppm of cold-extractable metal.

If values in excess of 20 ml are excluded as erratic, the threshold value for the 368 pairs of stream-sediment samples is 8 ml, which is approximately equivalent to 8 ppm of cold-extractable metal.

Interpretation

Sediment samples from active stream beds commonly have higher values than adjoining samples from floodplains. The inactive-sediment samples were tested first in the base-camp laboratory. More geochemical anomalies would have been disclosed by the preliminary tests, if the samples of active sediment had been tested first.
The cold-extractable metal values of the samples of stream-bed sediments have
greater dispersion than their floodplain-sediment pairs. The distribution of the active-
sediment values has greater negative skewness than that of the floodplain-sediment values. Better sorting in the floodplain sediments may account for these variations. The premise advocated by Hawkes and Webb (1962, p. 278) that floodplain-sediment values tend to be more erratic than active-sediment values is not borne out by the measures of central tendency of the two populations. Three samples of floodplain sedi-
ment and two samples of active sediment contain more than 20 ppm of cold-extractable metal. This group of values is too small to test that premise with relation to excep-
tionally erratic values.

A high degree of correlation was obtained between the samples of stream-bed sediments and floodplain sediments with two different coefficients of variation. For values of less than 2.4 ppm of cold-extractable metal, more metal tends to be con-
centrated in the active sediments. For values exceeding 2.4 ppm of cold-extractable metal, the floodplain sediments tend to have a higher metal content. Therefore, more small anomalous values can be detected by tests of active sediments. If a higher cut-
off is desired, large anomalous values might best be studied by analysis of floodplain sediments.

Relation of geochemical anomalies to regional geology

Mine workings

Near mine workings and mill sites and within their downstream valley trains, man-
induced high concentrations of heavy metals may mask natural geochemical anomalies. Sediments from stream WS5 yield high anomalous value of this type.

Veins

Outcrops of veins are primary geochemical anomalies. The high content of heavy metals in the sediments in the valley of stream A14 may be derived from the erosion of cappings containing metallic minerals.

Most anomalous areas of the Vienna district overlie rocks of the Idaho batholith. One source for geochemical anomalies within the pluton is limonite-stained quartz monzonite cut by quartz veinlets. The anomalies in the valleys of streams S48 and V19 can be traced, in part, to this type of source.

Some of the anomalous areas are in linear valleys whose courses may be controlled by fractures. The lineaments parallel the trends of the principal joint sets. Because known ore bodies, joints, and shear zones have a subparallel alignment within the Vienna district, it seems likely that some of the geochemical anomalies in the quartz monzonite may be derived from metalliferous zones oriented along the stream course or subparallel to it.

Most of the geochemical anomalies detected in the Vienna district appear to be in-
dependent of major structural features. Only two anomalies have a close spatial association with major faults. The valley of stream LB7, described above, crosses the Vienna fault. Sediments from adjacent streams, that cut the Vienna fault and both the quartz monzonite and the Wood River Formation, do not contain abnormal concentrations of heavy metals.
Glacial Deposits

Many geochemical anomalies are in stream valleys that are cut, wholly or in part, in glacial drift or postglacial alluvium. Most such anomalies are in glaciated valleys downstream from metalliferous veins. The moraine and outwash deposits appear to have been enriched in metals that the glaciers acquired from gossans and cropping and transported down the valleys. Some geochemical anomalies in sediments from tributaries that flow their entire courses across glacial deposits may result from this type of enrichment. Such anomalies suggest the presence of ore bodies within the glaciated area, but probably not beneath the glacial debris. Organic matter, especially in the valleys of ephemeral streams may intensify some geochemical anomalies within Pleistocene sediments. However, not all sediments rich in organic matter contain anomalous amounts of heavy metals; therefore, the geochemical anomalies within Pleistocene sediments seem to have some significance. In certain stream valleys that cross both quartz monzonite and Pleistocene sediments, such as the valley of stream J2, samples from the active stream beds contain less than the threshold amounts of heavy metals, whereas adjoining colluvial sediments contain heavy metals in excess of threshold values. The resulting geochemical anomalies may be derived from glacial drift rather than from the upstream bedrock terrane.

