STUDIES RELATED TO WILDERNESS

BOULDER-PIONEER STUDY AREA, IDAHO

GEOLOGICAL SURVEY BULLETIN 1497

STUDIES RELATED TO WILDERNESS

In accordance with the provisions of the Wilderness Act (Public Law 88-577, September 3, 1964) and the Joint Conference Report on Senate Bill 4, 88th Congress, the U.S. Geological Survey and U.S. Bureau of Mines have been conducting mineral surveys of wilderness, wilderness study, and primitive areas. Studies and reports of all primitive areas have been completed. Areas officially designated as "wilderness," "wild," or "canoe" when the Act was passed were incorporated into the National Wilderness Preservation System, and some of them are currently being studied. In the case of the wilderness study areas the mineral surveys constitute one aspect of the suitability studies. This report discusses the results of a mineral survey of some national forest lands in the Boulder-Pioneer wilderness study area, central Idaho, that is being considered for wilderness designation.

Mineral Resources of the Boulder-Pioneer Wilderness Study Area, Blaine and Custer Counties, Idaho

By U.S. GEOLOGICAL SURVEY *and* U.S. BUREAU OF MINES

A. Geology of the Boulder-Pioneer wilderness study area, Blaine and Custer Counties, Idaho

B. Aeromagnetic studies of the Boulder-Pioneer wilderness study area, Blaine and Custer Counties, Idaho

C. A geological and geochemical evaluation of the mineral resources of the Boulder-Pioneer wilderness study areas, Blaine and Custer Counties, Idaho

D. Economic appraisal of the Boulder-Pioneer wilderness study area, Blaine and Custer Counties, Idaho

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GEOLOGICAL SURVEY BULLETIN 1497

An evaluation of the mineral potential of the area

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STUDIES RELATED TO WILDERNESS

MINERAL RESOURCES OF THE BOULDER-PIONEER WILDERNESS STUDY AREA, BLAINE AND CUSTER COUNTIES, IDAHO

By U.S. GEOLOGICAL SURVEY and U.S. BUREAU OF MINES

SUMMARY

The results of a mineral resource survey of the Boulder-Pioneer wilderness study area, which covers 450 mi^2 (1,160 km^2) in south-central Idaho, indicate that the area has reserves of lead, zinc, and silver. In addition it has submarginal resources of base and precious metals, and tungsten. The potential for oil, gas, coal, or geothermal resources is very low.

The study area is a few miles northeast of Ketchum, Idaho, and comprises the southeast end of the Boulder Mountains and most of the Pioneer Mountains in the Sawtooth and Challis National Forests. The mineral survey by the U.S. Geological Survey and the U.S. Bureau of Mines conducted in the summers of 1973 and 1974 consisted of examinations of mines, prospects, and other mineralized localities, along with geochemical sampling, geologic mapping, and geophysical surveys.

The bedrock of the area consists of granitic gneiss and associated rocks of Precambrian age; metasedimentary rocks, mainly quartzite, schist, and marble of Ordovician and (or) older age; sedimentary rocks, mainly sandstone, siltstone, mudstone, shale, limestone, dolomite, and conglomerate of Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian, and Permian ages; intrusive quartz monzonite and associated silicic dikes of Tertiary age; and intermediate to silicic volcanic rocks of Tertiary age. Bedrock is locally concealed beneath glacial and lake deposits, alluvium, and talus, all of Quaternary age.

The Paleozoic rocks are complexly folded and are cut by east- to northeast-directed thrust faults of great displacement and by normal faults, some of which are large. The Pioneer Mountains are broadly anticlinal and consist of a northwest-trending core of gneiss, metasedimentary rocks, and plutonic rocks tectonically overlain by a

succession of thrust sheets of sedimentary rocks, some of which are slightly metamorphosed. The youngest sedimentary rock unit involved in major thrust faulting is the Wood River Formation of Middle Pennsylvanian to Early Permian age; emplacement of an early phase of the intrusive complex of the Pioneer window may have coincided with a late stage of the thrusting. However, thrust faulting was essentially completed before emplacement of Eocene plutonic rocks and eruption of related volcanic rocks; the volcanics are tilted and broken by normal faults but are otherwise disturbed very little.

The study area contains parts of five mining districts—Alta (also known as Alto), Copper Basin, Little Wood River, Lava Creek, and Warm Springs—and adjoins two others—Mineral Hill and Alder Creek (Mackay). Production from the seven districts to date totals about $65 million, of which only $870,000 was produced from within the area. Locations of mines, prospects, and areas of mineral potential within the study area are shown on plate 1. About 80 percent of the study area production came from lead-zinc-silver deposits of the Homestake and nearby mines ($340,000), the Phi Kappa mine ($174,000), the Eagle Bird mine ($130,000), and the Star Hope mine ($50,000). The indicated and inferred reserves in the study area are from these mines and total about 1.7 million tons (1.5 million t) of ore. The reserve ore grades range from 1.6 to 9.96 percent lead, 1.62 to 6.63 percent zinc, and 3.2 to 13.06 oz silver per ton (110 to 448 g/t). More than 2,600 lode claims and 11 placer claims have been located within the area, and hundreds more were located near the boundary.

One deposit of submarginal resources in the Alta district (pl.1, index map) consists of more than 1.4 million tons (1.27 million t) of tungsten-bearing tactite that averages 0.32 percent WO_3; four other deposits contain 106,000 tons (96,000 t) of submarginal resources that bear 2.42–4.40 percent lead, 1.80–8.75 percent zinc, and 1.0–6.3 oz silver per ton (34–216 g/t). In addition, the district has small submarginal resources of molybdenum and fluorite. Submarginal resources of the Warm Springs district, in the Homestake and six other prospects, total about 885,000 tons (803,000 t) in geologic structures that contain 1.0–8.22 percent lead, a trace to 42 percent zinc, and 0.4–3.5 oz silver per ton (14–120 g/t). Four deposits in the Little Wood district have 90,000 tons (82,000 t) of inferred resources with 2.83–27.4 percent lead, a trace to 6.4 percent zinc, and 3.3–4.4 oz silver per ton (113–151 g/t).

Several prospects in the Little Fall–Big Fall Creek area (fig. 1) may indicate potentially minable deposits; however, as workings are caved and the mineralized rocks are poorly exposed, no estimate of these resources can be made.

Analyses of stream sediment and rock samples indicate additional areas that may have mineral-resource potential (pl. 1). However, these areas are interpreted to have only low to moderate potential because (1) the size of known deposits in the study area is small, (2) the area lacks extensive zones of alteration, and (3) most of the anomalies are weak and widely scattered. The most favorable include the areas described as follows.

The first is an area about 10 mi (16 km) long and 4–6 mi (6.4–9.6 km) wide that extends from upper Star Hope Creek and Muldoon Canyon southeastward to Argosy Creek, in which many samples contain anomalous amounts of copper, lead, zinc, and silver (anomalies H–J, pl.1). The northwestern part of the area contains weakly anomalous amounts of molybdenum (anomaly K, pl. 1). The most favorable part of the anomalous area is along the ridge common to Argosy, Muldoon, and Left Fork Iron Bog Creeks and Muldoon Canyon where several rock samples contain anomalous amounts of arsenic and locally anomalous amounts of gold (anomalies L and M, pl. 1). The southeastern part of the anomalous area is centered approximately over Tertiary stocks, which the aeromagnetic data indicate to be parts of a much larger northwesterly trending pluton.

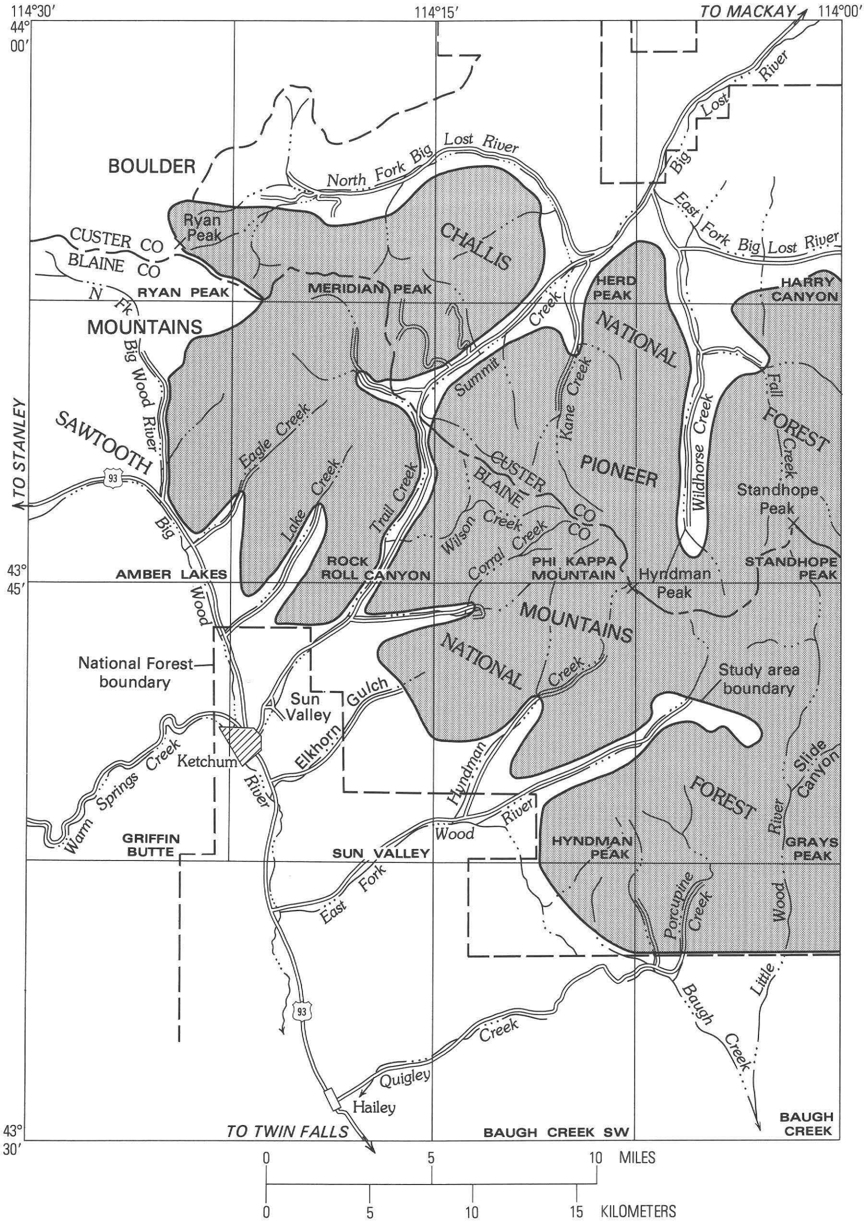
The second area is an east-trending area about 10 mi (16 km) long and 3–4 mi (5–6.4 km) wide that contains anomalous amounts of copper, lead, molybdenum, silver, zinc, and vanadium (anomalies A–E, pl. 1). The largest mine in the study area, the Phi Kappa, is on the east edge of the anomalous area, but other parts of it, particularly in the area common to the headwaters of Squib and Miller Canyons and Little Fall and Trail Creeks, have not been prospected.

The third is a large area in the drainage basins of Eagle Creek and middle and lower Trail Creeks, where numerous samples contained anomalous amounts of lead, silver, copper, and zinc, and a few in the south part of the area contained anomalous amounts of molybdenum (anomalies F and G, pl. 1). Most of the area has been thoroughly prospected, but a molybdenum-zinc anomaly (anomaly G, pl. 1) near the southwest end of the ridge between Lake and Trail Creeks has not been prospected, and it would appear to merit additional study.

Additional exploration may also be warranted in the area of the zinc-molybdenum-boron anomaly (anomaly R, pl. 1) in the upper parts of the drainage basins of Big Witch and Porcupine Creeks, Finley and Federal Gulches, Timber Draw, and Fisher Canyon, and northwestward across East Fork Wood River into the Sawmill Gulch drainage. The other anomalous areas shown on plate 1 are interpreted to have a low potential for mineral resources.

INTRODUCTION

The Boulder-Pioneer wilderness study area is in the part of central Idaho lying north of the Snake River Plain between the Big Wood and Big Lost Rivers, just northeast of the town of Ketchum (fig. 1). It is a



northwest-trending, roughly oval shaped mountainous area of about 450 mi^2 (1,160 km^2), exclusive of corridors along various access roads. The northeast half of the area is in the Big Lost River drainage within the Challis National Forest in Custer County; the southwest half is in the Big Wood River drainage within the Sawtooth National Forest in

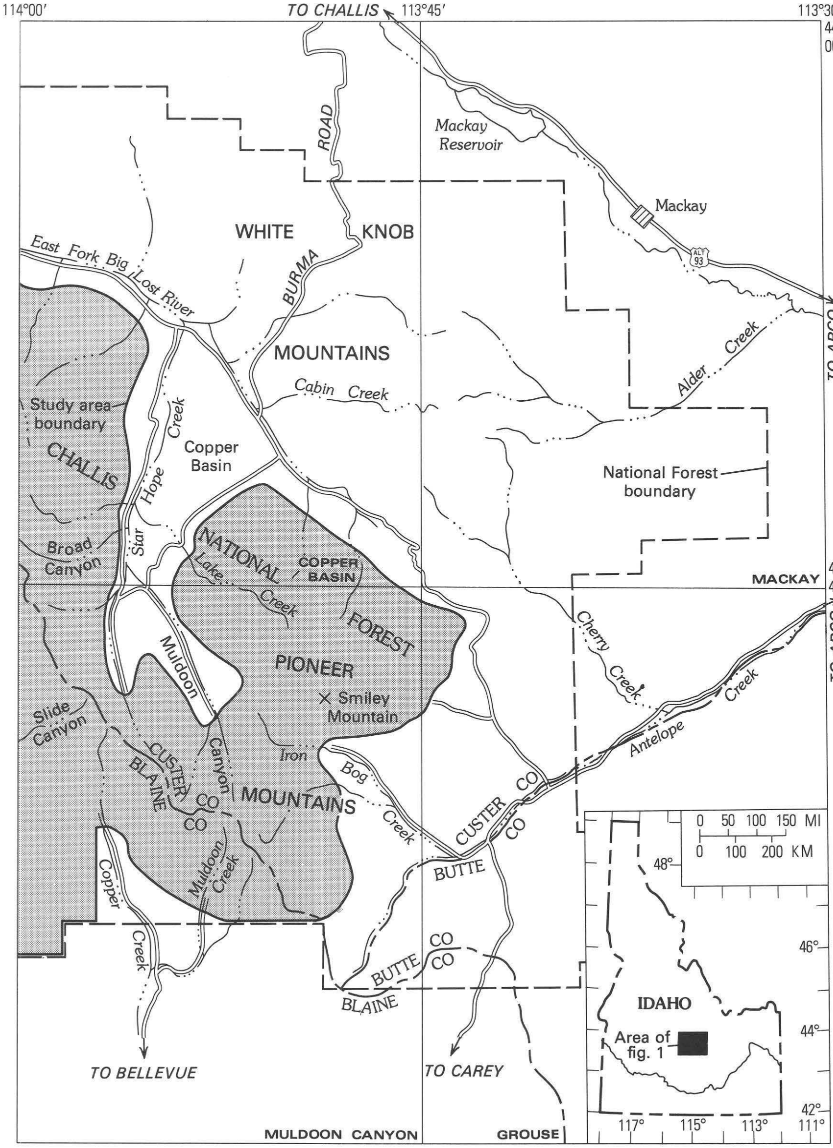


FIGURE 1.—Map of the Boulder-Pioneer wilderness study area, Idaho, showing principal roads and streams, and an index to topographic quadrangle maps. Base from U.S. Geological Survey 1:250,000 Hailey, Idaho Falls (1955).

Blaine County. The nearest highways are U.S. Highway 93 on the west side of the area along the Big Wood River and U.S. Highway 93 Alternate northeast of the area and connecting Arco, Mackay, and Challis. From Ketchum a road extends through Sun Valley up Trail Creek, across the low divide at Trail Creek Summit and down Summit Creek and Big Lost River to join U.S. Highway 93 Alternate northwest of Mackay; this road is paved for several miles at either end, but is graveled in the mountainous areas. A branch of the Trail Creek–Summit Creek road extends along East Fork Big Lost River into Copper Basin, whence it continues via Antelope Pass into the drainage of Antelope and Iron Bog Creeks. From U.S. Highway 93 a paved road leads up East Fork Wood River to the Triumph mine and from there gravel roads continue up the East Fork and Hyndman Creek. From Bellevue on U.S. Highway 93, a gravel road extends along Muldoon Creek. Other access roads are shown in figure 1.

Only a few of the many trails in the area are maintained and regularly traveled. These include the Boulder Creek–Boulder Lake and Fall Creek–Moose Lake trails from Wildhorse Creek; the Broad Canyon, Bellas Canyon, and Lake Creek trails out of Copper Basin; trails leading southeast from East Fork Wood River to Little Wood River via Iron Mine Creek and Box Canyon; and the trail up the Left Fork Iron Bog Creek. Except at Trail Creek Summit, the crest of the Pioneer Mountains is extremely rugged, and no trail crosses it anywhere in the 12 mi (20 km) airline distance between Kane Creek and the head of Little Wood River.

The Pioneer Mountains make up that part of the study area southeast of Trail and Summit Creeks and constitute more than three-fourths of the area; the rest of the area, northwest of Trail and Summit Creeks, is in the southeast part of the Boulder Mountains. The entire area is in the drainage basin of the Snake River, but only part of the runoff flows directly into the Snake. The southwest flank of the mountains is drained by the Big Wood River, which enters the Snake River 30 mi (50 km) northwest of Twin Falls; the northeast flank is drained by the Big Lost River, whose waters disappear into the porous lava flows of the Snake River Plain about 25 mi (40 km) northeast of Arco.

The topography of the study area is rugged and characterized by steep slopes throughout. Steep-walled, coalescing cirques and sharp, pinnacled divides (aretes) were carved by small mountain glaciers in the higher parts of the ranges, where the terrain is alpine in character (figs. 2, 3). The most scenic part of the range crest extends about 9 mi (15 km), from Devil's Bedstead to Standhope and Pyramid Peaks. U-shaped valleys were cut in the upper reaches of most major streams by larger valley glaciers issuing from the summit icefields; the most easily accessible and spectacular of these are drained by Trail Creek, Wildhorse Creek, North Fork Big Lost River, and the streams entering Copper Basin from the south and southeast. Altitudes range from about 6,000 ft (1,800 m) along the lower reaches of some valleys on the southwest margin of the area, to the 12,009 ft (3,660 m) summit of Hyndman Peak, the third highest in the State. Local relief from ridge

FIGURE 2.—Cirque at head of Boulder Creek, looking south from ridge at head of Little Kane Creek. Boulder Lake is just visible to left of cliff at lower center. Rocks are the Precambrian gneiss complex of Wildhorse Creek. Relief is about 2,500 ft (750 m).

FIGURE 3.—View looking west-northwest along crest of Pioneer Mountains. Old Hyndman Peak (11,745 ft; 3,580 m) at left; Hyndman Peak (12,009 ft; 3,660 m) at right center; Duncan Ridge (11,745 ft; 3,580 m) in background. Snowfields are at head of Wildhorse Creek. Rocks along crest are metasedimentary members of the Hyndman Formation (Middle Ordovician and (or) Proterozoic?).

crest to valley bottom, in nonglaciated as well as glaciated terrain, commonly is about 3,000 ft (900 m) but is as much as 4,000 ft (1,200 m) in places. A few small lakes occupy cirques; most of the lakes are only about a hectare in extent, and the largest cover less than 20 acres (8 hectares).

The climate of the Boulder-Pioneer region is rigorous. Winters are cold and snowfall usually is sufficiently heavy that snow persists in protected places until well into summer. Access to the high country depends largely on annual snowpack and runoff conditions, but foot travel within the higher parts of the study area normally is limited to the period July through September. Summers are warm, sunny, and dry, averaging under 1 in. (2.5 cm) of precipitation per month; at higher elevations the summer climate is ideal.

The principal present uses of the area are recreation and the grazing of cattle and sheep. Mining has been done sporadically within the study area for many years, but the total output of all types of ore probably has been less than 50,000 tons (45,500 t), even though substantial silver, lead, zinc, and copper have been produced from adjoining regions.

PREVIOUS INVESTIGATIONS

The earliest published geologic observations on the study area are those of Eldridge (1895), who traveled through the area by way of Big Lost River and Trail Creek and briefly described the geology and mineral deposits of the Deer Creek–Croy Creek area west of Big Wood River near Hailey. The same area was studied shortly thereafter by Lindgren (1900, p. 190–231), who also described a few mines east of the Big Wood River in Elkhorn Gulch and East Fork Wood River.

The geology and mineral deposits of the Mackay region were described in a comprehensive report by Umpleby (1917), which includes a small-scale geologic map of the east end of the study area and short sections on the Copper Basin mining district (p. 101–105) and Muldoon (Little Wood River) mining district (p. 105–110), parts of which are in the study area.

The geology and ore deposits of the Wood River region were studied in more detail by Umpleby, Westgate, and Ross (1930). That report contains a 1:125,000-scale geologic map that covers the western two-thirds of the study area.

Mineral resources of the eastern part of the Sawtooth National Recreation area, which adjoins the Boulder-Pioneer study area on the northwest, were evaluated by Tschanz and others (1974).

In addition to the foregoing broad investigations of mineralized areas, detailed examinations of parts of the Mineral Hill and Warm Springs mining districts were conducted by Anderson (1950), Kiilsgaard (1950), and Fryklund (1950); the Walton and White Mountain molybdenum prospects were studied by Kirkemo, Anderson, and Creasey (1965), (p. E55–E58); and part of the Alder Creek mining district was reported on by Nelson and Ross (1968).

The bedrock geology of the central Pioneer Mountains was described by Dover (1969), with emphasis on petrologic and structural aspects of rocks that make up the core of the present study area. The stratigraphy of rocks in and near the study area has been discussed by Bostwick (1955); Churkin (1962, 1963); Carter and Churkin (1977); Dover, Berry and Ross (1980); Dover and Ross (1975); Hall, Batchelder, and Douglass (1974); Mamet and others (1971); Nilsen (1977); Paull and others (1972); Paull and Gruber (1977); Roberts and others (1965); Ross (1934b, 1937, 1947, 1961, 1962a, 1962b); Sandberg, Mapel, and Huddle (1967); Sandberg and others (1975); and Spoelhof (1972).

The geology of the Mackay 30-minute quadrangle, which includes the Copper Basin, Mackay, Muldoon Canyon, and Grouse 15-minute quadrangles, was mapped by Nelson and Ross (1969); and parts of the same quadrangle have also been mapped by Bollmann (1971), Lukowicz (1971), Volkmann (1971), and Wolbrink (1970). Road logs of the geology along U.S. Highways 93 and 93 Alternate, and along the Trail Creek–Summit Creek road, were prepared by Ross (1963).

PRESENT INVESTIGATION AND ACKNOWLEDGMENTS

Geologic mapping and geochemical sampling in the Boulder-Pioneer study area were done by the U.S. Geological Survey, and investigation of known mineral deposits and mining claims by the U.S. Bureau of Mines.

Fieldwork of the U.S. Geological Survey was done during 4 months in the summers of 1973 and 1974 by F. S. Simons, J. H. Dover, W. E. Hall, S. W. Hobbs, C. M. Tschanz, and J. N. Batchelder. Betty Skipp aided in the geologic mapping of the southeasternmost part of the area. Assisting in the fieldwork were Jonathan Myers and G. J. Podsobinski in 1973 and S. J. Frost, C. A. Stiles, and John Keith in 1974.

Geologic mapping, mostly of a reconnaissance nature, was done on 1:24,000- and 1:62,500-scale topographic quadrangle maps and on aerial photographs at scales of about 1:20,000 and 1:40,000. A topographic base map at a scale of 1:62,500 was prepared from the quadrangle maps, and geology was compiled on this base (pl. 2). An aeromagnetic survey of the study area and contiguous areas was made by the U.S. Geological Survey in 1974, and the results appear on plate 3; interpretation of the aeromagnetics was made by D. R. Mabey. About 32 man-months of fieldwork were completed during the course of the Boulder-Pioneer study, but this report is based on more than twice that amount of cumulative fieldwork in the Boulder-Pioneer region, including mapping done by Dover, Hall, Tschanz, and Batchelder prior to the present study. Areas of primary mapping responsibility of individual authors are shown on plate 2.

Geochemical sampling was done concurrently with geologic mapping and a total of 2,095 rock and stream-sediment samples were collected. In addition, 23 rock samples were collected for radiometric age dating. Localities of all samples are shown on plate 4.

Most of the analytical work was done in the field under the supervision of J. A. Domenico, U.S. Geological Survey. Semiquantitative spectrographic analyses of all samples were made by J. A. Domenico with the assistance of W. D. Crim, R. T. Hopkins, and Steve Sutley, using the methods described by Grimes and Marranzino (1968). Chemical analyses were done by J. G. Frisken assisted by E. J. Hoffman and Richard Sanzalone, using the atomic absorption methods of Ward and others (1969), and the colorimetric tests of Ward and others (1963). Determinations of equivalent uranium (eU) were made by Z. C. Stephenson. Neutron activation analyses for uranium and thorium were done by H. T. Millard and D. A. Bickford. The computer storage, retrieval, and statistical program work was under the direction of L. O. Wilch with the assistance of R. J. Smith.

During the 1973 field season the geologic investigation was done on foot from base camps on Wildhorse and Star Hope Creeks; a helicopter was used briefly for two days in August. In 1974, some work was done on foot from base camps on East Fork Wood River and Copper Creek, and a helicopter was used for access to the more remote parts of the area from mid-July until September.

Fieldwork of the U.S. Bureau of Mines was done during the summers of 1973 and 1974 by E. T. Tuchek, James Ridenour, and Steven Schmauch, assisted by Earl Bennett, Stephen Brown, Richard Newcomb, and Edwin West; about 35 man-months were spent in the field. All known mines, prospects, and areas favorable for mineral deposits were mapped and sampled. Claim locations were obtained from official records of Blaine and Custer Counties, and survey plats of mining claims were obtained from the U.S. Bureau of Land Management. Production records were compiled mainly from U.S. Bureau of Mines sources. Field studies were mainly of lode deposits; placer claims are few and small, and their economic potential is minimal.

Samples were collected of both rocks and stream sediments, and some panned concentrates were made to test stream sediments for heavy minerals. A total of 1,312 samples were analyzed by fire assay, semiquantitative spectrometry, atomic absorption, colorimetry, or X-ray fluorescence. All samples were checked for radioactivity by a Geiger counter and for fluorescence by ultraviolet light. Samples from placer deposits were collected at 16 sites and concentrated onsite. Sample localities are shown on plate 4.

Fieldwork was done from base camps at several localities. Helicopters and horses were used to supply some base camps and to transport personnel.

We wish to acknowledge the help of U.S. Forest Service officials R. O. Benjamin, Forest Supervisor, Challis National Forest; Grant Thorson, District Ranger, Lost River Ranger District; E. A. Fournier, Forest Supervisor, Sawtooth National Forest; and G. L. Farr, District Ranger, Ketchum Ranger District. We wish to thank Ivan Taylor for maps and production data on the Phi Kappa mine, and to acknowledge the cooperation of other claim and property owners.

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Geology of the Boulder-Pioneer Wilderness Study Area, Blaine and Custer Counties, Idaho

By JAMES H. DOVER, U.S. GEOLOGICAL SURVEY

MINERAL RESOURCES OF THE BOULDER-PIONEER WILDERNESS STUDY AREA, BLAINE AND CUSTER COUNTIES, IDAHO

GEOLOGICAL SURVEY BULLETIN 1497-A

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By JAMES H. DOVER, U.S. GEOLOGICAL SURVEY

DESCRIPTION OF ROCK UNITS

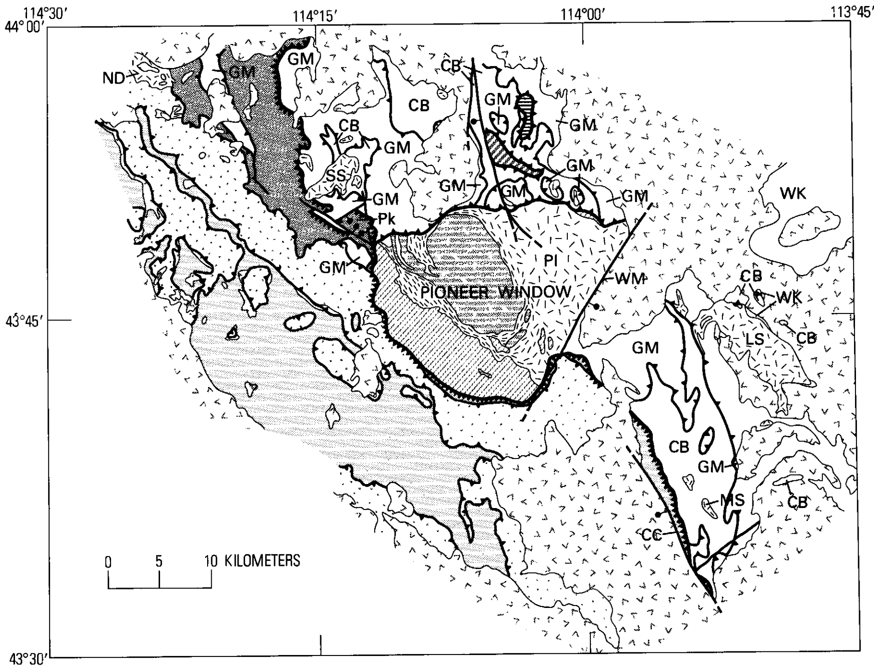
The Boulder-Pioneer study area displays a wide variety of rocks, ranging in age from Precambrian to Tertiary (pl. 2). Precambrian gneissose rocks form the core of the study area. Surrounding sedimentary and metasedimentary rocks of mainly Paleozoic age occur in an imbricate sequence of structural plates detached from the gneissic core and separated from one another by major thrust faults. Granitic igneous rocks of Late Cretaceous(?) to early Tertiary age intrude the older rocks. Volcanic rocks of Eocene age, at least in part coeval with the intrusives, unconformably overlie large tracts of pre-Tertiary rocks in and around the study area. Unconsolidated Quaternary surficial deposits are found mainly along stream courses and locally are extensive. Figure 4 shows the distribution of major petrologic and tectonic units.

PRECAMBRIAN ROCKS

GNEISS COMPLEX OF WILDHORSE CREEK

Heterogeneous gneisses occupy about 20 mi^2 (52 km^2) in the structural core of the Pioneer Mountains. A band of gneiss 3 mi (5 km) wide by 6 mi (9.6 km) long extends northwest across upper Wildhorse Creek in the north-central part of the study area, and a smaller belt occupying about 2 mi^2 (5.2 km^2) projects from the main band into the cirques of upper Kane Creek (pl. 2; fig. 4).

Dover (1969, p. 7–13) subdivided the gneiss complex into five compositionally distinct and roughly concordant units that aggregate about 7,000 ft (2,130 m) in thickness. Compositional banding is prominent in some units, and metamorphic foliation is well developed throughout. In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ND
GM
CB
SS
Pk
PI
PIONEER WINDOW
WM
WK
LS
MS
CC
0 5 10 KILOMETERS

EXPLANATION

ALLOCHTHONOUS SEDIMENTARY SEQUENCES

- WK — White Knob Limestone
- Copper Basin Formation
  - GM — Glide Mountain plate
  - CB — Copper Basin plate
- Wood River Formation
- Milligen Formation
- Devonian, Silurian, and Ordovician rocks, undivided

STRATIGRAPHIC SEQUENCES IN TECTONIC WINDOWS

- Parautochthonous(?) Devonian and Silurian rocks of the Dry Canyon window
- Parautochthonous(?) Devonian, Silurian, and Ordovician rocks of the Wildhorse window
- Allochthonous Ordovician and Proterozoic(?) metasedimentary rocks
- Allochthonous gneiss complex of Wildhorse Creek

MAJOR IGNEOUS ROCK UNITS

- Mainly Challis Volcanics
- ND — Dike complex of North Fork Lake
- SS — Summit Creek stock
- MS — Muldoon stock
- PI — Intrusive complex of the Pioneer window—Pattern shows approximate degree of fabric alinement
- LS — Lake Creek Stock

MAJOR FAULTS

- Pioneer thrust fault system—Sole thrust of allochthonous sequences of lower Paleozoic argillaceous rocks (western facies) of western Pioneer Mountains; also marks abrupt metamorphic break along Pioneer window contact. Sawteeth on upper plate
- Wildhorse thrust fault system—Sole thrust separating allochthonous Mississippian Copper Basin Formation sequences from pre-Mississippian sequences in tectonic windows; along Pioneer window contact, marks abrupt metamorphic break with metasedimentary rocks and coincides with sheared contact of intrusive complex. Sawteeth on upper plate
- Thrust fault (unnamed)—Sawteeth on upper plate
- High-angle normal fault—Bar and ball on downthrown side
  - WM — White Mountains fault
  - CC — Copper Creek fault
  - Pk — Phi Kappa Mountain fault block
- Contact

FIGURE 4.—Generalized map of major petrologic and tectonic units in the Boulder-Pioneer study area, Idaho.

this report, only three units are distinguished (pl. 2)—Dover's basal gneiss unit, his marble marker bed, and an upper, heterogeneous gneiss unit that includes his three units above the marble bed.

The basal unit ranges in composition from highly quartzitic, locally garnetiferous biotite gneiss, to leuco-trondhjemitic gneiss in which intermediate plagioclase (An_{20}–An_{56}) is abundant. In some places the contact between the quartzitic and feldspathic phases is irregular and gradational.

A calc-silicate marble bed overlies the basal gneiss unit. The marble forms prominent outcrops in the high cirques west of Wildhorse Creek, and makes distinctive circular or arcuate map patterns that reflect the cirque topography (pl. 2). In most places the marble bed ranges in thickness from 30 to 100 ft (9 to 30 m); in some places it appears to split into two or more layers separated by gneiss, and locally it may pinch out. The marble has been traced more or less continuously through the gneiss complex; it is shown separately on plate 2 because it is a distinctive marker horizon by which the generally domal structure of the gneisses can be demonstrated, and because locally it contains tungsten minerals. The mineral assemblage diopside-forsterite-phlogopite-calcic scapolite-calcite, in marble exposed along Wildhorse Creek, indicates a high metamorphic grade in the core of the gneiss complex.

The upper unit of heterogeneous gneisses includes (1) quartzitic biotite gneiss and leuco-trondhjemitic to quartz monzonitic gneiss that overlies the marble horizon and resembles the basal gneiss unit, except in having a greater proportion of rocks of granitic composition; (2) overlying dark quartzitic to mafic gneiss that is typically contorted and contains subordinate, thin layers of calc-silicate rock and quartzite intercalated in the lower part; and (3) gradationally overlying quartzitic to granitic gneiss containing purer and more abundant quartzite than in other parts of the gneiss complex, and well-developed cataclastic textures in the granitic gneisses. On the divide between Wildhorse and Kane Creeks, a prominent sill of quartz monzonite orthogneiss occurs within the upper gneiss unit. Dikes of amphibolite that show a range of deformational and metamorphic characteristics, and irregular injections of quartz monzonite aplite are particularly abundant in the quartzitic and mafic gneisses of the upper gneiss unit, and give it a more migmatitic aspect than other units of the complex. A discontinuous layer of sillimanite-biotite schist that transects layering at a low angle within the upper gneiss unit is inferred to mark a recrystallized thrust zone, and indicates the high metamorphic grade of the upper part of the gneiss complex.

The composition, continuity, and regularity of layering throughout the gneiss complex suggest a sedimentary origin, or possibly a volcanic or volcaniclastic origin, for the bulk of the gneisses. Cook (1956) and Dover (1969, p. 10) suggested that feldspathic phases of the gneisses were developed by metasomatism from originally more siliceous rocks. Some thin, nearly pure quartzite beds grade along strike into rocks rich in feldspar, indicating that metasomatism has occurred at least locally. The cataclastic, migmatitic, and metasomatic aspects of the gneisses, and their complex history of mafic dike injection, all serve to distinguish the complex of Wildhorse Creek from other metamorphic rocks in the study area, and suggest an early Precambrian age. Rb-Sr dating of the gneiss complex by R. E. Zartman is incomplete, but preliminary data suggest a Proterozoic X age of about 2 b.y. (written commun., 1976).

The gneiss complex of Wildhorse Creek is separated from unmetamorphosed Paleozoic rocks on the north by a major low-angle fault, and from metamorphosed and unmetamorphosed Paleozoic rocks elsewhere by intrusive igneous rocks.

PROTEROZOIC(?) AND PALEOZOIC ROCKS

The Proterozoic(?) and Paleozoic rocks in the region of the Boulder-Pioneer study area have been studied over a period of more than 70 years, and interpretations of stratigraphic relations and correlation of some rocks have changed significantly from time to time. These changes are summarized in table 1 for all of the Proterozoic(?) and Paleozoic rock units of plate 2. Previous nomenclature and age assignments, and usage in the present report are tabulated in chronological order for each unit.

ORDOVICIAN AND OLDER METASEDIMENTARY ROCKS

Medium- to high-grade metasedimentary rocks are distributed in a northwest-trending belt 9 mi (14 km) long and 1–3 mi (1.6–4.8 km) wide in the central part of the study area, south and west of the Precambrian gneiss complex (pl. 2; fig. 4). The scenic southwest-facing cirques at the heads of Hyndman, Corral, and Wilson Creeks are carved from these rocks.

The metasedimentary sequence was assigned to two formations, the Hyndman Formation and the overlying East Fork Formation, by Umpleby, Westgate, and Ross (1930, p. 9–17). Deformation has complicated reconstruction of the original stratigraphic sequence. Dover (1969, p. 15–22) described eight lithologic units that differ somewhat from those originally proposed by Umpleby, Westgate, and Ross, and assigned them informal member designations A to H; subsequent work has shown that Dover's highest member (H) is a tectonic repetition of lower members. In this report, the names Hyndman and East Fork as well as Dover's members A through G are retained.

TABLE 1.—*Nomenclature chart of Paleozoic rocks, Boulder-Pioneer wilderness study area, Idaho*

Lithologic unit[1]	Age and stratigraphic nomenclature	
	Previous reports	This report
Wood River Formation----	Carboniferous (Lindgren, 1900,-------- p. 89-90, 193-195). Pennsylvanian (Umpleby and others,---- 1930, p. 29-34). Middle Pennsylvanian-Early Permian---- (Hall and others, 1974; comprises 7 stratigraphic units, including Hailey Conglomerate Member at base).	Middle Pennsylvanian to Early Permian: Upper part (units 4-7 of Hall and others, 1974, and younger rocks). Lower part (units 1-3 of Hall and others, 1974).
White Knob Limestone----	Early Mississippian to Early Permian--- (Ross, 1962c).	Late Mississippian.
Copper Basin Formation--	Pennsylvanian (Umpleby and others,----- 1930; Wood River Formation, in part). Carboniferous (Ross, 1962c; Copper----- Basin Formation). Mississippian and Pennsylvanian------- (Copper Basin Group of Paull and others, 1972; Iron Bog Creek Formation at top; Brockie Lake Conglomerate; Muldoon Canyon Formation; Scorpion Mountain Formation; Drummond Mine Limestone; Milligen Formation of Paull and others, 1972, at base).	Mississippian: Copper Basin Plate: comprises upper clastic unit (upper four formations of Paull and others, 1972); Drummond Mine Limestone Member; Little Copper Member. Glide Mountain plate: coeval coarser clastic and carbonate-poor lithofacies than in Copper Basin plate; includes Green Lake Limestone Member and correlative limestone at Big Rocky Canyon.
Carey Dolomite----------	Middle and Early Devonian (Skipp------ and Sandberg, 1975).	Middle and Early Devonian.
Argillaceous rocks------	Ordovician; Phi Kappa Formation------- (in part) (Umpleby and others, 1930, p. 21-22). Pennsylvanian; Wood River Formation--- (in part) (Dover, 1969, p. 31).	Silurian and Devonian, undivided.
Milligen Formation------	Devonian(?) and Mississippian--------- (Umpleby and others, 1930, p. 25-29).	Early to Late Devonian.
Calcareous rocks of----- Wildhorse and Dry Canyon windows.	Late Ordovician to Late Devonian------ (Dover and Ross, 1975).	Ordovician to Devonian, undivided.
Trail Creek Formation---	Early Silurian (Umpleby and others,--- 1930, p. 23-24).	Early Ordovician to Middle Silurian, undivided.
Phi Kappa Formation-----	Early to Late Ordovician (Umpleby----- and others, 1930, p. 18-23).	
East Fork Formation-----	Algonkian(?) (Umpleby and others,----- 1930, p. 14-17; lower limestone member, quartzite member, upper limestone member). Latest Precambrian and early Paleozoic (Dover, 1969, p. 21-22; members E, F, G, and H of an unnamed sequence).	Late(?) and (or) Middle Ordovician; comprises members E, F, and G of Dover (1969).
Hyndman Formation-------	Algonkian(?) (Umpleby and others,----- 1930, p. 17; lower quartzite member, schist member, middle quartzite member, green hornfels member, and upper quartzite member). Latest Precambrian and early Paleozoic (Dover, 1969, p. 16-21; members A, B, C, and D of an unnamed sequence).	Ordovician and Proterozoic(?); comprises A, B, C, and D of Dover (1969).

[1]Also on plate 2.

HYNDMAN FORMATION

The Hyndman Formation as used herein comprises the lower four members (A–D) of Dover's (1969) unnamed metasedimentary succession, and aggregates at least 5,200 ft (1,580 m) in thickness. Rocks of the Hyndman Formation crop out mainly in the southeast half of the metasedimentary belt, but also are present in discontinuous thrust slices as far north as the Devil's Bedstead (pl. 2).

Member A, the basal unit, is pelitic schist and is estimated to be at least 2,000 ft (610 m) thick at the head of the East Fork Wood River. Andalusite-muscovite-biotite-quartz schist predominates along the East Fork, in the southern part of the outcrop belt, whereas staurolite-cordierite-garnet-sillimanite-andesine-quartz-two mica-schist is typical in the northern part. Orthoclase occurs with the sillimanite near intrusive contacts in schist that contains pods and lenses of granodiorite.

Member A grades abruptly into overlying gneissose quartzite of member B, which forms the summit of Hyndman Peak. A thickness of 1,200 ft (365 m) was reported by Dover (1969, p. 19) in Big Basin, at the head of Hyndman Creek. The quartzite is white to mottled, commonly has green spots, and contains 10–20 percent of microcline, plagioclase, biotite, pyroxene, hornblende, sericite, and other accessory minerals. Metamorphic foliation is moderately well developed; biotite-rich partings seem to define faint sedimentary crossbedding in some outcrops, and internal isoclinal flow folds in others.

Member B is overlain with a sharp contact by distinctively banded calc-silicate rocks of member C, which forms a prominent marker throughout the metasedimentary belt. A thickness of 600 ft (180 m) is estimated for member C in the cirques at the head of Hyndman Creek. The banding is generally sharp and uniform, and produces an attractive rock that typically splits into large slabs. Light-colored bands tend to be etched by weathering and are rich in calcite, grossularite, salite, ferric pistacite, and calcic scapolite; green or purplish bands are more resistant to weathering and contain more abundant biotite, ferrohastingsitic hornblende, microcline, quartz, and plagioclase. The relative proportions of these mineral constituents vary considerably from band to band, and the thickness of individual bands ranges from a fraction of an inch to several inches (a centimeter to several centimeters). The mineralogic banding reflects primary compositional layering in the original sediment; petrographic examination shows that little or no chemical interaction has occurred even between delicate layers of different composition. Some samples have rhythmically repeated groups of bands; the sequence of layers within each group reflects a gradation from argillaceous to limy sediment, and the overall pattern of repetition is suggestive of grading in a turbidite deposit (Dover, 1969, fig. 17). Locally the regularity of banding is disrupted by scour features and slump structures that formed before consolidation of the original sediment. The degree of preservation of primary sedimentary features in these medium- to high-grade metamorphic rocks is remarkable.

Member C is overlain more or less concordantly at most places by gneissose quartzite of member D, but at the head of East Fork Wood River, 6 ft (1.8 m) of quartz-pebble conglomerate marks the slightly discordant base of member D. About 1,400 ft (425 m) of beds assigned to member D crop out on the ridge between the two forks of Hyndman Creek. The quartzite is white and poorly sorted, and contains a suite of minor and accessory minerals resembling that of member B. Plagioclase and microcline constitute as much as 20 percent of some samples. Bedding is thick to massive, and coarse tabular crossbedding is common and well developed. The quartzite tends to split into slabs along micaceous partings and streaks that contain as much as 50 percent biotite. The quartzite of member D tends to be more vitreous than that of member B, lacks mottling and green spotting, has more and better developed crossbedding, and has irregularly distributed layers and lenses of granule and pebble conglomerate that contain pink to purplish quartz clasts.

EAST FORK FORMATION

The East Fork Formation comprises the upper three members (E–G) of the metasedimentary succession, and is at least 1,800 ft (500 m) thick. It occurs in thrust slices chiefly in the northwestern half of the metasedimentary belt (pl. 2).

Calc-silicate marble of member E overlies member D of the Hyndman Formation sharply and more or less concordantly, and forms prominent tan-colored dip-slopes at the ends of ridges between major cirques. Member E is about 700 ft (210 m) thick on the ridge between the two branches of North Fork Hyndman Creek. The lower part of the member is buff, massive, coarsely crystalline diopside marble that characteristically disintegrates into coarse calcite sand and contains the medium- to high-grade metamorphic assemblage green spinel-forsterite-alined phlogopite-diopside-calcite. The upper part contains light-gray to buff, thin- to medium-bedded marble that varies in its content of calcite, quartz, and the same suite of calc-silicate minerals; mineralogical variations from bed to bed are emphasized by differential weathering. Thin siliceous partings and quartzite interbeds increase in thickness and abundance upward toward the overlying quartzite of member F. Between the lower and upper parts of member E, a discontinuous zone as much as 10 to 20 ft (3 to 6 m) thick of siliceous rocks, including some quartzite, is present locally.

The upper siliceous part of member E grades into the overlying quartzite of member F. About 200–300 ft (60–90 m) of beds assigned to member F are present along the south branch of North Fork Hyndman Creek, where the member occurs in three large overturned folds. The quartzite is white, pink, yellowish brown, or mottled gray in color, and it can be distinguished from all other quartzites in the study area by its purity (99 percent or more of quartz) and its vitreous luster. The parent rock was a fine-grained and well-sorted sandstone with subrounded quartz grains, but at many places the original texture is masked by recrystallization to a coarse mosaic of interlocking quartz crystals as much as 5 mm across. Locally the quartzite is faintly laminated, and thin muscovite partings occur rarely. The upper 10 ft (3 m) of the quartzite is marked by crossbedding and a somewhat coarser grain size.

Marble of member G overlies member F sharply and concordantly. The marble is best exposed on the divide between the cirques of Corral and North Fork Hyndman Creeks, where at least 800 ft (240 m) of section is exposed beneath a thrust sheet containing members lower in the sequence. The lower part of member G tends to be coarsely crystalline, massive, and carbonaceous. Dark-gray calcite marble with disseminated quartz, diopside, and graphite predominates. Thin siliceous stringers are intercalated in the lowest part of the section and form knots and boudins where deformation was intense. Deformed crinoid columnals and unidentifiable remnants of shelly fossils can be recognized locally in these lower beds, generally within 100 ft (30 m) of the underlying quartzite. The upper part of member G consists of thin to medium beds of light-gray diopside-rich marble that alternate with darker gray beds of coarser calcite marble.

MARBLE AND SCHIST INCLUSIONS

Forsterite marble and garnetiferous biotite-quartz schist occur as inclusions within and marginal to the intrusive complex of the Pioneer window. They are best displayed at the head of East Fork Wood River but are present elsewhere along the range crest from Box Canyon to Hyndman Peak, and on the north and east sides of the intrusive complex. The marble resembles that of member E of the metasedimentary succession in composition, but the schist is more quartzitic and less aluminous than that of member A. The stratigraphic and structural relations of these rocks to the rest of the metasedimentary succession are uncertain.

AGE AND CORRELATION

The Hyndman and East Fork Formations were questionably assigned to the Algonkian(?) System (late Precambrian) by Umpleby, Westgate, and Ross (1930, p. 16–17). Dover (1969, p. 24–25) considered the Hyndman Formation to contain metamorphosed uppermost Precambrian rocks and the East Fork Formation to be composed of lower

Paleozoic rocks. Trilobite fragments found recently near the base of member G of the East Fork at the head of Cabin Gulch, on the southeast edge of the metasedimentary belt, comprise the following species according to R. J. Ross, Jr. (written commun., 1975):

Cryptolithoides sp.

Ceraurinid, probably *Ceraurinella* sp.

Possibly *Anataphrus* sp.

Ross stated that these forms are found in the Saturday Mountain Formation of Middle and Late Ordovician age. The premetamorphic lithology inferred for member G is comparable with that of the Saturday Mountain Formation, which is exposed widely in Idaho north and east of the study area. Quartzitic and carbonate rocks that underlie the type section of the Saturday Mountain near Clayton, Idaho, 30 mi (48 km) north of the study area (Hobbs and others, 1968), are strikingly similar to parts of the Boulder-Pioneer metasedimentary succession not only in overall sequence and thickness of individual units, but also in distinctive compositional and textural details. On the basis of lithologic similarities and fossil data, the following correlations are proposed.

[Asterisk (*) indicates unit dated]

	Boulder-Pioneer study area (this report)		Age based on fossil data	Clayton area, Idaho (Hobbs and others, 1968)
East Fork Formation	Member G*:	carbonaceous diopside-marble	Middle and Late Ordovician	Saturday Mountain Formation* (shaly dolomite)
East Fork Formation	Member F:	recrystallized, pure, fine-grained quartzite		Kinnikinic Quartzite
East Fork Formation	Member E:	bedded to massive, calc-silicate marble	Early Middle Ordovician	Ella Dolomite*
Hyndman Formation	Member D:	crossbedded, conglomeratic, feldspathic quartzite		Clayton Mine Quartzite

The green, banded calc-silicate rocks (member C) of the Hyndman Formation are strikingly similar in mineral composition and layering, and in their association with thick feldspathic quartzite and pelitic schist units (or argillite in less highly metamorphosed areas), to banded calc-silicate rocks assigned to the Yellowjacket Formation (Proterozoic Y) by B. F. Leonard (written commun., 1979) elsewhere in north-central Idaho. Alternatively, member C could be the metamorphic equivalent of a thin-bedded carbonate-siltstone unit of pre-Middle Cambrian age that lies between two thick quartzites in the lower part of the section at Clayton, Idaho (Hobbs and others, 1968). Although the Yellowjacket correlation is preferred here, correlation of the metasedimentary rocks of the Hyndman Formation remains speculative.

METAMORPHIC CHARACTER

The mineralogy and texture of rocks of the Hyndman and East Fork Formations indicate that they underwent medium- to high-grade regional synkinematic metamorphism. Metamorphism proceeded under moderate pressure at intermediate depth, and produced no significant changes in bulk chemical composition. Relict sedimentary textures that survived metamorphism are common. This simple history of isochemical metamorphism contrasts with the more complex history of the underlying Precambrian gneisses. Metamorphic intensity increases from medium grade in structurally high parts of the metasedimentary sequence to highest almandine-amphibolite grade (sillimanite + orthoclase) near pods of the mafic phase of the intrusive complex of the Pioneer window, indicating that a thermal gradient toward the mafic phase of the complex existed during regional metamorphism.

ORDOVICIAN, SILURIAN, AND DEVONIAN ROCKS

WESTERN SEQUENCE

PHI KAPPA AND TRAIL CREEK FORMATIONS

The Phi Kappa and Trail Creek Formations were originally defined by Westgate and Ross in Umpleby, Westgate, and Ross (1930). The formations crop out in a broad band extending northwest from the central part of the study area to its north edge (pl. 2; fig. 4). Using graptolite zonations, Churkin (1963) demonstrated that thrust faults repeat section in the Phi Kappa near Trail Creek Summit. Subsequent detailed mapping and the distribution of graptolites in 116 new collections now show the outcrop belt originally designated for the Phi Kappa and Trail Creek Formations to comprise an imbricate series of thrust-bounded slices. All sections of the Phi Kappa Formation originally reported by Westgate and Ross, and some sections reported by Churkin, were measured across unrecognized thrust faults that repeat Ordovician-Silurian section or juxtapose other lithostratigraphic units of diverse ages. Furthermore, banded siliceous rocks lithologically identical to those of the Trail Creek Formation at the type locality also were included with the Phi Kappa in some parts of the Ordovician-Silurian belt by previous workers. Recognition of these problems led Dover, Berry, and Ross (1980) to redefine the Phi Kappa and Trail Creek Formations and to reevaluate stratigraphic concepts previously published for these formations. The terms Phi Kappa and Trail Creek as used in this report follow their revised usage.

The revised Phi Kappa Formation consists mainly of black, red-brown-weathering, carbonaceous, locally silicified argillite and shale. Shaly parting is irregularly preserved because of deformation, silicification, and metamorphic recrystallization. The massive, gray, generally fine grained but locally conglomeratic Basin Gulch Quartzite Member (not mapped separately on pl. 2) occurs at the base, and the middle part typically is limy and contains a few thin limestone interbeds. Most of the coarser clastic rocks reported in previously measured sections of the Phi Kappa, as well as the sequence along Phi Kappa Creek from which the name originates, are excluded from the Phi Kappa as revised and are reassigned to two structural plates of Mississippian Copper Basin Formation. Other strata now excluded from the Phi Kappa are reassigned to the Trail Creek Formation and to an unnamed Devonian and Silurian unit. The Phi Kappa includes rocks of Early through Late Ordovician age (graptolite zones 2–4 through 15 of Berry, 1960) and also contains about 56 ft (17 m) of lithologically identical Early to Middle Silurian beds at the top that formerly were assigned to the Trail Creek Formation. The entire Phi Kappa section is no more than about 800 ft (240 m) thick, compared with the 12,700 ft (3,860 m) originally estimated. Essentially the same section of the revised Phi Kappa is structurally repeated in numerous thrust slices within the outcrop belt previously designated for the formation.

The restricted Trail Creek Formation consists of buff-weathering, dark- and light-banded, siliceous metasiltstone and very fine grained quartzite. Some samples of the Trail Creek contain as much as 50 percent of contact metamorphic tremolite in disoriented aggregates. This distinctive lithostratigraphic unit occurs along with the gradationally underlying Phi Kappa in imbricate thrust slices throughout the Ordovician-Silurian outcrop belt. No more than about 325 ft (100 m) of the restricted Trail Creek is known in any thrust slice. It grades over a distance of a few meters into Middle Silurian (middle Wenlockian) beds of the upper Phi Kappa, but no fossils have been found in the revised Trail Creek and its precise age is unknown.

The combined thickness of about 1,120 ft (340 m) for the revised Phi Kappa and Trail Creek Formations is a minimun owing to their occurrence in fault-bounded structural slices. However, the same time interval, from Early Ordovician through at least Middle Silurian, is represented by more than a thousand meters of quartzitic sandstone and carbonate deposits in the region of central Idaho north and east of the Boulder-Pioneer area.

MILLIGEN FORMATION

The Milligen Formation was named by Umpleby, Westgate, and Ross (1930, p. 25–29) for dominantly argillaceous rocks that were originally included in the lower part of the Wood River Formation of Lindgren (1900). The Milligen occupies a belt as much as 6 mi (9.6 km) wide by 25 mi (40 km) long on the southwest edge of the study area, and typically forms steep, grassy or sagebrush-covered ridges (pl. 2; fig. 4).

The Milligen Formation as mapped in the study area consists dominantly of gray-weathering, slabby, phyllitic or subphyllitic argillite, and black, thin-bedded to massive, carbonaceous to siliceous ("cherty") argillite. Subordinate interbeds of gray, poorly sorted, fine-grained quartzite, yellow-brown- to reddish- or orange-weathering dolomitic siltstone, and rare, thin beds of blue-gray, silty, micritic to granular bioclastic limestone occur in the lower part of the formation. Tan, dolomitic siltstone beds 100 ft (30 m) or more thick, and thin interbeds of gray micritic to silty limestone, bioclastic limestone, and chert-quartzite granule-to-pebble conglomerate are considered by Sandberg and others (1975) to be more common in the upper part. Locally, limestone interbeds contain contact metamorphic tremolite. Thin graphitic coal beds were reported by Umpleby, Westgate, and Ross (1930, p. 26), but no coal has been observed within the study area.

Four partial sections thought to aggregate at least 4,000 ft (1,200 m) in thickness were measured by W. E. Hall and John Batchelder (*in* Sandberg and others, 1975). However, their composite section is still tentative because the internal stratigraphy and structure of the Milligen was not mapped in detail, and correlation within the Milligen outcrop area is uncertain without better fossil control.

Exposures of the Milligen Formation are poor at its type locality in the vicinity of Milligan[1] Gulch, in the south-central part of the study area. No sections were measured by Umpleby and his coworkers because of poor exposures, scarcity of marker beds, and intensity of deformation; and no fossils were found that provided any reliable evidence of age. A Mississippian age was inferred by them for the bulk of the Milligen because of its carbonaceous aspect and because of a contact with overlying Pennsylvanian rocks that was described as gradational at one locality on Lake Creek (Big Wood River); however, they thought that Devonian strata might be present in the lower part. Dover (1969, p. 30, 32) questioned the evidence for a gradational contact at Lake Creek and considered the Milligen to be in tectonic contact with Pennsylvanian rocks elsewhere in the Pioneer Mountains region.

[1]The name Milligen Creek, from which the Milligen Formation was named, has been changed to Milligan Gulch on the 1967 Hyndman Peak 1:24,000 quadrangle used in compiling the base for plate 2.

The name Milligen also was applied to Lower Mississippian clastic rocks that lie between the Upper Devonian Three Forks Formation and Mississippian carbonate rocks (the Brazer Limestone of some workers) in the Lost River Range to the east and in other ranges as far east as southwest Montana (Ross, 1934, 1947, 1961, 1962a, 1962b; Churkin, 1962; Mapel and others, 1965; Sandberg and others, 1967). Poorly dated dark clastic rocks in the Bayhorse region north of the study area also were assigned to the Milligen by Ross (1937). Paull and others (1972) formerly used the name Milligen in the Pioneer Mountains for the basal clastic unit of their Mississippian and Pennsylvanian Copper Basin Group. Because of the problems posed by the Milligen at its type locality, Dover (1969, p. 29) cautioned against using the name beyond the outcrop area originally designated.

More recently, Sandberg and others (1975) reported an early Middle Devonian (Eifelian) conodont fauna from a bioclastic limestone bed about 1,000 ft (300 m) above the lowest exposures of the lower part of the Milligen at one locality, and early Late Devonian (early Frasnian) conodonts occur in limestone interbeds at three other localities in the upper part of the Milligen in the south half of the outcrop belt. The conodonts suggest an age ranging from Early Devonian through at least early Late Devonian for the bulk of the Milligen. However, the upper and lower contacts of the Milligen are tectonic, and therefore, stratigraphic relations at the top and bottom of the formation remain uncertain.

All recent workers now agree that (1) the Milligen is in major thrust fault contact with the overlying Wood River Formation (Sandberg and others, 1975), and (2) the type Milligen Formation differs significantly in lithology, structural style, and age from rocks called Milligen elsewhere. Sandberg (1975) proposed that the name Milligen be restricted to the Wood River area and that rocks previously called Milligen in the Lost River Range be renamed McGowan Creek Formation, a formation of Early and Late Mississippian age.

UNNAMED SILURIAN AND DEVONIAN UNIT

Rocks provisionally grouped here as an unnamed Silurian and Devonian unit are tectonically imbricated with the Phi Kappa and Trail Creek Formations in a northwest-trending belt as much as 5 mi (8 km) wide and 12 mi (19 km) long in the northern part of the study area, and most were originally included with the Phi Kappa Formation by Umpleby, Westgate, and Ross (1930, pl. 1). These rocks form rugged, densely forested slopes, mainly along upper Trail Creek and in the upper reaches of the North Fork Big Lost River (pl. 2; fig. 4).

The Silurian-Devonian rocks are dominantly black, siliceous to carbonaceous, locally phyllitic argillite, and buff-weathering, limy to dolomitic siltstone with wispy laminations; all gradations between these two lithologies exist. The siliceous and carbonaceous rocks generally resemble those of the Milligen Formation, and where they are phyllitic, the similarity is striking; the siltstone tends to be bleached and silicified near silicic intrusive igneous rocks in the northwest part of the outcrop belt. Dark quartzite, gray bioclastic limestone, and locally abundant chert-quartzite granule-to-pebble conglomerate are subordinate rock types. A distinctive calcareous siltstone bed at least 200 ft (60 m) thick forms prominent buff- to orange-colored bands and dip slopes that contrast sharply with the generally darker adjacent rocks. This rock typically breaks into slabs with abundant worm trails; no other fossils have been found. The siltstone previously was assigned to the Phi Kappa Formation by Umpleby, Westgate, and Ross (1930, pl. 1) and to the Wood River Formation by Dover (1969, p. 31), but is now included by Dover, Berry, and Ross (1980) in the Silurian-Devonian sequence. Structural repetitions of the siltstone are found northeast of upper Trail Creek and on Phi Kappa Mountain, and tectonic thickening may account for the anomalously thick siltstone on the ridge southwest of upper Summit Creek.

Conodonts have been recovered from the Silurian-Devonian rocks at several outcrops along the south fork of the North Fork Big Lost River in the northern part of the outcrop belt. Two samples of silty limestone similar to that found in the Milligen Formation yield Late Silurian (Ludlow) conodonts (C. A. Sandberg, written commun., 1975), indicating an age older than any known in the outcrop belt of the Milligen Formation. At two other localities, thin bioclastic limestone interbeds yield conodonts identified by A. G. Harris (written commun., 1974) as of an Eifelian or Middle Devonian fauna identical to that found in the lower part of the Milligen. A very late Devonian (late Famennian) age, distinctly younger than that of the upper part of the Milligen, was reported by Sandberg and others (1975) for yet another sample.

The lithic, faunal, and structural details of the complexly deformed Silurian-Devonian succession is uncertain and under continuing study. Although at least some of these rocks are equivalent in lithology, conodont fauna, and age with the Milligen Formation, other parts of the sequence seem to have closer affinity in lithology and age to the Silurian Trail Creek Formation than to the Milligen. The unnamed Silurian-Devonian rocks are separated from the main Milligen outcrop belt by allochthonous Pennsylvanian and Permian rocks, but structural continuity in the subsurface is probable; stratigraphic relations with the Trail Creek Formation are obscured by structural complexities. Studies in progress are directed to questions of how much of the unnamed Silurian-Devonian unit represents the Milligen Formation, and whether its Silurian part represents a stratigraphic gradation between the Milligen and Trail Creek Formations.

EASTERN SEQUENCE

ORDOVICIAN TO DEVONIAN ROCKS, UNDIVIDED, OF THE WILDHORSE AND DRY CANYON WINDOWS

Rocks ranging from Ordovician to Devonian in age are exposed in structural windows along lower Wildhorse Creek and Dry Canyon, near the north-central edge of the study area (pl. 2; fig. 4). Rocks in the windows are tectonically overridden by Mississippian rocks. Although several mappable units are present in the windows, all are grouped on plate 2.

Graptolitic Upper Ordovician rocks, which crop out in the northwest corner of the Wildhorse window (Dover and Ross, 1975), consist of 210 ft (64 m) of dark-gray, massive to medium-bedded dolomite and cherty dolomite; the base is not exposed. They are correlated with part of the Ordovician and Silurian Hanson Creek Formation of central Nevada, and part of the Ordovician Saturday Mountain Formation elsewhere in central Idaho.

The conformably overlying strata in the Wildhorse window are light-gray, platy, silty limestone and dolomitic limestone containing monograptid graptolites; a bed of interlayered black dolomite and chert is at the base. These beds were assigned by Dover and Ross (1975) to the Silurian part of the Roberts Mountains Formation. Only 130 ft (40 m) of Roberts Mountains was measured by Dover and Ross (1975). Identical rocks are present at Malm Gulch, 40 mi (64 km) north of the Wildhorse window in the Bayhorse region, where they previously were assigned to the Trail Creek Formation by Ross (1937).

In the Wildhorse window, at least 800 ft (245 m) of tan- to orange-weathering, slabby to blocky, slightly calcareous to dolomitic siltstone structurally overlies the measured Roberts Mountains section but is separated from it by a wide covered interval. The two sequences are generally concordant and may be in depositional contact. The siltstone contains soft sediment structures suggesting scour by bottom currents and minor subaqueous slumping. At the southwest corner of the window, near the junction of Fall and Wildhorse Creeks, the siltstone is dense and silicified and contains brachiopod molds and crinoid columnals. Silurian corals were identified by W. A. Oliver, Jr. (written commun., 1974) in samples collected from the siltstone by R. A. Paull. The siltstone is overlain in turn by light-gray, massive, cliff-forming dolomite capped by carbonate-cobble conglomerate and breccia. Locally, the siltstone-dolomite contact is marked by a channel containing weakly sheared conglomerate composed of dark-gray, well-rounded limestone boulders, but at most places the contact is sharp, concordant, and undisturbed. The dolomite resembles the Middle and Upper Silurian Laketown Dolomite of east-central Idaho, but C. A. Sandberg (written commun., 1975) has identified Devonian conodonts from the dolomite in the Wildhorse window. Dominantly carbonate rocks assigned to the Late Silurian and Early Devonian part of the Roberts Mountains Formation in the Fish Creek Reservoir window (Skipp and Sandberg, 1975; Skipp and Hall, 1975b) may have temporal equivalents in the siltstone-dolomite succession described here, but the two sequences differ lithologically, mainly in their silt content. However, the carbonate-cobble conglomerate and breccia of the Wildhorse window resemble rocks described as phenoplast conglomerate of limestone breccia in the upper unit (earliest Devonian) of the Roberts Mountains Formation at Fish Creek Reservoir.

In the Dry Canyon window, the rocks are mainly steeply dipping, east-facing, gray, medium- to massive-bedded limestone overlain by a thin, locally recrystallized bed of quartzose sandstone. Light-gray massive dolomite crops out below the limestone in the northwest corner of the window, but its contact with the limestone is poorly exposed. Corals, stromatoporoids, and conodonts identified by W. A. Oliver, Jr., J. W. Huddle, and C. A. Sandberg (written communs., 1973–1975) all indicate a Late Devonian age for the limestone. The dolomite-limestone-sandstone succession in the Dry Canyon window may be equivalent to the succession in the Fish Creek Reservoir window, which consists of the Devonian Carey, Jefferson, and Picabo Formations of Skipp and Sandberg (1975). Sandberg and others (1975) suggested that the Picabo Formation overlies the Frasnian part of the Jefferson Formation at Dry Canyon.

Stratigraphic and structural relations between the rock sequences of the Wildhorse and Dry Canyon windows are uncertain, but their apparently homoclinal structure, relative ages, and absence of internal deformation all suggest that no significant tectonic break separates the two sections. If not, the rocks of the two windows aggregate more than 900 m in thickness. They represent an eastern carbonate shelf facies that contrasts sharply in lithology and thickness with time-equivalent, deeper water rocks of the siliceous and argillaceous facies represented by the Phi Kappa, Trail Creek, and Milligen Formations and unnamed Silurian-Devonian unit of the allochthonous western sequence.

CAREY DOLOMITE

Carbonate rocks assigned to the Lower and Middle Devonian Carey Dolomite (Skipp and Sandberg, 1975) are present in small, isolated exposures along a major thrust fault in Garfield Canyon and along Mutual Gulch, both in the southeast part of the study area (pl. 2). At these localities, the Carey consists of blue-gray, micritic, thinly laminated, limy dolomite. Laminae consist of dark-gray, sulfide-bearing siliceous layers alternating with brownish limy layers. The rock is strongly deformed, is silicified and locally contains metamorphic tremolite, and is very tough and resistant. Beds of crinoidal hash at the Garfield Canyon locality yield conodonts assigned to the Middle Devonian (C. A. Sandberg, written commun., 1975). The lithology of the Carey Dolomite contrasts sharply with that of the time-equivalent lower part of the Milligen Formation.

LIMESTONE OF BUCK CANYON

Blue-gray, massive-bedded, shattered and vein-injected limestone crops out under the Tertiary Challis Volcanics in a narrow band just south of Buck Canyon, about 2 mi (3 km) south of the southeast corner of the study area (pl. 2). The limestone is folded and steeply dipping in places, is separated by a flat tectonic contact from the intensely deformed underlying clastic rocks, and appears to form a klippe. No fossils have been found in the limestone and its age is unknown. However, its structural position is similar to that of the Carey Dolomite.

MISSISSIPPIAN ROCKS

COPPER BASIN FORMATION

Ross (1960, 1962c) designated Carboniferous clastic and calcareous rocks near Copper Basin in the eastern part of the present study area as the Copper Basin Formation. He considered it to be a complexly intertonguing facies through which the argillaceous and arenaceous upper Paleozoic rocks of the Wood River region grade into dominantly calcareous rocks of similar age east of Copper Basin. The Copper Basin Formation of Ross was subdivided into six formations and raised to group status by Paull and others (1972), who also suggested that their Copper Basin Group might be separated by faults from the rocks of both the Wood River region and areas east of Copper Basin. The name Copper Basin is currently accepted as a unit of formation rank and of Mississippian age by the U.S. Geological Survey.

Rocks presently assigned to the Copper Basin Formation crop out extensively in the northeast half of the study area (pl. 2, includes CB and GM units of fig. 4), and include coarsely clastic and calcareous upper Paleozoic rocks of the northeastern Pioneer Mountains of Dover (1969, p. 32–35), which previously were included with the Pennsylvanian part of the Wood River Formation by Umpleby, Westgate, and Ross (1930, pl. 1). Two sequences of the Copper Basin are present, which comprise the Copper Basin and Glide Mountain thrust plates.

COPPER BASIN PLATE OF THE COPPER BASIN FORMATION

The principal exposures of the Copper Basin plate of the Copper Basin Formation occupy about 50 mi^2 (130 km^2) along Star Hope, Iron Bog, and Muldoon Creeks and along Muldoon Canyon in the area south of Copper Basin; other exposures, including some in structural windows through the tectonically overlying Glide Mountain plate, are in the north-central part of the study area. This plate contains the type sections of all the formations of the Copper Basin Group as defined by Paull and others (1972), but the upper four of their formations seem to be mappable only in the immediate vicinity of the respective type sections, because of facies changes. Consequently, we map only three units within the study area: a basal clastic unit equivalent to the Little Copper Formation of Paull and Gruber (1977), a middle limestone unit equivalent to the Upper Mississippian Drummond Mine Limestone of Paull and others (1972), and an upper clastic unit that corresponds to the Scorpion Mountain Formation of Paull and others (1972) and the lower part of the Muldoon Canyon Formation of Paull and others (1972). In this report, the names Little Copper and Drummond Mine are adopted with member rank for the lower two units of the Copper Basin plate of the Copper Basin Formation.

The basal unit or Little Copper Member consists of brown- to olive-green, medium- to thick-bedded, blocky argillite, and subordinate interbedded dark-gray quartzite and minor granule conglomerate. Locally the argillite is laminated and has graded bedding. Quartzite is poorly sorted, has an argillaceous matrix, and typically contains well-rounded, coarse quartz grains or granules of black argillite floating in an argillaceous matrix. Chert and siliceous argillite are the most common clasts in conglomerate interbeds. About 3,200 ft (975 m) of the Little Copper Member was measured by Paull and his associates on the ridge north of Little Copper Creek, in the southeast part of the study area (Paull and others, 1972). Near the junction of Wildhorse and Fall Creeks, the strongly deformed member is in thrust contact on pre-Mississippian rocks of the Wildhorse window; elsewhere the contact with underlying rocks is not exposed. No fossils have been found in the Little Copper Member, but an Early Mississippian (early? Kinderhookian) age is probable, because the unit grades into the overlying limestone of late Kinderhookian age.

The overlying Drummond Mine Limestone Member is composed mainly of gray, yellow-brown-weathering, slabby to platy, silty micritic limestone, but varies from silty limestone to calcareous siltstone. Locally the limestone is silicified and (or) recrystallized. Dark and light color banding is prominent where dark argillaceous laminations or thin interbeds are present. The middle and upper parts of the limestone contain more argillaceous beds than the lower part. Both contacts are gradational through 100 ft (30 m) or more. The thickness of about 2,650 ft (810 m) reported for the Drummond Mine by Paull and his colleagues at their type section is maintained at least as far south as the study area boundary; however, the amount of limestone in the unit diminishes southward and the clastic content of the middle part of the formation increases southward at the expense of limestone, to the extent that two different limestone units separated by a clastic interval can be mapped. Conodonts and foraminifers from bioclastic interbeds at numerous localities indicate the Drummond Mine to be early to late Kinderhookian (Early Mississippian) in age according to J. W. Huddle and C. A. Sandberg (written commun., 1975), and distinctly older than the Late Mississippian age reported by Paull and others (1972). Mackenzie Gordon, Jr. (written commun., 1975) reported Early Mississippian ammonoids from the limestone at the head of Little Copper Creek about 1 mi (1.6 km) south of Drummond Mine (Skipp and Hall, 1975b, p. 681). The middle limestone unit is a key marker bed within the Copper Basin Formation that has provided much of the critical fossil data from the formation; it also is the host rock of most of the mineralization in the northeast and southeast parts of the study area.

Following the usage of Nilsen (1977), the upper clastic unit includes the Scorpion Mountain Formation of Paull and others (1972) and the lower part of the Muldoon Canyon Formation of Paull and others (1972). The upper clastic unit consists predominantly of argillite, gritty sandstone, and granule conglomerate (Paull and others, 1972; Nilsen, 1977). Graded bedding is common throughout the unit but is best developed in the northern part of the outcrop belt, where groove casts, rip-up conglomerate, cut-and-fill structures, and convolutions indicate an environment of current scour, turbidity deposition, and sediment slump. A total thickness of about 4,820 ft (1,470 m) is estimated for the upper clastic unit from the thicknesses given by Nilsen. Dating of the upper clastic unit is tenuous because fossils are scarce and poorly preserved, and because of structural complications not recognized in the original descriptions of the units. A Late Mississippian age is most likely based on stratigraphic relations with the underlying Drummond Mine Limestone Member and based on correlation as indicated by stratigraphic position with more closely dated units nearby.

GLIDE MOUNTAIN PLATE OF THE COPPER BASIN FORMATION

Rocks of the Glide Mountain plate are well exposed at Glide Mountain on the southwest side of Copper Basin, and in the north-central part of the study area. They are dominantly clastic but include minor limestone and closely resemble the lithologic components of the Copper Basin plate, except that the clastic and carbonate components occur in drastically different proportions in the two thrust plates. Clastic rocks now included in the Glide Mountain plate were formerly assigned to the upper part of the Muldoon Canyon Formation of Paull and others (1972), the Brockie Lake Conglomerate of Paull and others (1972), and the Iron Bog Creek Formation of Paull and others (1972). Dark-colored blocky argillite, quartzite, gritty quartzite, and granule conglomerate predominate and typically occur in beds 3–6 ft (1–2 m) thick and interbedded with one another. However, the clastic rocks of the Glide Mountain plate are more coarse grained on the average than those of the Copper Basin plate. The Glide Mountain plate also contains cobble and boulder conglomerate with argillite, chert, and quartzite clasts as much as 1 m across. The limestone present in the Glide Mountain plate is much less abundant than in the Copper Basin plate. In Big Rocky Canyon at the north-central edge of the map area, a zone about 250 ft (75 m) thick contains thinly interbedded argillite, silty limestone and bioclastic limestone containing precisely the same upper Kinderhookian conodont assemblage as the much thicker Drummond Mine Limestone Member in the Copper Basin plate (A. G. Harris, written commun., 1979). In lithologic associations, thickness, conodont assemblage, and age, the limestone at Big Rocky Canyon resembles the Green Lake Limestone Member of Paull and others (1972), herein adopted and designated the Green Lake Limestone Member of the Copper Basin Formation.

Nilsen (1977) included the Green Lake Limestone Member in his Brockie subplate of the Copper Basin plate, but the discovery of the equivalent limestone at Big Rocky Canyon, along with other lithologic similarities and the continuity of map distribution, strongly indicates that his Brockie subplate and the Glide Mountain plate are stratigraphically and structurally equivalent (Dover, 1980). This interpretation is incorporated on the geologic map (pl. 2). The limestone at Big Rocky Canyon and the Green Lake Limestone Member are critical to dating the Glide Mountain plate of the Copper Basin Formation and to establishing the Glide Mountain plate as a Mississippian lithofacies equivalent to the sequence in the Copper Basin plate. Macerated plant remains are also abundant in argillaceous rocks of the Glide Mountain plate, but so far none have been identifiable (R. H. Tschudy, written commun., 1975). A meager collection of brachiopod, crinoid, and mollusk fragments found in dark argillite of the Glide Mountain plate on the east side of Big Black Dome west of Copper Basin are questionably referred to the Mississippian by J. T. Dutro, Jr. (written commun., 1974), and an unidentifiable brachiopod mold was found at another locality. Although the Copper Basin and Glide Mountain thrust sequences have gross lithologic differences and different styles of deformation, they can be separated with confidence in most places only by mapping the intervening thrust surface. The rocks of the Glide Mountain plate represent a more western, carbonate-poor and plant-rich, shallow marine to partly terriginous depofacies of the Copper Basin Formation than do those of the Copper Basin plate.

WHITE KNOB LIMESTONE

Two small outcrops in the northeast corner of the study area are assigned to the White Knob Limestone (pl. 2; fig. 4). Light- to medium-gray, massive micritic, cherty limestone that characteristically is scalloped or pitted on weathered surfaces is exposed at the base of the ridge between Anderson and Smelter Canyons. The chert is light tan and nodular; argillaceous partings are present locally. Conodonts, echinoderms, algae, and mollusks all indicate a Late Mississippian age according to J. W. Huddle, Betty Skipp, and E. L. Yochelson (written communs., 1974, 1975). Poorly preserved corals and brachiopods are indeterminate (J. T. Dutro, Jr., and W. J. Sando, written commun., 1974). Broadly folded White Knob Limestone crops out extensively just to the northeast, across Copper Basin Flat and the Swamps (Nelson and Ross, 1969), and locally contains interbeds of chert-quartzite pebble conglomerate.

White Knob Limestone also may be present on the north side of upper Lake Creek (Copper Basin) adjacent to the Lake Creek stock. Here the rock is strongly deformed and extensively recrystallized "echinoderm wackestone with largely pelletized mud matrix," from which Betty Skipp (written commun., 1975) identified paleotextularid of Late Mississippian to Pennsylvanian age. This rock is tentatively assigned to the White Knob because it is more massive and purer than the silty limestones in the upper unit of the Copper Basin Formation, and because the White Knob is the only unit of comparable lithology and age exposed in the vicinity.

PENNSYLVANIAN AND PERMIAN ROCKS

WOOD RIVER FORMATION

The Wood River Formation as originally defined by Lindgren (1900) included all argillaceous, sandy, and calcareous rocks of probable late Carboniferous age (including Permian of present usage) in the Big Wood River region. Umpleby, Westgate, and Ross (1930, p. 29–34) restricted the name Wood River to the sandy and calcareous upper part of the succession and assigned the lower, argillaceous part to the Milligen Formation. Coarse clastic and calcareous rocks in the north-central part of the study area originally correlated with the Wood River Formation by Umpleby and his coworkers and included in their measured sections are now assigned to the Mississippian Copper Basin Formation.

The Wood River Formation as now restricted by Hall, Batchelder, and Douglass (1974) occupies more than 100 mi^2 (250 km^2) in three broad, northwest-trending synclinal belts, all regarded as parts of a single large folded and imbricated thrust sheet that originally covered the entire southwest half of the study area (pl. 2; fig. 4). Small klippen of Wood River capping ridges at several places outside the main outcrop belts are remnants of the thrust sheet isolated by erosion. The formation forms steep-sided ridges and cliffs of moderate to high relief, and weathers to a limy soil that supports a heavier forest growth than does soil developed on the structurally underlying Milligen Formation. Slopes cut in the Wood River Formation commonly are mantled by slide-rock and surface rubble, or are covered with dense vegetation; the best exposures in the study area are along the Trail Creek road and in the east-facing cirques of the Boulder Mountains in the northwest part of the outcrop area, and on the flanks of Grays Peak in the southeast part of the outcrop area.

Sections of the Wood River Formation were measured by Umpleby (1971), Hewett (Umpleby and others, 1930), Bostwick (1955), and Thomasson (1959) on ridges east of Bellevue, about 10 mi (16 km) southwest of the study area. In a section 4.3 mi (6.9 km) east of Bellevue, on the north side of the Bellevue-Muldoon road, Hall, Batchelder, and Douglass (1974) subdivided the Wood River Formation into six units. With the addition of a seventh unit measured at a nearby locality, their composite Wood River section totals about 9,800 ft (3,000 m) in thickness. These units can be recognized throughout much of the study area and have been a guide to mapping the formation, understanding its internal structure, and demonstrating a tectonic contact with the underlying Milligen Formation. Another stratigraphically higher unit recognized at a third locality was not formally included with the Wood River Formation by Hall and his coworkers, but they informally designated equivalent strata in the study area as unit 8 of the Wood River.

Only two subdivisions of the Wood River Formation are shown on plate 2. The lower subdivision comprises the Hailey Conglomerate Member of Thomasson (1959) and units 2–3 of Hall, Batchelder, and Douglass (1974). The upper subdivision encompasses units 4–7 of Hall, Batchelder, and Douglass (1974) as well as the stratigraphically overlying unnamed rocks reported by Hall, Batchelder, and Douglass. A combined thickness in excess of 12,000 ft (3,660 m) is estimated for the Wood River Formation, of which our lower map unit contributes only about 1,100 ft (340 m) or less. The thickness estimated is a minimum because the top of the formation is not exposed.

The Hailey Conglomerate Member of the Wood River Formation is a distinctive cliff-forming unit of dark, chert-pebble conglomerate and poorly sorted quartzite. Unit 2 consists of medium- to thick-bedded, blue-gray, fine-grained limestone containing abundant crinoid columnals and fragments of bryozoans and brachiopods. Unit 3 is dominantly gray, pink- to lavender-weathering, thin-bedded, platy limestone and shaly limestone. Units 4 and 6 both are composed predominantly of gray, buff- to brown-weathering, thick-bedded, fine- to medium-grained calcareous sandstone and calcarenite, with subordinate interbeds of dark argillite, gray limestone, and (particularly in unit 6) thick beds of fine-grained olive-brown quartzite. These two units make up the bulk of the Wood River Formation, the thickness of unit 6 alone totaling about 5,700 ft (1,740 m). Units 4 and 6 are lithologically indistinguishable in most places but can be separated locally by their positions within the overall stratigraphic sequence and by the abundance and type of fusulinids they contain. Unit 4 contains sparse fusulinids that are restricted to the Late Pennsylvanian, whereas unit 6 contains more abundant fusulinids that range in age from Late Pennsylvanian to Early Permian. However, these criteria are unreliable where the sequence is complicated by thrusting or where fusulinids are absent. Unit 5 consists of brown or olive-brown, thick- to massive-bedded, typically shattered, fine-grained quartzite or slightly calcareous quartz-sandstone. The quartzite resembles similar but thinner quartzite beds in unit 6, especially in the northwest part of the area. Where described by Hall, Batchelder, and Douglass (1974), just southwest of the study area, unit 7 is characterized by banded rock composed of thin to medium beds of light-gray limestone or sandy limestone alternating with beds of dark cherty argillite. In the study area, however, the most characteristic lithology of unit 7 is laminated dark argillite that locally shows prominent grading, scour features, and small-scale crossbedding; quartzite as well as calcareous sandstone similar to that in units 4 and 6 is also present. Rocks stratigraphically overlying unit 7 are heterogeneous and poorly dated; they include brown-, tan-, or orange-weathering siltite, dolomitic siltstone, fine-grained sandstone or quartzite, calcareous sandstone, and dark argillite. Some of these rocks are similar to those of unit 7, whereas others resemble rocks that are provisionally assigned to the unnamed unit of Silurian and Devonian rocks.

The Hailey Conglomerate Member and units 2 and 3 are considered Middle Pennsylvanian (Des Moinesian) in age based on abundant fossil data obtained in this study (fusulinids identified by R. C. Douglass and nonfusuline calcareous foraminifers and algae identified by Betty Skipp), and reported in Hall, Batchelder, and Douglass (1974). Units 4–6 contain Late Pennsylvanian (Virgilian) through Early Permian (Wolfcampian) fusulinids (R. C. Douglass, written commun., 1975). Unit 7 also was assigned a Wolfcampian (and Leonardian?) age at the locality described by Hall, Batchelder, and Douglass (1974). Along the West Fork Trail Creek in the northwest part of the study area, rocks assigned to unit 7 (but that possibly are stratigraphically higher) yield a limited fauna of scaphopods and gastropods with fragments of pelecypods, bryozoans, and corals that are tentatively assigned to the late Early Permian (Leonardian-Word) by E. L. Yochelson (written commun., 1974). Chert-, phosphorite-, and evaporite-bearing carbonate rocks of equivalent late Early Permian age (part of the Phosphoria Formation) are distributed over wide areas in southeastern Idaho, northern Utah, and western Wyoming.

The nature of the lower contact of the Wood River Formation has been a topic of speculation. Umpleby, Westgate, and Ross (1930, p. 27, 75) stated that in at least one place the Wood River grades downward into the underlying Milligen Formation, but Dover (1969, p. 30) questioned their field evidence. Thomasson (1959, p. 12) interpreted the contact as an unconformity. Dover (1969, p. 32) indicated that a low-angle thrust fault forms the contact at most places, but was uncertain whether the contact is a zone of major displacement or an unconformity along which minor movement occurred as the Milligen and Wood River Formations moved together as an allochthonous block. Evidence now available suggests that the contact between the Wood River and Milligen Formations is a faulted unconformity and that movement along it has been substantial. The development, wide distribution, and composition of conglomerate at the base of the Wood River, combined with the hiatus present below it, suggest that the conglomerate was derived in part from, and was deposited on, the underlying Milligen Formation (Sandberg and others, 1975; Skipp and Hall, 1975a). The two formations were subsequently detached from one another and moved semi-independently as both were thrust eastward into the region of the present Boulder and Pioneer ranges.

MESOZOIC AND CENOZOIC ROCKS

UPPER CRETACEOUS(?) AND LOWER TERTIARY(?) ROCKS

CLASTIC ROCKS

Clastic rocks underlie the Challis Volcanics at many places in the study area, and rest unconformably on pre-Mesozoic rocks. These clastic rocks are equivalent at least in part to conglomerate mapped beneath the Challis Volcanics by Nelson and Ross (1969). The best exposures are near the confluence of Deer Creek and the East Fork Big Lost River, along Smiley Creek, on spur ridges northeast of Copper Basin, and on the divide between the drainages of Trail Creek and North Fork Big Lost River (pl. 2). At Deer Creek, Smiley Creek, and many other localities, the clastic rocks occupy paleovalleys that existed prior to volcanism and are being exhumed by modern erosion. At other places, such as on the divide between Wilson and Summit Creeks, gravels that cap present-day ridges record topographic inversion by postdepositional uplift and erosion. (See also Axelrod, 1968.)

