Geology and Mineral Deposits of the Minnie Moore and Bullion Mineralized Areas, Blaine County, Idaho

By Paul Karl Link *and* Ronald G. Worl

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Abstract

In the early 1880's the discovery of rich ores in the Minnie Moore and Bullion mineralized areas sparked a rush to settle and develop the Wood River valley. Silver and lead discoveries in these areas spurred the boom in mining after completion of the Oregon Short Line Railroad to Hailey in 1883.

In both areas the ore comprises galena, sphalerite, and tetrahedrite in a gangue of siderite, calcite, or quartz. Minor gold-bearing quartz veins are also present. The ore is in fissure and replacement veins along fracture systems that formed in Late Cretaceous time, after intrusion of nearby granodiorite or quartz diorite stocks. The ore formed under mesothermal conditions and heat was supplied by the nearby plutons. In the Minnie Moore area, the mineralized veins are cut by low-angle normal faults that are of probable Eocene age.

In the Minnie Moore mineralized area, the host rock is the middle part of the Devonian Milligen Formation, (the informal Lucky Coin limestone and Triumph argillite), which is the same stratigraphic level as the host ore in the rich Triumph mine northeast of Hailey.

In the Bullion mineralized area, the ore is hosted by the lower member of the Middle Pennsylvanian to Lower Permian Dollarhide Formation. Rich ore was mined in several tunnels that reached the Mayflower vein, a northwest-striking mineralized shear zone.

The deposits are thought to be mainly mesothermal veins that formed in association with Cretaceous magmatism. The syngenetic stratiform model of ore formation has often been applied to these deposits, however, no evidence of syngenetic mineralization was found in this study. Faulting has displaced most of the major orebodies and thus has made mining these deposits a challenge.

Introduction

Much of the early settlement of the Wood River valley in the 1880's stemmed from discoveries of silver-lead-zinc veins hosted by black argillite and limestone. The two most productive areas for the early miners were in the vicinity of the Minnie Moore mine (fig. 1, site 77) directly west of Bellevue and in the vicinity of the Bullion mine (fig. 1, site 14b) about 10 km (6.2 mi) west of Hailey up Bullion Gulch and Red Elephant Gulch (Elk Creek). The Minnie Moore and Bullion mines were commonly discussed in the early literature (Lindgren, 1900) and the "Wood River type" of lead-silver-siderite ore was extensively described in older economic geology textbooks (Lindgren, 1933). Detailed investigations of these areas were published by Umpleby and others (1930) when the mines were open and underground workings were accessible. Anderson and others (1950) presented the last detailed survey of the areas. After studying the trace element, sulfur isotope, and fluid inclusion data, Hall and Czamanske (1972) and Hall and others (1978) suggest that lead-silver deposits are mesothermal and formed by hydrothermal systems of meteoric water in faulted Paleozoic rocks near cooling plutons.

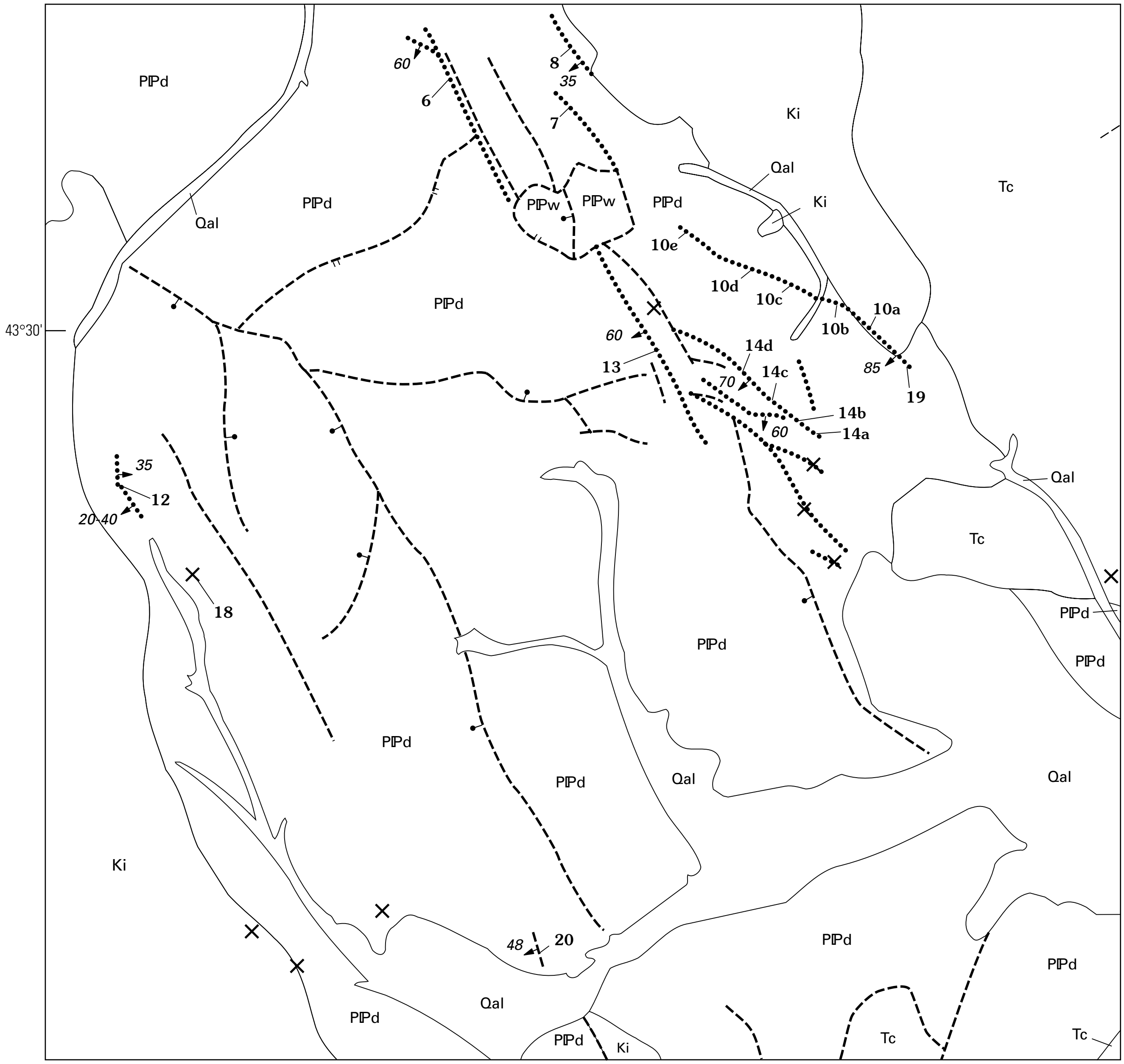
Hall (1985), in a geologic overview of the central Idaho black-shale mineral belt, assigned the host rocks in both areas to the Middle Pennsylvanian and to the Lower Permian Dollarhide Formation. Wavra and Hall (1989) further restricted this assignment to the upper member of the Dollarhide Formation. Our geologic mapping does not support these assignments; instead we place the Minnie Moore orebodies in the middle part of the Devonian Milligen Formation and the Bullion orebodies in the lower member of the Dollarhide Formation.

This paper briefly discusses the Minnie Moore (fig. 2) and Bullion (fig. 3) mineralized areas (see Worl and Johnson, 1995, page A2 for description of mineralized areas) in light of modern understanding of stratigraphic relationships. Previously unpublished geologic mapping conducted at 1:24,000 scale for both areas is presented and the important characteristics of the mineral deposits are reviewed, mainly by updating information contained in previous reports.

Historical Perspective

Past Production

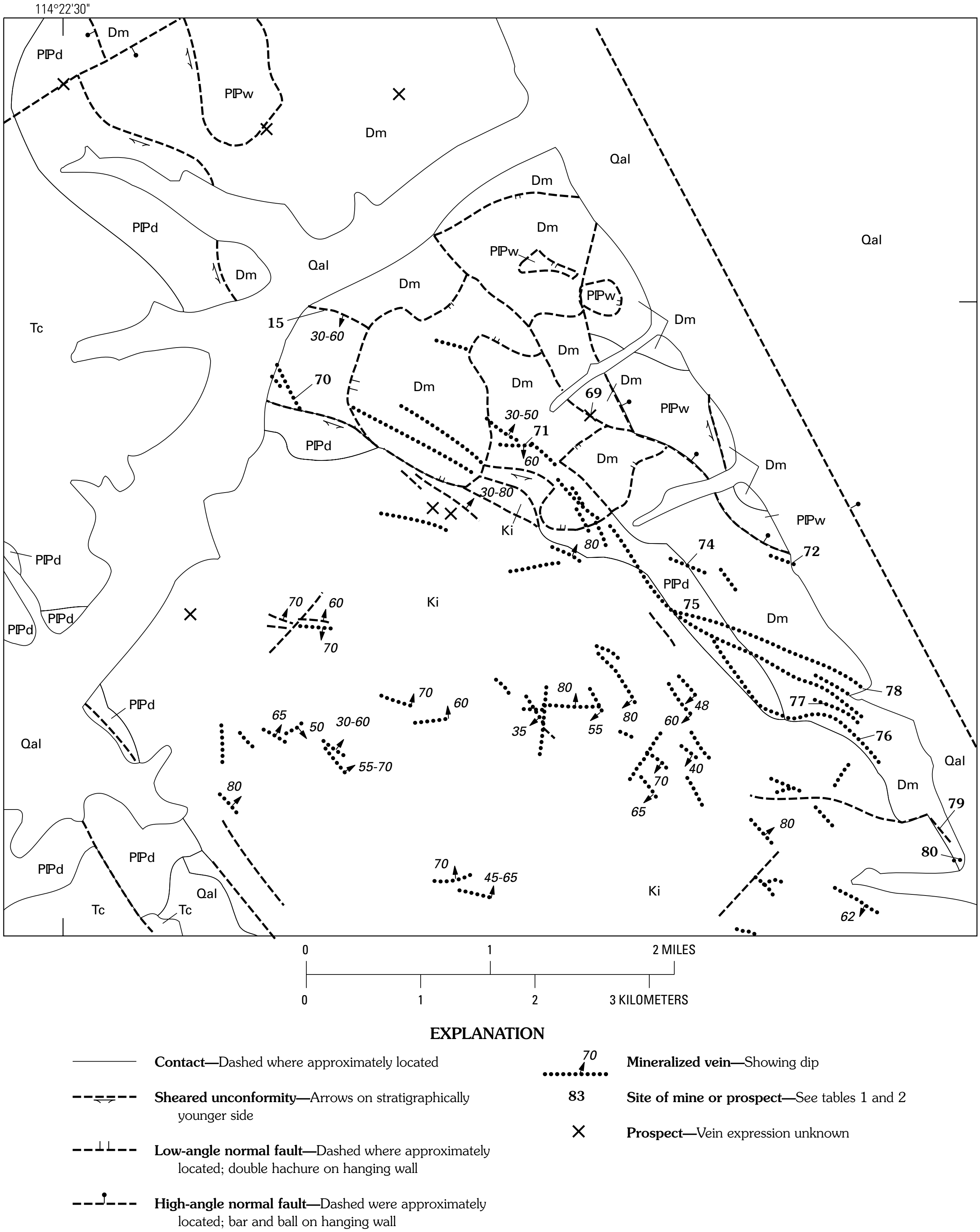
Ore was first discovered in the Wood River valley in 1880 at the site of the Minnie Moore mine (Hewett, 1930, p. 221). The 1880's were boom years. Construction of a large smelter in Ketchum in 1881 and completion of the Oregon Short Line to Hailey in 1883 and Ketchum in 1884 facilitated production.