The lower valley of the unnamed east fork of Smiley Creek (ES on Pl. 2) parallels the northeast-trending fault that extends from the vicinity of Vienna to Frenchman Creek. Within the lower reach of the stream, sediments from the active bed have the normal background content of heavy metals, whereas a sample of colluvium taken from an adjoining site contains an anomalous amount of heavy metals. Because the material in the stream bank is in part composed of Pleistocene drift derived from upstream metalliferous terrane, the geochemical anomaly seems more likely to have a genetic relation to the glacial drift rather than to the fault. The absence of ore bodies along or transecting major faults in the Vienna district lends support to this idea.
CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The probability is reasonable of finding new mineral deposits in the Vienna district that can be worked profitably at 1970 prices and costs. Additional ore bodies that are discovered are likely to be small and have no obvious surface expression; undiscovered lodes larger than the Webfoot are improbable.

The Vienna ores seem to have a common parentage with the Challis Volcanics; however, the volcanic rocks are unfavorable hosts for ore deposits. In the district, known veins are restricted to shear zones in the quartz monzonite pluton. Post-Challis block faults are barren. Limonite-stained zones in quartz monzonite are encouraging exploration guides.

If the volcanic rocks and mineral deposits of the Vienna district have a genetic relation, the traditional philosophy of search for similar new lodes only along the margins of plutons must be modified. Amenable host rocks that border the Challis Volcanics, such as limestone, dolomite, and plutonic rocks, warrant attention. Hypabyssal dikes could be ore bearers.

Stream sediment sampling is an effective geochemical exploration technique in glaciated areas. Secondary dispersion trains having syngenetic clastic and (or) epi-genetic hydromorphic patterns may be traced upstream to source areas. Anomalies on moraines also suggest the possibility of source areas upstream rather than adjacent mineral deposits.

Sample sites should be selected at points where fine-grained particles are abundant. Anomalies in organic sediments have limited value because most organic matter is enriched in heavy metals. Collection of pairs of samples from the active stream bed and floodplain increases the utility of the geochemical tests. Comparison of test results on the paired samples facilitates interpretation of the data and provides a check on the laboratory work. Active sediment samples in the Vienna district contain more extractable heavy metals than floodplain sediments where the values approach background concentrations. Hence, the analysis of active sediments may be more useful in isolating weak anomalies. At threshold values and above, floodplain sediments tend to have a higher metal content than active sediments. Hence, floodplain sediments may be used to trace persistent anomalies to their sources.

Contamination from mill tailings, mine dumps, mine workings, and scrap metal can mask independent, preexisting natural geochemical anomalies. The contamination precludes the use of geochemical tests in downstream trains to detect new ore deposits. Conversely, the tests may be used to find abandoned workings.

Cold-extraction of heavy metals soluble in aqueous ammonium citrate is a rapid, inexpensive test that works well in the Vienna sediments.

Testing for heavy metals yielded more useful data than did testing for copper in the Vienna sediment samples. The test of Hawkes using dithizone as an indicator was slightly more sensitive and better suited to field conditions than the 2,2'-biquinoline test of Canney and Hawkins.
RECOMMENDATIONS

The most favorable area for exploration for new ore bodies in the Vienna district extends along an arc from the lower valley of the east fork of Smiley Creek to the head of stream V3. The claims at the heads of Smiley and Vienna Creeks are within this area. The best places for search outside areas of known occurrences are in the watersheds of streams L18, A14, and J23.

Streams having sediments with metal contents equal to or exceeding threshold values should be reexamined. The cold ammonium-citrate test should be used to trace the dispersed heavy metals to the sources of anomalous metals.

Soil samples should be cut along lines parallel to the stream bed in the apparent source areas. If necessary, soil samples should be taken on a grid pattern over the entire fan-shaped area upslope from the farthest upstream anomalous readings to delineate the source areas.

In addition to the detailed geochemical testing a battery of geophysical tests including self-potential and induced polarization should be tried in the apparent source areas.