The clastic rocks are mostly pebble- to boulder-conglomerate composed of well-rounded clasts and representing stream gravels, and conglomerate or breccia made up of angular fragments and representing talus or other colluvial deposits; some finer grained detrital materials occur locally. Quartzite clasts set in a poorly sorted, moderately well cemented quartz-sand matrix are most abundant; some quartzite clasts are similar lithologically to quartzites of the Hyndman, East Fork, and Wood River Formations, and some may be from conglomerates of the Copper Basin Formation. Other locally derived materials are present in places. The clastic rocks described here are distinguished from volcanic conglomerate, laharic deposits, and other volcaniclastic rocks of the Challis Volcanics that formed during or after volcanism by the absence of volcanic clasts; clasts of plutonic igneous rocks are rare to absent.

Several hundred feet (100 m) or more of clastic rocks are present along the East Fork Big Lost River near the north-central edge of the map area, and along Steve Creek northeast of Copper Basin (pl. 2). A post-Albian, Late Cretaceous to Paleocene age is suggested by limited botanical evidence according to Pruitt (1971; Paull, 1974) and is compatible with the Eocene age of the overlying Challis Volcanics.

INTRUSIVE COMPLEX OF THE PIONEER WINDOW

Granitic intrusive rocks occupy nearly 50 mi^2 (130 km^2) in the central Pioneer Mountains. These rocks, which separate the gneiss complex of Wildhorse Creek from metasedimentary rocks of the Hyndman and East Fork Formations, occupy nearly 50 percent of a structural window (here named the Pioneer window) through surrounding allochthons of Paleozoic rocks. The intrusives crop out in a narrow belt that extends 8 mi (13 km) southeastward along the range crest from the head of Kane Creek to the head of the canyon of East Fork Wood River; from there the outcrops broaden to encompass the entire eastern one-third of the Pioneer window (pl. 2; fig. 4).

The intrusive complex of the Pioneer window is equivalent to the Pioneer Mountains pluton of Dover (1969, p. 37–44), who reported it to range in composition from clinopyroxene-hornblende-biotite quartz diorite and mafic granodiorite to leucocratic hornblende-biotite quartz monzonite. The rocks are coarse grained and hypidiomorphic, and range from even grained and moderately strongly gneissose for the quartz diorite and mafic granodiorite phase to nearly directionless and coarsely porphyritic for the quartz monzonitic phase. The mafic and foliated rocks (pl. 2) are restricted mainly to the narrow outcrop belt in the western part of the intrusive complex. Small directionless pyroxenite bodies enclosed within the granodioritic rocks probably are younger intrusives, but may be inclusions of older rock. The more felsic nonfoliated and porphyritic rocks (pl. 2) make up the broad eastern part of the complex, but they also occur locally intermixed with the mafic foliated phase. In upper Broad Canyon, Surprise Valley, and Fall Creek, the quartz monzonite contains irregular masses of medium-gray, fine-grained granodiorite as broad as 0.5 mi (0.8 m); the granodiorite inclusions have gradational contacts. All the various petrologic types also show weak to moderately strong cataclastic texture.

Petrologic evidence strongly suggests that the foliated mafic and directionless felsic phases of the complex represent two distinctly different intrusives. The contact inferred to separate the two intrusive phases has not been mapped but is shown diagrammatically on cross section B–B′ (pl. 2). In the narrow western part of the intrusive complex, foliation in the mafic phase of the intrusive complex is generally concordant with metamorphic wall rock foliation, and lenses of the intrusive rocks are concordantly interlayered in the metamorphic wall rocks along the intrusive contact. The gneissose structure is attributed to synmetamorphic intrusion under regional directed stress, because (1) at locally crosscutting contacts, the gneissose structure of the mafic intrusive phase is parallel to schistosity in wall rocks rather than to intrusive contacts; (2) paragenetic relations indicate that alined biotite (biotite II), which forms the foliation of the mafic intrusive phase, recrystallized after the development of annealed cataclastic zones, indicating recrystallization under metamorphic conditions in a rock already largely consolidated; and (3) the distribution of main assemblage synkinematic minerals in metamorphic wall rocks indicates a high-temperature gradient increasing toward the zone of mafic intrusive rock during regional metamorphism. No superimposed local, static contact metamorphic effects have been detected around the mafic foliated phase of the intrusive complex, even in the most reactive metamorphic units, indicating emplacement while the wall rocks were still hot. In contrast, the more felsic and nearly directionless eastern part of the intrusive complex is post-orogenic. It commonly has irregular and sharply crosscutting contacts, shows only weak cataclastic effects, and has weak flow structure imparted by locally alined tabular potassium-feldspar porphyroblasts as long as 1 in. (2.5 cm). W. E. Hall and J. N. Batchelder (written commun., 1975) reported that within 2,000 ft (610 m) of the quartz monzonite contact at the east edge of the complex, the Milligen and Wood River Formations show only weak contact-metamorphic effects, such as recrystallization of sericite to muscovite, incipient crystallization of tremolite, and introduction of a distinctive suite of trace elements.

Three samples of the quartz monzonite phase of the intrusive complex of the Pioneer window, all from the eastern part of the complex, give K-Ar ages on biotite averaging about 46 m.y. (Armstrong, 1975; R. E. Zartman, written commun., 1976). Biotite and hornblende mineral separates yielded K-Ar ages of 40.2±1.0 and 52.6±1.3 m.y., respectively, in one of the samples (R. E. Zartman, written commun., 1976). Preliminary unpublished U-Pb data on a fourth sample of the same rock indicated that overgrowths of zircon crystallized in Eocene time on zircon nuclei of Precambrian age (R. E. Zartman, written commun., 1976), suggesting contamination from the Precambrian basement through which the quartz monzonite was intruded or from which it was derived by partial melting. Only one sample of the mafic phase of the intrusive complex has been dated so far. Hornblende from strongly foliated granodiorite collected from a cirque at the head of Wildhorse Creek near the divide with the North Fork Hyndman Creek yields a K-Ar age of 65.9±1.6 m.y. (R. E. Zartman, written commun., 1976).

EOCENE ROCKS

POST-OROGENIC INTRUSIVE ROCKS

Three post-orogenic plutons of moderate size occur along a N. 60°W.-trending line passing through the eastern, post-orogenic part of the intrusive complex of the Pioneer window (pl. 2; fig. 4). In this report, these are informally named the Summit Creek and Lake Creek stocks, and the dike complex of North Fork Lake. All three plutons are composed of directionless porphyritic rocks that crystallized in a hypabyssal environment and have sharp, crosscutting contacts. Their emplacement, and that of the post-orogenic quartz monzonitic phase of the intrusive complex of the Pioneer window, domed the surrounding country rocks and probably was accompanied by uplift throughout the range. The stocks all postdate metamorphism and regional thrust faulting. They are alined on the axis of an elongate gravity low that extends northwest along the crest of the northern Pioneer Mountains into the Boulder Mountains, where similar plutons have been mapped (Tschanz and others, 1974), and all may connect at shallow depth with a large northwest-trending batholith or zone of batholiths (D. R. Mabey, written commun., 1975). Numerous smaller granitic bodies lie on the flanks of the regional gravity low and may be offshoots of the same batholithic source.

SUMMIT CREEK STOCK

The Summit Creek stock occupies about 3 mi^2 (8 km^2) along Summit Creek in the west-central part of the study area, and is well exposed along the Sun Valley–Mackay road (pl. 2; fig. 4). A smaller satellite of the same stock is in Little Fall Creek valley, about 1 mi (1.6 km) northwest of the main body.

The Summit Creek stock consists of medium-grained, hypidiomorphic, porphyritic hornblende-biotite quartz monzonite. The stock intrudes both the Copper Basin and Glide Mountain plates of the Copper Basin Formation and domes the thrust fault surface between them. Argillaceous wall rocks within 1,500 ft (460 m) of the intrusive contact are silicified and locally converted to hornfels, and along Phi

Kappa Creek they contain radially twinned cordierite porphyroblasts. A small offshoot of the stock cuts the Glide Mountain plate on the north side of Summit Creek opposite the confluence of Phi Kappa Creek.

A K-Ar age of 45.3±1.4 m.y. (Eocene) was obtained by Armstrong (1975, p. 26, no. YU-864) on biotite from the Summit Creek stock, and a Rb-Sr mineral isochron age of 49.7±1.0 m.y. and a K-Ar age of 47.3±2.0 m.y. on hornblende were determined by R. E. Zartman (written commun., 1975) on another sample from the same pluton.

LAKE CREEK STOCK

The valley of upper Lake Creek, in the southeastern part of the study area, is underlain by a quartz monzonite stock that has an outcrop area of about 10 mi^2 (26 km^2) (pl. 2; fig. 4). The stock is composed mainly of porphyritic pyroxene-hornblende-biotite quartz monzonite. Phenocrysts of plagioclase, pyroxene, and biotite are set in a fine-grained matrix of quartz, potassium-feldspar, and the other constituents. The matrix is much altered, and fresh samples of the stock are difficult to obtain; hornblende is extensively biotitized and biotite commonly is chloritized.

The stock intrudes the Copper Basin plate of the Copper Basin Formation. At places along the contact, the wall rocks are bleached, silicified, and converted to hornfels. An intensely deformed band of White Knob(?) Limestone on the north side of the stock contains tremolite. The Lake Creek stock is overlain by Challis Volcanics and lower Tertiary(?) to Upper Cretaceous(?) clastic rocks. Both of these units are locally bleached and silicified near the stock, and silicic dikes and veins that appear to extend from the east end of the stock penetrate the Challis on Smiley Mountain. Thus the Lake Creek stock is considered to be younger than the Challis, though perhaps only slightly so.

A Pb–α age of 50±10 m.y. on zircon from the Lake Creek stock was reported by Stern, Rose, and Worthing (Armstrong, 1975, p. 30–31); a K-Ar date of 47.7±1.4 m.y. for chloritized biotite was determined by Armstrong (1975, p. 27, no. YU-RAP 71–15).

DIKE COMPLEX OF NORTH FORK LAKE

An extensively altered zone of close-spaced, nearly coalescing dikes, here called the dike complex of North Fork Lake, floors the cirque containing North Fork Lake in the northwest corner of the study area (pl. 2; fig. 4). The dike network extends into the area southeast of the main injection zone; only the largest dikes are shown on plate 2. In the area of coalescing dikes, the dikes are extensively altered and their composition is poorly known, but most of the dikes extending to the southeast are of hornblende quartz porphyry. Some of the dikes that cut the Wood River

Formation in the cirques surrounding Kent Peak are 100 ft (30 m) or more across and can be traced for nearly 1 mi (1.6 km). At least one prominent dike cuts the Challis Volcanics on the divide between North Fork Big Lost River and Trail Creek. The North Fork stock and associated dikes are the most silicic of the intrusive rocks in the study area. Hornblende from one of the dikes has been dated radiometrically by the K-Ar method at 47.2 m.y. (R. E. Zartman, written commun., 1976).

OTHER STOCKS

Several quartz monzonite stocks 1 mi^2 (2.6 km^2) in extent or less occur in the study area (pl. 2; fig. 4). Small plutons on Muldoon Creek and Garfield Canyon, near the southeast edge of the study area, closely resemble the Lake Creek stock in composition, but have a medium-grained groundmass and are fresher. Biotite from the Muldoon Creek stock has been dated by the K-Ar method at 47.0 m.y. (R. E. Zartman, written commun., 1976). On the north side of the canyon of East Fork Wood River, a small, fine-grained and weakly foliated pluton intrudes Hyndman Formation. On the divide between the two forks of Hyndman Creek, unit E of the East Fork Formation is recrystallized to coarse, tremolite-bearing diopside-fels near a small exposure of quartz monzonite; the extent and distribution of the contact metamorphic aureole suggests that a larger pluton lies buried at shallow depth. On the south side of the North Fork Big Lost River, about 2 mi (3 km) downstream from the junction with Summit Creek, a small, altered stock intrudes and silicifies rocks of the Copper Basin Formation.

DIKES

Dikes and other small hypabyssal intrusive bodies are scattered throughout the study area. Some, such as the quartz porphyry dikes, are associated with one or another of the larger plutons already mentioned, whereas others have no exposed source. The dikes tend to occupy well-developed fracture sets, particularly those trending northeast and east. Only the largest of the dikes are shown on plate 2.

Sills and dikes of black diabase cut the eastern, quartz monzonitic phase of the intrusive complex of the Pioneer window and are best displayed in the cirques of Broad and Bellas Canyons and on Pyramid Peak (fig. 5); these sills and dikes are not shown on plate 2.

Porphyritic dikes of intermediate composition are most common on the crest of the Pioneer Mountains northwest of Kane Creek (pl. 2). They are similar in composition and texture to the Challis Volcanics and may represent small volcanic feeders. One dike cuts the Summit Creek stock in the cirque west of Phi Kappa Creek.

FIGURE 5.—Gently dipping mafic sills and dikes intruding quartz monzonite of the intrusive complex of the Pioneer window, on ridge between Broad and Bellas Canyons. View looking northeast from point on ridge 0.8 mi (1.3 km) southeast of Betty Lake. Canyon wall is about 1,500 ft (460 m) high.

Swarms of fine-grained silicic dikes and quartz porphyry dikes cut both structural plates of the Copper Basin Formation on the ridges between Star Hope Creek and Little Wood River, and are associated with locally intense alteration. Their occurrence resembles that of similar dikes associated with the North Fork stock, and they also may indicate a quartz monzonitic pluton in the shallow subsurface.

CHALLIS VOLCANICS

Volcanic rocks cover about 25 percent of the study area, mainly at moderate altitudes near its outer margins but also in isolated patches at high altitudes in the interior (pl. 2; fig. 4). They are most widely exposed in the east half of the study area, but extensive volcanic terranes bound the area on all sides. The present distribution of volcanics indicates that the volcanic field formerly covered most if not all of the study area. The volcanic rocks form prominent cliffs and rugged ridge crests in some places, and moderate, talus-covered slopes in others. They are correlated with the Challis Volcanics of the Casto region of Idaho (Ross, 1934) on the basis of similarity of lithology and age, and near continuity of outcrop.

The Challis Volcanics of the study area have not been studied in detail. Several types of volcanic materials have been recognized and mapped locally in the study area but are not distinguished on plate 2.

The bulk of the volcanics consists of dark porphyritic flow rocks and tuffaceous rocks of intermediate composition. Gray, red-brown, purple, and green hornblende andesite and latite predominate; darker basaltic rocks are present in a few places. The only extensive area of rhyolitic rocks is on the White Mountains ridge in the east-central part of the study area (pl. 2), where white to pink, flow-banded rhyolite, rhyolite breccia, and associated tuffaceous rocks probably were extruded near a vent. Altered, green to purple crystal tuff breccias (some with blocks more than 1 ft (30 cm) across), agglomerates, lahars, and dark flow rocks occur at the base of the volcanic pile at several localities and probably represent near-source deposits. They are best exposed on Kane Creek, Johnstone Creek, and upper Little Wood River, and in Bellas and Broad Canyons. Their distribution around the central part of the study area suggests that the intrusive complex of the Pioneer window may have been an important volcanic center. The Lake Creek quartz monzonite stock appears to intrude and locally alter and silicify both Challis Volcanics and lower Tertiary(?) to Upper Cretaceous(?) clastic rocks.

Armstrong (1975, p. 25) reported a K-Ar age of 42.0±1.3 m.y. on slightly altered volcanics from Smiley Creek, near the east edge of the study area (sample YU-RAP 71–18), and less reliable dates of 38.3±1.1 m.y. and 35.8±1.1 m.y. (samples YU-RAP 71–17 and YU-RAP 71–16) on altered volcanics from the same area. K-Ar dating by Armstrong indicates that the Challis ranges in age from 49.2±1.8 to 43.8±1.0 m.y. (Eocene) in the Boulder Mountains–White Cloud Peaks area to the northwest (Tschanz and others, 1974). That the Challis Volcanics and Eocene plutons of the study area are essentially coeval is strongly indicated by their nonsystematic crosscutting relations, petrologic similarities, and association in space and time.

QUATERNARY DEPOSITS

Poorly consolidated surficial deposits are found throughout the study area, mainly in valleys and other topographic depressions of the modern landscape. None of these materials has been dated directly; their origins and ages are inferred from their form, lithologic character, degree of consolidation, and distribution relative to present topography. Two broad classes of deposits are recognized, those that resulted from Pleistocene glacial and glaciofluvial processes, and those that formed by Holocene fluvial and colluvial processes.

PLEISTOCENE DEPOSITS

The glacial history of the Boulder-Pioneer region in general, and of the Copper Basin area in particular, has not been studied in detail. Cursory examination shows the study area to contain prominent moraines that mark major ice advances and record intermittent ice recession, lacustrine beds deposited in a lake that formed behind an ice dam, outwash gravels deposited by meltwater streams, and rock glaciers.

NONSTRATIFIED DRIFT

Nonstratified, boulder-rich, poorly sorted ice-contact debris is found in several major glacial valleys but is most spectacularly displayed in Copper Basin. It occurs in linear or arcuate, hummocky ridges, deposited as terminal, recessional, or lateral moraines or as kames, and in irregular patches on cirque and valley floors.

The largest glacier in the study area occupied most of Copper Basin. The Copper Basin ice lobe was at least 3 mi (5 km) wide and 6 mi (10 km) long, and was fed by tributary glaciers from major valleys to the south and southeast. Its terminus near the confluence of Star Hope Creek and East Fork Big Lost River is marked by a broad, low, arcuate set of nested terminal moraines composed of nonstratified drift; the trend and form of the ridges are shown diagrammatically on plate 2. The moraines merge upvalley with lateral moraines or kame deposits that also form multiple ridges and are dotted with kettle holes; the most extensive deposits constitute the prominent Potholes ridge on the east side of the basin. Smaller moraines in major valleys tributary to Copper Basin may either be recessional deposits of the main Copper Basin ice lobes or deposits of distinctly younger and less extensive valley glaciers. Prominent coalescing moraines also were deposited by relatively small glaciers in north-facing cirques just east of Copper Basin, and in valleys entering the basin from the west (pl. 2).

Terminal and lateral moraines much less extensive than those in Copper Basin also occur at the mouth of Wildhorse Creek, and isolated patches of drift perched 1,200–1,400 ft (370–430 m) above the floors of upper Wildhorse and Fall Creeks (pl. 2) define the limits of ice in those drainages. Several crude arcs of nonstratified drift that cross Summit Creek valley about 2 mi (3 km) above the mouth of Kane Creek (pl. 2) probably are remnants of recessional moraines. Terminal moraines have not been recognized on the southwest slope of the Boulder and Pioneer ranges. There, nonstratified drift occurs as lateral moraine or kame on valley sides, particularly at the junctions of major glacial valleys, and as patches of sub-glacial material on cirque floors.

OLDER OUTWASH GRAVEL

Older gravel, presumably deposited as glacial outwash by vigorous meltwater streams, is exposed in most major valleys in the study area (pl. 2). Terraces were cut in the gravels by younger streams meandering through the outwash trains. The deposits are crudely stratified, poorly sorted, and unconsolidated, and clasts are well rounded. These gravels differ from lower Tertiary(?) to Upper Cretaceous(?) conglomerates chiefly in their lack of consolidation and in the abundance of locally derived plutonic and volcanic clasts. Locally, as along Wildhorse Creek, the outwash deposits may merge upstream with either terminal or recessional moraines.

LACUSTRINE DEPOSITS

Fine-grained lacustrine deposits are thought to underlie Copper Basin Flat, a triangular area of about 3 mi^2 (8 km^2) in the eastern part of Copper Basin (pl. 2). The lake inferred to have occupied the flat probably formed by impounding of meltwater streams behind the main Copper Basin ice lobe during its maximum advance.

ROCK GLACIERS

Rock glaciers are well developed in places along the crest of the Boulder and Pioneer Mountains, mainly on the northeast side (pl. 2). The rock glaciers are composed entirely of large, angular blocks plucked or spalled from cirque headwalls, and they have distinct ridges that record patterns of former movement. No ice is apparent in the rock glaciers at present but their cores are not visible. Vegetation has not yet been established on them. Though they are included here with Pleistocene deposits, they may be much younger Neoglacial features.

HOLOCENE DEPOSITS

Fluvial and colluvial surficial deposits are present throughout the study area, but only the most prominent are shown on plate 2. These include major landslide deposits and recent stream deposits; colluvial materials generally are not shown.

LANDSLIDE DEPOSITS

Two of the most prominent landslide deposits in the study area are at the junction of Wildhorse and Fall Creeks in the north-central part of the study area, and on the north side of the White Mountains ridge on the southwest margin of Copper Basin. In both of these areas, the slides probably resulted from undercutting of glacially oversteepened valley walls by modern streams. The largest landslide in the study area caps the ridge between Corral and Hyndman Creeks, in the vicinity of Pioneer Cabin (W. E. Hall and J. N. Batchelder, written commun., 1975). The slide mass is composed entirely of shattered vitreous quartzite resembling metasedimentary member F of the East Fork Formation and rests on the Wood River Formation over an area of more than 1 mi^2 (2.6 km^2). The slide mass underlies and therefore predates Eocene deposition of the Challis Volcanics. Small modern landslides are most abundant in tuffaceous Challis Volcanics throughout the study area (W. E. Hall and J. N. Batchelder, written commun., 1975), but were not mapped separately in this study.

ALLUVIUM

Alluvial deposits along present stream courses are crudely stratified and include silt, sand, and gravel, much of which may represent reworked older surficial materials. Some swamp and iron-rich bog deposits in Iron Bog, Big Fall, and Little Fall Creeks are shown in plate 2 as Holocene alluvium.

QUATERNARY STREAM DEPOSITS, UNDIVIDED

In a few places, alluvium and older terrace gravels are not differentiated but are mapped together as Quaternary stream deposits, undivided. Locally this unit may also contain some unstratified talus and colluvium.

STRUCTURE

The Boulder and Pioneer Mountains lie within a belt of intense middle Paleozoic and Mesozoic orogenesis that extends from Mexico to the Arctic Ocean. Many parts of this belt have been studied in detail but in few places is the orogenic record more varied and better preserved than in the study area. Huge thrust sheets or allochthons, probably of two or more distinct ages and displaying a wide range of internal deformational styles, juxtapose time-equivalent sedimentary facies so different as to imply horizontal displacement of tens of kilometers. High-grade regional metamorphic rocks occur in two structural plates, both exposed in a structural window through overlying weakly metamorphosed or nonmetamorphosed allochthons. Plutonic rocks probably were emplaced in two intrusive phases, the first, or synorogenic phase, during regional metamorphism and an early stage of thrusting, and the second, or post-orogenic phase, after regional thrusting was completed, and coeval with widespread Challis volcanism. High-angle faults have formed intermittently since thrusting ceased but are not as abundant as in the Basin and Range province to the south and east.

MAJOR STRUCTURES AND TECTONIC UNITS RELATED TO REGIONAL THRUSTING

The rocks of the Boulder-Pioneer study area can be divided into five major structural or petrologic units (fig. 4), listed here from structurally lowest to highest:

1. metamorphic rocks and some igneous rocks constituting the crystalline core of the central Pioneer Mountains and exposed in a structural window here designated the Pioneer window;
2. dominantly calcareous sedimentary rocks of a lower and middle Paleozoic shelf facies (eastern facies) exposed in the Wildhorse and Dry Canyon windows;
3. allochthonous, dominantly argillaceous lower and middle Paleozoic rocks (western facies) of the southwestern Pioneer Mountains;
4. allochthonous Mississippian Copper Basin flysch; and
5. post-orogenic quartz monzonite stocks and Challis Volcanics.

Thrust faults of prime importance separating the first four of these major units are distinguished on maps and sections from thrusts separating sequences within the units, even though some of the internal thrusts also are large and represent great horizontal movement. The two most important regional thrusts are here named the Pioneer and Wildhorse thrust fault systems, and these are discussed separately. Internal structures and deformational styles related to regional thrusting within the major structural or petrologic sequences are briefly discussed in succeeding sections of this report.

Individual thrust faults can be dated by stratigraphic and intrusive crosscutting relations only within wide limits. Evidence that the thrusts are mainly Mesozoic in age is reviewed by Dover (1969, 1975, 1980) and by Hall, Batchelder, and Skipp (1975).

WILDHORSE THRUST FAULT SYSTEM

The Wildhorse thrust fault system comprises the thrust faults separating allochthonous sequences of the Mississippian Copper Basin Formation from Precambrian and lower to middle Paleozoic rocks of the Pioneer, Wildhorse, and Dry Canyon windows (pl. 2; fig. 4). Prior to broad doming by Eocene quartz monzonite intrusion, the Wildhorse thrust dipped gently westward and was rooted to the west of the Pioneer window. Presently, the system consists of a steeply folded eastern segment over the Wildhorse and Dry Canyon windows, a moderately northwest- to northeast-dipping segment forming the north boundary of the Pioneer window, and a partially eroded and largely unexposed segment that projects over the band of intrusive domes along the Pioneer range crest and into the subsurface to the west. West of the Pioneer window, the Wildhorse thrust system was overridden and truncated by the Pioneer thrust; the two thrust systems intersect in the cirque at the head of Right Fork Kane Creek (pl. 2).

The part of the Wildhorse thrust system forming the north boundary of the Pioneer window is well exposed along Boulder Creek and on the divides between all major streams draining the northeast flank of the crystalline window. Where the Wildhorse thrust system separates medium- to high-grade metamorphic rocks of the Pioneer window from allochthonous sequences of the Copper Basin Formation, intense shearing and tectonic slicing of rocks within a few hundred meters of the main detachment zone occurred in rocks both above and below it. Tectonic slices of various units of the Copper Basin plate of the Copper Basin Formation are present in the upper plate on the north side of Boulder Creek, and metasedimentary rocks below the main thrust have a similar structural style on the ridge between the two main forks of Fall Creek. Between these two localities, emplacement of the Eocene quartz monzonitic phase of the intrusive complex of the Pioneer window appears to have been closely controlled by the preexisting thrust, and the quartz monzonite is in sheared intrusive contact with the deformed Copper Basin (fig. 6).

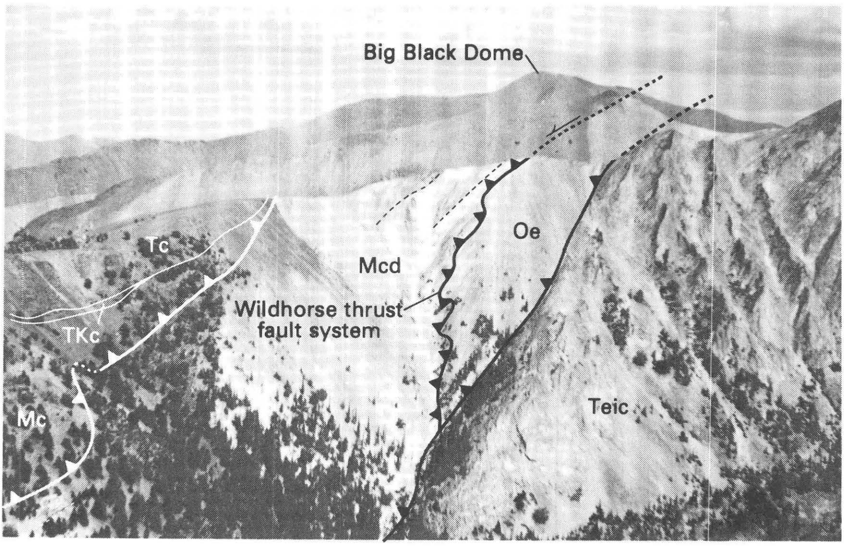

FIGURE 6.—West side of ridge between Surprise Valley and Left Fork Fall Creek, showing Wildhorse thrust fault system and contact relations on the north side of the Pioneer window. View is eastward across the mouth of Surprise Valley. Copper Basin plate (Mcd) of the Mississippian Copper Basin Formation overlies metasedimentary rocks of the Ordovician East Fork Formation (Oe) along part of the Wildhorse thrust fault system (heavy line with closely spaced sawteeth; sawteeth on upper plate) and is overridden by the Glide Mountain plate of Copper Basin Formation (Mc) (line with wider spaced sawteeth). Dip of the Wildhorse thrust fault system is eastward here where it has been tilted by intrusive doming. Rise of the felsic phase of the intrusive complex of the Pioneer window was largely controlled by the preexisting thrust fault, and the north contact of the pluton here is a sheared intrusive fault that locally coincides approximately with the preexisting thrust fault system (line with sparse sawteeth). Dotted lines on ground surface are bedding traces; those projected above ground are projections of fault traces. Tc, Tertiary Challis Volcanics; TKc, Tertiary and Cretaceous conglomerate.

Folded segments of the Wildhorse thrust system bounding the Wildhorse and Dry Canyon windows are steeply dipping in places, but flatten or reverse dip elsewhere, so that the thrusts can be traced continuously around the window exposures. Except for fracturing and local brecciation, little deformation is associated with the thrusts in the window rocks, but folding and shearing increase downward toward the main thrust surface in the overriding Copper Basin plate of the Copper Basin Formation, and truncations of major units occur.

The deformational style within the Copper Basin allochthons described below, combined with facies and paleogeographic reconstruction, suggest some tens of miles (kilometers) of east or northeast translation on the Wildhorse thrust fault system.

PIONEER THRUST FAULT SYSTEM

The Pioneer thrust fault system is the sole thrust of the allochthonous, dominantly argillaceous, lower and middle Paleozoic sequences (western facies) of the southwestern Pioneer Mountains and is the detachment along which they overrode various allochthonous sequences of the central and northwestern Pioneers. The thrust system can be traced southeastward across the center of the map from the North Fork Big Lost River at the north edge of the area to Muldoon Creek at the south edge. Component faults of the Pioneer system truncate stratigraphic contacts and structures in both overlying and underlying sequences, and in places, separate rocks of equivalent age but distinctly different sedimentary facies and metamorphic grade.

The central part of the Pioneer thrust system forms the west and southwest boundary of the Pioneer window and separates upper plate rocks of the Milligen and Wood River Formations from structurally underlying medium- to high-grade metasedimentary rocks of the Hyndman and East Fork Formations. This segment of the thrust system is strikingly displayed on the divides between all major streams draining the southwest flank of the crystalline window. Where the upper plate consists of Milligen argillite, a thick sheared and mylonitic zone is normally present. In most places where the upper plate is Wood River sandstone, the fault contact is remarkably sharp and adjacent rocks show relatively little local deformation considering the magnitude of movement inferred for the system. The fault is equally well defined, regardless of which crystalline unit is overridden.

The Pioneer thrust fault system is less obvious but can be readily mapped both north and south of the Pioneer window, where the overridden rocks are mainly clastic units of allochthonous Copper Basin flysch sequences. The best exposures north of the window are on Phi Kappa Mountain and the ridge between Park and Little Fall Creeks, where the thrust separates predominantly argillaceous rocks of somewhat similar appearance. In such places, the fault zone is typically marked by an intensely sheared and silicified zone less than 160 ft (50 m) wide (fig. 7). However, in places on Phi Kappa Mountain and locally in Miller Canyon, the fault zone contains as much as 10 ft (3 m) of distinctive, gray- to green-weathering breccia composed of carbonate-cemented bleached and leached argillite chips. South of the Pioneer window, the Pioneer thrust fault system is best exposed where it crosses Garfield Canyon and the road along the North Fork Copper Creek. At these places, the fault system is recognized mainly as a zone of intense shearing and silicification 160 ft (50 m) or more wide. It separates dark, blocky argillite of the Little Copper Member of the Mississippian Copper Basin Formation from overlying black, pervasively sheared and locally phyllitic, carbonaceous and siliceous argillite that is here assigned to the Devonian Milligen Formation (but which previously was included in the Copper Basin Formation by Dover and others (1976) and in the Copper Basin Group by Paull and others (1972)). In Garfield Canyon and Mutual

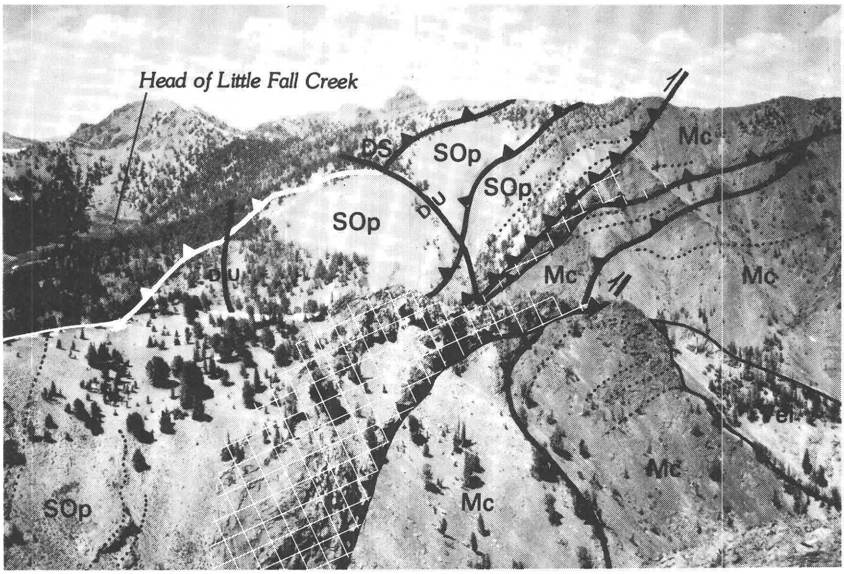

FIGURE 7.—Imbricate thrust faults in Paleozoic rocks of Little Fall Creek area; looking northward across middle part of Little Fall Creek from ridge between Little Fall and Park Creeks. Allochthonous rocks of the Phi Kappa and Trail Creek Formations (SOp) and Silurian-Devonian unit (DS) override rocks of the Glide Mountain plate of the Copper Basin Formation (Mc). Thrust fault with closely spaced teeth separates the DSO and Mc sequences, sawteeth on upper plate; wider spaced teeth on thrust faults within one sequence or the other; D, U, on downthrown and upthrown sides of high-angle faults, respectively; dotted lines are bedding traces. A satellite of the Summit Creek stock (Tei) was intruded to about the structural level of the silicified zone along the thrust fault between the two sequences.

Gulch, sheared and metamorphosed Carey Dolomite crops out in discontinuous exposures along the Pioneer thrust. Their lithology, structural position, and strong internal deformation suggest that they are tectonic slivers detached from structurally underlying eastern facies shelf rocks west of the Pioneer Mountains and dragged eastward into their present position along the sole of the western facies allochthons.

Much translation has been taken up within allochthons above the Pioneer thrust system by pervasive shearing and small-scale folding, particularly within argillaceous units. Deformational styles in individual stratigraphic and structural units vary and are described herein. However, sense of overturning and Paleozoic facies reconstruction indicate that the sequences above the Pioneer thrust fault system moved eastward and (or) northeastward a distance of several tens of miles (kilometers) or more relative to the structurally overridden rocks.

STRUCTURES WITHIN THE PIONEER WINDOW

The crystalline core of the central Pioneer Mountains is exposed in the Pioneer window and comprises the allochthonous metasedimentary sequence (Hyndman and East Fork Formations), the allochthonous gneiss complex of Wildhorse Creek, and the intrusive complex of the Pioneer window (pl. 2; fig. 4). Surrounding and structurally overlying allochthonous Paleozoic rocks are separated from the window rocks on three of four sides and part of the fourth by major thrust faults of the intersecting Wildhorse and Pioneer thrust fault systems; the east boundary of the window is complicated by a fault inferred from its linear map trace and aeromagnetic pattern to be a N. 30° E.-trending high-angle fault.

METASEDIMENTARY SEQUENCE

The Hyndman and East Fork Formations are complexly deformed into large, tight, eastward-overturned to recumbent folds and thrust faults. In some places, thrust faults can be traced into the cores of tightly appressed folds, indicating shearing of one fold limb over another during the folding process. Large folds with associated thrust faults are most prominent in the south half of the metasedimentary belt, whereas imbricate thrust faults bounding thin tectonic slivers presumed to have formed from the sheared limbs of recumbent folds are typical in the north half of the belt. Some details of internal structure are depicted on cross section B–B′ of plate 2, but map patterns in the metasedimentary belt are greatly simplified on plate 2.

Recrystallized mylonite along some thrust faults contains the mineral assemblage biotite-muscovite-quartz (Dover, 1969, p. 51), indicating a somewhat lower metamorphic grade than that of the wall rocks. A separate pattern is used on plate 2 to indicate thrust faults within the metasedimentary complex that contain recrystallized mylonite. Thrust faults, limbs and axial surfaces of isoclinal folds, and metamorphic foliation all generally trend about N. 40° W. and are moderately parallel through most of the metasedimentary belt. Exceptions are two north-trending folds with inverted stratigraphy that occur in what may be the overturned limb of a nappe in the southern part of the belt.

The metamorphic character of the metasedimentary rocks and the intensity, style, and asymmetry of deformation indicate that they were tectonically emplaced from the west or southwest, while the rocks were still hot and undergoing regional metamorphism.

GNEISS COMPLEX OF WILDHORSE CREEK

The gneisses of Wildhorse Creek form two strongly asymmetrical structural domes, the Wildhorse dome, which trends about N. 30° W. across upper Wildhorse Creek, and the smaller Kane Creek dome, which is centered on upper Kane Creek (Dover, 1969, p. 11–12). On plate 2, the Wildhorse dome is best expressed by a marble bed and by the contact with surrounding intrusive rocks; both domes are also defined by bedding foliation. The Wildhorse dome has a steep to overturned, isoclinally folded northeast flank and a more gently dipping southwest flank, as illustrated on cross section B–B′ (pl. 2). The Kane Creek dome is more irregularly intruded by the intrusive complex of the Pioneer window than is the Wildhorse dome.

The generally domal structure of the gneiss complex of Wildhorse Creek previously was thought to have formed by remobilization and doming in place of local Precambrian basement during generation and emplacement of the intrusive complex of the Pioneer Mountains (Dover, 1969, p. 59–60). This process now appears unlikely. Asymmetrical folding of the gneiss complex predates and is of an entirely different scale, style, and complexity than that associated with emplacement of the post-orogenic quartz monzonite phase of the intrusive complex of the Pioneer window, which broadly domes the allochthons overlying the window. Furthermore, the location of the gneiss domes along the southwest flank of the intrusive dome indicates that folding in the gneisses and intrusive doming were not genetically related. Structural asymmetry of the gneiss complex toward the northeast, in the same sense as structural asymmetry in the allochthonous metasedimentary sequence, and the general concordance in orientation and style of structures between these two metamorphic units, suggest that the gneiss complex of Wildhorse Creek also is allochthonous. It is now inferred to have been tectonically emplaced from the west, along with the metasedimentary sequence, during regional metamorphism, and well before Eocene quartz monzonite intrusion. The major thrust fault along which the gneiss complex is inferred to have overridden the unmetamorphosed carbonate shelf rocks of the Wildhorse and Dry Canyon windows is not exposed because of structurally overlying allochthons and emplacement of the quartz monzonite phase of the intrusive complex of the Pioneer window. Precambrian structures within the gneiss complex have not been fully analyzed or differentiated from structures related to Phanerozoic thrusting.

INTRUSIVE COMPLEX OF THE PIONEER WINDOW

The main quartz monzonitic phase of the intrusive complex of the Pioneer window clearly intrudes the metamorphic rocks of the Pioneer window, but its relation with the overriding allochthons is more complicated. Weak contact metamorphism of the Milligen and Wood River Formations and local silicification of the Drummond Mine Limestone Member of the Copper Basin Formation indicate that the quartz monzonite was intruded after these allochthons were emplaced. On the other hand, the contact between the quartz monzonite and the Copper Basin Formation on the north side of the window between Kane and Ramey Creeks is sharp and sheared and has been mapped as a fault on plate 2. The sequence of development of this contact as now envisioned is (1) thrusting of allochthonous Paleozoic cover over the metamorphic rocks of the Pioneer window along the Wildhorse and Pioneer thrust fault systems, (2) emplacement of the quartz monzonite phase of the intrusive complex of the Pioneer window to the level of, or partly along, these sole thrusts, and (3) shearing along the intrusive contact approximately coincident with the position of the sole thrusts. The weakness of contact metamorphic effects in the allochthons suggests that the quartz monzonite was emplaced in a relatively dry or semiconsolidated state that may have been capable of sustaining shear. Thus shearing along the intrusive margin may have occurred during emplacement and associated intrusive doming, or alternatively, it formed by differential movement along the intrusive margin as a result of later uplift of the crystalline core of the range. The contact of the intrusive complex is shown on plate 2 as a minor thrust fault both to emphasize its importance as a structural boundary, and to emphasize the control exerted on its shearing by preexisting major thrust faults.

The origin of more mafic and foliated rocks of the intrusive complex, which are restricted to a narrow belt between the metasedimentary rocks and the southwest side of the gneiss complex, is less certain. Field relations and petrographic evidence discussed by Dover (1969, p. 42–44) and on p. 47 of this report indicate that this phase of the intrusive complex was emplaced during metamorphism and deformation of the metasedimentary belt. Moreover, the fact that the medium to high regional metamorphic grade of the metasedimentary rocks increases toward the contact with the mafic phase implies a higher temperature for this phase of the intrusive complex than is inferred for the main quartz monzonitic phase. All of these data, along with preliminary aeromagnetic evidence that the mafic and foliated phase does not extend in the subsurface much beyond the area of surface exposure, are consistent with the interpretation that the more mafic and foliated rocks represent a structurally detached (or rootless), synorogenic phase of the intrusive complex of the Pioneer window that distinctly predates post-orogenic emplacement of the more directionless felsic phase of the complex. If so, the radiometric (K-Ar) age of the mafic phase may be less than its true age because of prolonged or renewed regional heating related to Eocene intrusion.

STRUCTURES WITHIN THE WILDHORSE AND DRY CANYON WINDOWS

Lower and middle Paleozoic carbonate rocks of the Wildhorse and Dry Canyon windows dip homoclinally to the east and northeast at moderate to steep angles. Contrary to the report of Paull and Rothwell (1973), we found no field evidence for thrust faulting within the window rocks, although minor, high-angle, normal(?) faults do cut the Wildhorse window in places. Eastward tilting of the window rocks probably resulted from drag below overriding allochthons, but if the window rocks themselves are allochthonous, then the tilted beds could be in folds associated with unexposed deeper level thrust faults.

STRUCTURES IN THE COPPER BASIN FORMATION, MAINLY EAST OF THE BOULDER-PIONEER MOUNTAINS CREST

COPPER BASIN PLATE

Broad and gentle folds are typical of most of the Copper Basin thrust plate of the Copper Basin Formation. In the region east and south of Copper Basin, beds dip homoclinally eastward at angles ranging from 15° to 80°. The axis of a broad, open syncline trends about N. 10° W. across both forks of Iron Bog Creek about 2 mi (3 km) above their confluence. Bedding is steep and locally overturned north of Lake Creek at the northeast edge of the study area, where the Copper Basin plate possibly lies in thrust fault contact on White Knob Limestone; the contact is not exposed except questionably on the north side of Lake Creek stock, but a buried thrust fault is inferred because the Copper Basin and White Knob sequences represent strikingly different facies of partly time equivalent Mississippian rocks.

The Copper Basin plate is much more intensely deformed around the Wildhorse and Dry Canyon windows, where the base of the allochthon is exposed (pl. 2, cross section B–B′). The most spectacular structures are associated with a recumbent fold that caps the high divide between Dry Canyon and Fall Creek. The fold is a large, eastward-overturned, recumbent anticline cored mostly by complexly folded and sheared Drummond Mine Limestone Member; a thrust fault below the overturned limb of the fold brings the limestone core over the upper clastic unit of the Copper Basin Formation of the Copper Basin plate.

GLIDE MOUNTAIN PLATE

The Glide Mountain plate of the Copper Basin Formation is characterized by pervasive folding on small and intermediate scales, and by well-developed axial-plane cleavage. Axial traces of only the largest of the folds are shown on plate 2. Folds and cleavage are ubiquitous but are particularly well displayed at Glide Mountain and in the valley walls of lower Summit Creek (fig. 8) and Kane Creek. The relation of cleavage to the axial planes of folds is not apparent everywhere but is clear both in outcrops where folds are present and from its regional pattern. Where cleavage is well developed, the rock splits into thin plates or slabs, and bedding may be difficult to recognize.

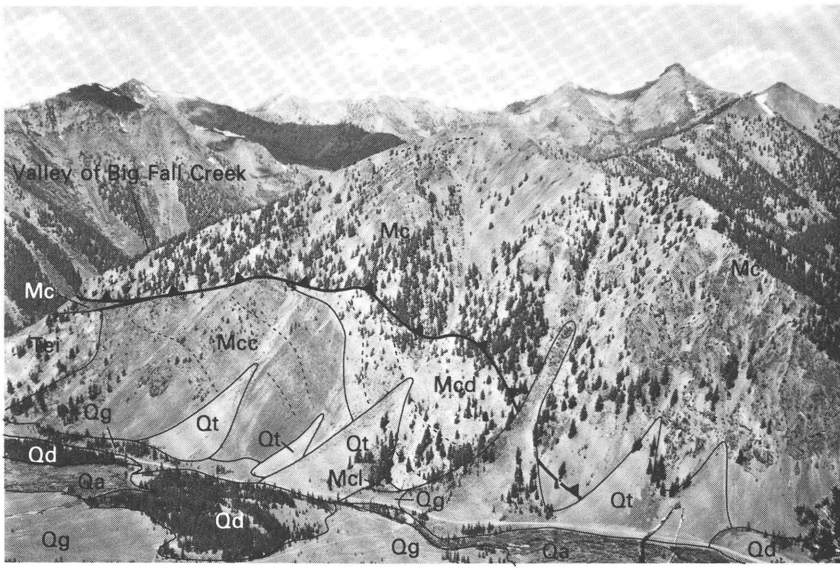

FIGURE 8.—Thrust fault (teeth on upthrust block) between two structural plates of the Copper Basin Formation (Mississippian); looking north-northwest across Summit Creek from the ridge between Phi Kappa and Kane Creeks. Dotted lines are bedding traces. Complex folds in the overriding Glide Mountain plate (Mc) are overturned toward the east; rocks of the overridden Copper Basin plate (Mcc, Mcd) dip homoclinally eastward and are truncated by the fault. The Summit Creek stock (Tei) rose to the level of the silicified zone along the thrust fault. Two small glacial moraines (Qd) cross the valley of Summit Creek. Qg, terrace gravels; Qa, alluvium; Qt, talus. Relief from valley floor to ridge crest about 2,150 ft (650 m).

Folds generally trend about N. 10° W. and are asymmetrical or overturned to the east, but locally the bedding is complexly contorted. Folding was related to thrust faulting. In places, folds increase in frequency and are more attenuated toward the thrust fault below the Glide Mountain plate but still maintain a consistent trend and direction of asymmetry, and locally the thrust fault itself is folded along the same axial trend. Internal folding is so intense as to imply horizontal shortening of at least the width of the Glide Mountain plate itself, and the entire plate moved en masse a considerably greater distance. Eastward asymmetrical folds are present on all sides of major structural domes in the study area, indicating that tectonic movement was from west to east across the entire area and that folds did *not* develop by local gravity sliding from within the Pioneer Mountains.

The base of the Glide Mountain plate is an intensely deformed fault zone at most places; the best exposures are on the ridge southeast of the junction of Kane and Summit Creeks, on the ridge south of Glide Mountain, and along Phi Kappa and Big Fall Creeks. The name Glide Mountain thrust, introduced by Nilsen (1977), is adopted here for this fault zone. Intense shearing, tight folding, and silicification are most typical of the thrust zone, but locally it contains slices and rolled blocks of structurally underlying rocks, including the lithologically distinctive Drummond Mine Limestone Member. In the Summit Creek area, the basal 100–400 ft (30–120 m) of the Glide Mountain plate is composed dominantly of sheared silicified mylonite and isoclinally folded thin-bedded siliceous argillite.

In the Copper Basin area, the Muldoon Canyon thrust of Nilsen (1977) is regarded as a continuation of the Glide Mountain thrust, and his Brockie and Scorpion subplates, which are separated by the thrust, are thought to be equivalent to the Glide Mountain and Copper Basin thrust plates, respectively, as presently mapped in the rest of the study area. Although this part of the Glide Mountain thrust was not recognized during the mapping for this report (Dover and others, 1976), its probable location is shown on plate 2, based on Nilsen's sedimentological subdivisions as related to our previous field observations. More detailed work may subsequently require revision of the location tentatively shown on plate 2.

STRUCTURES IN ALLOCHTHONOUS SEQUENCES OF THE WESTERN BOULDER AND PIONEER MOUNTAINS

All of the Paleozoic rocks of the southwest half of the study area are allochthonous. These thrust sequences structurally are soled by the Pioneer thrust system and contain some of the most intensely deformed rocks in the region. Deformational styles vary from sequence to sequence because of differences in gross lithology, structural level observed, and deformation history.

ALLOCHTHONS OF IMBRICATED PHI KAPPA AND TRAIL CREEK FORMATIONS AND UNNAMED SILURIAN AND DEVONIAN UNIT

At most places, shaly beds of the Phi Kappa and Trail Creek Formations and the unnamed Silurian and Devonian unit above the Pioneer thrust zone are sheared and silicified but are generally concordant with it; numerous thrust imbrications are present. Tan-weathering siltstone tentatively assigned to the unnamed Silurian and Devonian unit tends to be remarkably little deformed at the thrust fault and only moderately discordant to it. Bedding in the overridden Glide Mountain plate commonly is discordant to the thrust contact and is drag folded in places.

Internally, the Ordovician and Silurian belt contains large, tight, asymmetric to northeasterly overturned folds from which numerous imbricate thrust faults developed. (See pl. 2, cross section A–A′; fig. 8; see also Dover and others, 1980.) Folds with amplitudes of 1,000 ft (300 m) or more are best displayed on the ridge between Park and Little Fall Creeks, where the tan-weathering Trail Creek Formation forms a prominent marker zone within predominantly dark argillaceous rocks. Equally large but less obvious folds are common in the unnamed Silurian and Devonian unit. Axial zones of most folds are intensely sheared and silicified.

The Park Creek thrust fault of Churkin (1963) is typical of the imbricate thrust faults, but other equally well exposed and structurally important faults occur both above and below the Park Creek thrust. Most of the imbricate thrust slices contain upright beds and repeat section. Some of these thrust faults are not obvious in the field and can be demonstrated only by the repetition of sequences of graptolite zones.

On the west side of the ridge between upper Trail Creek and the head of Little Fall Creek, some thrust slices are folded and cut by north-trending high-angle faults. (See structure projected above ground level on pl. 2, cross section A–A′.)

Structural details are uncertain in the unmapped northern part of the Ordovician to Devonian outcrop belt near the North Fork Big Lost River, but the same style of deformation that affects the rest of the belt is known from reconnaissance to extend into that area.

The outcrop belt of Ordovician to Devonian rocks probably is structurally continuous with strata assigned to the Milligen Formation, but the connection between these two rock sequences is concealed by an allochthon of the Wood River Formation.

THE MILLIGEN ALLOCHTHON

In most of the southwestern Boulder and Pioneer region, the Milligen Formation is the structurally lowest of the exposed allochthonous sequences above the Pioneer thrust fault system (pl. 2, cross section B–B′).

The Milligen is internally deformed throughout, but the style and intensity of deformation vary from place to place. Phyllitic rocks occur in all parts of the section but tend to be most common in the lower part. However, they are not dominant, or even abundant, in large parts of the Milligen terrane. Incipiently crystallized chlorite and micaceous minerals impart the phyllitic sheen and indicate that deformation in the Milligen proceeded under low-grade (lower greenschist facies) metamorphic conditions. In places, phyllitic or subphyllitic rocks are demonstrably related to shearing along major faults or to the axial zones of large, tightly appressed folds. Two or more closely spaced shear cleavages are widely developed at a steep angle to bedding, and crinkle cleavage (Tschanz and others, 1974) is characteristic in many areas. Thin-bedded siliceous argillite is isoclinally folded on a small scale, and some larger folds in the upper part of the Milligen are outlined by interbeds of dolomitic siltstone. The areal extent of cleaved and phyllitic rocks also suggests that large recumbent folds or nappes may be common.

The internal structure of the Milligen outcrop belt is still poorly understood but may prove to be similar in style and complexity to that of the Phi Kappa and Trail Creek Formations. Although the Milligen Formation is generally considered to have been deformed during Mississippian time and to have been a source in the resulting Antler orogenic belt of clastic sediments in the Copper Basin Formation (Paull and Lukowicz, 1972; Sandberg and others, 1975), no Milligen structures of unequivocal Antler age have yet been identified (Dover, 1980). Crudely dateable structures involving the Milligen appear to be related to major Mesozoic thrusting, but the possibility that some may have an Antler ancestry cannot be ignored.

THE WOOD RIVER ALLOCHTHON

The middle and upper parts of the Wood River Formation are in thrust fault contact on metasedimentary rocks in the northwest part of the Pioneer window between Corral Creek and the south fork of Hyndman Creek (pl. 2). Along the southwest side of upper Trail Creek for a distance of about 7 mi (11 km), the Wood River is in thrust fault contact with the unnamed Silurian and Devonian unit (fig. 9). At most other places, the Wood River allochthon rests discordantly on the Milligen allochthon of the southwestern Boulder-Pioneer region.

The Wood River Formation is preserved in several northwest-trending synclinal belts produced by broad folding of the detachment surface (see p. 45) that separates it from the Milligen. The scale and style of this folding are illustrated on all of the structure sections, and the N. 50°–60° W. trend of the fold axes is shown on plate 2. The most prominent of the synclinal belts is up to 4 mi (6.4 km) wide and extends

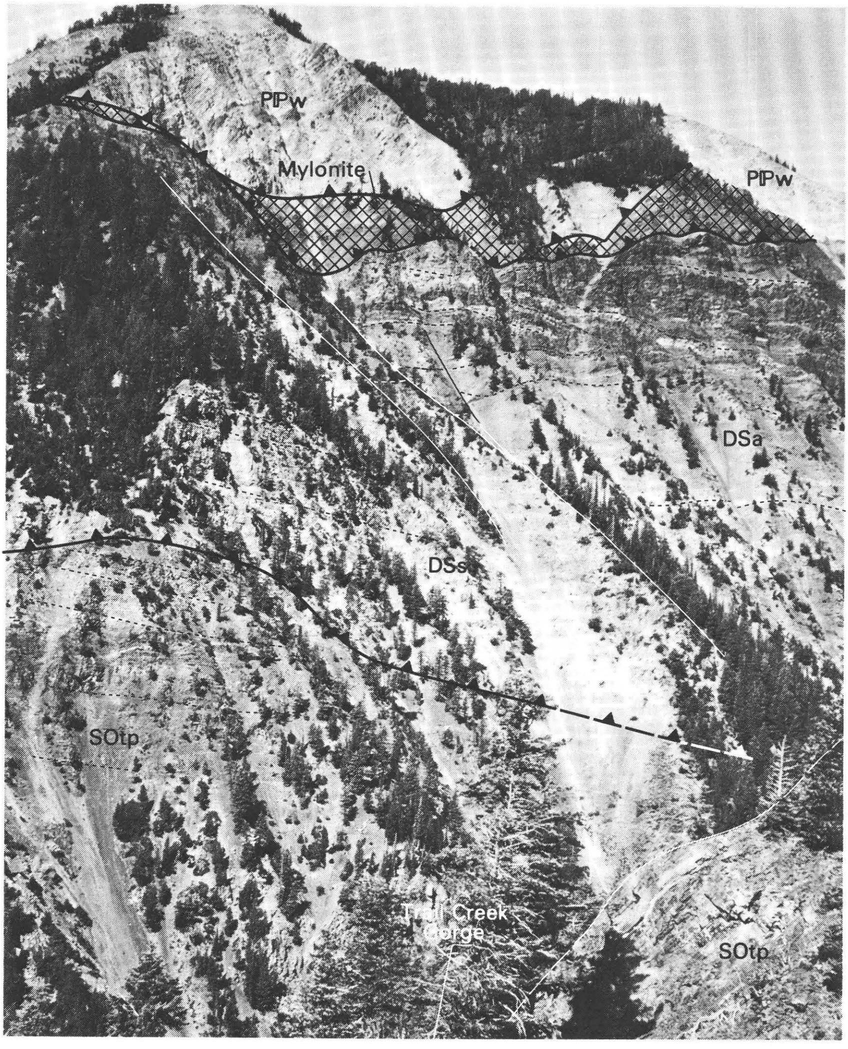

FIGURE 9.—Southwest wall of Trail Creek gorge, showing thrust faults in allochthonou Paleozoic rocks (dashed where approximately located; sawteeth on upper plat blocks). Wood River allochthon (PIPw) is thrust over rocks of the Silurian-Devonian sequence (DSa, DSs), which in turn are in thrust fault contact with the Phi Kappa and Trail Creek Formations (SOtp). Dotted lines, bedding traces. Looking westward from Trail Creek Summit on the road between Sun Valley and Mackay. Relief from valley floor to ridge crest about 2,000 ft (600 m).

continuously from the Little Wood River to beyond the northwest corner of the study area, a distance of at least 25 mi (40 km). Isolated klippen of Wood River rocks on high ridges within the main area of Milligen outcrops are erosional remnants of the other synclinal belts.

The origin of broad N. 10°–20° W.-trending cross-folds in the Wood River allochthon in the southern part of their outcrop area (pl. 2) is uncertain, but they probably predate the N. 50°–60° W. folding and may have formed during an early stage of thrusting.

The basal thrust zone, or Wood River thrust, truncates folds in the Wood River allochthon as well as in the Milligen, and folding within the two formations is disharmonic across it; the structural discordance does not appear to be pronounced on plate 2 because only two subdivisions of the Wood River are shown. Where the thrust surface coincides with the unconformity originally separating the Wood River and Milligen Formations, the Hailey Conglomerate Member at the base of the Wood River is strongly sheared, whereas the overlying strata are essentially continuous and intact. In the southern part of the outcrop belt, however, parts of the lower Wood River section were tectonically eliminated, and the resistant Hailey occurs as detached, strongly deformed, discontinuous lenses and blocks dragged along the base of the allochthon. In the northwest part of the belt, the main tectonic break appears to lie higher within the Wood River Formation so that units 4–7 of the upper part of the formation are in thrust contact with various units of the lower part, and lenses and narrow bands of weakly sheared to unsheared Hailey and associated carbonate rocks of the Wood River may still be in depositional contact on the Milligen.

STRUCTURAL ASPECTS OF EOCENE PLUTONS

The structural characteristics of the main quartz monzonitic phase of the intrusive complex of the Pioneer window were discussed previously.

The Summit Creek stock domed both the Copper Basin and Glide Mountain plates of the Copper Basin Formation and rose to a level closely controlled by the thrust zone between them. Its intrusive and structural relations are well exposed along Summit Creek near the confluence of Phi Kappa Creek (fig. 9). Structural control of the Summit Creek pluton resembles that of the quartz monzonitic phase of the intrusive complex of the Pioneer window.

Structural control of the Lake Creek stock and the dike complex of North Fork Lake is not apparent, but both intrude allochthonous sequences and therefore postdate regional thrust faulting.

The Eocene plutons provide a minimum age for the time(s) of major late Mesozoic thrusting; an older age limit for thrusting has not been established with certainty in the study area but various constraints are discussed by Dover (1969, p. 56; 1975, 1980), Sandberg and others (1975), and Skipp and Hall (1975a; 1975b, p. 686).

HIGH-ANGLE FAULTS

High-angle faults are common in the study area. Most have smooth, slickensided surfaces and are of small to moderate displacement; breccia and thin zones of gouge occur locally along some faults. Fault displacements commonly range from perhaps 100 to 300 ft (a few tens of meters to a hundred meters). Drag features are rare but where present are broad, simple warps that die out within a few tens of meters of the fault and in no way resemble the complex structures associated with thrust faulting. Where high-angle faults cut intensely deformed rocks, the strong deformation invariably is associated with low-angle thrust faults that predate high-angle faulting. Slickensides generally indicate oblique-slip with a subordinate horizontal component. Coincidence of most of the larger high-angle faults with the subsurface margins of Eocene plutons (based on aeromagnetic data) suggests that these faults are related to intrusion and have undergone synintrusive movement. Their linear traces and coincidence in trend with regional fracture patterns suggest that most of these are faults or fractures of older regional sets that controlled intrusion and were reactivated by intrusive doming, but a few may have developed initially during intrusion.

WHITE MOUNTAINS FAULT

The most prominent high-angle fault in the study area forms the east side of the Pioneer window (pl. 2; fig. 4) and was called the White Mountains fault by Dover (1969, p. 57). The fault strikes N. 30° E., dips steeply southeast, and can be traced at least 10 mi (16 km) from Ramey Creek near Big Black Dome to near Grays Peak. On the divide between Broad Canyon and Little Wood River, where the fault separates quartz monzonite of the intrusive complex of the Pioneer window from Challis Volcanics, the Challis is sheared and intensely silicified, and both the quartz monzonite and volcanic rocks are altered for a distance of 1,000 ft (300 m) from the fault. No estimate of throw is possible because marker beds are absent, but a minimum of several hundred feet (100 m) seems required. The White Mountains fault projects northeastward beneath unfaulted Quaternary glacial deposits along the northwest side of Copper Basin, suggesting that the basin originated during or after Challis time, but prior to the Quaternary, as a graben or half-graben.

COPPER CREEK FAULT

Along Copper Creek in the southwest part of the study area (pl. 2; fig. 4), Challis Volcanics and Paleozoic rocks are separated by a contact that is poorly exposed but has a linear trace for about 8 mi (13 km). Map relations indicate the contact to be a fault with steep southwest dip and moderate normal dip-slip movement, but the difficulty in tracing the fault along its projection through the volcanics to the northwest indicates that it may not have much post-Challis movement. Possibly it is an old fault bordering a steep-sided valley that subsequently was filled with Challis Volcanics and along which there has been only limited post-Challis reactivation.

A prominent fault trending N. 10° W. cuts the Paleozoic rocks east of Copper Creek and may be a branch of the Copper Creek fault.

PHI KAPPA MOUNTAIN FAULT BLOCK

Phi Kappa Mountain in the west-central part of the study area marks a structurally depressed, triangular block 2 mi^2 (5 km^2) in area that is bounded by three nearly vertical faults (pl. 2; fig. 4). The largest of the faults trends N. 50°–60° W. for about 6 mi (9.6 km) along upper Summit Creek; major displacement of several hundred feet (100 m) or more appears to be limited to the 2-mi (3-km) segment of the fault bounding the Phi Kappa Mountain block. The fault forming the east side of the block trends N. 10° W. and is alined with lower Phi Kappa Creek, but contacts crossing the creek do not appear to be significantly offset. The third fault trends N. 60° E., is only 2 mi (3 km) long, and terminates against the other two; but it has at least 500 ft (150 m) of throw. The Phi Kappa Mountain block is within a part of the Pioneer Range that regional gravity data indicate is underlain at relatively shallow depth by a granitic batholith; the block may be a fault-bounded segment of the batholith roof that collapsed.

OTHER FAULTS RELATED TO EMPLACEMENT OF THE SUMMIT CREEK STOCK

Steep faults of small displacement cut the Ordovician to Devonian sequences along upper Trail Creek and cut both thrust plates of the Copper Basin Formation near the Summit Creek stock (pl. 2). Faults with N. 10° W., N. 30° E., and N. 60°–70° E. trends are most common, but other orientations occur, and one fault with an arcuate trace is concave toward, and dips at 45° toward, the Summit Creek stock. Only the fault with the curved trace is likely to have formed initially as a result of strain induced by intrusion; the others are probably preexisting fractures that were reactivated during intrusive doming. Near the Summit Creek stock, numerous fractures contain siliceous dikes and veins; fractures farther removed from the stock typically are altered.

FAULT ZONES AT THE NORTH-CENTRAL EDGE OF THE STUDY AREA

Clusters of north-trending high-angle faults northwest of the junction of the North Fork Big Lost River and Summit Creek, and along the lower reaches of the East Fork Big Lost River, cut Challis Volcanics as well as deformed Paleozoic rocks (pl. 2). Displacements are generally

100 ft (30 m) or less. In the North Fork area, most of the faults either trend about N. 30° W. or between N. 10° W. and N. 10° E.; they have smooth, slickensided surfaces and are locally silicified. The most prominent faults in the East Fork area trend N. 10° E. and N. 30° E., but a few trending N. 30° W. are present. Here, Challis Volcanics and lower Tertiary(?) to Upper Cretaceous(?) conglomerate occupy N. 10° E.-trending pre-Challis valleys, suggesting that the N. 10° E. faults may have had a pre-Challis ancestry.

PATTERN OF FRACTURING

The foregoing descriptions indicate that high-angle faults in the study area tend to follow a few preferred orientations. The principal directions are N. 10° W. to N. 30° W. and N. 50°-60° W., parallel to the main trends of the earlier orogenic fabric (folds and thrust faults); N. 10° W. to N. 10° E. and N. 30° E., which also are the most prominent trends of topographic lineaments; and N. 50°-70° E., the dominant orientation of dikes in the study area. Topographic lineaments are marked by long, linear valleys such as those occupied by Wildhorse and Phi Kappa Creeks, and by alined valleys such as those of lower Trail and Summit Creeks. These lineaments generally do not indicate surface faults of large displacement. In the Boulder and White Cloud Mountains north of the study area, faults and lineaments also have a similar pattern (Tschanz and others, 1974).

AGE

All the high-angle faults observed in the study area postdate regional thrust faulting, most are associated with post-orogenic intrusion, and many cut Challis Volcanics. Possible fault control of pre-Challis topography and preferred orientation of dikes, including some that fed the Challis, indicate a very early Eocene or pre-Eocene ancestry for at least some of the high-angle faults. No faults have been observed in Quaternary surficial deposits.

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Aeromagnetic Studies of the Boulder-Pioneer Wilderness Study Area, Blaine and Custer Counties, Idaho

By DON R. MABEY, U.S. GEOLOGICAL SURVEY

MINERAL RESOURCES OF THE BOULDER-PIONEER WILDERNESS STUDY AREA, BLAINE AND CUSTER COUNTIES, IDAHO

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AEROMAGNETIC STUDIES OF THE BOULDER-PIONEER WILDERNESS STUDY AREA, BLAINE AND CUSTER COUNTIES, IDAHO

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INTRODUCTION

The aeromagnetic survey of the Boulder-Pioneer study area was flown in two parts. The western one-fourth was flown by Scintrex Airborne Geophysics, Inc., and compiled by the U.S. Geological Survey, and the eastern three-fourths was flown and compiled by Aerial Surveys. Flight lines were north-south, 1 mi (1.6 km) apart, and 12,000 ft (3,650 m) above sea level. The magnetic data for the western survey were compiled as a total intensity map and for the eastern survey as a residual total intensity map (pl. 3).

RESULTS

A good correlation exists between the magnetic anomalies and the surface geology. Magnetic highs are produced by all of the larger intrusive bodies. Smaller magnetic anomalies, both highs and lows, are produced by the volcanic rocks. Because of the high surface relief over most of the study area, the magnetic map reflects topography where the surface rocks are magnetic.

A zone of high magnetic intensity trends southeast across the study area, and the areas of highest magnetic intensity correspond to outcropping Tertiary intrusive bodies. A regional gravity low (Mabey and others, 1974) is approximately coincident with the magnetic feature associated with the Tertiary bodies. Together the gravity and magnetic data suggest that in this zone intrusive rock is more abundant in the subsurface than is suggested by the outcrops. Perhaps a batholith underlies an area extending the length of the study area from Smiley

Mountain on the southeast to North Fork Big Lost River on the northwest.

West of Scorpion Mountain a north-northwest-trending magnetic high is related to a large intrusive body that crops out in two places. Although the magnetic anomaly is somewhat affected by the volcanic rocks to the west, south, and east, the general form of the anomaly suggests a tabular mass trending north-northwest for about 8 mi (13 km) from near Argosy Creek. The body appears to dip toward the northeast.

A magnetic high centered near the site of Muldoon does not appear to be produced by the underlying volcanic rock. This anomaly suggests that an intrusive mass underlies the floor of the canyon at a relatively shallow depth.

Extending northwest from Smiley Mountain is a magnetic high produced by the Lake Creek stock. The form of the anomaly indicates that the sides of the mass are steep and, on the southwest side, nearly vertical. The stock appears to underlie the volcanic rocks at Smiley Mountain and the volcanic and sedimentary rocks along the ridge between Muldoon Canyon and Lake Creek. The small outcrop of intrusive rock near the mouth of Muldoon Canyon is near the northwest end of the main mass.

Northeast of Copper Basin, near Lime Mountain, is a large magnetic high produced by an intrusive body that lies outside the study area.

The eastern part of the intrusive complex of the Pioneer window produces an extensive and complex magnetic high. Over the gneiss dome within the intrusive complex the magnetic intensity is low relative to the areas of outcropping intrusive rock. The magnetic data suggest that the intrusive complex underlies the gneiss at relatively shallow depths east of Left Fork Wildhorse Creek and may underlie all of the gneiss dome at greater depth. Most of the local magnetic relief within the intrusive complex appears to reflect topography, as magnetic highs occur over the highest terrain. A possible exception is the magnetic low near the head of Fall Creek, which appears to reflect a less magnetic zone within the intrusive, an area where exposed intrusive rock is relatively thin, or an unmapped inclusion of granitic gneiss. The magnetic anomaly indicates that the intrusive mass locally extends beyond the exposed contacts on the south and southwest. A steep southeast-dipping to near-vertical contact is indicated on the southeast, and a south-dipping contact on the north.

The two elongated northwest-trending magnetic highs over the intrusive belt west of the gneiss dome are of lower amplitude than those over the larger, more felsic eastern part. The difference in magnetic expression is compatible with (but does not prove) the interpretation that the eastern and western parts of the intrusive complex of the Pioneer window represent two different intrusive phases. The form of these anomalies in the western intrusive belt and their lower amplitude suggest that the mass is relatively thin, especially in the arm crossing Wildhorse Creek. The horizontal extent of the mass appears to be about the same as the exposed extent. Magnetic relief over the mass reflects surface topography and the corresponding variation in thickness of the mass. No magnetic expression of the small intrusive 1.2 mi (2 km) to the south is apparent.

The extensive magnetic high over the Summit Creek stock suggests a domelike, northwest-plunging intrusive extending about 8 mi (13 km) northwest of the outcrop and centered about a mile (1.6 km) west of the largest outcrop. In the headwaters of the North Fork Big Lost River, several small intrusive bodies (North Fork dike complex) crop out near the northwest end of the magnetic high. These rocks may contribute to the magnetic high, but the largest outcrop has ı o magnetic expression and the main mass producing the anomaly is several thousand feet (about a thousand meters) below the surface.

The remaining large anomalies in the study area appear to be caused by Tertiary volcanic rocks. These anomalies reflect the thickness and elevation of the volcanics and are either highs or lows depending on the direction of remanent magnetization.

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A Geological and Geochemical Evaluation of the Mineral Resources of the Boulder-Pioneer Wilderness Study Area, Blaine and Custer Counties, Idaho

By FRANK S. SIMONS, U.S. GEOLOGICAL SURVEY

MINERAL RESOURCES OF THE BOULDER-PIONEER WILDERNESS STUDY AREA, BLAINE AND CUSTER COUNTIES, IDAHO

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HISTORY AND PRODUCTION

Little mining has been done within the study area, but the adjoining regions have a long history of sporadic mining activity that started with the discovery in 1879 of the Galena mine west of Bellevue and, more importantly, the discovery of the nearby Minnie Moore mine in 1880 (Ross, 1963, p. 1). In the early 1880's, discoveries were made in the Warm Springs, Mineral Hill, Little Wood River, Copper Basin, Alder Creek, and Alta (spelled Alto in some reports) districts (pl. 1). Combined production from these districts is valued at more than $65 million.

Much of the silver and lead and some gold from the Wood River region were produced between 1881 and 1891. During each year of that period, production was valued at more than $1 million (Umpleby and others, 1930, p. 82), mostly from the Mineral Hill district. Between 1880 and 1901, production from the Mineral Hill district totaled more than $16 million, and that from the Warm Springs district more than $3 million. Between 1902 and 1926, production of silver, lead, zinc, copper, and gold from Mineral Hill was $3,621,000, and from Warm Springs, $4,302,000 (Umpleby and others, 1930, p. 84). The most productive mine was the Minnie Moore in the Mineral Hill district, which from its discovery in 1880 until 1941 yielded about $9 million, mostly in silver and lead (Anderson, 1950, p. 10). Between 1936 and 1948, the Triumph mine in the Warm Springs district produced slightly more than 1 million tons (900,000 t) of ore having an estimated value of about $8 per ton

(Kiilsgaard, 1950, p. 47). The Queen of the Hills mine (later called the Silver Star–Queens) in the Mineral Hill district is reported to have produced $2.5 million (Anderson, 1950, p. 18), and the Mascot mines on the edge of the study area on East Fork Wood River produced lead and silver worth $200,000. Mineral deposits in both these districts are mainly quartz-carbonate-sulfide (galena-sphalerite-tetrahedrite-pyrite) veins in black argillite of the Milligen Formation and, to a lesser extent, in diorite and in sedimentary rocks of the Wood River Formation. Total production from the Warm Springs district was about $32 million, and that of the Mineral Hill district was about $16 million.

The potential of the Alder Creek district was discovered in 1884, and from 1901 until 1962 the district produced 57 million pounds (26 million kg) of copper (Vhay, 1964, p. 70) as well as appreciable amounts of silver, lead, and gold (Nelson and Ross, 1968, p. A29–A30). The principal mine, the Empire, was productive mainly between 1903 and 1930 and between 1939 and 1942; this mine yielded $12.7 million between 1912 and 1928 (Ross, 1930, p. 7). The ore deposits are irregular pipelike bodies of chalcopyrite and magnetite in granite porphyry, skarn, garnetite, and limestone. Total production of the district has been about $15.7 million.

Development of the Copper Basin district began in the 1880's, and the principal mine, the Copper Basin or Reed and Davidson, was located in 1888 (Umpleby, 1917, p. 103). Most of the production, about 200,000 lb (90,000 kg) of copper, has come from the Copper Basin mine (Vhay, 1964, p. 71). The ore bodies are in quartzite and limestone intruded by aplite and granite porphyry, and are highly oxidized. Silver and lead valued at about $50,000 came from a quartz-sulfide vein in quartzite at the Star Hope mine (Umpleby, 1917, p. 105).

The Little Wood River district, active since 1881, has yielded a small production of silver, lead, zinc, copper, and barite. The principal mine, the Muldoon (or Solid Muldoon) produced about $200,000 in silver by 1910 (Umpleby, 1917, p. 106) from replacement deposits along the bedding of quartzite and slate, and the Eagle Bird mine has had a production of about $130,000. Both the Eagle Bird and Idaho Muldoon mines had a small production during the 1940's (Anderson and Wagner, 1946, p. 14). Production of barite from the Muldoon barium mine was 2,400 tons (2,180 t). Total production of the district is somewhat more than $330,000.

The Alta mining district comprises several small and widely scattered mines and prospects in the drainage basins of Phi Kappa, Park, Little Fall, Big Fall, and Wildhorse Creeks (Umpleby and others, 1930, p. 203–208). The earliest prospecting apparently was in the 1890's. About $174,000 worth of lead, zinc, and silver contained in about 9,400 tons (8,530 t) of ore has come from replacement deposits in garnetized limestone at the Phi Kappa mine on Phi Kappa Creek. The Wildhorse tungsten deposits on Wildhorse Creek were discovered in 1953 (Cook, 1956, p. 12) and have yielded 118,000 lb (53,100 kg) of tungsten valued at $459,000. Total production from the district has been more than $640,000.

Three small mining areas, Antelope, Era, and Lava Creek, known collectively as the Lava Creek district (Anderson, 1929), are for the most part 5–15 mi (8–24 km) southeast of the study area; only a small part is shown on plate 1. Almost all the production from the district was made during the period 1884–1886, and values totaled about $500,000. In the Antelope area, the Antelope or Lead Belt mine has yielded a small production of silver and lead from veins in limestone and shale; it was being explored at the time of this study. Mines near the abandoned settlement of Era on Champagne Creek have produced perhaps $300,000 in silver from oxidized parts of veins in volcanic rocks; most production came from the Hornsilver mine. Mineral deposits in the Lava Creek area are lead-silver veins in volcanic rocks; the Hub mine produced $90,000.

SAMPLING AND ANALYTICAL PROGRAM

The geochemical sampling program of the U.S. Geological Survey consisted of the collection of 2,095 samples comprising 1,151 stream-sediment samples, 161 soil samples, and 783 rock samples (pl. 4).

Stream-sediment samples generally were collected at stream junctions and at intervals of no more than 1 mi (1.6 km) along streams that had only small or no tributaries. Most samples as collected weighed from 4 to 8 oz (110 to 220 g). All were dried and screened, and the minus-80-mesh fraction was analyzed by atomic absorption for zinc and gold; some samples also were analyzed by the same method for antimony, mercury, and tungsten. Five test samples were analyzed for citrate-soluble copper and for heavy metals. Uranium and thorium were measured in 156 samples by a neutron-activation method. All samples were analyzed semiquantitatively by emission spectrography for 30 elements; these elements, their chemical symbols, the lower limits of detectability, and abundances in some rock types are given in table 2. The quantity of each element in stream-sediment samples is contributed by two sources: rock particles making up the sample and material formerly in solution that has been adsorbed on the surfaces of these particles or possibly precipitated. For geochemical sampling, adsorbed materials are of particular interest because of the possibility that elements weathered from potentially valuable mineral deposits may thus be concentrated and more readily detected; hence, the most effective absorbents—clay- and silt-sized particles and organic muck—were sought preferentially. In some drainages, no sediment finer than sand was available, and in others no obvious stream-deposited sediment was found.

TABLE 2.—*Names, chemical symbols, lower limits of detectability, and abundances in some rock types of elements determined by the semiquantitative spectrographic method used in analyzing samples from the Boulder-Pioneer wilderness study area*

[In parts per million, except where indicated by asterisk (*), in percent, leaders (- -), not determined]

Element	Abundance				
	Lower limit of detect-ability	Continental crust (Taylor, 1964)	Shale (Turekian and Wedepohl, 1961)	Black shale in U.S. (Vine and Tourtelot, (1970)	Igneous rocks (Rankama, 1954)
Ca	*0.05	*4.15	*2.21	*1.5	*3.63
Fe	* .05	*5.63	*4.72	*2	*5
Mg	* .02	*2.33	*1.50	* .7	*2.09
Ti	* .002	* .57	* .46	* .2	* .44
Mn	10	950	850	150	1,000
Ag	.5	.07	.07	<1	.1
As	200	1.8	13	--	5
Au	10	.004	[a] .00X	--	.005
B	10	10	100	50	3
Ba	20	425	580	300	1,000
Be	1	2.8	3	1	2
Bi	10	.17	--	--	.2
Cd	20	.2	.3	--	.15
Co	5	25	19	10	23
Cr	10	100	90	100	200
Cu	5	55	45	70	55
La	20	30	92	30	18.3
Mo	5	1.5	2.6	10	2.5
Nb	20	20	11	--	24
Ni	5	75	68	50	80
Pb	10	12.5	20	20	15
Sb	100	.2	1.5	--	[b] 1(?)
Sc	5	22	13	10	20
Sn	10	2	6	--	40
Sr	100	375	300	200	220
V	10	135	130	150	150
W	50	1.5	1.8	--	1.5
Y	10	33	26	30	28.1
Zn	200	70	95	<300	111
Zr	10	165	160	70	185

[a]Order of magnitude estimate.

[b](?) not explained by Rankama (1954).

The mean content of various elements in stream-sediment samples from a given basin presumably is to some extent a measure of the amounts of these elements in the rocks underlying the basin. The abundant rock types of the Boulder-Pioneer study area are shale, sandstone, intermediate volcanics, and quartz monzonitic rocks; less abundant rocks are carbonates, silicic volcanic and dike rocks, and granitic gneiss. Among these rocks, shales ordinarily are richest in metals such as copper, lead, molybdenum, silver, vanadium, and zinc; intermediate volcanics and plutonic rocks are somewhat poorer; and sandstone and carbonate rocks are poorest (Parker, 1967, p. D13–D14, table 19). Twenty-nine drainage basins in the study area are illustrated in figure 10; the variations from basin to basin in amounts of the above-mentioned metals in stream-sediment samples are shown graphically in figure 11. (Basins M, U, and 6 are not included because only a few samples were collected from them.) The average combined contents (geometric means) of copper, lead, and zinc in samples from the basins, as well as the principal rock units underlying each basin, are given in table 3. Vanadium is not included in table 3 because the average vanadium content does not vary as markedly as might be expected in view of its wide range in average rocks (from 130 ppm in shales to 20 ppm in sandstone and carbonate rocks). Molybdenum and silver are excluded because they were detected in so few samples (less than one-third) that their average contents are not known. (These two metals vary rather similarly from basin to basin except for basins Q, N, W, and H.) Of the ten basins that yielded the most metal rich samples, as defined in table 3, all but two (basins I and N) are underlain in considerable part by rock units that contain appreciable amounts of fine-grained dark-colored sedimentary rocks that are grouped for convenience herein as black shale. On the other hand, basins A and 2, whose samples are lower in combined metal content, are also underlain extensively by black shale-rich units. The correlation between metal-rich stream-sediment samples and abundance of black shale in source areas is, of course, not perfect—all black shale units do not have the same or nearly the same metal contents, nor do they necessarily contain more copper, zinc, or especially lead, than any igneous rock unit (see table 9)—but some sort of relationship does appear to exist.

In order to determine, if possible, the mode of occurrence of certain metals in stream sediments, five large samples were collected at sites that previously had yielded samples containing highly anomalous amounts of zinc and less anomalous amounts of copper, molybdenum, and vanadium. The samples were collected from three drainage basins (Milligan Gulch, Federal Gulch, and Timber Draw) that were not known to have mineral deposits. Each sample was split into +80- and −80-mesh portions, and each split was analyzed colorimetrically for citrate-soluble copper and heavy metals (Ward and others, 1963, p. 27–29), by atomic absorption for zinc, and spectrographically for all the metals. Analytical results are given in table 4.

Table 4 shows that (1) citrate-soluble copper and heavy metals (mostly zinc) are consistently two to three times higher in the −80-mesh fraction than in the +80-mesh fraction, as would be expected if

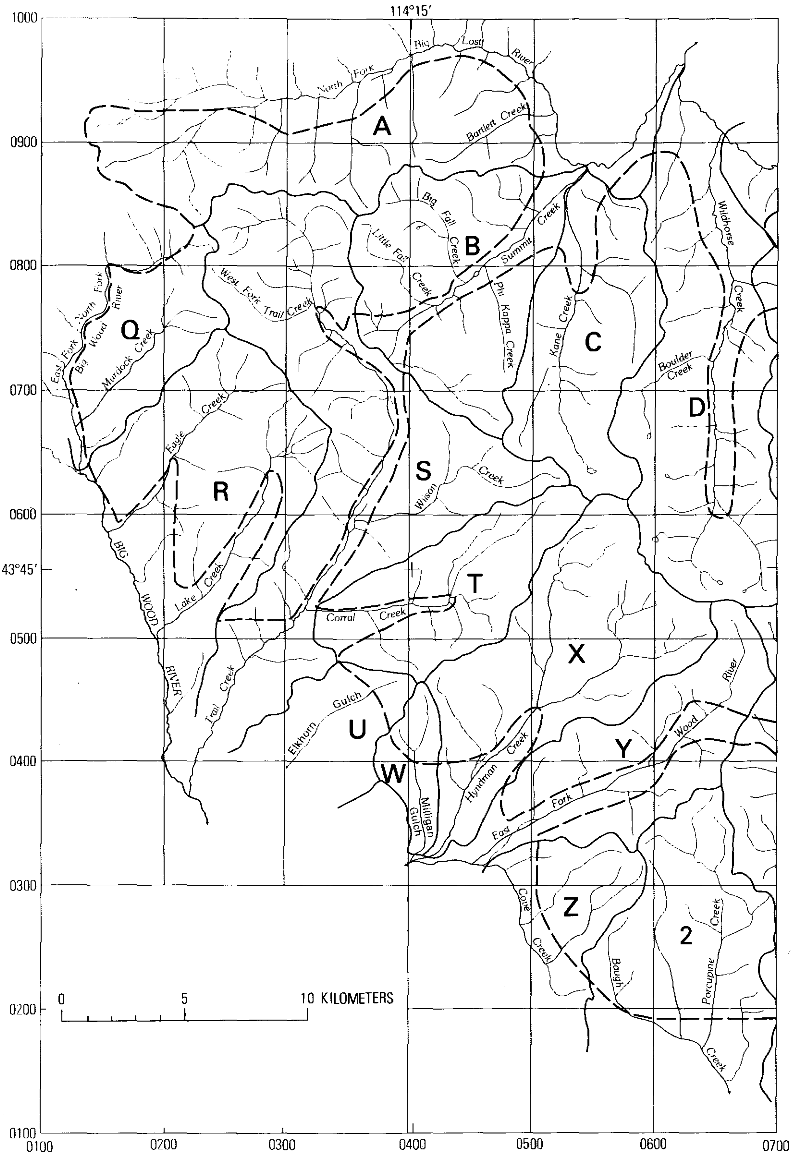
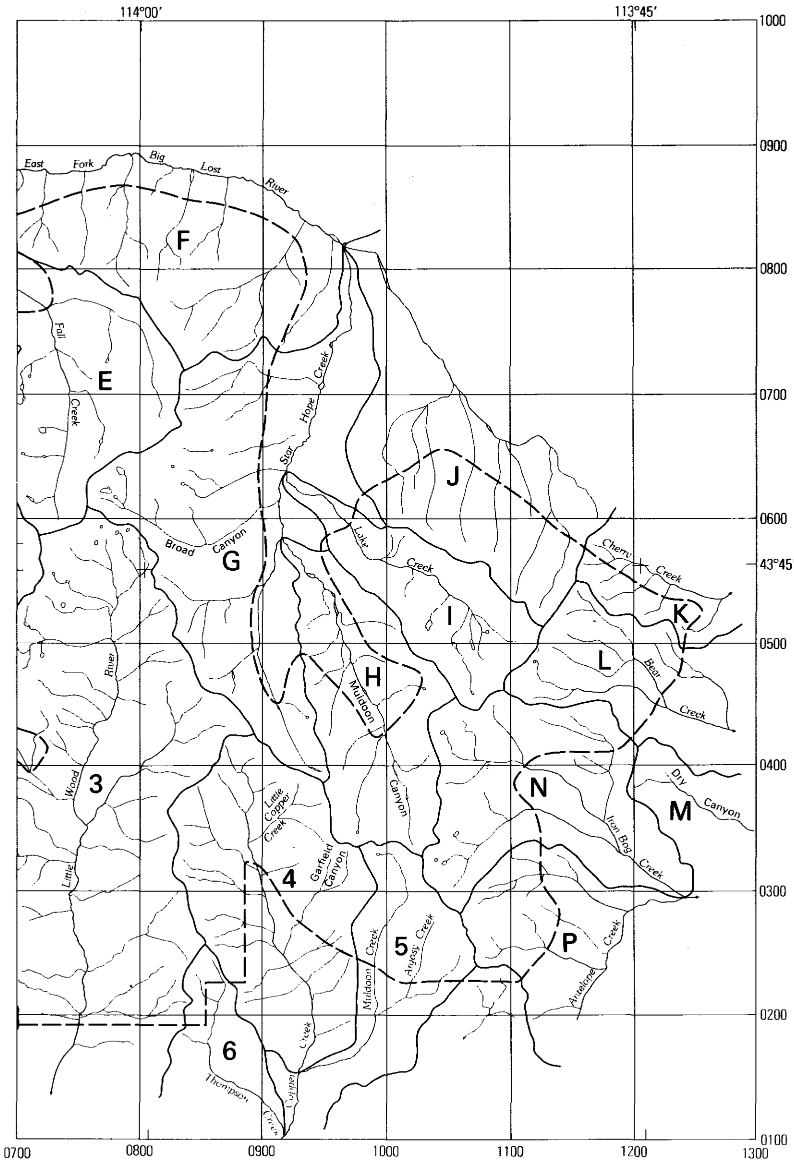


FIGURE 10.—Principal streams and drainage basins of the Boulder-Pioneer study area. Grid is in units of 5,000 m; origin of grid is at lat 43°30′ N., long 114°30′ W. Heavy solid line, study area outline. Dashed outlines indicate boundaries of basins, designated by letter or number.