EXPLANATION

Qal	**Quarternary surficial deposits**
Tc	**Challis Volcanic Group, undifferentiated (Eocene)**
Ki	**Cretaceous intrusive rocks associated with the Idaho batholith**
PIPw	**Wood River Formation (Lower Pennsylvanian to Middle Pennsylvanian)**
PIPd	**Dollarhide Formation (Lower Permian to Middle Pennsylvanian)**
Dm	**Milligan Formation (Devonian)**

Figure 1 (above and facing page). Geologic map with mines and prospects of the Minnie Moore and Bullion mineralized areas, Blaine County, Idaho. Mines and prospects, shown by number, correlate with tables 1 and 2: 6, Red Cloud mine; 7, Pass Group mine; 8, Narrow Gauge mine; 10, New York-Idaho Exploration Co. property; 10a, Idahoan mine; 10b, Eureka mine; 10c, Whale mine; 10d, Garfield mine; 10e, Baystate mine; 12, Wolftone mine; 13, Red Elephant mine; 14, Mayflower mine property; 14a, Ophir (Durango) mine; 14b, Bullion mine; 14c, Mayflower mine; 14d, Jay Gould mine; 15, Climax mine; 18, Black Barb mine; 19, Arizona Group mine; 20, Liberty Gem mine; 69, Rawhide 1, 2, and 3 prospect; 70, Commodore property; 71, Snoose mine; 72, Grover Crocker mine; 74, Sunshine prospect; 75, Oswego prospect; 76, Penobscot mine; 77, Minnie Moore mine; 78, Silver Star Queens mine; 79, McIrvin prospect; and 80, Telluride prospect.



The Minnie Moore mineralized area (fig. 2) has the largest historical production of silver, lead, and zinc in central Idaho. The major producers were the Minnie Moore (fig. 2, site 77), Silver Star Queens (site 78), and Snoose mines (site 71). The most significant period of production was from 1880 to about 1905, by which time all known deposits had been discovered and mined.

The Minnie Moore mine was developed in several stages. Underground workings were developed prior to 1884, but there

Table 1. Production information for the Minnie Moore and Bullion mineralized areas, Blaine County, Idaho.

[Sites are plotted by site numbers on figure 1]

Site no.	Site Name	Latitude (north) Longitude (west)	Production	Sources of data[1]
6	Red Cloud mine	43 31 5.35 114 26 50.3	Active between 1880 and 1902 with production of lead, silver, and gold worth $815,802. Active 1906–1925, 1941–1950, 1973; several thousand tons of ore yielded silver, lead, zinc, copper, and gold. Property developed on 11 levels; most production was from the number 9 level, 706 ft below the surface	1, 3, 6
7	Pass Group mine	43 30 58.48 114 26 5.98	Production during the period 1885–1899 was 198.3 tons of ore yielding 0.14 ounces of gold, 18,254.7 ounces of silver, and 242,372 pounds of lead; in 1911 7 tons ore yielding 99 ounces of silver and 1,571 pounds of lead; in 1940–1943 a few tens of tons yielding silver, lead and zinc	2, 3, 6
8	Narrow Gauge mine	43 31 15.20 114 26 3.03	Production during the period of 1883–1903 was 1,306.3 tons of ore that yielded 0.94 ounces of gold, 1,961 ounces of silver, and 19,650 pounds of lead	2, 3
10	New York–Idaho Exploration Co. property	43 29 56.60 114 24 57.7	During the period of 1883–1891 Eureka produced 1,079 tons that yielded 82,733 ounces of silver and 10,548,390 pounds of lead; Whale produced 253 tons that yielded 24,410 ounces of silver and 311, 089 pounds of lead; Bay State produced 197 tons that yielded 29,610 ounces of silver and 216,038 pounds of lead; Garfield produced 37 tons that yielded 4,053 ounces of silver and 43,003 pounds of lead; and King of Hill produced 47 tons that yielded 4,175 ounces of silver and 59,285 pounds of lead. During the period 1905–1923 Eureka produced 9,200 tons that yielded 0.02 ounces of gold, 144,962 ounces of silver, 1,755,000 pounds of lead and 12,268 pounds of copper. Eureka was also active in 1939 and 1968–1972, producing a few tens of thousands of tons of ore yielding significant silver, lead, zinc, copper, and some gold. Post-1902 production of a few tens of tons of ore from the Bay State and Whale yielded silver, lead, zinc, and copper	2, 3, 6
12	Wolftone mine	43 29 26.46 114 28 43.6	Several tunnels; the Sweed, the longest, totals about 2,000 ft. Production 1883–1898 totaled 262.3 tons yielding 0.13 ounces gold, 17,839 ounces silver, 244,583 pound lead, and 177 pounds copper. Production 1921–1927 of a few tons of ore yielded silver, lead, zinc and some copper and gold	3, 6
13	Red Elephant mine	43 29 55.50 114 25 34.6	9,000 feet of workings on six levels; most ore was from level 2, and none was from below level 5. Production during the period 1882–1900 was 8,231 tons that yielded 9.44 ounces of gold, 834,601 ounces of silver, and 8,655,493 pounds of lead and 781,433 pounds of copper; 1904–1918 6,927 tons that yielded 42.56 ounces of gold, 125,099 ounces of silver, and 853,409 pounds of lead; 1927–1947 a few thousand tons of ore yielded significant silver, lead, zinc, copper, and gold	1, 2, 3, 6

[Sites are plotted by site numbers on figure 1]

14	Mayflower mine	43 29 39.42 114 24 41.9	Production was from the Ophir, Bullion, Mayflower, Jay Gould, and other workings along one vein system. Jay Gould production during the period 1882–1906 was 40,019 tons yielding 4.78 ounces of gold, 422,565 ounces of silver, and 5,283,000 pounds of lead. Mayflower production during the period 1882–1901 was 3,606 tons yielding 545,493 ounces of silver and 4,308,000 pounds of lead. Bullion production during the period 1881–1908 was 3,276 tons yielding 485,182 ounces of silver and 3,518,000 pounds of lead. Ophir (Durango) production during the period 1888–1891 was 62.5 tons yielding 4,834 ounces silver and 24,205 pound lead. The Jay Gould (including the Apache workings) recorded several thousand tons of production, yielding silver, lead, zinc, copper, and gold in the period 1907–1917, 1925, 1933–1935, and 1948–1951. The Bullion has had intermittent production amounting to a few tens of tons of ore since 1908	1, 2, 3, 6
15	Climax mine	43 29 58.65 114 20 40.2	Production (mill) value of $80,000 1880's to 1950. Series of tunnels	1, 2, 3
18	Black Barb mine	43 29 1.74 114 28 19.3	Production 1889–1908 was 30.1 tons yielding 493 ounces gold, 1,741.7 ounces silver, and 29,862 pounds lead	2
19	Arizona Group mine	43 29 59.33 114 24 13.3	Production during the period 1888–1901 was 7.78 tons yielding 593 ounces silver and 7,781 pounds of lead; 1917–1918 65 tons yielding 3,637 ounces of silver and 57,610 pounds of lead; 1922–1925 silver, lead, and copper	2, 6
20	Liberty Gem mine	43 27 23.97 114 26 16.9	Worked intermittently since 1927; production of several hundred tons of ore yielded silver, lead, zinc, copper, and gold. Two shafts, 230 ft and 210 ft deep	1, 6
69	Rawhide 1, 2 & 3 prospect	43 29 27.53 114 18 56.0	Dozer cuts and 40 ft of tunnel	4
70	Commodore property	43 29 36.50 114 20 56.0	Dozer cuts and trenches, limited early production	5
71	Snoose mine	43 29 21.53 114 19 20.1	Production was prior to 1900, 1922–1923, 1930, 1941–1953. Production 1944–1950 4,416 tons yielding 181 ounces of gold, 16,997 ounces of silver, 445,766 pounds of zinc, 192,478 pounds of lead, and 16,398 pounds of copper. Several long tunnels and a 225 foot deep shaft; several hundreds of feet of working on the 100- and 200-foot levels	6
72	Grover Crocker mine	43 28 45.41 114 17 32.6	Worked intermittently prior to 1900, 1911–1940, and 1959–1961. Production (mill) value of $60,000 of lead-silver ore reported for the early days (prior to 1900); later production of a few hundred tons of ore yielded significant silver, lead, zinc, and some gold and copper. Four tunnels and an inclined shaft	1, 6
74	Sunshine prospect	43 28 45.18 114 18 18.3	Several tunnels	1
75	Oswego prospect	43 28 29.46 114 18 13.9	A few tens of tons of ore yielded silver and lead. Inclined shaft about 200 ft deep and five or six tunnels	1, 6
76	Penobscot mine	43 27 55.11 114 17 5.80	565-foot long tunnel and a 200-foot long tunnel. Production for 1883, 1887, 1900 totaled 1,005.6 ounces of silver and 17,000 pounds of lead	1, 2

Table 1. Production information for the Minnie Moore and Bullion mineralized areas, Blaine County, Idaho—*Continued.*

[Sites are plotted by site numbers on figure 1]

77	Minnie Moore mine	43 28 1.55 114 17 32.1	Extensive workings include three included shafts, the Minnie Moore at 30° to 1,100 ft slope length, the Relief at 20° to 800 ft slope length, and the Allen at 35° to a slope length of 850 ft, and the Rockwell vertical shaft that is 500 ft deep. Production 1881–1886 yielded 1, 059,205 ounces of silver and 14,206,266 pounds of lead; 1902–1906 57,632 tons of ore yielding 1,347,341 ounces of silver and 15,348,125 pounds of lead. From 1907–1926 reworked tailings from the Minnie Moore and Queen of the Hills mines and a small amount of crude ore totaling 60,896 tons yielded 109.7 ounces of gold, 212,977 ounces of silver, 1,896,349 pounds of lead, and 21,686 pounds of copper. The mine also recorded production in 1935 and 1941–1947. Promotional information circulated during the 1930's by various groups interested in the Minnie Moore mine listed a probable total production of 168,000 tons that averaged about 27 ounces silver per ton and 14.75 percent lead	1, 2, 3, 6
78	Silver Star Queens mine	43 28 12.22 114 17 22.7	750-foot long Moulton tunnel, the 2,475-foot long Lusk tunnel, and an inclined shaft to a vertical depth of 354 ft. Production 1884–1890 was 11,377 ton having a gross (mill) value of $1,265,608. The mine also recorded production in 1913–1914, 1923, 1926, and 1952–970. Total production to 1950 estimated at $2,500,000. Recorded post-1902 production of several hundred thousand tons of ore yielded significant silver, lead, zinc, and copper, and some gold and antimony	1, 2, 3, 6
79	McIrvin prospect	43 27 32.35 114 16 38.0	Four caved tunnels	1
80	Telluride prospect	43 27 19.33 114 16 28.7	Two closely spaced tunnels at the same level	1

[1]Sources of data:
1, Anderson and others (1950)
2, Umpleby and other (1930)
3, Lindgren (1900)
4, Staley (1962)
5, U.S. Geological Survey, Spokane Field Office, DMEA files
6, Mitchell and others (1991)

was only minor production. From 1884 to 1889, extensive operation yielded much of the mine's total production, and the mine was developed to the 900-foot level, at which point operations ceased because the ore was cut off at the flat Rockwell fault (fig. 2). Hewett (1930) gave an apparent profit for the period 1886–1889 of more than $625,000. The mine was reopened in 1900, and shortly after the continuation of the orebody was discovered below the Rockwell fault. This discovery spurred a major period of production from 1902 to 1906; however the orebody was found to be cut again at the 1000-foot level against the Minnie fault (fig. 2, section *A-A*'; fig. 4), and major operation ceased in 1906. Sporadic exploration to find a continuation of the orebody beyond the Minnie fault continued until 1927, at which time the mine was closed. During the period 1907–1920 tailings from previous operation were milled.