Preliminary geochemical testing of stream sediments should be done in a central laboratory under controlled conditions. Subsequent tests to delineate sources may be made in the field, but duplicate samples should be taken for later laboratory confirmation.
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Survey Bull. 1152, 100 p.


APPENDIX

ANOMALOUS-SAMPLE SITES

INTRODUCTION

At 10 sites, the cold-extractable heavy-metal content of active stream-bed and (or) floodplain sediments was 16 ppm, twice the threshold value. The anomalous areas upstream from these sites are represented by 0.1-inch thick lines in Plate 4.

At 13 sites, the cold-extractable heavy-metal content of either or both the active bed and floodplain sediments equaled the threshold value of 8 ppm, but did not exceed twice the threshold value. The anomalous areas upstream from these sites are represented by 0.05-inch thick lines on Plate 4.

Either or both sediment samples at many sites contain amounts of extractable heavy metals that exceed background values, but are less than threshold values. The anomalous areas upstream from these sites are represented by 0.025-inch thick lines in Plate 4. Sites at which neither sediment sample exceeds the background value of 2 ppm of cold-extractable heavy metal are represented in thin lines in Plate 4.

METAL CONTENT TWICE THRESHOLD

One area is contaminated by a mine dump; two others are in short valleys of intermittent or ephemeral streams. The remaining seven areas are more favorable for further exploration.

S48

The sample site is in unsurveyed SW¼ sec. 28, T. 6 N., R. 14 E., Boise Meridian. Perennial stream S48 enters Smiley Creek at the stock pen opposite the townsit of Vienna. The stream has a length of 0.9 mile and flows across quartz monzonite. Along its lower reach stream S48 has a width of 1 to 2 feet and crosses Quaternary sediments. Samples were cut upstream to avoid stock pen sources of contamination such as empty steel containers of sheep dip. The following results were obtained from geochemical tests on sediments from the sample site:

<table>
<thead>
<tr>
<th></th>
<th>Active Bed</th>
<th>Floodplain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold-extractable heavy metals</td>
<td>2 ppm</td>
<td>20 ppm</td>
</tr>
<tr>
<td>Cold-extractable copper</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Total-extractable copper</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td>Total-extractable zinc</td>
<td>25</td>
<td>300</td>
</tr>
</tbody>
</table>

Approximately 1,500 feet above the mouth of stream S48, a tributary enters from the northeast. Unsieved sediment from the 300-foot tributary contained 8 ppm of cold-extractable heavy metals. The branch stream heads in limonite-stained quartz monzonite, cut by quartz veinlets 1/4 to 1/16 inch wide that strike 090°. Background values were obtained from sediment samples taken from stream S48 above its intersection with the tributary.

V19

The sample site, 2 miles northeast of the mouth of Vienna Creek, is in unsurveyed NW¼ sec. 31, T. 6 N., R. 14 E., Boise Meridian. Stream V19 is a perennial stream.
fed from a tarn. The stream is 2,800 feet long and has a width of 6 inches to 1 foot; its entire course is in quartz monzonite. The gradient of the stream is very steep. The following results were obtained from geochemical tests on sediments from the sample site:

<table>
<thead>
<tr>
<th></th>
<th>Active bed</th>
<th>Floodplain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold-extractable heavy metals</td>
<td>4 ppm</td>
<td>20+ ppm</td>
</tr>
<tr>
<td>Cold-extractable copper</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total-extractable copper</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total-extractable zinc</td>
<td>25</td>
<td>100</td>
</tr>
</tbody>
</table>

Unsieved sediment taken from stream V19, where it crosses limonite-stained quartz monzonite 1,700 feet above its mouth, contained 16 ppm of cold-extractable heavy metals. Unsieved sediment from a point adjacent to the lake outlet, 2,800 feet above the mouth of stream V19, contained 18 ppm of cold-extractable heavy metals. The intermittent streams that drain into the lake were samples near their mouths. A draw trending 050° contains an intermittent organic-rich seep. An unsieved sample of sediment from this feeder contained 14 ppm of cold-extractable heavy metals. The extractable metal content of sediments from the other tributaries to the lake did not exceed background values.