A, North Fork Big Lost River
B, Summit and Phi Kappa Creeks
C, Kane Creek
D, Wildhorse Creek
E, Fall Creek

F, East Fork Big Lost River (lower part)
G, Star Hope Creek
H, Muldoon Canyon
I, Lake Creek (Copper Basin)
J, East Fork Big Lost River (upper part)



K, Cherry Creek
L, Bear Creek
M, Dry Creek
N, Iron Bog Creek
P, Antelope Creek
Q, North Fork Big Wood River and Murdock Creek
R, Big Wood River and Eagle and Lake Creeks
S, Trail and Wilson Creeks
T, Corral Creek
U, Elkhorn Gulch
W, Milligan Gulch
X, Hyndman Creek
Y, East Fork Wood River
Z, Cove Creek
2, Baugh and Porcupine Creeks
3, Little Wood River
4, Copper Creek
5, Muldoon Creek
6, Thompson Creek

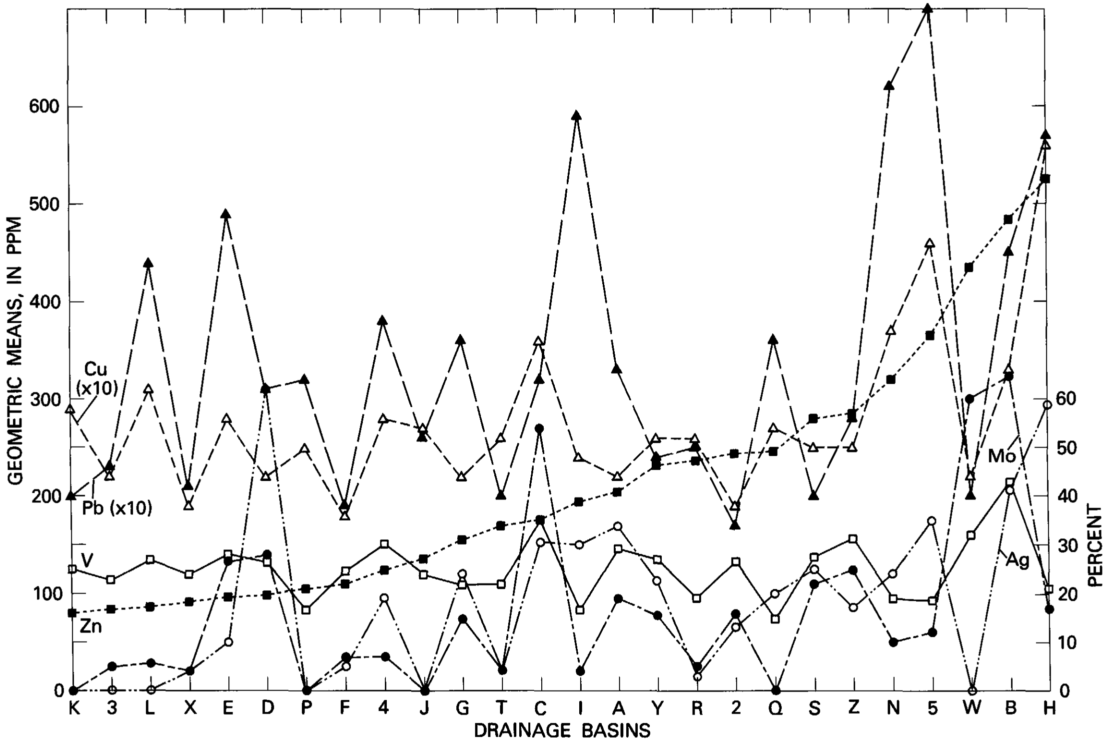


FIGURE 11.—Graph showing contents of selected elements in stream-sediment samples, by drainage basin. (See figure 10.) Ordinates for copper, lead, vanadium, and zinc (left-hand scale) are geometric means, in ppm; those for molybdenum and silver (right-hand scale) are percentages of samples in each basin that contain at least 0.7 ppm silver or 7 ppm molybdenum (one reporting interval above the detection limit for these elements). Basins are arranged from left to right in order of increasing average zinc content. Zinc analyzed by atomic absorption; other elements analyzed spectrographically.

TABLE 3.—*Combined contents of copper, lead, and zinc, in ppm, in stream-sediment samples, by drainage basin in order of decreasing metal content*

Basin	Number of samples	Combined[1] metal content	Principal rock units[2] underlying basin
H	29	641	Mcu; Mc; Tc.
B	54	560	Mc; SOtp, DSsa; Mcc, Tei.
5	17	521	Mcu; Mc; Dm; Mcd; Tc.
W	9	480	Dm.
N	21	420	Tc; Mcu.
Z	24	337	Dm; Tc; PPw.
S	126	325	PP; SOtp; DSsa; Dm.
Q	30	311	PPw; Dm.
R	151	290	PPw; Dm; Tc.
Y	44	281	Dm; PPw, Oe, Oh.
2	31	279	Dm; PPw; Tc.
I	23	278	Tei; Tc; Mcu.
A	89	269	Mc; DSsa; SOtp; Tc; PPw.
C	35	245	Mc; Tc; Tei; p€w.
T	25	214	PPw; Dm; Oe, Oh.
G	71	214	Mc; Tc, Tei.
4	67	191	Tc; Dm; Mc; Mcc, Mcd; Mcu; Tei.
J	19	188	Tc.
E	48	177	Tei; Mc, Mcd; Tc.
P	10	172	Tc; Mcu.
L	18	162	Tc.
D	81	153	p€w; Tc; Mc; Mcd, Mcc.
F	40	147	Tc; Mcu, Mcd.
X	72	132	Oe; Oh; Dm; PPw; Tc.
K	13	131	Tc.
3	153	130	Tc; PPw; Tei.
Total--	1312	220	

ROCK UNIT DESCRIPTIONS

Tc - Tertiary Challis Volcanics--andesitic to rhyolitic volcanics.
Tei - Tertiary (Eocene) intrusive rocks--quartz monzonitic stocks.
PPw - Permian and Pennsylvanian Wood River Formation--calcareous sandstone, some shale.
Mississippian Copper Basin Formation
  Mcu - Upper clastic unit of Copper Basin plate--sandstone, some black shale.
  Mc - Glide Mountain late--sandstone and black shale.
  Mcd - Drummond Mine Limestone Member--limestone.
  Mcc - Little Copper Member--black shale.
Dm - Devonian Milligen Formation--mainly black shale.
DSsa - Unnamed Devonian and Silurian unit--siltstone and black shale.
SOtp - Ordovician and Silurian Phi Kappa and Trail Creek Formations--mainly black shale.
Metasedimentary rocks
  Oe - Ordovician East Fork Formation
  Oh - Ordovician and(or) older Hyndman Formation.
p€w - Precambrian gneiss complex of Wildhorse Creek--mainly granitic gneiss.

[1]Sum of geometric means of copper, lead, and zinc. Copper and lead analyzed spectrographically; zinc analyzed by atomic absorption.

[2]Areally most abundant units are underlined.

TABLE 4.—*Copper, molybdenum, vanadium, zinc, and heavy metal content, in parts per million, of two size fraction samples of stream sediment*

[Semiquantitative spectrographic analyses unless otherwise stated. Sample numbers in parentheses are of original samples collected at the same localities. N, not detected; - -, no analysis made; *, colorimetric analysis for citrate-soluble copper or heavy metals; **, atomic absorption analysis]

Sample No.	Location	Principal rock units of drainage	Size fraction	Copper	Copper*	Molybdenum	Vanadium	Zinc	Zinc**	Heavy metals*
4370	Milligan Gulch------	Dm[1]	+80	30	N	20	150	700	480	45
4370	-----do-------------	Dm	-80	20	N	20	150	500	590	80
(0746)	-----do-------------	Dm	-80	20	--	15	150	700	520	--
4371	Lower Timber Draw---	Dm	+80	50	4	20	700	1,000	840	90
4371	-----do-------------	Dm	-80	100	10	20	700	1,500	1,200	+90
(0791)	-----do-------------	Dm	-80	20	--	5	150	300	390	--
4372	Upper Timber Draw---	Dm	+80	70	3	15	500	700	530	50
4372	-----do-------------	Dm	-80	70	10	20	300	1,000	870	90
(0789)	-----do-------------	Dm	-80	70	--	15	500	1,000	1,500	--
4373	Upper Timber Draw---	Dm	+80	70	10	30	1,000	1,000	870	90
4373	-----do-------------	Dm	-80	100	20	30	1,000	1,000	1,200	+90
(0790)	-----do-------------	Dm	-80	70	--	15	500	1,000	1,200	--
4374	Upper Federal Gulch-	Dm	+80	30	5	10	300	300	340	35
4374	-----do-------------	PPw[2]	-80	50	10	7	200	500	500	90
(0792)	-----do-------------	PPw	-80	30	--	20	300	700	820	--

[1]Milligen Formation.

[2]Wood River Formation.

they occur largely as metals adsorbed on mineral grains; (2) total zinc as determined by atomic absorption is also consistently higher in the fine fraction, although by less than 50 percent in all but one sample; (3) spectrographically determined copper and zinc are slightly higher in the fine fraction, whereas molybdenum and vanadium are essentially the same in both size fractions; and (4) about 10 percent of the total zinc and between 10 and 20 percent of the total copper are citrate soluble, the citrate-soluble metal content thus being approximately proportional to the total metal content. These results indicate that the −80-mesh component of stream sediments is more metal rich than the +80-mesh fraction, although the difference does not appear to be entirely due to adsorbed (citrate-soluble) metal. All three drainage basins are underlain largely by sedimentary rocks that include much black shale, but none of 25 rock samples collected in these basins contained detectable zinc (200 ppm or more), and only three contained more than background amounts of either copper or molybdenum. If these samples are representative of the rocks in the basins, then some kind of concentration apparently has occurred whereby the stream sediments now contain amounts of zinc (and molybdenum) at least several times higher than their parent rocks; this concentration, however, is only partly reflected by the amount of zinc that is citrate soluble. On the other hand, the rock samples may not be entirely representative of the respective drainage basins, and the anomalous metal contents may indicate mineralization, mainly of zinc, in one or more of the basins.

The density of stream-sediment sampling—the number of samples per unit area—depends on the nature of the drainage patterns and the availability of suitable material, and therefore is not uniform over the entire study area. The average sample density is about 2.6 per mi^2 (1 per km^2).

Rock samples comprised 160 samples of visibly altered or mineralized rock and 623 samples of apparently typical or unaltered rock. Samples weighed from 0.5 to 1 lb (0.25 to 0.5 kg). Samples of typical rock were collected in an attempt to establish a minor-element "signature" for the various rock units. All rock samples were analyzed spectrographically for 30 elements, and equivalent uranium (eU) was measured on 57 samples by a radioactivity scanning method. Samples of mineralized or otherwise altered rock were collected mainly from outcrops, and the most heavily iron stained or otherwise most strongly altered material was selected; all were analyzed by atomic absorption for gold and zinc, and some were analyzed similarly for antimony, arsenic, mercury, and silver.

We have relied heavily on semiquantitative spectrographic analyses of samples. As table 2 shows, the sensitivity of this method is quite adequate for many elements likely to be of interest in geochemical exploration. The most obvious exceptions are arsenic and zinc (detection limit

200 ppm), antimony (detection limit 100 ppm) and gold (detection limit 10 ppm). In addition, mercury is too quickly volatilized for even semiquantitative spectrographic measurement, and spectrographic sensitivities for uranium and thorium are very poor (detection limit for both elements is 100–200 ppm). In order to partly overcome these deficiencies in the spectrographic method, atomic-absorption analyses for several elements were made on selected samples. All samples of stream sediment, soil, and mineralized or altered rock were analyzed for gold (detection limit 0.05–0.1 ppm) and zinc. In addition, 141 stream-sediment samples were analyzed for antimony, but amounts found were so small (maximum 8 ppm) that routine analyses for this element were not made. Mercury was analyzed in 81 rock samples, mostly of mineralized rock, but amounts of more than 2 ppm were found in only 11 samples, all of which contained lead, zinc, lead and zinc, or lead, zinc, and copper minerals; no other analyses were made. Analyses of 22 rock samples for arsenic showed that in the 5 samples that contained 120 ppm or more, arsenic could be detected spectrographically and the spectrographic determinations agreed very closely with atomic absorption analyses, whereas for the 17 samples containing 60 ppm or less, no arsenic was detected spectrographically; we concluded that the additional information provided by the atomic-absorption analyses did not justify the expense and no more analyses were done.

A comparison of the two analytical methods for zinc showed that for 564 stream sediment and soil samples (of a total of 1,279) in which zinc was detected spectrographically, including amounts reported as L (detected but below the limit of determination), the spectrographically determined amount in 62 percent of the samples differed by only one reporting interval or less from the amount measured by atomic absorption and differed by two reporting intervals or less in 91 percent of the samples (spectrographic reporting intervals for zinc are, in ppm, L–200–300–500–700–1,000–1,500–2,000 and so on). Therefore semiquantitative spectrographic analysis is sufficiently accurate for determination of total zinc in areas of relatively high zinc background. However, of the 715 stream-sediment samples in which no zinc was detected spectrographically, 320, or 45 percent, were reported to contain 100–200 ppm zinc by atomic absorption analysis, so that the spectrographic method appears to be only marginally useful in areas in which anomalous zinc contents may be of the order of 100–200 ppm; and of course it is virtually useless in areas of very low zinc background, in which anomalous samples might contain less than 100 ppm zinc.

The following terms are used in the discussion of geochemical data in this report. *Background* is the range of amounts of a given element that is expectable or normal for a given kind of sample in a given area and comprises amounts less than a selected maximum, or *threshold* value. Samples that contain the threshold amount or more of an element are defined as *anomalous*. The threshold value may be specified in several ways. It may be set simply at an amount that would be attained in an arbitrarily determined percentage of samples; for example, for a lognormally distributed sample population it might be taken as the geometric mean multiplied by the square of the geometric deviation, and would be attained by about 2.5 percent of the samples. For a mixture of two or more geochemical populations such as, for example, materials derived from a mineralized area of relatively small extent—an ore deposit—mixed with materials of background composition derived from a broad area, a threshold may be determined by plotting a cumulative frequency curve on a probability graph. For a single lognormally distributed population, this curve will be a straight line, but if two populations are present, then the curve will be sigmoidal in form, will be tangent at each end to theoretical straight lines representing the two populations, and will have an inflection point midway between these lines. The high-value end of the sigmoidal cumulative curve is, of course, the part of interest in geochemical exploration, and a threshold may be defined conveniently as the value at which the slope of the curve changes because the number of high values is greater than the probable number in a single population (Lepeltier, 1969; Wedow and others, 1975). Other more rigorous methods for determining this threshold that are based on deriving the two individual population curves are discussed by Sinclair (1974) and Parslow (1974).

Cumulative frequency curves showing the distribution of contents of barium, boron, chromium, copper, lead, manganese, nickel, vanadium, and zinc in stream-sediment samples from the Boulder-Pioneer study area were plotted on log probability paper to see whether a graphical method for determining thresholds might be applicable to the entire study area (fig. 12). The curves for barium, boron, chromium, manganese, nickel, and vanadium do not depart notably from straight lines except at the low-value ends of the chromium, nickel, and vanadium curves, indicating that the distribution for these elements is approximately lognormal. The curve for copper departs somewhat more, and those for lead and zinc depart widely from straight lines. None of the curves, moreover, shows any tendency toward a sigmoidal form, and they do not serve to establish anomalous values of any of these elements over the entire study area. Such a result is not unexpected in view of the great diversity of source rocks, and consequently of geochemical background, in the area. The threshold values chosen for the geochemical maps are therefore to a considerable extent arbitrary; they are listed in table 5.

Two major creeks in the study area are named Lake Creek; in order to avoid confusion in the following discussions, they are referred to as Lake Creek (Big Wood River) and Lake Creek (Copper Basin), respectively.

The principal result of the sampling of stream sediments is the

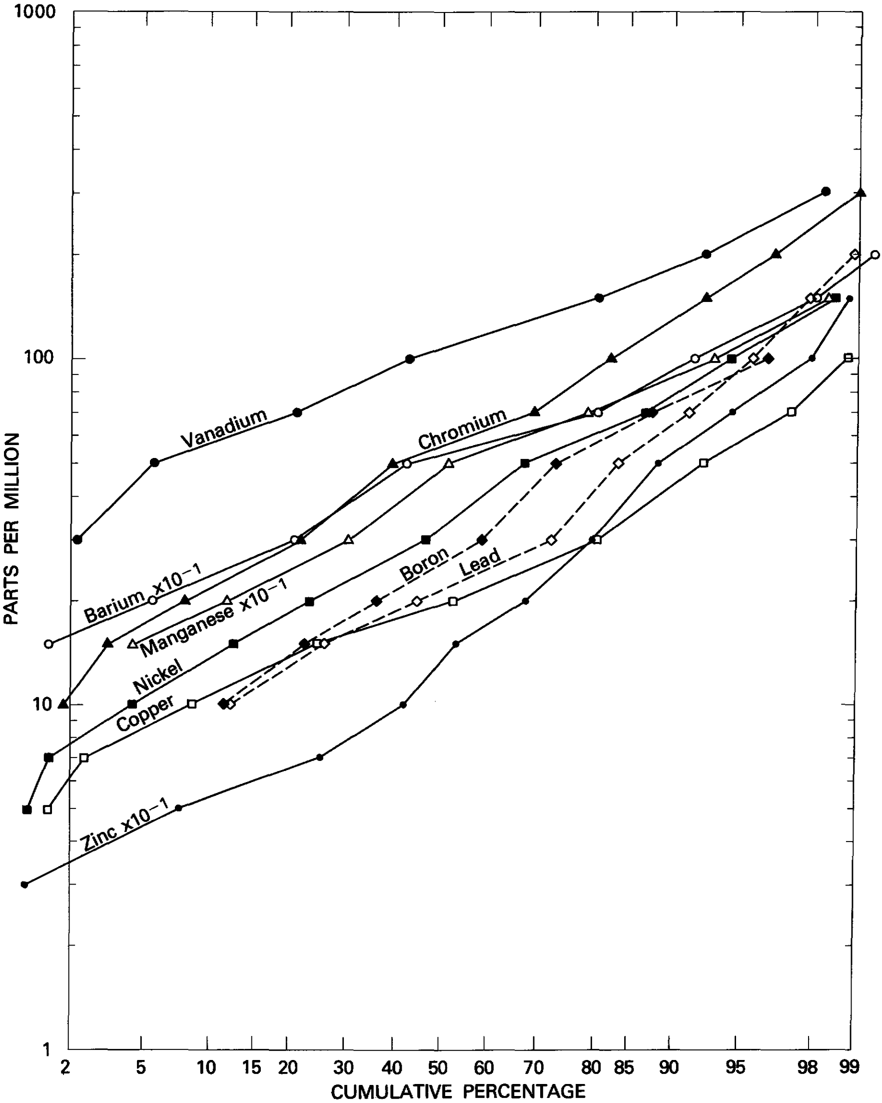


FIGURE 12.—Cumulative frequency curves showing distribution of contents of barium, boron, chromium, copper, lead, manganese, nickel, and vanadium in 1,312 stream-sediment samples (semiquantitative spectrographic analyses) and of zinc in 1,279 samples (atomic absorption analyses). Log probability plot.

recognition that anomalous amounts of several elements occur in many samples distributed over much of the study area and that they constitute widespread diffuse geochemical anomalies that are difficult to interpret. For instance, 32 percent of all samples contain at least 300 ppm zinc; 15 percent contain at least 7 ppm molybdenum (and 64 percent of these also contain 300 ppm or more zinc); 16 percent contain at

TABLE 5.—*Threshold values, in ppm, for selected elements in stream sediments, rocks, and mineralized rocks, Boulder-Pioneer wilderness study area, Idaho*

[L, detectable but below limit of determination shown in parentheses. N, not detected. Elements are listed in order of discussion in text]

Element	Stream sediment	Rock	Mineralized rock
Cu	70	70	70
Pb	100	70	100
Mo	10	7	7
Ag	1.5	.7	1.5
Zn	300	L(200)	100
Sb	N	100	100
As	200	200	200
Ba	2,000	2,000	2,000
Be	5	5	5
B	150	150	150
Cd	20	20	20
La	150	70	70
Nb	30	20	20
Bi	10	10	10
Sn	10	10	10
W	L(50)	L(50)	L(50)
Cr	200	200	200
Co	100	30	30
Ni	200	150	150
Au	L(0.05-0.1)	L(10)	L(0.05-0.1)
Mn	1,500	1,500	1,500
V	500	300	300

least 70 ppm lead; 7 percent contain at least 70 ppm copper; and 7 percent contain at least 300 ppm vanadium. Many of these samples reflect known mineralized areas in their respective drainage basins, and many others may owe their anomalous metal contents to an original high content in the source rocks (p. 106–115), but the abundance of certain elements in stream sediments points to several new areas of economic interest that merit some additional exploration; these areas are identified in the section on the various mineral commodities.

Sampling to obtain some idea of background contents of various elements in rock units of the study area was concentrated mainly on Paleozoic sedimentary rocks and Tertiary volcanic rocks, which together underlie more than three-fourths of the study area. Geochemical data on the Paleozoic rocks are discussed on pages 106–115, and those for four groups of igneous rocks are summarized in the accompanying table 9. Except for a somewhat higher than average content of barium in the volcanic rocks, none of the igneous rock averages differs much from those of Parker (1967, p. D13–D14).

Analytical data on 150 samples of mineralized or altered rocks appear in table 6. Most of these samples were of visibly mineralized rock from mines, prospects, or dumps and were collected mainly to determine whether any of the rarer elements such as bismuth, cadmium, gold, mercury, silver, or tin might be present. Findings on these and other elements are given in the respective sections on mineral commodities; in summary, although markedly high concentrations of many elements occur in various samples, most of the deposits sampled appear to be small and of little economic interest. However, the presence of mercury and other volatile elements in many of these samples suggests a possibly useful tool for prospecting in the study area. (See p. 166–167.)

GEOCHEMISTRY OF PALEOZOIC BLACK SHALES

Several elements of economic interest occur in anomalous amounts in many samples of both stream sediments and rocks from the study area. However, for most of these elements the samples appear to be widely dispersed rather than to be grouped so as to more or less clearly define geochemically anomalous areas that might warrant further exploration. A possible explanation for such diffuse geochemical anomalies is that some or all of the various anomalous elements are original constituents of, and were derived from, Paleozoic sedimentary rocks, which crop out over more than half of the study area.

The Paleozoic rocks are mainly fine- to coarse-grained siliceous clastic sediments. Rocks older than the Wood River Formation (Permian-Pennsylvanian) are dominantly fine grained and dark-colored rocks such as argillite, mudstone, siltstone, and shale; these rocks will be referred to collectively as black shale. The Ordovician, Silurian, and Devonian rocks (Phi Kappa, Trail Creek, and Milligen Formations and the unnamed Devonian and Silurian unit of pl. 2) are mainly black shale and have a combined thickness probably exceeding 5,000 ft (1,500 m). Rocks of the Mississippian Copper Basin Formation contain a much lower proportion of black shale; nevertheless, the formation contains at least 3,000 ft (900 m) of black shale in the Copper Basin area. The Wood River Formation contains many thin beds of black shale, particularly in its upper part, but in a total thickness of

9,800 ft (3,000 m) measured by Hall, Batchelder, and Douglass (1974), probably less than 100 ft (30 m) consists of black shale.

Shales have long been recognized as containing more of certain elements than most other sedimentary rocks; a comparison of the rare metal contents of shale, sandstone, and limestone-dolomite given by Krauskopf (1955, p. 416, table 1) shows that all the metals (except strontium) for which data are available are most abundant in shale. Among shales, the organic-rich black shales may have especially high amounts of many minor elements, from a few times to more than 100 times crustal abundance (Krauskopf, 1955, p. 417, table 2). Data assembled by Vine and Tourtelot (1970) on 779 samples of black shale, mostly from the United States, show that their average black shale has about the same minor element content as the average shale of Green (1959, table 2) or Turekian and Wedepohl (1961, table 2). However, many individual black shales are enriched by a factor of 2.5 or more in one or more of the 20 minor elements listed by Vine and Tourtelot (1970), notably manganese, boron, copper, lanthanum, nickel, and vanadium, and less notably, silver, molybdenum, and zinc among the elements discussed in this report. Of particular interest is sample set 4 of Vine and Tourtelot, their western facies or western assembly of Ordovician and Silurian black shales that includes samples from the Boulder-Pioneer study area; 12 percent of the 75 samples in this set are enriched in boron, 59 percent in barium, 9 percent in copper, 11 percent in lanthanum, and 17 percent in vanadium. All these elements except lanthanum are anomalous in many samples from the Boulder-Pioneer study area. On the other hand, the median zinc content of sample set 4 (less than 300 ppm) is the same as that for their average black shale; the median molybdenum content (less than 5 ppm) is below that of average black shale (10 ppm); and the median for lead (10 ppm) is only half that of average black shale.

Analytical data for 10 elements in 182 samples of black shale from the Boulder-Pioneer study area, together with the minimum enrichment value of Vine and Tourtelot (1970, p. 261–262; the content of a given element considered to define a metal-rich shale) are summarized in table 7. A single sample may be anomalous in several elements, and therefore the numbers of anomalous samples are not additive.

Table 7 shows that very few of the black shales of the Boulder-Pioneer area are enriched in any element, by the criteria of Vine and Tourtelot (1970); the only markedly exceptional element is barium, which is enriched in all samples that are anomalous in barium. Surprisingly, molybdenum is enriched in only three samples, and zinc in none, even though in the study area these metals occur in anomalous amounts in more samples of all kinds than any other element. In all, 71 samples are enriched in at least one of the elements of table 7; 56 of these are enriched only in barium, boron, or manganese, and the remaining 15

TABLE 6.—*Semiquantitative spectrographic analyses and chemical analyses of selected*

[s, semiquantitative spectrographic analysis; aa, atomic absorption; inst, instrumental analysis;

Sample	Mn-ppm s	Ag-ppm s	As-ppm s	B-ppm s	Ba-ppm s	Bi-ppm s	Cd-ppm s	Co-ppm s	Cr-ppm s	Cu-ppm s	La-ppm s	Mo-ppm s
0009	300	N	N	20	150	N	N	N	10	20	N	N
0019	500	.7	N	30	300	N	N	30	20	150	50	15
0042	50	N	N	N	150	N	N	N	10	5	N	N
0045	700	N	N	20	500	N	N	20	100	20	50	N
0046	300	N	N	30	700	N	N	15	150	50	30	5
0047	150	N	N	50	700	N	N	7	50	20	70	N
0050	150	N	N	50	700	N	N	5	70	20	50	N
0093	500	<.5	N	150	700	N	N	50	30	20	20	20
0189	150	.7	1,000	15	700	N	N	5	10	20	30	5
0190	100	.7	700	15	500	N	N	N	10	20	30	5
0219	1,500	70.0	200	10	3,000	150	N	5	100	500	30	10
0363	50	3.0	N	N	300	10	N	N	<10	30	70	N
0367	100	N	N	N	700	N	N	N	N	50	30	5
0388	70	.5	N	100	1,500	N	N	N	50	50	20	20
0420	70	N	N	N	150	N	N	N	20	5	N	15
0421	70	1.0	700	20	500	N	N	N	15	200	N	10
0478	200	100.0	N	<10	50	20	N	N	15	7,000	N	200
0507	3,000	3.0	N	10	700	N	N	10	50	2,000	N	N
0509	1,000	N	N	10	500	N	N	15	50	20	30	N
0511	50	N	300	30	700	N	N	N	10	70	N	5
0562	1,500	70.0	N	10	30	70	150	7	<10	500	N	30
0569	300	3.0	N	30	500	10	N	N	50	20	20	15
0632	700	2.0	>10,000	20	>5,000	N	N	<5	20	100	N	30
0661	>5,000	N	3,000	10	500	N	N	100	<10	15	50	70
0710	500	70.0	>10,000	20	300	N	150	N	10	1,000	50	N
0723	1,500	50.0	N	10	150	N	>500	150	30	150	70	5
0731	100	2.0	N	<10	1,500	N	N	N	15	100	20	N
0803	70	<.5	300	20	500	N	N	N	20	10	N	15
0805	150	.5	700	15	300	N	N	10	50	300	20	10
0829	150	N	1,000	50	200	N	N	5	50	20	N	N
0832	100	<.5	200	10	100	N	N	<5	15	20	30	N
1767	>5,000	N	N	N	50	N	N	30	15	700	N	N
2006	70	N	N	N	70	N	N	N	N	15	<20	N
2014	>5,000	N	N	N	150	N	N	30	30	20	N	N
2017	>5,000	<.5	700	N	700	N	N	7	N	20	N	N
2060	100	10.0	300	N	50	N	30	N	N	30	N	N
2074	1,000	150.0	700	N	70	20	N	N	<10	1,500	N	N
2075	100	<.5	N	N	30	N	N	N	N	20	N	N
2083	1,500	1.5	N	30	70	<10	N	N	N	700	N	N
2092	50	150.0	1,000	N	100	N	50	N	N	2,000	N	30
2093	150	2.0	N	N	200	N	20	N	30	500	20	N
2102	>5,000	N	N	20	N	N	N	30	N	30	N	N
2103	>5,000	<.5	7,000	N	N	N	N	N	N	15	N	N
2115	1,000	700.0	5,000	30	500	N	>500	<5	30	15,000	N	N
3101	300	2.0	N	30	300	N	30	5	70	20	20	15
3102	500	N	N	10	500	N	N	N	15	30	150	5
3104	50	N	N	N	300	N	N	N	10	30	N	N
3105	70	.5	N	50	700	N	N	7	20	50	N	5
3123	100	50.0	N	N	2,000	50	N	N	30	1,500	N	300
3227	70	N	N	N	300	N	N	N	10	20	N	N
3293	50	N	N	20	1,000	N	N	N	15	50	N	N
3359	150	.7	N	N	500	N	N	30	100	70	N	10
3372	3,000	3.0	2,000	N	500	N	N	10	70	70	20	N
3379	70	N	N	10	700	N	N	N	150	20	N	N
3386	300	N	N	30	300	N	N	N	20	5	N	N
3387	70	N	N	50	700	N	N	N	30	10	N	N
3390	2,000	N	N	<10	100	N	N	15	15	30	20	15
3392	3,000	N	N	15	150	N	N	20	15	5	70	N
4042	100	N	N	10	500	N	N	20	15	50	N	100
4043	70	N	N	10	700	N	N	N	15	20	30	N
4087	500	N	N	15	1,000	N	N	5	30	10	N	N
4089	30	N	N	30	700	N	N	5	30	50	N	15
4094	150	N	N	10	200	N	N	100	10	15	N	70
4099	30	N	N	30	700	N	N	N	20	15	50	N
4100	50	N	N	70	200	N	N	N	10	<5	N	N
4101	50	1.5	N	1,000	1,000	N	N	N	70	5	N	N
4114	700	N	N	10	1,500	N	N	10	30	30	30	N
4115	150	.7	N	15	1,000	<10	N	5	30	30	50	50
4116	100	.5	N	30	3,000	N	N	N	20	20	30	N
4117	300	N	N	20	1,500	N	N	7	30	30	30	N
4118	300	N	N	30	700	N	N	7	30	10	20	N
4119	200	N	N	30	1,500	N	N	5	30	50	N	N
4120	700	N	N	10	1,000	N	N	10	30	30	30	N
4121	700	N	N	20	700	N	N	20	70	50	70	N
4122	700	N	N	20	300	N	N	15	30	20	N	N

elements in 150 samples of mineralized or altered rock, Boulder-Pioneer study area

N, not detected; leaders (--), no analysis; <, less than; >, greater than; ppm, parts per million]

Sample	Ni-ppm s	Pb-ppm s	Sb-ppm s	Sn-ppm s	Sr-ppm s	V-ppm s	Y-ppm s	Zn-ppm s	Au-ppm aa	Hg-ppm inst	Zn-ppm aa
0009	15	10	N	N	N	20	N	N	N	.02	80
0019	50	50	N	N	N	100	30	N	N	.08	50
0042	15	N	N	N	N	30	N	300	N	.04	400
0045	70	20	N	N	N	150	15	N	N	.35	50
0046	70	10	N	N	N	100	10	N	N	.14	40
0047	15	10	N	N	N	100	10	N	N	.90	40
0050	20	15	N	N	100	70	<10	N	N	.65	40
0093	200	10	N	N	100	100	15	500	N	.10	800
0189	10	10	N	N	100	70	10	N	--	--	--
0190	5	<10	N	N	N	70	10	N	--	--	--
0219	30	3,000	N	70	N	150	15	700	N	.30	390
0363	<5	1,000	N	N	200	30	10	N	--	--	--
0367	7	20	N	N	150	30	N	N	N	.06	10
0388	50	10	N	N	150	200	20	N	.15	.30	10
0420	5	N	N	N	N	50	N	N	N	.12	80
0421	15	300	N	N	N	100	10	N	N	.18	50
0478	15	>20,000	N	10	N	100	15	1,000	N	.22	1,300
0507	15	300	N	150	200	150	15	<200	--	--	--
0509	30	10	N	N	100	150	20	N	N	.22	20
0511	10	50	N	N	200	100	10	N	N	.08	70
0562	15	7,000	N	N	N	30	10	>10,000	<.05	.10	11,000
0569	20	1,500	N	N	N	150	10	<200	N	.12	110
0632	30	100	150	N	200	200	10	300	<.05	<.02	220
0661	200	15	100	N	N	30	10	1,500	.15	--	3,800
0710	N	10,000	200	N	N	30	20	7,000	.10	--	8,300
0723	15	>20,000	100	N	150	100	<10	>10,000	<.05	--	89,000
0731	10	200	N	N	N	150	N	200	<.05	--	510
0803	15	15	N	N	N	150	10	N	N	--	90
0805	50	15	<100	N	N	150	30	N	<.05	--	25
0829	50	15	300	N	N	70	15	N	N	--	30
0832	7	15	N	N	N	50	10	N	<.05	--	25
1767	150	10	N	N	N	150	50	200	--	--	--
2006	10	50	N	N	N	<10	N	N	N	.04	40
2014	50	N	N	N	N	100	10	N	N	.04	80
2017	30	N	N	N	N	15	N	N	N	.14	60
2060	5	5,000	700	N	N	N	N	1,500	<.05	1.30	2,300
2074	<5	>20,000	1,000	15	150	15	10	N	.15	.12	120
2075	<5	50	N	N	N	<10	N	N	N	<.02	30
2083	7	70	N	N	300	20	50	500	N	.60	480
2092	10	20,000	2,000	N	N	50	N	5,000	N	>10.00	5,200
2093	70	70	<100	N	300	100	50	1,000	N	.35	760
2102	50	10	N	N	N	10	N	N	<.05	--	10
2103	15	50	<100	N	N	30	N	N	.05	--	10
2115	20	3,000	10,000	N	N	100	10	>10,000	N	--	57,000
3101	100	30	N	N	150	700	30	500	--	--	--
3102	10	20	N	N	150	70	15	N	--	--	--
3104	10	N	N	N	N	30	N	N	--	--	--
3105	30	N	N	N	N	150	15	300	--	--	--
3123	30	5,000	N	15	<100	700	15	300	--	--	--
3227	10	N	N	N	N	50	15	N	N	--	75
3293	15	10	N	N	N	100	15	N	<.05	--	45
3359	700	50	N	N	N	70	10	N	--	--	--
3372	70	50	N	N	N	100	10	<200	--	--	--
3379	20	20	N	N	N	70	10	N	--	--	--
3386	15	10	N	N	N	50	20	N	--	--	--
3387	30	N	N	N	N	100	20	200	--	--	--
3390	15	20	N	20	150	100	30	<200	--	--	--
3392	15	10	N	N	N	150	50	N	--	--	--
4042	200	N	N	N	N	300	20	500	N	--	460
4043	10	20	N	N	N	70	10	N	.05	--	35
4087	30	N	N	N	N	100	20	N	N	--	65
4089	50	30	N	N	1,000	150	70	N	N	--	85
4094	300	30	N	N	N	70	20	2,000	N	--	2,300
4099	20	N	N	N	N	100	15	N	N	--	70
4100	5	20	N	N	N	70	N	N	N	--	10
4101	5	150	N	50	N	200	15	N	N	--	10
4114	20	15	N	N	200	100	10	N	N	--	50
4115	70	20	N	N	N	200	20	N	<.05	--	95
4116	15	50	N	N	N	150	20	N	<.05	--	120
4117	20	30	N	N	150	150	20	N	<.05	--	130
4118	30	30	N	N	150	100	15	N	N	--	60
4119	15	30	N	N	N	150	10	N	N	--	30
4120	20	100	N	N	200	200	15	300	N	--	170
4121	50	70	N	N	N	150	30	N	<.05	--	140
4122	50	70	N	N	<100	100	15	N	N	--	45

TABLE 6.—*Semiquantitative spectrographic analyses and chemical analyses of selected elements in 150 samples of mineralized or altered rock, Boulder-Pioneer study area*—Continued

Sample	Mn-ppm s	Ag-ppm s	As-ppm s	B-ppm s	Ba-ppm s	Bi-ppm s	Cd-ppm s	Co-ppm s	Cr-ppm s	Cu-ppm s	La-ppm s	Mo-ppm s
4124	50	N	N	20	100	N	N	N	10	<5	N	N
4125	700	N	N	50	>5,000	N	N	7	15	15	N	N
4165	100	N	N	10	300	N	N	5	100	20	20	N
4185	150	N	N	15	300	N	N	N	10	15	20	15
4210	70	2.0	N	N	N	N	N	N	30	50	N	10
4234	100	N	N	10	700	N	N	5	150	100	30	5
4258	500	N	N	<10	700	N	N	10	150	30	20	N
4259	50	N	N	10	150	N	N	N	20	10	30	N
4269	700	N	N	<10	200	N	N	15	70	20	50	5
4270	700	N	N	<10	300	N	N	20	70	30	50	N
4271	700	N	N	<10	200	N	N	15	70	30	50	N
4273	200	N	1,500	<10	300	N	N	7	20	20	30	N
4274	300	N	N	10	700	N	N	5	50	5	30	N
4275	20	N	N	10	700	N	N	N	50	15	30	N
4276	70	N	N	N	700	N	N	N	70	20	20	N
4283	70	N	300	<10	500	N	N	N	10	20	N	N
4285	10	<.5	500	N	1,500	N	N	N	10	70	N	N
4286	100	3.0	1,000	N	700	N	N	<5	<10	30	N	N
4287	150	1.5	500	10	700	N	N	7	10	100	N	N
4288	20	.7	300	N	300	N	N	N	10	20	N	N
4289	30	7.0	3,000	N	200	N	N	N	10	100	N	7
4290	70	<.5	500	20	3,000	N	N	N	15	15	N	N
4316	200	10.0	N	20	500	N	N	N	15	50	30	5
4317	100	N	N	30	700	N	N	N	20	50	N	N
4318	50	N	N	15	500	N	N	N	15	70	N	N
4319	100	N	N	30	700	N	N	7	30	50	N	N
4320	70	<.5	N	15	200	N	N	<5	200	10	70	N
4321	100	<.5	N	70	1,000	N	N	<5	15	20	50	50
4326	300	N	N	30	200	N	N	20	70	30	70	N
4327	1,000	.7	1,500	30	30	20	N	15	N	700	N	N
4328	300	5.0	N	50	300	N	N	5	15	150	30	N
4331	150	N	700	100	300	N	N	5	15	30	20	20
4360	700	3.0	N	30	150	N	<20	15	20	30	20	N
4377	70	.7	300	20	1,000	N	N	N	30	150	30	<5
4378	200	1.0	700	20	>5,000	N	N	30	200	70	70	N
4379	700	5.0	1,500	10	500	15	<20	20	150	700	70	N
4392	200	.5	N	15	500	N	N	N	N	20	70	10
4393	200	1.0	N	30	300	N	N	15	70	70	30	<5
6252	5,000	N	N	50	700	N	N	15	50	700	50	<5
6253	100	N	N	10	150	N	N	N	15	50	N	N
6254	3,000	N	N	70	700	N	N	20	70	30	N	N
6255	300	N	N	30	150	N	N	200	70	<5	N	N
6256	500	N	N	10	100	N	N	N	10	<5	N	N
6257	500	N	N	N	150	N	150	N	10	20	N	N
6258	150	N	N	20	>5,000	N	N	15	15	50	N	<5
6262	300	N	N	15	100	N	N	N	30	<5	30	N
6263	70	<.5	N	50	300	N	N	N	30	15	20	5
6265	150	N	N	20	700	N	N	N	10	150	N	N
6270	500	10.0	N	N	50	N	>1,000	N	N	200	N	N
6271	500	70.0	N	N	20	N	>1,000	N	N	300	50	20
6272	300	10.0	N	N	100	N	>1,000	N	30	300	N	N
6273	700	N	N	50	150	N	50	N	70	10	N	N
6274	500	N	N	50	150	N	N	N	30	<5	N	N
6275	100	N	N	N	100	N	N	N	N	N	N	N
6277	150	7.0	N	15	70	N	>500	N	<10	500	20	N
6278	150	10.0	N	<10	50	N	50	N	N	100	N	N
6279	N	30.0	N	<10	50	N	200	N	N	150	N	N
6280	15	15.0	N	N	20	N	500	N	N	100	N	N
6289	500	3,000.0	N	20	150	N	N	N	N	1,500	N	N
6290	100	1,500.0	N	N	200	N	N	N	N	200	N	N
6291	100	200.0	N	N	70	N	N	N	N	300	N	N
6292	1,500	15.0	N	<10	<20	N	150	5	300	300	50	N
6293	1,500	5.0	N	N	70	N	>500	N	N	20	N	N
6294	>5,000	500.0	N	<10	100	500	>500	20	20	1,000	20	30
6295	700	1,000.0	N	N	300	<10	>500	N	N	1,000	20	N
6296	70	1,500.0	N	<10	300	<10	100	N	N	700	20	N
6297	50	150.0	N	10	300	N	>500	N	<10	700	20	N
6298	2,000	2.0	N	10	500	N	N	5	30	20	20	<5
6299	500	3,000.0	>10,000	<10	200	N	>500	N	N	>20,000	N	7
6300	70	7.0	N	50	1,000	N	N	N	70	200	20	15
6302	10	1.0	N	<10	200	N	N	N	70	20	N	5
6303	2,000	200.0	5,000	20	50	N	700	5	30	200	<20	7
6304	300	200.0	1,500	N	30	N	3,000	N	20	700	N	10
6305	200	1,500.0	2,000	N	500	N	150	N	7	30,000	N	N
6306	30	7.0	N	20	700	N	N	<5	50	50	<20	N

TABLE 6.—*Semiquantitative spectrographic analyses and chemical analyses of selected elements in 150 samples of mineralized or altered rock, Boulder-Pioneer study area*—Continued

Sample	Ni-ppm s	Pb-ppm s	Sb-ppm s	Sn-ppm s	Sr-ppm s	V-ppm s	Y-ppm s	Zn-ppm s	Au-ppm aa	Hg-ppm inst	Zn-ppm aa
4124	N	N	N	N	N	20	10	N	N	--	10
4125	15	20	N	N	200	50	10	N	N	--	30
4165	20	20	N	N	N	70	10	N	N	--	35
4185	15	30	N	N	N	70	15	N	N	--	110
4210	<5	100	N	N	N	20	10	N	.10	--	100
4234	15	20	N	N	300	150	10	<200	N	--	20
4258	20	20	N	N	200	150	15	N	N	--	20
4259	10	10	N	N	N	50	10	N	.05	--	10
4269	50	20	N	N	N	100	10	N	N	--	35
4270	70	15	N	N	N	100	10	N	N	--	45
4271	50	20	N	N	N	70	10	N	<.05	--	25
4273	15	30	N	N	N	50	10	<200	N	--	30
4274	10	20	N	N	300	70	N	N	N	--	5
4275	5	50	N	N	150	50	N	N	N	--	10
4276	7	30	N	N	200	70	N	N	N	--	150
4283	<5	50	N	N	N	20	N	<200	.10	--	90
4285	7	N	N	N	150	50	10	<200	.10	--	120
4286	5	700	N	N	N	30	10	<200	.10	--	85
4287	30	70	<100	N	700	70	20	500	.10	--	190
4288	5	200	N	N	N	70	N	<200	.10	--	80
4289	7	3,000	100	N	N	70	N	500	.05	--	270
4290	5	300	<100	N	N	100	10	N	N	--	80
4316	5	20,000	N	20	N	70	10	N	N	--	40
4317	5	30	N	N	N	150	N	N	N	--	45
4318	10	10	N	N	N	150	N	N	N	--	30
4319	30	N	N	N	N	100	10	200	<.05	--	140
4320	10	50	N	N	N	150	15	N	.10	--	150
4321	30	20	N	N	N	500	20	N	N	--	80
4326	70	30	N	N	N	70	20	200	N	--	70
4327	30	30	N	N	N	30	N	<200	.15	--	70
4328	10	1,000	N	N	N	30	N	300	N	--	420
4331	100	30	N	N	100	150	15	300	N	--	540
4360	30	1,500	N	N	150	50	15	500	N	--	340
4377	20	10	N	N	N	150	20	<200	N	--	140
4378	30	150	N	N	500	150	30	<200	N	--	120
4379	30	5,000	<100	N	N	150	30	1,500	N	--	1,300
4392	7	50	N	N	N	100	20	N	N	--	40
4393	70	15	N	N	N	300	30	<200	N	--	140
6252	100	30	N	N	N	70	200	700	N	.14	610
6253	20	<10	N	N	N	70	<10	N	N	.12	25
6254	500	30	N	N	N	200	15	1,000	<.05	.04	1,700
6255	300	10	N	N	N	30	70	300	N	.06	150
6256	15	15	N	N	200	50	15	N	N	.06	40
6257	10	<10	N	N	N	20	20	5,000	N	2.00	11,000
6258	70	10	N	N	N	150	15	1,500	N	.90	740
6262	10	10	N	N	100	30	30	N	N	.02	10
6263	15	30	N	N	N	200	10	N	N	.14	20
6265	30	50	N	N	N	15	10	N	<.05	.50	50
6270	20	500	N	N	N	50	20	>20,000	<.05	>10.00	130,000
6271	20	>50,000	<100	N	N	50	20	>20,000	N	>10.00	43,000
6272	20	1,000	N	N	N	30	<10	>20,000	N	>10.00	50,000
6273	70	300	N	N	N	100	20	1,000	N	1.00	570
6274	20	50	N	N	N	70	30	300	N	.30	480
6275	<5	N	N	N	N	30	N	N	N	.22	170
6277	15	15,000	N	N	N	15	N	>10,000	N	--	120,000
6278	30	20,000	N	N	N	20	<10	3,000	<.05	--	4,400
6279	N	>20,000	N	N	N	N	N	>10,000	<.05	--	34,000
6280	N	>20,000	N	N	N	N	N	>10,000	.05	--	57,000
6289	<5	>50,000	200	N	N	N	20	20,000	.05	>10.00	63,000
6290	N	>50,000	300	N	<100	N	N	300	<.05	2.00	720
6291	N	>50,000	200	N	N	20	N	20,000	N	>10.00	260,000
6292	100	20,000	<100	N	N	70	50	>10,000	.05	1.10	22,000
6293	10	150	N	N	N	<10	10	>10,000	N	6.00	480,000
6294	100	>20,000	<100	700	N	700	20	>10,000	<.05	.50	120,000
6295	10	>20,000	700	N	300	<10	10	>10,000	.05	>10.00	58,000
6296	<5	>20,000	700	N	300	10	10	>10,000	<.05	3.50	19,000
6297	7	>20,000	700	N	N	100	20	>10,000	N	>10.00	260,000
6298	30	1,000	N	N	N	70	30	<200	N	.35	300
6299	<5	>20,000	>10,000	15	N	50	10	>10,000	<.05	>10.00	32,000
6300	100	100	<100	N	N	200	20	700	N	.30	1,200
6302	5	70	N	N	N	2,000	10	700	N	.08	120
6303	15	50,000	N	30	30	20	10	>100,000	--	--	173,000
6304	10	>100,000	N	N	15	20	<10	>100,000	--	--	185,000
6305	<5	300	22,000	N	20	10	10	2,000	.06	--	--
6306	<5	200	N	N	15	15	15	N	--	--	--

TABLE 7.—*Summary of analytical data on 10 elements in 182 samples of black shale, Boulder-Pioneer wilderness study area. Semiquantitative spectrographic analyses*

[Numbers in parentheses are minimum content in parts per million considered anomalous for each element]

Rock unit	No. of samples	Number of anomalous samples									
		Ba (1,000)	B (150)	Cu (50)	Pb (70)	Mn (700)	Mo (7)	Ni (150)	Ag (1)	V (300)	Zn (L)[1]
Wood River Formation------------------	24	0	0	1	1	0	1	1	2	0	5
Copper Basin Formation:											
Clastic rocks of Glide Mountain plate	57	32	9	13	7	2	17	5	7	22	12
Copper Basin plate:											
Upper clastic unit----------------	9	2	1	2	0	1	0	0	0	1	3
Drummond Mine Limestone Member-----	4	3	1	1	1	0	0	0	0	0	0
Little Copper Member--------------	10	10	2	1	1	0	0	0	0	6	1
Milligen Formation--------------------	47	8	2	5	4	3	6	1	5	10	5
Unnamed Devonian and Silurian argillaceous rocks------------------	24	1	1	3	2	2	6	0	4	5	5
Phi Kappa and Trail Creek Formations---	7	0	2	4	1	1	2	1	1	2	4
Total----------------------------	182	56	18	30	17	9	32	8	19	46	35
Minimum enrichment value[2]--------------		1,000	200	200	100	1,000	200	300	7	1,000	1,500
Number of Boulder-Pioneer samples containing at least the minimum enrichment value--------------------		56	9	3	8	3	3	1	1	7	0

[1]L, detectable but below limit of determination.

[2]From Vine and Tourtelot (1970, table 4).

are listed in table 8 together with the element(s) in which they are enriched. Samples 4386, 4387, 4388, 4390, and 4391 are of drill-hole cuttings from the area between Bartlett and Little Burnt Creeks, and it is possible that their consistently high metal content, particularly of vanadium, may be attributed in part to the freshness of the samples.

Equivalent uranium (eU) was determined by a radioactivity scanning method on 32 samples of black shale, including 3 samples of mineralized black shale, but only 1 sample (6301) contained as much as 30 ppm eU, the lower limit of detection. The samples comprised 6 from the Wood River Formation, 14 from the clastic units of the Copper Basin Formation, 1 from the Drummond Mine Member of the Copper Basin, 6 from the Milligen Formation, 3 from the unnamed unit of Devonian-Silurian argillaceous rocks, and 2 from the Phi Kappa Formation, and they were selected to give a broad geographic coverage to the study area.

In summary, the black shales of the Boulder-Pioneer study area are not particularly metal rich in comparison with other black shales except for the lower clastic unit of the Copper Basin plate of the Copper

TABLE 8.—*Samples of black shale from Boulder-Pioneer wilderness study area, Idaho, that are enriched in copper, lead, molybdenum, nickel, silver, or vanadium; some also are enriched in barium*

Sample No.	Rock unit	Element(s) in which sample is enriched
0082	Phi Kappa Formation--------	Pb
2058	Milligen Formation---------	Cu (Ba)[1]
2071	-----do--------------------	V
4033	Lower clastic unit of Copper Basin plate of Copper Basin Formation---	Pb (Ba)
4139	Glide Mountain plate of Copper Basin Formation---	Pb (Ba)
4329	Phi Kappa Formation--------	Cu
4376	Wood River Formation-------	Pb
4386	Glide Mountain plate of Copper Basin Formation---	Mo, Ni, Pb, V
4387	-----do--------------------	Cu, Mo, V
4388	-----do--------------------	V (Ba)
4390	-----do--------------------	V (Ba)
4391	-----do--------------------	Pb, V
5172	Devonian and Silurian------	V
6301	-----do--------------------	Ag, Mo, Pb
6318	Milligen Formation---------	Pb

[1]Parentheses indicate enrichment of secondary importance.

Basin Formation, which contains unusually large amounts of barium. They do, however, contain many elements in amounts appreciably larger than in other rocks of the area, and they could be the source of anomalous amounts of metals such as copper, molybdenum, vanadium, and zinc that occur in many stream-sediment samples. These anomalous metal contents could also be derived from geochemical halos around concealed mineral deposits; in any case, interpretation of such anomalies in terrane underlain extensively by black shales, as is much of the Boulder-Pioneer study area, is difficult and uncertain.

Analytical data on 14 elements in 182 samples of black shale from the Boulder-Pioneer study area, and on four groups of igneous rocks from the same area for comparison, appear in table 9. Most groups of black shale are higher in boron, molybdenum, nickel, and zinc than are the igneous rocks; they are about the same in barium, copper, lead, and yttrium and are lower in manganese and strontium.

SAMPLING ALONG THE PIONEER THRUST FAULT SYSTEM

The Pioneer thrust fault system, which bounds most of the crystalline core of the Pioneer Mountains (p. 55–58), is marked locally by a wide zone of sheared and brecciated rock. In order to test whether this fault zone has been mineralized, samples were collected at most places along it where it was exposed adequately for sampling. Analytical data on the 19 samples collected are given in table 10. Most of the samples are virtually barren and even the most metal rich contain for the most part only small amounts of one or more metals. The richest sample (4360) is of soil from a small prospect pit in marble of the East Fork Formation just below the thrust fault; it contained traces of galena.

MINERAL COMMODITIES

In this section the various metals, minerals, or other commodities that were investigated during this study are discussed in three general groups: the major metals, copper, lead, molybdenum, silver, and zinc, which either have been produced in appreciable amounts in or near the study area or occur in anomalous amounts in a large number of samples; the minor metals or elements, antimony, arsenic, barium, beryllium, bismuth, boron, cadmium, chromium, cobalt, gold, iron, lanthanum, manganese, mercury, nickel, niobium, thorium, tin, tungsten, uranium, and vanadium, which do not fulfill either of the aforementioned criteria; and miscellaneous commodities such as fluorspar, minerals in placer deposits, mineral fuels, construction materials, and geothermal resources. Discussion of each commodity includes a brief history of its production, if any, in or near the study area; a summary of its distribution and abundance in all types of samples; and a

TABLE 9.—*Summary of analytical data on 14 selected elements (semiquantitative spectrographic analyses) in 13 groups of rocks, Boulder-Pioneer wilderness study area, Idaho*

[For cobalt, molybdenum, silver, strontium, and zinc, numbers are percent of samples in which element was present in measurable amount; detection limits in parts per million for each of these elements are shown in parentheses in heading. For other elements numbers are geometric means, in ppm; the number of samples in which an element was not present in measurable amount is given in parentheses. Leaders (- -), not measured]

Sample description	No. of samples	Ba	B	Cr	Co (5)	Cu	Pb	Mn	Mo (5)	Ni	Ag (0.5)	Sr (100)	V	Y	Zn (200)
							Black shales								
All black shales----------	182	527	56(8)	48(2)	40	20(12)	18(56)	88(5)	21	24(3)	22	18	178	17(33)	10
Wood River Formation-----	24	239	38(3)	73	33	13	18(7)	115	8	26	21	20	90	19(3)	12
Copper Basin Formation undivided--------------	80	932	71(4)	52(1)	41	23(2)	18(21)	83(3)	25	17(2)	9	9	160	15(17)	13
Glide Mountain plate of Copper Basin Formation-	40	871	68(3)	45(1)	37	21	18(14)	75(3)	33	27(1)	25	15	234	17(5)	12
Copper Basin plate of Copper Basin Formation:															
Upper clastic unit---	9	666	71(1)	68	22	29	14(4)	79	0	40	28	0	172	19	22
Little Copper Member-	10	1,750	87	75	60	25	22(3)	164	0	22	22	39	169	19(3)	10
Milligen Formation--------	64	414	43(1)	37	36	17(7)	16(19)	59(2)	14	31	4	2	214	19(3)	6
Unnamed Devonian and Silurian unit-----------	24	321	56	41(1)	35	19(2)	19(4)	122	26	37	0	0	234	22	4
Phi Kappa Formation-------	7	394	68	40	90	56	37(2)	227	40	26(1)	35	14	227	16(5)	14
							Igneous rocks								
Intrusive complex of Pioneer window----------	13	740	<10	--	--	22	17(1)	575	0	13	--	[1]355(2)	--	19	0
Tertiary quartz monzonite stocks-----------------	19	621	<10	--	--	21(2)	22	460	11	19(2)	--	[1]305(2)	--	15	0
Challis Volcanics---------	161	1,000(2)	<10	--	--	18(5)	24(5)	516	3	30(1)	--	[1]306(12)	--	15(9)	0
Silicic dikes (mainly or entirely Tertiary)-----	63	553	<10	--	--	18(16)	25(1)	260	6	16(17)	--	[1]231(27)	--	13(14)	0

[1]Geometric mean.

TABLE 10.—*Metal contents, in parts per million, of 19 samples of rock, or of soil derived therefrom, along the Pioneer thrust fault system*

[Samples 1 to 15 are listed in geographical sequence from the Devil's Bedstead toward the northeast and east; samples 16 to 19 are listed in sequence from the same place toward the south and southeast; localities on plate 2. Semiquantitative spectrographic analyses. Detection limit in parentheses; leaders (- -), not detected; L, detected but below limit of determination]

Sample Number	Field sample Number	Cu (5)	Pb (10)	Mo (5)	Zn (200)	Au (10)	Ag (0.5)
1	4087	10	--	--	65	--	--
2	4114	30	15	--	50	--	--
3	4115	30	20	50	95	--	0.7
4	4038	--	--	--	--	--	--
5	4039	10	10	--	--	--	--
6	4116	20	50	--	120	--	.5
7	4117	30	30	--	130	--	--
8	0367	50	20	5	--	--	--
9	4118	10	30	--	60	--	--
10	4119	50	30	--	30	--	--
11	4120	30	100	--	170	--	--
12	4121	50	70	--	140	--	--
13	4122	20	70	--	45	--	--
14	3103	20	10	--	--	--	--
15	3104	30	--	--	--	--	--
16	4360	30	1,500	--	340	--	3
17	0832	20	15	--	25	L	L
18	2011	20	100	10	--	--	--
19	0805	300	15	10	25	L	.5

short evaluation of its economic potential in the study area. In addition, discussions of most commodities are accompanied by sample maps that show locations of anomalous samples and concentrations of elements in the richest samples.

In general, the term "rock sample" as used herein refers to apparently typical or unaltered rock, and the term "mineralized rock sample" refers to visibly mineralized or altered rock; in the title of the sample locality maps, however, "rock sample" embraces both such samples.

COPPER

Substantial amounts of copper have been produced from several mining districts adjoining or near to the Boulder-Pioneer study area. The largest district by far is Alder Creek (Umpleby, 1917; Ross, 1930, p.

7-18), which between 1901 and 1962 yielded 57 million pounds (26 million kg) of copper, mainly from replacement deposits in White Knob Limestone (Mississippian) (Vhay, 1964, p. 70). Other productive districts are Warm Springs (4.2 million pounds; 1.9 million kg); Mineral Hill (1 million pounds (454,000 kg) between 1916 and 1962); Copper Basin (200,000 lb (91,000 kg) between 1917 and 1960); and Lava Creek (90,000 lb (41,000 kg) between 1923 and 1948). Copper output from districts immediately adjoining the study area (Warm Springs, Mineral Hill, Copper Basin) has been mainly byproduct; only in Copper Basin was copper the principal metal produced.

No appreciable production of copper has come from any of the small mines within the study area; almost all of it, about 60,000 lb (27,000 kg), has come from the Phi Kappa, Eagle Bird, and Homestake mines. Copper minerals have been reported previously from the Basin, Muldoon, and Idaho Muldoon mines and from prospects on Little Fall, Big Fall, and Little Copper Creeks.

Anomalous copper was detected in amounts of 70 ppm or more in 97 stream-sediment samples (7 percent of all such samples), 24 rock samples (4 percent of all such samples), and 61 mineralized rock samples (38 percent of all such samples) (fig. 13); 101 stream-sediment samples contained 50 ppm copper. Of the stream-sediment samples, 18 contained 100 ppm and 17 contained 150–300 ppm; that is, 35 samples, or 2.7 percent of all samples, contained more than 70 ppm. The highest copper content in stream-sediment samples was 300 ppm in five samples: 0468, 0469, and 0470 from the head of the west branch of Muldoon Canyon; 0714 from Garfield Canyon below the Eagle Bird mine; and 4345 from upper Muldoon Creek. The highest copper content in a rock sample was 300 ppm, in sample 2058 of apparently unaltered argillite of the Milligen Formation from a prospect dump on Sawmill Gulch, a northern tributary of East Fork Wood River. The highest copper contents of mineralized rock samples were 30,000 ppm (3 percent) in sample 6305 from a prospect at the head of Murdock Creek; 20,000 ppm and 15,000 ppm in samples 6299 and 2115 from the Daisy (Mattie) mine on the east side of lower Trail Creek and 7,000 ppm in a malachite-bearing sample (0478) from a prospect 0.5 mi (0.8 km) south of Green Lake (Muldoon Canyon) and in a chalcopyrite-bearing sample (6307) of an unprospected calcite-quartz vein west of Trail Creek.

Of the 24 rock samples anomalous in copper, 15 are of Paleozoic black shale, and most of the rest are of various igneous rocks. If the minimum amount of copper considered anomalous is reduced from 70 to 50 ppm, then another 51 rock samples, including 15 black shales, would be added and 30 out of 75 rock samples (40 percent) would be black shales. In all, 30 out of 182 samples of black shale, or 16 percent, contain 50 ppm or more copper, as compared with 32 samples (18 percent)

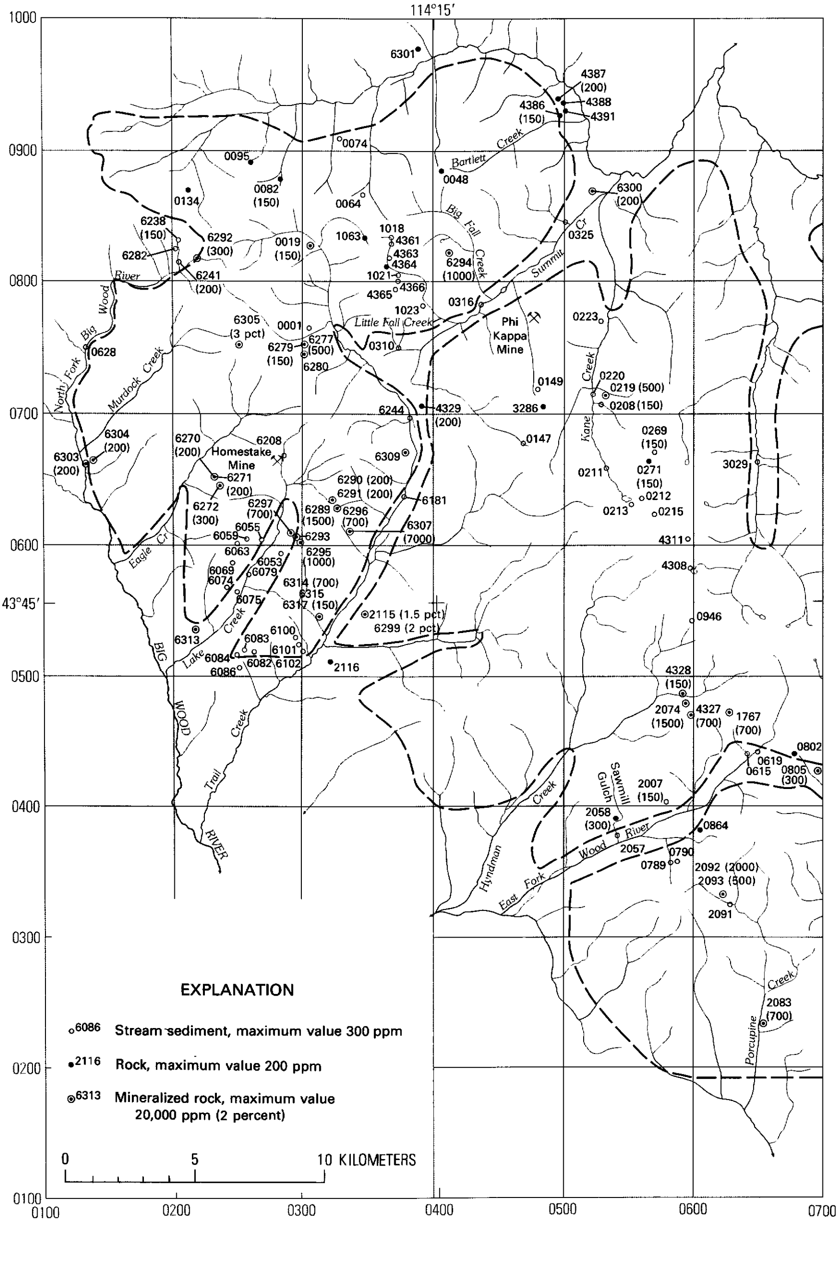
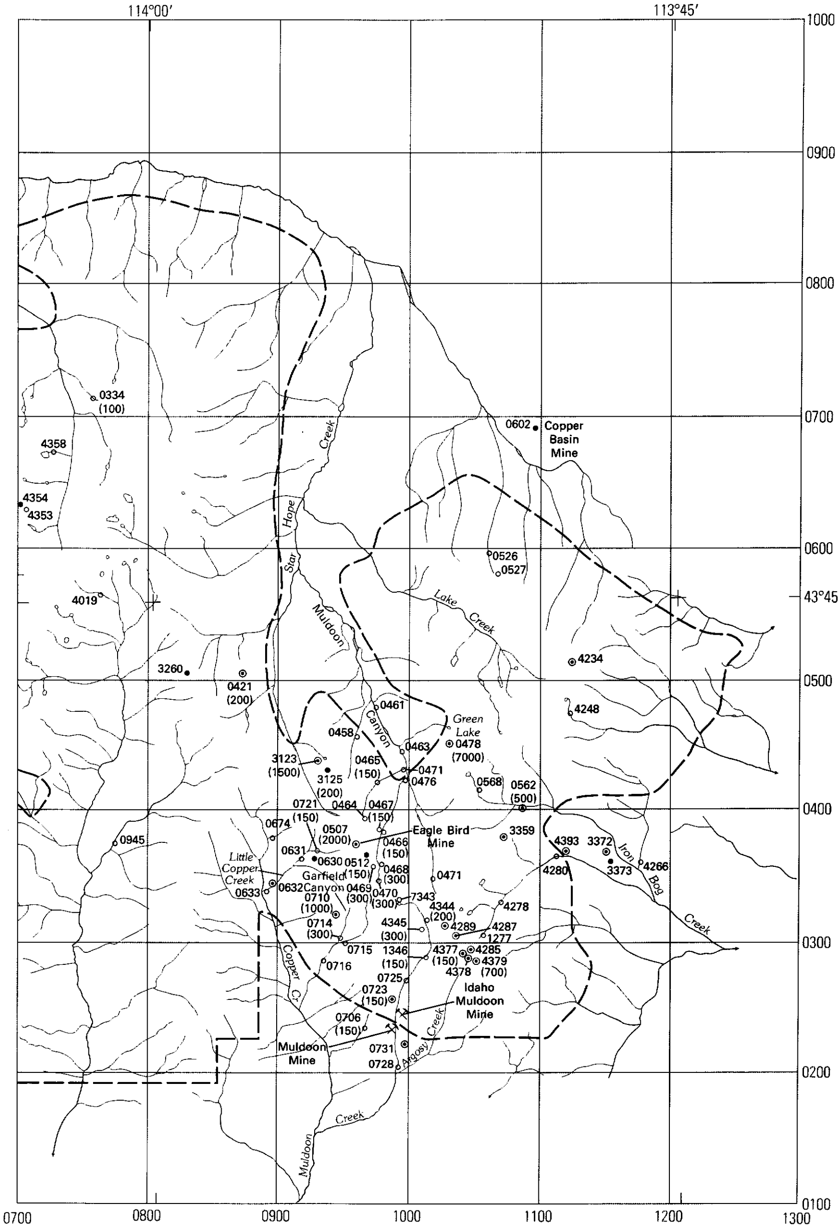


FIGURE 13 (above and facing page).—Localities of stream-sediment and rock samples containing 70 ppm or more copper, Boulder-Pioneer study area; values of 150 ppm or more shown in parentheses. Numbers without parentheses are sample numbers. Grid is in units of 5,000 m; origin of grid is at lat 43°30′ N., long 114°30′ W. Base from U.S. Forest Service 1:62,500 Sawtooth and Challis National Forests, Idaho, n.d.



anomalous in molybdenum, 46 samples (25 percent) anomalous in vanadium, and 35 samples (19 percent) anomalous in zinc.

Samples containing anomalous amounts of copper are concentrated to some extent in the southeastern one-fifth of the study area, are concentrated to a lesser extent in the western one-fifth, and except for some minor concentrations in the drainages of Kane Creek and East Fork Wood River, are largely lacking in the remainder of the area. Many of the anomalous samples in the southeast part reflect known mineralization in Copper and Muldoon Creeks and Garfield and Muldoon Canyons. The anomalous samples in the large unprospected area on the divide between Argosy and Left Fork Iron Bog Creeks are from fractured and iron-stained quartzite conglomerate of the Copper Basin Formation and contain small amounts of lead, zinc, silver, and gold, in addition to copper. The anomalous stream-sediment samples in upper Muldoon Creek and the west branch of Muldoon Canyon may indicate similar low-grade mineralization possibly related to buried parts of the Garfield Canyon–Muldoon Creek stocks, although four rock samples from the area contained only background amounts of copper.

Cumulative frequency curves showing distribution of copper contents of stream-sediment samples from several drainage basins, and from the entire study area, appear in figure 14. Curves for both Muldoon Canyon and Muldoon Creek lie above the area of the "composite curve" and above the curve for the entire study area, and lie well above them at their high value ends. In both drainages, about 20 percent of the samples contain 100 ppm or more of copper, whereas only about one percent of all stream-sediment samples from the entire study area contain that much copper. It appears, therefore, that the northwesterly trending area in the headwaters of Muldoon, North and South Forks Little Copper, and Left Fork Iron Bog Creeks, and Muldoon and Garfield Canyons might warrant some additional exploration. This area is approximately coextensive with a magnetic high centered about 1 mi (1.6 km) west of Scorpion Mountain (pl. 3). This magnetic high probably reflects a largely concealed northwest-trending pluton whose exposed portions are the small stocks in Garfield Canyon and Muldoon Creek. This pluton may have been the source of copper and other metals contained in samples from the area.

LEAD

Lead has been the principal metal produced in mining districts that adjoin the Boulder-Pioneer study area, and indeed the Warm Springs and Mineral Hill districts together have produced more lead, as well as more zinc and silver, than any district in Idaho except Coeur d'Alene (Kiilsgaard, 1964, p. 189). Although complete data on production are not available, both the Warm Springs and Mineral Hill districts are accorded magnitude 2, signifying production plus potential reserves of from 50,000 to 1,000,000 tons (45,400 to 907,000 t), by Kiilsgaard (1964, p. 184–186). Lead production from Blaine County between 1880 and 1901, most of it from the Warm Springs and Mineral Hill districts, was about 73,500 tons (66,680 t) (Umpleby and others, 1930, p. 82). From

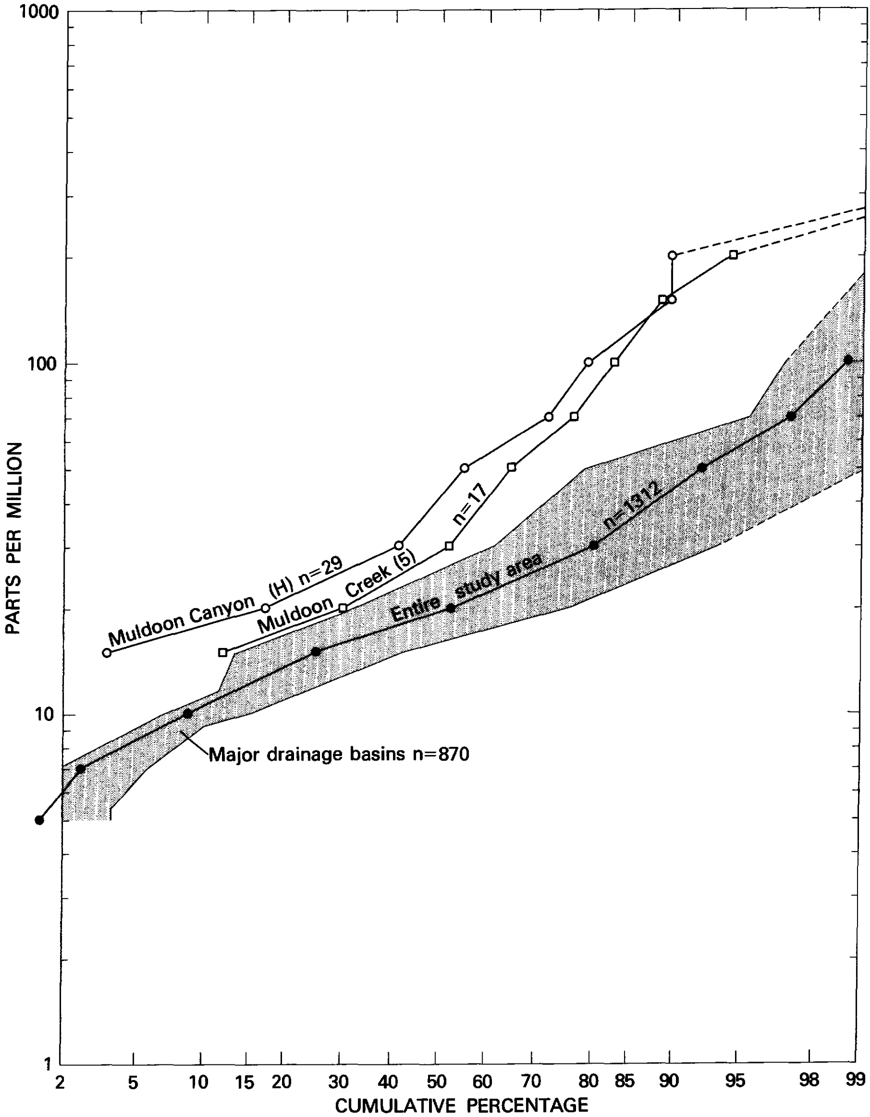


FIGURE 14.—Cumulative frequency curves showing distribution of copper in stream-sediment samples from Muldoon Canyon (drainage basin H), Muldoon Creek (drainage basin 5), and the entire study area. Diagonally lined area contains cumulative frequency curves for samples from major drainage basins A, B, D, G, R, S, X, 3, and 4. Log probability plot; dashed line segments are projections toward cumulative percentages >99. Drainage basin designation from figure 10 in parentheses; n, number of samples.

1902 to 1926, production from Mineral Hill was about 14,000 tons (12,700 t) and from Warm Springs, about 13,000 tons (11,800 t) (Umpleby and others, 1930, p. 84).

Total production of lead from deposits within the study area is not known but is estimated at about 2.5 million pounds (1.1 million kg). The most productive mines for lead have been the Homestake with 1,586,000 lb (720,000 kg), Eagle Bird with 672,000 lb (305,000 kg), and Phi Kappa with 480,000 lb (218,000 kg). The Muldoon mine was reported by E. H. Finch to have yielded $200,000, mostly in silver; at this mine, silver was contained largely in argentiferous galena in the amount of approximately 1 oz per 20 lb of lead (3.1 g/kg) (Umpleby, 1917, p. 106, 110) and at an estimated silver price in 1900 of $0.60 per oz (Ross, 1963, fig. 5), as much as 6,600,000 lb (3 million kg) of lead may have been produced. The Star Hope mine is estimated to have produced about $50,000 during the 1880's (Umpleby, 1917, p. 105); if most of this amount is attributable to silver, then at the same ratio of silver to lead and the same average price for silver, about 1,660,000 lb (750,000 kg) of lead may have been produced.

Lead in amounts of 100 ppm or more was detected in 116 samples (9 percent of all samples) of stream sediments (fig. 15). The highest amounts were 2,000 ppm in sample 6208 from upper Lake Creek (Big Wood River), which also contained 10 ppm silver, and 1,500 ppm in sample 0706 from upper Deep Gulch below the Deep Gulch prospect. Fifteen samples contained 300 ppm or more, whereas 58 samples contained only 100 ppm.

Lead in the amount of 70 ppm or more was found in 24 rock samples and 64 mineralized rock samples (fig. 15). Paleozoic black shales made up 17 of the 24 rock samples, although only shales of the Phi Kappa Formation are richer in lead than other rock units of the area. (See table 9.) The highest lead content of any rock sample was 700 ppm in sample 0922 from a rhyolite porphyry dike on the relatively favorable unprospected divide between Copper Creek and Slide Canyon; this sample also contained 20 ppm silver. This sample is from the same general area discussed in the section on copper (page 120) as warranting some prospecting. Twelve rock samples contained only 70 ppm lead.

The lead content of mineralized rocks is extremely variable and ranges from less than 10 ppm to more than 100,000 ppm (10 percent). Thirty-four samples contained 3,000 ppm (0.3 percent) or more, and 23 contained 20,000 ppm (2 percent) or more; the most lead-rich sample (6304) was from a prospect on lower North Fork Big Wood River. Samples of lead-zinc ore from prospects east of Eagle Creek (6271), on lower North Fork Big Wood River (6303), and on the east side of upper Lake Creek (Big Wood River) (6289, 6290,and 6291) contained 5 percent lead. The highest lead content detected outside prospected areas was 2 percent in sample 6292 from a mineralized outcrop on the East Fork North Fork Big Wood River. This sample also contained 2.2 percent zinc and traces of copper, antimony, and silver.

The areal distribution of samples anomalous in lead resembles that of samples anomalous in copper in that lead-rich samples are also concentrated in the southeast and northwest parts of the study area. The diffuse lead anomaly (or anomalies) in the northwest corner may be related to the Summit Creek stock, which extends northwestward in the subsurface, judging from the extent of the northwest-trending magnetic high associated with the stock (pl. 3). Alternatively, the anomaly may be related to Paleozoic black shales in that area; of the 12 rock samples containing 70 ppm or more, 10 are of black shales. In the southeast corner, some anomalous samples reflect known mineralization on Little Copper and Muldoon Creeks and in Garfield Canyon, and others may reflect a northwesterly trending buried pluton. Samples from the unprospected area on the divide between Argosy and Left Fork Iron Bog Creeks are also anomalous in copper, zinc, silver, and gold. In the southeastern area, 20 of 59 samples anomalous in lead are also anomalous in silver, and 25 are also anomalous in copper. However, stream-sediment samples containing anomalous lead are much more abundant than anomalous copper samples in drainages such as Lake Creek (Copper Basin) and Fall Creek, which are underlain extensively by quartz monzonitic rocks of the Lake Creek stock and intrusive complex of the Pioneer window, and Bear Creek, which is underlain mainly by Challis Volcanics. The association of lead-rich stream-sediment samples with igneous rocks of different kinds suggests that the lead may have been a primary constituent of these rocks, but it could also indicate unrecognized mineralization in the respective basins.

A group of cumulative frequency curves showing distribution of lead in stream-sediment samples from several drainage basins appears in figure 16. The curves for Muldoon Creek and Muldoon Canyon are similar to those for copper (fig. 14) and, like them, lie well above the curve for the entire study area and the "composite curve" for six other basins. The lead curve for Iron Bog Creek also lies well above the composite curve. The curve for Summit Creek is mostly above the composite curve, but some of the anomalous samples from this drainage may reflect known mineralization on Phi Kappa and Little Fall Creeks. Samples from drainage basins R (Big Wood River and Eagle, Leroux, and Lake Creeks) and 4 (Copper Creek) on figure 10 include several that are highly anomalous in lead as indicated by the high values at the upper ends of their respective curves; basin R has four samples that contain 200 ppm or more lead, and basin 4 has five such samples (fig. 16). However, three of the four samples from basin R probably reflect known lead-zinc-silver mineralization in upper Lake Creek, and four of the five samples from basin 5 reflect similar mineralization at the head of Garfield Canyon.

In summary, except in the large and unprospected area at the headwaters of Muldoon Creek, Muldoon Canyon, and Iron Bog Creek, and perhaps in the areas between Summit Creek and North Fork Big

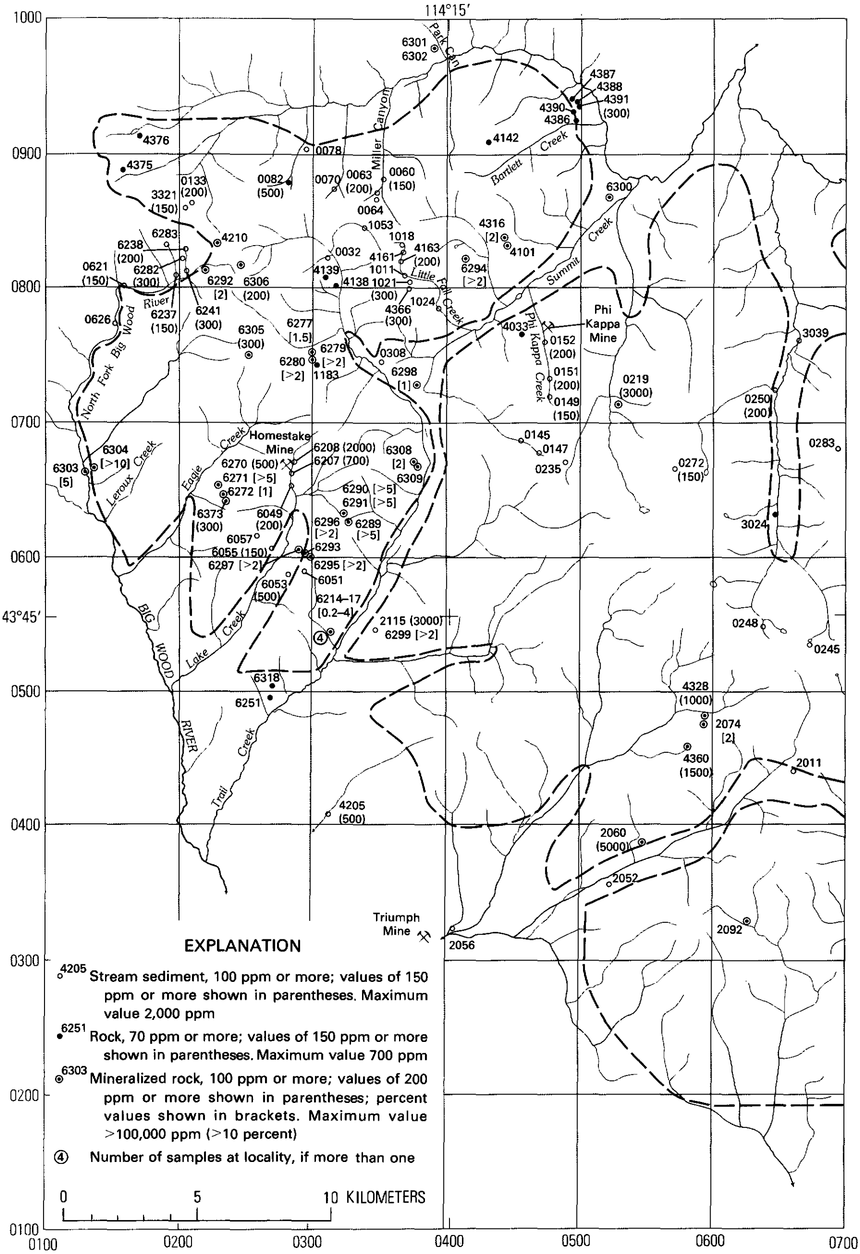
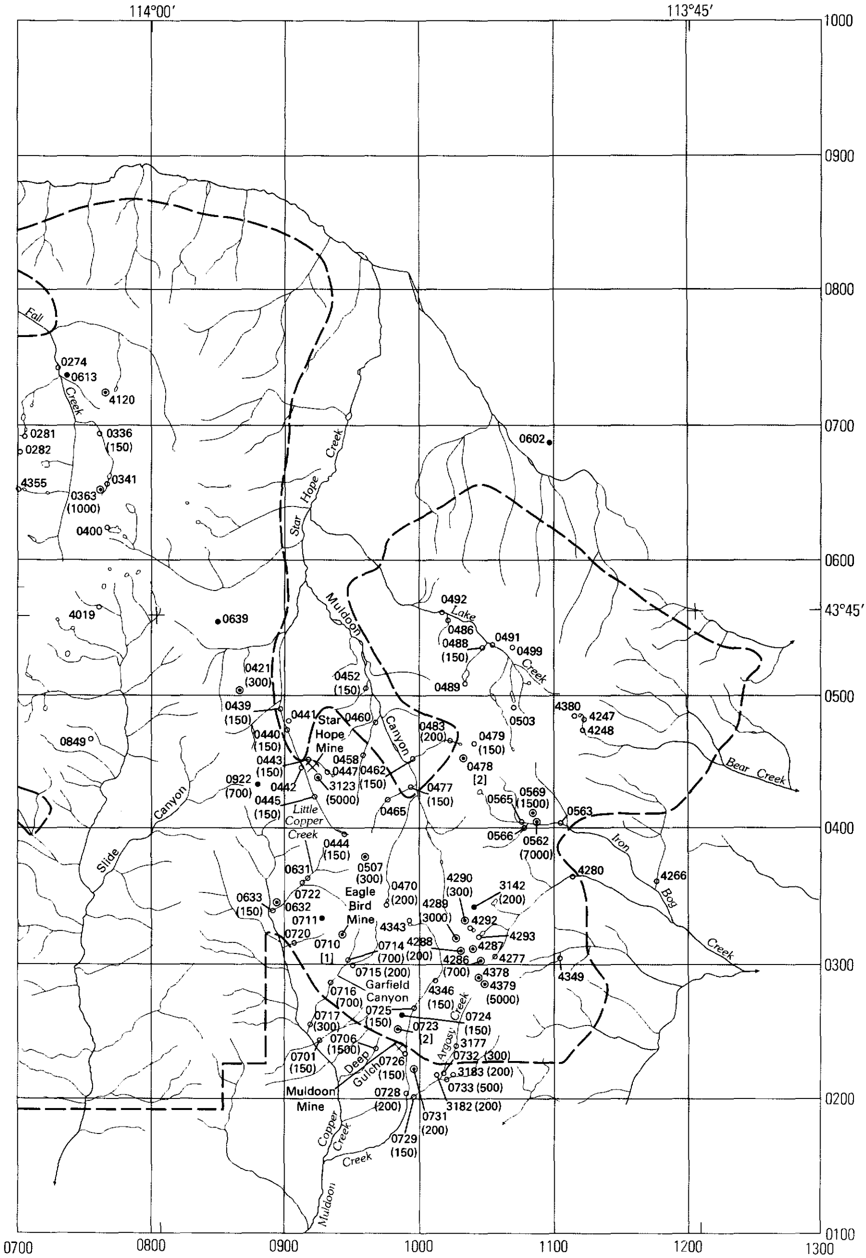


FIGURE 15 (above and facing page).—Numbered localities of stream-sediment and rock samples containing lead. Grid is in units of 5,000 m; origin of grid is at lat 43°30′ N., long 114°30′ W. Base from U.S. Forest Service 1:62,500 Sawtooth and Challis National Forests, Idaho, n.d.