In 1932, the Rockwell shaft was sunk to explore the southeast extension of the Silver Star Queens (fig. 1, site 78, Queen of the Hills) vein, and three years later the Hershey crosscut was driven to explore the southeast extension of the Minnie Moore vein system. The mine was out of operation from about 1935 until the 1940's at which time the Rockwell shaft was reopened and the Queen of the Hills (Silver Star Queens) vein systems were mined. Some of the ore mined in the 1940s appears to have also come from the Minnie Moore mine and Minnie Moore footwall vein systems. The Silver Star Queens operations ceased in the early 1970's.

The Snoose mine (fig. 1, site 71), in Colorado Gulch north of the Minnie Moore and Silver Star Queens mines (fig. 2, section *B-B*'; fig. 5), had its major period of production during the 1940's. Several smaller mines near the Snoose produced small amounts of lead-silver ore on an intermittent basis from 1900 into the 1980's.

The Bullion mineralized area includes the Red Elephant mine (fig. 1, site 13) in Red Elephant Gulch and the Mayflower (site 14c), Bullion site (site 14b), Jay Gould (site 14d), and Ophir (site 14a) mines in Bullion Gulch (Fryklund, 1950). The four mines in Bullion Gulch are interconnected and lie along the major northwest-striking Mayflower fault zone (fig. 3, section *D-D*'; fig. 6). Very rich lead-silver ore was mined from 1880 to 1889 and the town of Bullion flourished. Old tailings were treated starting in the summer of 1949, after the construction of a 100-ton mill.

Exploration Activity

The region experienced several surges of exploration for base- and precious-metals that coincided mainly with periods of production of the major mines. The U.S. Government Defense Minerals Exploration Administration (DMEA) exploration program supported work in the Silver Star Queens mine during the 1950's.

The most recent systematic exploration activity in these areas took place during the early 1980's when the central Idaho black-shale mineral belt (Hall, 1985) was evaluated by several major mining companies for bedded syngenetic massive sulfide deposits. The Minnie Moore and Bullion mineralized areas were major targets because of host-rock lithology and the massive tubular nature of some of the orebodies. Exxon Minerals drilled several exploration holes in the Bullion area, and Getty Minerals supported new exploration and drilling in the Triumph area (Turner and Otto, 1995). In 1994, however, there is little exploration activity in either the Minnie Moore or Bullion areas. The two areas are close to the rapidly growing Wood River valley and any further mineral exploration will have to consider societal impacts of mining on this developing area.

Geologic Setting

Terrane Description

The Minnie Moore and Bullion mineralized areas are in carbonaceous argillite, limestone, and fine-grained sandstone of the Devonian Milligen Formation and the Middle Pennsylvanian to Lower Permian Dollarhide Formation, and are in the central Idaho black-shale mineral belt (Hall, 1985). The Paleozoic rocks are intruded by Late Cretaceous granitoids: the Croesus stock (quartz diorite) immediately west of the Minnie Moore area and the Deer Creek stock (granodiorite) immediately east of the Bullion area.

Host Rocks

Milligen Formation

The Minnie Moore mineralized area (fig. 2) is underlain mainly by the Devonian Milligen Formation. In the northeastern part of the area the Milligen lies unconformably beneath the Middle Pennsylvanian Hailey Member of the Wood River Formation. On the west side of the Minnie Moore area, the Milligen is interpreted to lie unconformably beneath the Middle Pennsylvanian to Lower Permian lower member of the Dollarhide Formation, although a basal conglomerate is not present and exposures are poor.

In the Triumph area, 16 km (10 mi) to the northeast, the Milligen Formation contains mappable informal members (Turner and Otto, 1988, 1995; Link and others, 1995). There, the Milligen Formation is at maximum 647 m (2,000 ft) thick and consists of a lower member of black argillite, purple siltite, and bedded chert (more than 48 m [150 ft] thick), a middle section containing black calcareous argillite and bedded chert (the informal Triumph argillite, as thick as 152 m [500 ft] thick), and lenticular intervals of coarse-grained sandstone (the informal Cait quartzite, 1–20 m [0–66] thick) and dark-gray to black carbonaceous silty limestone (the informal Lucky Coin limestone, as thick as 244 m [800 ft]). The upper 183 m (600 ft) of the Milligen Formation contains dark- to light-gray and brown fine-grained sandstone and minor black argillite, purple siltite, chert, and conglomerate (the informal Independence sandstone). Recognition of these members in the Minnie Moore area allowed mapping of the divisions shown on figure 2, although the units are generally thinner than in the Triumph area and the section is attenuated by faulting.

There has been disagreement, especially in the wave of exploration of the last fifteen years, about the formation assignment of the rocks in Minnie Moore and Bullion areas (compare our maps with those of Hall, 1985, and Wavra and Hall, 1989). Late in his life, W.E. Hall changed his assignment of the host rock in both areas from Milligen to Dollarhide Formation. C.S. Wavra carried this line of reasoning farther and assigned the host rocks in both areas to the upper member, Dollarhide Formation. The root of this stratigraphic confusion is that carbonaceous black shale or siltstone of the Triumph argillite (Milligen Formation) resembles similar fine-grained strata in both the upper and lower members of the Dollarhide Formation. Also, dark-gray limestone of the Lucky Coin limestone resembles similar limestones of the lower member of the Dollarhide Formation. Recognition in the Minnie Moore area of the stratigraphic units present in the Triumph area, and especially the coarse-grained sand grains of the Cait quartzite in the immediate area of the Minnie Moore mine supports, however, our interpretation that the strata belong to the Milligen Formation, as designated by Hewett (1930) and Anderson (1950).

Anderson (1950, p. 15) reported that mine geologists (R.T. and W.J. Walker) at the Minnie Moore mine informally divided the Milligen Formation from bottom to top into the Defiance argillite (±800 ft [248 m]), the Penobscot "formation" (containing 30 ft [9 m]) of lower Penobscot limestone, 40 ft [12 m] of intermediate argillite, and 80 ft [24m] of upper Penobscot limestone, and the Michigan argillite (±100 ft [30 m]). We interpret the Penobscot unit to correlate with the Lucky Coin limestone and the surrounding argillites to belong to the Triumph argillite and the lower argillite member. Quartzite is reported, though it is described as fine grained. Neither Hewett (1930) nor Anderson (1950) reported the coarse-grained sandstone beds that we correlate with the Cait quartzite.

Table 2. Description of mines and prospects in the Minnie Moore and Bullion mineralized areas, Blaine County, Idaho.

[Mines are prospects are plotted by site numbers on figure 1. First synonym is map number from Hustedde and others (1981) (for example 813), second synonym is the USGS Mineral Resources Data System record number (for example WO13678). Commodities are listed in approximate decreasing order of importance. Mineral deposit types: 19A, polymetallic replacement deposits; 22E, polymetallic veins in black shale; 22H, polymetallic quartz veins and lodes. Locations and information sources are given in table 1]

Site No.	Site name (synonyms)	Deposit type	Commodities present	Description
6	Red Cloud mine 158 WO13595	22E	Pb, Ag, Au, Cu, Zn	Three major vein systems: Red Cloud strikes N. 23° W. and dips at a high angle west; Hanging Wall, a splay off the Red Cloud strikes N. 50° W. and dips 60° SW.; and Ridge is an unproductive vein that strikes N. 45° W. and dips 70°–90° SW. Ore bodies are mostly galena and sphalerite in a siderite gangue that contains locally abundant quart and arsenopyrite.
7	Pass Group mine 159 WO13692 Argent claim	22E	Ag, Pb, Au	Main orebody is irregularly shaped and at the intersection of northwest-trending fracture systems in dark calcareous argillite. Ore is in clayey gouge zones as wide as 6 ft; the gouge is locally replaced by vein quartz. Abundant pyrite and sparse galena, sphalerite, chalcopyrite, and tetrahedrite are in the quartz.
8	Narrow Gauge mine 160 WO13698	22E, 22H	Ag, Pb, Zn, Au, Cu	Narrow fissure vein in black calcareous argillite strikes northwest and dips steeply southwest. High-grade ore consists of galena, sphalerite, and chalcopyrite that is present as streaks and bands in a siderite gangue.
10	New York-Idaho Exploration Co. Property 167 King of the Hills a. Idahoan 191 WO1390 b. Eureka 183 WO13605 c. Whale 182 WO13689 d. Garfield 174 WO13691 e. Baystate 161 WO13688	22H, 19A, 22E	Ag, Cu, Pg, Au	Several properties are along the main fracture system that trends N. 40° W. and along several subsidiary fracture systems. These fracture systems in places show little evidence of mineralization. Ore is present as fissure fillings and replacement of country rock in places in unfractured rock at a distance from the fissures. Ore consists of galena, sphalerite, and tetrahedrite in a gangue of crushed country rock, quartz, siderite, calcite, and pyrite. Ore was mostly low grade, averaging 8 percent lead and 9 ounces of silver per ton but locally was as high as 60 percent lead and 65 ounces of silver per ton.
12	Wolftone mine 171 WO13710	22E	Ag, Pb, Cu, Zn, Au	Deposits are along three vein systems. One system strikes about north and is vertical; a second strikes a little east of north and dips 35° E.; and the third strikes N. 30° W. and dips 20°–40° SW.
13	Red Elephant mine 172 WO13672	22E, 19A, 22H	Pb, Ag, Zn, Au, Cu	Ore consisting of galena, sphalerite, and tetrahedrite in a gangue of siderite, calcite, quartz, and pyrite is present as fissure filling and replacement along a major northwest-trending fault system. Host rock is dark calcareous argillite. The ore-bearing part of the fissure has roughly the form of a blunt wedge pointing downward. The vein is cut by a major fault with a 3–6-foot-wide zone of gouge that strikes N. 30° W. and dips 60° SW. Five distinct orebodies were worked, mostly on level 2. Much of the outcrop of the vein is a siliceous gossan as wide as 10 ft.