V3

The sample site, 0.6 mile east of the mouth of Vienna Creek is in unsurveyed Sec 35, T. 6 N., R. 13 E., Boise Meridian. Perennial stream V3 is 0.5 mile long; at the sample site near its mouth, it had a width of 1 foot at time of sampling. Throughout its course, stream V3 traverses quartz monzonite. The following results were obtained from geochemical test on sediments from the sample site:

<table>
<thead>
<tr>
<th></th>
<th>Active bed</th>
<th>Floodplain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold-extractable heavy metals</td>
<td>20+ ppm</td>
<td>4 ppm</td>
</tr>
<tr>
<td>Cold-extractable copper</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total-extractable copper</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total-extractable zinc</td>
<td>100</td>
<td>25</td>
</tr>
</tbody>
</table>

L18

The sample site, 2.4 miles southeast of Vienna, is in unsurveyed NW1/4 Sec 2, T. 5 N., R. 14 E., Boise Meridian. Stream L18 is perennial; it is 0.3 mile long and had a width of 6 inches at time of sampling. The entire course of the stream is in quartz monzonite. The following results were obtained from geochemical tests on sediments from the sample site:

<table>
<thead>
<tr>
<th></th>
<th>Active bed</th>
<th>Floodplain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold-extractable heavy metals</td>
<td>20 ppm</td>
<td>4 ppm</td>
</tr>
<tr>
<td>Cold-extractable copper</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Total-extractable copper</td>
<td>25</td>
<td>20</td>
</tr>
<tr>
<td>Total-extractable zinc</td>
<td>750</td>
<td>200</td>
</tr>
</tbody>
</table>
The sample site is 1.6 miles southwest of the mouth of Vienna Creek in unsurveyed NE\(^{1/4}\) sec. 30, T. 5 N., R. 13 E., Boise Meridian. Stream J2 is perennial and has a length of 0.6 mile. At the sample site, the stream had a width of 6 inches at time of sampling. Most of the stream course is in quartz monzonite, but the lowest segment crosses an end moraine before entering Johnson Creek. The following results were obtained from geochemical tests on sediments from the sample site:

<table>
<thead>
<tr>
<th></th>
<th>Active bed</th>
<th>Floodplain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold-extractable heavy metals</td>
<td>4 ppm</td>
<td>20 ppm</td>
</tr>
<tr>
<td>Cold-extractable copper</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total-extractable copper</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total-extractable zinc</td>
<td>25</td>
<td>100</td>
</tr>
</tbody>
</table>

The anomalous heavy-metal content of the floodplain sediment sample may be derived from the Johnson Creek moraine rather than from the valley of stream J2.

The sample site, 1.6 miles southwest of the mouth of Jakes Gulch, is in unsurveyed S\(^{1/4}\) sec. 5, T. 6 N., R. 13 E., Boise Meridian. Stream A14 is intermittent and is 0.5 mile long. Its entire course is in quartz monzonite. Ballard (1922, fig. 1) mapped a mine in the vicinity of the headwaters of stream A14. The following results were obtained from geochemical tests on sediments from the sample site:

<table>
<thead>
<tr>
<th></th>
<th>Active bed</th>
<th>Floodplain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold-extractable heavy metals</td>
<td>20+ ppm</td>
<td>20+ ppm</td>
</tr>
<tr>
<td>Cold-extractable copper</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total-extractable copper</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total-extractable zinc</td>
<td>400</td>
<td>400</td>
</tr>
</tbody>
</table>

The sample site, 0.7 mile northwest of the mouth of Vienna Creek, is in unsurveyed NE\(^{1/4}\) sec. 34, T. 6 N., R. 13 E., Boise Meridian. J15 is a dry wash, 0.5 mile long, at times occupied by an ephemeral stream. The wash crosses quartz monzonite and near its mouth, Quaternary sediments. The following results were obtained from geochemical tests on sediments from the sample site:

<table>
<thead>
<tr>
<th></th>
<th>Active bed</th>
<th>Floodplain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold-extractable heavy metals</td>
<td>16 ppm</td>
<td>1 ppm</td>
</tr>
<tr>
<td>Cold-extractable copper</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total-extractable copper</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total-extractable zinc</td>
<td>25</td>
<td>25</td>
</tr>
</tbody>
</table>

The sample site, 0.4 mile northwest of the mouth of Vienna Creek, is in unsurveyed NW\(^{1/4}\) sec. 35, T. 6 N., R. 13 E., Boise Meridian. J13 is a dry wash, 0.5 mile long, at times occupied by an ephemeral stream. The wash crosses quartz monzonite, and near
its mouth. Pleistocene sediments. The samples appear to be composed of soil rather than stream sediment. The following results were obtained from geochemical tests on the samples:

<table>
<thead>
<tr>
<th></th>
<th>Bottom</th>
<th>Bank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold-extractable heavy metal</td>
<td>16 ppm</td>
<td>4 ppm</td>
</tr>
<tr>
<td>Cold-extractable copper</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total-extractable copper</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total-extractable zinc</td>
<td>50</td>
<td>25</td>
</tr>
</tbody>
</table>

**WS5**

The sample site is 1.2 miles southwest of Vienna in unsurveyed SW¼ sec. 32, T. 6 N., R. 15 E., Boise Meridian; Stream WS5, approximately 600 feet long, is and intermittent tributary of the west fork of Smiley Creek. The entire course of the stream is in quartz monzonite. It heads in the Webfoot mine dump and traverses flotation mill tailings near its mouth. Samples were cut upstream from the tailings. The following results were obtained from geochemical tests on sediments from the sample site:

<table>
<thead>
<tr>
<th></th>
<th>Active bed</th>
<th>Floodplain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold-extractable heavy metal</td>
<td>20+ ppm</td>
<td>20+ ppm</td>
</tr>
<tr>
<td>Cold-extractable copper</td>
<td>25</td>
<td>7</td>
</tr>
<tr>
<td>Total-extractable copper</td>
<td>150</td>
<td>20</td>
</tr>
<tr>
<td>Total-extractable zinc</td>
<td>750</td>
<td>400</td>
</tr>
</tbody>
</table>

**METAL CONTENT EQUALS THRESHOLD**

**ES**

The sample site, 0.3 mile northeast of the Smiley Creek ford at Vienna, is in unsurveyed SW¼ sec. 28, T. 6 N., R. 14 E., Boise Meridian. The unnamed east fork of Smiley Creek, ES, is 1 mile long and has a drainage area of approximately 1 square mile. Most of the watershed is underlain by quartz monzonite. The first mapped tributary to the north, ESL, traverses Challis Volcanics. The east fork of Smiley Creek follows a fault for 0.15 mile downstream from its intersection with stream ESL. The lowermost reach of stream ES crosses Quaternary sediments. The following results were obtained from geochemical tests on sediments from the sample site:

<table>
<thead>
<tr>
<th></th>
<th>Active bed</th>
<th>Floodplain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold-extractable heavy metals</td>
<td>1 ppm</td>
<td>8 ppm</td>
</tr>
<tr>
<td>Cold-extractable copper</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

The anomalous heavy metal content of the floodplain sediment may be derived from the underlying glacial drift, whereas the low metal content of active sediment may reflect conditions in the entire watershed. The low heavy-metal content of sediment samples from the chief tributaries of the east fork of Smiley Creek favors this conclusion.
The sample site, 1.5 miles south of Sawtooth, is in unsurveyed SE\(\frac{1}{4}\) sec. 5, T. 6 N., R. 14 E., Boise Meridian. Stream LB7 is intermittent and has a length of 0.3 mile. It crosses the Vienna fault. The upper part of its course is in the Wood River Formation; the lower part is in quartz monzonite. The following results were obtained from geochemical tests on sediments from the sample site:

<table>
<thead>
<tr>
<th>Active bed</th>
<th>Floodplain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold-extractable heavy metals</td>
<td>2 ppm</td>
</tr>
<tr>
<td>Cold-extractable copper</td>
<td>0</td>
</tr>
</tbody>
</table>

B18

The sample site, 2 miles southwest of Sawtooth, is in unsurveyed SW\(\frac{1}{4}\) sec. 6, T. 6 N., R. 14 E., Boise Meridian. Stream B18 is approximately 4,500 feet long; it traverses quartz monzonite and, near its terminus, Quaternary sediments. B18 is a steep, intermittent stream that forms an alluvial fan near its mouth. Its distributaries do not enter Smiley Creek. Samples were cut from within the alluvial fan. The following results were obtained from geochemical tests on the sediments:

<table>
<thead>
<tr>
<th>Active bed</th>
<th>Floodplain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold-extractable heavy metals</td>
<td>4 ppm</td>
</tr>
<tr>
<td>Cold-extractable copper</td>
<td>0</td>
</tr>
</tbody>
</table>

Unsieved stream sediment from points 1,500 feet, 2,700 feet, and 4,200 feet upstream from Smiley Creek contained as much as 9 ppm of cold-extractable heavy metals. However, no differences were noted in the country rock at these points.

J23

The sample site, 2.5 miles northwest of the mouth of Vienna Creek, is in unsurveyed SE\(\frac{1}{4}\) sec. 21, T. 6 N., R. 13 E., Boise Meridian. Stream J23 is intermittent and has a length of 0.6 mile. It flows across quartz monzonite for most of its course, but crosses Quaternary sediments before entering Johnson Creek. The follow results were obtained from geochemical tests on sediments from the sample site:

<table>
<thead>
<tr>
<th>Active bed</th>
<th>Floodplain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold-extractable heavy metals</td>
<td>6 ppm</td>
</tr>
<tr>
<td>Cold-extractable copper</td>
<td>0</td>
</tr>
</tbody>
</table>

S40+

The sample site is in unsurveyed S\(\frac{1}{4}\) sec. 21, T. 6 N., R14 E., Boise Meridian, 0.2 mile south of the upper wooden bridge across Smiley Creek. Streams S40+ is narrow and intermittent; its entire 0.2-mile traverses Quaternary sediments. Two samples were cut upstream from the Vienna road. Both are composed of dark gray to black clay, rich in organic matter. The following results were obtained from geochemical tests on the samples:
Cold-extractable heavy metals
Cold-extractable copper

-44-

Active bed Floodplain
14 ppm 4 ppm
0 0

B2

The sample site, 0.8 mile southwest of Sawtooth, is in NE 1/4 sec. 31, T. 7 N., R. 14 E., Boise Meridian. B2 is a dry wash that may on occasion be occupied by an ephemeral stream. It traverses glacial drift that caps the underlying Wood River Formation. Samples from the wash might better be termed "soil" rather than "sediment". The following results were obtained from geochemical tests on the samples:

Cold-extractable heavy metals
Cold-extractable copper

Bottom Bank
8 ppm 4 ppm
0 0

B4

The sample site, 1 mile southwest of Sawtooth, is in NE 1/4 sec. 31, T. 7 N., R. 14 E., Boise Meridian. B4 is a dry wash that may on occasion be occupied by an ephemeral stream. It traverses glacial drift that caps the underlying Wood River Formation. Samples from the wash might better be termed "soil" rather than "sediment". The following results were obtained from geochemical tests on the samples:

Cold-extractable heavy metals
Cold-extractable copper

Bottom Bank
8 ppm 4 ppm
0 0

F6

The sample site, 2.4 miles southwest of the mouth of Frenchman Creek, is in unsurveyed NW 1/4 sec. 14, T. 6 N., R. 14 E., Boise Meridian. F6 is a draw, 700 ft. long, that traverses Quaternary sediments and may on occasion be occupied by a wet-weather stream. Samples from the draw are composed of soil rather than of stream sediment. The following results were obtained from geochemical tests on the samples:

Cold-extractable heavy metals
Cold-extractable copper

Bottom Bank
2 ppm 8 ppm
0 0

J9

The sample site 0.7 mile southwest of the mouth of Vienna Creek is in unsurveyed NW 1/4 sec. 2, T. 5 N., R. 13 E., Boise Meridian. J9 is a dry wash traversed at times by an ephemeral stream. The wash is cut in quartz monzonite. The following results were obtained from geochemical tests on the samples:

Cold-extractable heavy metals
Cold-extractable copper

Bottom Bank
4 ppm 8 ppm
0 0
The sample site, 0.7 mile southwest of the mouth of Jakes Gulch, is in unsurveyed NE\(\frac{1}{4}\) sec. 4, T. 6 N., R. 13 E., Boise Meridian. All is a shallow draw, 0.3 mile long, in quartz monzomite. Rarely, the draw is occupied by an ephemeral stream. Samples cut from the bed and bank of the draw are of soil rather than stream sediment. The following results were obtained from geochemical tests on the samples:

<table>
<thead>
<tr>
<th></th>
<th>Bottom</th>
<th>Bank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold-extractable heavy metals</td>
<td>8 ppm</td>
<td>8 ppm</td>
</tr>
<tr>
<td>Cold-extractable copper</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**V23**

The sample site, 1.8 miles southwest of Vienna, is in unsurveyed SE\(\frac{1}{4}\) sec. 31, T. 6 N., R. 14 E., Boise Meridian. Stream V23 is intermittent and has a length of 0.2 mile. Along its upper course it passes a dump on the Diamond Prince claim. The following results were obtained from geochemical tests on sediments from the sample site:

<table>
<thead>
<tr>
<th></th>
<th>Bottom</th>
<th>Bank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold-extractable heavy metals</td>
<td>8 ppm</td>
<td>8 ppm</td>
</tr>
<tr>
<td>Cold-extractable copper</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**V24**

The sample site, 1.9 miles southwest of Vienna, is in unsurveyed SE\(\frac{1}{4}\) sec. 31, T. 6 N., R. 14 E., Boise Meridian. Stream V24 is intermittent and has a length of 0.3 mile. It passes an old prospect near its head. The following results were obtained from geochemical tests on sediments from the sample site:

<table>
<thead>
<tr>
<th></th>
<th>Active bed</th>
<th>Floodplain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold-extractable heavy metal</td>
<td>8 ppm</td>
<td>8 ppm</td>
</tr>
<tr>
<td>Cold-extractable copper</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**WS8**

The sample site, 1.5 miles southwest of Vienna, is in unsurveyed SW\(\frac{1}{4}\) sec. 32, T. 6 N., R. 14 E., Boise Meridian. Stream WS8 drains the southeast quadrant of the cirque at the head of the west fork of Smiley Creek. The country rock in the entire watershed of stream WS8 is quartz monzomite. Sediment samples were cut upstream from a small ore bin near the mouth of the stream. The following results were obtained from geochemical tests on sediments:

<table>
<thead>
<tr>
<th></th>
<th>Active bed</th>
<th>Floodplain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold-extractable heavy metals</td>
<td>12 ppm</td>
<td>8 ppm</td>
</tr>
<tr>
<td>Cold extractable copper</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

High anomalous readings exceeding 20 ppm of cold extractable heavy metals were obtained from unsieved sediments from the west and middle forks of stream WS8. The west fork is a perennial stream about 600 feet long. It heads in the portal of an unnamed adit, probably one of the lower Solace tunnels cited by Ross (1927a, p. 16), and skirts the base of the dump from the workings. Galvanized iron sheets, possibly parts of a small flume, are in the stream bed near the mine portal. The middle fork of WS8 is an intermittent stream, approximately 1,600 feet long, that heads in the Solace mine dump. Background values were obtained from sediment samples from the intermittent east fork of stream WS8.
SAMPLE SITES

SYMBOLS

/ 548 Sediment samples
X 57 Rock samples
@ 29-3 Rock samples (R.K. Reid, 1961)

VIENNA DISTRICT, BLAINE AND CAMAS COUNTIES, IDAHO