Lost River and between Trail and Eagle Creeks, no anomalies indicative of promising new occurrences of lead were revealed by this study.

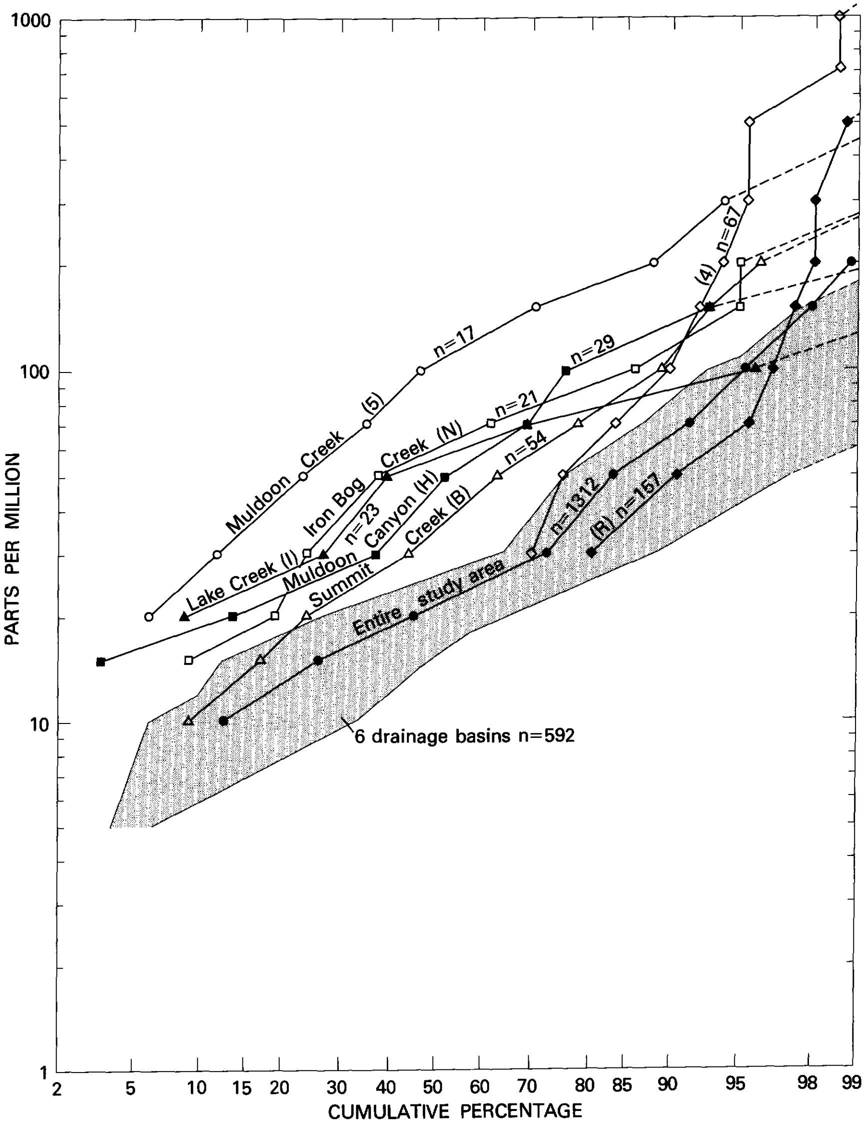


FIGURE 16.—Cumulative frequency curves showing distribution of lead in stream-sediment samples from drainage basins of Muldoon Canyon, Muldoon Creek, Lake Creek (Copper Basin), Iron Bog Creek, and Summit Creek, and from the entire study area; high value ends of cumulative frequency curves for samples from drainage basins R (Big Wood River and Eagle, Leroux, and Lake Creeks) and 4 (Copper Creek); and area (diagonally lined) within which lie cumulative frequency curves for samples from drainage basins A, D, G, S, X, and 3. Log probability plot; dashed line segments are projections toward cumulative percentages >99. Drainage basin designation from figure 10 in parentheses; n, number of samples.

MOLYBDENUM

No production of molybdenum has been reported from any mining district adjoining or near to the study area. Molybdenite has been reported from copper ore at the Empire mine in the Alder Creek district (King, 1964, p. 137) and from the Bullion mine in the Mineral Hill district (Umpleby and others, 1930, p. 94).

Within the study area, molybdenite occurs at the Walton (Anda) prospect on Little Fall Creek and at the White Mountain prospect south of Little Fall Creek (Kirkemo and others, 1965, p. E55–E58), and also at the Hard to Find tungsten deposit on Wildhorse Creek (Cook, 1956, p. 17). Scheelite ($CaWO_4$) that has a high molybdenum content occurs at a prospect on Little Fall Creek (Cook, 1956, p. 20). The Walton prospect was explored by two diamond drill holes in 1969, but results were discouraging and exploration was discontinued.

Molybdenum in trace amounts is very widespread in the study area (fig. 17). It was detected in amounts of 10 ppm or more in 144 stream-sediment samples (11 percent of all such samples); 92 of these, or 64 percent, also contained 300 ppm or more zinc. An additional 63 samples contained 7 ppm molybdenum; thus, a total of 207 samples, or 15 percent of all stream-sediment samples, contained 7 ppm or more molybdenum (fig. 11). The highest molybdenum content was 70 ppm in sample 0036 from Bartlett Creek. Forty-three samples contained 20 ppm or more.

Molybdenum was detected in amounts of 10 ppm or more in 36 rock samples, and five others contained 7 ppm molybdenum; 32 of the samples were Paleozoic black shales. The highest molybdenum content was 200 ppm in 3 samples: 6301 of radioactive black shale from uranium prospects northwest of the confluence of Park Canyon and North Fork Big Lost River, and 4386 and 4387 of black shale in cuttings from drill holes on the end of the ridge between Bartlett and Little Burnt Creeks; 3 other samples (4161, 4388, and 4391) of drill hole cuttings from the same area contained 100 ppm molybdenum. Of the 41 samples containing 7 ppm or more molybdenum, 12 also contained 300 ppm or more zinc, and in 4 more zinc was detected.

Molybdenum was detected in amounts of 10 ppm or more in 32 samples of mineralized rock, and in 3 other samples the molybdenum content was 7 ppm. The highest molybdenum content of any rock sampled was 300 ppm, in a fault breccia(?) at the Star Hope mine; one sample (0478) from a copper prospect south of Green Lake contained 200 ppm; and another (4042) that contained 100 ppm was collected on the ridge northwest of Boulder Lake across a zone 350 ft (110 m) wide of argillite in the Glide Mountain plate of the Copper Basin Formation cut by widely spaced, narrow, iron-stained seams. Of the mineralized rock samples that contained 7 ppm or more molybdenum, 15 also contained

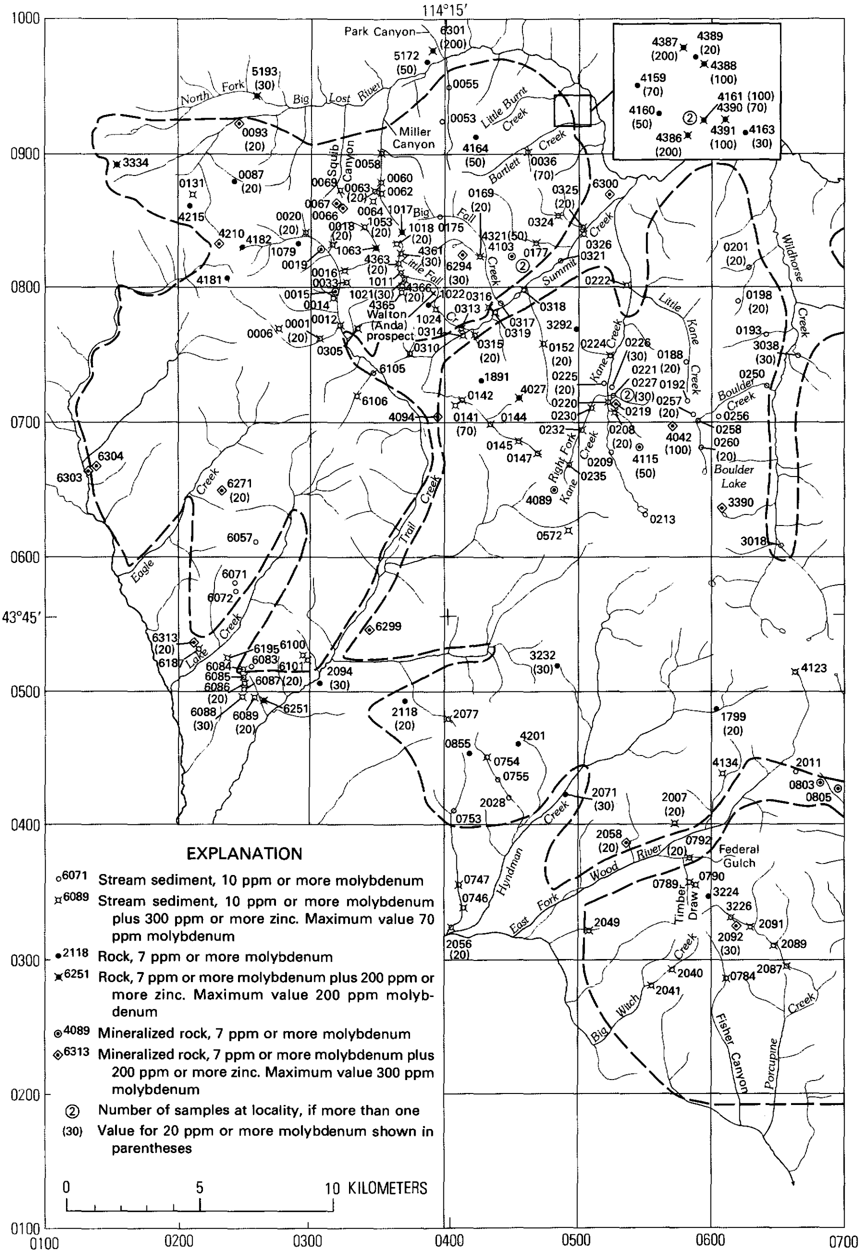
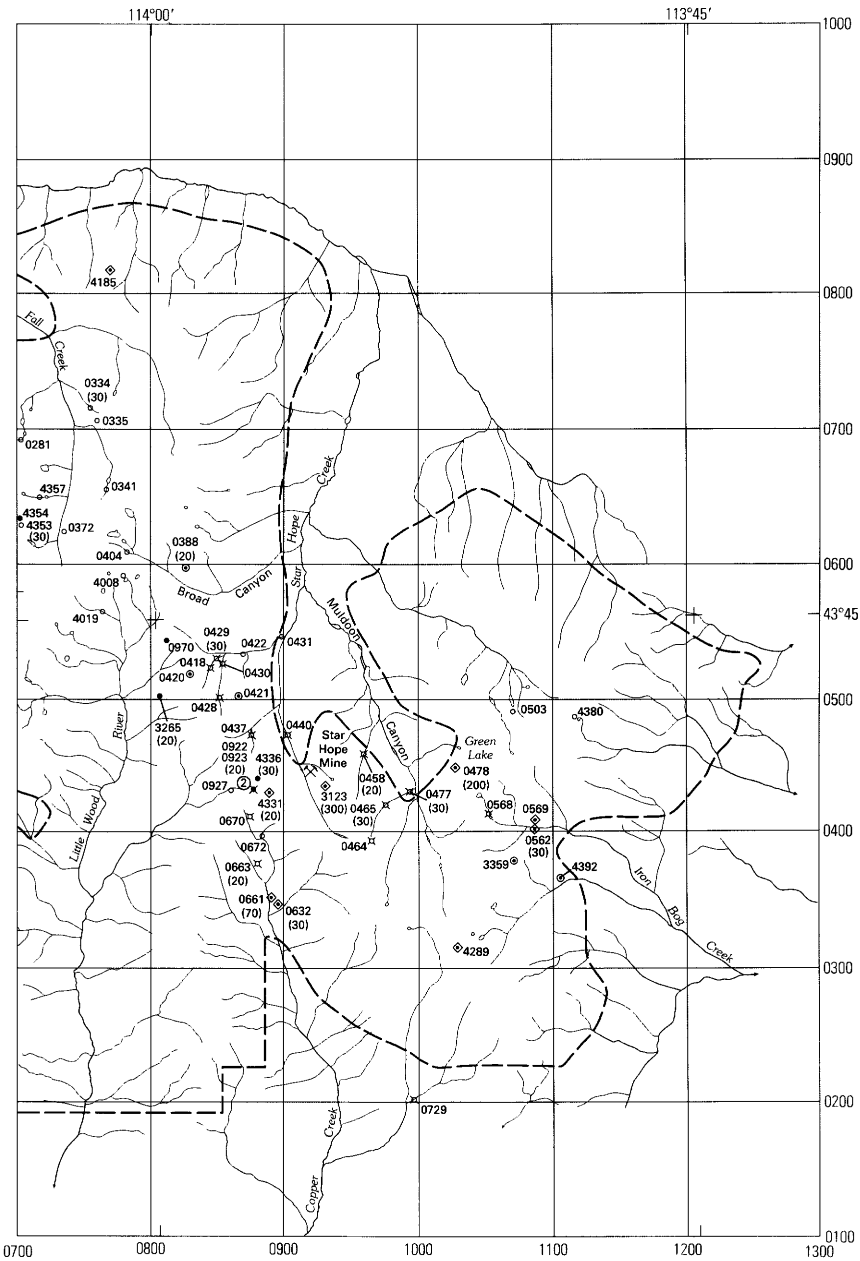


FIGURE 17 (above and facing page).—Localities and sample numbers of stream-sediment and rock samples containing 10 ppm or more and 7 ppm or more molybdenum, respectively, and mineralized rock samples containing 7 ppm or more molybdenum and 200 ppm or more zinc. Grid is in units of 5,000 m; origin of grid is at lat 43°30′ N., long 114°30′ W. Base from U.S. Forest Service 1:62,500 Sawtooth and Challis National Forests, Idaho, n.d.



300 ppm or more zinc (maximum 12 percent zinc); and 6 others contained 100–270 ppm zinc.

The largest concentration of samples anomalous in molybdenum is in the general area common to the headwaters of Squib and Miller Canyons and Big Fall, Little Fall, and upper Trail Creeks. Within this area, 27 stream-sediment samples contain 10 ppm or more molybdenum; of these, 8 contain 20 ppm and 2 contain 30 ppm. All but 2 of these 27 samples also contain 200 ppm or more zinc. Furthermore, eight samples of rock or mineralized rock contain 10–30 ppm molybdenum; five of these rocks are Paleozoic black shales, one (1022) is from the Summit Creek stock, one (6294) is from a prospect in Big Fall Creek, and one (1017) is of quartzite. Four rock samples contain 200 ppm or more zinc. In addition to molybdenum and zinc, numerous samples from this area also are anomalous in copper (fig. 13), lead (fig. 15), and vanadium (fig. 31), and a few are anomalous in silver (fig. 19).

This area is on the northeast side of a large, northwesterly trending magnetic high (pl. 3) that is believed to reflect a buried northwesterly extension of Summit Creek stock; the stock itself is exposed only on the southeast edge of the anomalous area around the Walton (Anda) molybdenum prospect. The Walton deposit itself appears to be subeconomic, but the polymetallic anomalous area adjoining it to the northwest appears to warrant additional exploration. Although the abundance of vanadium suggests the likelihood that much of the anomalous amounts of various metals detected, particularly in the many stream-sediment samples, were original constituents of the black shales that underlie much of the area, the anomalous samples also may indicate subsequent mineralization, perhaps some sort of redistribution and enrichment of original metal content by heat and (or) fluids derived from an underlying concealed pluton.

Another less concentrated group of anomalous samples is in the large area between Wildhorse and Kane Creeks, including Boulder, Little Kane, and Right Fork Kane Creeks. About 20 stream-sediment samples in this area contain 10 ppm or more molybdenum, and of these 7 contain 20 ppm and 2 contain 30 ppm. Four samples of mineralized rock also contain 10 ppm or more, the maximum molybdenum content being 100 ppm. A few of the samples, particularly the stream-sediment samples from Right Fork Kane Creek, are also anomalous in zinc, but the only other element present in anomalous amounts in more than a few samples within the entire area is niobium, which occurs in 10 samples in upper Kane Creek (fig. 25), which is underlain largely by the intrusive complex of the Pioneer window (p. 166–167). The surrounding area is underlain mainly by gneiss complex of Wildhorse Creek, Challis Volcanics, and the Glide Mountain plate of the Copper Basin Formation. Possible sources of molybdenum are the aforementioned broad zone of slightly altered Copper Basin rocks on the ridge northwest of Boulder Lake (sample 4042; 100 ppm), altered rocks along the Pioneer thrust fault (sample 4115; 50 ppm), or black shales in the Copper Basin Formation (table 9).

A third, minor, concentration of anomalous samples is in the area common to the headwaters of Big Witch, Fisher, and Porcupine Creeks and Timber Draw and Federal Gulch. Within this area, 10 stream-sediment samples and 2 rock samples contain at least 10 ppm molybdenum and 2 of the samples contain 20 and 30 ppm, respectively. All but one of the samples also contain 200 ppm or more zinc, the highest zinc content being 1,500 ppm in stream-sediment sample 0789 from Timber Gulch. No other element is present in anomalous amounts in more than a few samples from this entire area. The area is underlain mainly by Milligen Formation; a small part is underlain by Wood River Formation. The source of the molybdenum is unknown; the anomalous stream-sediment samples in lower Porcupine Creek probably reflect known mineralization at the Silver Knight prospect (sample 2092), and black shales of the Milligen Formation are known to contain appreciable amounts of both molybdenum and zinc (table 9), but the stream-sediment samples from Timber Draw and Federal Gulch, which are highly anomalous in zinc as well as being anomalous in molybdenum, may indicate unrecognized mineralization somewhere in their headwater areas.

A magnetic low of about 100–150-gamma amplitude is centered roughly on the divide west of the head of Fall Creek, near the contact of quartz monzonite of the intrusive complex of the Pioneer window to the east with the gneiss complex of Wildhorse Creek to the west (fig. 18). The magnetic low reflects either an unmapped block of gneiss or alteration of the intrusive rocks that resulted in the destruction of magnetite. The magnetic low appears to be within a large low-level molybdenum anomaly. Molybdenum was detected in 32 of the 53 stream-sediment samples shown in figure 18, although it was detected in only one of the 9 rock samples; 27 stream-sediment samples (about 50 percent of the samples, or more than twice the percentage in the study area taken as a whole) contained at least 5 ppm molybdenum, 6 contained at least 10 ppm, and one sample contained 30 ppm. The only other element that seems to be anomalous in more than a few samples is lanthanum, which occurs in 11 stream-sediment samples, all of them in the drainages of Broad Canyon and Little Wood River, in amounts of 100–700 ppm. However, two stream-sediment samples contained 70 and 150 ppm bismuth, respectively, and tungsten also was detected in the former. The combination of possible widespread alteration and the persistent occurrence of small amounts of molybdenum in stream sediments suggest that the area may warrant some additional study.

SILVER

The Warm Springs and Mineral Hill districts west and south of the Boulder–Pioneer study area have been major silver producers since their discovery in the early 1880's. Between 1880 and 1901, silver production from Blaine County, most of it from these two districts, was

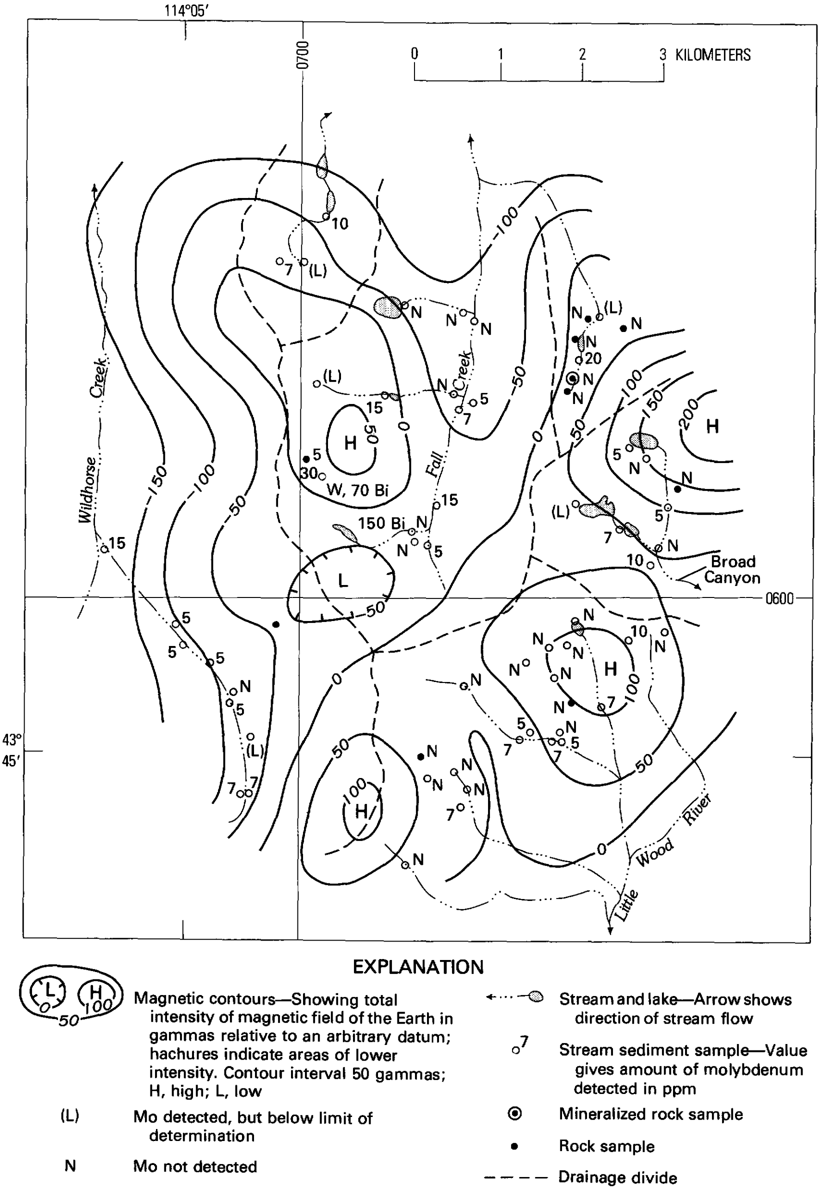


FIGURE 18.—Aeromagnetic map of upper Fall Creek area showing sample localities and content of molybdenum in ppm. Bismuth (Bi) content shown in ppm for two samples; tungsten (W) detected in one sample, but amount below limit of detection. Grid is in units of 5,000 m; origin of grid is at lat 43°30′ N., long 114°30′ W.

about 12,900,000 oz (400,000 kg); and between 1902 and 1926, the Mineral Hill district yielded about 2,300,000 oz (71,500 kg) and the Warm Springs district, about 2,500,000 oz (78,000 kg) (Umpleby and others, 1930, p. 82, 84). The Empire mine in the Alder Creek district was reported by Ross (1930, p. 8) to have produced about 768,000 oz (24,000 kg) of silver between 1912 and 1928. Most of the silver produced in the region was contained in galena or in various lead-silver sulfosalts (Hall and Czamanske, 1972), but some silver sulfosalts also have been reported by Umpleby, Westgate, and Ross (1930, p. 94), Kiilsgaard (1950, p. 49, 52–53), and Hall and Czamanske (1972).

Production of silver from mines within the study area is estimated at more than 165,000 oz (5,100 kg). The principal sources have been the Homestake mine with 98,500 oz (3,060 kg), the Eagle Bird mine with 39,000 oz (1,210 kg), and the Phi Kappa mine with 27,500 oz (855 kg). The Muldoon mine was reported by E. H. Finch (Umpleby, 1917, p. 106) to have produced $200,000, mostly in silver, and the Star Hope mine was reported by Umpleby, Westgate, and Ross (1930, p. 105) to have yielded $50,000 in lead and silver; thus, at an average price of $0.60 per oz for silver, these two mines may have produced as much as 415,000 oz (13,000 kg) of silver.

Silver was detected in amounts of 1.5 ppm or more in 59 stream-sediment samples and in amounts of 1 ppm or more in 20 samples of rocks and 55 samples of mineralized rocks (fig. 19). Of the stream-sediment samples, 27, or 46 percent, contained only 1.5 ppm. The highest silver contents of any stream-sediment samples were 10 ppm in sample 6208 from the upper Lake Creek (Big Wood River), and 7 ppm in sample 4277 from the upper end of Left Fork Iron Bog Creek. The highest silver content in rocks was 20 ppm in a rhyolite porphyry dike on the divide between Copper Creek and Slide Canyon (sample 0922) and 10 ppm in radioactive metal-rich black shale at a uranium prospect northwest of the confluence of North Fork Big Lost River and Park Canyon (sample 6301); no other rock sample contained more than 3 ppm. Paleozoic black shales constituted 19 of the 22 anomalous samples. The highest silver contents of mineralized rocks were 3,400 ppm or about 110 oz/ton (3,400 g/t) in copper-lead-zinc-silver-antimony ore from the Daisy (Mattie) mine just east of lower Trail Creek (sample 6299) and 3,000 ppm in sample 6289 of copper-lead-zinc-silver ore from a vein at the head of Lake Creek (Big Wood River). Two other samples, 6305 at head of Eagle Creek (copper-silver ore) and 6290 at head of Lake Creek (Big Wood River) (lead-silver ore), contained 1,750 and 1,500 ppm, respectively.

The distribution of samples anomalous in silver is similar to that of anomalous copper samples, except that no concentration of stream-sediment samples appears in the Lake Creek (Big Wood River) drainage. Silver anomaly distribution is also similar to that of anomalous lead samples, except that no anomalous silver samples occur in the Lake Creek (Copper Basin) drainage. The anomalous stream-sediment samples along Little Fall Creek in the northwest corner of the

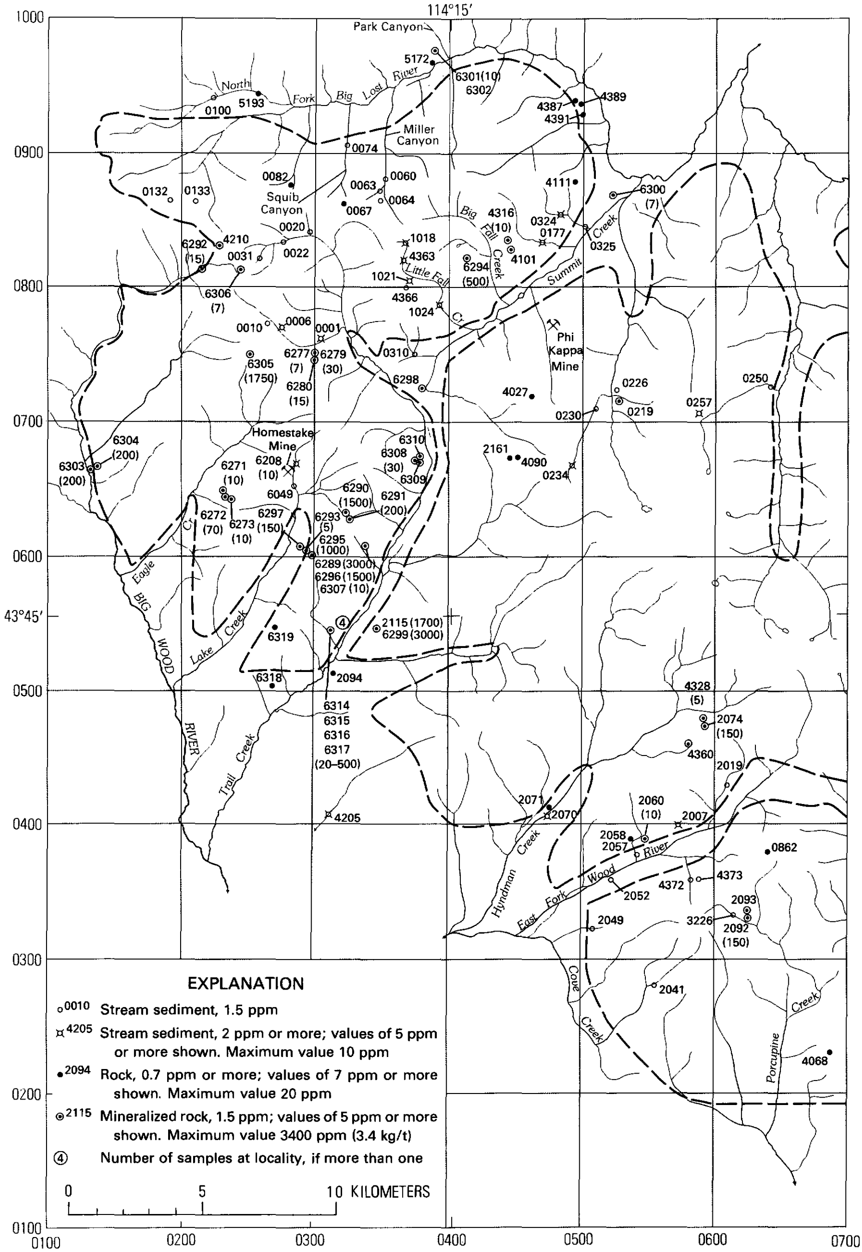
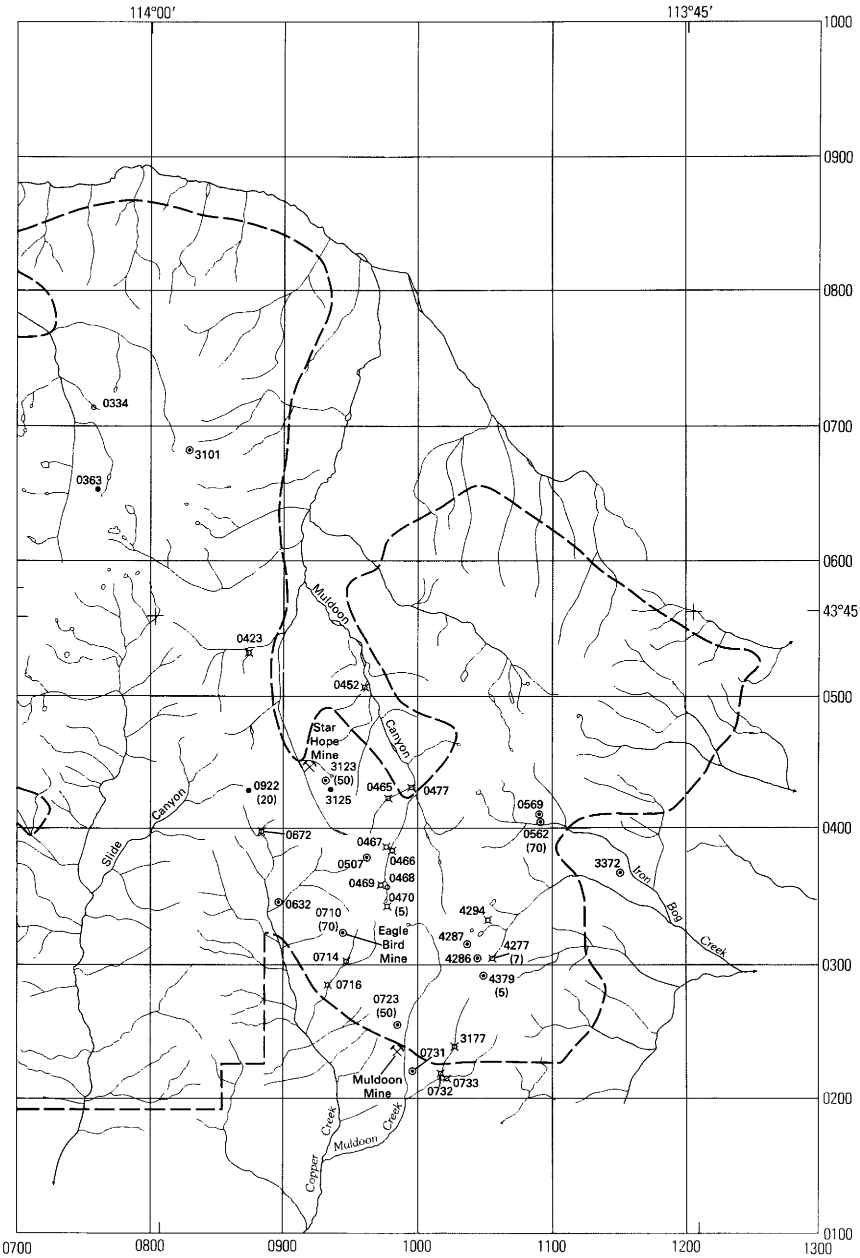


FIGURE 19 (above and facing page).—Localities of stream-sediment and rock samples containing silver. Grid is in units of 5,000 m; origin of grid is at lat 43°30′ N., long 114°30′ W. Base from U.S. Forest Service 1:62,500 Sawtooth and Challis National Forests, Idaho, n.d.



study area reflect known minor mineralization at the head of the creek. As discussed in the section on molybdenum, the area around the headwaters of Squib and Miller Canyons, and Big Fall, Little Fall, and upper Trail Creeks, which has a number of samples anomalous in silver, is anomalous in molybdenum and zinc as well as lead and to a lesser extent copper; and these anomalies may reflect mineralization or enrichment over the buried northwesterly prolongation of the Summit Creek stock. However, all the anomalous rock samples in this area are of Paleozoic black shales (Phi Kappa Formation, unnamed Devonian-Silurian unit of argillaceous rocks, Glide Mountain plate of the Copper Basin Formation), which underlie much of the area; inasmuch as some of these rocks are relatively high in silver, the anomalous stream-sediment samples may have derived some of their silver from them. In the southeast corner of the study area, almost all the samples anomalous in silver are also anomalous in copper and usually also in lead, and the discussion in the section on copper is applicable. (See p. 117–120.) The very low level silver anomaly shown by some stream-sediment samples in drainages heading 3–4 mi (5–6 km) east of the confluence of East Fork Wood River and Cove Creek is approximately coincident with a molybdenum-zinc anomaly discussed on p. 131.

ZINC

Moderate amounts of zinc have been produced from the Warm Springs and Mineral Hill districts. Between 1902 and 1926, the Mineral Hill district produced 1,600 tons (1,450 t) of zinc (as compared with 14,000 tons (12,700 t) of lead) and the Warm Springs district, 2,450 tons (2,200 t) of zinc (as compared with 13,000 tons (11,800 t) of lead) (Umpleby and others, 1930, p. 84). Between 1946 and 1948, the Triumph mine in the Warm Springs district produced 656,000 tons (595,100 t) of ore averaging 6.57 percent zinc (about 43,000 tons (39,000 t) of contained zinc) (Kiilsgaard, 1950, p. 47). Production from the nearby Alder Creek and Lava Creek districts is unknown but presumably small; Ross (1930, p. 9) reported production of about 20 tons (18 t) of zinc from the Empire mine in the Alder Creek district during the period 1926–1928.

Total production of zinc from deposits within the study area is unknown but probably is somewhat less than 3 million pounds (1.36 million kg). Nearly 1 million pounds (454,000 kg) of zinc was produced from oxidized ore mined at the Homestake mine, and about 742,000 lb (337,000 kg) of zinc was produced from similar ore at the Lake Creek group of mines. The Phi Kappa mine has produced about 475,000 lb (215,000 kg) of zinc, and the Eagle Bird mine about 313,000 lb (142,000 kg). Production from other mines seems to have been small, but most of them probably have produced some zinc inasmuch as sphalerite (zinc sulfide) has been reported from most sulfide ore deposits in the area and is clearly a widespread mineral.

Zinc was found in more stream-sediment samples and in greater amounts than any other element of economic interest in the study area (table 11). It was detected in amounts of 300 ppm or more in 337 samples, or 25 percent of all samples (fig. 20); 92 of these samples, or 27 percent of them, also contained 10 ppm or more of molybdenum. (Most of the molybdenum-bearing samples are from the northwestern part of the study area; see fig. 17.) The highest zinc content was 4,000 ppm, in sample 6208 from upper Lake Creek (Big Wood River). Sample 6170, from Antelope Creek (Trail Creek drainage), contained 3,600 ppm zinc; sample 1012, from near the head of South Fork Little Fall Creek, contained 3,400 ppm zinc; and sample 6046, from the middle part of the Lake Creek (Big Wood River) drainage, contained 3,000 ppm zinc. Eleven other samples contained from 2,000 to 2,600 ppm zinc, and 28 samples contained 1,000 to 1,800 ppm zinc. Zinc contents of 1,000 ppm or more are given in parentheses in figure 20.

TABLE 11.—*Zinc content in parts per million of stream-sediment samples from the Boulder-Pioneer wilderness study area, Idaho*

Analytical method	Total Number of samples	300 ppm or more	200-299 ppm	L[1]	100-199 ppm
Spectrographic----	1,312	301	131	132	---
Atomic absorption-	1,279	294	186	---	328

[1]L, detected but below limit of determination; leaders (---), not measured.

The distribution of zinc contents of stream-sediment samples as determined by atomic absorption analyses is shown by a histogram (fig. 21) and a cumulative frequency curve (fig. 22). Geometric mean and median zinc contents of these samples are very high; in particular, figure 22 shows that a threshold value of 290 ppm, which would be expected if 2.5 percent of the samples are considered anomalous and if values are distributed lognormally, is attained instead by 28 percent of all samples as shown by extrapolation of the low-value end of the curve. However, the mean zinc content of samples grouped by individual drainage basins differs markedly, and therefore threshold zinc content was also determined for each basin except basins M, U, and 6 (fig. 10), which had too few samples (table 12); 76 samples that contain these amounts or more (anomalous samples) are shown by the symbol A or (A) on figure 20.

The symbol A in figure 20 is intended to designate those stream-sediment samples that are anomalous in zinc (samples that contain at least a threshold amount of zinc as defined on p. 103) in drainages that have apparently very different background levels of zinc (table 12). An

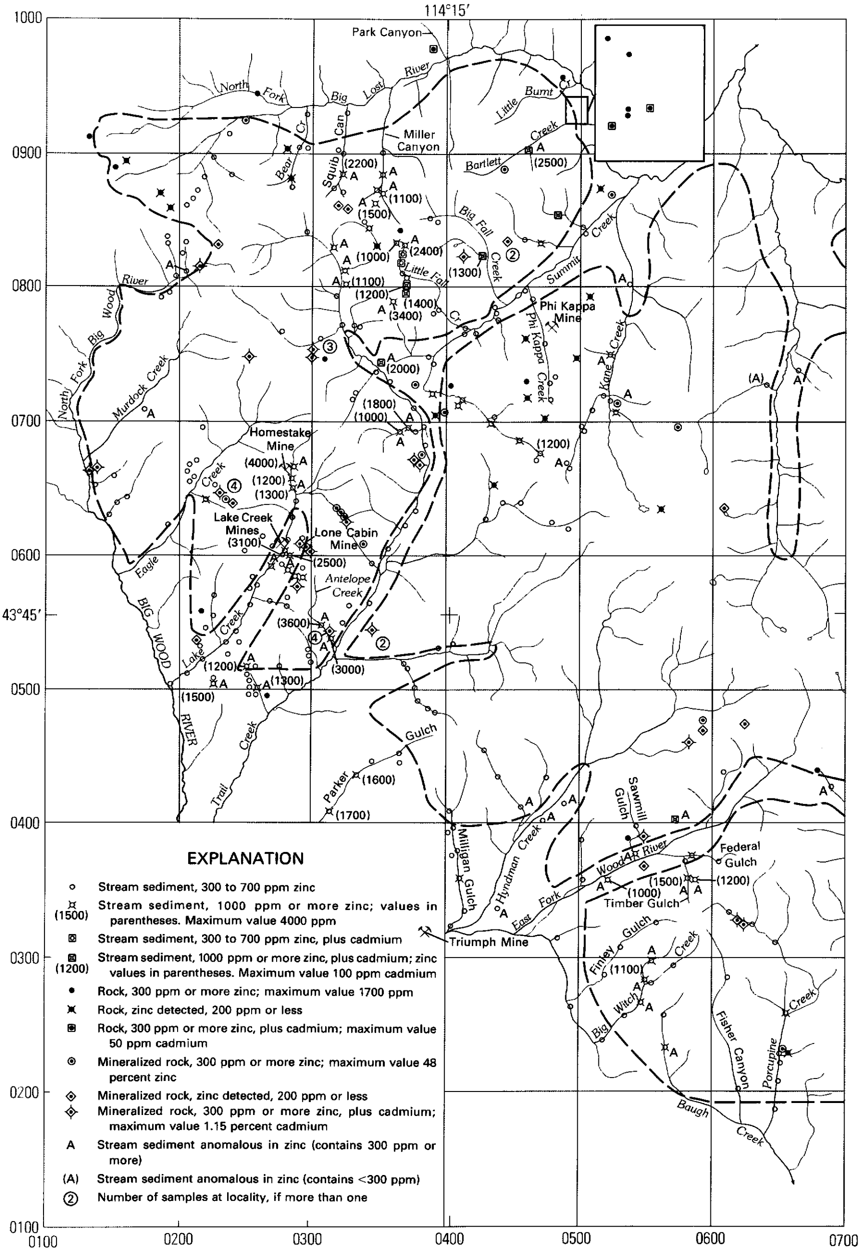
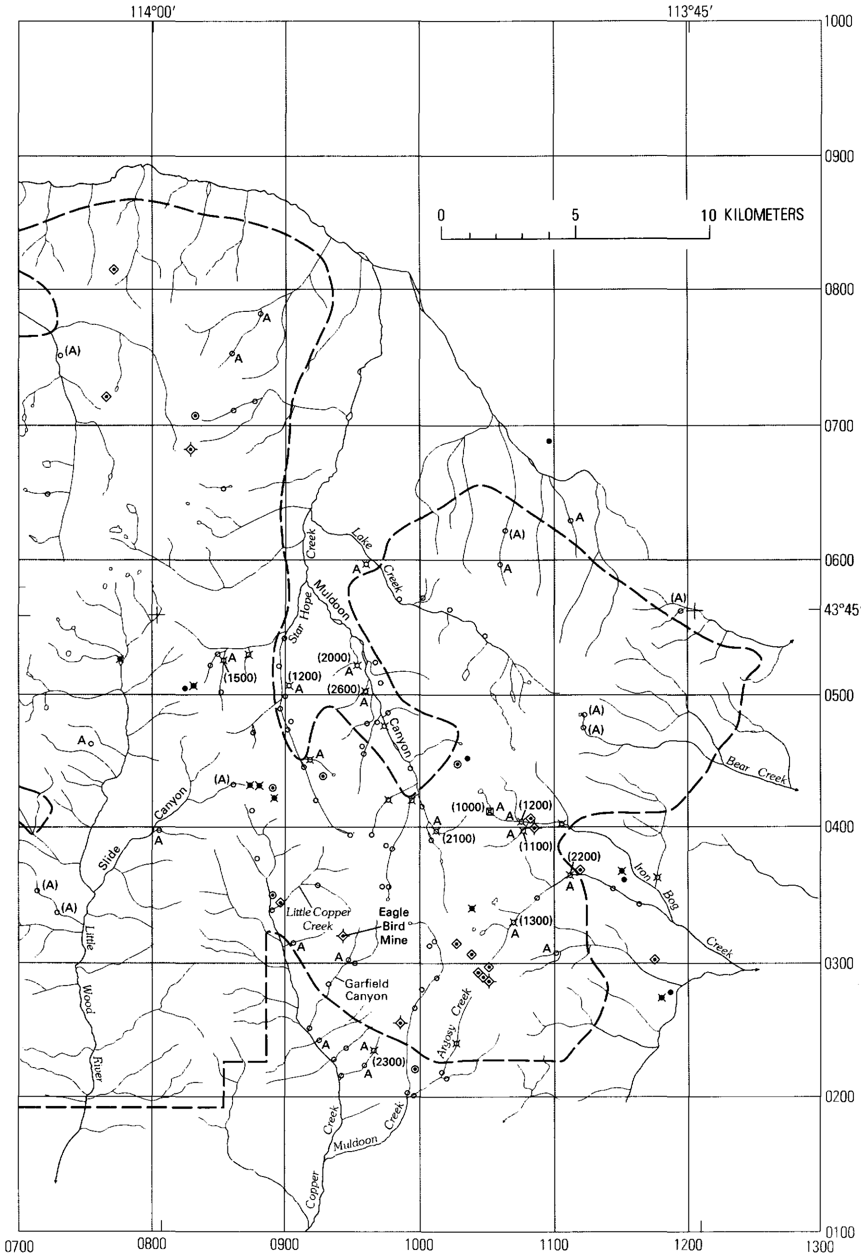


FIGURE 20 (above and facing page).—Localities of stream-sediment and rock samples containing zinc or zinc plus 20 ppm or more cadmium. Grid is in units of 5,000 m; origin of grid is at lat 43°30′ N., long 114°30′ W. Base from U.S. Forest Service 1:62,500 Sawtooth and Challis National Forests, Idaho, n.d.



assumption underlying the concept of threshold in geochemical exploration is that the range of values obtained from a suite of stream-sediment samples includes some that reflect the presence of ordinary

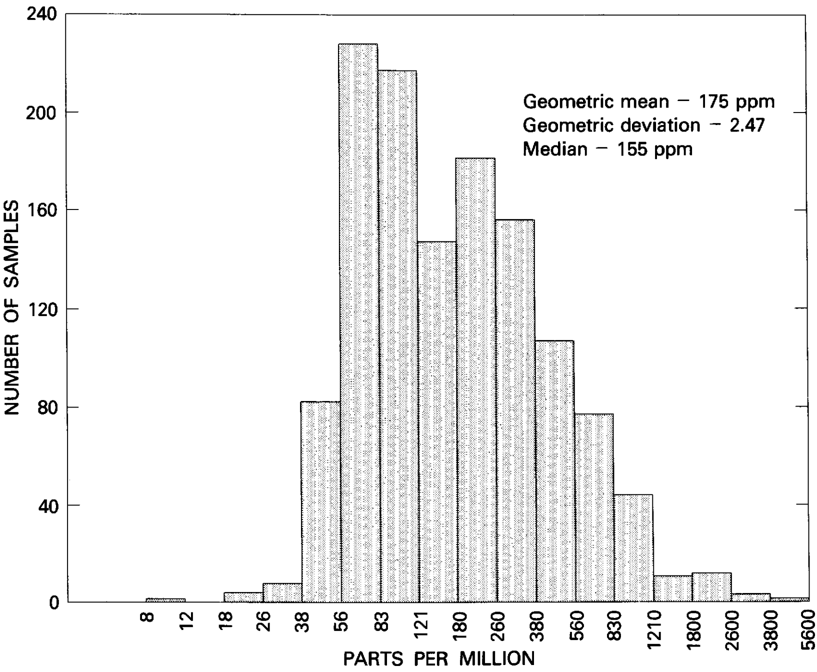


FIGURE 21.—Histogram showing distribution of zinc contents in 1,279 stream-sediment samples (atomic absorption analyses).

(unmineralized) rocks in the drainage basin under study. In a highly mineralized basin, it might be possible that no sample could be obtained that was not derived from mineralized rocks, and that all samples would be anomalous in the sense that they contained substantially more of a given element than they would if the area were not mineralized. The distribution of values could be lognormal, the log probability plot of the cumulative frequency curve could be a straight line, and no threshold could be defined because none existed. It seems likely that in drainage basins such as H, B, N, and R (table 12), which have very high apparent thresholds, and perhaps in a few others that have apparent thresholds of 850 ppm zinc, so many of the samples are anomalous that the method described on p. 103 is not applicable. Samples designated by A or (A) on figure 20 therefore are those that by almost any definition of threshold would be considered anomalous. Despite the seemingly high values for thresholds in many drainages, these samples do in fact emphasize the areas that by other criteria are believed to be most favorable for further exploration. Furthermore, no area considered favorable would have been overlooked if *only* the samples labeled A or (A) had been considered.

Zinc was reported in amounts of 300 ppm or more in 24 samples of rock and was detected in 23 other samples, for a total of 47 samples; of

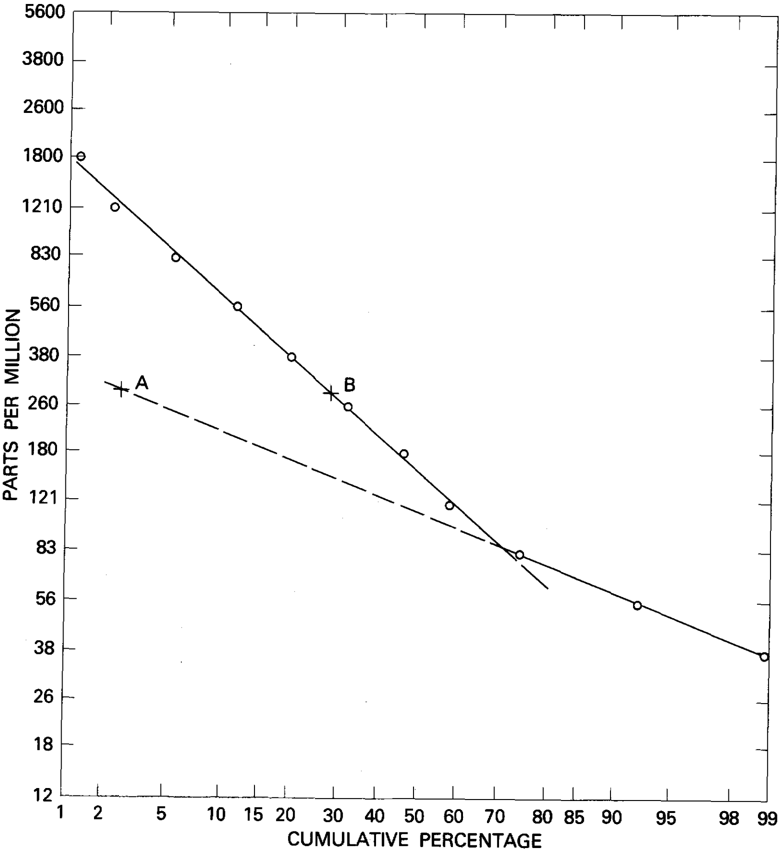


FIGURE 22.—Log probability plot of cumulative frequency curve of zinc content of 1,279 stream-sediment samples (atomic absorption analyses). A, percentage of samples (2.5 percent = 32) expected to contain 290 ppm or more if zinc contents of sample population are distributed lognormally; B, actual percentage of samples (28 percent = 358) that contained 290 ppm or more.

these, 35 were Paleozoic black shales. Fourteen of these samples also contained 10 ppm or more molybdenum, and two others had 7 ppm. The highest zinc contents were 1,700 ppm, in sample 6253 of quartzite from near the south end of the ridge west of Lake Creek (Big Wood River); 1,100 ppm in black shale from a uranium prospect (sample 6301) northwest of the confluence of North Fork Big Lost River and Park Canyon; and 1,000 ppm, in sample 2058 of black shale from Sawmill Gulch and sample 4391 of drill hole cuttings of black shale from the ridge between Bartlett and Little Burnt Creeks.

Zinc was reported in amounts of 300 ppm or more in 56 samples of mineralized rocks and in amounts of 100–270 ppm in 22 other samples. Several samples contained visible sphalerite and consequently had

TABLE 12.—*Zinc content of stream-sediment samples (atomic absorption analyses), in parts per million, by drainage basin in order of decreasing zinc content*

Basin	No. of samples	Geometric mean	Minimum zinc content considered anomalous[1]	No. of anomalous samples
H	29	528	1,800	3
B	54	482	1,800	2
W	9	438	850	0
5	17	366	850	0
N	21	321	1,000	5
Z	24	284	850	3
S	126	280	850	10
Q	30	248	850	2
2	31	243	850	1
R	157	239	1,250	5
Y	44	231	850	5
A	87	204	850	5
I	23	195	570	1
C	35	177	570	4
T	25	168	850	0
G	71	156	850	3
J	19	135	270	3
4	67	125	570	5
F	40	110	270	2
P	10	105	270	1
D	50	100	180	2
E	48	99	180	1
X	72	92	400	4
L	18	87	130	2
3	153	85	270	6
K	13	82	130	1
All samples[2]	1,279	175	1,070	76

[1]Geometric mean x (geometric deviation)^2, reduced to approximate lower limit of corresponding reporting interval.

[2]Includes samples from drainage basins M, U, and 6.

relatively high zinc contents; 26 samples contained more than 10,000 ppm (1 percent) zinc, and 14 others had 1,000 ppm or more. The maximum zinc contents were 48 percent in zinc ore from the Lone Cabin mine on the east side of Lake Creek (Big Wood River), 30 percent in sulfide ore from a prospect on Antelope Creek (lower Trail Creek area), and 26 percent in lead-zinc-silver ore from a prospect at the head of

Lake Creek (Big Wood River) (sample 6291) and in lead-zinc-silver ore from the Lone Cabin mine (sample 6297).

Sample data on zinc are difficult to interpret because of the apparently very high background level of this element, particularly in areas underlain extensively by Paleozoic black shales. However, anomalous zinc is associated with anomalous copper and lead in some areas (drainage basins of Iron Bog, Muldoon, and Summit Creeks and Muldoon Canyon), and in other areas with anomalous molybdenum (drainage basins of Summit Creek and Milligan Gulch, fig. 10), and these are probably the most favorable areas for further exploration. The most likely area for additional prospecting is the headwater area common to Copper, Muldoon, Argosy, and Iron Bog Creeks and Muldoon Canyon, already noted in the section on copper. Another favorable area is the headwater area common to upper Trail Creek, Little Fall and Big Fall Creeks, and Miller and Squib Canyons, already noted in the section on molybdenum, and the headwater area common to Big Witch and Porcupine Creeks, Fisher Canyon, and Timber Draw and Federal Gulch, also noted in the section on molybdenum. The area between Kane and upper Summit Creeks, including Phi Kappa Creek, and the drainage basin of Milligan Gulch (most of which lies outside the study area) have numerous stream-sediment samples anomalous in zinc and molybdenum.

ANTIMONY

No production of antimony has been reported from the study area or nearby mining districts, but antimony minerals, especially sulfosalts such as bournonite, tetrahedrite and boulangerite, are known from many of the mineral deposits (Umpleby and others, 1930, p. 98–100, 114–115, 178–182; La Heist, 1964a, p. 45–46; Hall and Czamanske, 1972).

Antimony was detected spectrographically in only 22 out of 150 samples of mineralized rock and was found by chemical analyses in amounts of more than 100 ppm in 3 other samples (fig. 23). The greatest amounts found were in copper-lead-zinc-silver ores: 52,000 ppm (5.2 percent) (atomic absorption analysis) in ore from the Daisy (Mattie) mine just east of lower Trail Creek (sample 6299; pl. 4); 22,000 ppm in ore from a prospect on the divide at the head of Murdock and Eagle Creeks (sample 6305); and 10,000 ppm in another sample (2115) of ore from the Daisy (Mattie) mine. Sample 2092, of low-grade oxidized lead ore from the Silver Knight prospect on upper Porcupine Creek, contained 2,000 ppm antimony as well as more than 10 ppm mercury. Antimony and arsenic clearly are associated geochemically, as 13 of the 25 samples anomalous in antimony were also anomalous in arsenic.

All but two of the mineralized rock samples in which antimony was detected are from small prospects of little economic promise. Samples

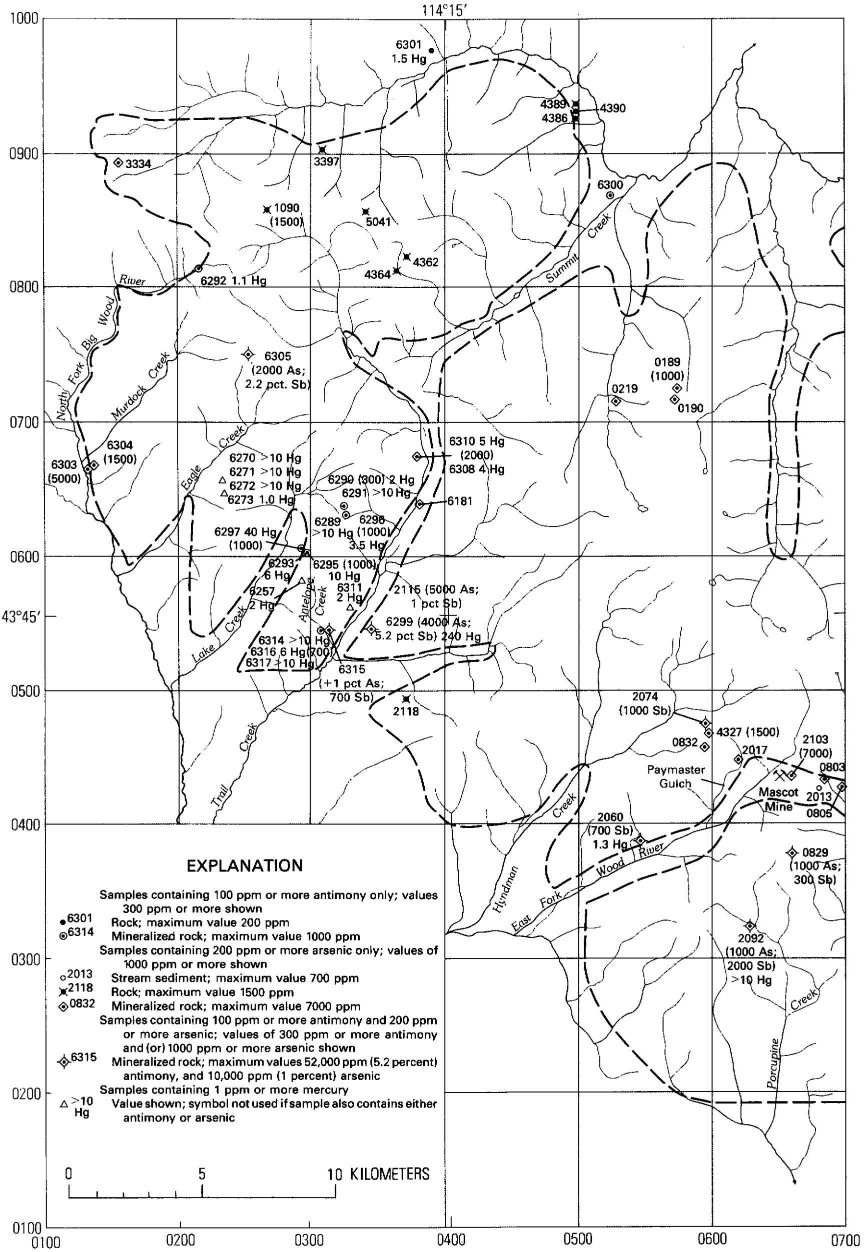
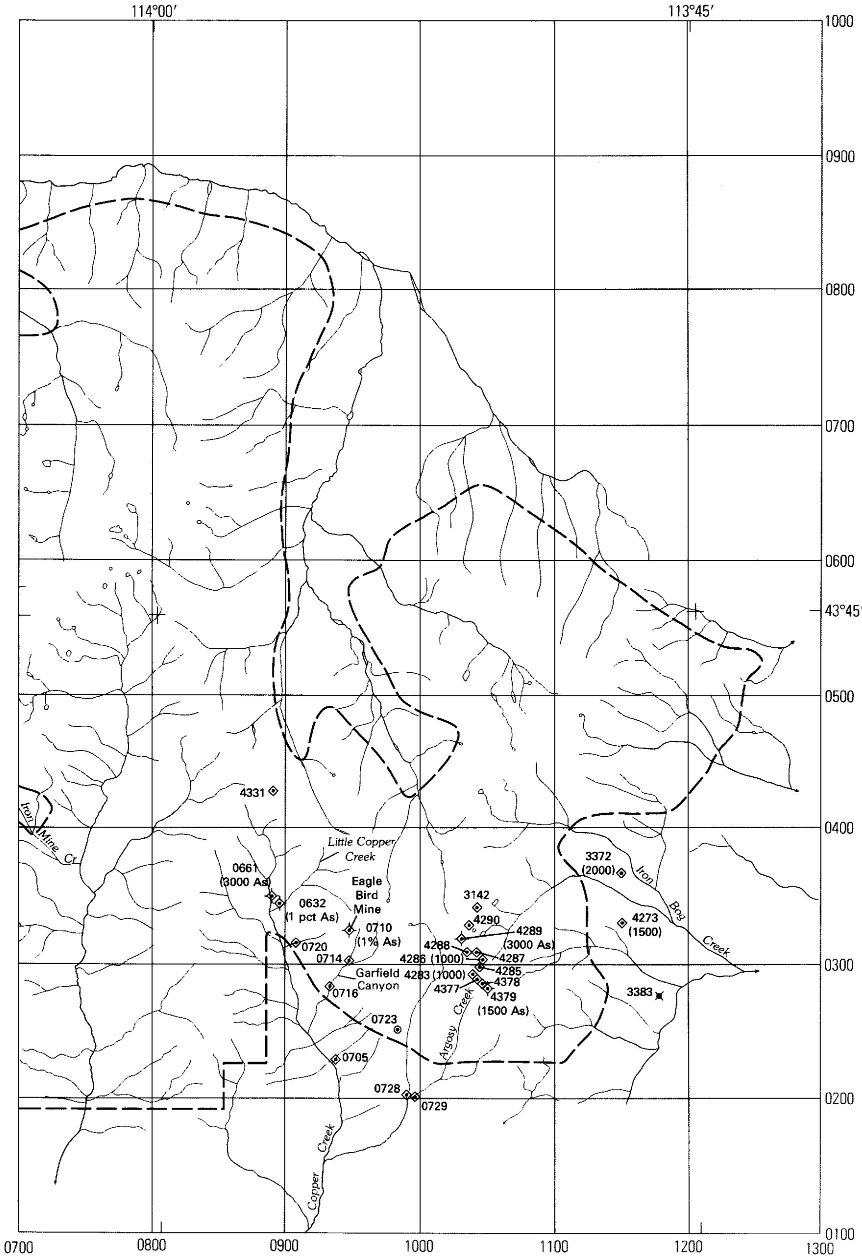


FIGURE 23 (above and facing page).—Localities of stream-sediment and rock samples containing antimony, arsenic, and mercury, or some combination of these elements. Grid is in units of 5,000 m; origin of grid is at lat 43°30′ N., long 114°30′ W. Base from U.S. Forest Service 1:62,500 Sawtooth and Challis National Forests, Idaho, n.d.



4289 and 4379 are from weakly mineralized and highly oxidized narrow breccia zones in quartzite conglomerate in the Copper Basin Formation on the divide between Argosy Creek and Left Fork Iron Bog Creek. Both these samples also contained anomalous amounts of silver, arsenic, copper, lead, and zinc; in addition, sample 4289 had 7 ppm molybdenum, and sample 4379 had 15 ppm bismuth.

No antimony was detected spectrographically in any stream-sediment or rock sample, although the relatively high detection limit (100 ppm) of this analytical method would not preclude the occurrence of antimony in amounts of possible interest in geochemical exploration; however, in 141 samples of stream sediment analyzed for antimony by an atomic absorption method, the highest amount found was 8 ppm.

ARSENIC

Arsenic-bearing minerals such as arsenopyrite and the arsenic-antimony sulfosalts are common in the mineral deposits of the region but no production of arsenic has been reported.

Arsenic was detected in 8 samples of stream sediment, 10 rock samples, and 38 samples of mineralized rock (fig. 23); it clearly is more abundant in the study area than antimony, its close geochemical associate, and its greater abundance is emphasized by the fact that the limit of detection by spectrographic analysis (200 ppm) is twice that of antimony. The highest arsenic content found was more than 10,000 ppm (1 percent) in weakly mineralized rock from a prospect on lower Little Copper Creek (sample 0632), in oxidized lead-silver ore from the Eagle Bird mine in Garfield Canyon (sample 0710), and in lead-zinc ore from a prospect on Antelope Creek (lower Trail Creek area; sample 6315). Pyritic black shale from near the Mascot mine on East Fork Wood River contained 7,000 ppm arsenic (sample 2103), and lead-zinc ore from a prospect on lower North Fork Big Wood River contained 5,000 ppm arsenic (sample 6303).

Arsenic-rich samples are particularly concentrated in three areas, from west to east: a west-northwest-trending belt extending from Hyndman Creek across East Fork Wood River to the head of Iron Mine Creek and that includes the Mascot mine, the Copper Creek drainage, and the head of Left Fork Iron Bog Creek. Samples from the Hyndman Creek–Iron Mine Creek belt are of mineralized or altered lower Paleozoic rocks along or near the Pioneer thrust fault, a fault which along most of its length is not notably mineralized (p. 114). Samples from Copper Creek are either rocks from prospects, or stream sediments from drainages below known mines. Those from the head of Left Fork Iron Bog Creek are anomalous also in copper, lead, zinc, silver, and gold as previously noted.

Several other elements of economic interest occur in anomalous amounts in some arsenic-rich rock samples. The degree of association is suggested by the fact that of 48 samples anomalous in arsenic, 13 of them were also anomalous in antimony, 24 in copper, 22 in lead, 15 in silver, 20 in zinc, 14 in molybdenum, and 11 in gold.

Inasmuch as more than 75 percent of rock samples containing anomalous amounts of arsenic were altered and showed evidence of mineralization, it appears that in general the arsenic has been introduced into the rocks rather than being an original constituent. Arsenic in anomalous amounts thus may be taken as evidence of some sort of mineralizing activity, and its fairly high degree of association with several metals suggests that it may be a useful indicator element in geochemical exploration in the study area.

BARIUM AND BARITE

Large amounts of barite ($BaSO_4$) have been produced at the Sun Valley mine northwest of Hailey (Umpleby and others, 1930, p. 160–161; Kiilsgaard, 1950, p. 60; Brobst, 1964, p. 47). Near the study area, 2,400 tons (2,170 t) of barite was mined at the Muldoon barium mine at the head of Deep Gulch (Brobst, 1964, p. 47), and other nearby barite occurrences outside the study area were being explored in 1974. Abundant large loose blocks of barite are exposed just south of the study area in an open cut in sandstone and conglomerate in the Copper Basin Formation near the south end of the ridge between Muldoon and Argosy Creeks; the barite seems to be of excellent quality but the amount available appears to be small and the area is remote from major transportation facilities.

Barium was detected in amounts of 2,000 ppm or more in 26 samples of stream sediments, 32 samples of rocks, and 7 samples of mineralized rocks (fig. 24). The highest amount found was more than 5,000 ppm in stream-sediment sample 0706 from Deep Gulch below the Muldoon barium mine and in samples 4125 and 4378 of mineralized rock, from the ridge above the Sunshine mine on East Fork Wood River and from the divide between Argosy Creek and Left Fork Iron Bog Creek respectively. As much as 5,000 ppm barium was found in three samples of apparently unmineralized rock and in one stream-sediment sample.

Samples containing anomalous amounts of barium are for the most part widely scattered. The largest concentration of samples seems to be in the Copper Creek drainage, in which 12 samples (6 stream-sediment, 5 rock, and 1 mineralized rock) are anomalous; much of the barium in this area probably is an original constituent of or was derived from black shales of the Copper Basin Formation, particularly the lower clastic unit. Although barite is not uncommon as a gangue mineral in base-metal deposits of the region, especially those in Copper and Muldoon Creeks, barium is not abundant in stream-sediment samples from

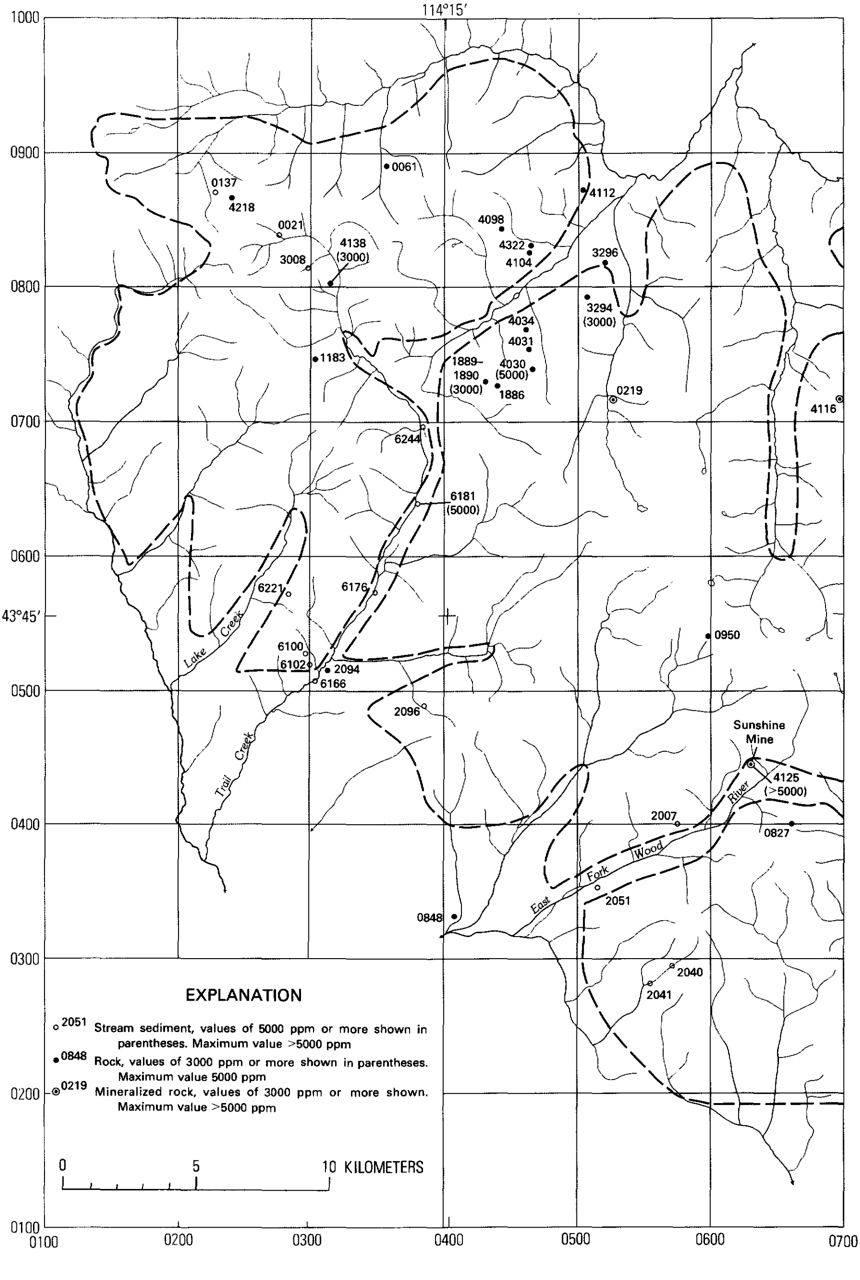
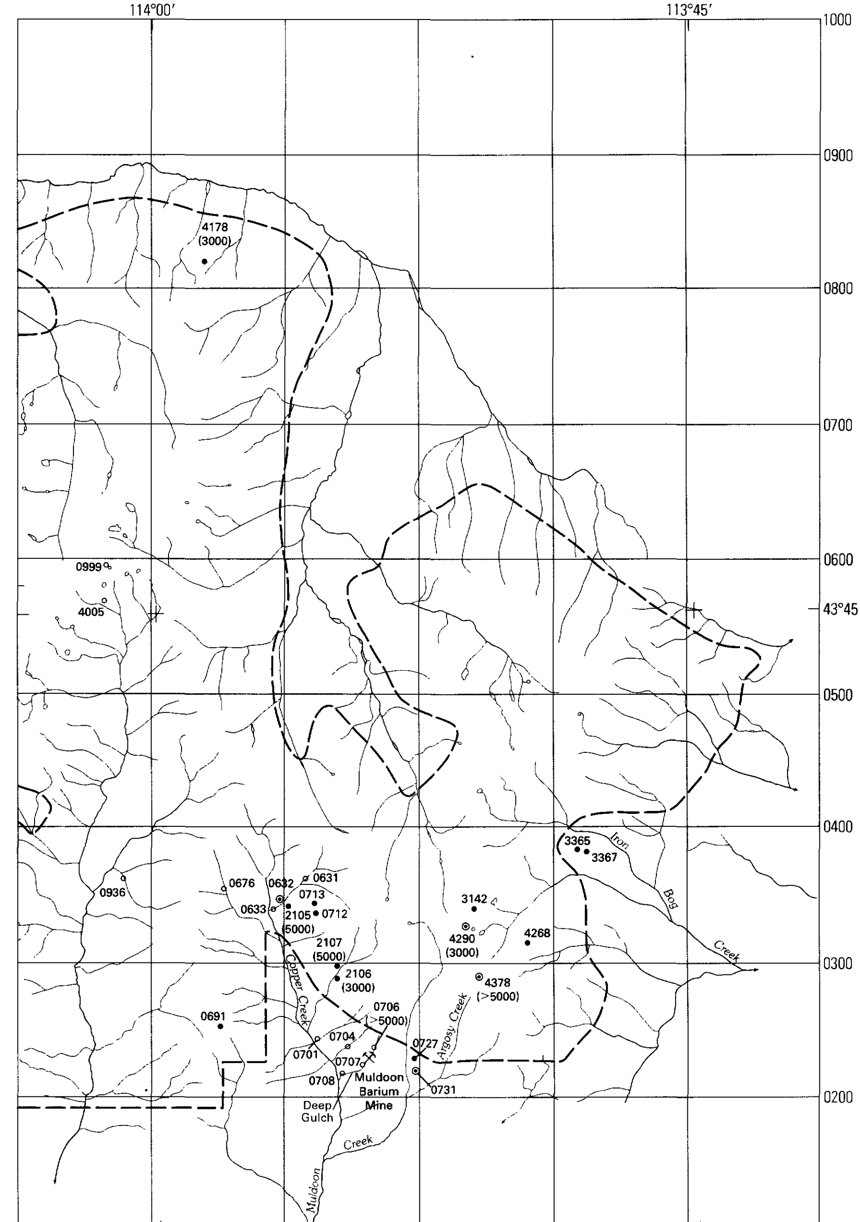


FIGURE 24 (above and facing page).—Localities of stream-sediment and rock samples containing 2,000 ppm or more barium. Grid is in units of 5,000 m; origin of grid is at lat 43°30′ N., long 114°30′ W. Base from U.S. Forest Service 1:62,500 Sawtooth and Challis National Forests, Idaho, n.d.



drainages such as Lake Creek (Big Wood River) that are known to be mineralized, and it does not appear to be a very useful element in geochemical prospecting except possibly for barite itself.

BERYLLIUM

Beryllium in amounts of 5 ppm or more was reported in only four stream-sediment and seven rock samples (fig. 25). The highest beryllium content in stream sediments was 10 ppm, in sample 0425 from upper Bear Canyon in a drainage basin underlain entirely by andesitic to rhyolitic volcanic rocks. In rocks, the highest amount was 7 ppm, in quartz monzonite from the south fork of Little Copper Creek (sample 0630), in mud deposited at the mouth of a prospect adit on Deadman Creek (sample 0661), in copper-lead-zinc ore from the Black Rock prospect at the end of the road up Big Fall Creek (sample 6294), and in rhyolite tuff from White Mountains (sample 0638); this latter sample is from the same main drainage basin as stream-sediment sample 0425 but is in a different tributary drainage. No unusual concentrations of beryllium are indicated by the geochemical data.

BISMUTH

Trace amounts of bismuth have been reported from Copper Basin and the Triumph mine area (Kaiser and others, 1954, p. 49–50; La Heist, 1964b, p. 195–197). Smelter slag from Copper Basin contains 0.01 percent of Bi_2O_3; lead concentrate from the Triumph–North Star–Independence mine group contains 0.02 percent Bi_2O_3; and zinc concentrate from the same mine group contains 0.01 percent Bi_2O_3.

Bismuth was detected in seven samples of stream sediments, nine samples of mineralized rocks, and two samples of other rocks (fig. 26). The highest amount, 500 ppm, was in zinc ore from the Lone Cabin mine on the east side of Lake Creek (Big Wood River) (sample 6293). Amounts of 150 ppm were found in stream-sediment sample 0369 from upper Fall Creek and sample 0219 of highly oxidized mineralized rock from a prospect near the end of the road up Kane Creek. Three of the samples of mineralized rock also contained a little tin (maximum 70 ppm). All the bismuth-bearing stream-sediment samples were from the upper parts of Fall and Wildhorse Creeks but are widely scattered and do not appear to indicate any notable concentration of bismuth. However, all but one of the stream-sediment samples in which tungsten was detected are also from this general area, and bismuth therefore might be a usable indicator in exploration for possible tungsten deposits because its lower limit of spectrographic detection (10 ppm) is much smaller than that for tungsten (50 ppm).

BORON

The use of boron as an indicator element for certain high-temperature mineral deposits and pegmatites has been suggested by Boyle (1971), who noted that the boron occurs most commonly in the complex silicate tourmaline. The occurrence of boron-rich samples in and near mineralized areas of the Absaroka Primitive Area and vicinity was noted by Wedow and others (1975, p. B63, B68; fig. 13).

Boron was detected in amounts of 150 ppm or more in 42 stream-sediment samples, 25 rock samples, and 2 samples of mineralized rock (fig. 25). The only samples containing appreciably more than 150 ppm were mineralized rock sample 4101, pyritic quartzite of the Glide Mountain plate of the Copper Basin Formation from the ridge east of Big Fall Creek (1,000 ppm); and rock sample 4093, black shale of the same rock unit on the ridge south of Summit Creek (500 ppm). All but seven of the rocks containing anomalous amounts of boron are Paleozoic, mostly Mississippian, black shales, and it seems likely that these rocks may have a high original boron content; the average boron content of clays and shales is 100 ppm (Parker, 1967, p. D13).

As is evident in figure 25, samples anomalous in boron are almost entirely in the west half of the study area. Samples are somewhat concentrated in the area between Summit and Phi Kappa Creeks (9 samples); this concentration may reflect the presence of the Summit Creek quartz monzonite stock and its associated mineralization, although all six rock samples are of Paleozoic black shales. Other concentrations of samples are in an area centered roughly at the head of Little Fall Creek that contains a few small base-metal prospects (8 samples); in the middle part of Lake Creek (Big Wood River) in an area of base-metal mineralization (11 samples); and in an area west and south of the headwater region of Finley Gulch, Big Witch Creek, and Fisher Canyon in which neither plutonic intrusive rocks nor mineral deposits are known (11 samples) but in which many samples are anomalous in zinc, molybdenum, and silver. The latter two areas are underlain extensively by Paleozoic black shales; however, with one exception (sample 6319), anomalous boron contents in these areas are found only in stream-sediments sampled.

Boron thus does seem to be associated with mineralization in some places in the study area, although such an association may be obscured by a high original boron content in much of the potential host rock.

CADMIUM

Cadmium in the amount of 0.02 percent has been reported in zinc concentrate from the Triumph–North Star–Independence group of mines (Kaiser and others, 1954, p. 50). None has been reported previously from within the study area.

Cadmium in amounts of 20 ppm (the limit of detection by spectrographic analysis) or more was detected in 10 samples of stream sediments, 34 samples of mineralized rock, and 3 samples of other rocks; and traces of cadmium were found in 2 other samples of

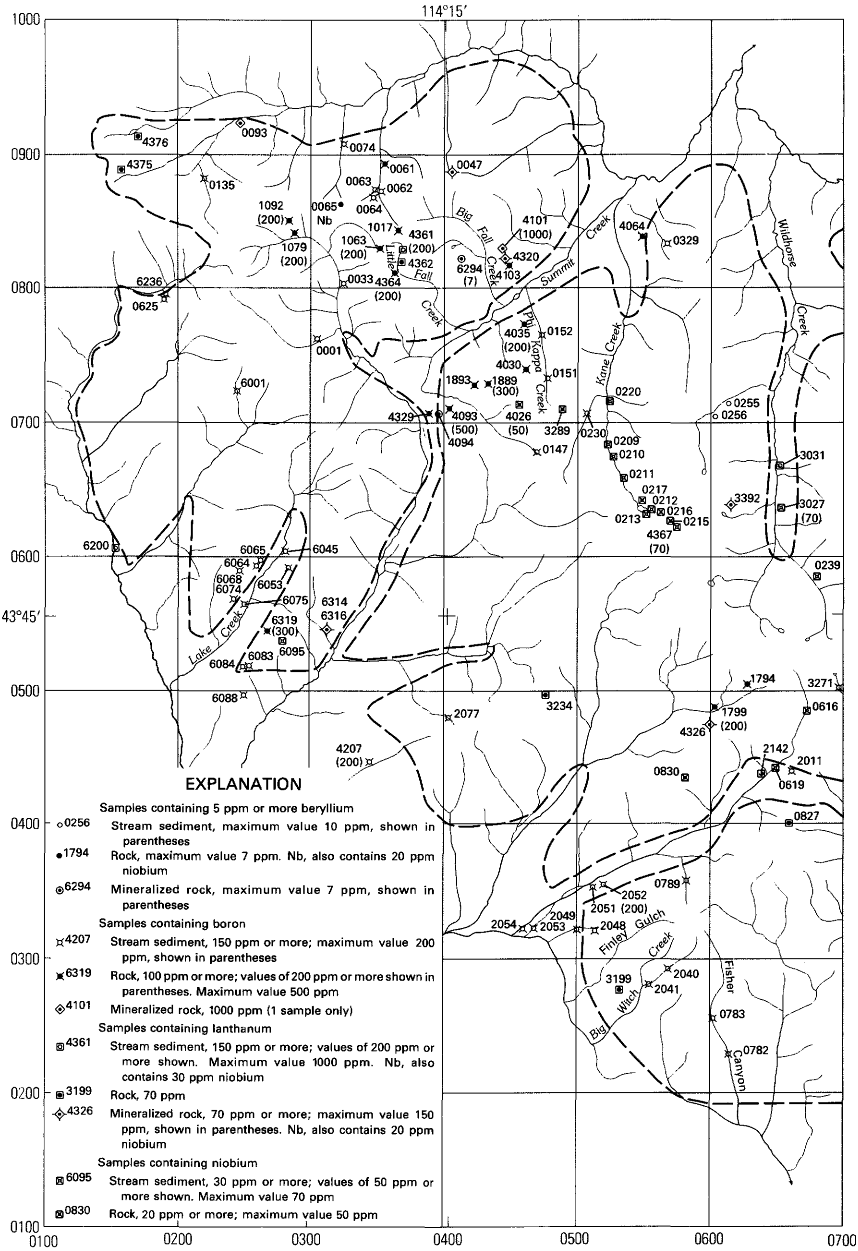
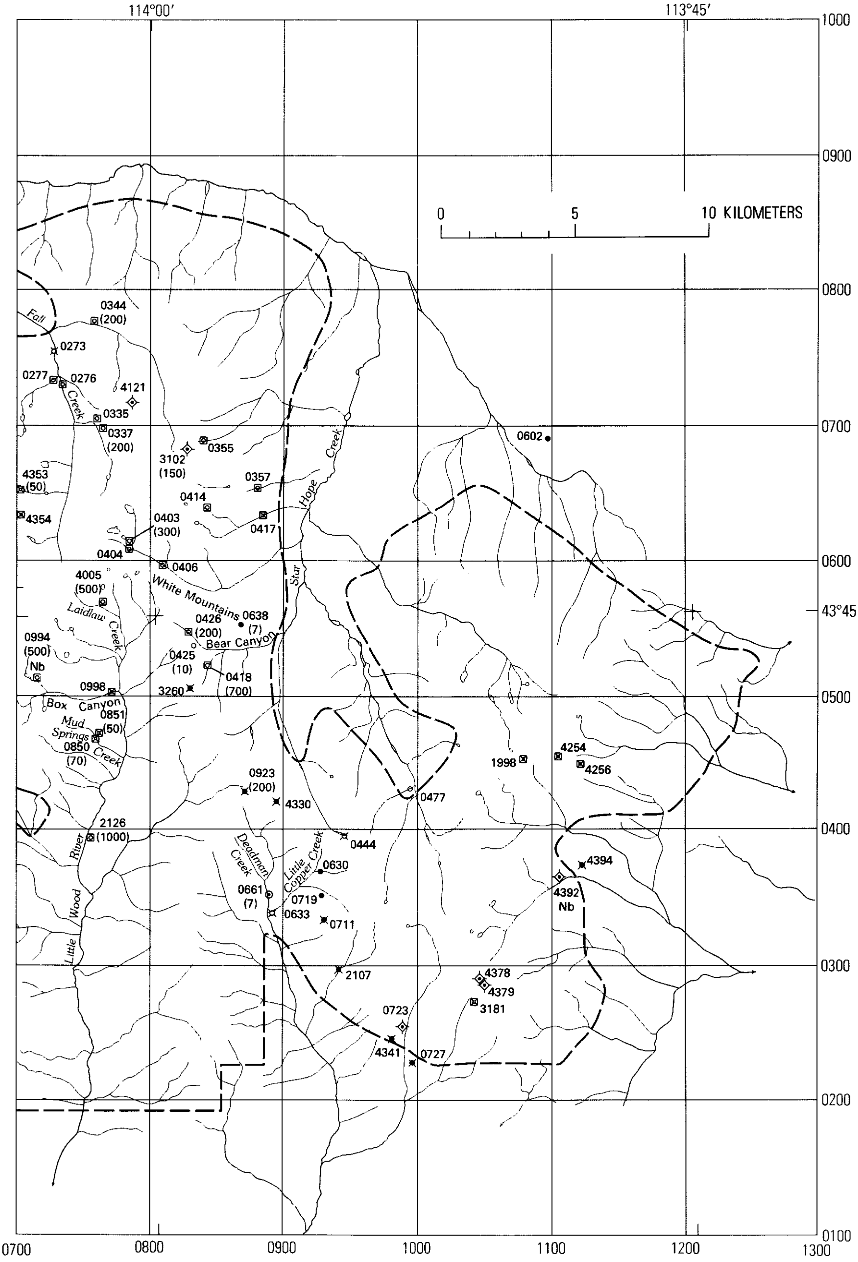


FIGURE 25 (above and facing page).—Localities of stream-sediment and rock samples containing beryllium, boron, lanthanum, or niobium. Grid is in units of 5,000 m; origin of grid is at lat 43°30′ N., long 114°30′ W. Base from U.S. Forest Service 1:62,500 Sawtooth and Challis National Forests, Idaho, n.d.



mineralized rocks (fig. 20). The highest amounts found were 11,500 ppm (1.15 percent), in copper-lead-zinc-silver-antimony ore from the Daisy (Mattie) mine east of lower Trail Creek (sample 6299); and 2,400

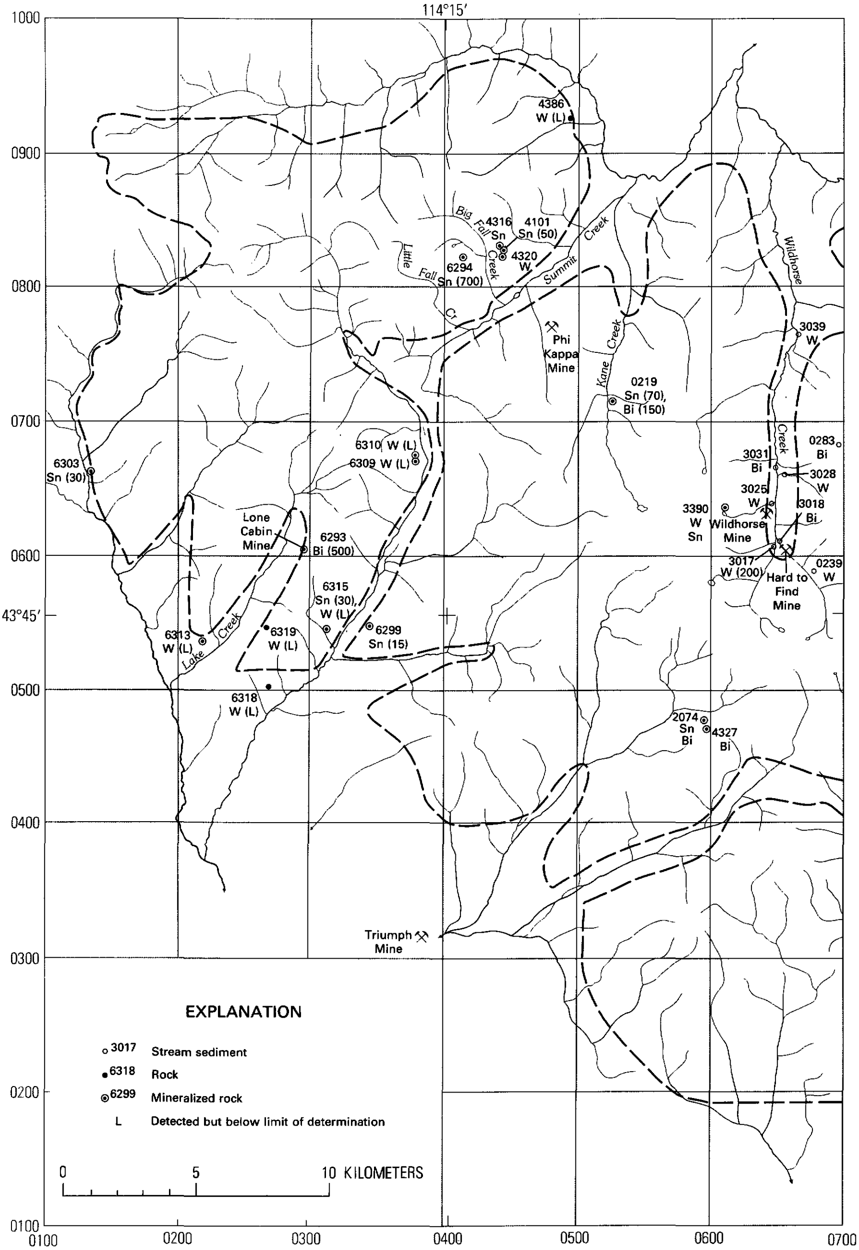
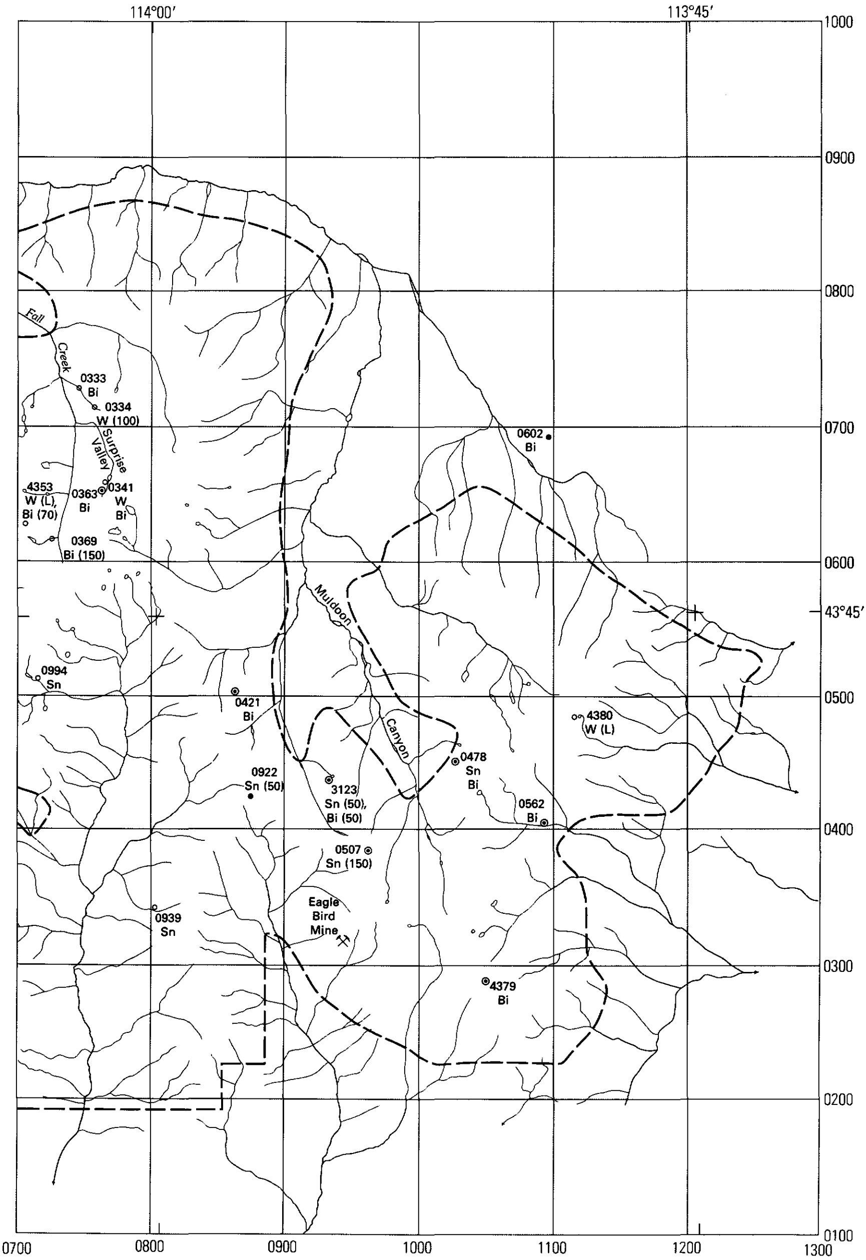


FIGURE 26 (above and facing page).—Localities of stream-sediment and rock samples containing bismuth (Bi), tin (Sn), or tungsten (W). Values of 50 ppm or more bismuth, 30 ppm or more tin, and 100 ppm or more tungsten shown. Grid is in units of 5,000 m; origin of grid is at lat 43°30′ N., long 114°30′ W. Base from U.S. Forest Service 1:62,500 Sawtooth and Challis National Forests, Idaho, n.d.



ppm, in lead-zinc-silver ore from a prospect on lower North Fork Big Wood River (sample 6304). Five other samples of mineralized rock contained more than 1,000 ppm cadmium: 6270, 6271, and 6272, from prospects on the east side of Eagle Creek; and 6314 and 6315 from a prospect on Antelope Creek (lower Trail Creek area).