Table 2. Description of mines and prospects in the Minnie Moore and Bullion mineralized areas, Blaine County, Idaho—*Continued.*

[Mines are prospects are plotted by site numbers on figure 1. First synonym is map number from Hustedde and others (1981) (for example 813), second synonym is the USGS Mineral Resources Data System record number (for example WO13678). Commodities are listed in approximate decreasing order of importance. Mineral deposit types: 19A, polymetallic replacement deposits; 22E, polymetallic veins in black shale; 22H, polymetallic quartz veins and lodes. Locations and information sources are given in table 1]

14	Mayflower mine 179 WO13676 a. Ophir (Durango) b. Bullion 190 c. Mayflower d. Jay Gould 178	22E, 22H, 19A	Pb, Ag, Zn	The Mayflower vein strikes N. 50° W. and dips 45°–60° SW. Ore is in lenticular bodies as thick as 50 ft and several hundred feet long that formed from fissure filling and replacement of black calcareous argillite country rock. Some of the orebodies are flat-laying lenses that extend away from the fissure zone. Vein material is generally within distinct walls as much as 12 ft apart, but locally vein walls are indistinct and the vein is defined by disseminated calcite, siderite, and pyrite in argillite. Ore consists of galena, tetrahedrite, sphalerite, and minor chalcopyrite in a gangue of siderite and minor quartz and post-ore calcite. There is about 40 ft of oxidation, and the surface expressions are siliceous gossans. Higher grade ore averaged 90–125 ounces of silver per ton and 50–65 percent lead.
15	Climax mine 184 WO13662	22E	Pb, Ag, Zn, Au, Cu	Several mineralized fracture or fissure zones strike northwest and dip northeast; the main ore zone trends west and dips south as much as 60°. Host rocks are folded and extensively faulted carbonaceous and limey shale. Orebodies composed of galena, tetrahedrite, sphalerite in a gangue of siderite are offset by a series of almost flat faults.
18	Black Barb mine 189 WO13711	22E	Ag, Pb, Au	Unknown.
19	Arizona Group mine 192 WO13709	22E	Ag, Pb, Cu	Arizona vein strikes about N. 30° W., dips very steeply to the southwest, and is hosted by dark calcareous argillite.
20	Liberty Gem mine 234 WO13591	22E	Pb, Ag, Au, Zn	Three veins are reported, but only one has been productive. The productive vein is 30 in. thick, and strikes N. 15° W., and dips 48° SW. Irregular masses of lead ore are in fault gouge in a shear zone. A 1939 assay of crude ore was 0.15 ounces per ton gold, 18.4 ounces per ton silver, and 18.9 percent lead.
69	Rawhide 1, 2, & 3 prospect 185	22E	Zn, Ag, Pb, Au	Oxidized zone in shale contains oxide minerals of zinc, manganese, and iron in siderite gangue. One grab sample contained 0.02 ounces of gold per ton, 3.19 ounces of silver per ton, 12.5 percent zinc, and 2 percent lead.
70	Commodore property 193	22E, 22H	Zn, Ag, Pb	Calcite and quartz veinlets containing some siderite within the fractured zone and hanging wall of a 40–60-foot-wide northwest-trending, northeast-dipping fault zone. Sulfide minerals are present as disseminations in the black shale wall rock and the vein material and are mainly concentrated in the hanging wall.

Table 2. Description of mines and prospects in the Minnie Moore and Bullion mineralized areas, Blaine County, Idaho—*Continued.*

[Mines are prospects are plotted by site numbers on figure 1. First synonym is map number from Hustedde and others (1981) (for example 813), second synonym is the USGS Mineral Resources Data System record number (for example WO13678). Commodities are listed in approximate decreasing order of importance. Mineral deposit types: 19A, polymetallic replacement deposits; 22E, polymetallic veins in black shale; 22H, polymetallic quartz veins and lodes. Locations and information sources are given in table 1]

71	Snoose mine 194 Jensen-Stevens mine Dickey mine Pacific mine	22E, 22H	Ag, Pb, Zn, Cu, Au	Two types of mineralized veins are in the Snoose mine: polymetallic veins and a polymetallic quartz vein and lode. The two main polymetallic veins (Footwall and Hangingwall veins) are parallel, about 90 ft apart, trend northwest, and dip northeast. The Footwall vein strikes N. 45° W. and dips 50° NE. at the surface and 30° NE. at the 150 foot level. This vein is 2–18 ft wide. The Hangingwall vein is in a shear zone that is about 40 ft across. Strike of the vein ranges from N. 28° W. to W. Dip of this vein system ranges from 57°–64° NE. on the footwall and from 65° to 75° NE. on the hanging wall. Ore composed of brownish sphalerite, fine-grained galena, tetrahedrite, pyrite, marcasite, and minor amounts of qaurtz and siderite is distributed in the shear zone as bunches and stringers. One bin of ore contained 25–30 percent lead, 20 percent zinc, 75 ounces of silver per ton, and .22 ounces of gold per ton. The polymetallic quartz vein and lode is similar to the veins in the Magdalena and Croesus mines (Worl and Lewis, in press) and may represent an eastern extension of those vein systems. This vein system, which strikes west and dips 60° S., contains an ore shoot 300 ft long and several ft wide that has values in gold and silver. The thin-bedded blackish argillite and limestone wall rocks strike about N. 55° W. and dip 60° SW.
72	Grover Crocker mine 195 WO13657 Queen Bess	22E	Ag, Pb, Zn, Au, Cu	Orebodies worked prior to 1900 were lodes 2–3 ft wide. Recently worked ore bodies consist of 6–12 inch zones of thin seams, small bunches, and pods of siderite with some brownish sphalerite, cubic and gneissic galena, and scattered crystals of arsenopyrite. This ore is associated with “rolls” with a northeast dip in a major crushed zone that strikes N. 80° W. and dips southwest. The black argillite host rocks show considerable variation in attitude.
74	Sunshine prospect 204 WO13660	22E, 19A	Pb, Ag	Several hundred feet workings in several short tunnels in argillite and black limestone. No data are available on the mineral deposits.
75	Oswego prospect 205 WO13658	22E, 19A	Pb, Ag	Workings explore three mineralized zones. (1) A bedded vein in white marblized limestone with walls about 6 ft apart, but no visible ore remains. (2) A vein in white marblized limestone composed of several feet of oxidized material and strikes N. 20°–30° W. and dips 60° NE. (3) A zone of fissuring 8–10 ft wide in argillite strikes N. 35°W., dips 70° SE. and contains prominent bands of iron and manganese oxides.
76	Penobscot mine 218 WO13653 Riverview	22E, 19A	Pb, Ag, Sb, Zn	A N. 9° W. -trending shear zone that dips 60°SW. in shale and argillite contains some pods and stringers of quartz and calcite, and in places galena, arsenopyrite, stibnite, and sphalerite. In one location siderite, sphalerite, and pyrite are present as replacement of shale.

Table 2. Description of mines and prospects in the Minnie Moore and Bullion mineralized areas, Blaine County, Idaho—*Continued*.

[Mines are prospects are plotted by site numbers on figure 1. First synonym is map number from Hustedde and others (1981) (for example 813), second synonym is the USGS Mineral Resources Data System record number (for example WO13678). Commodities are listed in approximate decreasing order of importance. Mineral deposit types: 19A, polymetallic replacement deposits; 22E, polymetallic veins in black shale; 22H, polymetallic quartz veins and lodes. Locations and information sources are given in table 1]

77	Minnie Moore mine 219 WO02482 Relief 213	22E, 19A	Ag, Pb, Cu, Au, Zn	Several roughly parallel fissure veins of northwest strike and southwest dip are in argillite and limestone a short distance from the contact of quartz diorite and sedimentary rocks. The veins dip approximately parallel to the contact. The Minnie Moore vein strikes west-northwest and dips 25°–35° SW. but in places is almost horizontal. This vein may be along a thrust fault that is almost parallel, with, but locally crosscuts bedding. The Minnie Moore orebody is blanketlike and varies considerably in thickness and grade. The ore zone is 1,200 ft long and composed of individual bodies as long as 400 ft and as wide as 18 ft. The orebody is zoned; the western zone composed of a band of massive siderite several ft thick containing 2 percent lead and 46 ounces per ton silver. The eastern zone is composed of calcite and sulfide minerals and the middle zone grades from sphalerite ore to calcite ore. There was no change in this pattern of zoning through 1,400 ft of depth. Most off the ore mined averaged 10 percent lead and 20 ounces per ton silver (milling ore). Some of the ore was direct shipping ore composed of solid galena that was in bands and lenses a few inches to 10 ft thick. The Minnie Moore vein system closely parallels, but does not cut the contact with the quartz diorite. The Bergman vein, which strikes N. 30° W. and dips 40°–45°W. also closely parallels the quartz diorite contact and follows a single lithologic unit and may be a continuation of the Minnie Moore vein. The McIrvin vein is 2,000 ft southeast along strike of the Bergman vein and is probably a continuation of that vein. Several veins in the Minnie Moore vein footwall have a similar northwest strike but dip at a steeper angle. Host rocks generally strike northwest and dip 30° SW. and are folded around an axis that plunges south.
78	Silver Star Queens mine 221 WO60186 Queen of the Hills	22E, 19A	Pb, Zn, Ag, Cu, Sb, Sn	Two parallel vein systems are about 100 ft apart; the Hangingwall vein strikes N. 70° W. and dips 60°–65° SW. and the footwall vein is a splay of the Hangingwall vein. The main orebody had a stope length of 500 ft and was made up of sulfide lenses, including dark-brown sphalerite, 2–6 ft thick. Ore is present as a fracture filling of open space and as a replacement of wallrock. Marcasite present as a film coating on the other sulfide minerals suggests that the calcite and marcasite may have been deposited at a later time. Host rocks of black siliceous argillite strike N. 40°–50° W. and dip 25°–35° SW. and are folded.
79	McIrvin prospect 231 WO13655	22E	Pb, Zn, Sb	A small vein strikes N. 60° W. and dips 60°SW. and is a possible extension of the Bergman vein in the Minnie Moore mine. Ore is reported to have been jamesonite, stibnite, and reddish brown sphalerite. Black argillite along the mineralized zones has been silicified and pyritized and locally contains massive quartz and much pyrite.
80	Telluride prospect 823 WO13656	22E	Pb, Zn	A vein of quartz and gossan in black argillite and gray limestone contains reddish sphalerite, galena, and some pyrite. The vein strikes N. 70° E. and dips steeply southeast.

Dollarhide Formation

Regionally the Dollarhide Formation is as thick as 2,000 m (6,560 ft) (Wavra and others, 1986) and contains three informal members (Mahoney and others, 1991; Link and others, 1995). The strata present at the west end of Minnie Moore Gulch are thought to belong to the lower member of the Dollarhide Formation (more than 800 m [2,640 ft] thick) because they contain thick black limestone beds and gray sandstone beds that are nowhere coarser than fine grained, an attribute that distinguishes sandstones of the Dollarhide Formation from the coarse-grained sands of the Cait quartzite in the Milligen Formation. Further, as stated by Wavra and Hall (1989), limestones are uncommon in the upper member of the Dollarhide Formation; thus that assignment is doubtful for the ore hosts in Minnie Moore Gulch.

Structure and Metamorphism

Minnie Moore Area

In the Minnie Moore area, the Late Cretaceous Croesus quartz diorite stock to the west has produced contact metamorphism in limestones of the Milligen Formation. Minerals include diopside, tremolite, biotite, tourmaline, wollastonite, garnet, and scapolite(?) (Hewett, 1930).

The Minnie Moore area contains tight and locally eastward overturned map-scale folds (Lindgren, 1900), as well as local areas of mesoscopic folds. In several places in the Wood River area, including Colorado Gulch in the Minnie Moore area, the Milligen Formation contains two generations of folds, an earlier set of small-scale folds probably formed during the Devonian and Mississippian Antler Orogeny and a later large-scale set probably formed during the Cretaceous Sevier Orogeny (Turner and Otto, 1988, 1995; Burton and Link, 1995). Wavra and Hall (1989) used the presence of a cleavage or foliation as a means to distinguish Milligen Formation. We found, however, that structural fabric in the Milligen is heterogeneous and that the formation does not contain the same structural elements everywhere.