All samples that contained anomalous amounts of cadmium also contained anomalous quantities of zinc, at least 500 ppm, as would be expected in view of the close geochemical association of these two metals. All samples that had 100 ppm or more of cadmium contained more than 700 ppm of zinc, and the two samples richest in cadmium contained more than 3 percent zinc. However, no cadmium was detected in the vast majority of the 337 stream-sediment samples, 47 rock samples, and 78 mineralized rock samples that are anomalous in zinc.

Of the 10 stream-sediment samples that contained detectable cadmium, 8 are from drainages in the metal-rich northwest part of the study area (p. 129–130, 133–136). Many stream-sediment and rock samples from this area had anomalous amounts of copper, molybdenum, vanadium, and zinc. Although appreciable amounts of cadmium occur in zinc ore at some prospects in the study area, these prospects are small and appear to have little economic potential.

CHROMIUM, COBALT, AND NICKEL

Chromium, cobalt, and nickel are commonly associated in mafic and ultramafic rocks, and therefore they are considered together in this report. No chromium or nickel has been reported previously from the study area, and the only reported occurrence of cobalt is in trace amounts (0.02 percent) in copper slag from the Copper Basin area (Kaiser and others, 1954, p. 49).

Localities of samples that contained anomalous amounts of these three metals are shown in figure 27.

Chromium in amounts of 300 ppm or more was found in 44 stream-sediment samples, and in amounts of 200 ppm or more in 11 rock samples and 3 mineralized rock samples. The highest amount found was 2,000 ppm, in sample 0191 of amphibolite from the Devils Bedstead on the ridge between Kane and Wildhorse Creeks. Sample 0271 from the same area contained 700 ppm chromium, 200 ppm nickel, and 100 ppm cobalt. None of these amounts is unusual for this kind of rock; according to Parker (1967, p. D13), average ultramafic rocks contain 1,600–2,000 ppm chromium, 2,000 ppm nickel, and 150–200 ppm cobalt. Other rock samples containing 300–700 ppm of chromium were mostly intermediate to felsic igneous rocks, but sample 6292 of lead-zinc ore from the head of East Fork of North Fork Big Wood River contained 300 ppm, and siltstone (sample 3342) from the upper part of the Wood River (?) Formation near Ryan Peak contained 200 ppm. The complete lack of the kinds of ultramafic rocks that are typical hosts for chromite deposits indicates that no economic concentrations of this metal are likely to be present in the study area.

Cobalt was detected in about 95 percent of all stream-sediment samples, mainly no doubt because of the great sensitivity of the spectrographic analytical method for this element. However, it was detected in amounts considered anomalous (100 ppm in stream sediments, 30 ppm in rocks) in only 3 stream-sediment samples, 11 samples of mineralized rocks, and 1 rock sample. The highest amounts found were 200 ppm, in hematitic sandstone (sample 6255) of the Wood River Formation on the ridge between Eagle and Lake Creeks and 150 ppm, in stream-sediment sample 0430 from near the mouth of a north-flowing tributary of Bear Canyon and in sulfide ore (sample 0723) from the Champion prospect on the west side of Muldoon Creek. All three stream-sediment samples also contained anomalous amounts of nickel (200 ppm or more). No potentially economic concentrations of cobalt were revealed by this study.

Nickel in amounts considered anomalous (200 ppm in stream sediments and 150 ppm in rocks) was detected in 17 samples of stream sediments, 8 samples of mineralized rock, and 21 samples of rocks. The highest nickel content, 700 ppm, was in sample 3359 of gossan in Challis Volcanics on the ridge between the Left and Right Forks of Iron Bog Creek, and in stream-sediment sample 0036 from a north-flowing tributary of Bartlett Creek. Anomalous amounts of nickel occur in a wide variety of rocks, including intermediate and mafic dikes and volcanics (11 samples), silicic dikes (2 samples), silicic fine-grained sedimentary rocks (9 samples), tectonic breccia (2 samples), gossan of uncertain derivation (4 samples), and tufa (1 sample). The samples are widely scattered except for a group of 10 stream-sediment samples and 4 rock samples in the northwest corner of the study area within an area of about 35 mi^2 (90 km^2). This area is underlain in large part by black shales of Ordovician to Permian age; three of the four rock samples are of black shale, and the nickel is probably an original constituent of these rocks.

GOLD

Gold production from mining districts near the Boulder-Pioneer study area seems to have been about 200,000 oz (6,200 kg) (Bergendahl, 1964, p. 98). The principal producers were mines of the Camas district 10 mi (16 km) southwest of Hailey, which yielded perhaps 100,000 oz (3,100 kg) (Anderson and Wagner, 1946, p. 9–10); the Alder Creek district, which according to Bergendahl (1964, p. 98) produced 33,500 oz (1,000 kg); and the Independence–Triumph–North Star group of mines; according to Umpleby, Westgate, and Ross (1930, p. 179), the North Star mine produced 16,000 oz (500 kg) of gold between 1885 and 1901, most of it in 1886. No gold production has been reported from within the study area, although iron ore from the Iron Clad claim at the head of Paymaster Gulch is reported to have contained as much as 0.8 oz gold per ton (27.5 g/t), and ore from the Mars claim at the head of Iron Mine

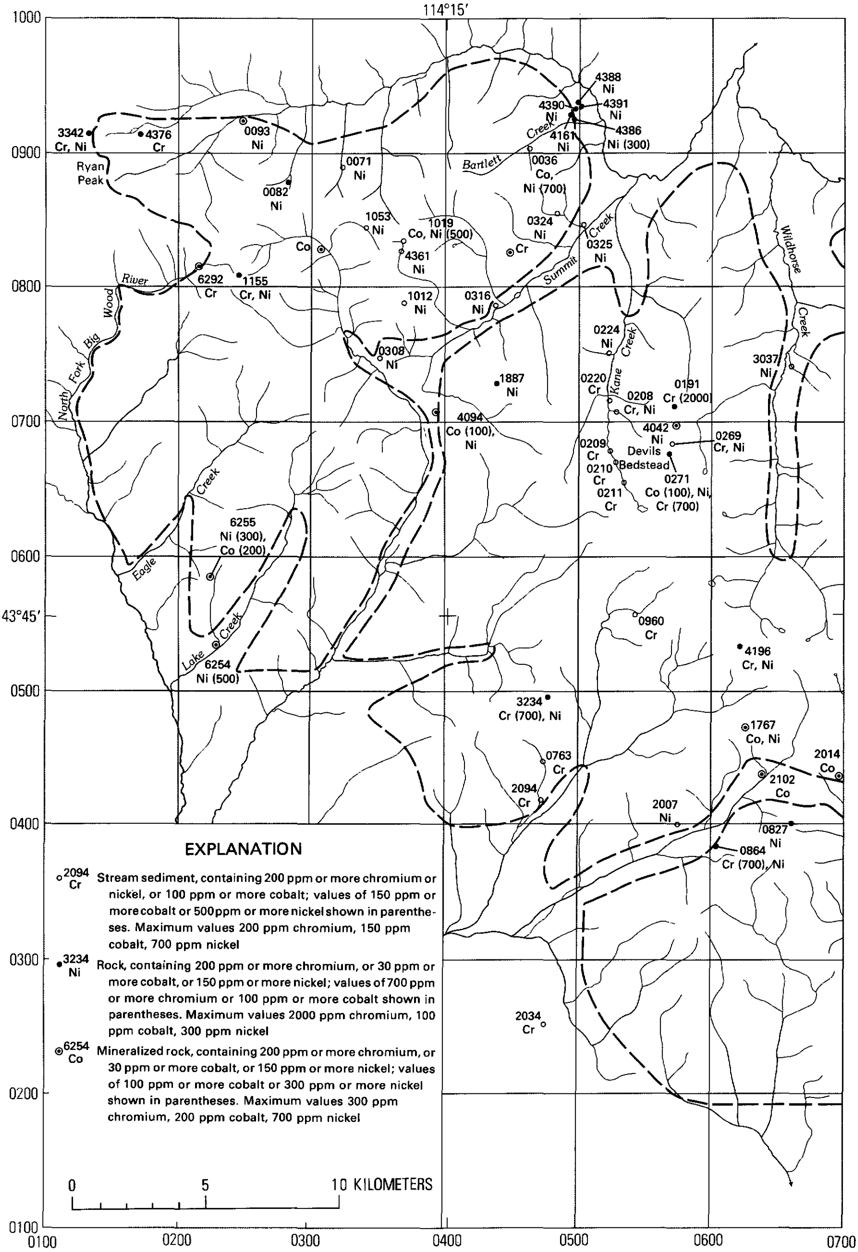
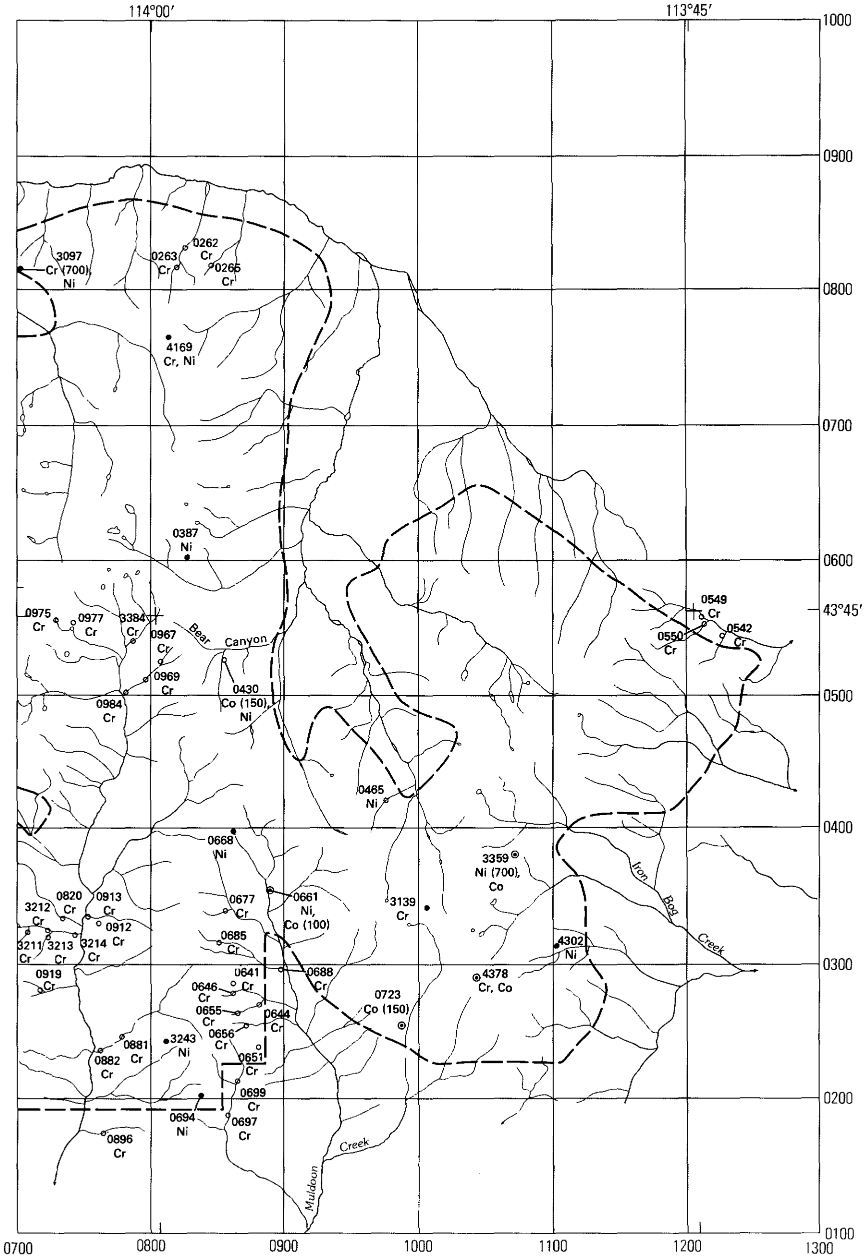


FIGURE 27 (above and facing page).—Localities of stream-sediment and rock samples containing chromium (Cr), cobalt (Co), or nickel (Ni). Grid is in units of 5,000 m; origin of grid is at lat 43°30′N., long 114°30′ W. Base from U.S. Forest Service 1:62,500 Sawtooth and Challis National Forests, Idaho, n.d.



Creek is said to have contained as much as 0.3 oz gold per ton (10.3 g/t) (Umpleby and others, 1930, p. 87, 199).

Gold was detected in 31 samples of stream sediments and 45 samples of mineralized rock (fig. 28); it was detected only by the atomic-absorption method of analysis. The highest gold content of any sample was 0.30 ppm in stream-sediment sample 4205 from Parker Gulch downstream from several formerly productive mines and 2 mi (3 km) outside the study area. Two other stream-sediment samples, 0443 from Star Hope Gulch below the Star Hope mine and 6267 from a headwater tributary of Eagle Creek, contained 0.2 ppm gold. Gold was reported only as L (detected but below the limit of determination) in 21 of the 31 stream-sediment samples. The highest gold content of any mineralized rock was 0.15 ppm, and in 24 of the 45 samples the amount reported was L. Six mineralized rock samples that contained 0.1 ppm gold are of weakly altered, iron-stained quartzite conglomerate of the Copper Basin Formation near the divide between Left Fork Iron Bog Creek and Argosy Creek. Some of these samples also contain anomalous amounts of copper, molybdenum, lead, and zinc, and all contain at least 300 ppm arsenic.

With the possible exception of the just-noted Argosy Creek–Iron Bog Creek area, no economically interesting concentrations of gold were revealed by this study; and indeed the entire region, including the mining districts adjacent to the study area but excepting the Camas district, seems to be one of very low gold potential.

IRON

A small production of magnetite ore for use as smelter flux has been reported from the Iron Clad mine at the head of Paymaster Gulch and the Mars claim at the head of Iron Mine Creek; this ore is said to have contained $6–$16 per ton in gold (Umpleby and others, 1930, p. 199). Abundant magnetite has also been reported from copper deposits in the Alder Creek district (Umpleby, 1917, p. 53–54; Asher, 1964, p. 107).

Although a number of iron-rich gossans were seen and sampled during this study, no concentration of iron ore of economic importance was found.

LANTHANUM

Lanthanum and yttrium are the only two rare-earth elements reported by semiquantitative spectrographic analysis in this study. No unusual amount of yttrium was detected in any sample.

Lanthanum was detected in anomalous amounts in 19 stream-sediment samples (150 ppm or more) and in 7 rock and 12 mineralized rock samples (70 ppm or more) (fig. 25). The highest amount found was 1,000 ppm, in stream-sediment sample 2126 from a small west-sloping tributary of Little Wood River in the SE¼ sec. 14, T. 4 N., R. 20 E. This sample also contained 1,000 ppm zirconium, the most found during the study. The rocks in the corresponding drainage basin are Challis Volcanics and Wood River Formation, which nowhere seemed to contain unusual amounts of lanthanum. Two other stream-sediment samples contained 500 ppm lanthanum: 0994 from upper Box Canyon and 4005 from upper Laidlaw Creek, both headwater tributaries of Little Wood River that drain mainly quartz monzonitic rock of the intrusive complex of the Pioneer window. No rock sample contained amounts of lanthanum unusual for the rock type.

All but three of the anomalous stream-sediment samples are from Fall Creek, Little Wood River, east-flowing tributaries of Star Hope Creek, or Wildhorse Creek, drainages that are underlain largely or entirely by quartz monzonite of the intrusive complex of the Pioneer window. Plutonic rocks of this composition contain an average of 60 ppm of lanthanum (Parker, 1967, p. D14), so either the intrusive complex of the Pioneer window is slightly higher than average in lanthanum or some concentration has occurred in the sediments samples; in any case, lanthanum levels are not believed to be high enough to indicate any unusual amounts of rare-earth elements in the parent rocks.

MANGANESE

No production of manganese has been reported from the study area or its vicinity, nor was any manganese ore found either previously or during this study.

Manganese was detected in the amount of 1,500 ppm or more in 81 stream-sediment samples, 11 rock samples, and 24 mineralized rock samples (fig. 29). Only 13 samples contained more than 3,000 ppm; the highest amount, more than 5,000 ppm (0.5 percent), was in eight samples of mineralized rock from gossan zones (2014, 2017, and 6252), mine dumps (0661, 2101, 2103, and 6294), and a breccia zone in quartzite of the Hyndman Formation (1767).

As is shown by figure 29, the samples anomalous in manganese are widely scattered throughout the study area but seem to be slightly concentrated in and around the borders of the plutonic-metamorphic core area of the Pioneer Mountains; in the drainage basins of Eagle and Lake Creeks in an area underlain mainly by Devonian and Pennsylvanian sedimentary rocks; and near the east edge of the study area in a region underlain extensively by Tertiary volcanic rocks. No obvious association between manganese and mineral deposits can be recognized except possibly in the Mascot mine area. Although some mineralized rocks contain anomalous amounts of manganese, most do not, and stream-sediment samples do not reflect the small mineral deposits known to exist in, for example, Little Fall, Phi Kappa, and Right Fork Iron Bog Creeks.

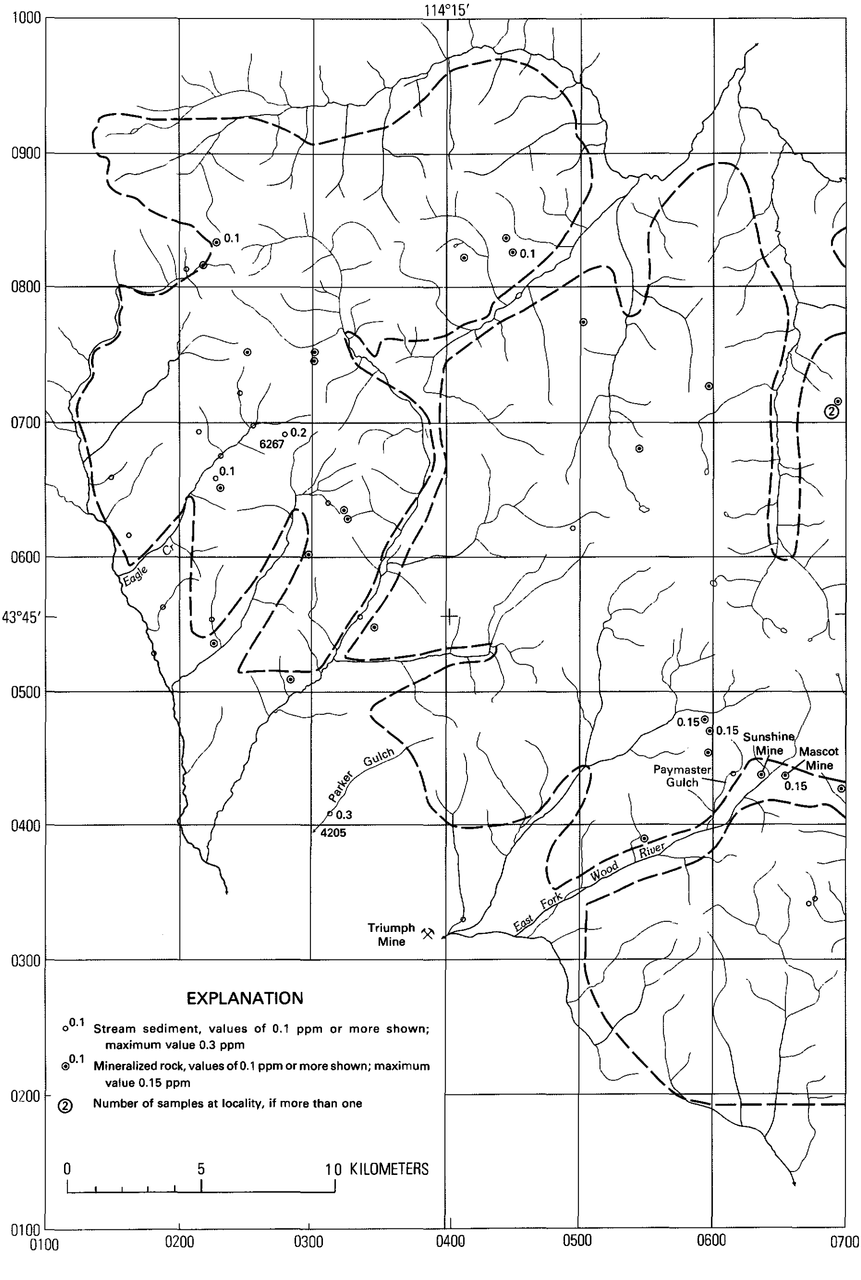
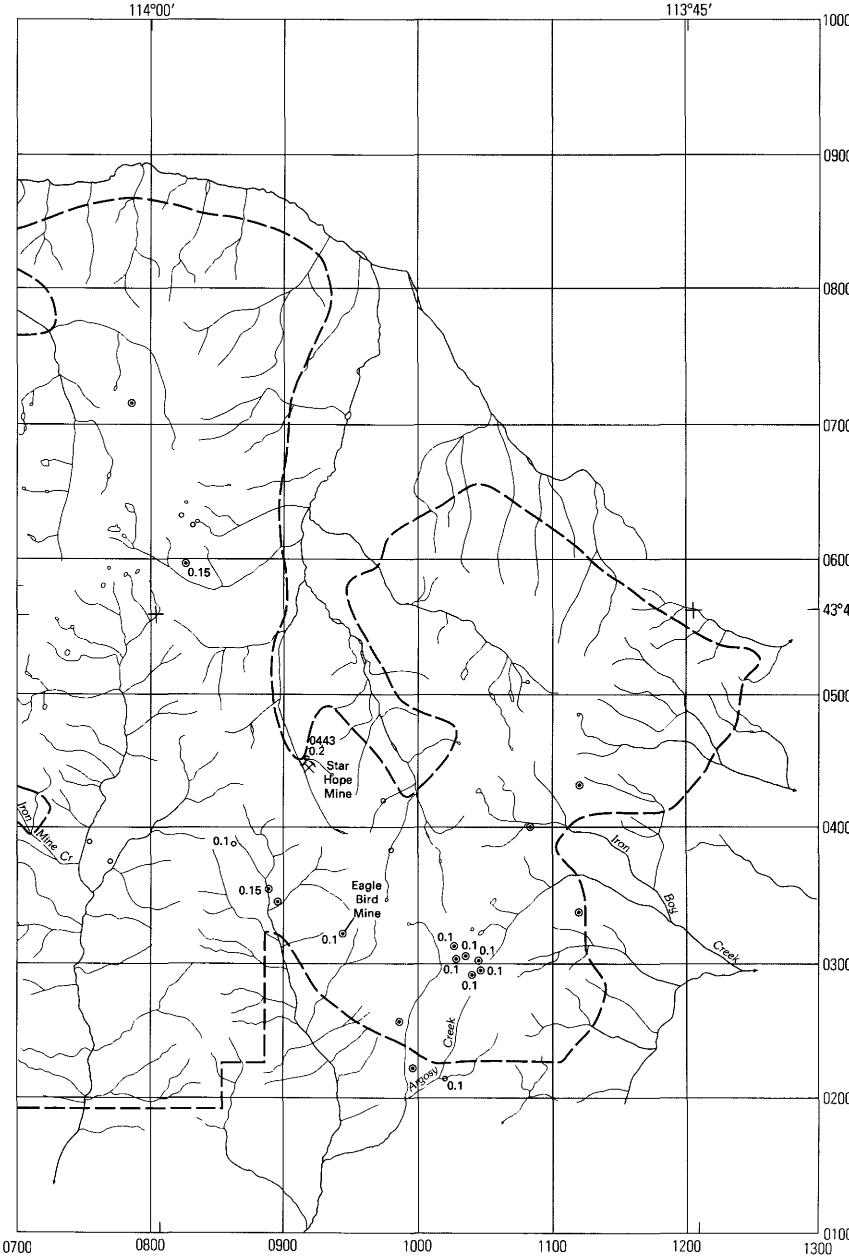


FIGURE 28 (above and facing page).—Localities of stream-sediment and rock samples in which gold was detected. Grid is in units of 5,000 m; origin of grid is at lat 43°30′ N., long 114°30′ W. Base from U.S. Forest Service 1:62,500 Sawtooth and Challis National Forests, Idaho, n.d.



MERCURY

Mercury has been reported from the Dockwell tunnel of the Bonnie mine southwest of Gimlet (Umpleby and others, 1930, p. 161; Bailey, 1964, p. 123) but none has been reported previously from within the study area.

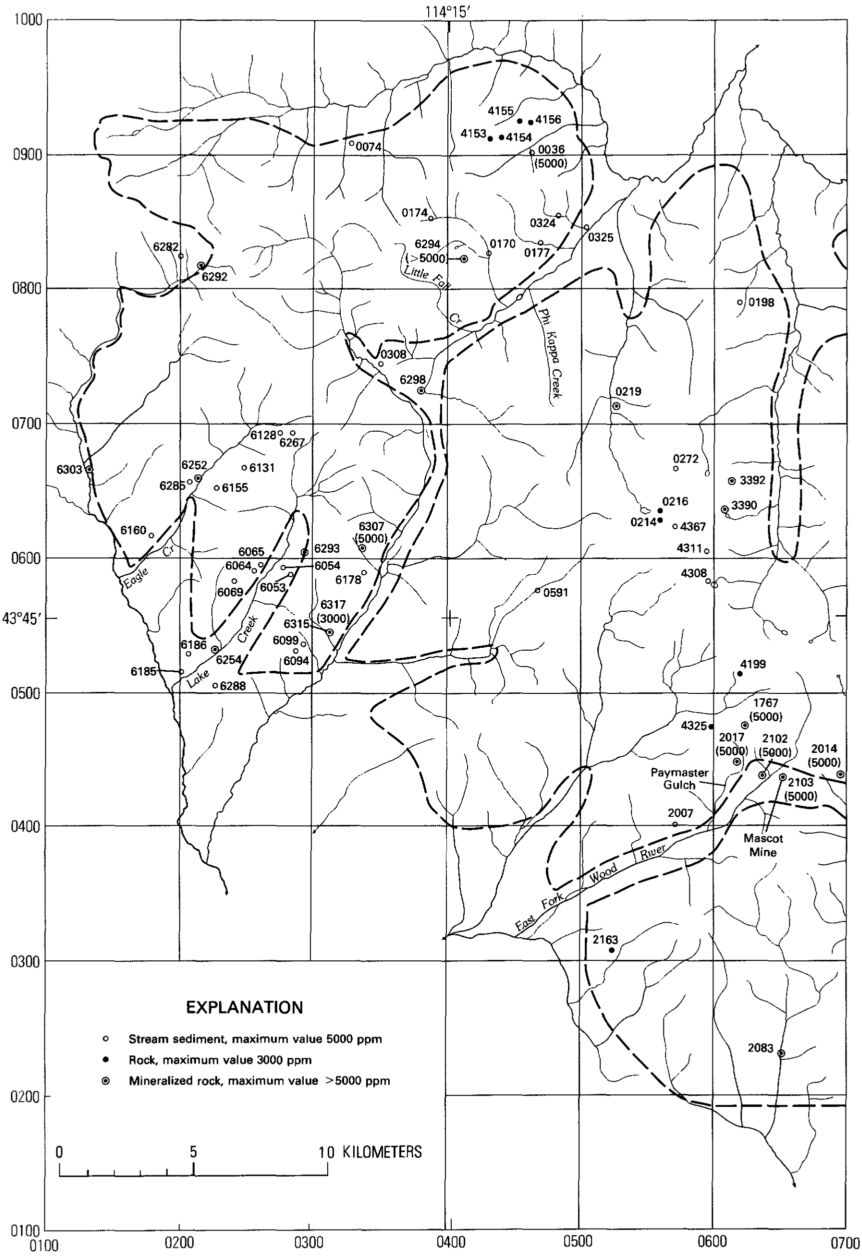
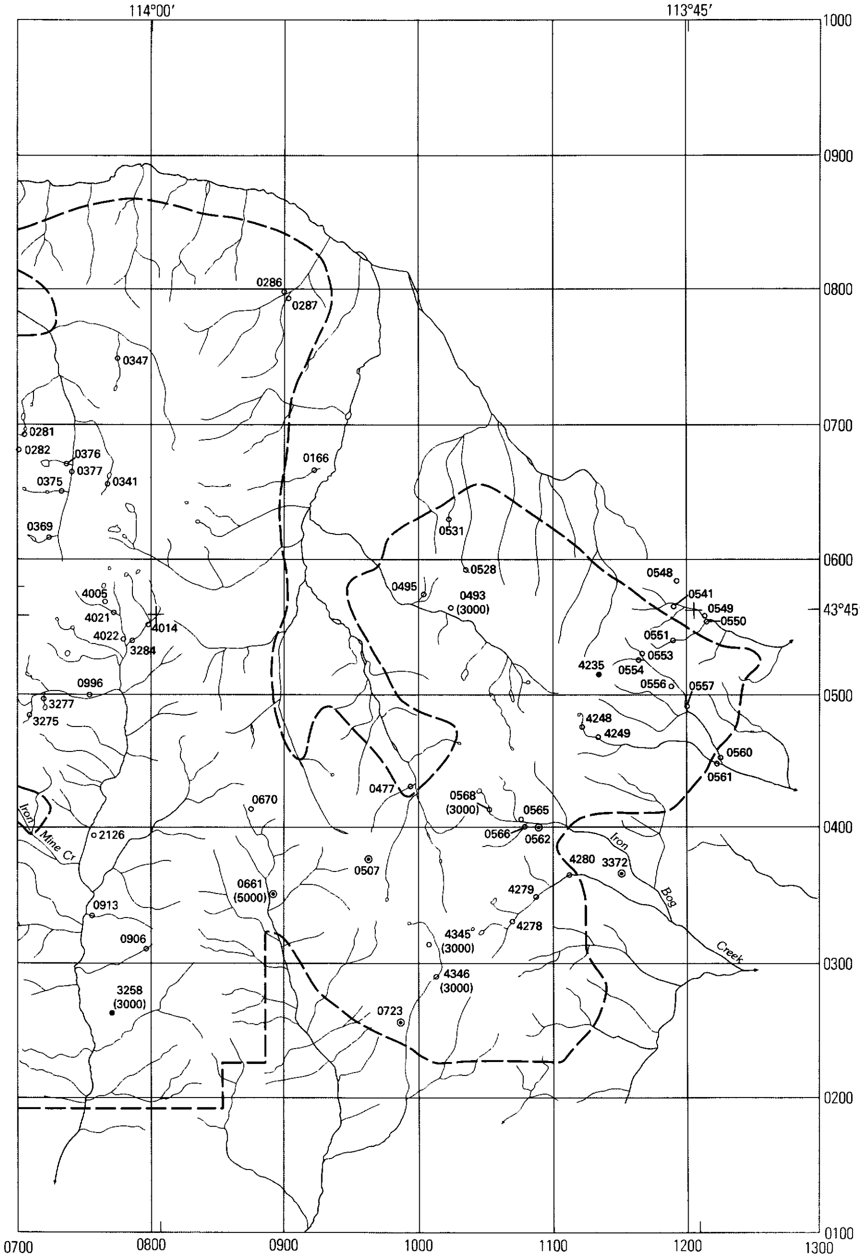


FIGURE 29 (above and facing page).—Localities of stream-sediment and rock samples containing >1,000 ppm manganese. Grid is in units of 5,000 m; origin of grid is at lat 43°30′ N., long 114°30′ W. Base from U.S. Forest Service 1:62,500 Sawtooth and Challis National Forests, Idaho, n.d.



During this study, 69 samples of mineralized rocks and 12 samples of other rocks were analyzed for mercury. Most of these were from the area northwest of Trail and Summit Creeks. The highest amounts routinely measured, more than 10 ppm, were found in 11 samples of mineralized rock (fig. 23): sample 6299 of complex base-metal ore containing 240 ppm mercury from the Daisy (Mattie) mine on the east side of lower Trail Creek; samples 6295 and 6297 of copper-lead-zinc ore containing 10 and 40 ppm mercury, respectively, from the Lone Cabin mine on the east side of Lake Creek (Big Wood River); three samples (6270, 6271, and 6272) of high-grade lead-zinc ore from prospects on the southeast side of Eagle Creek in sec. 6, T. 5 N., R. 18 E.; two samples (6289 and 6291) of copper-lead-zinc-silver ore from prospects at the head of Lake Creek (Big Wood River); two samples (6314 and 6317) of lead-zinc ore from a prospect on Antelope Creek (lower Trail Creek area); and sample 2092 of low-grade oxidized lead ore from a prospect near the head of Porcupine Creek. Only 12 other samples, all of mineralized rock, contained 1 ppm or more of mercury, and only 8 others, also of mineralized rock, contained as much as 0.4 ppm. The highest mercury content in any nonmineralized rock was 0.18 ppm.

No stream-sediment sample was analyzed for mercury, nor were most rock samples, but the very low levels of mercury in most analyzed samples, and the apparent lack of mercury minerals in the study area, indicate that concentrations of economic interest are not likely to be found.

More than one-half of the samples that contain 1 ppm or more mercury also contain 100 ppm or more antimony and (or) 200 ppm or more arsenic, and all but three of them also contain substantial amounts of at least one of the metals copper, lead, molybdenum, silver, zinc, or cadmium (table 13). The association of the three "volatile" or far-traveled elements antimony, arsenic, and mercury with metalliferous ores or metallized rock in at least the west and southwest parts of the study area suggest that they might be used as indicators of possible concealed ore deposits. (See also p. 147.) The fact that about one-half of the mineralized rocks that contain even as little as 0.4 ppm mercury also contain anomalous amounts of at least one of the metals listed in table 13 suggests that mercury analyses might be useful for scanning of samples collected during the preliminary stage of a program of geochemical exploration in favorable parts of the study area.

NIOBIUM

Niobium was detected in anomalous amounts (30 ppm or more) in 21 samples of stream sediment and 4 samples of rock; 7 other rock samples contained 20 ppm niobium. Localities of all these samples are shown in figure 25. The highest niobium content found was 70 ppm, in stream-sediment samples from a tributary of upper Wildhorse Creek (3027), Mud Springs Creek (0850), and the head of Kane Creek (4367).

Samples anomalous in niobium are distributed similarly to those

TABLE 13.—*Amounts of selected elements, in parts per million, in mineralized rocks that also contain 1 ppm or more mercury. Mercury and zinc analyzed by atomic absorption, other elements spectrographically*

[L, detected but below limit of determination; N, not detected]

Sample	Element								
No.	Hg	As	Sb	Ag	Cu	Mo	Pb	Zn	Cd
2060	1.3	300	700	10	30	N	5,000	2,300	30
2092	10+	1,000	2,000	150	2,000	30	20,000	5,200	50
6257	2.0	N	N	.5	20	N	L	11,000	150
6270	10+	N	N	10	200	N	500	130,000	100+
6271	10+	N	L	70	300	20	50,000+	43,000	1,000+
6272	10+	N	N	10	300	N	1,000	50,000	1,000+
6273	1.0	N	N	.5	10	N	300	570	50
6289	10+	N	200	3,000	1,500	N	50,000+	63,000	N
6290	2.0	N	300	1,500	200	N	50,000+	720	N
6291	10+	N	200	200	300	N	50,000+	260,000	N
6292	1.1	N	L	15	300	N	20,000	22,000	150
6293	6.0	N	N	5	20	N	150	480,000	500+
6295	10	L	700	1,000	1,000	N	20,000+	58,000	100+
6296	3.5	N	700	1,500	700	N	20,000+	19,000	500+
6297	40	N	700	150	700	N	20,000+	260,000	500+
6299	240	10,000+	10,000+	3,000	20,000+	7	20,000+	32,000	500+
6301	1.5	N	L	20	70	200	100	1,100	30
6308	4.0	N	N	30	30	N	20,000	25,000	150
6310	5.0	2,000	N	3	30	L	20	650	N
6311	2.0	N	N	L	30	N	L	80	N
6314	10+	N	100	20	700	N	5,000	25,000	1,000+
6316	6.0	N	700	500	50	N	40,000+	20,000	1,000
6317	10+	N	N	20	150	N	2,000	2,500	1,000

anomalous in lanthanum. All but two of the anomalous stream-sediment samples are from drainages underlain in whole or in part by quartz monzonitic rocks of the intrusive complex of the Pioneer window; eight of these samples are from upper Kane Creek, as are two rock samples in which niobium was detected (0216, a biotite schist inclusion in quartz monzonite, 30 ppm; and 0217, gneissose quartz monzonite, 20 ppm). No unusual concentrations of niobium are indicated by our data; according to Parker (1967, p. D13), the average niobium content of all intermediate to felsic igneous rocks is about 20 ppm.

TIN

Tin has been reported in trace amounts from copper slag from the Copper Basin area (0.03 percent), in lead concentrate from the Triumph–North Star–Independence group of mines (0.03 percent), and in zinc concentrate from the same group of mines (0.02 percent) (Kaiser and others, 1954, p. 49–50). It has not been reported from within the study area.

During this study, tin was detected in 2 samples of stream sediment, 12 samples of mineralized rock, and 1 sample of rock (fig. 26). The highest concentration, 700 ppm, was in copper-lead-zinc ore from a prospect at the end of the road up Big Fall Creek (sample 6294). The next highest concentration, 150 ppm, was in sample 0507 of skarn from a prospect near the head of the west fork of Muldoon Canyon in the NW¼ sec. 24, T. 4 N., R. 21 E. Sample 0219 of thoroughly oxidized mineralized rock from a prospect near the end of the road up Kane Creek contained 70 ppm of tin. Tin-bearing samples are very widely scattered, and seven samples contained only 15 ppm or less, so that no potentially economic concentrations are indicated within the study area.

TUNGSTEN

Tungsten ore has been mined at the Wildhorse mine on the west side of Wildhorse Creek (Cook, 1956, p. 12–17); production from 1954 to 1956 was 149,220 lb (67,500 kg) of WO_3 valued at $459,000. In addition, tactite deposits containing a little scheelite ($CaWO_4$) have been described from other places on Wildhorse Creek (Cook, 1956, p. 17–18), at the Phi Kappa mine (Cook, 1956, p. 18), on Little Fall Creek just north of Summit Creek (Cook, 1956, p. 19–20), and from the Eagle Bird mine (Cook, 1956, p. 12); and wolframite ($(Fe, Mn) WO_4$) has been recognized in a quartz vein near the mouth of Big Fall Creek (Cook, 1956, p. 31). Information on these occurrences is summarized by Hobbs (1964, p. 231–232). Tungsten minerals also have been reported from the nearby Alder Creek district and the Midnight mine in the Mineral Hill district (Hobbs, 1964, p. 231–232).

Tungsten was detected in amounts of 50 ppm or more in seven samples of stream sediment and two samples of mineralized rock (fig. 26), and was detected (L) in two other stream-sediment samples, in three rock samples, and in four mineralized rock samples. Five of the stream-sediment samples were from Wildhorse Creek in an area of known tungsten mineralization, and the other two were from Surprise Valley, 3–4 mi (5–6 km) east of Wildhorse Creek, whose entire drainage basin is underlain by quartz monzonitic rocks. The mineralized rock samples containing 50 ppm or more tungsten are from a tactite lens west of Wildhorse Creek (sample 3390; 70 ppm) and from a felsite dike on the ridge east of Big Fall Creek (sample 4230; 60 ppm).

The Wildhorse mine, comprising the Steep Climb, Hard to Find, and Beaver deposits, is the only mine in the study area known to have produced tungsten ore. Scheelite-bearing tactite bodies similar to those at the Wildhorse mine occur at many places in middle and upper Wildhorse Creek, particularly on the Pine Mouse group of claims; but their small size and great difficulty of access appear to have discouraged exploration. Other areas in which tungsten has been detected appear to have little or no economic potential.

URANIUM AND THORIUM

Prospecting for uranium has been done at several places in and near the study area, including Park Canyon and the North Fork Big Lost River (Corral Creek–Little Burnt Creek area). Although small amounts of supergene uranium minerals have been found, no commercial deposits have been reported nor has any uranium been produced from the uranium prospects. However, our colleague C. M. Tschanz (written commun., 1976) reported that, according to the former owner, $1,140 was paid for the uranium contained in a black, heavy, radioactive mineral (brannerite(?)—a complex oxide of uranium, thorium, titanium, and other metals) that made up part of a shipment of 840 lb (381 kg) of scheelite (tungsten) concentrate from a prospect at the margin of the Summit Creek stock in Little Fall Creek. Thorium-bearing minerals have been reported from placer deposits of the Camas district southwest of the study area, but no occurrences of thorium minerals are known from the study area.

Stream-sediment samples from 156 localities (fig. 30) were analyzed for uranium and thorium by neutron-activation analysis. Uranium was determined in 146 samples in amounts ranging from 1.3 to 122 ppm. The mean uranium content is 10 ppm, and the median content is 5 ppm. The uranium content of the 30 samples that contained 10 ppm or more is shown in figure 30. About two-thirds of these samples are from drainage basins underlain wholly or in large part by quartz monzonitic rocks (including gneiss)—Kane, Wildhorse, Fall, Star Hope, and Lake Creeks, Little Wood River, and Surprise Valley—and the rest are from streams that drain mainly Paleozoic sedimentary rocks, or Tertiary volcanic rocks, or both. The highest uranium contents are 122 ppm, in sample 0491 from upper Lake Creek (Copper Basin; mostly quartz monzonitic rocks), and 109 ppm, in sample 0153 from the mouth of Phi Kappa Creek (mostly sedimentary rocks). Except for sample 0153, none of the samples derived from sedimentary-volcanic terrane contains more than 23 ppm uranium, and most contain less than 5 ppm, whereas 12 samples derived from quartz monzonitic terrane contain 25 ppm or more uranium and almost all contain at least 10 ppm.

Thorium was determined in 127 stream-sediment samples in amounts ranging from 4 to 119 ppm. The average thorium content is 20 ppm and the median content is 10 ppm. The thorium-to-uranium ratio for 127 samples ranges from 0.49 to 4.99; the average ratio is 2.25 and the median ratio is 2.04. The thorium content of the 24 samples that contain 20 ppm or more is shown in figure 30; all but 3 of these samples also contain 10 ppm or more uranium. Of the 13 samples that have the highest combined total content of thorium and uranium, 12 are from drainages underlain almost entirely by quartz monzonitic rocks of either the intrusive complex of the Pioneer window or the Lake Creek stock.

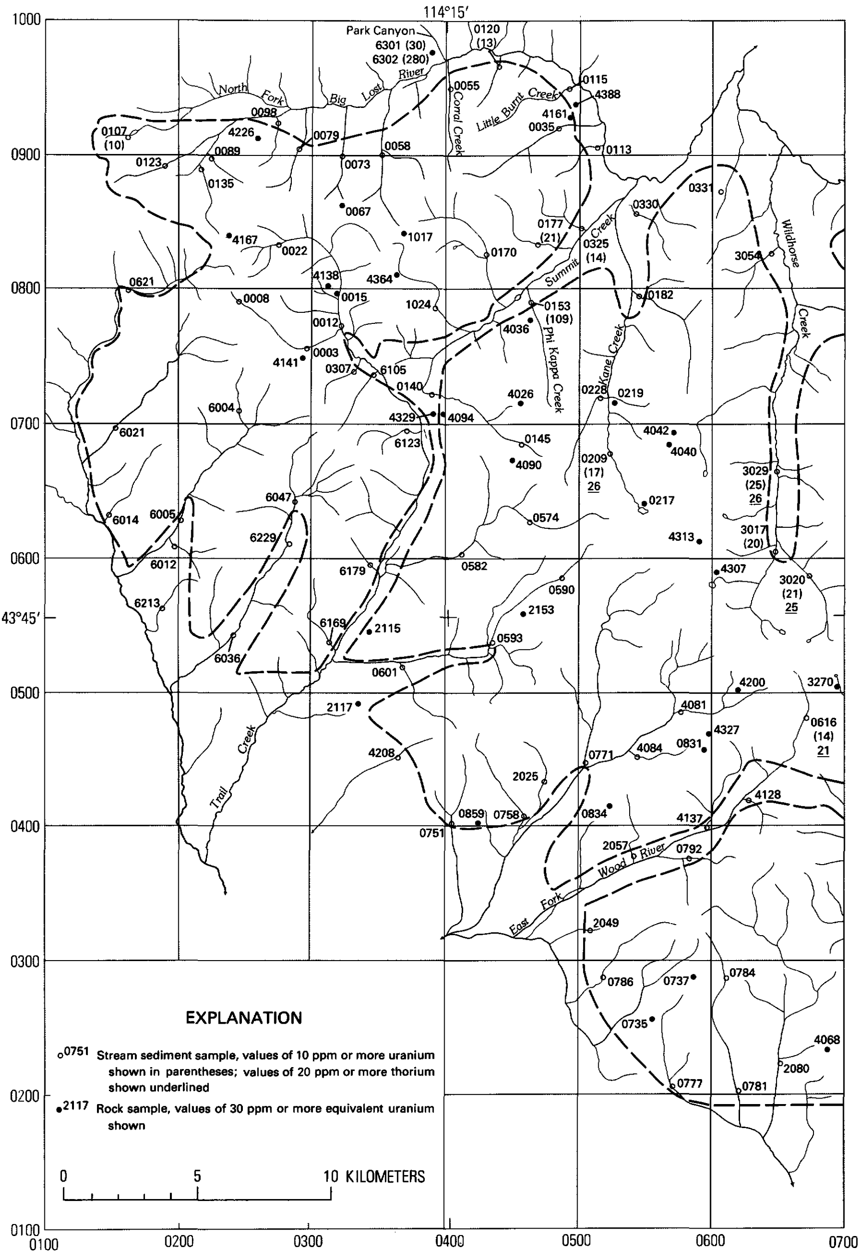
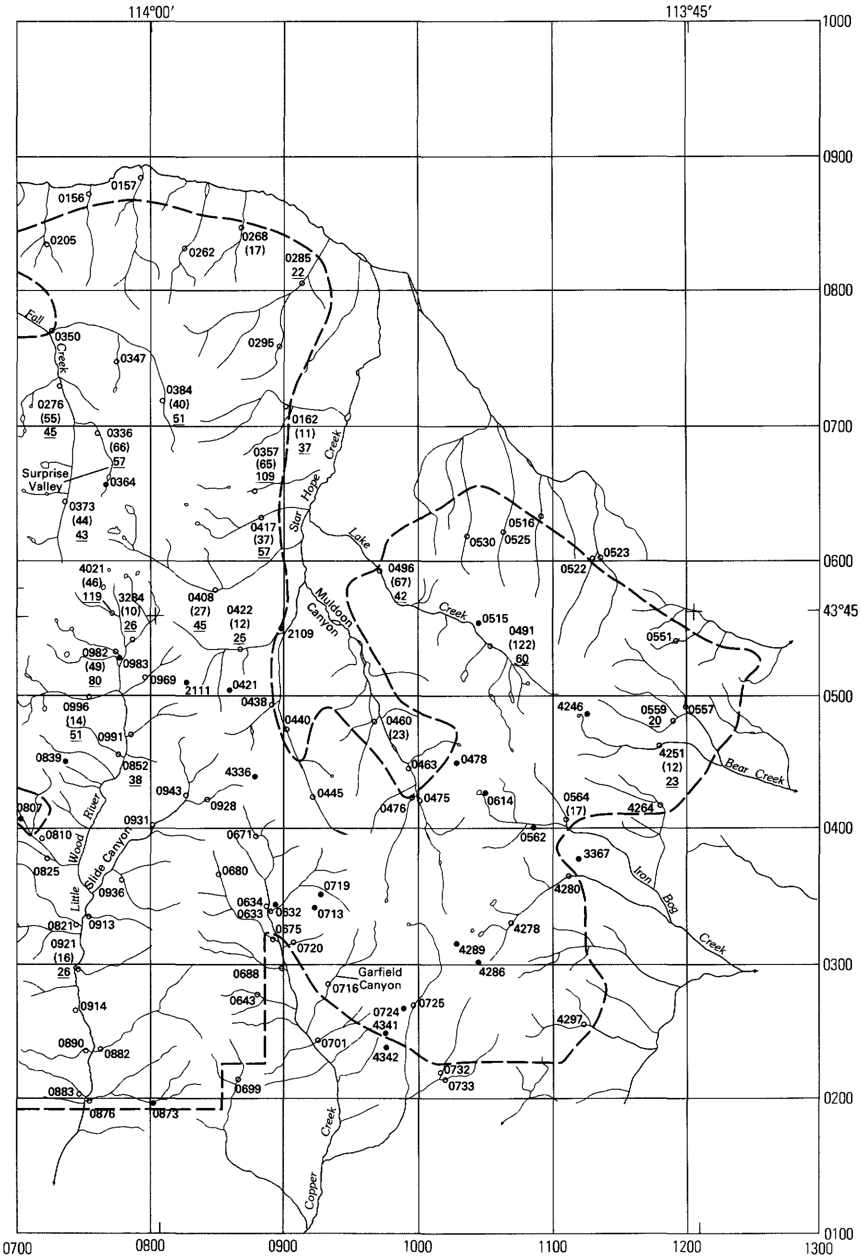


FIGURE 30 (above and facing page).—Localities of stream-sediment samples analyzed for uranium and thorium and of rock samples analyzed for equivalent uranium (eU). Grid is in units of 5,000 m; origin of grid is at lat 43°30′ N., long 114°30′ W. Base from U.S. Forest Service 1:62,500 Sawtooth and Challis National Forests, Idaho, n.d.



Samples of 58 rocks representing all the major rock units of the area except Challis Volcanics, and selected to give a broad geographic coverage of the study area, were analyzed for equivalent uranium (eU) by a radioactivity scanner; the lower limit of detection was 30 ppm. Sample localities are shown in figure 30. Samples were of the Summit Creek, Lake Creek, Muldoon Canyon, and Garfield Canyon stocks (5 samples), the intrusive complex of the Pioneer window, (3 samples), sub-Challis clastic rocks (2 samples), Paleozoic black shales from all formations (32 samples), Paleozoic quartzite or quartzite conglomerate (6 samples), lower Paleozoic metasedimentary rocks (4 samples), Precambrian metamorphic rocks (3 samples), fault breccia (1 sample), gossan (1 sample), and autunite(?)-bearing black shale (1 sample). Twelve samples were of mineralized rocks, and two (4161 and 4388 south of Little Burnt Creek) were of drill hole cuttings. Only two samples were found to contain as much as 30 ppm eU; sample 6302, of autunite(?)-bearing black shale from a prospect near the confluence of Park Canyon and North Fork Big Lost River, contained 280 ppm eU; and black shale from the same locality (sample 6301) contained 30 ppm eU. C. M. Tschanz reported (written commun., 1976) that sample 6302 contained 410 ppm uranium, and that tailings from 50 to 70 tons (45 to 64 t) of scheelite ore from a prospect on Little Fall Creek contained 300 ppm U_3O_8 (equivalent to about 250 ppm uranium).

Most stream-sediment samples that contain relatively high amounts of uranium are from drainage basins underlain mainly by quartz monzonitic rocks; all but two of the samples containing 20 ppm or more uranium, and about 65 percent of the samples containing 10 ppm or more, are from such terrane. No mineralogic study has been made of these samples and the mode of occurrence of the uranium in them is unknown, but some study might be worthwhile, especially of the six samples that contain very high amounts of 50 ppm or more. Some more detailed sampling might also be justified in the Lake Creek (Copper Basin) drainage, which yielded two samples containing 122 and 67 ppm uranium, respectively. Only one sample that had a high uranium content came from a drainage basin underlain mostly by sedimentary rocks (sample 0153 from Phi Kappa Creek; 109 ppm uranium); the occurrence is unusual, and some additional sampling might be warranted.

VANADIUM

Vanadium has not been reported previously from the study area, but anomalous amounts (500 ppm or more in stream sediments, 300 ppm or more in rocks) were found in 23 samples of stream sediments and soils, and in 53 rock samples (fig. 31). The highest vanadium content in stream sediments was 1,000 ppm, and in rocks 2,000 ppm.

The vanadium appears for the most part to be contained in, or derived from, black shale or its metamorphosed equivalents. All but seven of the rock samples containing anomalous amounts of vanadium are black shale of Mississippian age (29 samples) or Ordovician to Devonian age (17 samples). Furthermore, 18 of the 23 anomalous stream-sediment samples are from the northwest corner of the study area in a region extensively underlain by black shale, and 16 of the anomalous rock samples including 6 samples of chips from drill holes on the hill at the northeast end of the ridge between Bartlett and Little Burnt Creeks, are from the same area. In contrast, vanadium is conspicuously low in samples of mineralized rock, and only 8 out of 160 samples (3101, 3123, 4042, 4321, 4393, 6294, 6301, and 6302) contain 300 ppm or more; all but samples 3101 and 3123 are from fine-grained Paleozoic sedimentary rocks and some or all of the vanadium content may be primary. Nevertheless, the fact that most of the samples anomalous in vanadium are from the northwest part of the study area, a region that also has many samples anomalous in copper, lead, molybdenum, and zinc, suggests that some vanadium has been introduced into, or at least enriched in, the anomalous rocks. (See p. 130.)

Samples containing anomalous amounts of vanadium commonly also contain anomalous amounts of certain other metals, as is shown in table 14.

FLUORSPAR

Minor amounts of fluorspar (fluorite) have been reported from the Basin group of lead-zinc-copper prospects, said to be just north of the confluence of Park and Summit Creeks (Umpleby and others, 1939, p. 206; Anderson and Van Alstine, 1964, p. 82, 84); and a small deposit of siliceous fluorite at the Purple Spar prospect on Little Fall Creek is described on p. 203–205. No production of fluorspar has been reported from the study area or its immediate vicinity.

PLACER DEPOSITS

The only productive placer deposits known in the region are those along Rock and Camp Creeks in the Camas district about 10 mi (16 km) southwest of Hailey and far outside the study area (Parker, 1964, p. 141–142; Anderson and Savage, 1964, p. 215–216; Savage, 1961, p. 47–56; 1964, p. 220). These placers have produced a little gold and are reported to contain ilmenite, rutile, and zircon as well as minerals containing niobium, tantalum, thorium, uranium, and rare earths. No placers have been exploited in the study area; although it is probable that some deposits of heavy minerals exist, they are likely to contain mainly noneconomic minerals such as magnetite, ilmenite, zircon, and garnet, and to have little gold or other valuable minerals.

CONSTRUCTION MATERIALS

Sand and gravel have been mined at many places along Big Wood River below Ketchum, along Little Wood River around Carey, and

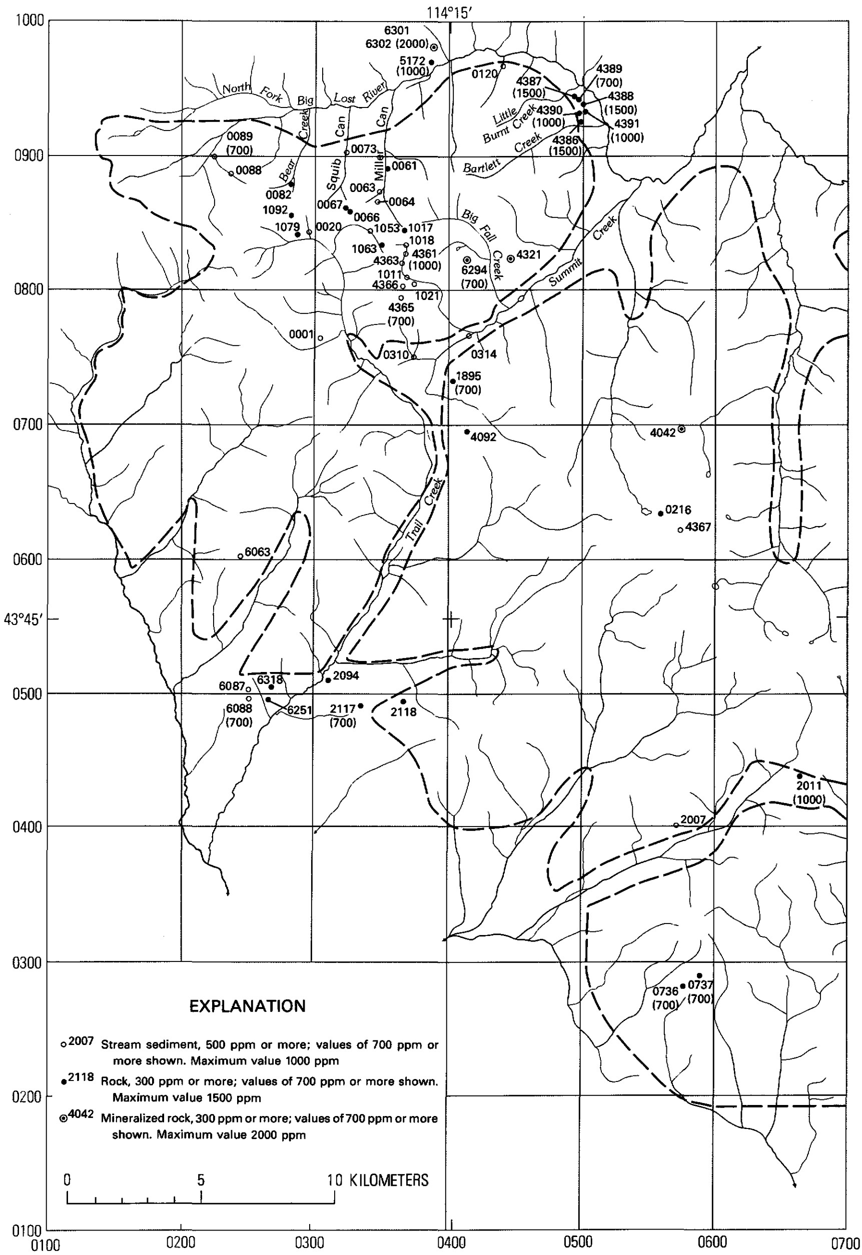
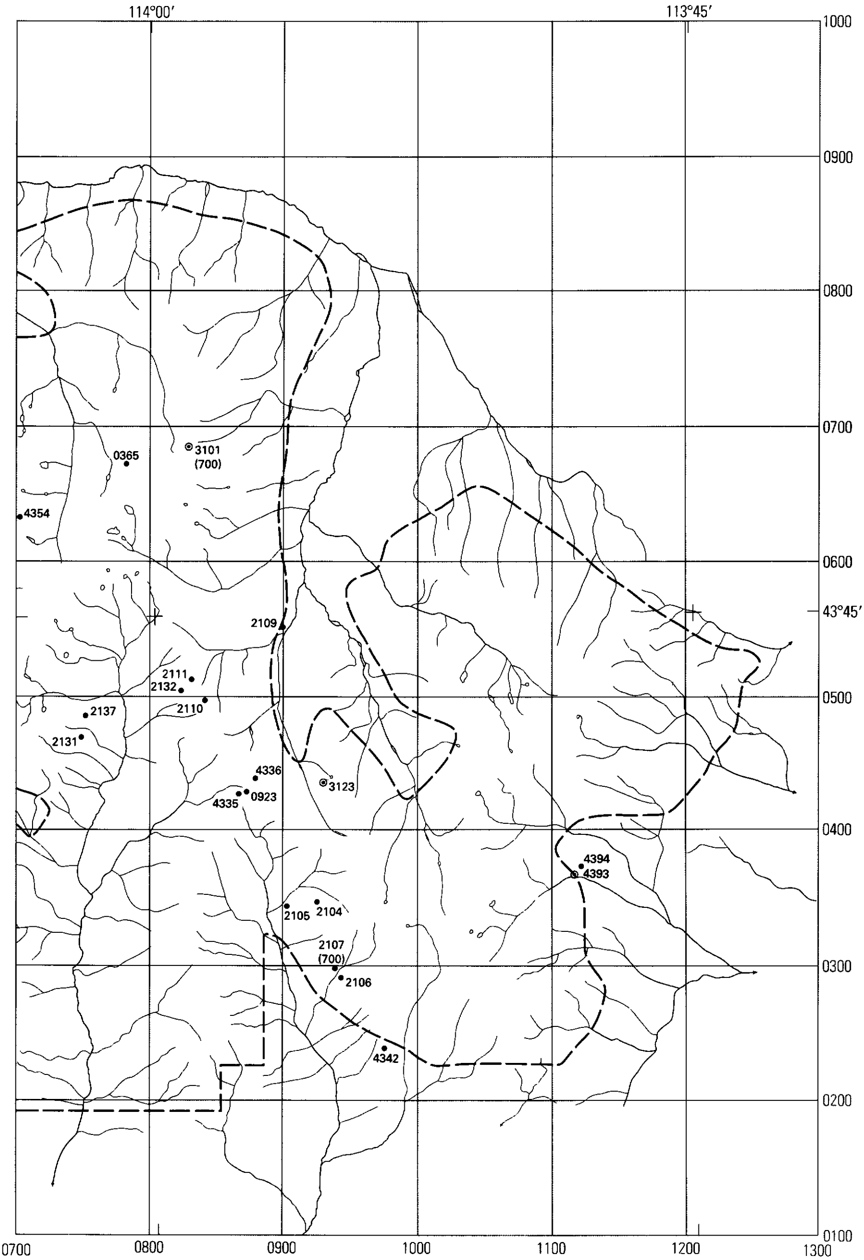


FIGURE 31 (above and facing page).—Localities of stream-sediment and rock samples containing vanadium. Grid is in units of 5,000 m; origin of grid is at lat 43°30′N., long 114°30′W. Base from U.S. Forest Service 1:62,500 Sawtooth and Challis National Forests, Idaho, n.d.



along Big Lost River below Chilly (Charboneau, 1964, p. 171). Abundant deposits of sand and gravel exist in and near the study area along the upper Big Lost River (Summit Creek, lower Wildhorse Creek, East

TABLE 14.—*Number of samples and percentage of samples (in parentheses) anomalous in vanadium that also contain anomalous amounts of copper (≥50 ppm), lead (≥70 ppm), molybdenum (≥7ppm), and zinc (detected spectrographically)*

Sample type	Metal			
	Cu	Pb	Mo	Zn
Stream sediments and soils	15	13	19	2
(23 samples)	(65)	(57)	(83)	(91)
Rock and mineralized rocks	16	13	26	24
(53 samples)	(30)	(25)	(40)	(45)

Fork Big Lost River, and Copper Basin). However, no appreciable production has come from the study area, and suitable material is readily available in more accessible places.

No building stone or road material has been quarried within the study area, and although some rocks, such as calc-silicate member C of the Hyndman Formation and marble in members E and G of the East Fork Formation, are attractive, none of them are especially well suited for either use, particularly inasmuch as abundant basalt lava and cinders are available elsewhere in Idaho (basalt of Snake River Group in southern Idaho, Columbia River Basalt Group in northern Idaho).

Limestone occurs in the study area as a major part of the Drummond Mine Member of the Copper Basin plate of the Copper Basin Formation and also as thin beds in many of the other sedimentary rock units. However, no production is known; none of the limestone formations that are principal sources elsewhere in the region occur in the study area; and the limestone beds are too impure, or too thin, or both, to constitute commercially attractive sources.

COAL AND GRAPHITE

Graphitic material considered to be metamorphosed coal has been reported from the Parker mine on Elkhorn Creek and the Evelyn prospect west of lower Trail Creek by Umpleby, Westgate, and Ross (1930, p. 113–114, 185–187, 192) and by Ross (1941, p. 16). Both occurrences are outside the study area. Neither coal nor graphite has been reported from the study area, and except for scattered occurrences of graphitic slate or argillite, they were not recognized during this study.

PETROLEUM AND NATURAL GAS

No production of petroleum or natural gas has been reported from in or near the study area, or indeed from anywhere in Idaho in commercial quantities; the exploratory wells nearest to the study area are more than 75 mi (120 km) distant (Savage, 1964, p. 147–150). Almost the entire study area is underlain by Tertiary volcanic rocks, plutonic and metamorphic rocks of various ages, and Paleozoic sedimentary and somewhat metamorphosed sedimentary rocks, few of which are suitable hydrocarbon reservoir rocks. Autochthonous or parautochthonous Paleozoic sedimentary rocks possibly more favorable for accumulation of hydrocarbons may underlie some of the study area, but the few scattered and small outcrops of these rocks give almost no clues to either their distribution at depth or their oil and gas potential. The probability that accumulations of petroleum or natural gas occur within the study area is considered to be very small.

GEOTHERMAL RESOURCES

Many hot springs occur within a few miles (a few kilometers) of the study area on the west and south sides along and near the Big Wood River, and several have been developed as resorts, including Russian John Hot Springs, Easly Warm Springs, Guyer Hot Springs, Clarendon Hot Springs, Hailey Hot Springs, Lava Creek Hot Springs, and Condie Hot Springs (Stearns and others, 1937, p. 81–82, 146–147; Waring, 1965, p. 29–30). Some of these springs presumably are related to volcanism whose principal manifestation has been the basaltic lavas of the Snake River Plain. No hot springs have been reported from the study area, and none were noted during this study. Dozens of cold springs, some of substantial discharge, were seen, but most were clearly related to seasonal runoff inasmuch as their discharges were maximum during late spring and early summer and had decreased noticeably by the end of summer. No volcanic rocks younger than the lower Tertiary Challis Volcanics occur in the study area. Rocks beneath the area are believed to be for the most part either Paleozoic sedimentary rocks, some slightly metamorphosed and many fine-grained, or plutonic and metamorphic rocks; thus they do not constitute very suitable reservoirs. The potential for geothermal energy resources in the study area is therefore low.

SUMMARY OF MINERAL POTENTIAL

Mineral production from the Boulder-Pioneer study area totals less than $1 million despite the fact that approximately $65 million worth of mineral commodities has been produced from the seven districts that adjoin or partially occur within the study area. Our work shows the study area to have small reserves of lead, silver, and zinc, and substantial resources of molybdenum and possibly copper. A moderate potential for discovery of additional resources of copper, lead, molybdenum, silver, zinc, and barium (barite) exists in several areas as outlined by analyses of stream-sediment and rock samples, especially in the area between upper Star Hope Creek and Muldoon Creek southeastward to

Argosy Creek, an east-trending area west of the Phi Kappa mine, and in the drainage basins of Eagle Creek and middle and lower Trail Creeks. The study area has a small potential for discovery of new resources of gold, tungsten, and uranium. The potential for discovery of resources of other metals, minerals, fossil fuels, or geothermal energy is considered to be low.

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Economic Appraisal of the Boulder-Pioneer Wilderness Study Area, Blaine and Custer Counties, Idaho

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U.S. BUREAU OF MINES

MINERAL RESOURCES OF THE BOULDER-PIONEER WILDERNESS STUDY AREA, BLAINE AND CUSTER COUNTIES, IDAHO

GEOLOGICAL SURVEY BULLETIN 1497-D

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ECONOMIC APPRAISAL OF THE BOULDER-PIONEER WILDERNESS STUDY AREA, BLAINE AND CUSTER COUNTIES, IDAHO

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U.S. BUREAU OF MINES

SETTING

Mineral production from mines within the study area is valued at approximately $870,000. Of this total, 40 percent was from zinc, 40 percent from lead, 17 percent from silver, 3 percent from copper, and less than 1 percent from gold.

Mineral deposits in the study area are within a mineralized belt that extends northward from the Lava Creek district on the south through the Warm Springs, Galena, Vienna, East Fork, Yankee Fork, and Clayton districts. Parts of five State mining districts (Ross, 1941) cover the study area (fig. 32). Total mineral production from the Warm Springs district is about $32 million; Alta district (in some reports spelled Alto), $640,000; Little Wood River district, $330,000; Copper Basin district, $100,000; and Lava Creek district, $500,000. Mines within the study area in the Warm Springs, Alta, and Little Wood River districts have produced more than $820,000. Mines in the study area in the Copper Basin district have produced about $50,000. Production from the Lava Creek district came from mines several miles outside the study area. Mines in the study area with the most production are the Homestake in the Warm Springs district (pl. 4, No. 106), Phi Kappa in the Alta district (pl. 4, No. 17), the Eagle Bird in Little Wood River district (pl. 4, No. 60), and the Star Hope in Copper Basin district (pl. 4, No. 32). No placer production has been recorded from the study area. The Mineral Hill district lies to the west of the study area and the Alder

[1]Mining Engineer, Western Field Operation Center, Spokane, Wash.
[2]Geologist, Western Field Operation Center, Spokane, Wash.

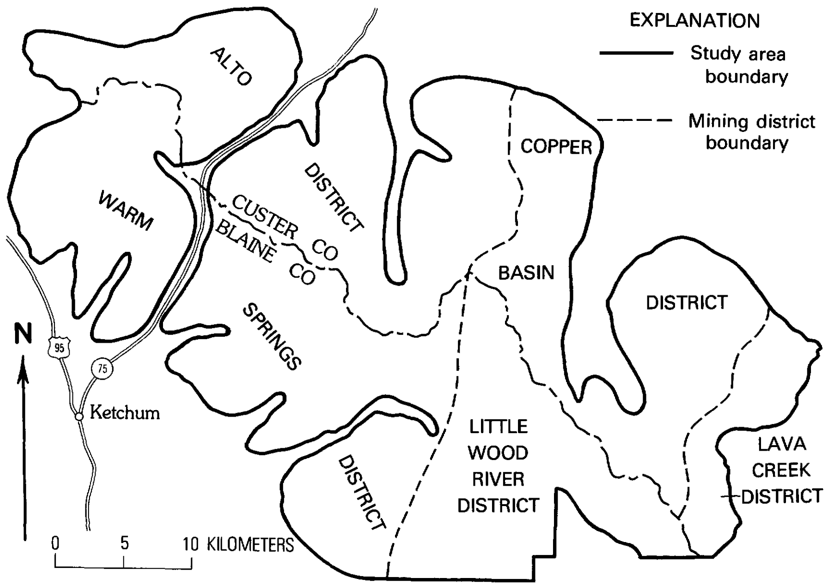

FIGURE 32.—Index map showing mining districts.

Creek district to the east. Production from the Mineral Hill district is listed at $16 million (Umpleby and others, 1930; U.S. Bureau of Mines, unpub. data), and Alder Creek district at $15.7 million (U.S. Bureau of Mines, unpub. data).

Several mines adjacent to the study area have recorded production. The mines of the Triumph-Parker mineral belt (pl. 4, No. 95) have produced in excess of $10 million (Umpleby, 1930), principally from silver-lead-zinc ores, although some gold and copper are present. Ore occurs as lenses in a series of major shear zones, most of which strike west-northwest and dip moderately southwest. Ore also occurs as replacement bodies in limestone related to the major shears.

The Mascot mines (pl. 4, No. 80) have produced $200,000, principally from lead and silver. Some iron ore used for flux was shipped to the Ketchum smelter and reportedly contained as much as $16 gold per ton ($17.64/t) (Umpleby, 1930). The ore occurs as lenses in northwest-trending shear zones similar to the Triumph-Parker mineral belt.

The Wildhorse mines (pl. 4, No. 27), produced over $459,000 from tungsten ores during 1954–1956. The tungsten ore, scheelite, occurs as lenses and pods in a well-defined marbleized bed within gneisses and schists. The pods seem to be related to aplite and alaskite dikes.

The Copper Basin mine (Reed and Davidson group) (pl. 4, No. 35) produced about $50,000 from copper ores (Umpleby, 1917). Dikes of granite, aplite, and granite porphyry traverse the sedimentary rocks along general northward-trending courses. Ore bodies occur both adjacent to the dikes and along particular beds of the sedimentary rocks well removed from the dikes.

The Muldoon Barium Co. holdings (pl. 4, No. 48), produced 2,400 tons (2,200 t) of barite, which was used at the Atomic Energy Commission's installation near Arco, Idaho, as shielding material for atomic reactors. The Muldoon Barium Co. is actively developing one of three barite veins and a nearby silver-lead-zinc vein. The owners have stockpiled 4,000 tons (3,600 t) of base-metal ore. The barite veins are irregular and range from 1.5 to 14 ft (0.5 to 4.3 m) thick. One vein may be 1 mi (1.6 km) long.

METHODS OF EVALUATION

Courthouse records and reports on mineral deposits were used to determine the location of claims and mineral deposits, and the historical significance of the mining districts. Owners and previous owners of mineral properties were contacted and histories, production records, and U.S. Department of the Interior unpublished data were obtained when available. Permission to examine and publish data was sought from owners of active claims. Descriptions of the few properties for which permission was refused are taken from earlier reports and are not supported or augmented by Bureau of Mines field examinations or sample data.

All mines, prospects, and claims were sought in the field. Some claims were not found because of relocations or vague descriptions. Lode properties were examined and, if warranted, were mapped. Samples were taken from all workings whether mineralized material was apparent or not. A few placer claims were examined by sampling near-surface gravel.

RESOURCE TERMS

Resources have been classified according to the following definitions (U.S. Bureau of Mines, 1976) in this report:

Resource.—A concentration of naturally occurring solid, liquid, or gaseous materials in or on the Earth's crust in such form that economic extraction of a commodity is currently or potentially feasible.

Reserve.—That portion of the identified resource from which a usable mineral and energy commodity can be economically and legally extracted at the time of determination. The term *ore* is used for reserves of some minerals.

Indicated.—Reserves or resources for which tonnage and grade are computed partly from specific measurements, samples, or production data and partly from projection for a reasonable distance or geologic evidence. The sites available for inspection, measurement, and sampling are too widely or otherwise inappropriately spaced to permit the mineral bodies to be outlined completely or the grade established throughout.

Inferred.—Reserves or resources for which quantitative estimates are based largely on broad knowledge of the geologic character of the deposit and for which there are few, if any, samples or measurements. The estimates are based on an assumed continuity or repetition, of which there is geologic evidence; this evidence may include comparison with deposits of similar type. Bodies that are completely concealed may be included if there is specific geologic evidence of their presence. Estimates of inferred reserves or resources should include a statement of the specific limits within which the inferred material may lie.

Paramarginal.—The portion of subeconomic resources that (1) borders on being economically producible or (2) is not commercially available solely because of legal or political circumstances.

Submarginal.—The portion of subeconomic resources which would require a substantially higher price (more than 1.5 times the price at the time of determination) or a major cost-reducing advance in technology.

PRESENT STUDY AND ACKNOWLEDGMENTS

Fieldwork by the Bureau of Mines, performed during the 1973 and 1974 field seasons, totaled 35 man-months. Field investigations were performed by Ernest Tuchek, James Ridenour, and Steven Schmauch assisted by Earl Bennett, Stephen Brown, Richard Newcomb, and Edwin West.

The Bureau of Mines study emphasized investigation of lode deposits. Placer deposits were given cursory examinations because of their small size and apparent lack of mineral potential.

The authors extend appreciation to claim holders and property owners for their cooperation. Special acknowledgment is due Ivan Taylor for providing us with maps and production data on the Phi Kappa mine.

The U.S. Forest Service personnel, in particular G. Tom Farr of the Ketchum Ranger Station, aided investigations.

SAMPLING AND ANALYTICAL METHODS

A total of 1,343 lode samples and 16 placer samples were analyzed. Most lode samples ranged from 5 to 10 lb (2.3 to 4.5 kg). Three types of lode samples were taken: chip, a series of continuous chips of rock across or along an exposure; grab, an unselected assortment of rock pieces from a rockpile or exposure; and select, handpicked material of the highest grade rock available. Most lode samples were fire assayed to determine the gold and silver content. Samples containing visible metallic minerals were analyzed by atomic absorption, colorimetric, or X-ray fluorescent methods. At least one sample from each type of mineralized structure on a property was analyzed by semiquantitative spectrometry. If anomalous amounts of economic elements were detected in a sample by spectrometry, the element was further analyzed by more accurate methods. All samples were checked for the presence of radioactive and fluorescent minerals.

Placer samples were taken from claimed gravel deposits. Samples were concentrated onsite using a 14-in. (36-cm) gold pan. The lack of significant heavy minerals in the gravels made further processing unnecessary.

MINERAL COMMODITIES

ECONOMIC CONSIDERATIONS

The principal mineral commodities in the Boulder-Pioneer wilderness study area are lead, zinc, silver, copper, tungsten, molybdenum, barite, fluorite, and gold (table 15). National and world data for the following section are from U.S. Bureau of Mines Commodity Data Summaries, January 1978, and Engineering and Mining Journal, November 1978. Resource estimates are based solely on those

TABLE 15.—*Principal mineral commodities in Boulder-Pioneer wilderness study area, Idaho*

[Data measured in inch-pound units; 1 ton = 1.1 t; N.A., not available; leaders (- -), none]

Property	Reserves (tons)	Resources (tons)	Commodity
Phi Kappa mine----	1,655,000	---	Lead, silver, zinc.
Alto Silver-Quartz group.	---	18,400	Do.
Star No. 1--------	---	500	Do.
Long Trail--------	---	67,000	Do.
Silver Dew--------	---	20,000	Do.
Homestake mine----	7,000	730,000	Do.
High Grade--------	---	3,750	Do.
Long Grade mine---	---	32,500	Do.
Lake Creek group mine.	5,000	---	Zinc.
Price group mine--	---	100,000	Do.
Gamble group------	---	11,000	Lead, silver.
Lost Dump---------	---	2,500	Zinc, lead, silver.
Eagle Bird mine---	28,500	---	Do.
Solid Muldoon mine	N.A.	N.A.	Silver, lead.
Rippeto-----------	35,000	---	Silver, lead, zinc.
Silver Eagle------	---	15,000	Do.
Garfield group----	---	1,500	Do.
Idaho Muldoon-----	---	1,000	Do.
Scorpion group----	---	15,000	Do.
Mutual Gulch------	---	18,000	Copper, lead, silver.
Purple Spar-------	---	1,000	Fluorite.
Anda (Walton Moly) group.	---	50,000	Molybdenum.
Pine Mouse group--	---	1,400,000	Tungsten.
Total---	1,730,500	2,487,000	

properties for which tonnage and grade were calculated. Potentially large amounts of inferred resources may be present where data were insufficient to calculate tonnage and (or) grade.

LEAD

An estimated 1.55 million tons (1.4 million t) of lead were consumed by the United States in 1977. The main consuming industries are transportation, electrical, construction, paints, and ammunition. Canada, Peru, Mexico, and Australia provided most of the 291,000 tons (264,000 t) imported in 1977. Domestic demand for lead is expected to increase through 1985 at an annual rate of 1.8 percent, but environmental considerations are expected to curtail future demands. Average price per pound in October 1978 was 36.6 cents (80.7 cents per kg).

Nearly 2.5 million pounds (1.1 million kg) of lead valued at $273,000 was produced from the study area, where lead is found in association with zinc and silver. Approximately 2.7 million tons (2.5 million t) of mineral-bearing material in various reserve and resource categories containing from 0.7 to 22.4 percent lead are estimated for this area.

ZINC

An estimated 1.25 million tons (1.14 million t) of zinc were consumed by the United States in 1977. Canada, Australia, and Belgium-Luxembourg accounted for most of the 570,000 tons (520,000 t) imported in 1977. Principal uses of zinc were in construction materials, transportation equipment, electrical equipment, machinery, and chemicals. Demand for zinc is expected to increase at 2.6 percent annually through 1985. The average price for zinc in October 1978 was 32.8 cents per pound (72.3 cents per kg).

Zinc in the study area was produced as a coproduct of lead-zinc mining, and production has amounted to more than 2.6 million pounds (1.18 million kg) valued at approximately $270,000. Estimated resources are 2.7 million tons (2.5 million t) of material containing from 1.8 to 42 percent zinc.

SILVER

An estimated 165 million oz (5.13 billion g) of silver were consumed in the United States in 1977. Approximately one-fourth of this amount was produced domestically, principally as a byproduct of base-metal mining operations. Canada, Mexico, and Peru supplied 76 percent of the imported silver. Primary uses for silver are silverware, photographic materials, and electrical equipment. The demand for silver is expected to increase at an annual rate of 2 percent through 1985, resulting in increased reliance on foreign imports. The average silver price during October 1978 was $5.918 per oz ($0.191 per g).

More than 150,000 oz (4.7 million g) of silver valued at approximately $118,000 were produced from the study area. Silver in the study area occurs in lead-zinc deposits, containing an estimated 2.7 million tons (2.5 million t) of resources, ranging from 0.4 to 19.5 oz silver per ton (14 to 669 g/t).

COPPER

Domestic consumption of refined copper was estimated at 2.3 million tons (2.08 million t) in 1977. About 17 percent of apparent copper consumption was imported during 1977, principally from Canada, Peru, and Chile. The major uses of copper include electrical, construction, and industrial machinery. The average price per pound during October 1977 was 70.5 cents ($1.55 per kg). Demand for copper is expected to increase at an annual rate of 3 percent through 1985.

Production from the study area was more than 60,000 pounds (27,000 kg) of copper valued at approximately $16,500. Nearly all lead-zinc-silver deposits in the area contain small amounts of copper, which could be produced as a byproduct of base-metal mining. Potentially large copper deposits occur outside the study area in the Copper Basin district.

TUNGSTEN

The United States produced an estimated 45 percent of the 15.6 million pounds (7.1 million kg) of tungsten consumed in the United States in 1977. The major foreign suppliers are Canada, Bolivia, Peru, and Thailand. Principal uses of tungsten are in metal working, construction machinery, transportation, lighting, and electrical equipment. The demand for tungsten is projected to increase at 6 percent annually through 1985. The average price for a short-ton unit of tungsten trioxide (WO_3) ore, 65 percent minimum, was $130.28 in October 1978. Tungsten has not been produced within the study area, but 7,461 short-ton units (67,686 kg) valued at $459,000 were produced in the Alta district. The mines are just outside the study area in Wildhorse Canyon. Major potential sources of tungsten in the study area are in tactite. The deposits are irregular and tonnage and grade difficult to estimate, but tonnage may amount to more than 1.4 million tons (1.3 million t) containing from 0.02 to 1.68 percent WO_3.

MOLYBDENUM

Less than 4 percent of the 57 million pounds (26 million kg) of molybdenum consumed in the United States in 1977 was imported. Primary foreign sources are Chile and Canada. Major uses for molybdenum are in transportation, oil and gas industry, and machinery. The projected annual growth rate for molybdenum through 1985 is 5 percent. Prices paid for molybdenum in October 1977 ranged from $4.95 per pound ($10.90/kg) for concentrate to $6.10 per pound ($13.45/kg) for ferromolybdenum. Molybdenum in the study area occurs principally in quartz veins in quartz monzonite. These veins contain an estimated 50,000 tons (45,000 t) of material averaging 0.21 percent MoS_2. No molybdenum has been produced in the study area.

BARITE

The principal use for barite is as a weighting agent in oil- and gas-well drilling muds. The estimated 1977 domestic consumption of barite was 2.5 million tons (2.3 million t). Approximately 38 percent of the domestic consumption of barite in 1977 was imported, mainly from Ireland, Peru, and Mexico. Prices ranged from $19 to $53 per ton ($21–$58/t) for carload lots of unground barite for drilling mud grade to $80–$96 per ton ($88–$106/t) for carload lots of water ground barite for drilling mud grade. The demand for barite is expected to increase at 2.2 percent annually through 1985. Large deposits of barite may extend into the study area in the Little Wood River district.

FLUORSPAR

The estimated 1977 domestic consumption of fluorspar was 1.5 million tons (1.3 million t). Approximately 80 percent was imported, principally from Mexico and Spain. Average prices for October 1977 ranged from $91 per ton ($100/t) for metallurgical grade to as much as $115 per ton ($127/t) for acid and ceramic grades. Producers of steel fluxes, industrial chemicals, and aluminum industries are major consumers of fluorspar. The demand for fluorspar is expected to increase by about 3 percent annually through 1985.

Most of the fluorspar occurrences are in the Little Fall Creek and Phi Kappa Creek drainages in the Alta district, where the mineral is associated with chalcedony and quartz as fracture fillings in fault zones. The largest deposit is estimated to contain about 1,000 tons (900 t) of 50–95 percent CaF_2.

GOLD

Domestic gold production in 1977 was about one-fourth of an estimated 4.3 million oz (134 million g) consumed. Most United States gold imports came from Canada and Switzerland. Jewelry manufacturing, industrial, and the dental profession are the principal consumers. Gold price averaged $206.60 per oz ($7.3/g) during October 1977. Gold would be produced as a byproduct from base-metal lode deposits in the study area, but is not expected to significantly affect the economics of these deposits.

MINING CLAIMS

Blaine and Custer County records list more than 2,600 lode claims and 11 placer claims within the study area. The earliest known prospecting activity occurred in 1864, but mining did not commence until the early 1880's. Many of the original and subsequent claims have been relocated, some several times. Fourteen claims have been patented.

Lode claims are concentrated in three areas; most occur along a mineral belt that extends from the head of Little Copper Creek to the mouth of Muldoon Creek in the Little Wood River district. A second concentration of claims is in the area of Little Fall and Phi Kappa Creeks. A third is along a mineralized belt trending northwesterly from Trail Creek to the North Fork Big Wood River. Smaller clusters occur throughout the study area. Hundreds of claims have been located just outside the study area in the Warm Springs district and in Copper Basin.

ALTA DISTRICT

The Alta[1] district occupies the northern quarter of the study area (fig. 32). Since 1881 there have been 998 claims located in the district (table 16). One claim in the area has been patented. Most exploration work

[1]In some records and reports spelled Alto.

TABLE 16.—*Summary of recorded mining claims, 1880–1973, Alta district*

Decade	No. of lode claims
1880–89	31
1890–99	12
1900–09	59
1910–19	48
1920–29	104
1930–39	46
1940–49	63
1950–59	246
1960–69	315
1970–	74
Total----	[1]998

[1]As of June 1, 1973.

was completed prior to 1920, and development has been intermittent, with the 1950's and early 1960's being the most productive.

The Alta district is the most important, based on production (table 17) and mineral potential. Total production from the district is more than $640,000. The district contains the largest single silver-lead-zinc deposit in the study area.

TABLE 17.—*Recorded metal production, 1926–1966, Alta district*

[Leaders (- -), no data]

Year	Mine	Ore (Mg)	Gold (g)	Silver (g)	Copper (kg)	Lead (kg)	Zinc (kg)
1926	Phi Kappa---	37	---	15,519	66	1,631	3,463
1928	Black Rock--	45	---	8,584	104	5,167	3,014
1935	Unknown-----	3.6	---	1,337	---	132	125
1944	Unknown-----	14	---	8,677	55	481	---
	Long Trail--	33	---	18,722	---	743	2,001
1947	Unknown-----	3	---	2,177	---	204	204
1948	Unknown-----	21	---	7,215	---	650	735
	Phi Kappa---	21	---	8,117	14	728	937
1951	Phi Kappa---	117	---	13,715	148	5,633	4,458
1952	----do------	1,409	124	46,961	2,461	50,382	34,057
1955	Unknown-----	32	---	2,364	1,225	2,722	1,724
1956	Phi Kappa---	1,001	---	61,858	3,103	53,979	45,345
1957	----do------	1,411	404	438,106	6,886	47,115	70,076
1961	----do------	163	---	45,188	350	4,021	7,229
1962	----do------	191	31	48,671	272	5,806	11,113
1965	----do------	1,555	---	112,022	---	2,177	2,540
1966	----do------	2,613	---	64,004	---	46,539	36,333
	Total-----	8,670	559	903,237	14,684	228,110	223,354

Mineral deposits in the district contain lead, zinc, silver, tungsten, copper, molybdenum, and fluorite. Significant mineral occurrences are in a belt from 2 to 3 mi (3 to 5 km) wide that extends from the headwaters of Little Fall Creek through Phi Kappa Creek and Kane Creek drainages. The mineralized belt is in Paleozoic sedimentary strata. Additional deposits in older metamorphic rocks occur on upper Wildhorse Creek. The metamorphic and sedimentary rocks have been intruded by rocks generally of granitic composition and have been deformed and displaced.

Lead-silver-zinc-copper deposits occur in quartz fissure-filling veins concordant and discordant with bedding, and as metasomatically altered limestone beds (tactite). Tungsten minerals occur adjacent to sedimentary rock–quartz monzonite contacts, and where aplite dikes crosscut dolomitic marble. Molybdenite rosettes are found in quartz veins, in quartz monzonite. Fluorite occurs as fissure fillings.

Two areas with significant resource potential in the district are the Little Fall Creek–Phi Kappa Creek area and the upper Wildhorse Creek area.

PHI KAPPA MINE

The Phi Kappa mine (pl. 4, No. 17) is on the east side of Phi Kappa Creek and can be reached by a graded, seasonal road from Trail Creek road. Elevation of the main adit is about 8,000 ft (2,400 m).

The Phi Kappa discovery was made in January 1885, and the claim patented the following December. Many claims have been located and relocated around the patented ground. Current locations, the Black Bear Nos. 1–19, are held by the lessee of the Phi Kappa claim. Work on the property has been intermittent and has concentrated about the main workings (fig. 33). By the early 1920's, more than 2,000 ft (600 m) of excavations had been completed on these workings. In 1952, 1,741 ft (530.7 m) of diamond drilling was done. Drifting on the ore zone at the 8200 level (at 2,499 m) and in the main 8040 level (at 2,450 m) was begun at this time, resulting in the current total of more than 4,200 ft (1,280 m) of drifts, crosscuts, and stopes. Additional workings include several cuts, pits, and shallow shafts.

A small amount of ore may have been mined and milled prior to 1926, but it apparently was not recorded. Recorded production from the mine totals 9,386 tons (8,517 t) of ore with an average recovered content of 0.0015 oz gold per ton (0.051 g/t), 2.9 oz silver per ton (99.4 g/t), 0.157 percent copper, 2.6 percent lead, and 2.5 percent zinc, valued at about $174,000.

During 1975, approximately 2,000 tons (1,800 t) of ore were broken from the north stopes between the upper and lower levels of the mine (Ivan Taylor, oral commun., 1975). The ore was transported by truck to Mackay, Idaho, for milling tests. Mill capacity is about 140 tons (130 t) per day. Lead concentrates from the ore have been sold, and zinc concentrates will be shipped when the mill circuitry is perfected. Silver contents in the ore from this stope are about 6 oz per ton (190 g/t). A mill of similar capacity is planned for the mine property.

Country rocks consist of argillite, limy argillite, argillaceous limestone, limestone, slate, and quartzite, which strike nearly due north and dip 40°–60° E. The strata have been intruded by granitic and diabase dikes with little alteration of the adjacent rock. Quartz monzonite crops out on the west side of Phi Kappa Creek opposite the property. On the east side of the creek, the argillite-limestone sequence is overlain by a thrust plate of clastic rocks.

The ore zone is a metasomatically altered limestone bed at the base of the calcareous upper half of the sedimentary sequence. Main constituents of the zone are as much as 50 percent diopside, as much as 50 percent grossularite, and as much as 15 percent sulfides. The sulfides in decreasing order of abundance are galena, sphalerite, pyrite, and chalcopyrite, which occur as lenses, pods, isolated grains, and fine-grained disseminations. Other minerals identified are augite, calcite,

FIGURE 33.—Main workings, Phi Kappa mine, viewed toward the northeast.

idocrase, sericitized feldspar, quartz, and fluorite. The main ore zone ranges from 2 to 5 ft (0.70 to 1.50 m) thick, averaging 4 ft (1.20 m) thick. Additional zones and stringers ranging from 2 in. to 3 ft (5 cm to 1 m) thick are present above and below the main zone, but are not as laterally continuous. Several minor faults are present, some of which have offset the ore zone. Occasionally they are lined with pale-green euhedral fluorite. The main ore zone can be traced for about 4,000 ft (1,200 m) along strike (pl. 5). On the south end, it is apparently terminated by a fault; the north end is terminated by Summit Creek valley. A normal fault in the vicinity of the Clifton adit (fig. 33) dropped the ore zone approximately 400 ft (120 m) stratigraphically, and is the only major displacement. A 1,000-ft (330-m) segment of the zone exposed on the north side of Summit Creek (fig. 34) contains no visible sulfides and appears less altered than the zone exposed at the main workings. Silver content of a sample of the zone exposed on the north side of Summit Creek was 0.01 oz per ton (0.34 g/t).

The upper 8200 level (2,500 m) of the main workings (fig. 35) ranges from 0 to 70 ft (0 to 21 m) beneath the surface and consists of 830 ft (253 m) of drifts. The lower 8040 level (2,450 m) is 200 ft (61 m) downdip on the ore zone and consists of 2,910 ft (887 m) of drifts and crosscuts. Several hundred cubic feet (some tens of cubic meters) of material has been stoped from both levels. Underground workings are in very good condition and need no timber for ground support. Small cuts exposing the ore zone are the only surface workings on the property which has two loading facilities, a powder magazine, and a toolhouse.

Weighted by length, 95 chip samples taken from the main ore zone average 3.20 oz silver per ton (110 g/t), 0.08 percent copper, 3.35 percent lead, and 3.48 percent zinc. Zinc concentrate, from a shipment of ore made in 1952, contained 0.48 percent cadmium. A bulk sample of ore taken from the north drift stope was beneficiated. The zinc concentrate assayed 0.50 percent cadmium and the lead concentrate assayed 0.10 percent cadmium. Approximately 55,000 tons (49,900 t) of measured reserves and 1.6 million tons (1.5 million t) of indicated reserves are on the claims. Total reserve estimates are based on a length of 4,000 ft (1,200 m), a depth of 1,000 ft (300 m), and a 4-ft (1-m) average thickness.

Thirty-four samples were cut from smaller sulfide-bearing tactite zones related and similar to the main ore zone. Metal content ranged from nil to 0.01 oz gold per ton (nil to 0.34 g/t), 0.02–23.9 oz silver per ton (0.68–820 g/t), 2.02 percent copper, 0.01–6.43 percent lead, and 0.01–10.3 percent zinc. Weighted averages were not computed because these samples were taken from several zones. Additional reserves are indicated in these discontinuous zones.

FIGURE 34.—Summit Creek outcrop of the Phi Kappa mineralized zone, showing sample localities R337–340.

Data for samples shown in figure 34

[All samples chip; all taken from across altered zone. N, none detected]

Sample		Gold	Silver
No. R-	Length (m)	(g/t)	
337	0.9	N	N
338	.9	N	N
339	.9	N	N
340	1.1	N	3.4

ALTO SILVER-QUARTZ GROUP

The Alto silver-quartz prospect lies on the west side of the North Fork Little Fall Creek (pl. 4, No. 5). U.S. Bureau of Mines records show some production in 1935, but the prospect has apparently been idle since the 1940's.

Workings (fig. 36) consist of a 300-ft (91-m long) main adit, one caved adit, one caved shaft, and five small cuts and pits. The workings range in elevation from 9,060 to 9,240 ft (2,760 to 2,820 m).

Country rock is slightly calcareous slate with some argillite and sandstone interbeds. The rocks strike a few degrees west of north and dip 40°–45° SW. The rocks have been sheared in an east-west direction with the largest shear zone oriented at approximately N. 75° W. Dips range from 45° to 80° NE. The shear zones are 3 in. to 5 ft (8 cm to 1.5 m) thick and average about 3 ft (1 m) thick. Material in the shear zones consists of a moderately to heavily limonite stained quartz-calcite gangue enclosing fragments of wall rock. The shear zone material has been replaced by as much as 20 percent sulfides: about 10 percent pyrite, 6 percent galena, 4 percent sphalerite, and occasionally as much as 1 percent chalcopyrite. Pyrite and galena occur both as cubes and as fine-grained masses and sphalerite only as fine-grained masses. Wall rock adjacent to the shear zones is bleached and pyritized to a maximum of about 4 in. (10 cm).

A moderately thick soil mantles much of the immediate area, concealing possible extensions of the zones. The main shear zone is exposed for 265 ft (81 m) in the main adit. Judging from the alinement of workings across the creek to the east, the main zone or related zones could

[1]The spelling "Alta" is from Umpleby, Westgate, and Ross (1930) and Ross (1963); the spelling "Alto" was used for the same district by Ross (1941). We maintain "Alta" for the district but "Alto" for this group.

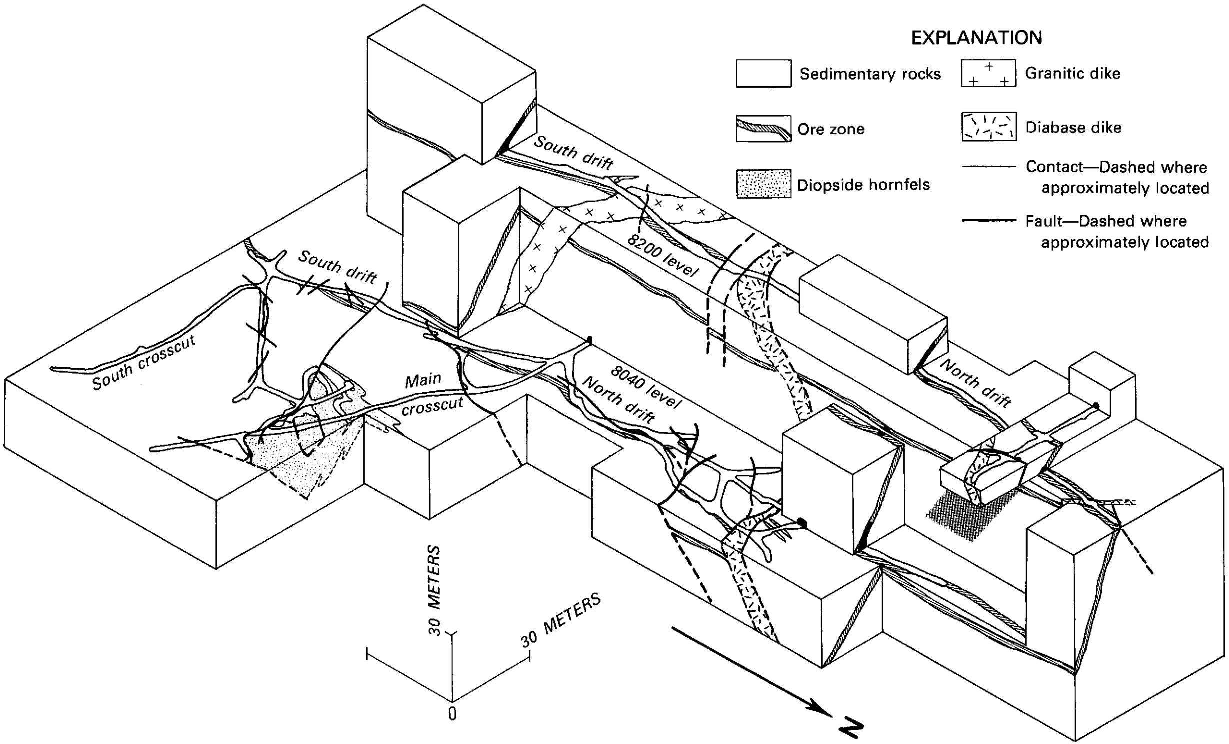

FIGURE 35.—Block diagram of the main workings of the Phi Kappa Mine.

extend along strike as much as 1,500 ft (450 m). The westward extension appears to be terminated against a massive sandstone unit in apparent fault contact with the slate.

Seven samples were taken on the surface and five samples were cut from the main adit. Weighted by length, samples of the main zone averaged 4.9 oz silver per ton (170 g/t), 2.4 percent lead, 2.0 percent zinc, and trace amounts of copper and gold.

A total of about 18,400 tons (16,700 t) of submarginal resources are estimated to occur in the main shear zone. Tonnages could be significantly larger if the zone extends southwestward across Little Fall Creek.

STAR NO. 1

The Star No. 1 claim is near the head of a small cirque that forms the western part of the Little Fall Creek Basin (pl. 4, No. 10). No record of production is known, and the claim appears to have been idle for several years.

A single adit at 9,500 ft (2,900 m) elevation was driven into siliceous argillites with thinly interbedded limestone and carbonaceous slates. Bedding strikes N. 10° E. and dips 63° NW. The adit crosscuts a quartz vein that strikes about N. 75° E. and dips 25°–35° SE (fig. 37). The vein, averaging slightly greater than 2 ft (0.6 m) in thickness, is a fissure-filling replacement type controlled by a shear zone. Silicified shear breccia and quartz contain as much as 20 percent crystalline and massive sulfides. The sulfides consist of about 50 percent galena, 40 percent pyrite, 8 percent sphalerite, and 2 percent chalcopyrite, occurring as blebs, pods, stringers, and disseminations in massive quartz. Country-rock alteration adjacent to the zone is limited to bleaching and to occasional very fine grained pyrite cubes within 2 in. (5 cm) of the controlling shear structure.

Weighted by length, 12 samples taken across the zone average 4.7 oz silver per ton (160 g/t), 4.40 percent lead, 1.85 percent zinc, and 0.13 percent copper. The zone is exposed only along strike for approximately 45 ft (14 m) and downdip for approximately 65 ft (20 m). About 500 tons (450 t) of submarginal resources are indicated underground. The grade of the samples indicates that the prospect has good potential for discovery of minable resources.

PURPLE SPAR CLAIMS

The Purple Spar claims are on the northeast side of Little Fall Creek at an elevation of about 9,000 ft (2,800 m) (pl. 4, No. 13).

The fluorite occurrence came to the attention of the U.S. Geological Survey in 1943 and was examined by the U.S. Bureau of Mines in 1945. No production has been recorded from the claims, and little work has been done on the deposit.

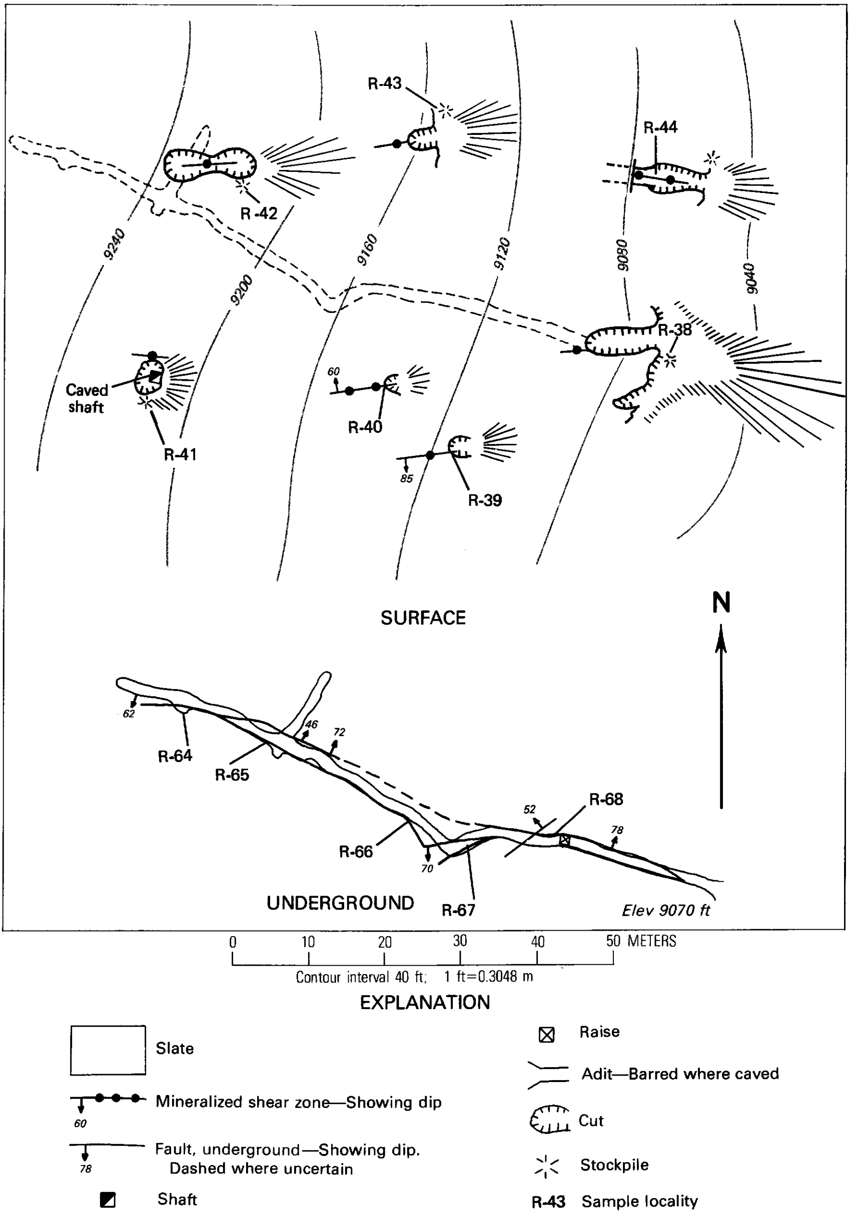

FIGURE 36.—Alto silver-quartz group workings.

Country rock in the vicinity of the claims consists of interbedded quartzite and argillite. The strata are gently folded and dip about 30° NW. The rocks on the west side of Little Fall Creek have been intruded by a quartz monzonite stock. A pronounced fault, striking N. 45° E. and dipping 70° NW., cuts the strata. The more siliceous portions of the

Data for samples shown in figure 36

[Tr, trace; N, none detected; Leaders (--), not analyzed]

Sample				Gold	Silver	Lead	Zinc
No. R-	Type	Length (m)	Description	(g/t)		(percent)	
38	Grab--	--	Stockpile----------------	N	48	0.91	0.41
39	Chip--	0.9	Across mineralized zone with quartz stringers--	N	41	.75	.034
40	--do--	.9	-----do-----------------	N	14	.24	.35
41	Grab--	--	Stockpile----------------	Tr	79	7.36	1.51
42	--do--	--	-----do-----------------	7	501	1.48	.23
43	--do--	--	-----do-----------------	Tr	96	4.15	4.87
44	Chip--	.6	Across quartz vein-------	Tr	446	7.17	.25
64	--do--	.6	Quartz-cemented breccia--	N	137	1.88	2.50
65	--do--	1.5	-----do-----------------	N	10	--	--
66	--do--	.6	-----do-----------------	N	45	1.03	.88
67	--do--	.9	-----do-----------------	N	99	1.61	.68
68	--do--	1.1	-----do-----------------	N	542	7.49	6.37

fault form bold outcrops that can be traced upslope from 8,800 ft (2,700 m) to the ridge crest at about 10,200 ft (3,100 m) (fig. 38).

The fault zone is as much as 50 ft (15 m) wide and contains veins and veinlets of white, green, and purple, fine- to coarse-grained euhedral fluorite in a matrix of chalcedony, drusy quartz, and brecciated country rock. Calcite is present in some fractures. The largest and best exposures of fluorite are lens-shaped and range in thickness from 6 in. to 6 ft (15 cm to 2 m) and in length from 1 to 100 ft (0.3 to 30 m). Except for chalcedony and quartz in the pods, the fluorite is relatively pure. Fluorite is restricted to the southwest end of the vein. The northeast end of the zone is composed almost entirely of quartz. A fault zone, located about 1,000 ft (300 m) southeast of the main fault zone, is also composed essentially of quartz with minor fluorite stringers.

Samples taken across fluorite lenses in the main zone contained between 49 percent and 95 percent CaF_2.

Approximately 1,000 tons (900 t) of fluorite-rich material are inferred on the claims. The material would have to be beneficiated because the silica content is too high to meet market requirements. However, the fluorite readily breaks from the quartz and chalcedony and could be handsorted. The deposit is too small to warrant a mill. That further surface exploration would disclose additional resources is very doubtful, but additional material might be found at depth.

ALTO SILVER GROUP

Near the head of the south tributary of Little Fall Creek are two caved adits of the Alto Silver group (pl. 4, No. 9). Elevation of the main workings is 9,110 ft (2,770 m).

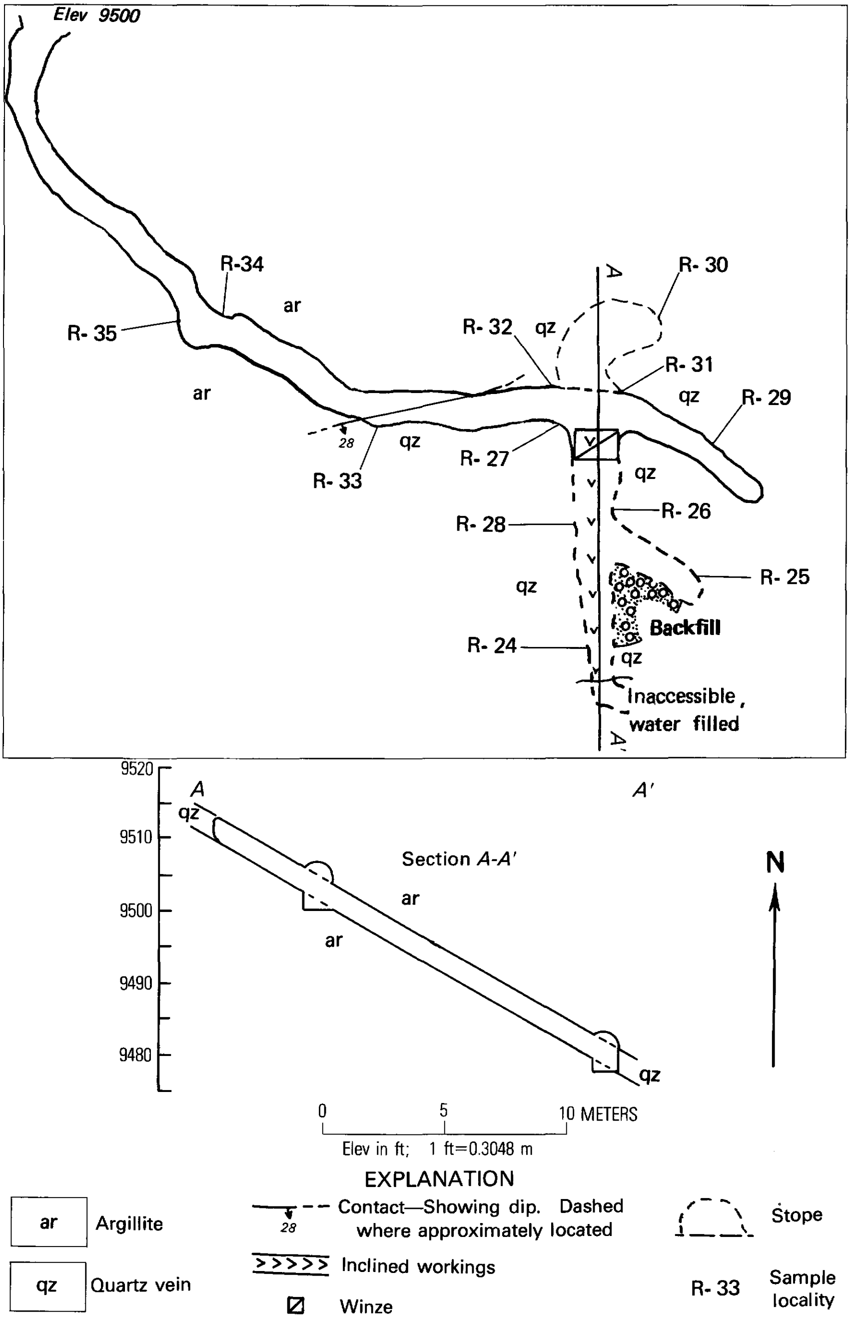

FIGURE 37.—Star No. 1 adit.

Data for samples shown on figure 37

[All samples chip]

Sample			Gold[1]	Silver	Copper	Lead	Zinc
No. R-	Length (m)	Description	(g/t)		(percent)		
24	0.8	Quartz vein----	N	113	0.019	2.77	0.29
25	.2	Upper part of quartz vein--	3	151	.36	1.81	.77
26	.8	Quartz vein----	Tr	185	.083	6.76	2.88
27	.6	---do----------	Tr	144	.13	8.40	5.08
28	.8	---do----------	Tr	51	.037	1.23	.90
29	.4	---do----------	Tr	309	.60	3.07	.60
30	.9	---do----------	Tr	79	.18	4.54	1.77
31	.9	---do----------	Tr	165	.10	3.75	2.24
32	.6	---do----------	.3	477	.10	11.0	4.46
33	.3	---do----------	N	14	.019	.19	.96
34	.9	Vein in back---	N	141	.089	3.26	.34
35	.5	---do----------	Tr	171	.25	2.28	.80

[1]N, none detected; Tr, trace.

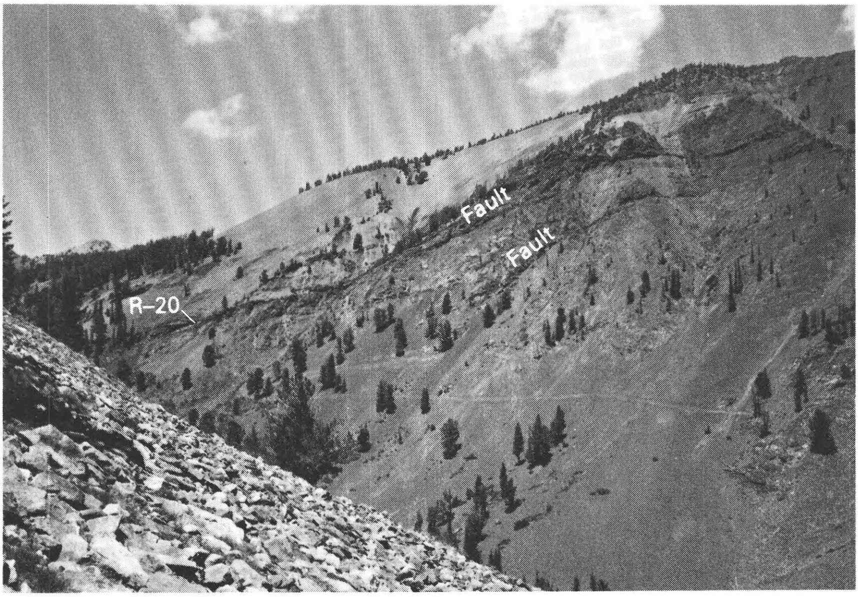

FIGURE 38.—Purple Spar fluorite occurrence and sample locality viewed toward the northeast. Sample localities R-21, 22 are downhill and out of sight from R-20.

Umpleby (Umpleby and others, 1930, p. 207) described a property on Little Fall Creek that may have been the Alto Silver. He described a 300-ft (91-m)-long main adit and a small adit a few feet (about one meter) west. A cabin and some dozer scrapes are 700 ft (210 m) east from the adits. Bureau of Mines records indicate 41 tons (37 t) of ore produced for the years 1944, 1947, and 1948. The property has apparently been idle since 1948.

Country rock is argillite with some interbedded slate. The rocks strike nearly due north and dip moderately to the west. As described by Umpleby, the vein strikes N. 85° E., dips 57° NW., and consists of overlapping lenses of limonite-stained vuggy quartz averaging about 6 in. (15 cm) thick. The vein is 50–75 ft (15–23 m) long. The vugs are lined with smithsonite and cerussite. Dump material contains about 30 percent sulfides consisting of 70 percent finely crystalline pyrite and 30 percent blebs of finely crystalline galena. Sphalerite and chalcopyrite are present in small quantities.

Two select samples from the dump assayed as much as 5.4 oz silver per ton (185 g/t), 0.92 percent lead, and 1.13 percent zinc. Copper was detected by spectrographic analysis in one sample. On the basis of past production, the mine has potential for discovery of mineral resources.

ANDA (WALTON MOLY) GROUP

The Anda group of 95 claims was located in 1969 by Norandex, Inc. The claims, which cover nearly the entire Little Fall Creek drainage, were filed on molybdenum anomalies detected by geochemical sampling. Exploration and subsequent drilling was concentrated on a molybdenite occurrence exposed by several small cuts about 1½ mi (2 km) northwest from the mouth of Little Fall Creek (pl. 4, No. 12). Elevation of the best exposures is slightly more than 8,300 ft (2,530 m). The U.S. Geological Survey visited the prospect in 1942 and parts of their unpublished data are used freely.

The prospect is adjacent to the contact between a small Tertiary quartz monzonite stock and Paleozoic sedimentary rocks. The stock contains numerous narrow aplite dikes near its eastern margin, but the dikes are less common to rare near the west edge. Two sets of nearly vertical, thin quartz veins occur with the dikes; one set, striking N. 10° W. to N. 10° E., is apparently barren, while the second set, striking N. 20°–30° W., carries molybdenite. The molybdenite-bearing veins are between 20 and 40 ft (6 and 12 m) in length. The molybdenite occurs as rosettes as large as 1 in. (2 cm) in diameter. Small amounts of pyrite, generally less than 1 percent, were observed. Occasionally mineralization occurs in the quartz monzonite adjacent to the quartz veins.

Some molybdenum mineralization occurs in two areas (fig. 39). The upper exposure is about 40 ft (12 m) in length and consists of several quartz veins, one of which is 3 ft (0.9 m) thick. Although the exposure is oriented N. 45° W., the individual quartz veins trend N. 10°–20° W. Samples taken across this exposure average, weighted by length, 0.92 percent MoS_2.

The lower area consists of two distinct exposures 100 ft (30 m) apart. A typical exposure, as taken from the U.S. Geological Survey description, consists of:

Thickness (ft)	Thickness (m)	Rock description
1.2	0.37	Quartz vein.
.8	.24	Quartz monzonite.
1.3	.40	Quartz vein.
.7	.21	Quartz monzonite.
1.7	.21	Quartz vein.
1.9	.58	Quartz monzonite.
.8	.24	Quartz vein.
2.4	.73	Quartz monzonite.
1.0	.30	Quartz vein.
1.8	.55	Quartz monzonite.
Total- - 12.4	3.83	

Eight chip samples taken across the northern exposure of the lower area contained a weighted average of 0.21 percent MoS_2. One sample taken along a single vein contained 0.44 percent MoS_2. A sample taken at the southern exposure across the 50-ft (15-m)-wide quartz veinlet zone assayed 0.029 percent MoS_2.

The Anda (Walton Moly) group is estimated to contain less than 50,000 tons (45,000 t) of 0.22 percent MoS_2. Although the large molybdenite rosettes may have some value as mineral specimens, the small tonnage and lack of continuity do not encourage large-scale commercial exploitation. The occurrence has inferred submarginal resources.

BLACK ROCK

The Black Rock claims are near the Big Fall Creek Lake at about 9,100 ft (2,800 m) elevation (pl. 4, No. 14). U.S. Bureau of Mines records indicate 50 tons (45 t) of ore produced in 1928 had an average recovered content of 5.52 oz silver per ton (189 g/t), 0.23 percent copper, 11.39 percent lead, and 6.64 percent zinc.

Country rock is slightly calcareous argillite striking northerly and dipping gently west. Several irregular granitic dikes intrude the sedimentary rocks. A fault, near the upper workings, trends nearly due west. The ore zone is not exposed. Umpleby and others (1930, p. 207) described the deposit as follows:

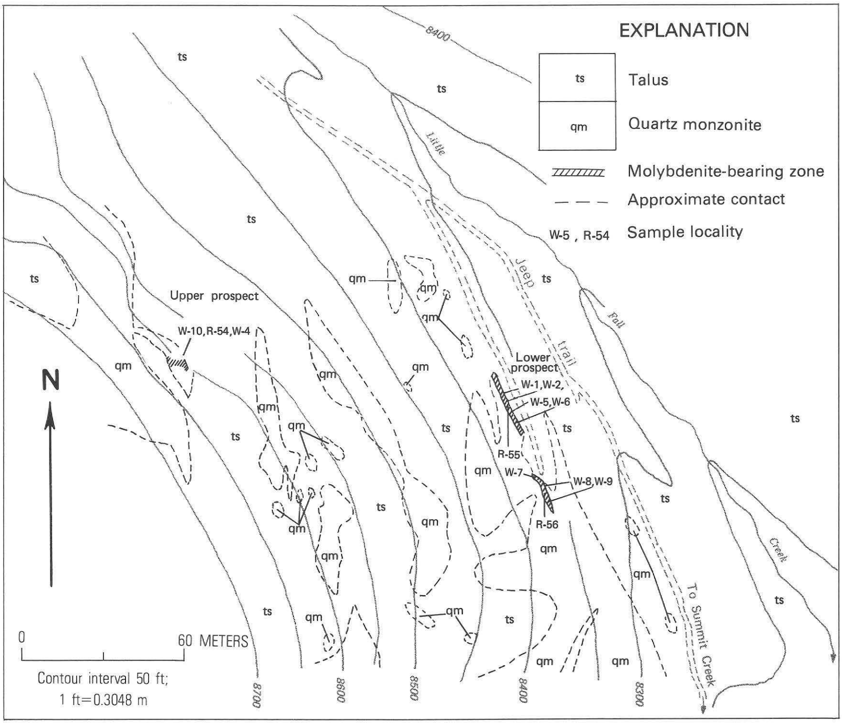

FIGURE 39.—Anda (Walton Moly) group.

The ore has replaced the slate beds. In general, the replacement followed the bedding, but in detail it was very irregular. The mass of ore that is being followed in the tunnel overlies a white bed that consists of coarse calcite and metamorphic minerals. The principal metallic minerals are galena, sphalerite, and pyrite. A little chalcopyrite is present in some specimens.

Workings consist of two adits separated vertically by about 40 ft (12 m). The upper adit, now caved, was reported by Umpleby and others (1930, p. 206) to be about 100 ft (30 m) long. The lower adit was driven for about 150 ft (45 m) to crosscut the ore zone, but work was halted before the zone was reached.

A select sample of heavily iron oxide-stained honeycombed quartz assayed 1.3 oz silver per ton (45 g/t), 8.7 percent lead, 5.92 percent zinc, and 0.06 percent antimony. Production from the mine and the possible size of the structure indicate that the property may have some potential for the discovery of lead-zinc-silver resources.

LONG TRAIL CLAIM

The Long Trail prospect is near the head of Little Fall Creek (pl. 4, No. 2), at about 9,200 ft (2,800 m) elevation. Workings are inaccessible,

Data for samples shown in figure 39

[All samples chip. Leaders (--), not analyzed]

Sample			Gold[1]	Silver	MoS_2
No.	Length (m)	Description	(g/t)		(percent)
Lower area					
W-1	0.9	Along strike of single vein-----	--	--	0.44
W-2	1.3	Across zone-------	--	--	.10
W-5	2.4	---do-------------	--	--	.25
W-6	2.1	---do-------------	--	--	.20
W-7	1.1	---do-------------	--	--	.34
W-8	1.5	---do-------------	--	--	.24
W-9	3.8	---do-------------	--	--	.11
R-55	3.0	---do-------------	N	3	.25
R-56	.3	---do-------------	N	3	.32
Upper area					
W-4	0.8	Across zone-------	--	--	1.91
W-10	2.3	---do-------------	--	--	.60
R-54	3.0	---do-------------	N	7	.92

[1]N, not detected.

and only a single select dump grab sample, assumed to be representative of the vein, was taken.

Part of the following information is taken from unpublished data of John W. Taber, Mining Engineer, U.S. Bureau of Mines, who visited the property in 1941. Shipments of 37 and 16 tons (33.6 and 14.5 t) of ore were made during the period of 1943–1944. Most of the basin in which the claim is located is underlain by thin-bedded slates and argillites. The rocks in the vicinity of the workings are not sufficiently exposed to reveal their orientation. A well-defined fracture is filled with sulfide-bearing quartz. The vein strikes N. 60° W., dips 55°–60° NE., and consists of coarse honeycombed quartz on the hanging wall and sulfide-bearing ore 2.5 ft (0.76 m) thick on the footwall. The sulfides are finely crystalline pyrite, sphalerite, galena, and chalcopyrite. Pockets of more coarsely crystalline galena and sphalerite are present in the vein. A 16-ton (14.5-t) shipment of quartz, principally from the hanging wall, assayed 0.01 oz gold per ton (0.3 g/t) and 19.8 oz silver per ton (679 g/t), as well as 0.07 percent copper. A sample of the sulfide-bearing material from a stockpile assayed 19.5 oz silver per ton (669 g/t), 7 percent lead, and 13.5 percent zinc. A sample of galena from a pocket in the vein assayed 19.2 oz silver per ton (659 g/t), 22.4 percent lead, and 17.3 percent zinc.

The vein was exposed by shallow trenches along a strike length of 130 ft (40 m); an additional 670 ft (200 m) can be inferred by spring seepage. The cuts are now badly sloughed. A short adit is also caved. Two cabins are on the property.

A dump grab sample taken at the caved adit during the current study assayed 6.3 oz silver per ton (216 g/t), 2.78 percent lead, and 8.75 percent zinc.

If the vein persists along the indicated length of 800 ft (240 m) and averages 2.5 ft (0.76 m) in thickness, approximately 67,000 tons (61,000 t) of relatively high grade material may be present. Because of the small tonnage, this inferred resource is submarginal.

SILVER DEW PROSPECT

The Silver Dew prospect is at the head of Phi Kappa Creek at slightly less than 9,000 ft (2,700 m) elevation (pl. 4, No. 20).

No production has been recorded, and it appears that the claim has been inactive for many years.

Country rock is argillite and sandy mudstone. The rocks are poorly exposed, but appear to trend northward. Exploration was on a west-trending, steeply south dipping shear zone that crops out intermittently along the surface for about 400 ft (120 m). The zone is filled with quartz and breccia. The quartz appears to contain few sulfides and the hanging wall is moderately iron oxide stained. The zone averages 3 ft (1 m) thick.

Workings consist of four adits on two levels (fig. 40). Three shorter adits on the upper level total less than 100 ft (30 m) in length. The main adit, on the lower level, is filled with water and inaccessible, but it is more than 500 ft (150 m) long, as estimated from the size of the dump. The adit was apparently driven to crosscut the quartz-filled shear zone at depth.

Material on the dump of the main adit consists of silicified argillite and vein quartz. The argillite contains as much as 10 percent one-fourth-inch (0.63-cm) cubes of pyrite. The quartz vein contains 15 percent galena, pyrite, and chalcopyrite. Fine-grained pyrite is also present in veinlets of quartz in the country rock.

Three chip samples were taken across the shear zone from surface or near-surface exposures, and three grab samples were taken from dumps. Grab samples contained as much as 1 oz silver per ton (34 g/t), 2.42 percent lead, and 2.32 percent zinc. Although the surface samples

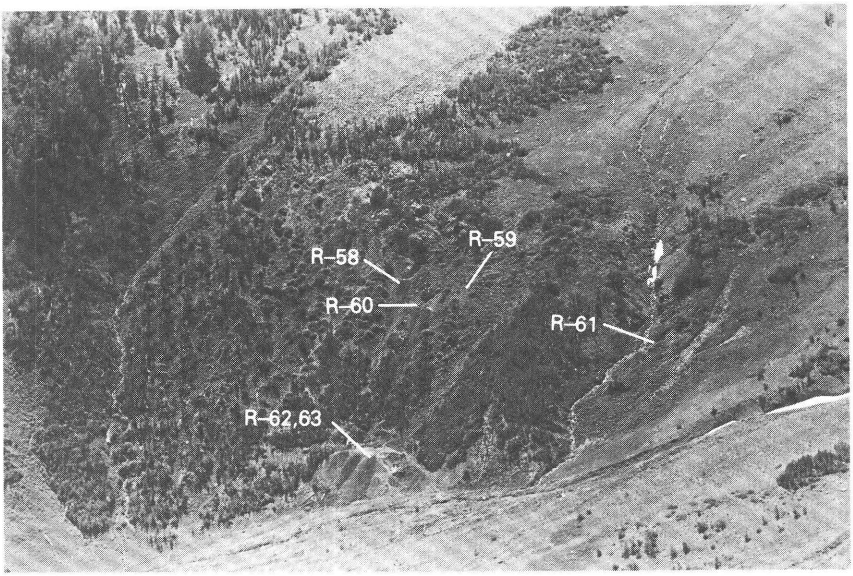

FIGURE 40.—Silver Dew prospect showing sample localities, viewed toward the east.

Data for samples shown in figure 40

[Leaders (--), not analyzed]

Sample				Gold[1]	Silver[2]	Lead	Zinc
No. R-	Type	Length (m)	Description	(g/t)		(percent)	
58	Chip--	0.9	Across quartz-filled shear zone---------	N	3	--	--
59	--do--	.9	---do----------------	N	10	--	--
60	Grab--	--	Iron-oxide-stained quartz------------	N	10	--	--
61	Chip--	.9	Across quartz-filled shear zone---------	N	Tr	--	--
62	Grab--	--	Silicified argillite with veinlets of quartz------------	N	34	1.70	3.86
63	--do--	--	Quartz shear filling material----------	N	24	2.42	2.32

[1]N, none detected.

[2]Tr, trace.

are relatively barren, grab samples indicate a possibility for the discovery of submarginal resources of depth. The inferred resource, based on a length of 400 ft (120 m), a depth of 200 ft (61 m), and an average thickness of 3 ft (1 m) is approximately 20,000 tons (18,000 t).

TOPSEY, BIJU, NOREX, AND HI NOTE GROUP

The Topsey, Biju, Norex, and Hi Note claims are near the head of Wildhorse Creek at elevations between 8,500 and 10,000 ft (2,600 and 3,000 m) (pl. 4, No. 25; fig. 41).

The claims are located along a northwesterly-trending tactite zone in schists and gneisses, which is intermittently exposed for about 2¼ mi (4 km). The zone is conformable with the country rocks. These rocks have been intruded by numerous granitic and aplitic dikes. The metamorphic rock–granitic rock relationship is locally migmatitic.

Tactite exposures range from 8 to 115 ft (2 to 35 m) long and are as much as 0.6 mi (1 km) apart. The zone ranges from 3 to 13 ft (0.9 to 4 m) thick and averages 6 ft (2 m) thick. The epidote-rich tactite contains quartz, calcite, biotite, garnet, and sparsely disseminated scheelite.

Eleven tactite samples contained from <0.02 to 4.3 percent WO_3 and averaged 0.15 percent.

The tactite zone is so poorly exposed that a resource estimate could not be made. The mineralogy of the zone is similar to tactites exposed at the Wildhorse mine and the zone may contain minable ore shoots.

PINE MOUSE GROUP

The Pine Mouse claims are on the west side of Wildhorse Creek about 1 mi (1.6 km) south from Wildhorse Campground, between 8,200 and 9,800 ft (2,500 and 3,000 m) elevation (pl. 4, No. 24; fig. 41).

A tactite zone on the claims in gneiss and schist country rock is intermittently exposed for about 1 mi (1.6 km). The zone is conformable with the country rock and trends west and northwest. The metamorphic rocks have been intruded by numerous granitic dikes and small irregular granitic bodies.

The tactite zone can be traced by numerous, closely spaced exposures for 3,500 ft (1,000 m). An additional 1,800 ft (550 m) can be inferred. Thirty to 40 percent of the zone is missing, interrupted by granitic dikes and small granitic bodies. The zone is traceable over a vertical distance of 1,600 ft (490 m). The eastern 1,000 ft (300 m) of the zone is composed of two parallel tactite beds 10 to 15 ft (3 to 5 m) apart. One bed is 2 ft (0.6 m) thick, the other 3.0 to 6.0 ft (1 to 2 m) thick. The thicker bed is continuous and averages 5.0 ft (1.5 m) thick for 3,500 ft (1,000 m).

The epidote-rich tactite contains quartz, calcite, biotite, garnet, and sparsely disseminated scheelite. Ten samples from the tactite zone contained from <0.02 to 1.68 percent WO_3 and averaged 0.32 percent.

The tactite zone is similar mineralogically to the tactite at the Wildhorse mine and may be an extension. The zone appears to contain at least 1.4 million tons (1.3 million t) of tungsten-bearing resource. This estimate is based on outcrops of the mineralized zone of 3,500 ft

(1,070 m), 5 ft (1.5 m) thick, and projected to a depth of 1,600 ft (500 m).

BROWN ZONE

The brown zone is west of the tactite zones and ranges in elevation between 9,000 and 10,800 ft (2,700 and 3,300 m) (fig. 41). The zone is from 40 to 100 ft (12 to 30 m) thick and is intermittently exposed for about 2½ mi (4 km). The zone consists of limonitic, altered gneiss with thin lenses of marble and tactite. Five samples taken from the altered gneiss contained only trace amounts of tungsten.

Two areas within the brown zone, a few hundred feet (about 100 m) apart, contain significant amounts of tungsten. One area near the footwall of the brown zone (samples T–344, 345, 391, 392, and 393) is a lens 1.0 ft (0.30 m) thick intermittently exposed for 120 ft (37 m). The lens consists of a center core of calcite with a black amphibole layer on both hanging and footwalls. The amphibole layers contain disseminated scheelite. Samples taken from the lens averaged 0.55 percent WO_3.

The second area is a 220-ft (67-m)-long, 2.5-ft (0.76-m)-thick marble lens with a 1- to 2-in. (2- to 5-cm)-thick scheelite-bearing zone along the footwall. The scheelite-bearing zone is 60 ft (18 m) long. A sample (T–346) taken across the lens contained 0.32 percent WO_3.

Three samples (P–8, 9, and 10) taken from tactite lenses within the northern exposures of the brown zone contained no WO_3.

Scheelite-bearing areas within the brown zone are too small for economic considerations.

MISCELLANEOUS PROPERTIES

Several district properties have little or no economic potential or are not sufficiently exposed to permit evaluation. These properties are listed in table 18.

WARM SPRINGS DISTRICT

Part of the Warm Springs mining district includes the southwest side of the study area (fig. 32). It is accessible by seasonal roads from the Trail Creek road and by seasonal roads along the East Fork Wood River, Hyndman Creek, Lake Creek, Eagle Creek, and the North Fork Big Wood River. Since 1880, six hundred and forty-three lode claims have been located in the study area's portion of the Warm Springs district (table 19). One lode claim, near the head of Lake Creek within the study area boundary, is patented.

Mining activity has been sporadic, but the period 1917–1948 was the most productive. Bureau of Mines records indicate that total value of

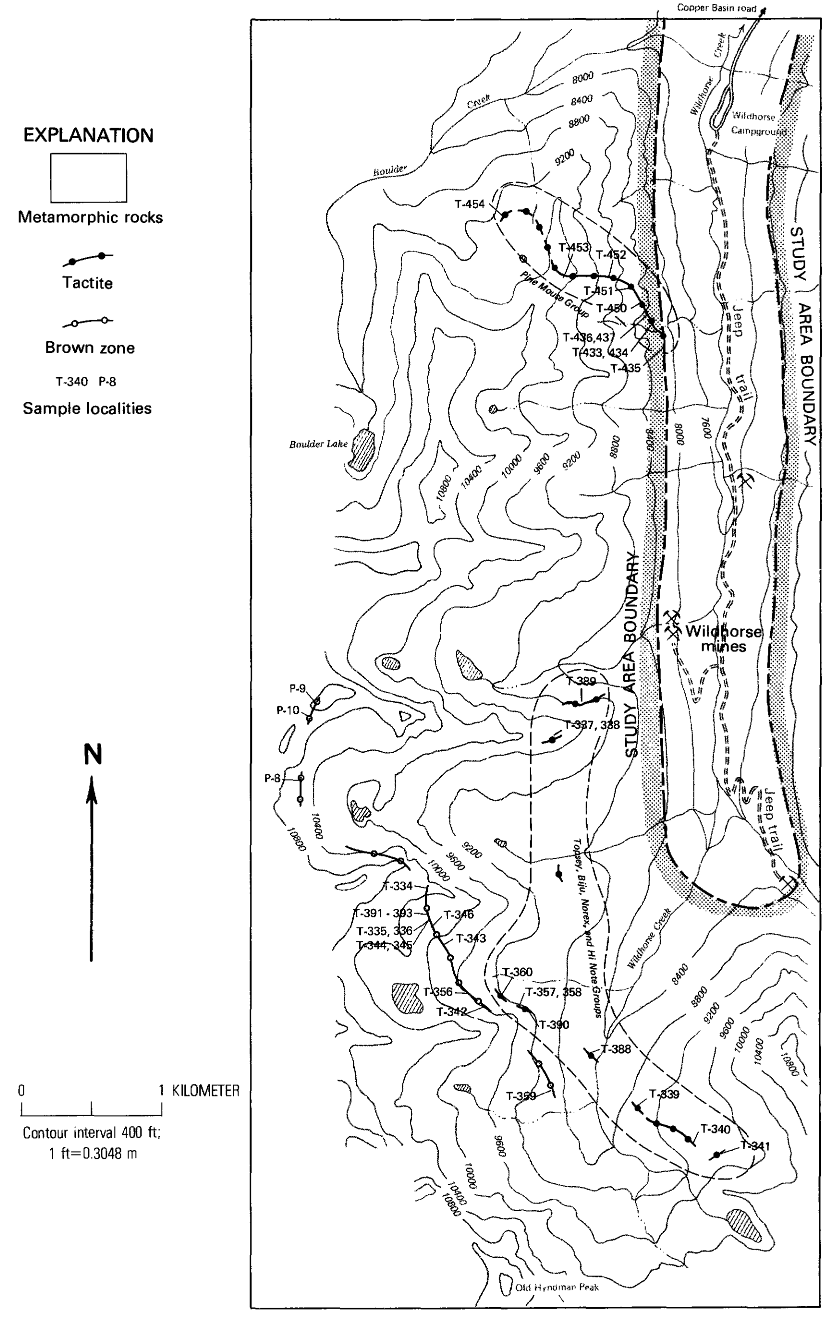

FIGURE 41.—Scheelite-bearing tactite occurrences and related zones, Wildhorse Creek.

Data for samples shown in figure 41

Sample				WO_3
No.	Type	Length[1] (m)	Description	(percent)[2]
Topsey, Biju, Norex, and Hi Note group				
T-337	Chip---	2.7	Tactite----------	0.4
T-338	--do---	.3	---do------------	4.3
T-339	--do---	1.4	---do------------	.03
T-340	--do---	1.2	---do------------	.07
T-341	--do---	3.0	---do------------	.05
T-357	--do---	1.2	---do------------	<.02
T-358	--do---	.6	---do------------	.04
T-360	--do---	4.1	---do------------	<.03
T-388	--do---	.9	---do------------	.14
T-389	--do---	2.4	---do------------	<.02
T-390	--do---	1.3	---do------------	<.02
Pine Mouse Group				
T-433	Chip---	1.4	Tactite----------	0.09
T-434	--do---	.8	---do------------	.43
T-435	--do---	3.0	---do------------	.12
T-436	--do---	1.5	---do------------	<.02
T-436	--do---	2.0	---do------------	<.02
T-450	--do---	.6	---do------------	.30
T-451	--do---	1.8	---do------------	.62
T-452	--do---	1.8	---do------------	.12
T-453	--do---	1.8	---do------------	.12
T-454	--do---	1.5	---do------------	1.68
Brown zone				
T-334	Chip---	8.8	Limonite-stained altered gneiss-	<0.03
T-335	--do---	.5	Tactite----------	<.03
T-336	--do---	4.6	Limonite-stained altered gneiss-	<.03
T-342	--do---	17.1	---do------------	<.03
T-343	--do---	15.5	---do------------	<.03
T-344	--do---	.3	Tactite----------	.35
T-345	--do---	*.3	---do------------	.20
T-346	--do---	.3	---do------------	.32
T-356	--do---	.6	---do------------	<.02
T-359	--do---	3.4	Limonite-stained altered gneiss-	<.03
T-391	--do---	*0.2-0.3	Tactite----------	.34
T-392	--do---	*0.2-0.4	---do------------	.94
T-393	--do---	.2	---do------------	.91
P-8	Grab---	--	do------------	N
P-9	Chip---	.8	Marble-----------	N
P-10	--do---	1.2	---do------------	N

[1]Leaders(--), not analyzed.

[2] , less than value shown.

N, none detected.

*Composite.

TABLE 18.—*Miscellaneous properties, Alta district*

Map No.	Property name	Summary	Number and type of workings	Sample data
1	Prospect	An irregular quartz vein in black fissile argillite is near an andesite porphyry dike contact. The vein strikes N. 10° to 30° E. and dips 75° W. It ranges from 0.2 to 0.9 m thick and can be traced for 30 m on the surface. The quartz is limonite stained and contains less than one percent disseminated pyrite.	One caved shaft and one sloughed pit.	Two samples of quartz and one of iron-oxide stained andesite porphyry, trace gold, copper, lead, and 0.34 gram silver per metric ton.
3	Prospect	Vuggy, limonite-stained honeycomb quartz with small amounts of malachite from vein which may have been as thick as 20 cm. Structure not exposed.	Two sloughed cuts	One sample; 30.6 grams silver per metric ton.
4	Lucky Strike	Quartz vein striking N. 83° W. and dipping 40° NE. in argillite and sandstone. Finely crystalline pyrite and galena comprise as much as 20 percent of the rock.	Small inclined shaft and two sloughed adits.	One sample; trace gold, 7 grams silver per metric ton, 0.30 percent lead, and 0.02 percent zinc.
6	Prospect	Quartz stringers, veinlets, and veins in gray argillite; zone trends northwest. Much gossan present.	Three cuts	Three chip samples; trace gold, as much as 27 grams silver per metric ton, 0.5 percent lead, and 0.08 percent zinc.
7	Prospect	Limonite-stained zone in argillite, structure not visible. Quartz vein material on dump is vuggy and contains about 15 percent sulfides, mostly pyrite and galena. Some andesite porphyry float in vicinity.	Partially caved adit 4.6 m long.	Select grab sample; trace gold, 175 grams silver per metric ton, 7.56 percent lead, 1.64 percent zinc, and 0.04 percent copper.
8	Prospect	Quartz vein as much as 0.2 m thick in slate and argillite.	Two small sloughed pits.	Two grab samples; 3 grams silver per metric ton.

11	White Elephant group.	Quartz vein dipping gently to the west in argillite and slate near quartz monzonite stock. Several small stringers of quartz in country rock. Scheelite occurs as small 2-mm disseminated crystals mainly in fractures in the igneous rock near its contact with the sedimentary strata.	Three adits and several small cuts.	Seven samples; nil to 17 grams gold, trace to 17 grams silver per metric ton, and 0.06 to 0.40 percent WO_3.
15	Prospect	Light-gray limonite-stained rhyolite porphyry dike intrudes black carbonaceous argillite. The dike strikes N. 85° W., dips 60° NE., and is 2.6 m thick.	Two trenches	Two samples across the dike; 6.8 grams silver per metric ton and trace copper, lead, and molybdenum.
16	Get Set, Ready, Go, and Mini group.	Anomalous amounts of uranium and vanadium in a crinkly, black carbonaceous shale. Some areas are covered with a volcanic agglomerate. A mining company conducted intensive surface exploration followed by a drilling program. Drilling discovered significant uranium and vanadium mineralization; however, the company did not exercise their option on the property.	Four drill sites	Scintillation counter readings at one site; 16 times above background. One sample from the site; 0.11 percent U_3O_8 and 0.07 percent vanadium.
18	Big Joe and Lost Summer group.	Many narrow quartz veins in quartz monzonite near a contact with argillite. The veins range from 5 to 15 cm in thickness, average 15 m in length and are 3 to 7.6 m apart. These veins are found in a zone about 75 m wide. Molybdenite occurs as widely scattered crystals in quartz; an occasional crystal is as large as 1.2 cm in diameter.	Two pits	Four samples; two samples taken from quartz veins; averaged 0.38 percent molybdenum and trace copper and lead. Two random chip samples of quartz monzonite; trace copper, lead, and molybdenum.
19	Prospect	Gossan zone in quartzite. Heavily limonite stained siliceous zone as much as 1.2 m thick contains fine-grained pyrite and galena. The zone trends N. 62° W. and dips 40° SW.	Forty-five-m-long dozer trench, one pit, and an inclined shaft.	Eight samples; three samples from upper workings; no gold or silver. Five samples from lower workings; trace gold, and as much as 27 grams silver per metric ton, 0.8 percent lead, and 0.11 percent zinc.

TABLE 18.—*Miscellaneous properties, Alta district*—Continued

Map No.	Property name	Summary	Number and type of workings	Sample data
21	Quanta------- group.	A quartz-filled shear zone, striking----- N. 20° to 25° E. and dipping 60° to 80° NW., is intermittently exposed for 0.4 km. The zone is as much as 9 m thick and averages 0.9 m thick. Country rocks are calcareous and siliceous argillite with interbedded slate and quartzite.	Two adits totaling- 96 m, one 15 m-deep shaft, and seven pits.	Fifteen samples; averaged 38 grams silver per metric ton, 0.47 percent zinc, and 0.03 percent copper.
22	Prospect-----	Gossan zone 15 m wide with possible------ quartz vein as much as 0.3 m thick. Country rock unknown.	Two sloughed------- pits, small.	One grab sample; 1 gram gold per metric ton, trace silver.
23	Prospect-----	Clayey, limonite-stained contact zones--- between the dike and argillite. The contact zones range from 0.2 to 0.6 m thick.	One 52-m-long------ adit.	Three samples from contact zones; trace metal values.
26	Sir Rocko----	A shear zone with well-defined walls----- and erratic lenses of molybdenite-bearing quartz intrudes banded granitic gneiss. The shear zone strikes N. 80° to 85° W., dips 70° S., to vertical and has an exposed strike length of 64 m and vertical exposure of 55 m. Quartz-filled portions of the shear zone range from 0.3 to 2 m thick. Molybdenite is sparsely disseminated throughout the quartz and sporadically concentrated in a 3-5-cm-thick zone along the footwall, hanging wall, or both.	One trench---------	Five samples across the shear zone and quartz; trace molybdenum and other metallics.

TABLE 19.—*Summary of recorded mining claims, 1880–1973, Warm Springs district*

Decade	No. of lode claims
1880-89	185
1890-99	28
1900-09	30
1910-19	134
1920-29	77
1930-39	18
1940-49	76
1950-59	35
1960-69	39
1970-	21
Total----	[1]643

[1]As of June 1, 1973.

production from the district from 1900 to the present is more than $32 million. Of this amount, more than $340,000 came from within the study area (table 20). The value of the ore produced prior to 1900 is unknown. Since 1900 production values can be divided as follows: 50 percent zinc, 31 percent lead, 19 percent silver, and less than 1 percent gold and copper. About 90 percent of the district's total production came from mines in the Triumph-Parker mineral belt adjacent to the southwest boundary of the study area. The Triumph-Parker mineral belt structures and the mineralized structures on the Mascot group mines (pl. 4, No. 80) do not extend into the study area.

The rocks of the district are complexly folded and faulted Paleozoic sedimentary rocks intruded by several Tertiary granitic bodies and dikes.

Mineral deposits are associated with a series of major shear zones, most of which strike northwest and dip moderately to the southwest. Ore bodies along the shear zones occur as fissure fillings and as replacements of interbedded limestones.

Principal areas of interest are on Lake Creek and East Fork Wood River, and they contain silver-lead-zinc deposits.

HOMESTAKE MINE (MERRY MACK AND DEBORA GROUP)

The Homestake mine is west of Lake Creek near its headwaters (pl. 5, No. 106, and fig. 42). The property consists of 1 patented and 19 unpatented claims. Discovery was made during the late 1800's and exploration, development, and production have progressed sporadically

TABLE 20.—*Recorded metal production, 1885–1963, from portion of Warm Springs district within study area*

[Leaders (- - -), no data]

Year	Mine	Ore (t)	Gold (g)	Silver (g)	Copper (kg)	Lead (kg)	Zinc (kg)
[1]1885	Homestake-------	62	---	98,379	---	28,406	---
1886	----do----------	41	---	65,721	---	22,863	---
1887	----do----------	1	---	2,768	---	551	---
1888	----do----------	7	---	12,472	---	2,415	---
1891	----do----------	54	---	95,424	---	20,047	---
1892	----do----------	43	---	78,908	---	16,154	2,645
1893	----do----------	48	---	61,180	---	14,095	---
1895	----do----------	72	---	87,182	---	24,649	---
1897	----do----------	12	---	19,626	---	5,233	---
1898	----do----------	7	---	11,601	---	3,309	---
1900	----do----------	1	---	622	---	257	---
1903	----do----------	17	31	25,287	---	7,870	2,336
1914	----do----------	43	---	54,866	---	16,802	---
1915	----do----------	64	---	94,273	---	28,690	---
1916	----do----------	230	---	330,314	---	89,775	---
1917	Homestake-------	47	---	66,778	---	16,311	---
	Lake Creek mines	159	---	---	---	---	50,803
1918	Homestake-------	143	---	216,912	---	59,010	---
	Lake Creek mines	1,022	---	---	---	---	285,841
1919	Homestake-------	23	---	39,874	---	12,269	---
1921	----do----------	35	---	71,848	106	16,545	---
1922	Homestake-------	13	---	25,069	83	3,373	---
	Price group-----	31	---	---	---	---	8,220
1923	Homestake-------	298	---	280,456	750	51,101	---
1924	----do----------	230	---	232,775	33	56,921	---
1925	----do----------	73	31	72,532	339	9,516	8,867
1939	----do----------	5	---	2,893	---	603	---
1940	----do----------	13	---	12,597	---	2,848	2,654
1941	Homestake-------	78	---	---	---	5,806	22,453
	Unknown---------	9	---	15,956	---	582	---
	Horseshoe-------	1	---	715	---	542	---
1942	Homestake-------	29	---	4,448	---	907	---
1943	Homestake-------	195	31	43,389	164	7,006	21,773
	Horseshoe-------	91	31	3,266	---	3,561	10,406
1944	Homestake-------	887	124	123,914	868	25,919	96,208
1945	----do----------	682	62	70,635	203	14,522	74,279
1946	----do----------	747	156	164,162	401	38,972	98,086
1947	----do----------	792	124	185,312	689	40,516	86,901
1948	----do----------	22	---	25,722	9	6,583	3,225
1949	Homestake-------	44	---	22,363	77	4,082	7,363
	Unknown---------	3	---	1,648	---	1,361	---
1950	Homestake-------	61	---	31,227	171	3,150	14,609
1951	----do----------	81	---	25,349	132	3,500	7,834
1956	Unknown---------	250	---	995	---	499	---
1962	Homestake-------	907	31	49,112	45	21,092	1,542
1963	----do----------	343	404	257,999	408	37,558	22,544
	Total-----------	8,016	1,025	3,086,569	4,478	725,771	828,589

[1]Data for 1885-1903 from Umpleby and others (1930).

since then. U.S. Bureau of Mines and U.S. Geological Survey records indicate that total ore production from 1885 to 1963 was 7,108 tons (6,448 t) from which 33 oz (1,030 g) of gold were recovered from 5,198 tons (4,716 t), 98,511 oz (3,064,000 g) of silver from 7,022 tons (6,370 t), 9,877 lb (4,480 kg) of copper from 5,962 tons (5,409 t), 1,585,590 lb (719,200 kg) of lead from 7,108 tons (6,448 t), and 1,043,471 lb (473,300 kg) of zinc from 5,494 tons (4,984 t)[1].

Twenty-three percent of the ore was produced between 1885 and 1924 and when the metallic minerals were saved the recovered content averaged 38.6 oz silver per ton (1,478 g/t), 33.3 percent lead, and 8.3 percent zinc. Seventy-seven percent of the ore was produced between 1925 and 1963; however, it only averaged a recovered content of 6.5 oz silver per ton (223 g/t), 4.5 percent lead, and 9.5 percent zinc when the metallic minerals were saved. Apparently earlier production consisted of select, hand-sorted ore.

Country rock in the vicinity of the Homestake mine is predominantly gray to black carbonaceous argillite cut by numerous randomly oriented calcite stringers. Folding and overthrusting has resulted in a general southwest-trending structural pattern with major fold axes usually inclined to the southwest. Normal faults striking northwest and northeast have produced shear systems with moderately large displacements. Mineralization produced commercial grade deposits in some of these shear zones.

A DMEA (Defense Minerals Exploration Administration) project contract was let in 1951 to determine the grade and character of ore in the unoxidized part of the Homestake mineralized shear zone. The objective was not met and the project terminated in 1954.

Because most of the workings are now inaccessible, much of the following information was taken from unpublished DMEA file data.

The Homestake mineralized shear zone has an average strike of N. 25° W. and dips 45°–75° SW. It can be traced on the surface for about 1 mi (1.6 km) and can be inferred for more than 3 mi (5 km) based on adjacent workings (fig. 43). The shear zone is strong with well-defined walls as much as 10 ft (3.1 m) apart. Ore minerals persist throughout the structure over widths ranging from 3 in. to 7 ft (8 cm to 2.1 m). Except for small local sulfide lenses, the ore is oxidized throughout the exposed portions. Ore minerals are smithsonite, calamine, and cerussite with remnants of galena in crushed wall rock, quartz, calcite, and hematite.

Ore shoots ranged from 10 to over 200 ft (3 to more than 60 m) long and were as much as 300 ft (90 m) deep. Much of the stoped ore was 1–3 ft (0.3–1 m) thick, but in places was as much as 7 ft (2 m) thick. The rake of the ore bodies is directly downdip or slightly to the south. Ore

[1]Copper and zinc were not recovered from about one-half of the ore shipments.

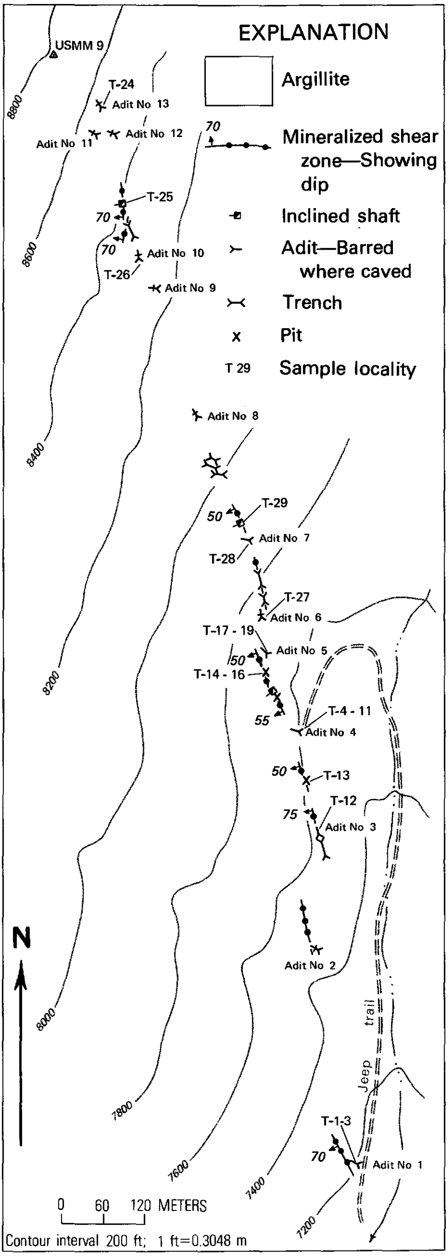

FIGURE 42.—Homestake mine.

occurs frequently in portions of the shear zone where one or both walls are buff-colored massive argillite, and is most often absent if both walls are of black thin-bedded argillite.

Data for samples shown in figure 42

[Tr, trace; N, not detected. Leaders (--), not analyzed]

Sample				Gold	Silver	Copper	Lead	Zinc
No. T-	Type	Length (m)	Description	(g/t)		(percent)		
1	Chip---	0.5	Shear zone breccia and gouge-	Tr	7	Tr	3.4	10.40
2	--do---	.2	-----do-----	Tr	120	Tr	.13	1.45
3	--do---	.3	Shear zone breccia and gouge, minor malachite staining.	N	N	Tr	Tr	4.17
4	--do---	.3	Sheared, brecciated, altered-country rock.	Tr	7	Tr	Tr	.16
5	--do---	.9	Sheared, brecciated, altered-country rock; minor disseminated galena.	Tr	82	--	2.88	6.01
6	--do---	2.4	Sheared, brecciated, altered-country rock.	Tr	24	--	.28	4.70
7	--do---	.8	-----do-----	Tr	117	--	3.78	9.36
8	--do---	.2	-----do-----	N	3	--	.47	7.24
9	--do---	1.4	-----do-----	Tr	247	--	4.78	12.90
10	--do---	2.0	-----do-----	N	3	--	1.53	6.65
11	--do---	.9	-----do-----	Tr	24	--	.42	4.53
12	--do---	.8	-----do-----	N	3	--	Tr	.71
13	--do---	.5	-----do-----	1	21	--	.18	1.90
14	--do---	.9	Sheared, brecciated, altered-country rock; minor disseminated galena.	Tr	48	--	1.42	5.09
15	--do---	.7	Sheared, brecciated, altered-country rock.	N	3.4	--	Tr	.8
16	--do---	.4	-----do-----	Tr	13.7	--	.18	.44
17	--do---	1.0	-----do-----	Tr	34	--	1.04	4.19
18	--do---	1.2	-----do-----	Tr	48	--	1.55	6.36
19	--do---	.5	-----do-----	Tr	48	--	1.82	7.3
24	Grab---	--	Sheared, brecciated country--rock with boxworks, calcite stringers and streaks of galena.	Tr	472.1	--	8.41	45.5
25	Chip---	.2	Sheared, brecciated, iron---oxide-stained country rock; <1 percent relic galena.	Tr	476.5	--	8.14	12.8
26	Grab---	--	Sheared, brecciated country--rock with limonite-filled boxworks; 20 percent galena and sphalerite as pods and streaks.	Tr	370.2	--	6.84	38.6
27	Chip---	.2	-----do-----	Tr	247.8	--	9.38	12.8
28	--do---	1.3	Sheared, brecciated, iron----oxide-stained country rock; <1 percent relic galena.	N	318.8	--	8.55	1.12
29	--do---	.7	-----do-----	N	24	--	1.47	12.2

Workings consist of 13 adits, 3 inclined shafts, and 11 pits and trenches, scattered through a distance of 5,000 ft (1,500 m) along the Homestake shear zone. Six adits (1, 2, 4, 5, 6, and 7; fig. 42) comprise the major workings; more than 6,000 ft (1,830 m) of underground excavations extend over a vertical distance of 650 ft (200 m). Stopes in adits 1 and 2 reportedly were the most productive in the mine. Of the six principal adits, only No. 4 (fig. 44) was completely open; adits 1, 5, and 7 were caved a short distance from their portals (figs. 45, 46, and 47).

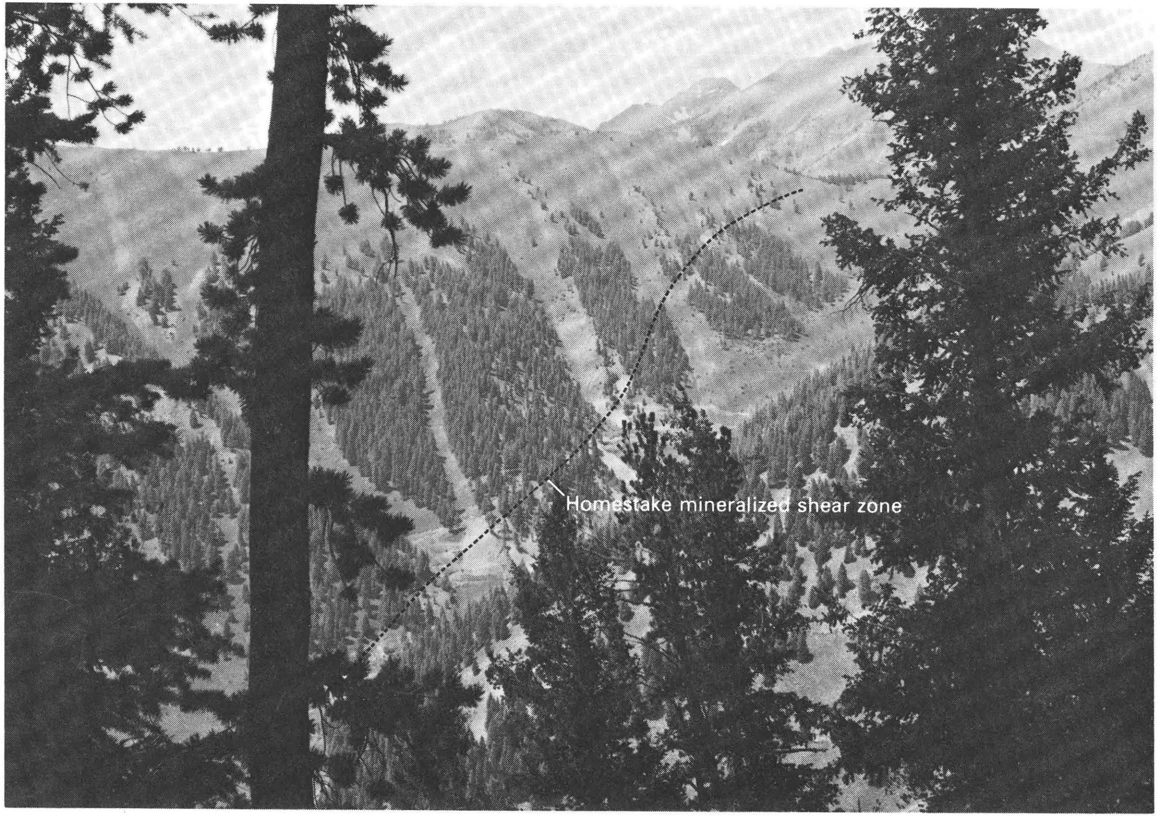

FIGURE 43.—Workings along the Homestake mineralized shear zone.

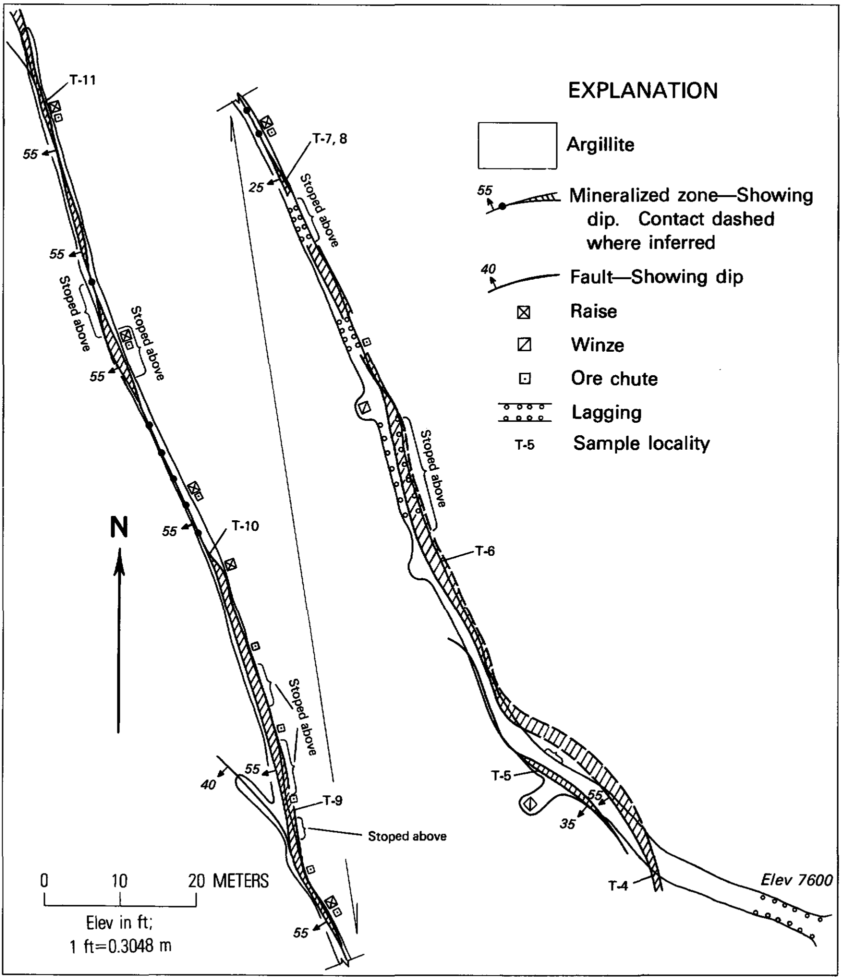

FIGURE 44.—Adit No. 4, Homestake mine.

Analysis of 23 samples from the Homestake mineralized shear zone indicate an uneven distribution of silver, lead, and zinc. Sample values ranged from 0 to 13.9 oz silver per ton (0 to 477 g/t), a trace to 9.38 percent lead, and 0.16 to 12.9 percent zinc. They averaged 2.4 oz silver per ton (82 g/t), 2.17 percent lead, and 5.67 percent zinc. Two select samples from an ore stockpile contained an average of 12.3 oz silver per ton (422 g/t), 7.62 percent lead, and 42 percent zinc.

The zone is traceable on the surface for a slope distance of 5,240 ft (1,597 m) and can be inferred for 3 mi (5 km). It is exposed on the surface and in the workings for a vertical distance of 1,400 ft (400 m) and averages 2.5 ft (0.80 m) in width. Approximately one-half the traced

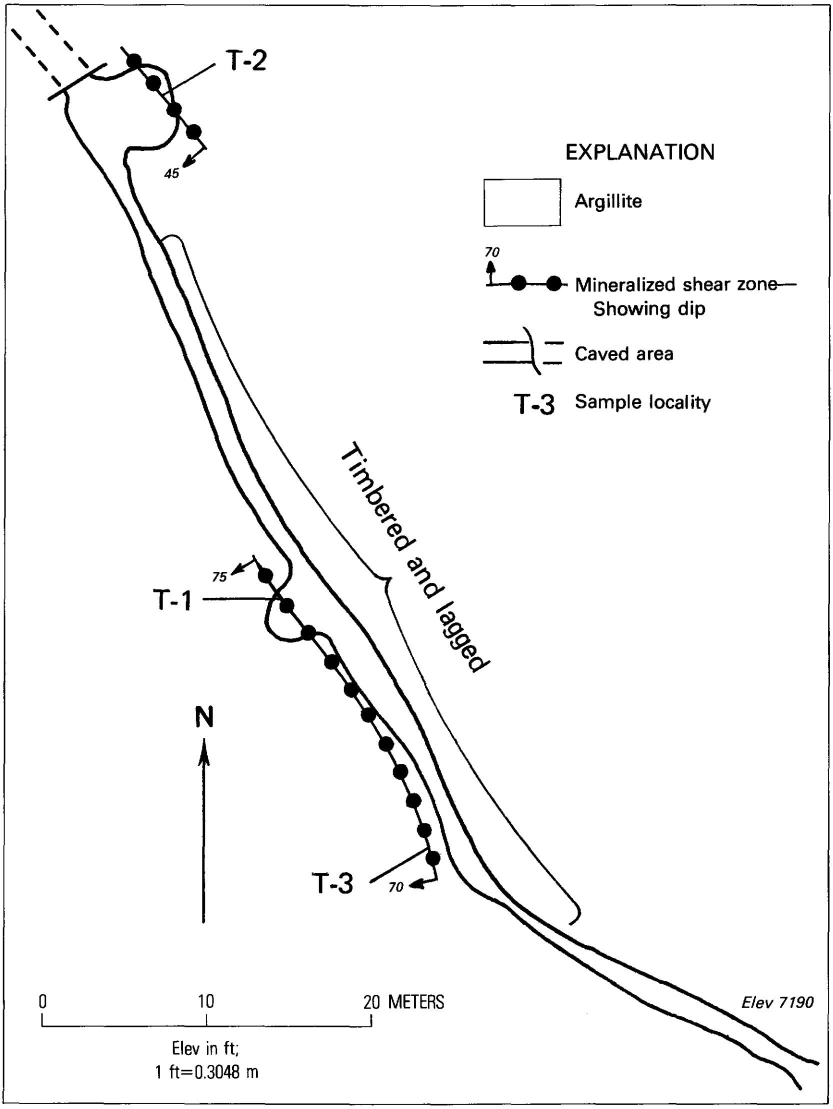

FIGURE 45.—Adit No. 1, Homestake mine.

outcrop distance has been explored and developed to a depth of 650 ft (198 m) and produced 7,108 tons (6,448 t) of ore. Comparable reserves probably exist in the unexplored traceable portion of the zone and at least 730,000 tons (662,000 t) of indicated submarginal resources have been estimated.