The mineralized Milligen Formation in Minnie Moore Gulch is at the crest of a regional anticline with Wood River Formation on the east and Dollarhide Formation on the west. In Minnie Moore Gulch, bedding in the Milligen Formation generally strikes northwest and dips steeply. This section is shown as west-facing and in stratigraphic order on the upright limb of an eastward overturned anticline on figures 2 and 4 (section *A-A*'). Detailed mapping would probably reveal local structural complexities in the overturned anticline. The argillites on the east end of Minnie Moore Gulch are tentatively mapped as the lower argillite member of the Milligen Formation.

Colorado Gulch

Several critical geologic relations were identified in Colorado Gulch that were key to the interpretation of the structure in the Minnie Moore area (fig. 2, section *B-B*'; fig. 5). The identification of the host rocks at the Snoose mine as Milligen or Dollarhide Formations, has been contentious. Hall (1985) and Wavra and Hall (1989) labeled these rocks as Dollarhide Formation, in contrast to earlier reports. We, however mapped the sheared Milligen-lower Dollarhide contact west of the Snoose mine (fig. 2). The ore-bearing vein in the Snoose mine is hosted by folded black argillite and limestone of the Lucky Coin limestone, Devonian Milligen Formation.

Our mapping shows several eastward overturned folds in the Milligen Formation and unconformably overlying Eagle Creek member of the Wood River Formation (fig. 2) in Colorado Gulch. Sheared pods of Hailey Member of the Wood River Formation are exposed along this unconformity. This contact was mapped as the “Wood River thrust fault” by Hall (1985), however it is now thought to be a locally sheared unconformity (Burton and others, 1989; Rodgers and others, 1995).

Rocks assigned to the lower member of the Dollarhide Formation are present on the west (upper) ends of Colorado and Star Gulches in a northward-widening band east of the Croesus stock. This is one of the few places where the Dollarhide and Milligen Formations are in contact. The exposed contact is sharp and linear, and beds are parallel across it. These features suggest that the contact is a sheared unconformity, comparable to the sheared unconformity between the Milligen and Wood River Formations; on the west limb of the anticline, the contact is exposed east of the Snoose vein (fig. 2, section *B-B*';fig. 5). A low-angle, shallow dipping, top-to-the-west normal fault cuts the upper parts of the Colorado Gulch. Between Colorado and Star Gulches, this fault cuts the Snoose vein in its footwall. The fault also cuts the ridge to the north of Colorado Gulch, but no members of the Milligen Formation were not mapped in this area.

Bullion Area

The Bullion mineralized area (fig. 3) is underlain by the lower and middle members of the Pennsylvanian and Permian Dollarhide Formation, which are folded into upright and west-overturned map scale folds (fig. 3, section *D-D*'). This is one of the few places in the Wood River area where folds verge westward.

The lower member of the Dollarhide Formation hosts most of the mineralized rock (Skipp and others, 1994). Fryklund (1950), following Umpleby and others (1930), labeled these rocks as Wood River Formation, though he notes, “it is possible that Milligen formation is also present” (p. 64). An unpublished map (circa 1970) of W.E. Hall labels the dark-colored rocks in the Bullion area as Milligen Formation. Hall (1985) showed the rocks as Dollarhide Formation, and Wavra and Hall (1989) showed them as upper member, Dollarhide Formation.

The lower member of the Dollarhide Formation in the Bullion area contains fine- to medium-grained sandstone, black siltite and black limestone or marble. A distinctive lithology in the lower member is channelized disorganized conglomerate that contains mainly intrabasinal soft-sediment clasts of siltstone and sandstone. The lower member occupies both sides of Bullion Gulch and the central part of Red Elephant Gulch. The rocks

EXPLANATION FOR FIGURES 2-7

Qal — **Quaternary surficial deposits**

Challis Volcanic Group (Eocene)

Tcd — **Potassium-rich dacite, latite, and trachyte lavas**—Includes a variety of lavas and flow breccias. Potassium-rich dacite dominates this unit and is strongly porphyritic containing as much as 30 percent phenocrysts of plagioclase and hornblende and lesser amounts of biotite and pyroxene; quartz and sanidine are rare. Proportion and amount of all phenocryst types vary greatly

Tcs — **Volcaniclastic sedimentary rock**—Includes sandstone and mudstone; locally contains woody fragments and other organic debris, and cobble to boulder conglomerate containing clasts of granodiorite (Skipp and others, 1994)

Cretaceous intrusive rocks associated with the Idaho Batholith

Kgdk — **Potassium-rich hornblende-biotite grandiorite**—Gray, medium- to coarse-grained, equigranular to porphyritic horneblende-biotite granodiorite and granite containing conspicuous books of biotite. Includes the informal Hailey granodiorite of Schmidt (1962) and Deer Creek Stock

Kqd — **Quartz diorite**—Brown, medium-grained, eqigranular pyroxene-biotite quartz diorite. Includes Croesus stock

Sun Valley Group (Lower Pennsylvanian to Middle Pennsylvanian)

PIPwe — **Eagle Creek Member (Lower Permian to Middle Pennsylvanian)**—Calcareous sandstone, sandy and silty limestone, quartz arenite, siltstone, and argillite (880-1,300 m). Defined by Mahoney and others (1991) to include units 3, 4, 5, and 6 of the Wood River Formation of Hall and others (1974)

IPwh — **Hailey Member (Middle Pennsylvanian)**—Pebble to boulder conglomerate and bioclastic limestone (0-200 m). Conglomerate contains clasts of argillite, chert, and fine-grained quartzite and interfingers with and is overlain by bioclastic and biostromal limestone (unit 2 of Hall and others,1974). Unit is revised from Hailey Conglomerate Member of Hall and others (1974) by Mahoney and others (1991)

Dollarhide Formation (Lower Permian to Middle Pennsylvanian)

Pdu — **Upper member (Lower Permian)**—Dark-colored and carbonaceous siltstone, silty and sandy limestone, argillite, and minor conglomerate (more than 900 m thick)

Pdm — **Middle member (Lower Permian)**—Light-colored, fine- to medium-grained calcareous sandstone, siliceous sandstone, sandy limestone, silty argillite, and minor conglomerate (300 m). Identical to sandy parts of the Eagle Creek Member, Wood River Formation

PIPdl — **Lower member (Lower Permian to Middle Pennsylvanian**—Dark-colored and carbonaceous calcareous sandstone, calcareous siltstone, sandy and silty limestone and marble, argillite, and minor granule to boulder conglomerate (more than 800 m thick). In Kelly Gulch contains phyllite foliated quartzite, and calc-silicate schist. Conglomerate overprint indicates conglomerate lens

Milligen Formation (Devonian)

Dm — **Milligen Formation, undifferentiated (Devonian)**—Black, generally cleaved, argillite and phyllite; black, thinly bedded quartzite; brown to maroon, calcareous sandstone and siltstone, black, carbonaceous limestone; gray sandy limestone; brown, finely laminated dolomite; and green to brown shales (more than 660 m). Near faults and fold axes the competent lithologies are generally well cleaved and tightly folded, whereas component units are generally boudined

Dmi — **Independance (Upper? Devonian)**—Light- to dark-gray and brown calcareous sandstone and siltstone, and siltstone in laminated and graded beds, green to purple shale, and black cleaved argillite (more than 183 m thick). Mapped only in Minnie Moore area

Dmt — **Triumph Argillite (Middle? Devonian)**—Black, well-cleaved argillite and phyllite and black, thinly bedded chert (as much as 152 m). Mapped only in Minnie Moore area

Dmc — **Cait quartzite (Middle Devonian)**—Distinctive black coarse-grained argillaceous sandstone (0-20 m). Unit is lenticular in the Triumph Argillite and in the upper part of the Lucky Coin Limestone. Mapped only in Minnie Moore area

Dmlc — **Lucky Coin Limestone (Middle? and Lower? Devonian)**—Black and dark-gray argillaceous thin- to medium-bedded limestone, black argillite (as much as 244 m thick)

Dml — **Lower member (Lower? Devonian)**—Black and dark-gray cleaved argillite and phyllite; black thinly bedded chert; and green to purple shale (more than 48 m thick). Mapped only only in Minnie Moore area

Contact—Dashed where approximately located

70 **Strike and dip of bedding with top determined**

Vertical bedding

70 **Overturned bedding with top determined**

Sheared unconformity—Arrows on stratigraphically younger side

Anticline—Showing overturn; arrows point down dip of axial plane

Syncline—Showing overturn; arrows point down dip of axial plane

Thrust fault—Dashed where approximately located, dotted where concealed, queried where uncertain

Low-angle normal fault—Dashed where approximately located, dotted where concealed, queried where uncertain; double hachure on hanging wall

High-angle normal fault—Showing dip. Dashed where approximately located, dotted where concealed, queried where uncertain; bar and ball on hanging wall

70 40 **Fault**—Showing dip of fault and trend and plunge of slickenlines on fault surface

Breccia

Dike

Adit; shaft

Line of cross section

Form lines showing bedding orientation in cross section

70 **Mineralized vein**—Showing dip (modified from Lindgren, 1899; Umpleby and others, 1930; Anderson and others, 1950). Some veins are named in the Mayflower, Eureka, and Minnie Moore areas. Some veins occupy fault zones; some are sheared or faulted

Mineralized fault

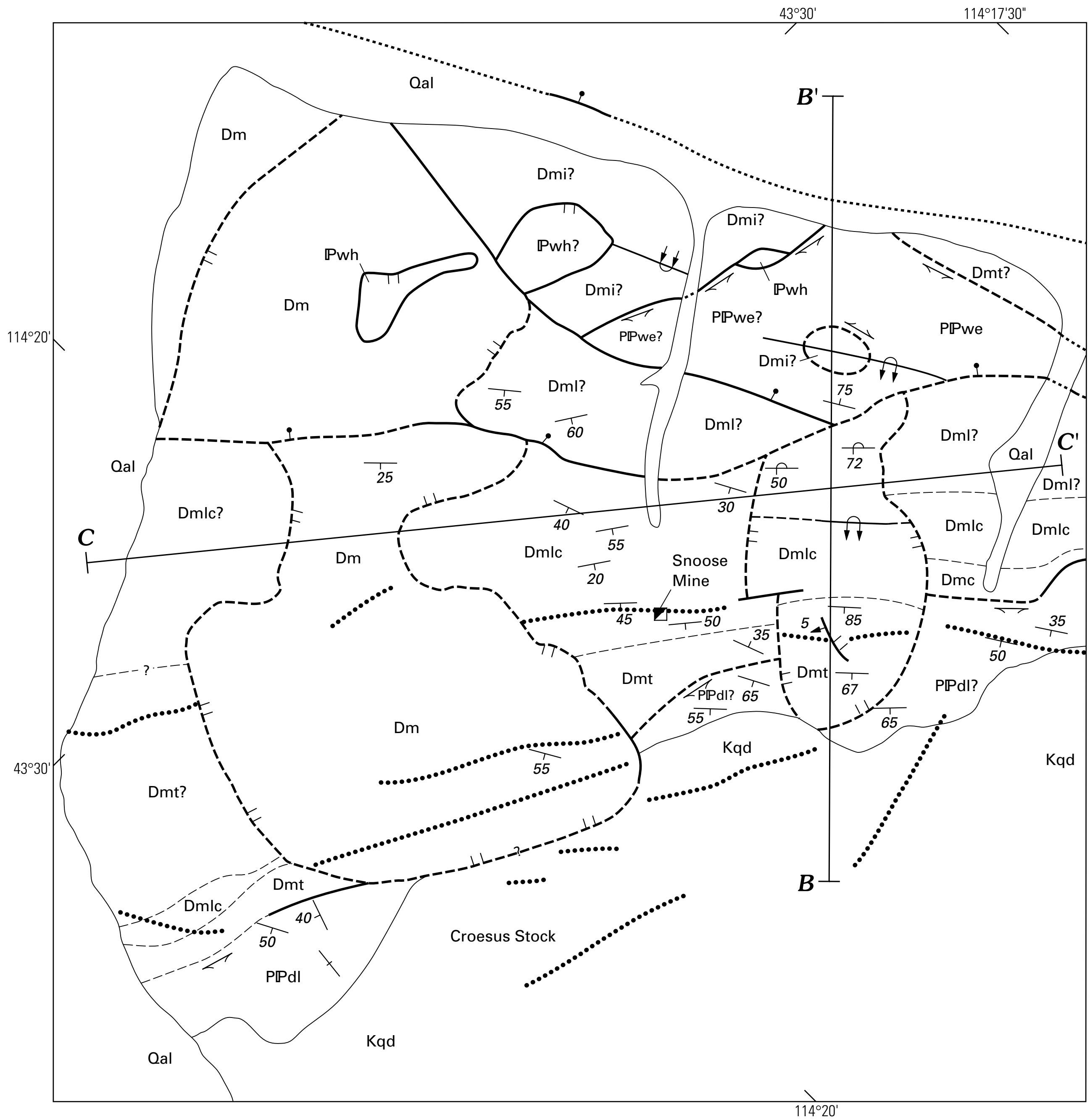


Figure 2 (above and facing page). Geologic map of the Minnie Moore mineralized area, Blaine County, Idaho.