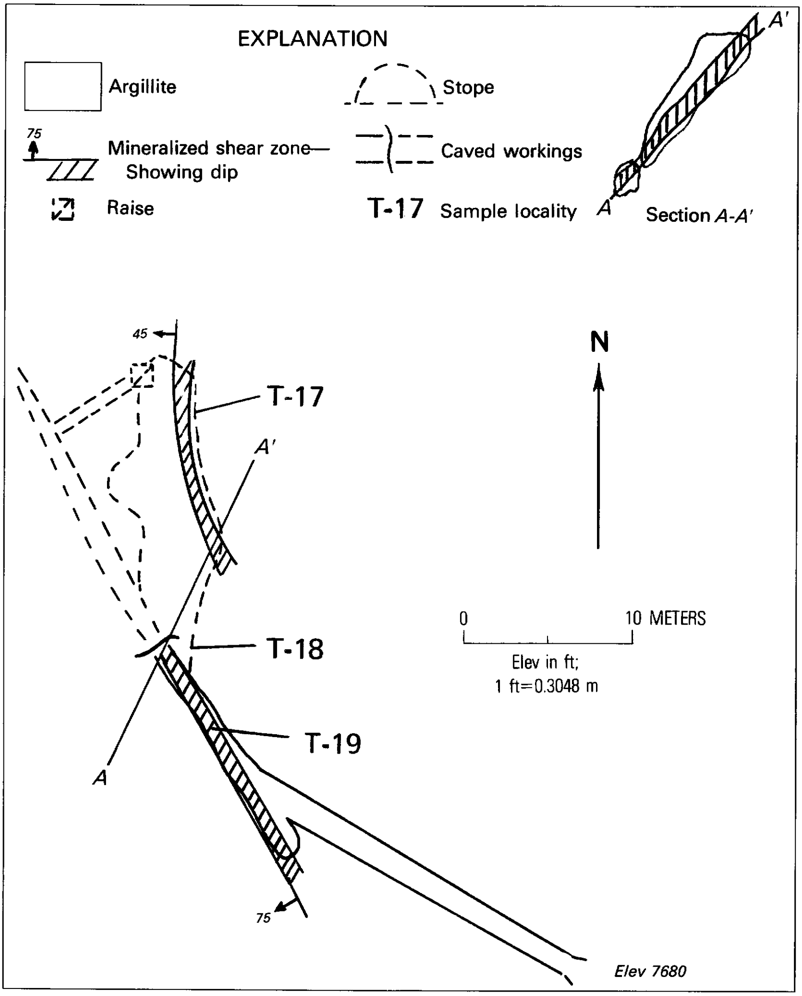

FIGURE 46.—Adit No. 5, Homestake mine.

HIGH GRADE PROSPECT

The High Grade prospect is near the ridge top between Lake and Eagle Creeks (pl. 4, No. 107). The shear zone exposed by the prospect is probably the northwest extension of the Homestake shear zone. No record of production exists, but some ore was probably removed from the lower adit.

The country rock, trend, and mineralogy of the shear zone are similar to the Homestake, but the shear zone is not as strong. The oxidized breccia-filled shear zone strikes N. 35° W. and dips 55°–80° SW., and it

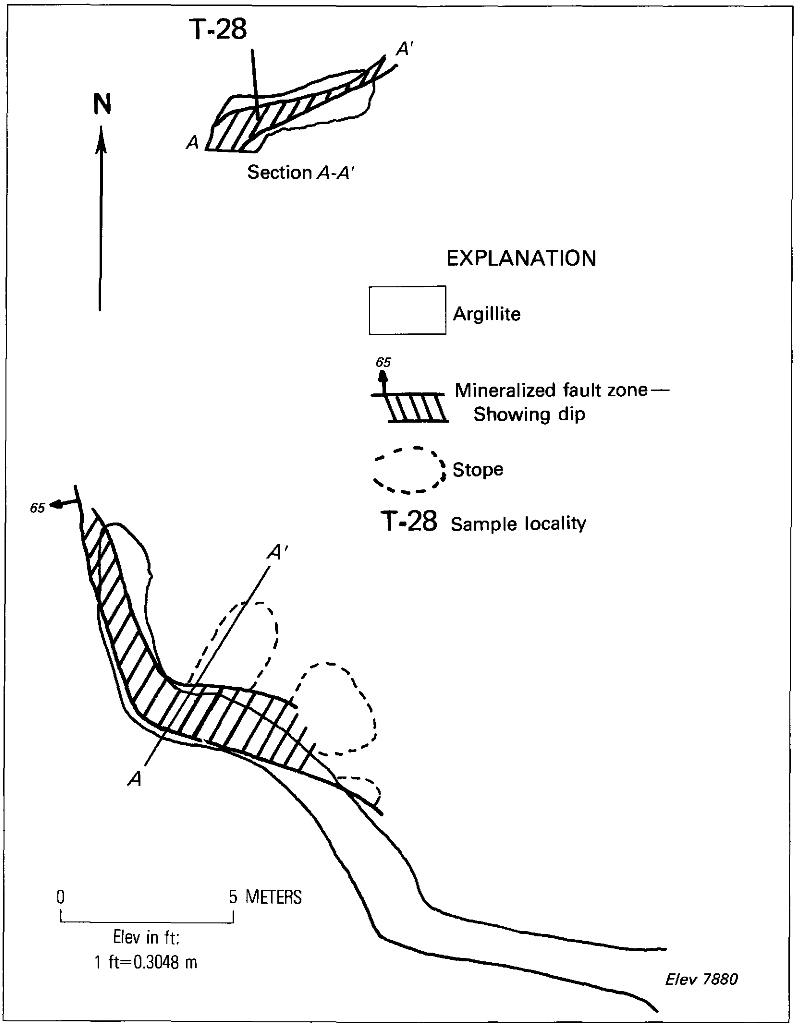

FIGURE 47.—Adit No. 7, Homestake mine.

can be traced for more than 300 ft (91 m). Exposed by the 160-ft (49-m)-long lower adit, the shear zone ranges from 0.4 to 1.5 ft (0.12 to 0.46 m) in thickness (fig. 48). It has been stoped at two places. A small stope measures 20 by 2 by 15 ft deep (6.1 by 0.6 by 4.6 m). A larger stope is 20 by 2.5 by 50 ft high (6.1 by 0.8 by 15 m). The zone thickness pinches down to less than 1.0 ft (0.3 m) at the end of the stopes. On the shear zone southeast of the lower adit and up the hill are two sloughed pits and three small caved adits.

Three samples taken from the shear zone averaged 3.5 oz silver per ton (120 g/t), 1.76 percent lead, and 5.33 percent zinc. A sample of select mineralized rock from the caved adit dump contained 15.5 oz silver per ton (532 g/t), 21.9 percent lead, and 0.76 percent zinc.

Assuming that the shear zone is continuous for 300 ft (90 m) and averages 1 ft (0.3 m) in thickness for a depth of 150 ft (45 m), the indicated and inferred mineral resource is approximately 3,750 tons (3,402 t) containing 3.5 oz silver per ton (120 g/t), 1.76 percent lead, and 5.33 percent zinc. The select grab sample indicates that the average grade might be higher.

LONG GRADE MINE (DEBORA GROUP)

The Long Grade mine is east of Lake Creek, 1,800 ft (550 m) above the valley floor (pl. 4, No. 104). The property can be reached by unimproved mine road. The only production recorded from the mine was in 1943–1944: 100 tons (90 t) of ore averaged 0.01 oz gold per ton (0.34 g/t), 3.05 oz silver per ton (104.6 g/t), 4.81 percent lead, and 20.01 percent zinc. Probably the ore came from adit No. 3.

Five short adits expose a northwest-trending, breccia-filled, mineralized shear zone in gray argillite (fig. 49). Exposed intermittently for about 650 ft (200 m), it resembles the Homestake shear zone and is thought to be the southeast extension. The zone contains lead and zinc carbonates and minor amounts of galena, sphalerite, and pyrite in calcite, hematite, and crushed wall rock. The strike ranges from N. 10° to 30° W. and dips 30° to 50° SW. The thickness ranges from 1 to 5 ft (0.3 to 2 m) with metallic mineral streaks from 2 to 8 in. (5 to 20 cm) thick occurring sporadically as elongated irregular lenses.

The three accessible adits range from 32 to 50 ft (10 to 15 m) in length. Adit No. 2 has stopes above and below adit level and was not safe to enter. Adit No. 4 was caved at the portal.

Analysis of mineralized shear zone samples from each accessible adit and from the portal exposure of adit No. 2 average 2.4 oz silver per ton (82 g/t), 0.7 percent lead, and 4.1 percent zinc.

Based on an average thickness of 2 ft (0.6 m), a length of 650 ft (200 m), and a depth of 300 ft (90 m), the zone is estimated to contain about 32,500 tons (29,500 t) of submarginal resources.

LAKE CREEK GROUP MINE (LAKE VIEW NOS. 1 AND 2)

The Lake Creek group is about 800 ft (240 m) northwest of Lower Lake Creek Lake, 900 ft (270 m) above the valley floor (pl. 4, No. 102).

U.S. Bureau of Mines records show that 742,160 lb (336,640 kg) of zinc was recovered from 1,302 tons (1,182 t) of ore during 1917 and 1918.

Workings are on a zinc-bearing shear zone, often filled with massive calcite, in a light-gray, limy argillite (fig. 50). The zone strikes N. 40° W., dips 80° SW. to vertical, is intermittently exposed for 900 ft (270 m), and averages 3 ft (1 m) thick. Massive white calcite is found

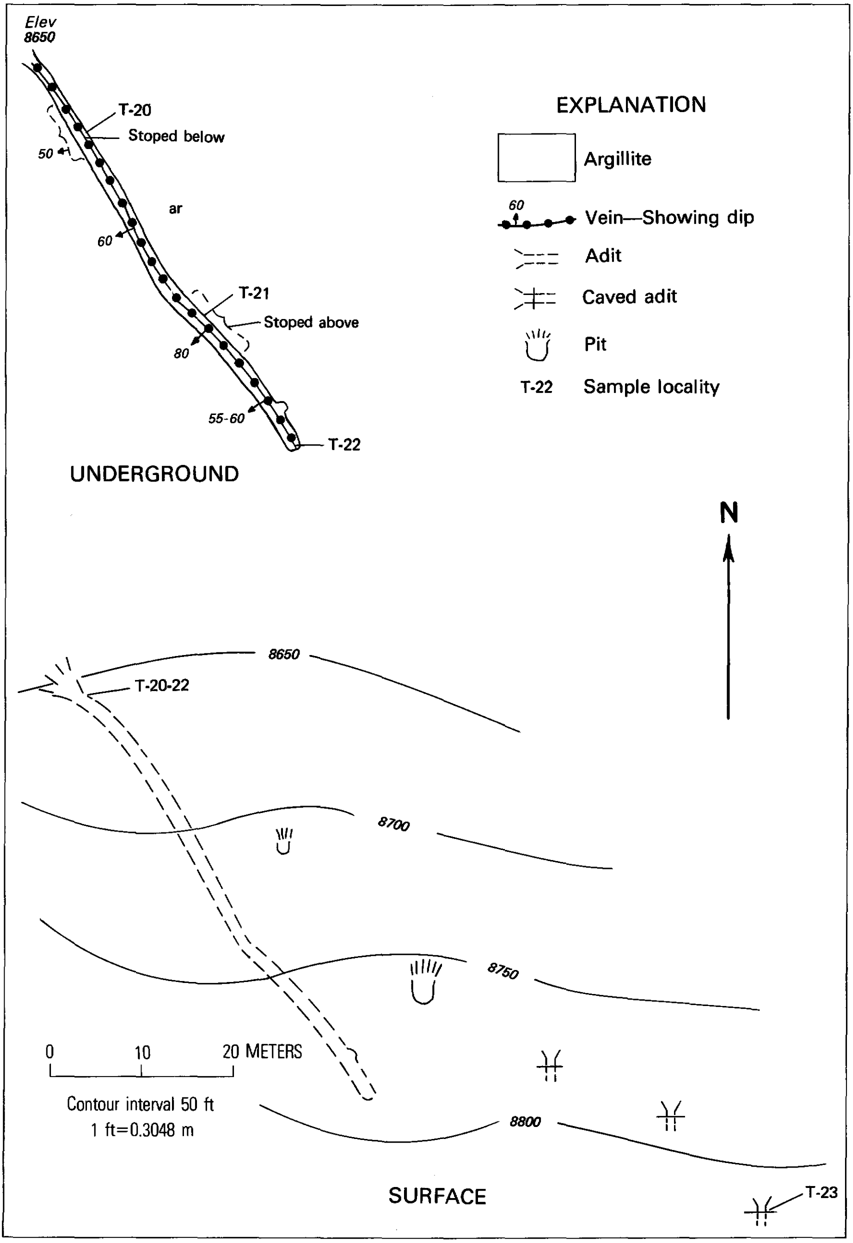

FIGURE 48.—High Grade prospect.

predominantly on the hanging-wall side of the shear zone, but in places occurs both on the hanging wall and footwall. The calcite-filled portion of the shear zone ranges in thickness from thin stringers to 4 ft (1.2 m)

Data for samples shown in figure 48

[Tr, trace; N, not detected]

Sample				Gold	Silver	Lead	Zinc
No. T-	Type	Length (m)[1]	Description	(g/t)		(percent)	
20	Chip---	0.3	Iron-oxide-stained,---- breccia-filled shear.	1	130	3.07	11.10
21	--do---	.3	-----do---------------	Tr	75	1.05	3.98
22	--do---	.3	-----do---------------	N	151	1.18	.91
23	Select-	--	Iron-oxide-stained,---- clayey fault breccia, 5 percent galena.	Tr	531	21.90	.76

[1]Leaders (--), unknown.

(fig. 51). Between the calcite and footwall is a brecciated zone consisting of crushed wall rock, gouge, calcite, quartz stringers, and hematite. The brecciated zone ranges from 0.3 to 3.5 ft (0.09 to 1 m) in thickness. Sulfides were not visible in any samples.

Two adits, two trenches, and two pits are on the shear zone. Adit No. 1 is caved 260 ft (80 m) from the portal. It probably continues another 80 ft (24 m) and connects with the ore chute that collars at the surface in trench No. 1. Three samples taken from the shear zone and calcite exposed by adit No. 1 contained 0 to 0.2 oz silver per ton (0 to 6.9 g/t), a trace to 0.21 percent lead, and a trace to 0.30 percent zinc.

Ore has been removed from a trench 165 ft (50 m) long by 25 ft (8 m) deep above adit No. 1 (trench No. 1, fig. 50). The shear zone is exposed only at the northwest end of the trench. The southeast end is caved and the bottom covered with rock debris. A sample from a 15-ft (5-m)-long adit (No. 2), near the center of trench No. 1, contained a trace of gold, 0.4 oz silver per ton (14 g/t), 0.14 percent lead, and 4.91 percent zinc.

Northwesterly from trench No. 1, the shear zone has been explored for 230 ft (70 m) by a shallow trench and two small pits. Beyond the workings, minor amounts of iron-oxide-stained calcite float occurs sporadically for 300 ft (90 m). A sample taken across the shear zone exposed in trench No. 2 contained a trace of gold, 1.5 oz silver per ton (51 g/t), 0.2 percent lead, and 26.0 percent zinc.

A select sample of material from a stockpile near a caved pit contained a trace of gold, 1.9 oz silver per ton (65 g/t), 0.54 percent lead, and 42.4 percent zinc.

Sampling indicates that the ore mined from trench No. 1 does not persist to the adit level 60 ft (18 m) below. The ore probably terminated at the bottom of the trench. The 200-ft (61-m)-long portion of the shear zone from trench No.1 to the small pits contains a high-grade zinc resource. Assuming a depth of 100 ft (30 m), and an average width of 3 ft (0.9 m), there would be approximately 5,000 tons (4,500 t) of ore containing 1.5 to 1.9 oz silver per ton (51 to 65 g/t) and 26 to 42 percent zinc.

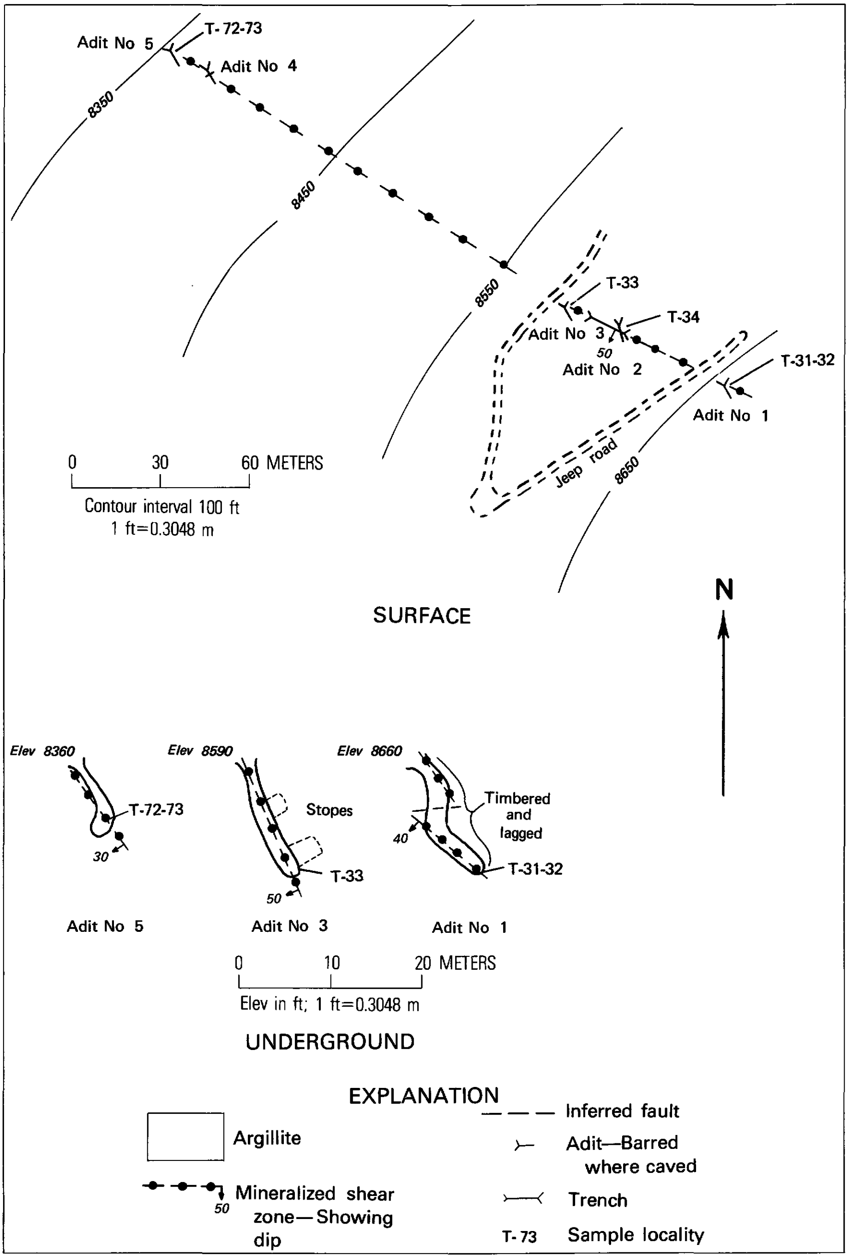

FIGURE 49.—Long Grade mine.

At the Price group mine, southeast of Lake Creek (pl. 4, No. 101), is a similar zinc-bearing shear zone that seems to be an extension of the Lake Creek group structure. The area between the two surface ex-

Data for samples shown in figure 49

[All samples chip; Tr, trace; N, not detected; leaders (--), not analyzed]

No. T-	Length (m)	Description	Gold (g/t)	Silver (g/t)	Copper (percent)	Lead (percent)	Zinc (percent)
31	0.6	Brecciated, oxidized, clayey shear zone.	1	326	Tr	Tr	7.90
32	.6	Fractured, gray argillite with calcite stringers.	N	48	--	1.63	6.91
33	.3	Brecciated, oxidized, clayey shear zone.	N	3	--	3.29	10.3
34	.7	----do----	N	3	--	Tr	Tr
72	.5	Iron-oxide-stained, massive calcite.	Tr	17	--	.63	.79
73	.5	Brecciated, oxidized, clayey shear zone.	Tr	17	--	Tr	.17

posures is covered by overburden, but seems to be a good exploration target for additional zinc deposits.

PRICE GROUP MINE (BIG DOE ZINC PROPERTY)

The Price group is about 1,300 ft (400 m) southeast of Lower Lake Creek Lake, 1,000 to 1,600 ft (290–490 m) above the valley floor (pl. 4, No. 101). Ore was shipped from the property during World War I, although the amount has not been recorded (Umpleby and others, 1930, p. 195). In 1950, 3 tons (2.7 t) of smithsonite ore were shipped from the winze extending below adit No. 4. The ore assayed 37 percent zinc and 0.4 percent lead.

Two separate veins were explored (fig. 52). Adits Nos. 3 and 4 and several pits are on the "calcite vein," a persistent shear zone that can be traced for about 1,000 ft (300 m). The "calcite vein" has well-defined walls, ranges from 0.5 to 3.5 ft (0.15 to 1 m) thick, strikes N. 40° W. and dips 80° SW. to vertical. Calcite occurs as veinlets within the shear-zone breccia and as elongated lenses along the breccia. The calcite lenses are as much as 3 ft (0.9 m) thick and comprise 75 percent of the shear zone. Smithsonite occurs as irregular lenses, pods, and streaks in both the calcite and the breccia.

In adit No. 4 a body of smithsonite as much as 2.5 ft (0.76 m) thick was discovered about 50 ft (15 m) from the portal and drifted on for 50 ft (15 m) (fig. 52). The ore body has been stoped both above and below the adit level, and no appreciable amount of ore remains. Two samples cut at the ends of the stope averaged 1.2 oz silver per ton (41 g/t), a trace of lead, and 16.4 percent zinc. In the remaining 65 ft (20 m) of adit, the shear zone pinches and swells from 5 in. to 3.5 ft (13 cm to 1 m); no mineralized rock was noted. A sample taken across the shear zone near the face contained 0.3 oz silver per ton (10 g/t), a trace of lead, and 0.34 percent zinc.

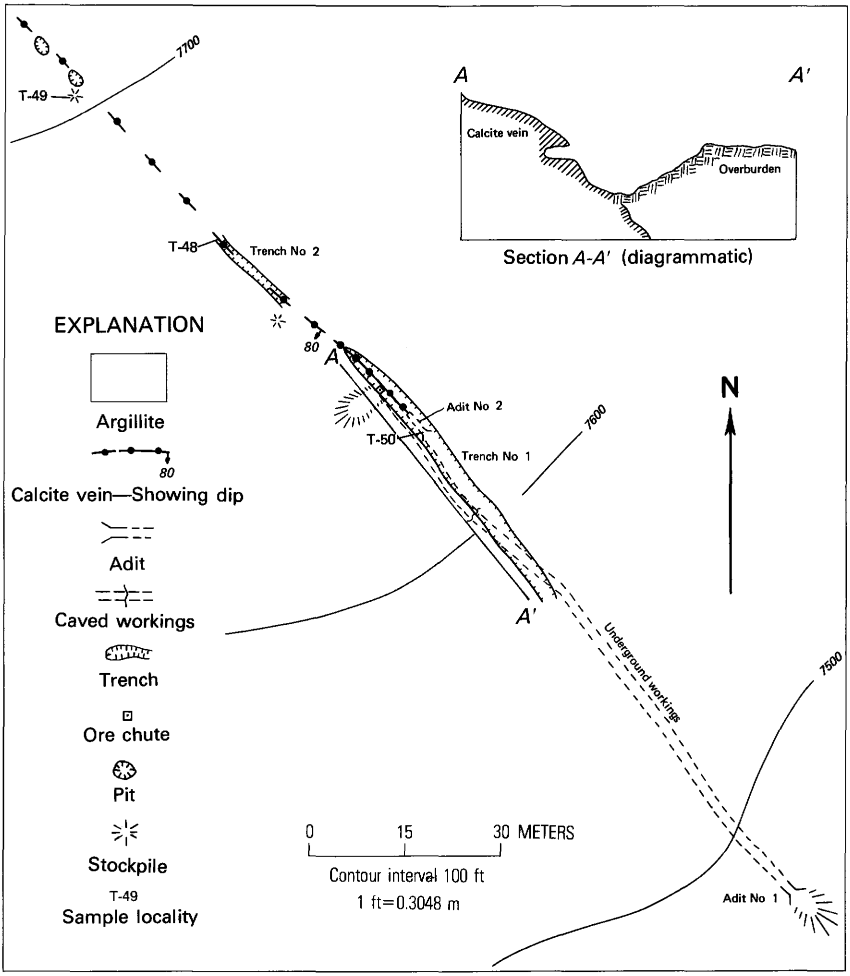

FIGURE 50.—Lake Creek group mine.

A select sample of vuggy, iron-oxide-stained, massive calcite with some sphalerite, taken from a stockpile near the portal of adit No. 4, contained 0.8 oz silver per ton (27 g/t), 0.91 percent lead, and 20.10 percent zinc.

An "L"-shaped trench and short inclined shaft, 15 ft (5 m) above the adit, expose a 2.5-ft (0.76-m)-thick section of the "calcite vein." A sample taken from the vein near the incline contained 0.6 oz silver per ton (21 g/t), 0.88 percent lead, and 9.25 percent zinc.

Two shallow pits were excavated on the "calcite vein" southeast of adit No. 4. The first pit, 140 ft (43 m) southeast of the adit, exposes a 4.0-ft (1.3-m) thickness of the "calcite vein." A sample taken across the structure contained 1.2 oz silver per ton (41 g/t), 1.21 percent lead, and

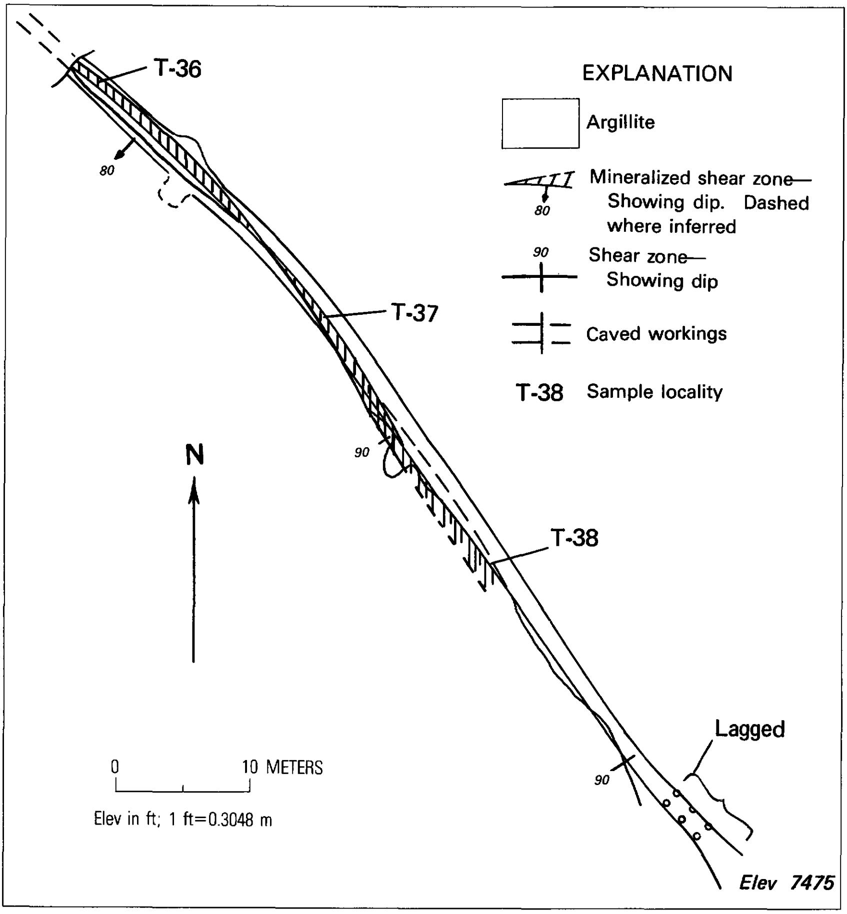

FIGURE 51.—Adit No. 1, Lake Creek group mine.

Data for samples shown in figures 50 and 51

[Tr, trace; N, not detected]

Sample No. T-	Type	Length (m)[1]	Description	Gold (g/t)	Silver (g/t)	Lead (percent)	Zinc (percent)
36	Chip----	0.7	Fault gouge and calcite---	N	7	Tr	0.30
37	--do----	.7	-----do------------------	N	N	Tr	Tr
38	--do----	.6	Fault gouge---------------	N	3	0.21	.29
48	--do----	1.0	Calcite-------------------	Tr	51	.20	26.00
49	Select--	--	Vuggy, iron-oxide-stained calcite.	Tr	65	.54	42.40
50	Chip----	1.1	Fault gouge and breccia---	Tr	14	.14	4.91

[1]Leaders (--), unknown.

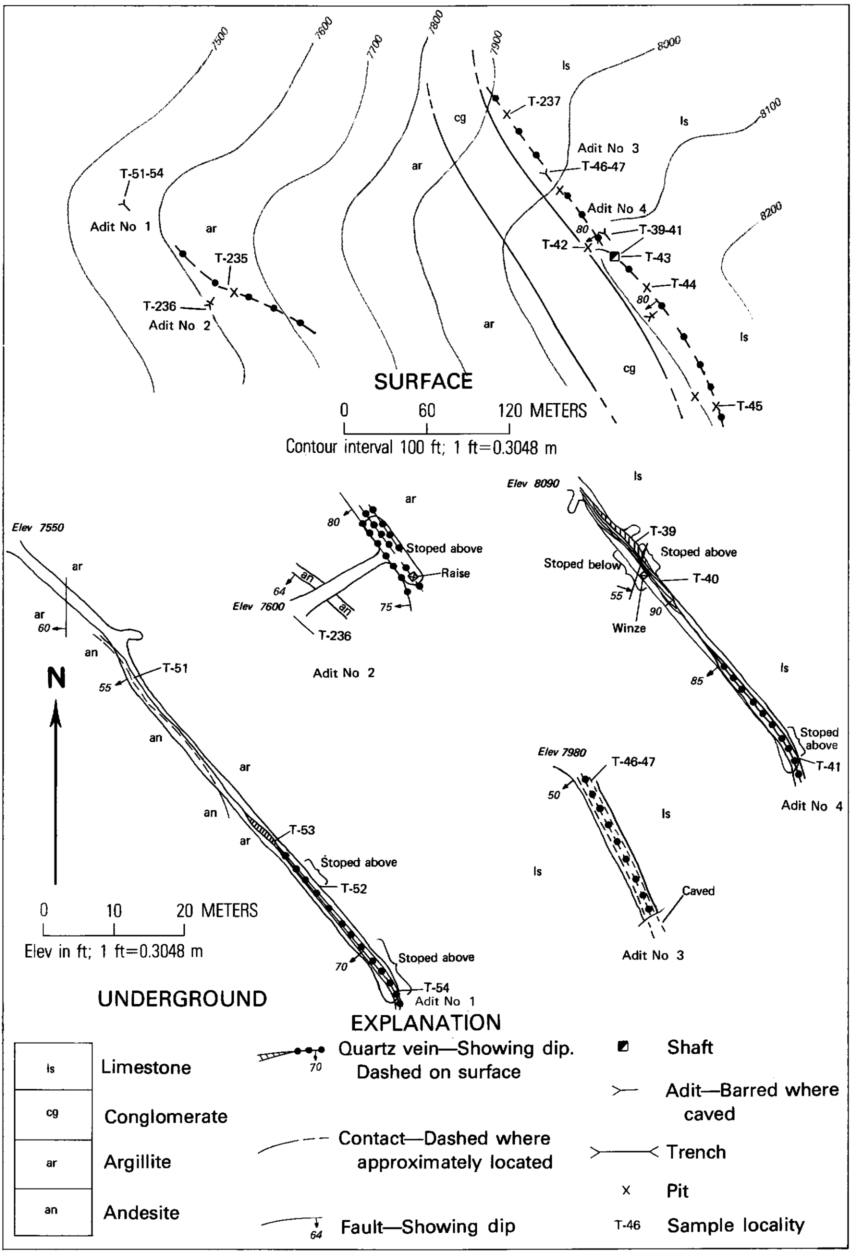

FIGURE 52.—Price group mine.

10.90 percent zinc. The second pit, 430 ft (131 m) southeast of the adit, is caved. A sample of vuggy, iron-oxide-stained calcite from the dump contained 0.7 oz silver per ton (24 g/t), 0.54 percent lead, and 32.60 percent zinc.

Data for samples shown in figure 52

[Tr, trace; N, not detected. Leaders (--), not measured]

Sample				Gold	Silver	Lead	Zinc
No. T-	Type	Length (m)	Description	(g/t)		(percent)	
39	Chip---	0.8	Calcareous, oxidized breccia zone---	N	22	Tr	14.30
40	--do---	.3	-----do-----------------------------	N	84	0.12	21.70
41	--do---	.5	-----do-----------------------------	N	10	Tr	.34
42	Select-	--	Honeycombed calcite with 10 percent-sphalerite.	N	28	.91	20.10
43	Chip---	.8	Iron-oxide-stained, massive calcite-and fault gouge.	N	21	.88	9.25
44	--do---	1.2	-----do-----------------------------	N	42	1.21	10.90
45	Select-	--	Iron-oxide-stained and honeycombed--calcite and breccia.	N	22	.54	32.60
46	Chip---	1.2	Iron-oxide-stained, brecciated------calcite and country rock.	N	7	Tr	.32
47	--do---	1.5	Iron-oxide-stained, massive calcite-	N	N	Tr	Tr
51	--do---	.2	Iron-oxide-stained fault gouge------	N	3	Tr	Tr
52	--do---	.8	Sheared, black, carbonaceous--------argillite with quartz stringers.	N	7	.43	2.84
53	--do---	.6	Iron-oxide-stained quartz-----------	N	3	Tr	.15
54	--do---	.9	Highly sheared, carbonaceous fault--gouge.	N	7	Tr	Tr
235	Grab---	--	Limonite-stained, white, vitreous---quartz.	N	7	--	--
236	--do---	--	Limonite-stained, white, vitreous---quartz with minor galena.	0.3	48	1.63	N
237	--do---	--	Limonite-coated quartz-calcite------intergrowths.	N	Tr	Tr	5.93

Adit No. 3 is caved 70 ft (21 m) from the portal. The adit is timbered and lagged tight, and the shear zone is exposed only at the portal. The shear zone consists of 4 ft (1.3 m) of crushed country rock, calcite stringers, gouge, and hematite, and 5.0 ft (1.5 m) of massive calcite on the hanging-wall side. A sample across the breccia contained 0.2 oz silver per ton (6.9 g/t), a trace of lead, and 0.32 percent zinc. A sample from the calcite contained a trace of lead and zinc.

One shallow caved pit is on the "calcite vein" 150 ft (46 m) northwest of adit No. 3. A select sample of limonite-stained, quartz-calcite vein material taken from the dump contained a trace of silver and lead, and 5.93 percent zinc.

Adit No. 1 was driven southeasterly to intersect a quartz vein exposed by adit No. 2 (fig. 52). The adit, 270 ft (82 m) long, intersects and follows an andesite dike for 85 ft (26 m). Beyond the dike, the adit follows a shear zone with stringers and lenses of quartz which locally contain 1-in. (2.5-cm) blebs of galena. The shear zone strikes N. 40° W. and dips 70° SW., and is 2.5–3 ft (0.8–0.9 m) thick near the face. Three samples taken from the shear zone contained 0.1–0.2 oz silver per ton (3.5–7 g/t), a trace to 0.43 percent lead, and a trace to 2.84 percent zinc.

Adit No. 2 (fig. 52) is caved. Previous reports indicate that a 50-ft (15-m)-long crosscut was driven to explore quartz stringers exposed on the surface. The zone averages 5 ft (1.5 m) in thickness and contains ½–2-in. (1.3–5.1-cm)-thick quartz stringers that follow argillite bedding. Small blebs of galena were observed in some quartz stringers. A grab sample taken of quartz stringer material from the dump contained 0.01 oz gold per ton (0.34 g/t), 1.4 oz silver per ton (48 g/t), 1.63 percent lead, and no zinc.

The "calcite vein," which is intermittently exposed along strike for about 1,000 ft (300 m) and vertically for 400 ft (120 m), averages 3 ft (1 m) in thickness. It contains an inferred resource of 100,000 tons (91,000 t). Samples from workings along the "calcite vein" for 400 ft (120 m) southeast of adit No. 1 indicate that ore-grade material is present. Because of the erratic and podlike distribution of zinc carbonate ore, an average grade cannot be calculated. A similar zinc deposit, the Lake Creek group mine on the northwest side of Lake Creek (pl. 4, No. 102), appears to be an extension of the "calcite vein." Overburden covers the area between the two surface exposures. This appears to be a favorable area to explore for additional zinc deposits. The quartz vein has low metallic content and is not considered a potential mineral resource.

DAISY (MATTIE) MINE

The Daisy mine is east of Trail Creek about 1 mi (1.6 km) north of the junction of Corral and Trail Creeks (pl. 4, No. 93). The property is 800 ft (240 m) above the valley floor at about 7,100 ft (2,200 m) elevation.

No record of production from the mine exists, but past operators of the mine stated that two carloads of ore containing high-grade zinc and a small amount of lead and cadmium were removed from the stope in the main workings. Samples taken during the present study contained only trace amounts of cadmium.

Country rock is carbonaceous argillite with interbeds of limestone and quartzite. The sediments generally strike east and northeast and dip 35°–55° S. and SE. In many places, the sediments are highly contorted and crumpled.

Workings consist of eight adits (four caved), two inclined shafts, and two pits, which expose silver-lead-zinc-bearing quartz veins and lenses (fig. 53). Underground workings total more that 1,000 ft (300 m).

Adit No. 1 is 190 ft (58 m) long. It follows a 0.2–0.7-ft (0.06–0.21-m)-thick quartz vein striking N. 80° E. and dipping 30°–35° SE. The vein is exposed for 90 ft (27 m) and is terminated by a fault. A 12-ft (4-m)-long drift and 21-ft (6-m)-long inclined raise on the fault zone did not intersect the vein beyond the fault. The remaining 100 ft (30 m) of adit is devoid of mineralized rock.

Three samples were taken from the vein and one across the 4-ft (1.2-m)-wide fault zone. One sample taken from the quartz vein contained a trace of gold, 3.9 oz silver per ton (134 g/t), 11.6 percent lead, and 0.3 percent zinc. The other samples from the quartz vein and the fault zone contained only trace amounts of gold, silver, lead, and zinc.

Adit Nos. 2 and 3 are caved (fig. 53). Apparently they were driven on a 2-ft (0.6-m)-thick white quartz vein exposed at the surface. The vein strikes due east and dips 50° S. It could not be traced beyond the 10-ft (3-m)-long outcrop near the adits. A sample across the vein contained trace amounts of gold, silver, lead, and zinc.

Much of the following information has been taken from unpublished DMEA files because most of the main workings are inaccessible. The main workings, adit Nos. 4 and 5 and inclined shaft No. 9, consist of three levels. The upper and intermediate levels are accessible from the surface by portals and are connected by a small stope. The third, and lowest level, is accessible from the surface by an inclined shaft and is connected to the stope by a short raise. The three levels comprise about 700 ft (210 m) of workings. The upper and intermediate levels were accessible to the stope at the time of examination. The inclined shaft leading to the third level was caved 20 ft (6 m) below the collar. Other workings in the immediate vicinity of the main workings are two short adits (one caved) and an inclined shaft, caved 10 ft (3 m) from the collar (fig. 53, workings 6, 7, and 8).

The main workings expose an irregular northeast-striking, southeast-dipping fault zone 80 ft (25 m) along strike and 100 ft (30 m) downdip. Coalescing and dispersing shear planes that are erratic in attitude characterize the zone. It passes in places into areas of crumpled and contorted bedding. Due to the erratic and irregular character of shearing, ore occurs in isolated quartz lenses, stringers, and pods.

These quartz bodies are generally of short lateral and vertical extent. Most quartz is barren, but at a few places it contains disseminations and streaks of sphalerite and galena. The DMEA reports describe one small, high-grade sphalerite pod within a quartz lens exposed at the top of a raise from the lowest level. A 1.1-ft (0.34-m)-long DMEA sample taken across the widest part of the lens contained a trace amount of gold, 0.1 oz silver per ton (3.4 g/t), 42.4 percent zinc, and 0.67 percent cadmium. This pod could contain 20 tons (18 t) of ore. The upper continuation of the pod contains only barren quartz.

A small pod of ore between the intermediate and upper levels has been mined out. The stope is approximately 4 by 10 by 30 ft (1 by 3 by 9 m) and reportedly contained two carloads of ore. Continuation of the structure above the stope shows a quartz vein as much as 1 ft (0.3 m) thick with minor specks of galena and sphalerite. Two samples (G-6 and 8) of the quartz vein contained 0.1 oz silver per ton (3.4 g/t) and trace amounts of gold, lead, and zinc.

The inclined shaft, leading to the lowest level, and caved 20 ft (6 m) below the collar, is along a vuggy, iron-oxide-stained quartz vein. It averages 1 ft (0.3 m) in thickness and pinches out at 15 ft (5 m). Two samples of the vein averaged 11 oz silver per ton (377 g/t), 9.6 percent lead, and 34 percent zinc. The vein may contain about 45 tons (41 t) of high-grade ore.

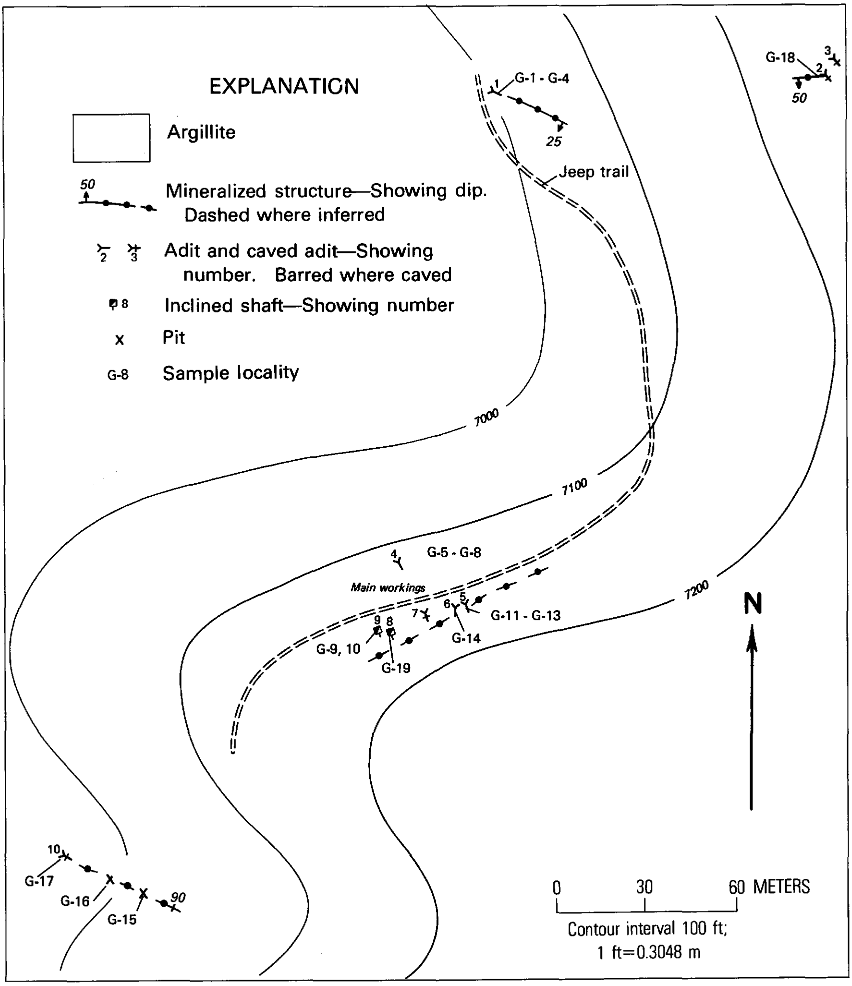

FIGURE 53.—Daisy (Mattie) mine.

Elsewhere in the main workings small quartz stringers and lenses as much as 1 ft (0.3 m) thick contain lead and zinc, but not in minable quantities.

About 400 ft (120 m) southwest of the main workings, a caved adit and two pits expose a 1–2.5-ft (0.30–0.76-m)-thick quartz vein. It strikes N. 75° W., has a vertical dip, and can be traced intermittently for over 100 ft (30 m). Three samples taken from the quartz vein contained 0.1 oz silver per ton (3.4 g/t) and trace amounts of gold, lead, and zinc.

Additional small pods of high silver-lead-zinc–bearing material are likely in the fault zone exposed by the main workings. However, exploration and development costs would probably exceed the metal value.

Data for samples shown in figure 53

[All samples chip. Tr, trace; N, not detected. Leaders (--), not analyzed]

Sample			Gold	Silver	Copper	Lead	Zinc
No. G-	Length (m)	Description	(g/t)		(percent)		
1	0.08	Quartz with galena---	Tr	134	--	11.60	0.30
2	.2	Iron-oxide-stained--- quartz.	N	N	--	Tr	Tr
3	1.2	Iron-oxide-stained--- argillite.	Tr	3	--	Tr	Tr
4	.03	Clayey fault gouge---	Tr	3	--	Tr	Tr
5	.6	Clayey fault gouge--- and quartz.	N	N	--	Tr	Tr
6	.5	Iron-oxide-stained--- quartz.	Tr	3	--	Tr	Tr
7	.1	Quartz with galena--- and sphalerite.	Tr	333	--	9.87	7.81
8	.7	Iron-oxide-stained--- shear zone.	Tr	3	--	Tr	Tr
9	.3	Quartz with galena--- and sphalerite.	Tr	45	--	15.10	28.50
10	.3	-----do--------------	Tr	720	0.71	4.15	39.60
11	.3	Quartz--------------	N	N	--	Tr	Tr
12	.3	-----do--------------	Tr	3	--	Tr	.58
13	.3	-----do--------------	Tr	38	--	Tr	Tr
14	.2	-----do--------------	Tr	17	--	1.26	.98
15	.3	-----do--------------	Tr	3	--	Tr	Tr
16	.3	Vuggy quartz---------	Tr	.3	--	Tr	Tr
17	.5	Quartz--------------	Tr	3	--	Tr	Tr
18	.6	-----do--------------	.7	3	--	Tr	Tr
19	.5	Iron-oxide-stained--- and sheared argillite.	.7	3	--	Tr	Tr

BROADWAY MINE

The Broadway mine southeast of Hyndman Peak is 3¼ mi (5 km) up Hyndman Creek (pl. 4, No. 88). Two groups of workings expose separate structures at 7,700 ft (2,300 m) elevation. No record of production from the property exists.

The lower workings trend N. 85° E., are spread over approximately 120 ft (36 m), and consist of three sloughed pits and a caved adit. The dump of the caved adit had the only mineralized rock, consisting of quartz and siderite with sparse blebs of sphalerite. A sample contained trace amounts of copper and lead, and 0.20 percent zinc.

The upper workings 112 ft (34 m) higher, and 170 ft (52 m) south of the lower workings, consist of a caved adit and an inclined shaft. The shaft is more than 35 ft (11 m) deep. A 7.5-ft (2.3-m)-thick white quartz vein, which strikes N. 35° W. and dips 60° SW., was exposed in the

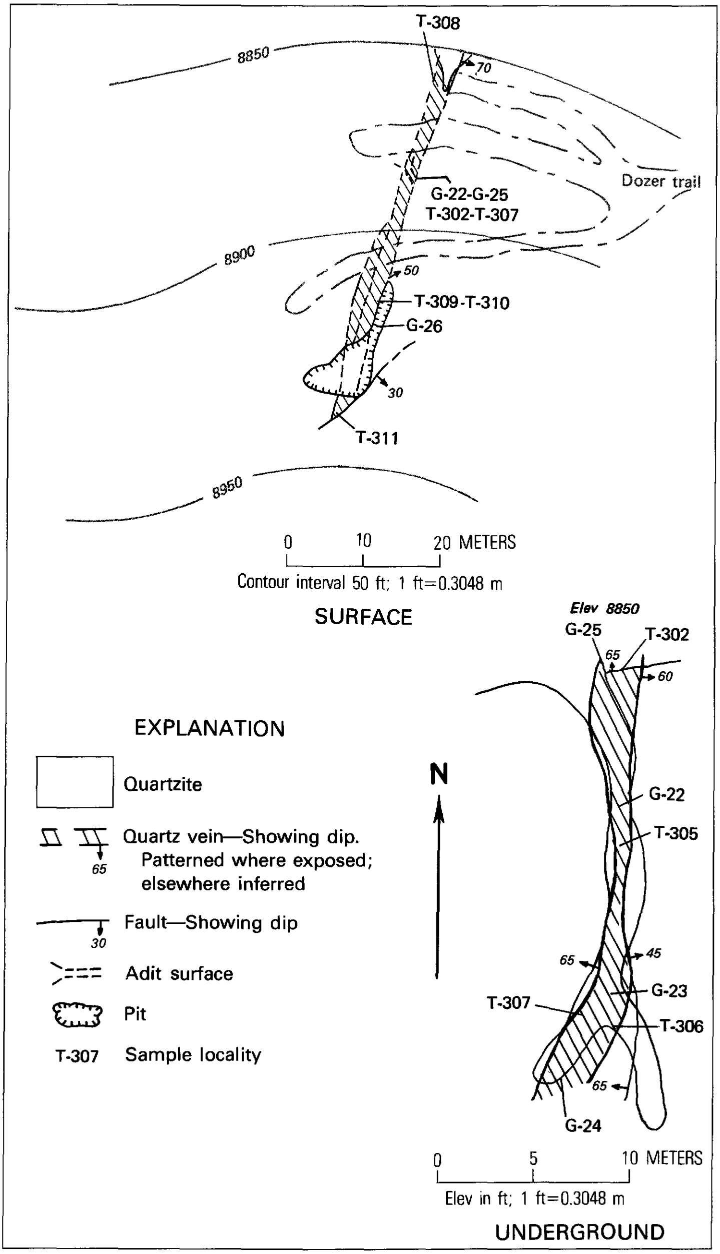

FIGURE 54.—Gamble group prospect.

workings. The central zone of the vein contains erratically distributed pods of galena, which are as much as 0.5 ft (0.15 m) across and 1.5 ft (0.46 m) long. Five to ten percent of the vein is galena. It can be traced

Data for samples shown in figure 54

[All samples chip. Tr, trace; N, not detected. Leaders (--), not analyzed]

Sample			Gold	Silver	Copper	Lead	Zinc
No.	Length (m)	Description	(g/t)		(percent)		
G-22	2.4	Iron-oxide-stained---milky-white quartz.	N	N	Tr	1.76	Tr
G-23	3.0	-----do--------------	Tr	51	Tr	2.16	Tr
G-24	1.5	-----do--------------	Tr	31	Tr	4.15	Tr
G-25	2.1	-----do--------------	0.7	41	Tr	Tr	Tr
G-26	4.6	-----do--------------	Tr	17	Tr	.43	Tr
T-302	2.1	-----do--------------	N	N	Tr	Tr	Tr
T-305	1.2	Iron-oxide-stained---milky-white quartz with malachite and galena.	N	10	Tr	.32	Tr
T-306	1.5	-----do--------------	N	38	Tr	2:19	Tr
T-307	1.2	-----do--------------	N	10	Tr	1.13	Tr
T-308	2.0	-----do--------------	N	27	Tr	1.30	Tr
T-309	2.6	Iron-oxide-stained---milky-white quartz.	Tr	3	Tr	Tr	Tr
T-310	2.0	-----do--------------	N	3	Tr	Tr	Tr
T-311	2.3	Iron-oxide-stained---milky-white quartz with less than 1 percent galena.	N	7	--	.27	Tr

intermittently on the surface for about 100 ft (30 m). A 7.5-ft (2.3-m)-long sample taken across the vein, at the collar of the inclined shaft, contained a trace of gold, 3.4 oz silver per ton (117 g/t), 6.41 percent lead, and 14.0 percent zinc. Exploration might disclose a minable body of ore.

GAMBLE GROUP PROSPECT

The Gamble group prospect is at the end of the Hyndman Creek road (pl. 4, No. 91). A 75-ft (23-m)-long adit and a bulldozer trench expose a 2–15-ft (0.6–5-m)-thick quartz vein in quartzite country rock (fig. 54). The vein strikes N. 10°–20° E., dips 50° to 70° E., and is intermittently exposed for 175 ft (53 m) along strike and for 85 ft (26 m) downdip. It is massive white quartz containing scattered blebs of galena and sparsely disseminated pyrite, chalcopyrite, and bornite. Some fractures have iron-oxide coats. Less than 1 percent of the vein material is sulfides. Samples averaged 0.6 oz silver per ton (21 g/t), 1 percent lead, and only a trace of gold, copper, zinc, and other metals.

More than 11,000 tons (10,000 t) of indicated submarginal resource is estimated to occur on the property.

AUBURN GROUP PROSPECT

The prospect is on the ridge between Lake and Trail Creeks at about 9,500 ft (2,900 m) elevation (pl. 4, No. 105). No record of production from the property exists.

Three adits, one shaft, and several pits are on a northwest-trending shear zone in gray quartzite. Only one adit and one pit are open. The mineralized zone can be followed by old workings from the crest of the ridge northwestward for more than 300 ft (90 m) (fig. 55), but no mineralized rocks are exposed. The dumps contain siliceous, limonitic, vuggy vein material with some remaining sulfides. Four select dump samples contained an average of 14.9 oz silver per ton (511 g/t), 8.88 percent lead, and 32.8 percent zinc. The lead and zinc values are probably in carbonates.

A pit on the ridge crest and an adit 100 ft (30 m) southeast expose the shear zone. It is 4 ft (1 m) thick on the ridge crest and consists of clayey, calcareous, limonitic quartzite breccia. A sample contained 0.6 oz silver per ton (21 g/t), 0.62 percent lead, and 2.28 percent zinc.

The zone exposed in the adit ranges from 2 to 3.5 ft (0.6 to 1 m) in thickness and consists of clayey limonite-stained quartzite breccia. It strikes N. 40° W. and dips 65° SW. Two samples taken across the zone contained as much as 0.1 oz silver per ton (3.4 g/t), and trace amounts of lead and zinc.

Samples indicate that the northwestern 230 ft (70 m) of the zone contain high silver-lead-zinc values. Because of the lack of exposed mineralized rock in place, tonnage cannot be estimated.

LOST DUMP PROSPECT

The Lost Dump prospect is south of the West Fork Trail Creek at 8,200 ft (2,500 m) elevation (pl. 4, No. 117). No record of production from the property exists.

Mineralized rock occurs along a contact between a medium-grained quartzite and underlying argillite. The contact strikes easterly and dips 45° northerly. Dip parallels the hillside slope (fig. 56).

The mineralized zone has been prospected to a greater extent downdip than along strike. The lowest working, a caved adit, may have drifted along the mineralized zone and is probably connected to a short adit and inclined winze 22 ft (7 m) higher. Dump size indicates that the adit was probably 200–300 ft (60–90 m) long. The dump consists of predominantly black argillite with stringers of quartz and calcite. Some pieces of massive pyrite are as much as 1 ft (0.3 m) thick with streaks and blebs of galena and sphalerite. A select sample of this material contained 0.05 oz gold per ton (1.7 g/t), 0.78 percent lead, 6.53 percent zinc, and trace amounts of silver, copper, and cadmium.

The mineralized contact is exposed in a 35-ft (11-m)-long adit 22 ft

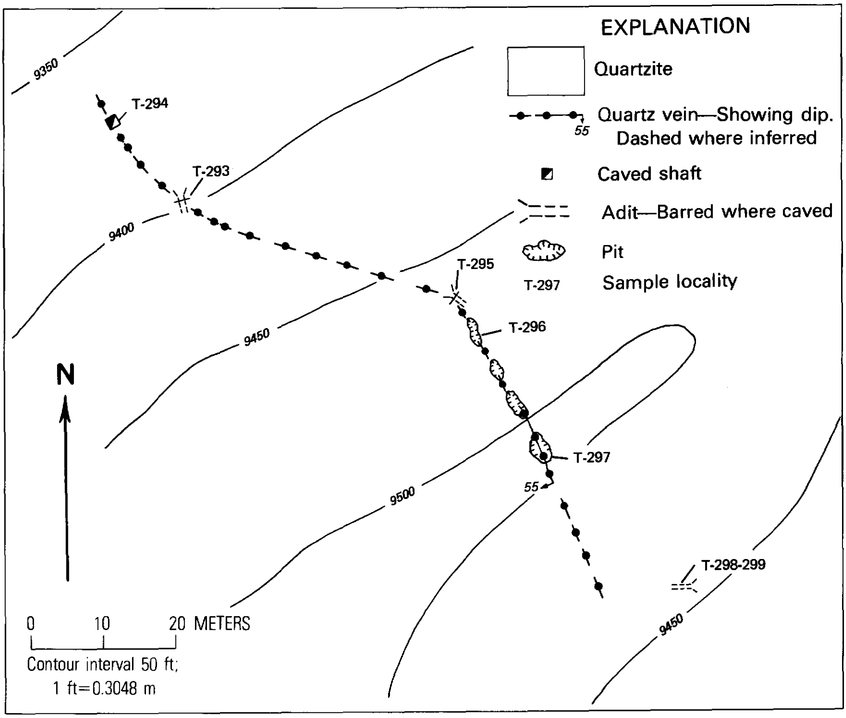

FIGURE 55.—Auburn group prospect.

Data for samples shown in figure 55

[Tr, trace; N, not detected]

Sample				Gold	Silver	Lead	Zinc
No. T-	Type	Length (m)[1]	Description	(g/t)		(percent)	
293	Grab---	--	Siliceous, limonitic, vuggy--vein material; some remaining galena.	Tr	339	7.99	43.4
294	--do---	--	-----do---------------------	0.3	1,378	16.6	21.80
295	--do---	--	-----do---------------------	N	257	5.96	34.6
296	--do---	--	-----do---------------------	N	72	.99	31.7
297	Chip---	1.2	Clayey, calcareous, limonitic breccia zone; no visible sulfide.	N	21	.62	2.28
298	--do---	.7	-----do---------------------	N	3	Tr	Tr
299	--do---	.9	-----do---------------------	N	N	Tr	.17

[1]Leaders (--), unknown.

(7 m) above the caved adit. The contact was intersected at 25 ft (8 m) and followed downward. The mineralized contact zone, from the hanging wall down, is 0.2–0.3 ft (0.06–0.09 m) of gouge, 1–1.5 ft (0.30–0.46 m) of massive pyrite with streaks and blebs of galena and sphalerite, and 0.5–0.7 ft (0.15–0.21 m) of brecciated black argillite containing quartz,

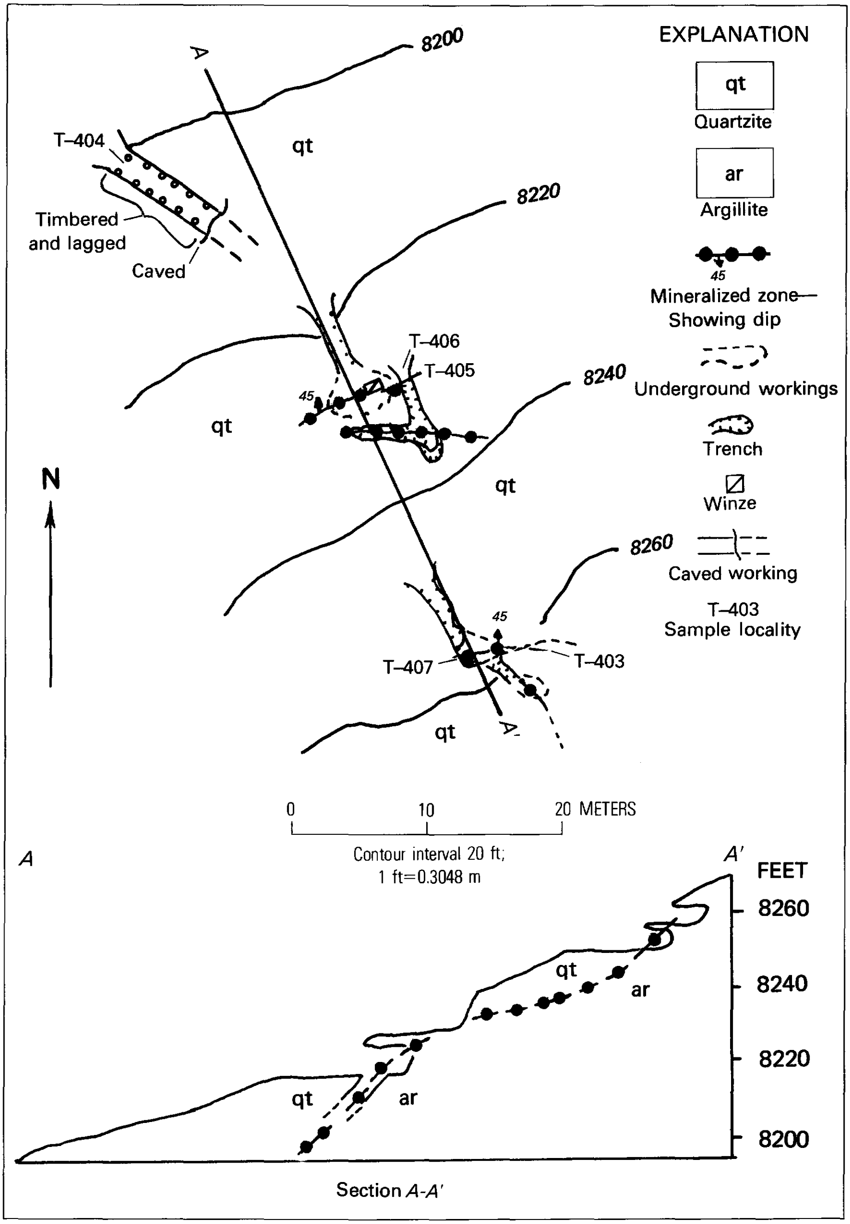

FIGURE 56.—Lost Dump prospect.

pyrite, galena, and sphalerite. A sample across the zone near the inclined winze contained 0.31 percent lead and 2.95 percent zinc.

A sloughed trench 17 ft (5 m) above the caved adit contains pieces of limonitic brecciated quartz containing as much as 30 percent galena

Data for samples shown in figure 56

[Tr, trace; N, not detected]

Sample				Gold	Silver	Lead	Zinc
No. T-	Type	Length (m)[1]	Description	(g/t)		(percent)	
403	Chip---	0.5	Vuggy, limonitic quartz with- streaks and blebs of galena and sphalerite.	N	7	1.00	0.20
404	Grab---	--	Massive pyrite with dissemi-- nations of galena and sphalerite.	1.7	Tr	.78	6.53
405	Chip---	.8	-----do-----------------------	N	N	.31	2.95
406	Grab---	--	Black argillite breccia and quartz with masses and pods of galena and sphalerite.	N	7	8.02	9.75
407	Chip---	.5	-----do-----------------------	N	14	2.00	Tr

[1]Leaders (--), unknown.

and sphalerite. A select sample of this mineralized material contained 0.2 oz silver per ton (7 g/t), 8.02 percent lead, and 9.75 percent zinc.

Sixteen feet (5 m) above the trench are two small pits or dog holes. The mineralized contact zone exposed by these pits ranges from 1.5 to 2.0 ft (0.5 to 0.6 m) in thickness and consists of limonitic, vuggy, brecciated quartz with streaks and blebs of galena, sphalerite, and minor pyrite. Two samples taken across the mineralized zone contained 0.3 oz silver per ton (10 g/t), 1.54 percent lead, and 0.1 percent zinc.

The mineralized zone averages 2 ft (0.6 m) in thickness and is exposed downdip for about 70 ft (22 m). By inferring a strike length of 140 ft (43 m) and inferring an additional 35 ft (11 m) of depth, there may be 2,500 tons (2,300 t) of mineralized rock, containing as much as 0.05 oz gold per ton (1.71 g/t), 0.4 oz silver per ton (14 g/t), 8.02 percent lead, and 9.75 percent zinc.

MISCELLANEOUS PROPERTIES

Several district properties with little or no economic potential, or which were insufficiently exposed to permit evaluation, were examined. These properties are listed in table 21.

LITTLE WOOD RIVER DISTRICT

The Little Wood River district, which includes the southern part of the study area (fig. 34), is accessible by approximately 23 mi (37.0 km) of road from Carey, Idaho. Jeep trails extend to the headwaters of Little Copper Creek and up Muldoon Creek.

In the study area mineral deposits are found chiefly in Paleozoic sedimentary rocks that have been intruded by a Tertiary quartz monzonite stock. The stock is exposed in Garfield Canyon and near the head

TABLE 21.—*Miscellaneous properties, Warm Springs district*

Map No.	Property name	Summary	Number and type of workings	Sample data
78	Prospect-----	Absence of mineralized rock on the dumps.- Rocks on the dumps are black crinkly argillite. One dump contains some rhyolite and a second dump contained sparse, small pieces of pyritized quartz.	Five caved----- adits probably range from 15 to 30 m long.	Four samples of dump material; trace gold, as much as 17 grams silver per metric ton, and a trace lead. One contained 2.84 percent copper.
79	Queen-------- Victoria-White Cloud.	Tactite contact zones in dolomitic marble- near granodiorite. The contact zone is very irregular and a number of sedimentary inclusions lie close to the granodiorite contact. The tactite zones are limonite stained and epidote rich. In places the tactite contains pods of galena and sphalerite. These pods are discontinuous and range from 0.67 to 0.98 m thick. Some of the rock is high grade, but pods are small and sparse.	Two groups ---- of workings, 1,500 m apart. Lower workings consist of one 44-m-long adit, two shafts and five pits. Upper workings consist of three shallow trenches, prospect pit, and short crosscut adit.	Seven chip and four select grab samples; nil to 1.4 grams gold per metric ton, nil to 219 grams silver per metric ton, trace to 4.78 percent lead, and trace to 31.5 percent zinc.
81	Silver------- Knight.	Milky-white quartz vein in carbonaceous--- argillite and quartzite. The vein strikes N. 15° W., dips 75° NE., and is 2-8 m thick. The vein is exposed for 38 m along strike and 24 m downdip.	One caved adit-- probably 15 m long, and two shallow trenches.	Two samples; trace amounts of silver, lead, and zinc.
82	Prospect-----	Two separate structures: a quartz-calcite lens in black carbonaceous argillite and a 0.9-m-thick fault zone. The lens outcrop trends north for 29 m and is 5 m thick and 12 m wide. The 0.9-m-thick clayey fault zone strikes N. 5° W. and dips 60° W.	Two adits,---- one caved: caved adit estimated to be 120-150 m long. Open adit is 55 m long.	Nine samples; trace amounts of silver, copper, lead, and zinc.

83	Prospect-----	A 1.1-m-thick quartz-calcite vein in------ quartzite country rock. Vein trends N. 25° E. and is poorly exposed for 15 m.	One caved------ adit.	Two samples across the vein; 3 grams silver per metric ton and trace amounts of gold, copper, and lead.
84	Leilani------	A quartz-siliceous country rock lens in--- argillite near a northwest-trending argillite-quartzite contact. The lens parallels the contact. The exposed part of the lens measured 12.2 m long by 7.9 m by 4.6 m thick. Pyrite, galena, and sphalerite occur as erratic and sparsely distributed pods and as fracture fillings.	One 24-m-long-- adit and one shallow trench.	Three samples across the lens; as much as 45 grams silver per metric ton, 1.49 percent lead, and 0.35 percent zinc. The samples averaged 21 grams silver per metric ton, 0.58 percent lead, and 0.11 percent zinc.
85	Blue Bell----	Country rock is carbonaceous argillite---- and quartzite. Upper workings follow a 0.6-0.9-m-thick quartz vein for 14 m, which has been offset by a 0.9-m-wide fault zone. The vein strikes N. 50° E. and dips 45° to 55° SE. The fault which cuts the vein strikes N. 65° E. and dips 45° SE. The lower adit crosscuts and drifts along the fault for 30 m.	Two adits,----- upper adit contains 27 m of workings, the lower adit 67 m of workings.	Twelve samples; as much as 24 grams silver per metric ton.
86	Prospect-----	A north-trending zone of quartz veinlets,- in gray quartzite. The zone is as much as 2 m wide and can be traced for over 120 m. The veinlets are 3-8 cm thick and dip steeply both east and west. Galena-rich pods and blebs occur in some of the quartz veinlets but sample results indicate that the overall grade is too low for economic consideration.	Four caved----- adits and five pits.	Four samples; three select samples from quartz veinlets; average 339 grams silver per metric ton, 13.56 percent lead and trace amounts of copper and zinc. One sample across the 2.4-m-wide zone; 65 grams silver per metric ton and 2.57 percent lead.
87	Prospect-----	Workings are spaced along a N. 45° W.----- trend for 230 m. Dumps indicate that workings are on a milky-white quartz vein in a quartzite country rock. Pieces of quartz are as much as 0.23 m across. Some pieces contain disseminated pyrite and galena. No mineralized rock is exposed in place.	Five caved----- adits probably range from 30 to 120 m long.	Five select dump samples; up to 0.3 gram gold per metric ton, 243 grams silver per metric ton, 13.6 percent lead, and 2.61 percent zinc.

TABLE 21.—*Miscellaneous properties, Warm Springs district*—Continued

Map No.	Property name	Summary	Number and type of workings	Sample data
89	Prospect-----	The open adit follows a mineralized bedding-plane shear zone in gray argillite for 8 m. At 5 m from the portal, the zone was followed downdip for 9 m. The shear zone strikes N. 75° E. and dips 35° SE. Two small siliceous pods with minor galena are exposed by the adit.	Two adits,----- one caved.	Two samples across pods; trace gold, 3 and 10 grams silver per metric ton, and 0.22 and 0.39 percent lead.
90	Candy-------- Mountain.	A narrow quartz vein and fault zone in---- dark-gray to black argillite. The vein strikes N. 25° to 55° E., dips 30° to 40° SE., and ranges from 0.06 to 0.18 m thick. Even though ore-grade material is exposed by the workings, the deposit is too small for economic consideration.	Three adits,--- a 41-m-long adit, a 16-m-long adit, and one caved.	Ten samples; as much as a trace gold and 216 grams silver per metric ton, 16.9 percent lead, and 5.95 percent zinc. The samples averaged a trace gold, 46 grams silver per metric ton, 3.6 percent lead, and 1.54 percent zinc.
92	Outcrop------	Pyrite-bearing quartz vein in a gneissic-- quartzite. The vein is 1.5 m thick, strikes N. 30° E. and can be traced for 150 m.	None-----------	One sample; trace amounts of metal values.
94	White Cloud--	Dump material is predominantly black------ carbonaceous argillite with some milky-white, vuggy, limonite-stained quartz. Apparently, workings were on a quartz vein. Quartz float, blocks as much as 1.2 by 3 by 3 m, is in the vicinity of the workings. No quartz was observed in place.	Two caved------ adits 30 m apart at the same elevation. Adits trend N. 70° E.	Two grab samples of quartz; as much as 10 grams silver per metric ton and trace amounts of gold, lead, and zinc.
96	Prospect-----	A location notice on a talus slope.------- The talus slope is limonite-stained gray argillite and some white glassy quartz and calcite.	None-----------	One select sample; trace amounts of copper and lead.

97	Outcrop------	A 7.6- by 15-m outcrop of gray, massive--- argillite intruded by numerous northwest-trending quartz veinlets. The white, glassy quartz stringers range from 5 to 13 cm thick.	None-----------	One composite sample from quartz stringers; trace amounts of copper and lead.
98	Prospect-----	A 0.1-m-thick, clayey, mineralized-------- shear zone in bedded gray argillite. The shear zone strikes N. 20° E. and dips 30° SE. Small pods of galena occur in the country rock to a depth of 0.15-0.3 m on the footwall side of the shear zone.	Two adits,----- one 12 m long and one caved. One sloughed trench.	Two samples; one sample across the shear zone and mineralized footwall; trace silver, copper, and lead, and 0.61 percent zinc. One sample of select mineralized material from the dump of caved adit; trace gold, 17 grams silver per metric ton, a trace copper, 2.89 percent lead, and 2.34 percent zinc.
99	Prospect-----	A 0.37-m-thick quartz vein and several---- strong shear zones in light- to dark-gray argillite, and black carbonaceous argillite.	One adit,------ 85 m long.	Five samples; one sample from the quartz vein and four from clayey shear zones; nil to trace gold, nil to 7 grams silver per metric ton, trace amounts of copper and lead.
100	Prospect-----	A 0.3-m-thick, vuggy quartz vein with----- streaks of galena, along a chert-pebble conglomerate-limestone contact. The vein is exposed for 7.6 m. Contact trends N. 10° E. and dips 34° to 40° W.	Two sloughed--- pits.	One sample across vein; 72 grams silver per metric ton, 2.81 percent lead, and a trace gold.
103	Meg Nos.----- 1 and 2.	No mineralized rock in place observed----- but limonite stained, vuggy, white glassy quartz, calcite, and limonite-stained, gray argillite are on the dump.	One caved------ adit.	One select sample from dump; trace amounts of lead and zinc.
108	Silver------- Mountain Nos. 1 and 2.	A mineralized fault breccia zone in dark-- gray, bedded limestone. The zone strikes N. 15° to 25° W., dips 35°-40° SW., and is exposed for 76 m. The zone averages 0.9 m thick on the surface but narrows to 0.3 m near bottom of a 9-m-deep shaft.	Five shallow--- inclined shafts (one open), four pits, and one 14-m-long adit.	Four chip samples across the zone; 141 grams silver per metric ton and small amounts of copper, lead, and zinc.

TABLE 21.—*Miscellaneous properties, Warm Springs district*—Continued

Map No.	Property name	Summary	Number and type of workings	Sample data
109	Prospect-----	Three milky-white quartz veins intrude---- gray, fissile argillite. The quartz is limonite stained and in places vuggy. Veins range from 0.6 to 2 m thick. Two veins trend northwest and dip 30° SW. The third trends northeast and dips 35° SE. One 0.6-m-thick vein contains small pods and streaks of chalcopyrite. Due to surface cover and talus, the veins cannot be traced for more than 30 m.	One bulldozer-- cut and one small pit.	Three samples from veins; trace gold, as much as 10 grams silver per metric ton, 0.6 percent copper, and trace amounts of lead and zinc.
110	Prospect-----	Mineralized, northeast-trending contact--- zone between chert-pebble conglomerate and overlying limestone. Quartz stringers and lenses as much as 1.5 m thick are along contact and are traceable for 61 m. The dump of a sloughed pit in limestone, near the contact, contains pieces of gossan material with small seams of galena.	One sloughed--- pit.	Two samples; one select sample from dump, 0.3 gram gold and 17 grams silver per metric ton, 0.45 percent lead, and 8 percent zinc. One sample across the quartz lens; 0.3 gram gold per metric ton, and trace amounts of copper, lead, and zinc.
111	Strike------- Three.	Two mineralized zones in a chert-pebble--- conglomerate; a 0.6-m-thick clayey shear zone and a 0.3-m-thick fractured zone which contains several quartz stringers.	Two adits,----- 29 and 14 m long.	Three samples; two samples from the shear zone; 3 grams silver per metric ton, a trace lead, and as much as 2.73 percent zinc. One sample from the fractured zone; a trace gold, 10 grams silver per metric ton, 2.03 percent lead, and 0.24 percent zinc.
112	Outcrop------	Milky-white quartz vein in chert-pebble--- conglomerate. Vein strikes N. 20° to 25° W., dips 45° to 65° NE., and is intermittently exposed for 150 m. Vein ranges from 1.7 to 4.6 m thick and in places contains minor amounts of disseminated pyrite.	None-----------	Four samples across the vein; trace amounts of metal values.

113	Outcrop------	A 15-m-long quartz lens trending N.------- 15° W. that is as much as 0.3 m thick. Country rock is medium-gray argillite. Abundant quartz float along the Murdock Creek trail for more than 1.6 km, above and below the quartz lens.	None-----------	Two samples; one sample from the quartz lens and one of quartz float; trace amounts of gold, copper, and lead, and 10 grams silver per metric ton.
114	Prospect-----	An easterly trending sheared and frac- --- tured zone and a second intersecting northeasterly trending fractured zone in a fine-grained gray quartzite. The zones range from less than 0.15 to 0.6 m thick. Minor amounts of limonite and malachite stain fractured and sheared surfaces.	One adit,------ 17 m long.	Two samples; trace amounts of gold, silver, copper, and lead.
115	Wonder group-	A 1.5-1.8-m-thick heavily limonite-------- stained quartz-orthoclase pegmatite dike trends east in a black carbona- ceous argillite and is intermittently exposed for 21 m. A series of small white quartz veins crop out about 366 m southwest of the dike.	One small------ sloughed pit.	Two samples; one sample from the dike; trace gold, 7 grams silver per metric ton, and 0.1 percent copper. One sample from the quartz veins; trace amounts of gold and silver.
116	Prospect-----	Country rock is a fissile dark-gray------- argillite. White, glassy, limonite- stained quartz is on the dumps of the caved adit and sloughed pit. No quartz was observed in place.	One caved------ adit and one small sloughed pit.	Two select dump samples; 7 grams silver per metric ton, and trace amounts of copper, lead, and zinc.
118	Prospect-----	Northwest-trending zones of brecciated---- country rock and narrow shears. Brec- cia zones are healed with calcite and as much as 1.2 m wide. Shear zones are as much as 0.3 m thick. Country rock is interbedded argillite and quartzite with minor limestone.	Eight shallow-- pits and trenches.	Six samples; as much as 168 grams silver per metric ton and trace amounts of other metals.

TABLE 21.—*Miscellaneous properties, Warm Springs district*—Continued

Map No.	Property name	Summary	Number and type of workings	Sample data
119	Glacier------ group.	Two northeast-trending mineralized,------- breccia-filled shear zones in dark-gray siliceous argillite. The larger zone is 2.4 m thick and is intermittently exposed for 76 m. The smaller breccia filled zone is 0.3-0.8 m thick and is exposed for 30 m. Three meters northwest of the larger zone, two pits expose a fractured and altered siliceous rock which contains veinlets and blebs of pyrite, galena, and sphalerite. The rock may be a northwest-trending dike but exposures are too poor to determine thickness trend and relationship to the breccia-filled zone.	One 85-m-long-- adit, one 4.6-m-deep shaft, four pits.	Ten samples; samples taken from the larger breccia filled zone averaged 10 grams silver per metric ton, 0.59 percent lead, 0.08 percent zinc, and a trace copper. Samples taken from the smaller breccia filled zone averaged 17 grams silver per metric ton, 1.94 percent lead, 0.93 percent zinc, and trace amounts of gold and copper. A select sample taken of the fractured siliceous rock near the larger zone contained 3 grams silver per metric ton, 13.10 percent lead, and 11.40 percent zinc.
120	Big Pine----- group.	A poorly exposed structure trending N.---- 50° E. and dipping 50° to 55° NW. in a medium-gray quartzite. The structure parallels bedding and is mineralized across a width ranging from 6 to 8 m. The structure is limonite stained and contains pods of quartz with disseminated galena and pyrite. The extent of the structure is not known.	Two cuts-------	Two samples; trace gold, 137 and 213 grams silver per metric ton, 0.12 and 0.39 percent copper, 1.43 and 2.96 percent lead, and 0.30 and 2.09 percent zinc. A small amount of arsenic was also detected.
121	Prospect-----	Several clay-filled shears in a highly---- contorted, fissile, gray to black argillite. The shears strike N. 5° W. to N. 35° W. Some dip 30° to 60° SW. and others 45° to 75° NE. The shears range from 0.15 to 0.61 m thick and are filled with limonite-stained clayey fault gouge.	One 70-m-long-- adit with several side drifts, crosscuts and raises. The raises range from 4.6 to 15 m long.	Three samples from major shears; nil to a trace gold, nil to 7 grams silver per metric ton, trace amounts of copper and lead, and 0.13 to 0.55 percent zinc.

of Muldoon Creek. An anticline trends northwestward across the Pioneer Mountains divide into Copper Basin, and is obscured on the south, west, and east by volcanic rocks. Paleozoic rocks have been extensively fractured, providing many conduits for mineralizing fluids. The resulting deposits are generally small and because of numerous displacements they are difficult to trace. Sulfide-bearing deposits are more prevalent in limestone beds but also occur in argillaceous rocks. The deposits are usually irregular but well-defined shoots localized at the intersections of bedding-plane faults and high-angle cross faults. Galena, sphalerite, silver-bearing minerals, and chalcopyrite, in order of decreasing abundance, are the main minerals.

Anderson (Anderson and Wagner, 1946, p. 15) reported that "some of the ore is in grains and small irregular veinlets and masses scattered through the rock in and along the fractured rock of the fault zones, but some of it also occurs in compact seams in and along bedding plane fractures, here and there forming bodies of massive ore."

Quartz is the main gangue mineral with minor calcite. Although some barite has been mined in the district, the bulk of known occurrences are south of the study area.

The Little Wood River district's first claims in the area were located in 1880. Since then, approximately 657 claims have been recorded (table 22). A number of patented claims near the mouth of Blackspar Canyon, a tributary to Copper Creek, do not extend into the study area. Although mining activity has been sporadic, U.S. Bureau of Mines records indicated production in every decade since 1901 (table 23). During the past 10 years most mining activity has been limited to assessment work. The district has a recorded production value of $330,000, a small amount of which may have come from mines outside the study area. In decreasing order of importance, mineral commodities produced were lead, zinc, silver, copper, and gold. Activity was concentrated in a 2-mi (3.2-km)-wide belt trending northwest along the axis of the anticline from near the mouth of Muldoon Creek to about one-half mile (0.8 km) north of Little Copper Creek. Centers of interest developed in Little Copper Creek drainage, Garfield Canyon, Mutual Gulch, and on the east flank of Muldoon Ridge.

The Eagle Bird and associated claims, near the head of Garfield Canyon, warrant exploration. Sample results from numerous workings at Muldoon Creek to the head of Little Copper Creek indicated economic values of silver, lead, and zinc. The deposits, although individually small, might be mined and milled collectively under favorable economic conditions. The presence of silver, lead, and zinc in sufficient quantities encouraged several thousand feet (over a thousand meters) of exploration adits and shallow pits. Exact tonnage is difficult if not impossible to estimate, because the ore minerals generally occur in short thin seams and stringers. Because deposits are small and irregular, the

TABLE 22.—*Summary of recorded mining claims, 1880-1973, Little Wood River district*

Decade	No. of lode claims
1880-89	170
1890-99	25
1900-09	83
1910-19	74
1920-29	44
1930-39	19
1940-49	48
1950-59	45
1960-69	145
1970-	4
Total------	[1]657

[1]As of June 1, 1973.

cost of conventional underground exploration methods would be prohibitive. A more feasible method would involve modern surface geophysical instruments, concentrating on a possible extension of the larger and relatively higher grade structures.

EAGLE BIRD MINE

The Eagle Bird and John A. Logan patented mining claims are on the north side of Garfield Canyon at about 9,240 ft (2,800 m) elevation (pl. 4, No. 60).

The Eagle Bird claim was located in 1883, and the John A. Logan, formerly the Hard Times, was located in 1887. They were surveyed for patent in 1899. The present group of nine consists of seven unpatented claims surrounding two patented ones. All recorded production came from the Eagle Bird claim. U.S. Bureau of Mines records (table 23) indicate a total production of 4,436 tons (4,024 t), which had a recovered content of 0.005 oz gold per ton (0.17 g/t), 8.8 oz silver per ton (302 g/t), 0.2 percent copper, 7.6 percent lead, and 3.5 percent zinc. Value of production was approximately $130,000, with lead accounting for about 55 percent, followed by zinc, silver, copper, and gold. Activity on the property prior to 1943 was sporadic, and apparently the mine has been idle for the past 20 years. The property was examined by a DMEA field team, and parts of their unpublished data (1943) are used freely in the following description.

TABLE 23.—*Recorded metal production, 1929–1965, Little Wood River district*

Leaders (- - -), none recorded

Year	Mine	Ore (t)	Gold (g)	Silver (g)	Copper (kg)	Lead (kg)	Zinc (kg)
1929	United Mines---- (Garfield group)	9	---	2,177	14	564	---
1938	Eagle Bird------	136	---	6,064	95	1,164	---
1943	----do----------	27	---	19,562	45	5,865	---
1944	----do----------	182	31	60,832	294	17,357	5,653
1945	----do----------	336	62	116,158	366	33,697	2,989
1946	----do----------	188	---	44,473	171	11,478	8,402
1947	Eagle Bird------	379	62	106,362	503	27,445	15,610
	Unknown---------	47	---	7,464	93	1,686	1,709
1948	Eagle Bird------	647	93	218,571	938	46,580	19,701
1949	----do----------	513	62	168,002	606	41,024	19,958
1950	----do----------	791	93	224,697	1,769	52,527	34,338
1951	Eagle Bird------	288	62	62,791	2,525	16,705	14,026
	Rippeto---------	25	---	9,703	127	4,189	273
	Hecla-Carrier---	1	---	902	---	127	---
1952	Eagle Bird------	387	218	123,280	440	33,723	13,927
	Prince Pine-----	1	---	187	283	66	26
1953	Eagle Bird------	149	31	64,408	---	17,172	7,382
1955	Scorpion--------	1	---	1,306	272	---	---
1956	----do----------	2	31	529	318	---	---
1965	----do----------	2	31	1,710	660	-----	---
	Total-----------	4,111	776	1,239,117	9,539	311,369	143,994

The Eagle Bird and associated workings are in medium- to thick-bedded, dark-blue-gray to black, locally siliceous limestones. The beds strike northerly to northwesterly and dip from 30° to 60° NE. Fractures occur in two principal sets: (1) northwest-trending reverse bedding-plane faults, and (2) westerly to northwesterly high-angle reverse cross faults. A third, weakly developed set of fractures trends northeasterly. The bedding plane faults locally cross the bedding planes. The cross faults usually consist of zones of fractured rock and gouge that are locally bleached and limonite stained. All three sets of faults contain sulfides. Known ore deposits only occur along and near two distinct zones of bedding-plane faults, one exposed underground and one on the surface. Replacement-type ore deposition apparently was controlled by the intersection of these faults with high-angle cross faults. The shapes and sizes of the ore shoots are not completely known, but they appear to be roughly tabular. Where the fault zones narrow and steepen, sulfide content is reduced.

Sulfide minerals include galena, with subordinate sphalerite, arsenopyrite, complex antimonides, pyrite, and in places a little chalcopyrite. Sulfides occur both as scattered grains, and as nearly pure irregular to tabular-shaped lenses. Lenticular sulfide masses are as much as 3 ft (1 m) thick and may extend for tens of feet (several meters) along strike and downdip. The oxidized portions of the deposits contain cerussite, anglesite, iron oxides, and where arsenopyrite is present, scorodite. Gangue is principally limestone breccia, quartz, and sericite. Alteration of the rock in and near the deposits consists mainly of a softening and bleaching of the normally resistant limestone. In other areas of presumably more intense hydrothermal activity the rock was metamorphosed to a creamy-white marble.