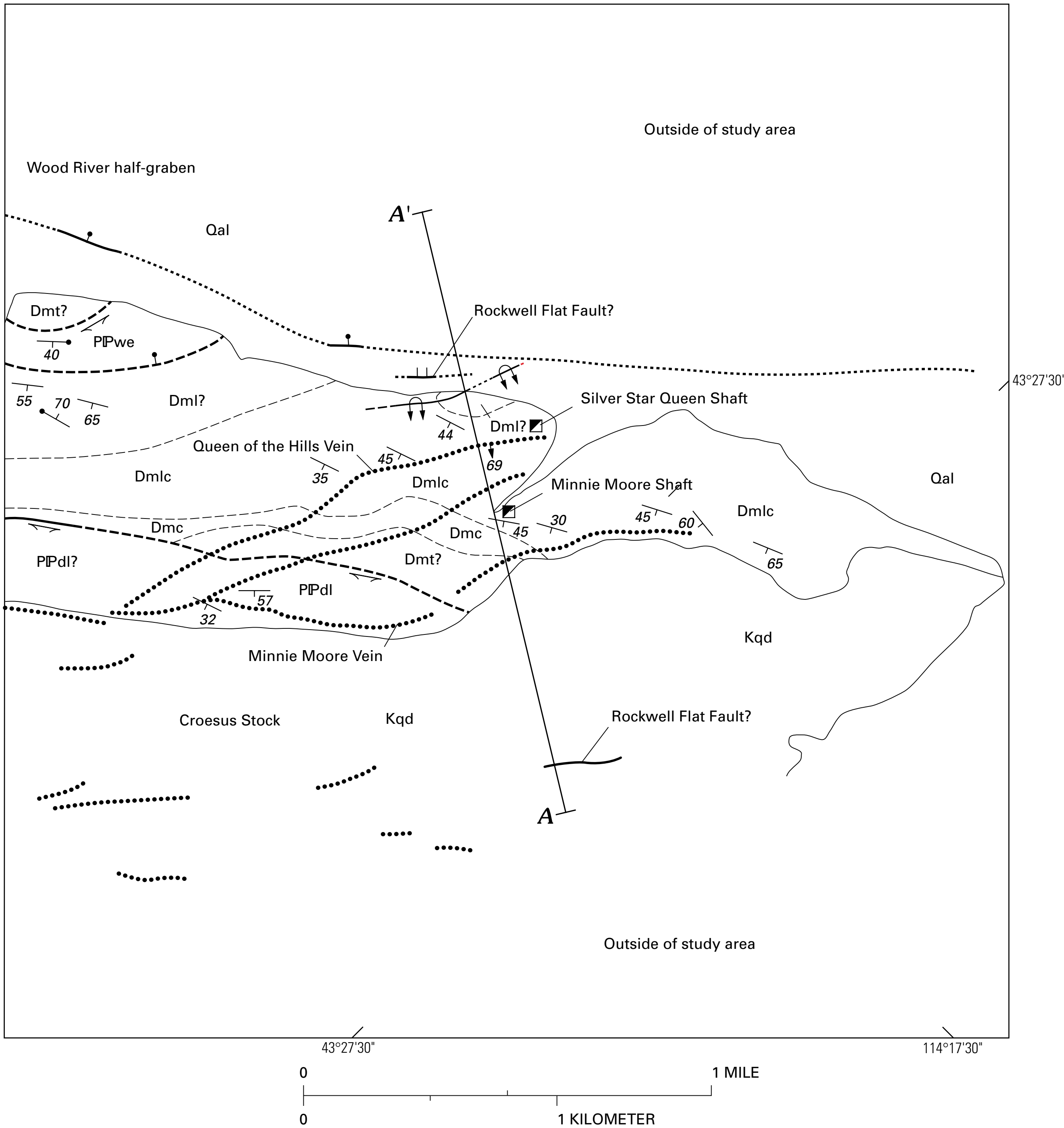
east of Bullion Gulch are mapped as being stratigraphically high in lower member Dollarhide Formation, because the middle member quartzite is not present. They are intruded on the east by the Deer Creek stock.

In the Bullion area the middle member of the Dollarhide Formation (regionally about 300 m [984 ft] thick) contains silicified sandstone that crops out as light-gray to brown quartzite that forms the high ridge between Red Elephant and Bullion Gulches. These rocks were shown as Wood River Formation on the map of Hall (1985). The mineralized veins of the Bullion area do not extend southward into the middle member Dollarhide Formation. The middle member, much less silicified, is also present in west-dipping beds on the ridge of Kelly Mountains.

Black shale or siltite on the west side of the Bullion area, west of the Kelly Mountain ridge (fig. 3), is tentatively identified as the upper member of the Dollarhide Formation.

Host Structures for Mineralization

Known ore deposits in the Minnie Moore and Bullion mineralized areas are localized along fault systems that formed during and after Late Cretaceous intrusion of plutons related to the Idaho batholith. These structural hosts include both high- to moderate-angle normal faults and low- to moderate-angle reverse faults. Veins along both types of faults are characterized



by changes in strike and both flattening and steepening of dip. There is evidence for contemporaneous and post-mineralization movement along many structures; however, maps of the area (Umpleby and others, 1930; Anderson and others, 1950; Hall, 1985; this paper) demonstrate that most of these mineralized fault systems or shear zones do not have mappable stratigraphic offset. Anderson (1950, p.11) accounted for this lack of offset by hypothesizing that faults along which there was significant movement are not mineralized either because "they contained so much gouge that the ore solutions could not enter or circulate along them, or because they are post-mineral."

Minnie Moore Area

Mineralized veins in the Minnie Moore (fig. 1, site 77) and Silver Star Queens (site 78, section *A*-*A*') mines strike northwest, subparallel with bedding (fig. 2, section *A*-*A*'; fig. 4). The

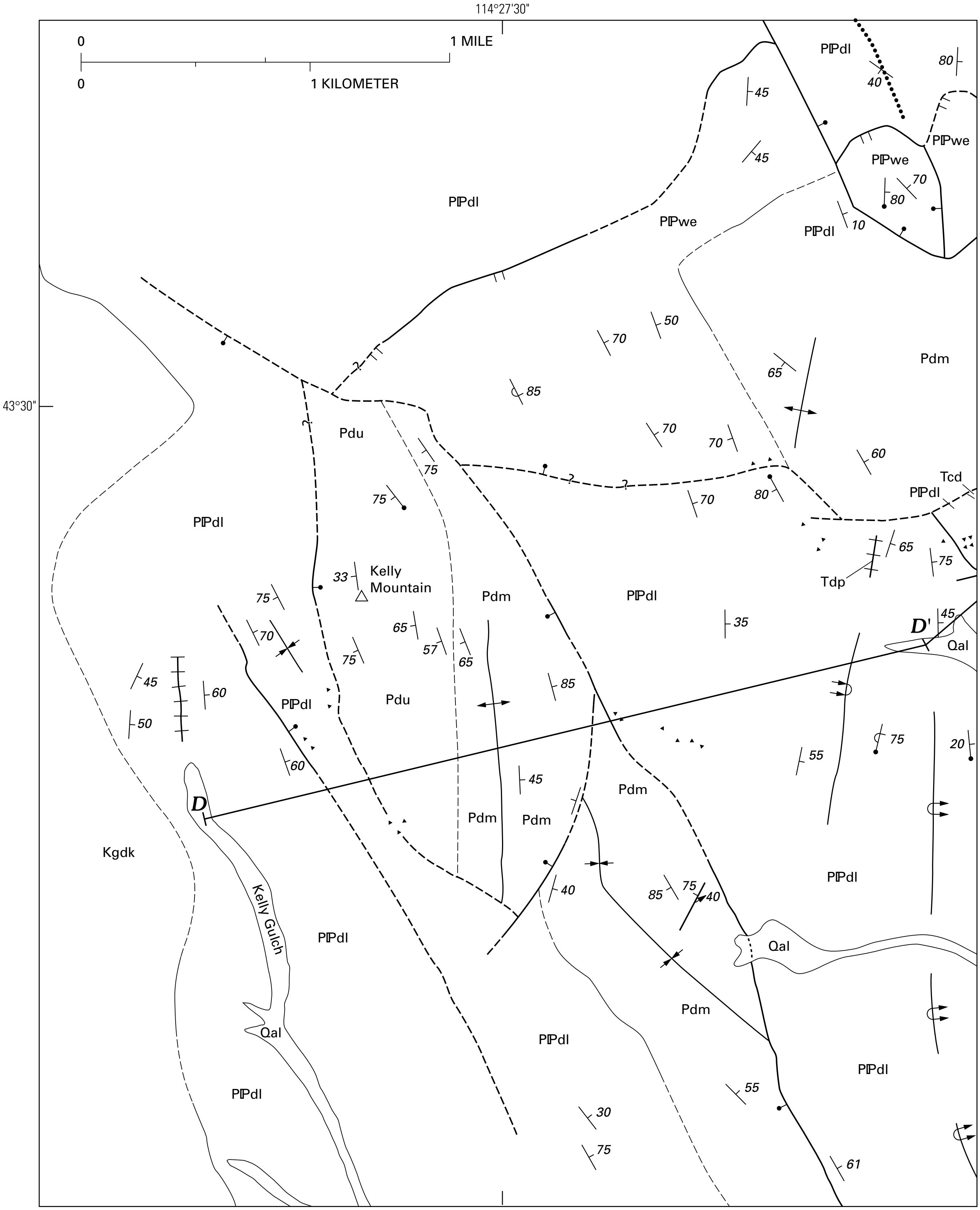
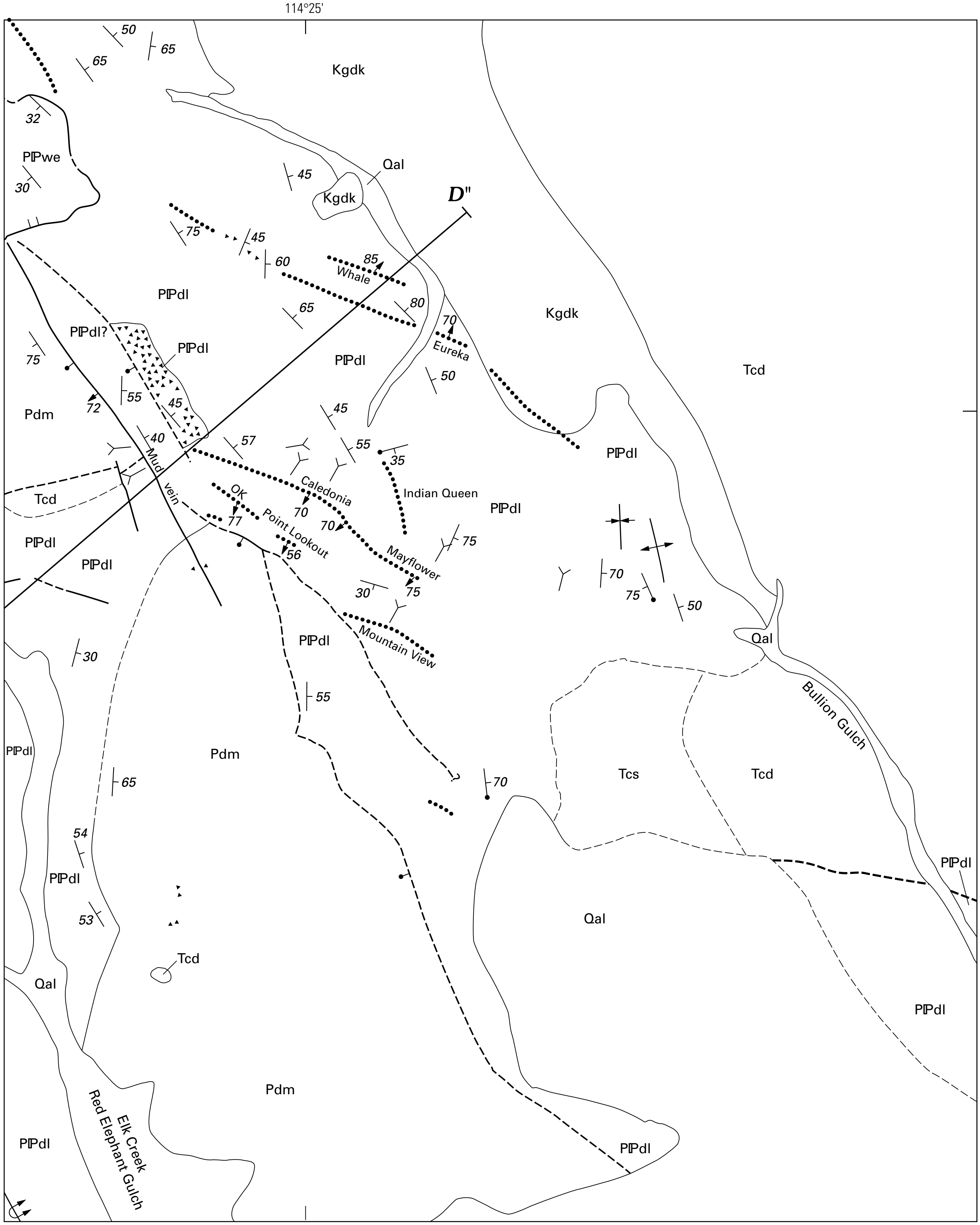


Figure 3 (above and facing page). Geologic map of the Bullion mineralized area, Blaine County, Idaho.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Mayflower
Mountain View
PPdl
Qal
Bullion Gulch
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Elk Creek
Red Elephant Gulch
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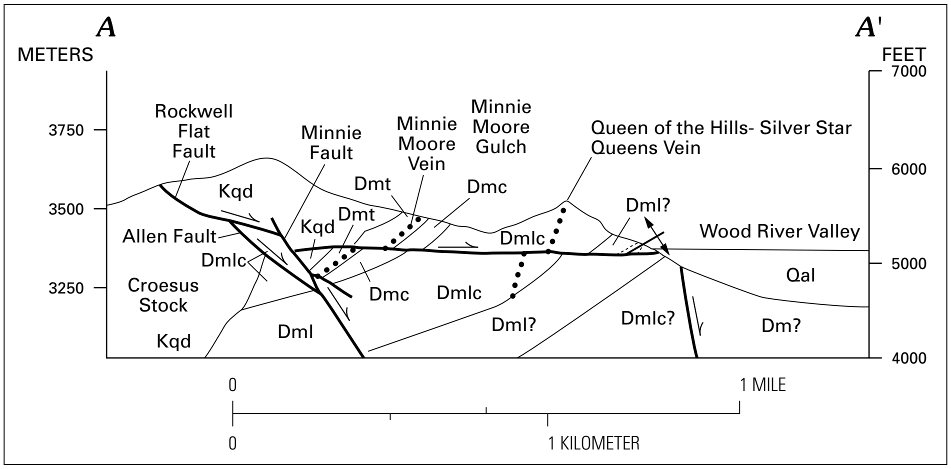

Figure 4. Geologic cross section *A–A'* through the Minnie Moore and Silver Star Queens veins, Minnie Moore mineralized area. Location of cross section shown on figure 2.

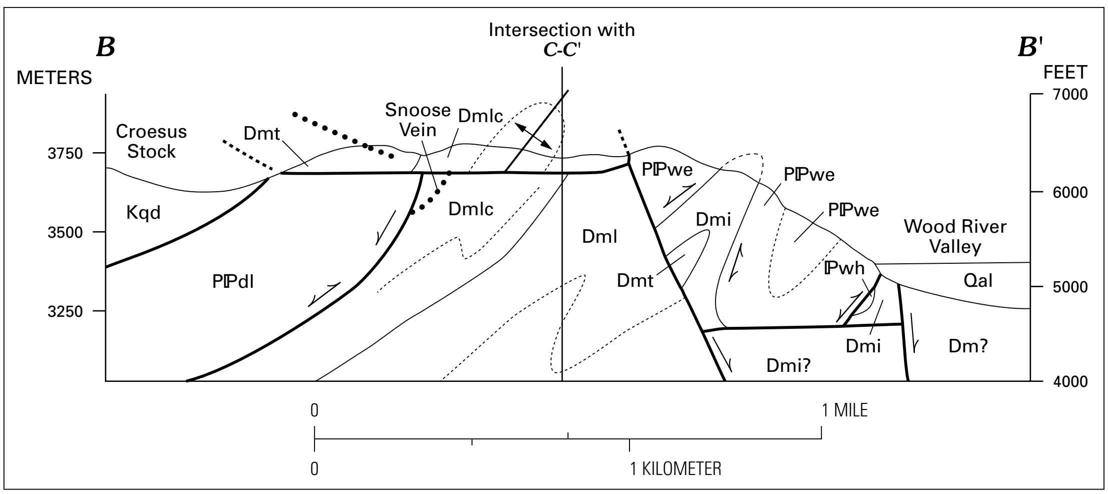

Figure 5. Geologic cross section *B–B'* through the Snooze vein, Minnie Moore mineralized area. Location of cross section shown on figure 2.

Minnie Moore vein was the richest of these veins and varied in dip from 25° to 35° SW., though in places it was almost horizontal (Anderson, 1950). The vein was never more that 200 ft (61 m) below the intrusive contact of the Croesus stock.

In Colorado and Star Gulches, ore is hosted by high-angle fracture systems (Snoose vein, fig. 1, section *B-B'*; fig. 5) that trend northwest and dip mostly southwest.

Bullion Area

Host structures for mineralized veins in the Bullion area are a system of almost parallel northwest-striking fractures of the Mayflower and Eureka fault systems, none of which have mappable separation at 1:24,000 scale (fig. 3). The Mayflower system strikes about N. 50° E. and dips 70°–85° to the southeast on the surface; underground the dip is as shallow as 30° (Anderson and others, 1950, p. 66). Although there are suggestions of reverse movement along many of the mineralized structures, the last movement as recorded by slickensides is either normal or horizontal. In the Bullion area some mineralized fractures or veins (including the Eureka vein, fig. 3, section *D-D'*; fig. 6) extend into the Deer Creek stock, but are not extensively mineralized in the granodiorite host rock.

Post-Mineralization Faults

Veins in the Minnie Moore mineralized area and quartz diorite of the Croesus stock are cut by several "post-mineral faults" (Hewett, 1930, p. 234-237). The Rockwell flat fault in the Minnie Moore mine has top-to-the-northeast offset of about 60 m (200 ft) (fig. 2, section *A-A'*; fig. 4). The northwest-striking Minnie oblique-slip fault cuts both the Rockwell flat fault and the Minnie Moore vein. The vein was not found again southeast of the Minnie fault, despite extensive exploration.

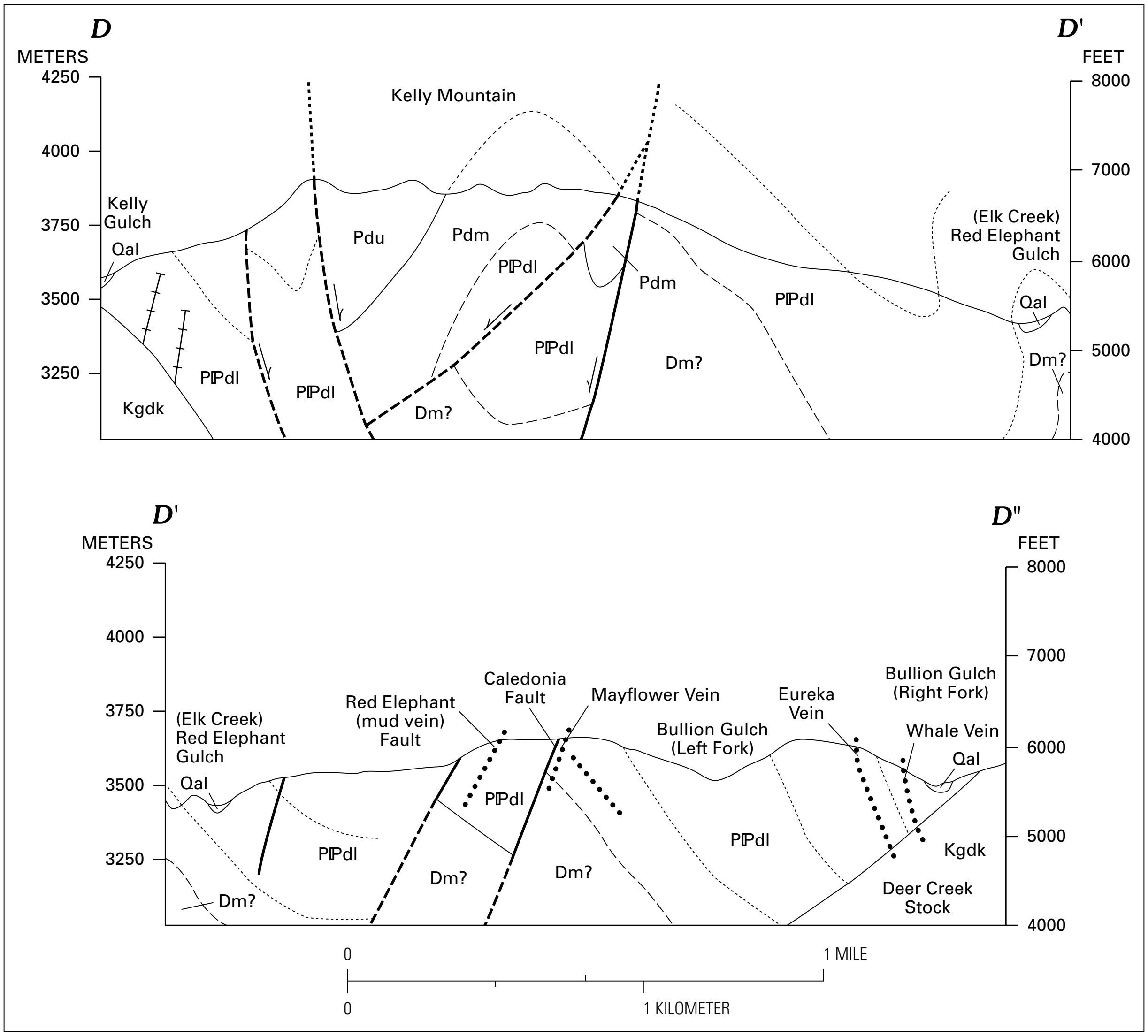

Figure 6. Geologic cross section *D–D′–D″* through the Red Elephant, Mayflower, Eureka, and Whale veins, Bullion mineralized area. Location of cross section shown on figure 3.