The Eagle Bird workings consist of two adits, three shafts, and a pit (figs. 57, 58). The main adit includes about 780 ft (240 m) of crosscuts and drifts. Stopes extend from the main level to the surface. An inclined winze was sunk to a reported depth of 90 ft (27 m), but it is water filled to within 30 ft (9 m) of the collar. A second adit west of the main adit was driven into barren limestone.

Twenty-one chip samples were taken across the two distinct mineralized shear zones. They contained a weighted average of 9.4 oz silver per ton (322 g/t), 8.37 percent lead, and 1.62 percent zinc. Semiquantitative spectrographic analyses of selected samples indicate as much as 5 percent arsenic.

The two areas most favorable for exploration are the main workings and the discovery pit. Ore remains in the hanging wall, footwall, and backs of all the stopes, and is also exposed in the walls and sills of the drifts below the stopes. The shoots now open to inspection have not been fully developed. A second area considered favorable for exploration lies beneath the zone exposed in the discovery pit. This area may contain one or more shoots of the quality mined from the main adit. Because the shoots are irregularly shaped, computation of remaining ore is difficult, but it is estimated that 6,000 tons (5,000 t) of ore-grade material remain above the main level. An additional 10,000 tons (9,000 t) is inferred below. These estimates are based on an average thickness of 5 ft (1.5 m), a strike length of 200 ft (61 m), a depth of 100 ft (30 m) below the level, and an average back height of 60 ft (18 m). If the 5-ft (1.5-m)-thick zone exposed at the surface north of the major east-west fault continues to the main level, an additional 12,500 tons (11,300 t) of ore-grade material can be inferred.

SOLID MULDOON MINE

The Solid Muldoon and Stonewall Jackson patented lode claims are west of Muldoon Creek about 4 mi (6 km) northeast of the old Muldoon townsite (pl. 4, No. 46). Workings (fig. 59) are from 7,320 to 8,200 ft (2,200 to 2,500 m) elevation. Permission to examine the property was not granted. Therefore, most of the following narrative is taken from Anderson and Wagner (1946).

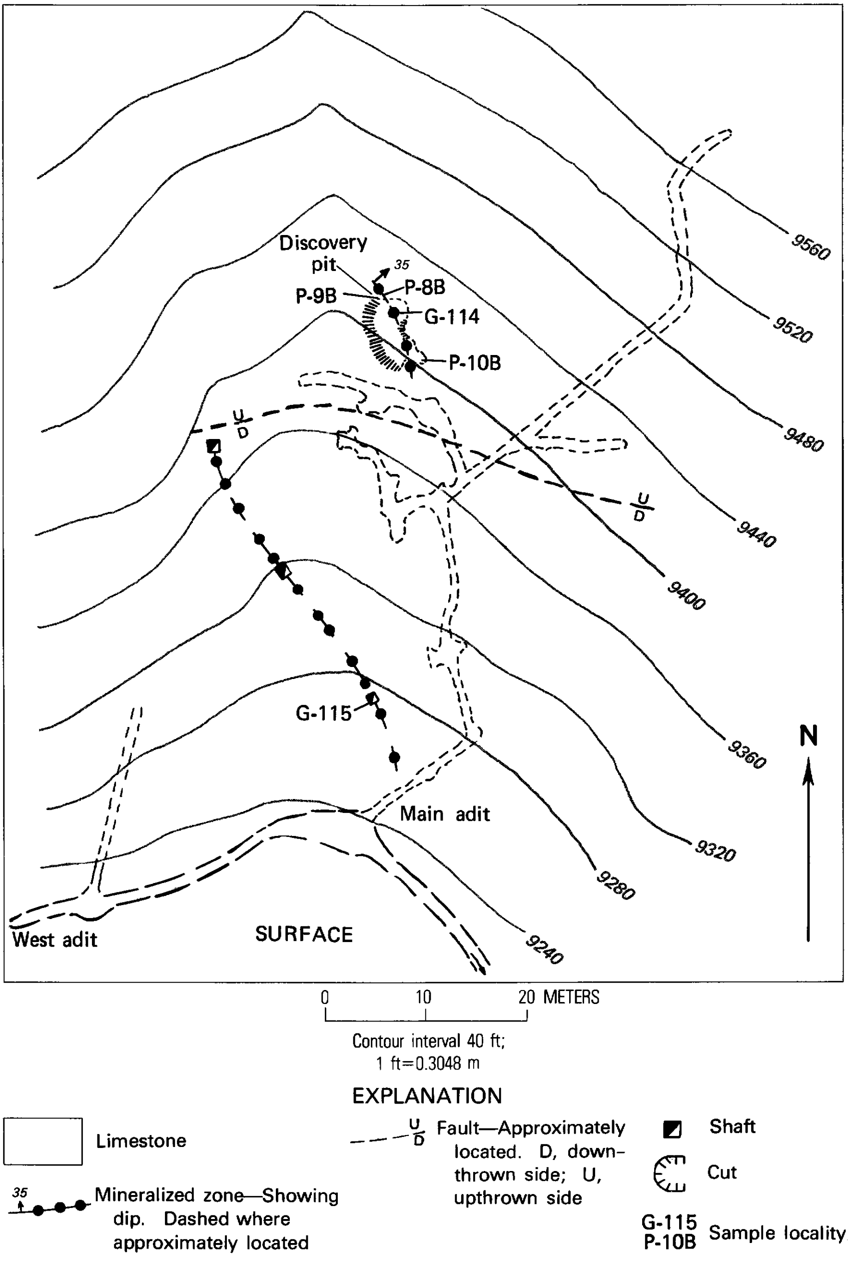

FIGURE 57.—Surface workings, Eagle Bird mine.

The claims were located in 1881 and surveyed for patent in 1886. Most activity occurred prior to 1911. Production totaled nearly $200,000 in lead-silver ore (Finch, 1917). U.S. Bureau of Mines records show

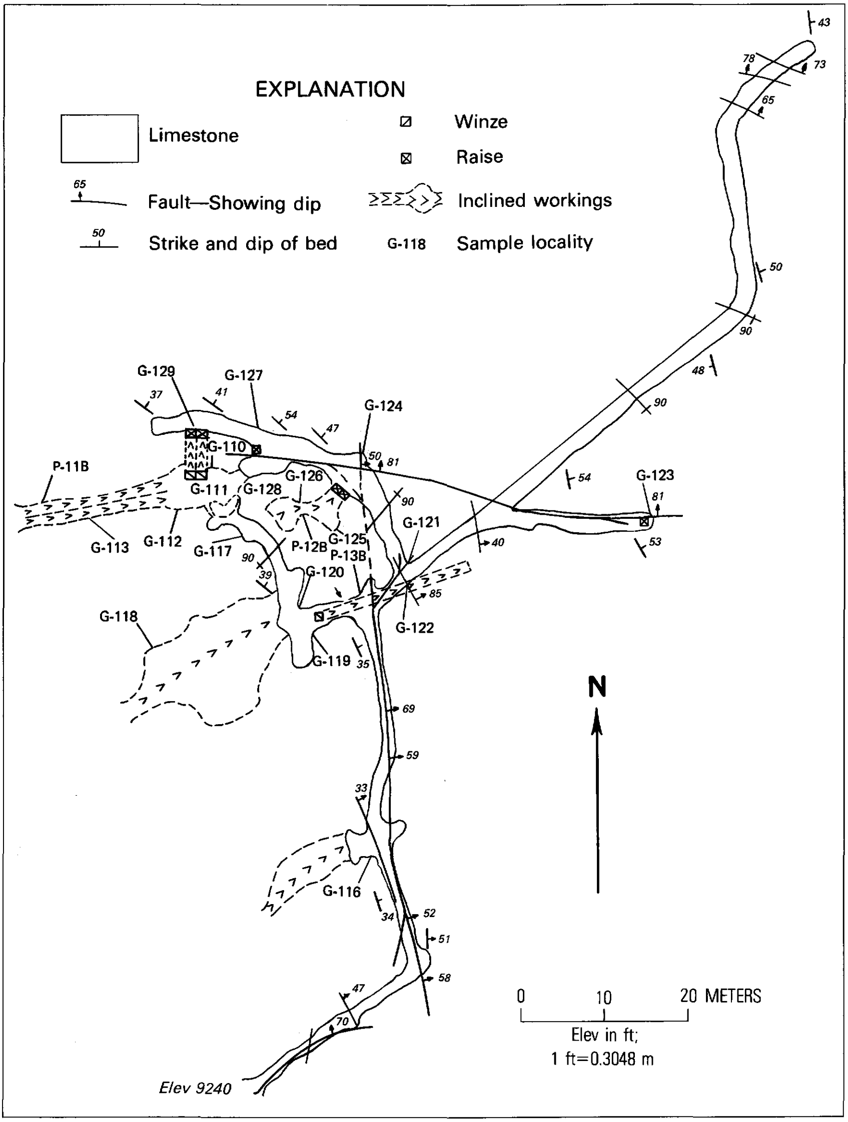

FIGURE 58.—Main adit, Eagle Bird mine.

some production from 1909 to 1948. Reprocessed tailings are believed to have accounted for most of this production. The property included a small mill, now dismantled.

Country rock is quartzite and slate, intruded by porphyry dikes. The sedimentary rocks strike northwesterly and dip moderately to the northeast. Replacement deposits occur along bedding planes generally adjacent to the dikes. The principal metallic minerals are argentiferous

Data for samples shown in figures 57 and 58

[Tr, trace; N, not detected. Leaders (--), not analyzed]

Sample				Gold	Silver	Lead	Zinc
No.	Type	Length (m)	Description	(g/t)		(percent)	
Surface							
EWP -8B	Chip---	0.5	Across ore zone---------	--	521	18.6	1.6
EWP- 9B	--do---	1.2	-----do-----------------	--	453	17.2	.7
EWP-10B	--do---	1.0	-----do-----------------	--	562	15.5	1.8
BPG-114	--do---	2.1	-----do-----------------	Tr	339	15.2	.71
BPG-115	--do---	1.5	-----do-----------------	Tr	531	12.7	.37
Underground							
EWP-11B	Chip---	1.3	Across ore zone---------	--	950	14.7	0.5
EWP-12B	--do---	.6	-----do-----------------	--	487	11.7	12.6
EWP-13B	--do---	1.0	-----do-----------------	--	45	1.4	N
BPG-110	--do---	.9	-----do-----------------	Tr	333	6.89	4.38
BPG-111	--do---	1.5	-----do-----------------	Tr	343	7.64	5.58
BPG-112	--do---	2.1	-----do-----------------	Tr	405	6.14	1.98
BPG-113	--do---	1.8	-----do-----------------	Tr	391	10.1	1.07
BPG-116	--do---	1.6	-----do-----------------	Tr	336	9.64	.18
BPG-117	--do---	1.4	-----do-----------------	Tr	113	3.68	.60
BPG-118	--do---	1.6	-----do-----------------	Tr	141	3.43	.49
BPG-119	--do---	1.9	-----do-----------------	Tr	117	4.41	.47
BPG-120	--do---	1.9	-----do-----------------	Tr	93	2.70	1.44
BPG-121	--do---	.6	Mineralized fault zone--	0.3	178	5.65	2.11
BPG-122	--do---	.9	-----do-----------------	Tr	134	4.81	1.97
BPG-123	--do---	1.3	-----do-----------------	Tr	14	.42	.73
BPG-124	--do---	2.5	Across ore zone---------	Tr	165	5.23	.48
BPG-125	--do---	1.5	-----do-----------------	Tr	291	6.91	1.91
BPG-126	--do---	1.2	-----do-----------------	Tr	250	6.70	1.60
BPG-127	--do---	1.2	-----do-----------------	Tr	367	8.61	4.50
BPG-128	Random-grab.	4.6	Ore zone----------------	Tr	418	9.25	8.12
BPG-129	Grab---	--	Ore---------------------	.3	271	10.8	.51

galena, pyrite, sphalerite, and chalcopyrite. Some ore shoots were reported to contain 70 percent lead across a thickness of 12–20 ft (4–6 m). Tenor of the ore was better in the upper levels than in the lower.

The deposits were worked from seven levels totaling more than 2,000 ft (610 m) of drifts and 900 ft (275 m) of crosscuts. Several stopes were excavated in the upper levels.

Most of the patented claims are outside of the study area, although the northwestern end of the Stonewall Jackson claim is in the study area. The Solid Muldoon structure appears to trend across Muldoon Ridge, indicating a possible extension into the study area.

RIPPETO CLAIM

The Rippeto claim, one of the original locations in Garfield Canyon, located and patented in 1883, lies northeast of the Eagle Bird mine (pl. 4, No. 57). Elevation of the main workings is about 9,500 ft (2,900 m).

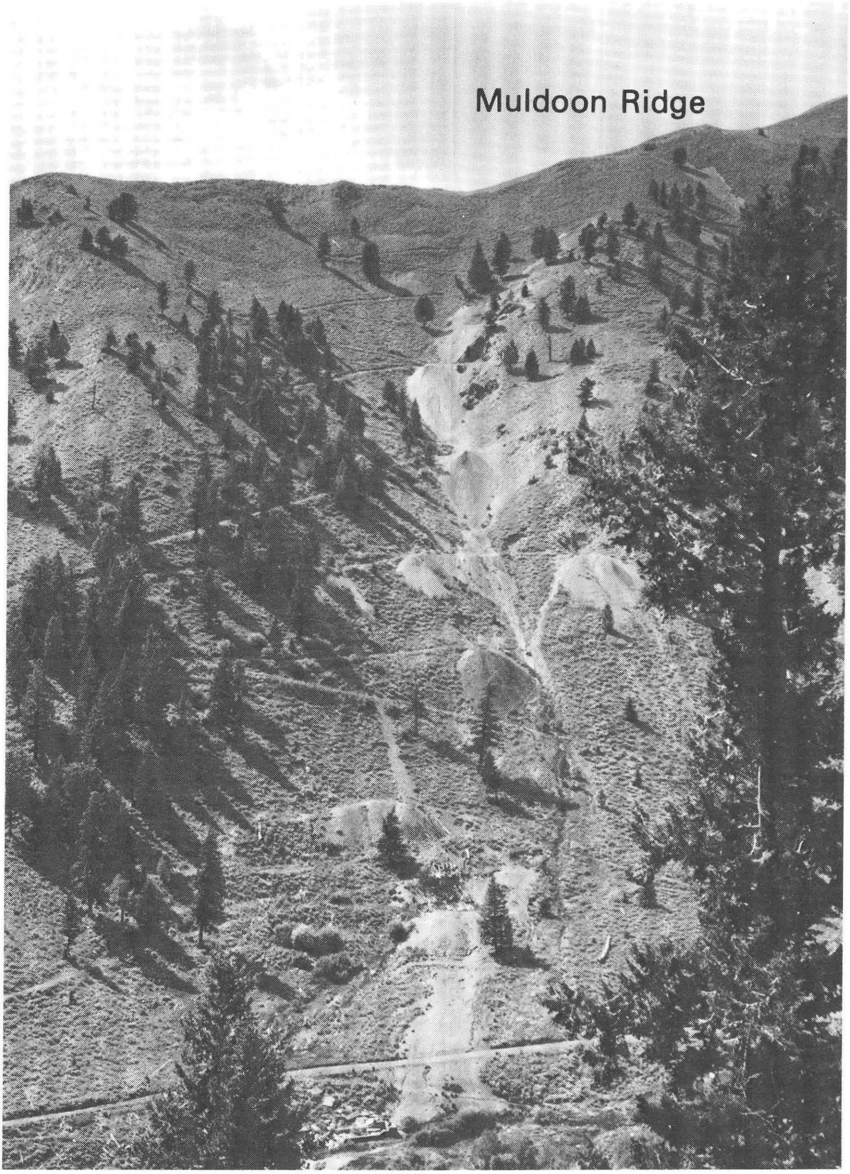

FIGURE 59.—The Solid Muldoon mines, viewed toward the northwest.

U.S. Bureau of Mines records (table 23) list 28 tons (25 t) of ore, with an approximate value of $2,070. The claim has been idle since the 1950's.

Limestone, with thinly interbedded argillite, underlies the claim. The rocks strike northerly and dip moderately to the northeast. Workings consist of three adits and five pits (fig. 60). Two adits and the pits expose a high-angle fault trending N. 85° E. The fault zone is traceable

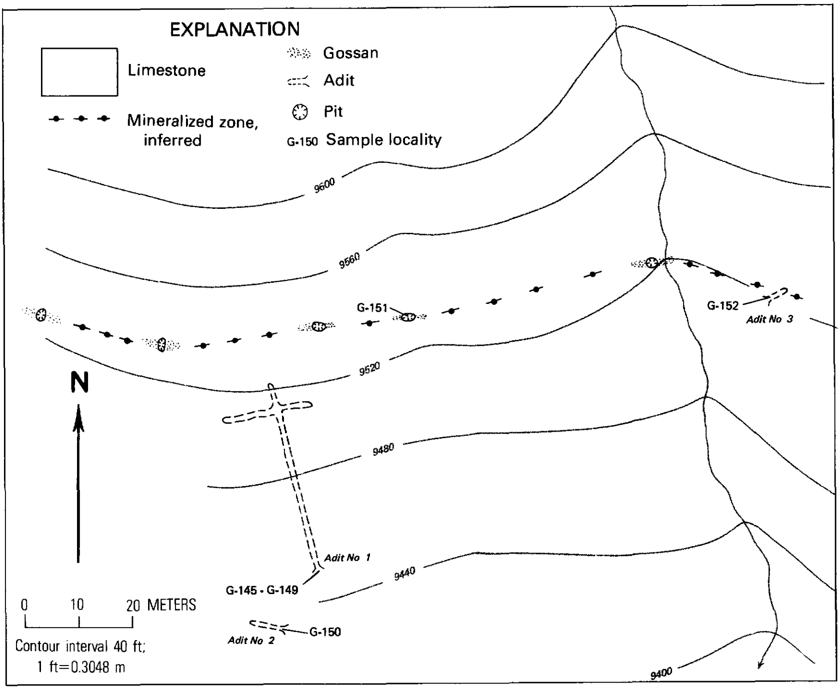

FIGURE 60.—Rippeto claim workings.

Data for samples shown in figure 60

[All samples chip; Tr, trace; N, not detected]

Sample No. G-	Length (m)	Description	Gold (g/t)	Silver (g/t)	Lead (percent)	Zinc (percent)
145	0.4	Across fault zone-----------	N	233	7.10	1.92
146	.9	-----do---------------------	N	254	7.34	1.61
147	1.0	-----do---------------------	Tr	75	3.54	1.81
148	.8	-----do---------------------	Tr	206	4.73	.18
149	.6	-----do---------------------	Tr	79	4.02	2.42
150	.3	Across bedding-plane fault--	N	339	27.4	.076
151	1.5	Across gossan in pit--------	N	151	5.67	.037
152	.9	Across fault zone-----------	N	79	2.37	.040

on the surface by gossan zones for about 500 ft (150 m). Adit No. 1 crosscuts the zone about 100 ft (30 m) in from the portal and follows it 60 ft (18 m). In the adit the thickness of the zone averages 3 ft (0.9 m). It is highly limonite stained, but contains no visible sulfides. Adit No. 3 on the east end of the zone is 15 ft (5 m) long. The zone at this point is 2.3 ft (0.7 m) thick.

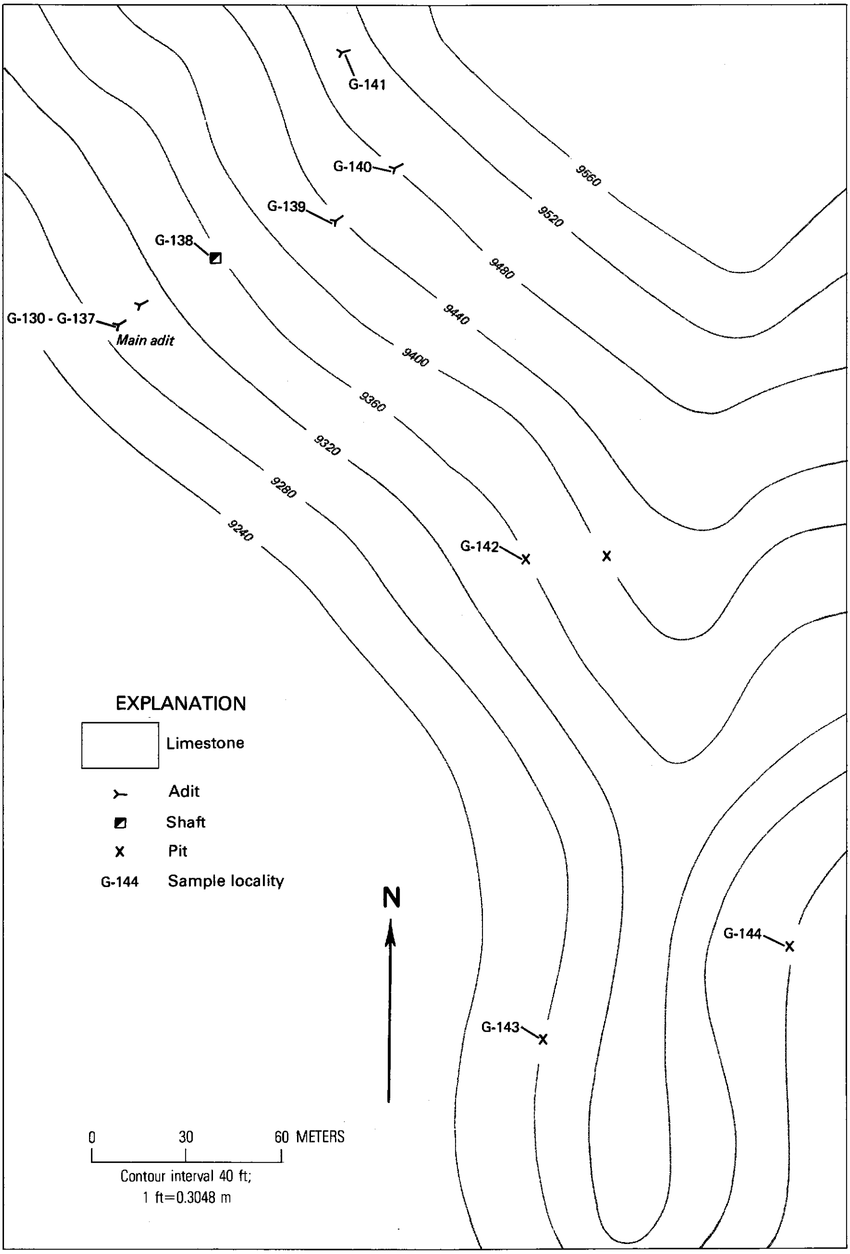

FIGURE 61.—Silver Eagle claim workings.

Weighted by length, seven samples taken from underground and surface exposures of the zone averaged 4.4 oz silver per ton (151 g/t), 4.91 percent lead, and 0.9 percent zinc.

Data for samples shown in figure 61

[All samples chip. Tr, trace; N, not detected]

Sample			Gold	Silver	Lead	Zinc
No. G-	Length (m)	Description	(g/t)		(percent)	
130	0.8	Across fault zone----	Tr	7	0.53	1.11
131	.9	Across gossan zone---	Tr	27	1.07	6.55
132	1.2	Across fault zone----	Tr	415	.44	3.12
133	1.2	-----do--------------	Tr	41	1.14	1.24
134	1.2	-----do--------------	Tr	27	5.09	3.20
135	.2	-----do--------------	Tr	117	2.64	5.91
136	.4	-----do--------------	N	27	.22	6.84
137	.3	-----do--------------	N	27	.24	4.33
138	1.0	-----do--------------	N	158	9.84	1.53
139	.5	-----do--------------	N	55	3.53	3.34
140	.6	-----do--------------	N	7	.40	1.99
141	1.1	-----do--------------	N	7	.42	.32
142	2.1	Iron-oxide-stained--- quartzite.	Tr	103	6.86	1.91
143	.8	Quartz-granitic dike-contact.	N	38	3.31	1.42
144	1.2	Alteration zone in--- granitic dike.	Tr	31	.88	.53

Adit No. 2 is 25 ft (8 m) long and crosscuts a 1.0-ft (0.3-m)-thick bedding plane shear zone that strikes N. 15° W. and dips 60° NE. A sample across the shear zone contained 9.9 oz silver per ton (340 g/t), 27.4 percent lead, and a trace of zinc. A bedding plane shear, a few inches (few centimeters) thick crosscut by the west end of the drift in adit No. 1, may be the same structure.

There may be as much as 35,000 tons (32,000 t) of inferred reserves on the claim. Tonnage was calculated by using the traceable length of 500 ft (150 m), a depth of 250 ft (76 m), and a width of 3 ft (0.9 m).

SILVER EAGLE CLAIM

The main adit of the Silver Eagle prospect is at about 9,650 ft (2,941 m) elevation, east of the Eagle Bird mine (pl. 4, No. 56). No production has been recorded.

Country rock is limestone with interbedded argillite and quartzite. The rocks strike northeasterly and dip 25°–60° SE. Mineral deposits occur along a fault striking east-northeast and dipping 85° SE. to vertical. The zone can be traced for about 400 ft (120 m) along strike and ranges in thickness from 3 in. to 4 ft (8 cm to 1.2 m), averaging about 2 ft

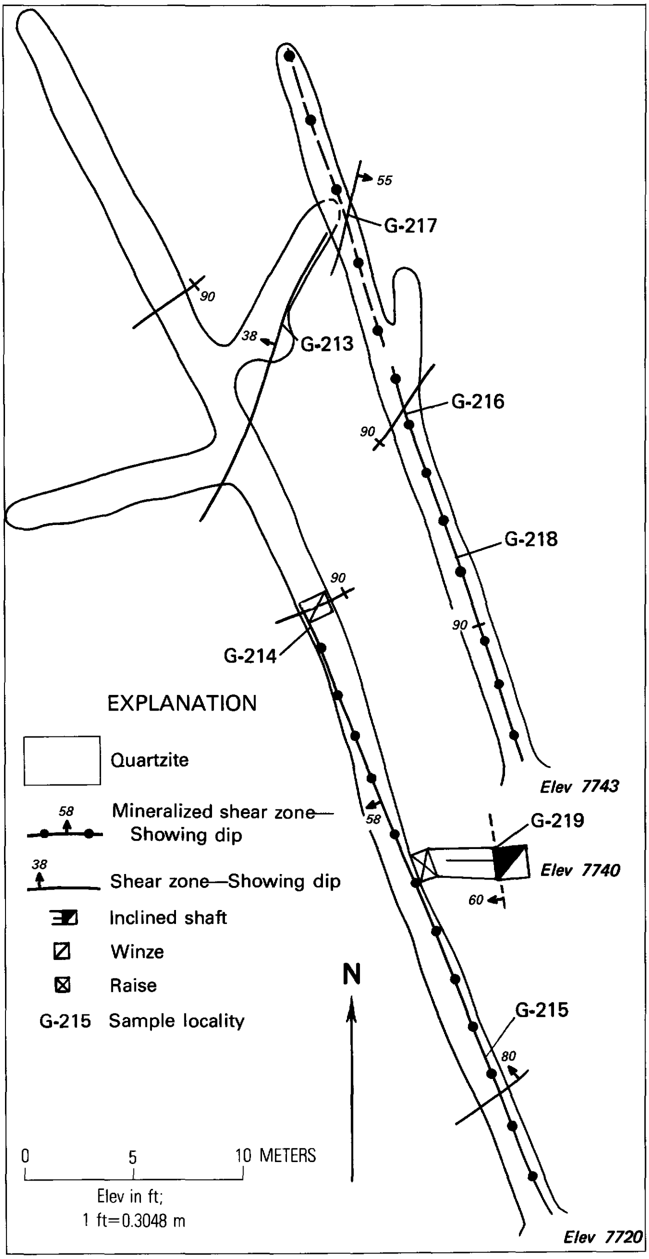

FIGURE 62.—Adit-group B, Garfield group.

(0.6 m). No sulfides were observed in the highly iron-oxide-stained rocks.

Workings consist of five adits, a shaft, and four pits (fig. 61). The

Data for samples shown in figure 62

[All samples chip. Tr, trace; N, not detected. Leaders (--), not analyzed]

Sample		Gold	Silver	Copper	Lead	Zinc
No. G-	Length (m)	(g/t)		(percent)		
213	0.4	0.7	24	--	1.42	0.67
214	.4	N	171	--	5.09	2.81
215	.4	N	309	0.16	8.02	.14
216	.5	N	302	--	8.48	6.87
217	1.8	Tr	134	--	5.76	.95
218	.2	N	82	--	4.15	1.08
219	.2	N	432	--	14.7	.96

main adit is about 700 ft (210 m) long. The others total 300 ft (90 m).

Fifteen samples were taken on the claim. Weighted by length, nine samples from the fault zone (130, 132–134, 136–140) averaged 3.3 oz silver per ton (113 g/t), 2.83 percent lead, and 2.53 percent zinc. About 15,000 tons (13,600 t) of inferred resource are in the main fault zone. Tonnage was calculated by using the traceable length of 400 ft (120 m), a depth of 200 ft (60 m), and a width of 2 ft (0.6 m).

GARFIELD GROUP

The Garfield group, consisting of at least 32 unpatented lode claims, begins near the mouth of Garfield Canyon and includes most of the area and workings between the Eagle Bird mine and the forks of the creek in Garfield Canyon (pl. 4, No. 53). No production is known to have specifically come from this claim group.

Several clusters of workings (designated A, B, C, and D) on the claim group were investigated, but only adit-group B was found to have mineral potential. Groups A, C, and D are listed in table 24.

At group B, two adits and an inclined shaft are on the north side of Garfield Canyon above the main road into the canyon. The adits total about 300 ft (90 m) in length and are 25 vertical feet (8 m) apart. Elevation at the portal of the lower (main) adit is about 7,700 ft (2,300 m). An inclined shaft, now caved, connects the adits (fig. 62).

Country rock, mainly quartzite, has many faults that trend N. 20° W. and dip from 60° SW. to vertical. Small faults, exposed in the two adits, generally strike northwestward and dip southwesterly, northeasterly, and vertically. The main fault zone exposed in both adits, and at the collar of the shaft, averages about 1.2 ft (0.4 m) in thickness and has a strike length of about 160 ft (50 m). The zone consists of iron-oxide-stained quartz-cemented gouge and has as much as 15 percent sulfides.

The sulfides are primarily galena and pyrite, but sphalerite and chalcopyrite are present.

Weighted by length, five main fault zone samples averaged 7.8 oz silver per ton (268 g/t), 7.88 percent lead, and 3.07 percent zinc. Based on a strike length of 160 ft (48.8 m), a depth of 80 ft (24.4 m), and a width of 1.2 ft (0.37 m), it is estimated that 1,500 tons (1,360 t) of inferred resources are in the main fault zone.

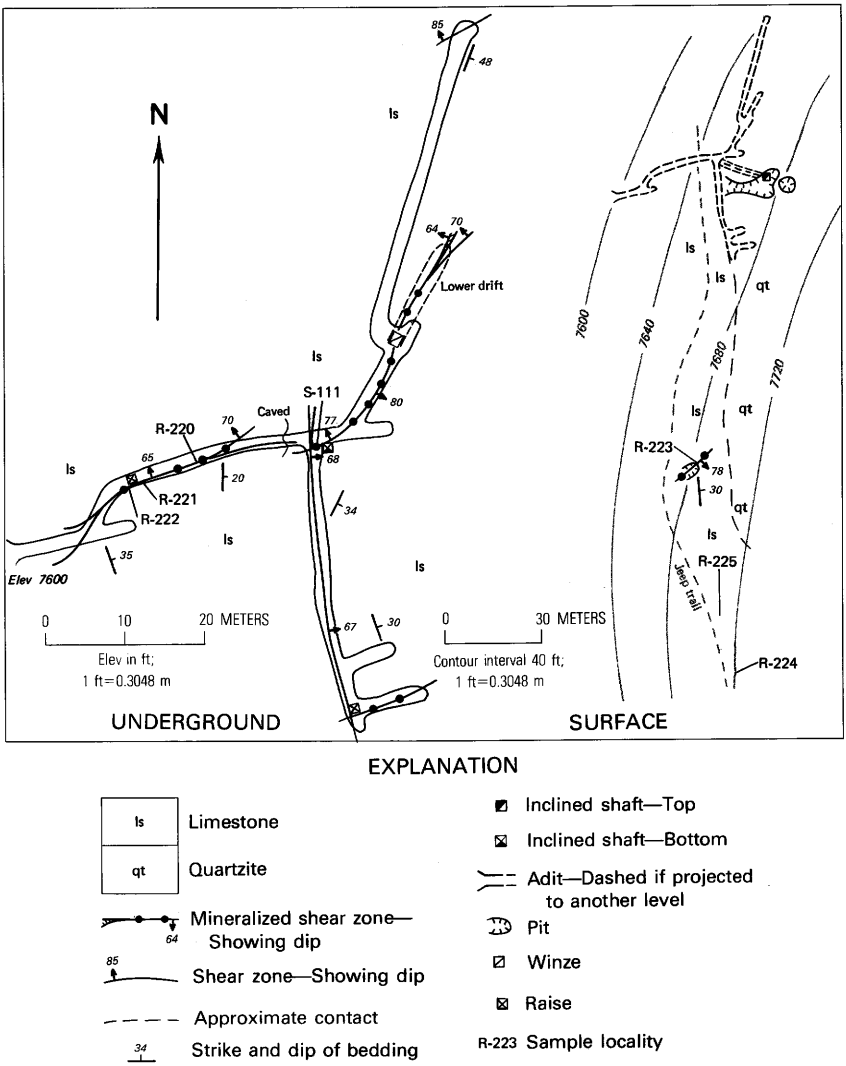

FIGURE 63.—Idaho Muldoon mine.

IDAHO MULDOON MINE

The Idaho Muldoon mine is east of Muldoon Creek about 4 mi (6 km) northeast of the old Muldoon townsite (pl. 4, No. 44). It was located in 1908 as part of the unpatented claim group surrounding the Stonewall Jackson and Solid Muldoon claims. No ore is known to have been produced. Only 120 ft (37 m) of the main adit was open when the property was visited. However, it was examined in 1943 by the U.S. Bureau of Mines, and parts of their unpublished data are used in the following description.

Country rock is predominantly limestone and interbedded quartzite, which strike northerly and dip 20°–50° E. The strata have been fractured along strike, but at an angle steeper than the bedding angle (fig. 63).

A cross fault exposed underground contains a small stringer of galena and sphalerite in a gangue of quartz and calcite; it can be traced for about 150 ft (46 m) and ranges in thickness from a small seam to 1.67 ft (0.51 m), averaging about 1 ft (0.3 m). Alteration zones exposed on the south end of the property are apparently unrelated to the main structure.

Claim development consisting of drifts and crosscuts and a shaft connecting the main level with the surface total 500 ft (150 m).

Weighted by length, three samples from the mineralized structure averaged 4.3 oz silver per ton (148 g/t), 5.02 percent lead, and 6.40 percent zinc. If the structure persists to a depth of half its strike length, about 1,000 tons (900 t) of submarginal resources are estimated on this claim.

CHAMPION PROSPECT

The Champion prospect is west of Muldoon Creek about one-fourth mile (0.4 km) above the Muldoon mine (pl. 4, No. 42). No record of production exists; however, rock has been removed from two stopes above adit No. 2 (fig. 64).

Data for samples shown in figure 63

[Tr, trace; N, not detected. Leaders (--), not analyzed]

Sample				Gold	Silver	Copper	Lead	Zinc
No.	Type	Length (m)	Description	(g/t)		(percent)		
R-220	Random--chip.	--	From vein----------	Tr	130	0.65	5.01	4.49
R-221	Chip----	0.5	Across iron-oxide--stained vein.	Tr	41	.27	2.78	2.23
R-222	--do----	.6	-----do------------	Tr	96	.50	3.91	3.13
R-223	--do----	.1	-----do------------	Tr	147	.001	5.89	7.00
R-224	Random--chip.	--	Iron-oxide-stained-zone.	Tr	51	--	--	--
R-225	Chip----	.3	Iron-oxide-stained-vein.	Tr	31	--	--	--
S-111	--do----	.5	-----do------------	--	314	--	8.5	14.4

Country rock is essentially a banded quartzite intruded by rhyolite dikes. Limestone occurs at the portal of adit No. 4.

Workings consist of five adits, an inclined shaft, and seven pits and trenches (fig. 64). Major workings expose one north-trending bedding-plane shear zone and three northeast-trending mineralized cross-shear zones. The shear zones are irregular and range in thickness from 0.75 to 3.7 ft (0.23 to 1.13 m). Galena, sphalerite, chalcopyrite, and pyrite occur as thin irregular pods and lenses in a gangue of crushed wall rock, quartz, and hematite.

Adit No. 1 is caved at the portal. A sample was taken from material on the dump, but no mineralized rock was noted. Sample results showed trace amounts of economic minerals.

Adit No. 2, 370 ft (110 m) west of adit No. 1, crosscuts a northeasterly trending mineralized shear zone and then drifts southwesterly for 215 ft (65.5 m) along it (fig. 65). The shear zone strikes N. 75° E. and dips 75°–80° SE. It has been stoped up an average of 30 ft (9 m) at two places. The shear zone ranges from 1.0 to 3.7 ft (0.3 to 1.1 m) in thickness, tending to narrow toward the face. The walls are irregular but well defined. At the east end, the zone is offset. Further crosscutting 85 ft (26 m) to the northwest failed to locate the shear zone. Galena and sphalerite occur as thin pods and lenses in a gangue of gouge, crushed wall rock, quartz, and hematite. Seven samples taken from the zone averaged 3.3 oz silver per ton (113 g/t), 2.70 percent lead, and 1.53 percent zinc, and contained trace amounts of gold and copper.

A caved trench 200 ft (60 m) west of adit No. 2 is probably on the same shear as adit No. 2. A sample taken from the dump contained 0.3 oz silver per ton (10 g/t).

A second northeasterly trending mineralized shear zone, 400 ft (120 m) north of adit No. 2, is exposed by two trenches, a cut, and a 50-ft (15-m)-long adit. The shear zone outcrops intermittently for about 450 ft (140 m). It strikes N. 60° E., dips 75°–85° NW., and ranges from 0.8 ft (0.2 m) thick in adit No. 3 to 1.8 ft (0.5 m) in the trench above the adit (fig. 64). The shear zone contains galena, chalcopyrite, and pyrite disseminated through quartz. Samples taken from the shear zone averaged a trace of gold, 11.3 oz silver per ton (387 g/t), 0.48 percent copper, 4.5 percent lead, and 0.44 percent zinc.

Adit No. 4 was apparently driven to intersect the portion of the second mineralized shear zone exposed by adit No. 3 (fig. 64). Through a length of 420 ft (128 m), the adit follows three narrow nonmineralized shear zones. None of zones appear related mineralogically to the second major mineralized shear zone. The three shear zones range from 0.5 to 1.5 ft (0.1 to 0.5 m) thick and are filled with iron-oxide-stained fault gouge and an occasional quartz stringer. Six samples taken from the zones contained trace amounts of economic minerals.

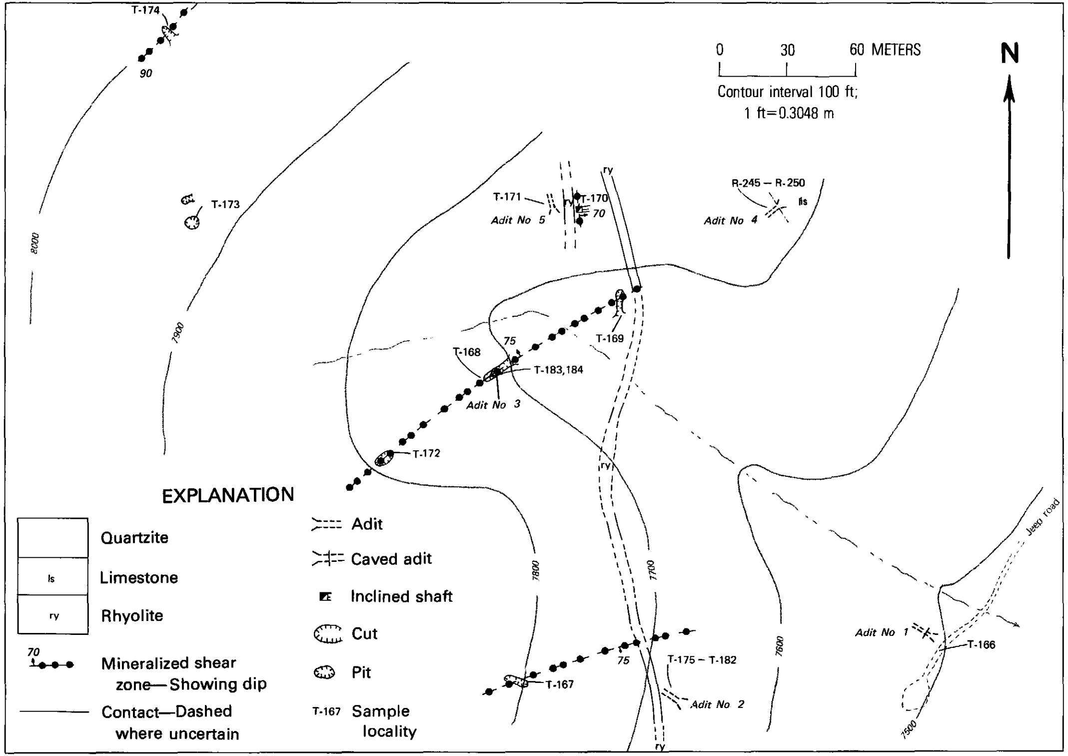

FIGURE 64.—Champion prospect.

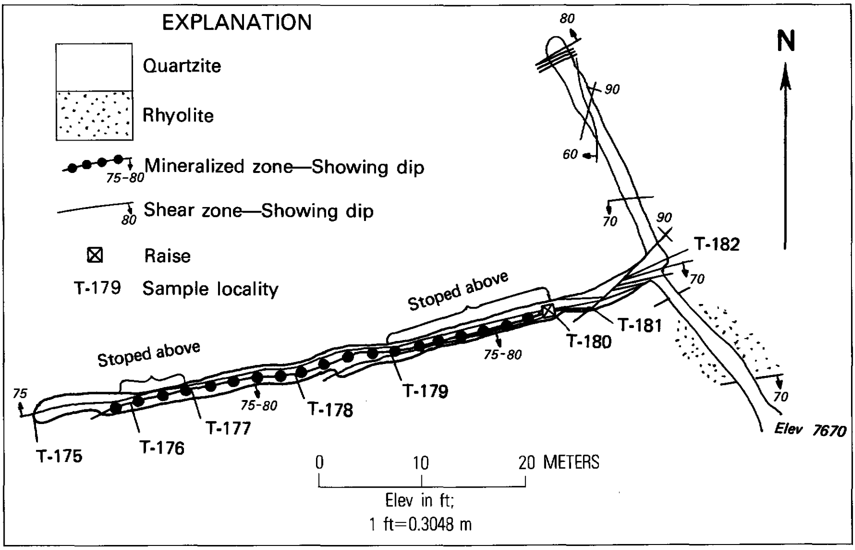

FIGURE 65.—Adit No. 2, Champion prospect.

One hundred and fifty feet (46 m) northwest of the second mineralized zone, a 30-ft (9-m)-deep inclined shaft exposes a bedding-plane shear zone that contains iron-oxide-stained drusy quartz with small pods of galena. The zone strikes N. 8° W., dips 70° NE., and is as much as 3.6 ft (1.1 m) thick. It cannot be traced beyond the inclined shaft. A sample taken across the zone contained trace amounts of gold and copper, 3.2 oz silver per ton (110 g/t), 3.00 percent lead, and 0.20 percent zinc.

Twenty-five feet (8 m) northwest of the inclined shaft, a 20-ft (6.1-m)-long adit is on a gossan zone in quartzite adjacent to a rhyolite dike. The irregular gossan is 8 by 5 by 6 ft (2.4 by 1.5 by 1.8 m) and consists of vuggy quartz, limonite, and hematite. A sample taken from the gossan contained 0.01 oz gold per ton (0.3 g/t), 4.2 oz silver per ton (144 g/t), and 2.00 percent lead.

A third northeast-trending mineralized shear zone, 640 ft (195 m) northwest of the second mineralized shear, is exposed by a 20-ft (6-m)-long cut. The shear strikes N. 40° E., dips vertically, and is 0.8 ft (0.2 m) thick. A sample taken from the shear zone contained a trace of gold and 0.2 oz silver per ton (7 g/t).

The southeastern shear zone has been extensively developed and appears mined out, but additional shoots may occur along extensions of the zone. The middle shear zone is not of sufficient width to be considered a resource. The northwestern shear contains only trace amounts of economic minerals. The bedding-plane shear does not contain a minable-grade material.

Data for samples shown in figures 64 and 65

[Tr, trace; N, not detected. Leaders (--), not analyzed]

Sample				Gold	Silver	Copper	Lead	Zinc
No.	Type	Length (m)	Description	(g/t)		(percent)		
T-166	Grab--	--	Quartzite-------------------	N	N	Tr	Tr	N
T-167	--do--	--	Iron-oxide-stained quartzite-	N	10	--	0.56	--
T-168	Chip--	0.5	Quartz with disseminated----- pyrite, chalcopyrite and galena.	0.3	130	0.26	1.92	0.24
T-169	--do--	.2	-----do--------------------	N	456	46	2.82	.30
T-170	--do--	1.1	Iron-oxide-stained drusy----- quartz with galena.	Tr	110	Tr	3.00	.20
T-171	--do--	2.4	Gossan; vuggy quartz with---- limonite and hematite.	.3	144	Tr	2.00	N
T-172	Grab--	--	Iron-oxide-stained quartz----	Tr	17	Tr	1.11	.46
T-173	--do--	--	Iron-oxide-stained, vuggy----- quartz.	Tr	55	--	1.69	--
T-174	Chip--	.2	-----do--------------------	Tr	7	--	.80	--
T-175	--do--	.3	Clayey shear with quartz,---- hematite and minor galena.	Tr	58	Tr	1.56	.65
T-176	--do--	.8	Brecciated, clayey shear----- with quartz, hematite, and galena.	Tr	17	--	.59	.20
T-177	--do--	1.1	-----do--------------------	Tr	27	--	1.59	.56
T-178	--do--	1.0	Brecciated, clayey shear----- with quartz, hematite, galena, and chalcopyrite.	Tr	110	Tr	2.41	5.77
T-179	--do--	1.1	-----do--------------------	Tr	45	Tr	.85	.59
T-180	--do--	.7	-----do--------------------	Tr	120	.33	3.93	.85
T-181	--do--	1.4	-----do--------------------	Tr	288	.14	5.90	1.51
T-182	--do--	.4	Iron-oxide-stained fault----- gouge.	Tr	99	--	2.85	.68
T-183	--do--	.2	Quartz with disseminated----- pyrite, chalcopyrite, and galena.	Tr	850	.61	11.7	.45
T-184	--do--	.2	-----do--------------------	Tr	449	.87	4.80	1.03
R-245	--do--	.5	Iron-oxide-stained fault----- gouge.	Tr	7	Tr	Tr	N
R-246	--do--	.3	Iron-oxide-stained fault----- gouge with occasional quartz stringers.	N	N	--	--	--
R-247	--do--	.2	Iron-oxide-stained fault----- gouge.	Tr	N	--	--	--
R-248	--do--	.3	-----do--------------------	Tr	Tr	--	--	--
R-249	--do--	.5	-----do--------------------	N	65	--	--	--
R-250	--do--	.5	-----do--------------------	N	3	--	--	--

SCORPION GROUP AND ASSOCIATED WORKINGS

Numerous adits and small cuts were excavated in the area between Garfield Canyon and the head of Deep Gulch (fig. 66). Country rock is limestone and argillite with thin beds of conglomerate, quartzite, and shale. Several silicic and mafic dikes cut the strata. The rocks form part of a northerly trending anticline that has been faulted and sheared along and across the bedding. Mineralized zones are replacement-type deposits and quartz fissure-fillings containing lead, zinc, silver, and copper minerals in a gangue of quartz and calc-silicate minerals. Barite

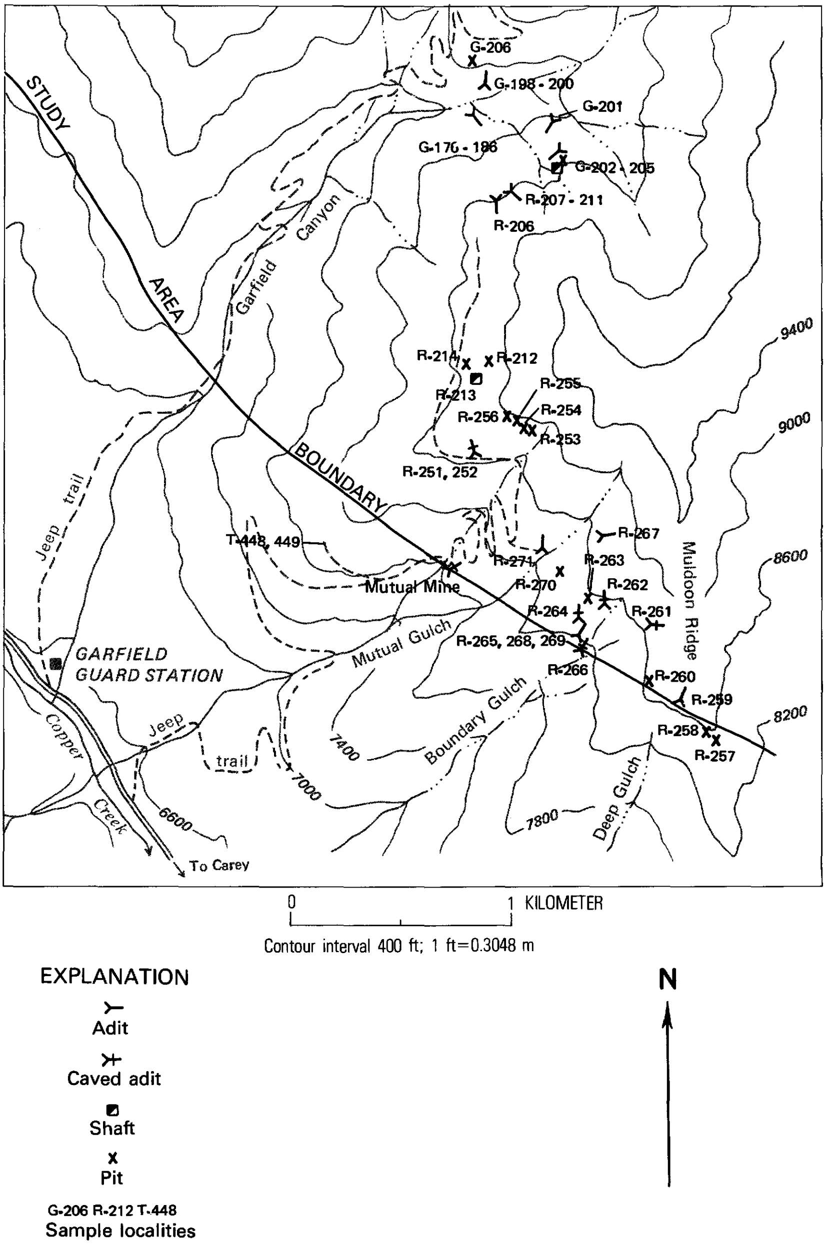

FIGURE 66.—Index to workings, Garfield Canyon–Deep Gulch prospects.

is also present in fracture fillings. Workings are grouped for convenience as the Scorpion group, Mutual Gulch workings, Boundary Gulch workings, and Muldoon Ridge workings.

Data for samples shown in figure 66

[Tr, trace; N, not detected; leaders (--), not analyzed; <, less than amount shown]

Sample				Gold	Silver	Copper	Lead	Zinc	Barite
No.	Type	Length (m)	Description	(g/t)		(percent)			
G-176	Chip--	2.8	Across shear zone--	N	7	--	0.021	0.036	--
G-177	--do--	.8	Across fault zone--	Tr	34	--	.13	.32	--
G-178	--do--	.6	-----do-----------	N	7	--	.040	.11	--
G-179	--do--	.7	-----do-----------	N	3	--	.004	.008	--
G-180	--do--	.7	-----do-----------	N	3	--	.026	.034	--
G-181	--do--	.4	-----do-----------	N	21	--	.44	.059	--
G-182	--do--	.5	Across mineralized-fault zone.	N	3	--	.022	.060	--
G-183	--do--	.4	-----do-----------	Tr	41	--	1.61	5.57	--
G-184	--do--	.5	-----do-----------	Tr	178	--	4.89	3.83	--
G-185	--do--	1.2	-----do-----------	Tr	120	--	6.85	5.21	--
G-186	--do--	.6	-----do-----------	0.3	199	0.11	8.00	9.70	--
G-198	--do--	.9	Contact between---- andesite and limestone.	N	3	--	.011	.015	--
G-199	--do--	.9	Contact between---- granite and limestone.	N	21	--	.052	.020	--
G-200	--do--	.3	Across fault zone--	N	3	--	<.001	.008	--
G-201	--do--	.3	Across shear zone--	N	3	--	1.63	1.68	--
G-202	--do--	.5	-----do-----------	N	41	--	2.78	8.50	--
G-203	--do--	.8	-----do-----------	N	86	--	2.86	.85	--
G-204	--do--	.2	-----do-----------	Tr	1125	--	32.3	.27	--
G-205	--do--	.5	-----do-----------	Tr	65	--	7.57	.27	--
G-206	--do--	.6	Across mineralized-fault zone.	Tr	65	.074	.14	1.92	--
R-206	--do--	1.2	Across mineralized-shear zone.	Tr	247	.12	3.95	2.78	--
R-207	--do--	.3	Across fault-------	N	17	.024	.037	.53	--
R-208	--do--	.8	Across mineralized-shear zone.	N	154	.011	.43	3.15	--
R-209	--do--	.9	-----do-----------	N	130	.033	3.95	2.25	--
R-210	--do--	.6	-----do-----------	Tr	254	.010	9.21	3.52	--
R-211	Grab--	--	Iron-oxide-stained-vuggy quartz.	N	583	--	--	--	--
R-212	--do--	--	-----do-----------	4.5	230	--	--	--	--
R-213	--do--	--	-----do-----------	N	315	--	--	--	--
R-214	--do--	--	Iron-oxide-stained-quartz breccia.	N	N	--	--	--	--
R-251	--do--	--	Barite-bearing----- material.	N	48	--	--	--	62.00
R-252	--do--	--	Iron-oxide-stained-vuggy quartz.	Tr	69	--	--	--	--
R-253	--do--	--	Quartzite----------	1.3	346	--	--	--	--
R-254	--do--	--	Vuggy quartz-------	.3	391	--	--	--	--
R-255	--do--	--	Iron-oxide-stained-vuggy quartz.	.7	264	--	--	--	--
R-256	--do--	--	-----do-----------	2.4	285	--	--	--	--
R-257	Chip--	.3	-----do-----------	N	3	--	--	--	--
R-258	--do--	.8	Quartz vein--------	.3	141	.002	4.13	.047	--
R-259	--do--	.9	-----do-----------	Tr	285	.19	7.14	.30	--
R-260	Grab--	--	Iron-oxide-stained-vuggy quartz.	Tr	31	--	--	--	--
R-261	--do--	--	-----do-----------	Tr	3	--	--	--	--
R-262	--do--	--	-----do-----------	.3	209	--	--	--	--
R-263	--do--	--	-----do-----------	Tr	315	--	--	--	--
R-264	--do--	--	-----do-----------	Tr	93	--	--	--	--
R-265	--do--	--	-----do-----------	.3	669	--	11.4	.32	--
R-266	--do--	--	Iron-oxide-stained-carbonaceous material.	N	N	--	--	--	--
R-267	Chip--	.3	Quartz vein--------	.3	65	--	--	--	--
R-268	--do--	.5	Across shear zone--	N	N	--	--	--	--
R-269	--do--	.3	-----do-----------	Tr	151	8.32	2.55	2.94	--
R-270	Grab--	--	Iron-oxide-stained-vuggy quartz.	.3	55	--	--	--	--
R-271	--do--	--	-----do-----------	Tr	82	6.02	--	--	--
T-448	--do--	--	Barite------------	--	--	--	--	--	92.9
T-449	Chip--	.3	Barite vein--------	--	--	--	--	--	94.8

SCORPION GROUP

The Scorpion group consists of 12 unpatented lode claims including the Garfield Antimony Nos. 1-3, and Pay Day Nos. 1-3 unpatented claims (pl. 4, No. 52). The claims were located under the current names in the early 1950's and held by assessment work to the present. U.S. Bureau of Mines records indicate 5 tons (4.5 t) of material with a recovered content of 0.4 oz gold per ton (12 g/t), 22.8 oz silver per ton (709 g/t), 28 percent copper, and 2 percent zinc were produced (table 23).

Most of the workings are on the south side of Garfield Canyon, and include six adits, a shallow shaft, and two pits. A mineralized fault zone, which is from 2 in. to 1 ft (5 cm to 0.3 m) thick and in limestone, is exposed in the pit on the north side of Garfield Canyon creek. The zone appears to strike N. 30° E. and dip 60° NW. and can be traced for about 30 ft (9 m). Sample G-206 assayed a trace gold, 1.9 oz silver per ton (65 g/t), 0.07 percent copper, 0.14 percent lead, and 1.92 percent zinc. About 150 ft (45 m) below the pit is a 235-ft (72-m)-long adit in limestone cut by andesite and granitic dikes. Samples G-198 through G-200 from this adit assayed from 0.1 to 0.6 oz silver per ton (3 to 21 g/t), trace to 0.05 percent lead, and trace to 0.02 percent zinc.

Across the creek to the south is a 1,170-ft (357-m)-long adit in limestone. Two mineralized fault zones were drifted on for about 375 ft (114 m). The zones strike northeasterly and dip from 65° northwesterly to vertical, and they range in thickness from 1.7 to 3.9 ft (0.52 to 1.2 m), averaging 2.4 ft (0.8 m) thick. Weighted by length, four samples (G-183 through G-186) averaged 4.0 oz silver per ton (137 g/t), 5.96 percent lead, and 5.98 percent zinc. If the structure persists to a depth of its strike length, about 15,000 tons (13,600 t) of inferred resources are estimated in the mineralized fault zones. Samples taken across other structures (G-176 through G-182) in the adit ranged from 0.1 to 1.0 oz silver per ton (3 to 34 g/t), 0.004-0.44 percent lead, and trace to 0.32 percent zinc.

An adit 1,200 ft (366 m) due east is caved 40 ft (12 m) from the portal, but it appears to be approximately 250 ft (75 m) in length. A fault was crosscut 30 ft (9 m) from the portal. A sample (G-201) assayed 0.1 oz silver per ton (3 g/t), 1.63 percent lead, and 1.68 percent zinc. About 350 ft (105 m) higher and to the south of the caved adit is a prospect pit and a caved vertical shaft. The pit exposes a shear zone trending N. 67° E. and dipping 78° NW. in limestone. The shear zone is 1.5 ft (0.5 m) thick and can be traced for 20 ft (6 m) along strike. A sample (G-202) assayed 1.2 oz silver per ton (41 g/t), 2.78 percent lead, and 8.50 percent zinc. The shaft apparently excavated on the shear zone is 20-30 ft (6-9 m) deep. Fifty feet (15 m) below the pit is an adit trending S. 54° W. for 150 ft (45 m) along the shear zone exposed in the pit. The zone is 1.5 ft (0.5

m) thick at the portal, swells to 2.5 ft (0.8 m) thick 40 ft (12 m) into the adit, and then pinches down rapidly to 2–3 in. (5–8 cm) at the face. Weighted by length, three samples (G–203, G–204, and G–205) from the shear zone averaged a trace of gold, 5.7 oz silver per ton (195 g/t), 7.70 percent lead, and 0.59 percent zinc.

A fifth adit is about 1,000 ft (300 m) S. 57° W., and at the same elevation. A small pocket of relatively high grade ore was stoped from the hanging wall of a bedding-plane fault about 100 ft (30 m) into the adit. Production listed for the Scorpion group probably came from this working. Weighted by length, four samples of the zone (R–207 through R–210) averaged 4.5 oz silver per ton (154 g/t), 3.69 percent lead, and 2.61 percent zinc. A sixth adit in a limestone outcrop is 40 ft (12.2 m) higher and 300 ft (90 m) southwest. Bedding strikes N. 20° W., dips 58° NE., and is highly iron oxide stained along bedding planes. A sample (R–206) of this zone contained 7.2 oz silver per ton (250 g/t), 3.95 percent lead, 2.78 percent zinc, and 0.12 percent copper. Samples indicate that the mineralized zones have a potential for discovery of minable resources.

MUTUAL GULCH AREA WORKINGS

Workings in the Mutual Gulch area (fig. 66) include nine pits, one short adit, two caved adits, and a shallow inclined shaft (pl. 4, No. 51). The old Mutual mine produced 49 tons (45 t) of ore with a recovered content of 44 oz silver per ton (1,500 g/t) and 41.8 percent lead, from 1901 through 1904, according to U.S. Bureau of Mines records. The mine reportedly has 4,000 ft (1,200 m) of underground workings, but is now caved. Workings in Mutual Gulch are generally in argillaceous rocks.

Three grab samples (R–212, R–213, and R–214) of vuggy, iron-oxide-stained quartz were taken from two pits and an inclined shaft on the north side of the ridge dividing Garfield Canyon and Mutual Gulch. One sample contained 9.2 oz silver per ton (315 g/t); another contained 0.13 oz gold per ton (4.5 g/t) and 6.7 oz silver per ton (230 g/t). Semiquantitative spectrographic analyses indicate the presence of lead in quantities greater than 5 percent in two of the samples. Just over the ridge are four pits in line with the structure in the inclined shaft. Samples from the pits (R–253 through R–256) contained from 0.01 to 0.07 oz gold per ton (0.3 to 2 g/t) and from 7.7 to 11.4 oz silver per ton (264 to 391 g/t). The material is vuggy, iron-oxide-stained quartz and may be an extension of the structure exposed by the shaft.

About 1,000 ft (305 m) southwesterly down the ridge is a caved adit, estimated to be 200 ft (60 m) long. A roadcut near the portal exposes a 4–6-in. (10–15-cm)-thick vein of barite. A grab sample (R–251) assayed 1.4 oz silver per ton (48 g/t) and 62 percent $BaSO_4$. A grab sample (R–252) of vuggy, iron-oxide-stained quartz from the dump contained a trace of gold and 2.0 oz silver per ton (69 g/t). Recently a roadcut about 2,500 ft (760 m) southwest of the adit exposed a zone of barite veins and stringers approximately 175 ft (50 m) wide. Two veins are 1.5 ft (0.5 m) thick each, and a third is 1.0 ft (0.3 m) thick. The veins strike N. 10°–15° E., dip 80° SE., and can be traced along strike for about 50 ft (15 m). Two samples (T–448 and T–449) of the veins contained 92.9 and 94.8 percent $BaSO_4$.

A pit, a 15-ft (5-m)-long adit, and a 50-ft (15-m)-long adit are in the south fork of Mutual Gulch. The longer adit, although uncompleted, was excavated to crosscut a large quartz-filled fissure. The fissure trends northwesterly and is exposed intermittently along strike for about 200 ft (60 m); it appears to be at least 10 ft (3 m) wide. A grab sample (R–271) of the quartz assayed a trace gold, 2.4 oz silver per ton (82 g/t), and 6.02 percent copper. If the fissure extends to a depth one half its strike length, it contains an estimated 18,000 tons (16,300 t) of inferred resources. A few feet (few meters) higher, and about 500 ft (150 m) southeast, is a sloughed cut along the apparent strike of the quartz-filled fissure. A sample (R–270) of iron-oxide-stained vuggy quartz contained 0.01 oz gold per ton (0.34 g/t) and 1.6 oz silver per ton (55 g/t). About 1,000 ft (300 m) uphill to the northeast, a 15-ft (5-m)-long adit exposes a 1-ft (0.3-m)-thick quartz vein. The structure strikes N. 72° E. and dips 80° to 90° SE. A sample (R–267) cut from the vein assayed 0.01 oz gold per ton (0.34 g/t) and 1.9 oz silver per ton (65.2 g/t). Samples indicate that the mineralized zones have a potential for discovery of minable resources.

BOUNDARY GULCH AREA WORKINGS

Four caved adits, an 850-ft (260-m)-long adit, and a pit are near the head of Boundary Gulch (pl. 4, No. 50). Country rock is mainly argillite. The No. 1 or main adit trends N. 40° E., crosscutting a northwesterly trending shear zone and latite porphyry dike. The shear zone ranges from 4 in. to 5 ft (10 cm to 1.5 m) in thickness and dips moderately to the northeast. Adjacent strata have been altered, generally within less than 2 ft (0.6 m) of the shear zone. A chip sample (R–269) across the zone assayed a trace of gold and 4.4 oz silver per ton (151 g/t), 8.32 percent copper, 2.55 percent lead, and 2.94 percent zinc. About 50 ft (15 m) downhill to the southeast of No. 1 adit is No. 2. It is estimated to be 300 ft (90 m) in length. No sulfides were observed in material on the dump, and a sample (R–266) of the moderately iron oxide stained argillite contained no economic minerals. No. 3, a short, caved adit due north of No. 1 adit, apparently intersected a small quartz vein. A sample of the material (R–264) assayed a trace of gold and 2.7 oz silver per ton (93 g/t). A small pit and a short, caved adit (No. 4) are northeast of No. 3 adit. Grab samples (R–262 and R–263) from the dumps contained 0.01 oz gold per ton (0.34 g/t) and 6.1 oz silver per ton (209 g/t), and a trace of gold and 4.2 oz silver per ton (144 g/t), respectively. About 400 ft (122 m) southeast and 100 ft (30 m) above is the caved No. 5 adit. A sample (R–261) of quartz from the workings contained 0.1 oz silver per ton (3.4 g/t). Samples indicate that the mineralized zones have a potential for discovery of minable resources.

MULDOON RIDGE PROSPECTS

Three small pits and a 10-ft (3-m)-long adit are on, or near, the crest of Muldoon Ridge (pl. 4, No. 49). The workings are in general alinement with, and probably related to, the Solid Muldoon structures in Muldoon Creek drainage. Grab samples (R–261 through R–264) of iron-oxide-stained quartz material contained from a trace to 0.01 oz gold per ton (0.34 g/t) and 0.1 to 9.2 oz silver per ton (3.4 to 316 g/t).

MISCELLANEOUS PROPERTIES

Several properties in the district were examined that have little or no economic potential or that are not sufficiently exposed to permit evaluation. These properties are listed in table 24.

COPPER BASIN DISTRICT

The Copper Basin district, in the northeastern part of the study area, is accessible by seasonal roads from Trail Creek road, Antelope Pass, or Mackay, Idaho.

The floor of the basin, covered chiefly by glacio-fluvial sediments, is excluded from the study area. Country rocks in the sides of the basin are Paleozoic sedimentary rocks, Eocene Challis Volcanics, and Tertiary plutons with associated dikes and sills. The Paleozoic rocks have been folded and faulted. Generally, the strata strike northerly and dip moderately to steeply both east and west. Metal-bearing deposits are replacements along fissures near intrusives. Deposits containing lead, zinc, silver, and copper occur in Star Hope Creek canyon, on the east flank of Muldoon Canyon, and in the basin of the head of Lake Creek.

First recorded mining activity in the basin was in 1881 with the discovery of sulfide-bearing veins in the canyon of Star Hope Creek. In 1888, copper deposits were discovered near the mouth of the basin, outside the study-area boundary. Since 1881, the date of the first claim, approximately 289 claims have been located in that portion of the district within the study area (table 25), and five claims are patented. U.S. Bureau of Mines records listed a total production of 92 tons (83.5 t) of ore from the district with a recovered content of 2.33 oz silver per ton (79.9 g/t), 5.5 percent copper, 10.4 percent lead, and 7.1 percent zinc,

TABLE 24.—*Miscellaneous properties, Little Wood River district*

Map No.	Property name	Summary	Number and type of workings	Sample data
40	Grey Eagle---	Three northeasterly trending mineralized--- shear zones and one northwesterly trending bedding-plane shear in interbedded argillite, quartzite, and siliceous limestone. Northeast shear zones dip 65° SE. and range from 0.3 to 0.7 m thick Bedding-plane shear is as much as 0.5 m thick and dips 75° SW.	Three adits,--- 18 m, 7 m long, and one caved. Two sloughed pits; two sloughed trenches.	Eight samples; seven samples across northeasterly trending shear zones; as much as 103 grams silver per metric ton, 3.25 percent lead and 1.82 percent zinc. One sample across bedding plane shear; 336 grams silver per metric ton, 12.9 percent lead, and 1.45 percent zinc.
41	Contact------ prospect.	Pyritized shear zone along a southwest- --- erly trending granite-argillite contact. The shear zone ranges from 0.6 to 1.5 m thick and can be traced for 46 m. Pyrite also occurs in irregular pods as much as 0.9 m thick along some joints in the granite.	Two adits, 11-- m and 6 m long.	Two samples across contact; 45-55 grams silver per metric ton, a trace copper, 0.20-0.70 percent lead, and a trace to 0.59 percent zinc.
43	Logan-------- Tunnel.	A fault and shear zone, containing quartz-- fissure-fillings, trending northeastward in gray quartzite. Lower adit (main) caved; upper adit develops clay-filled gouge in shear zone striking N. 80° E. and dipping 80° SE. Zone contains no visible sulfides and is as much as 0.8 m thick.	Three adits,--- 88 m, 3 m long, and one caved.	Five samples; as much as 0.3 gram gold and 151 grams silver per metric ton.

45	American------ mine.	Country rock is thinly bedded argillite,--- quartzite, and limestone intruded by andesite porphyry dikes. Major workings expose a mineralized contact between the sediments and a southwest-trending andesite dike. Massive galena and sphalerite with pyrite occur as sparse, irregular pods averaging 0.15 m thick in the sediments along the contact. The contact zone is bleached and silicified. Disseminated pyrite occurs in host beds as much as 2 m away from the contact.	Three adits,--- 14 m, 17 m long, and one caved. Four sloughed pits.	Seven samples; as much as 62 grams silver per metric ton, 0.26 percent copper, 4.86 percent lead, and 5.99 percent zinc.
47	Lucky Boy---- group.	Country rock is a granule conglomerate----- intruded by andesite dikes. Workings explore iron-oxide-stained, northeasterly trending shear zones in conglomerate contacts, and gossan zones along dike-conglomerate contacts.	Six sloughed--- pits, one shaft, 11 m deep, three caved adits. Mineral survey plate shows that the caved adits contained over 335 m of underground workings.	Nine samples; two samples from an 0.24-m-thick shear and an 0.23-m-thick shear; trace gold, 250 and 401 grams silver per metric ton, 13.0 and 17.1 percent lead, and 0.91 and 1.21 percent zinc. Select dump sample from one adit; 0.7 gram gold and 182 grams silver per metric ton, 7.22 percent lead and 0.68 percent zinc. Six samples from shears, contact zones and dikes; trace amounts of metals.
53	Garfield----- group, adit-group A.	Granite dike cuts quartzite and calcareous quartzite country rock. Some limonite staining near contact of dike and quartzites and along several faults and minor shear zones exposed in adits. Minor amounts of pyrite visible.	Three adits,--- one 70 m long and two caved. Five prospect pits.	Five samples; nil to trace gold, trace to 3 grams silver per metric ton, as much as 0.15 percent lead, and 0.19 percent zinc.

TABLE 24.—*Miscellaneous properties, Little Wood River district*—Continued

Map No.	Property name	Summary	Number and type of workings	Sample data
53	Garfield----- group, adit-group C.	Iron-oxide-stained shear and fault zones--- in quartzite, argillite, and limestone country rock occasionally cut by granitic dikes. Majority of the zones range from 0.06 to 0.46 m thick, but one zone is as much as 1.4 m thick.	Four adits,---- 20 m, 24 m, 52 m, and 70 m long.	Twenty-three samples, 16 samples taken underground, 7 samples from the surface; 15 underground samples; nil to 69 grams silver per metric ton, trace to 0.68 percent lead, cent lead, and trace to 0.62 per-cent zinc. One underground sample; 213 grams silver per metric ton, 1.53 percent copper, 0.44 percent lead, and a trace zinc. Four sur-face samples across shear zones; 41-263 grams silver per metric ton, and 0.33-2.30 percent lead. Three select samples from dumps; 165-617 grams silver per metric ton, trace to 1.65 percent lead, up to 2.13 percent copper.
53	Garfield----- group, adit-group D.	Iron-oxide-stained shear zone a few-------- centimeters thick and 5 m long in quartzite country rock.	Three sloughed-pits.	One sample; trace gold, 3 grams silver per metric ton, 0.044 percent lead, and 0.026 percent zinc.
54	Scorpion----- Ridge prospect No. 2.	Contact between limestone and a granitic--- dike trends S. 75° E., and dips 65° NE. Zone is heavily limonite stained with minor copper staining. No visible sulfides.	Two prospect--- pits, one adit 9.1 m long.	Two samples; as much as 0.3 gram gold and 14 grams silver per metric ton, 0.05 percent lead, and 0.08 percent zinc.

55	Scorpion Ridge prospect No. 1.	Replacement-type deposits in limestone at the intersection of bedding-plane and high-angle cross faults. The main cross fault trends southwest for 46 m, and averages 0.9 m in thickness. A second cross fault is exposed for 38 m and averages 0.8 m in thickness. Galena, pyrite, and arsenopyrite are present in small lenses.	One adit, 59 m long, one inclined shaft, two small pits.	Nine samples; seven samples from main high-angle fault; average 48 grams silver per metric ton, 1.25 percent lead, 1.69 percent zinc. Two samples from second fault; average 96 grams silver per metric ton, 4.70 percent lead, and 1.41 percent zinc.
59	John A. Logan.	Small iron-oxide-stained shear zone in limestone.	One adit	One sample; trace amounts of metals.
61	Monarch fraction.	Bedding-plane shear zones in quartzite and limestone range in thickness from a few centimeters to 0.46 m. The zones strike northeast and dip westerly and easterly. The zones are heavily limonite stained and vuggy.	Two adits, 7.6-m, 22.9 m long. One shaft 3.7 m deep, and one prospect pit.	Four samples; three samples averaged 110 grams silver per metric ton, 2.74 percent lead, and 1.4 percent zinc. One sample across a 0.3-m-thick shear; 384 grams silver per per metric ton, 11.1 percent lead, and 1.57 percent zinc.
62	Smuggler	Fault zones in limestone and calcareous country rock. The fault zones are as much as 1.2 m thick and contain little sulfide mineralization. Contacts between dikes and country rock are barren. Shear that averaged 0.3 m thick contained highest assay values.	Two adits, with 187 and 276 m of workings. Two pits.	Sixteen samples; 14 samples; nil to 127 grams silver per metric ton, as much as 4.73 percent lead and 4.53 percent zinc. Two select samples; 360 and 401 grams silver per metric ton, 7.17 and 18.8 percent lead, and 7.82 and 10.90 percent zinc.
64	Prospect	A 0.6-m-thick, heavily limonite stained brecciated fault zone in a dark-gray to black argillite. The zone can be traced only 15 m.	Two adits, one 4.6 m long, and one caved.	Two samples; one sample across the zone; 24 grams silver per metric ton, 0.15 percent lead, and a trace gold, copper, and zinc. One select dump sample; 240 grams silver per metric ton, 2.23 percent lead, and 0.82 percent zinc.

TABLE 24.—*Miscellaneous properties, Little Wood River district*—Continued

Map No.	Property name	Summary	Number and type of workings	Sample data
65	Prospect-----	A 0.3-m-thick brecciated fault zone and a 2.1-m-thick rhyolite dike in dark-gray to black argillite.	Two pits-------	Two samples; samples from fault zone; 1.00 percent lead and trace gold and copper. Sample from dike; trace amounts of metals.
66	Trudy B. No. 1.	A contact between a 1.8-m-thick rhyolite dike and volcanic country rock.	One caved adit, trends S. 50° W., probably more than 30 m long.	Sample across the dike; trace amounts of metals.
67	Prospect-----	Dump material is black, carbonaceous argillite with small pieces of quartz and siderite. No sulfides were observed.	One caved adit, less than 30 m long.	One select dump sample; 3 grams silver per metric ton and trace amounts of metal values.
68	Copper Bell group.	Numerous, randomly oriented quartz fracture fillings in contorted argillites and slates. The largest fracture filling is 1.1 m thick and traceable for 24 m. Sulfides in zone consist of pyrite, galena, and sphalerite, totaling less than 5 percent of rock.	Four adits, 11 m, 69 m, 98 m long, and one caved. Two shallow water-filled shafts and five small pits.	Sixteen samples; trace gold and as much as 17 grams silver per metric ton, 1.84 percent lead, 0.21 percent zinc, and 1.04 percent copper.
69	Prospect-----	Dump material is black carbonaceous argillite with small pieces of limonite-stained quartz. No sulfides were observed.	Caved adit----- less than 30 m long.	One select dump sample; 3 grams silver per metric ton and trace amounts of other metal values.
70	Snowball----- group.	Small, weakly mineralized bedding-plane shear zones in limestone with interbedded shale and quartzite. The zones are lightly iron oxide stained, contain no visible sulfides, and are discontinuous. A few scattered pieces of material are malachite stained.	Two sloughed pits.	One grab sample; 24 grams silver per metric ton, 1.84 percent lead, 0.08 percent zinc, and 0.04 percent copper.

71	Hecla- ------ Carrier.	Small scattered replacement deposits in--- limestone along an east-trending fault zone dipping 70°-75° S. Outcrop length of fault zone is about 90 m; it is as thick as 0.9 m, averaging about 0.3 m.	Two adits, 38-- m, 55 m long. One pit.	Thirteen samples; 11 chip samples from two adits; averaged (weighted by length) 151 grams silver per metric ton, and 0.21 percent copper. Two samples; as much as 6.7 grams silver per metric ton, 5.68 percent lead, and 4.22 percent zinc.
72	Silver Mint-- Nos. 1 and 2.	Shear zones with quartz-vein fissure------ fillings as much as 0.5 m thick, that parallel and crosscut bedding in northerly trending limestone beds. Heavy limonite staining and some malachite staining along zones which contain pyrite and some scattered lead-zinc sulfides.	Two adits,----- one caved, one pit.	Four samples; trace gold, as much as 374 grams silver per metric ton, 0.7 percent copper, 3.09 percent lead, and 2.12 percent zinc.
73	Prince Pine-- group (Drummond mine).	Small cross faults, bedding-plane faults-- and small aplite dikes in limestone. Country rock strikes northerly and dips 55° E. Dikes strike N. 30° E., and dip steeply to the south. Heavy limonite staining near shear zones, and some copper carbonates occur on footwall.	Two small------ adits, one caved.	Two samples; trace gold, as much as 27 grams silver per metric ton, and 0.54 percent copper.
75	Prospect-----	No mineralized rock in place. Adit dump-- consists of andesite and some limonite-stained pyritized barite.	Caved adit,---- trends north, probably less than 30 m long.	Grab sample of barite; trace amounts of metal values.
76	Prospect-----	Altéred rhyolite that is heavily limonite-stained and siliceous. No ore minerals seen.	Caved adit probably less than 30 m long.	One dump sample; 17 grams silver per metric ton and trace copper and lead.
77	Mona F.----- group.	Green andesite.	None.	One sample of andesite; no significant metal values.

TABLE 25.—*Summary of recorded mining claims, 1880–1973, Copper Basin district*

Decade	No. of lode claims
1880-89	44
1890-99	13
1900-09	17
1910-19	3
1920-29	10
1930-39	2
1940-49	32
1950-59	37
1960-69	104
1970-	27
Total-----	[1]289

[1]As of June 1, 1973.

valued at about $7,500. Umpleby (1917, p. 103) stated that about $50,000 of ore was produced from the Star Hope mine prior to 1917. Recent activity has been limited to sporadic assessment work.

Mineralized areas in the district are the upper canyon of Star Hope Creek and the basin at the head of Lake Creek. Although several occurrences of metals are known, the deposits are apparently small, low grade, erratic, and difficult to explore.

STAR HOPE MINE

The Star Hope and Gold Dollar patented claims (pl. 4, No. 32) are near the head of the canyon of Star Hope Creek. Elevation of the main portal is about 9,160 ft (2,800 m).

The claims were located and patented in 1889. The majority of exploration and development work was done during the 1890's. The property was last worked in 1954. Umpleby (1917, p. 105) reported that $50,000 of lead-silver ore was said to have come from the mine. The property was examined in 1955 by a DMEA field team. Because permission was not granted, the property was not examined during the present investigation, nor is DMEA information included in the following description.

Rocks in the vicinity of the mine are carbonaceous argillite and quartzite with thin interbeds of limestone intruded by rhyolite and granitic dikes. The sedimentary strata are folded and crumpled and generally strike northwest and dip northeast. Galena, tetrahedrite, and chalcopyrite occur in quartz veins, along fractures across the veins, and in brecciated portions of the veins.

The mine consists of five levels, totaling about 2,150 feet (655 m) of underground workings, ranging in elevation from 9,160 to 9,460 ft (2,800 to 2,880 m).

Based solely on past production, additional ore shoots and (or) significant amounts of resources may remain.

MACKINAW GROUP

The Mackinaw group of three patented claims is on the west side of Star Hope Creek about 3 mi (5 km) south of the Copper Basin road (pl. 4, No. 30). The main workings are at about 8,400 ft (2,560 m) elevation.

The Mackinaw claims were located in 1899 and 1906, and patented in 1913. U.S. Bureau of Mines recorded 80 tons (73 t) of ore produced in 1954, but it is believed that as much as 300 tons (270 t) of ore may have been mined from the main adit. The recovered content from listed production was 2.44 oz silver per ton (83.7 g/t), 5.0 percent copper, 12.0 percent lead, and 8.2 percent zinc, valued at about $6,850.

The main workings are in a small wedge-shaped block of limestone in fault contact on the west and south with argillites, and mantled on the northeast side by alluvium. The limestone beds have been contorted and fractured along and across bedding planes. The country rock generally trends northwest and dips moderately to the northeast. The largest and best occurrence of sulfides is in a zone along a bedding plane exposed in the main workings. The zone strikes N. 35° W. and dips 50° NE. Stringers and blebs of galena, chalcopyrite, and sphalerite are in a gangue of brecciated country rock and quartz. The average thickness of the zone is about 4 ft (1.2 m).

The main working is an irregularly shaped excavation, 20 by 40 ft (6.1 by 12.2 m). In addition, six small adits and pits have been dug.

Three samples of the zone contained weighted averages of 19.3 oz silver per ton (662 g/t), 7.01 percent copper, 13.6 percent lead, and 5.7 percent zinc.

The zone was not observed on the surface because of moderately thick soil. Because the dip of the mineralized zone is greater than the slope of the surface, any updip extension would be expected to crop out in less than 50 ft (15. m). If the zone continues downdip, a minable resource may be present.

MISCELLANEOUS PROPERTIES

Several properties in the district with little or no economic potential or insufficiently exposed to permit evaluation were examined. These properties are listed in table 26.

TABLE 26.—*Miscellaneous properties, Copper Basin district*

Map No.	Property name	Summary	Number and type of workings	Sample data
28	Prospect-----	A series of narrow, pyritized shear zones in granodiorite. The shear zones strike N. 55° to 60° E. and dip 35° NW. The granodiorite between the shear zones has been silicified and limonite stained. The sheared area is 3.4 m thick, 3.0 m wide, and 9 m long. The pyritized shear zones are 0.3-0.9 m apart and average 5 cm thick.	One adit, 4.6 m long.	Two samples; trace gold and 17 grams silver per metric ton.
29	Ajax group---	An altered, brecciated zone in quartzite near a granodiorite contact. The zone trends N. 60° E. and dips 50° SE; it is conformable with the quartzite country rock. The zone is irregular and ranges from 1.8 to 3.0 m in thickness and is exposed for about 50 m along strike, is heavily limonite stained, and in places contains pods of pyrite. Narrow cross fractures are in places filled with galena.	Three pits, one caved inclined shaft, and one caved adit.	Five samples across the zone; as much as 82 grams silver per metric ton and 0.99 percent lead.
	Bent Pine Tree group.	Contact alteration zones as much as 1.5 m thick in limestone adjacent to porphyry dikes.	Three adits, 5 m, 6 m, and 9 m long. One caved adit, estimated to be 6 m long, and one small pit.	Five samples; four samples across zones; averaged trace gold, 7 grams silver per metric ton, 0.08 percent copper, 0.08 percent lead, and 0.09 percent zinc. Grab sample of iron-oxide-stained porphyry; trace gold, 17 grams silver per metric ton, 1.9 percent copper, 3.36 percent lead, and 2.6 percent zinc.

33	Candy Cane group.	Metal-bearing, fine-grained silicic and mafic dikes along fractures and fault zones, as much as 1 m thick in limestone and argillite.	Two adits, 4.0 m and 4.6 m long. Caved adit, estimated 25 m long, and a small pit.	Four samples; two samples of iron-oxide-stained argillite; trace gold. Two samples from fracture zones; 1.07 and 19.1 percent copper, one contained 0.85 percent lead, and 0.002 percent zinc.
34	Prospect	A 1.2-m-thick northerly trending shattered zone 15 m long and two northeast-trending shears in a pink to light-gray limy argillite. The shattered zone is silicified and contains stringers of calcite.	One adit, 37 m long.	Four samples; one sample from a 0.6-m-thick shear zone; trace gold, 24 grams silver per metric ton, 8.40 percent lead, and 6.89 percent zinc. Three samples from other zone; averaged trace gold, 7 grams silver per metric ton, 0.43 percent lead, and 0.89 percent zinc.
36	Prospect	A milky-white to clear quartz vein in diorite-porphyry intrusive. The vein strikes N. 45° E. and dips vertically. It ranges from 0.1 to 0.2 m thick and is exposed for 15 m along strike.	One pit	One sample; trace amounts of metal values.
37	Prospect	Location of workings indicate a northeast-trending quartz structure in diorite. The structure is not exposed on the surface. Limonite-stained vuggy quartz on dumps.	Two adits, one caved, and a caved shaft.	One dump sample; 55 grams silver per metric ton and trace amounts of gold, copper, and lead.
39	Prospect	Limonite-stained andesite porphyry. No visible ore minerals.	Three shallow bulldozer cuts.	One sample; trace amounts of metal values.

LAVA CREEK DISTRICT

The Lava Creek district extends into the southeast corner of the study area (fig. 32). The district had a brief period of mining activity prior to the turn of the century, particularly from silver mines a few miles (few kilometers) south of Antelope Valley in Butte County (Anderson, 1929, p. 30). Custer County records indicate that only a few claims were located on Right Fork Iron Bog Creek at the foot of Smiley Mountain. Only one claim was found, which apparently lacks mineral potential; it is discussed in table 27.

TABLE 27.—*Silver Bell property*

Map No.	Property name	Summary	Number and type of workings	Sample data
38	Silver Bell---	Quartz-filled, brecciated fracture zone as much as 0.46 m thick dipping 65° SE. to vertical on a trend of N. 20° E. Country rock is argillite. Zone locally contains 20 percent sulfides, chiefly pyrite and galena.	Two adits------	Two samples; as much as 175 grams silver per metric ton, 1.94 percent lead, 0.15 percent zinc, and trace amounts of gold and copper.

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