A major low-angle top-to-the-northwest normal fault terminates the mineralized veins north of Star Gulch (fig. 1, section *C–C′*; fig. 7)).

Mineral Deposits

Classification

Most ore deposits in the Minnie Moore and Bullion areas are in typical “Wood River-type” galena, sphalerite, tetrahedrite veins that have a siderite gangue (Lindgren, 1933; Hall and others, 1978). They are classified as polymetallic vein and replacement deposits by Worl and Johnson (1995) and consist of polymetallic fissure filling and replacement veins hosted by rocks of the Milligen and Dollarhide Formations (black shale terrane of Worl and Johnson, 1995). Replacement of sheared and broken host rock was the main mechanism for ore formation (Umpleby and others, 1930, p. 91). The replacement orebodies are generally aligned along fault zones. The orebodies are sharply defined lenses or shoots of varying size and distribution; the fracture systems otherwise show little evidence of mineralization or hydrothermal alteration. Gold-bearing polymetallic quartz vein and lode deposits (Worl and Johnson, 1995) characterized by quartz, pyrite, chalcopyrite and arsenopyrite are also present in the Minnie Moore area. These are most common in the intrusive rocks of the Idaho batholith (Croesus stock and the informal Hailey granodiorite of Schmidt, 1962) just to the west of the Minnie Moore area (fig. 1) (Worl and Lewis, in press). Where both types are present, commonly in the same structure, the polymetallic (siderite-lead-silver) veins are younger than the gold-bearing quart veins and lodes (Anderson and others, 1950, p.10).

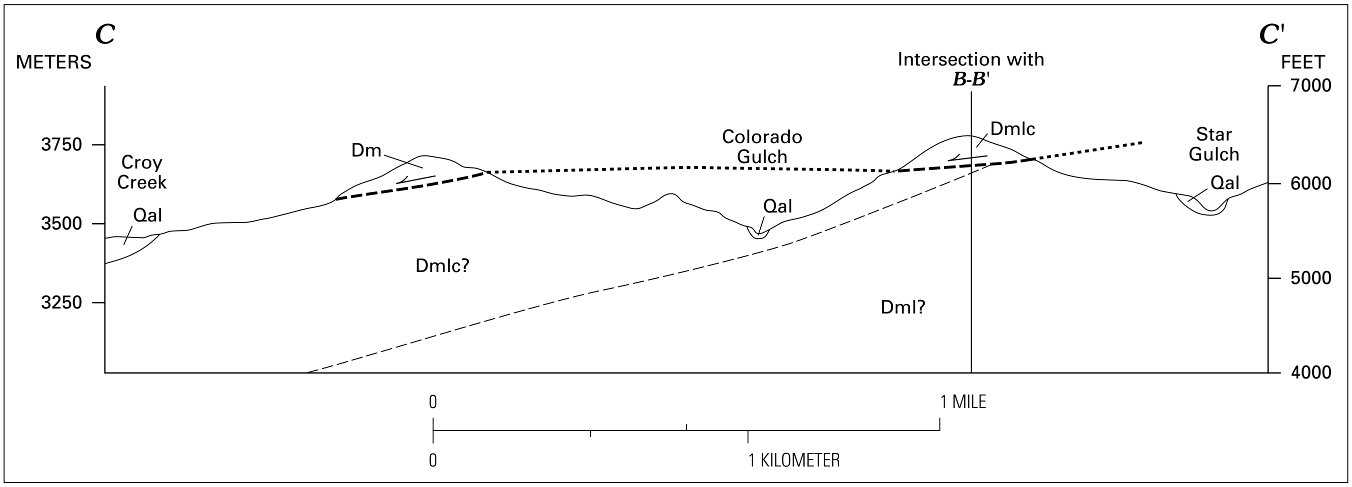

Figure 7. Geologic cross *C–C′* section through Colorado Gulch and Star Gulch, Minnie Moore mineralized area. Location of cross section shown on figure 2.

Mineralogy

The ore in both the Minnie Moore and Bullion areas is characterized by uniform mineralogy and texture throughout the individual bodies and throughout the two mineralized areas. Generally the deposits contain galena, sphalerite, and tetrahedrite as the principal ore minerals and siderite as the principal gangue mineral. Other minerals commonly present include chalcopyrite, pyrite, arsenopyrite, quartz, and calcite. In the Minnie Moore area siderite is “clearly closely associated with the ore mineralization” (Anderson and others, 1950, p. 71). Crushed wallrock is commonly a major portion of the gangue.

The ore at the Minnie Moore mine (fig. 1, site 77) consists of galena, pyrite, sphalerite, gray copper, chalcopyrite, and arsenopyrite in a gangue of siderite, quartz, calcite, and crushed country rock (Anderson, 1950). The ore at the Silver Star Queens mine (site 78) consists of sphalerite, galena, tetrahedrite, pyrite and marcasite in a gangue of quartz, siderite, and calcite.

Isotopic, Age, and Fluid Inclusion Data

Ore in the Minnie Moore and Bullion areas is mesothermal and is associated with the Late Cretaceous Croesus and Deer Creek stocks. The ore occupies northwest-striking faults and fracture systems, a few of which cut the nearby intrusive rocks. Maximum ages for the veins are given by the adjacent stocks. The Deer Creek stock has been dated at 90.4±0.2 Ma and 94.4±0.3 Ma on biotite and hornblende, respectively, using the 40Ar-39Ar method (L.W. Snee, written commun., 1991). The Croesus stock is older than the intruding 84-Ma Hailey granodiorite (Worl and Lewis, in press).

Fluid inclusion from ore in several mines have homogenization temperatures of 244°–307°C, and freezing-stage measurements suggest salinities of 3.2–4.8 weight percent NaCl (Hall and others, 1978).

Sulfur isotope studies from sulfide minerals suggest a shallow crustal source (Hall and others, 1978; Howe and Hall, 1985). Lead isotope ratios of galena from the polymetallic veins suggest an ultimate lead source from buried Precambrian crust (Sanford and Wooden, 1995), either directly from batholith-driven hydrothermal convection cells or from remobilization of lead concentrated in syngenetic deposits in the Dollarhide and Milligen Formations and which originally came from a Precambrian source.

Description of Orebodies

The Minnie Moore orebody is a gently inclined blanket like body 365 m (1200 ft) long and as wide as 5.5 m (18 ft). Before mining, the orebody was made up of irregular lenses of sulfides that were followed by individual stopes within the mine. The ore bodies consisted of three zones, mainly siderite on the west and calcite on the east and an intermediate zone between. The minable ore was confined to the middle and eastern zones.

The ore zone at the Silver Star Queens mine occupied veins striking northwest and dipping southwest. The principal ore shoot had a stope length of almost 152 m (500 ft) and was made up of sulfide lenses as thick as 2 m (6 ft) (Anderson, 1950).

The vein in the Snoose mine (fig. 1, site 71) strikes northwest and dips 50° NE. (Anderson, 1950, p. 23). The ore contains sphalerite and galena with abundant pyrite.

Orebodies in the Bullion area (Mayflower and Red Elephant mine areas, fig. 1, sites 14 and 13) are gouge-filled fractures along the Mayflower fault zone.

Alteration

Generally, ore minerals in both the Minnie Moore and Bullion area are hosted by fresh black argillite and limestone. There is no pervasive alteration pattern or guide to location of ore minerals. The rock along the mineralized fissures shows some bleaching with formation of sericite, carbonate, and pyrite.

Supergene enrichment was not important in the Wood River area (Umpleby and others, 1930, p. 110), and the maximum depth of oxidation was about 15m (50 ft). At the surface some veins are oxidized to iron and manganese oxides and intermixed lead and zinc carbonates and sulfates.

Genesis and Ore Controls

The orebodies of the Minnie Moore and Bullion areas formed during faulting that occurred shortly after Late Cretaceous magmatic activity (Hall and others, 1978). This is demonstrated by the fact that the orebodies occupy post-intrusive rocks.

The Minnie Moore orebodies are in the middle part of the Milligen Formation. They are hosted by the Lucky Coin limestone and the Triumph argillite. The orebodies are in close proximity to tongues of sand in the Cait quartzite, which is the same stratigraphic position as the ore in the Triumph area. The metals may have been remobilized from primary stratiform syngenetic deposits, as suggested regionally by Hall (1985), Howe and Hall (1985) and for the Triumph area by Turner and Otto (1995).

The source of the ore metals in the Bullion area is uncertain. Wavra and Hall (1989) suggested that syngenetic stratiform mineralized rock is in the upper member of the Dollarhide Formation and that the Mayflower vein could be remobilized from it. We map these rocks, however, as lower member, Dollarhide Formation, but do not discount syngenetic stratiform mineralization. Another option is that the ore is remobilized from Milligen Formation that unconformably underlies the Dollarhide Formation at shallow depths in the Bullion area.

The polymetallic veins represent one end member of a family of veins and replacement deposits that formed during the late stages of formation of the Idaho batholith. The other end member is represented by gold-quartz veins (polymetallic quartz veins and lodes) (Worl and Johnson, 1995). The polymetallic quartz veins and lodes are hosted mainly by plutonic rocks; examples are the Croesus mine and in the Hailey Gold Belt (Worl and Lewis, in press).

Exploration Guides

Although stratigraphic location of the host rock is different in the Minnie Moore and Bullion areas, the ore deposits are of similar types and are hosted by similar dark-gray to black argillite and limestone. Syngenetic stratiform exploration models predict that stratabound silver-lead-zinc deposits are present in both the Minnie Moore and Bullion areas (see Hall, 1985; Wavra and others, 1986; Wavra and Hall, 1989); however the mined structures are fault-zone hosted veins, and no syngenetic model has not been extensively tested in exploration efforts in the area. Post-mineralization faulting is a major concern.

Discovery of new vein deposits similar to those already mined, that is, veins along northwest- striking faults, is unlikely because the faults have been extensively prospected. However, because the veins are cut by low-angle faults, they may be relocated across these faults, as suggested by Anderson (1950) for the Minnie Moore area.

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