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Title: Volcanic Stratigraphy and Epithermal Mineralization of the DeLamar Silver Mine, Owyhee County, Idaho

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The DeLamar Silver Mine is in the north-trending Owyhee Mountains of southwest Idaho. As part of the Silver City region it is included in the Basin and Range physiographic province.

The lithologic units of the Silver City region, surrounding the DeLamar Silver Mine, are composed mostly of Cretaceous granitic rocks and Miocene volcanic rocks. The volcanic rocks which vary in composition from basalt to rhyolite are predominant in aerial extent. Regional structure is dominated by a set of N10-20°W trending oblique-slip, high angle faults and a less pronounced set trending N75°W. These faults may be related to crustal extension in the Basin and Range province and to rifting in the Snake River Plain. The mineral deposits of the Silver City region occur mostly as epithermal vein fillings of fractures and faults. The predominant trend of the veins is north-northwest.

The DeLamar Silver Mine is in a complex Miocene volcanic sequence. Units of various compositions including basalt, latite, rhyolite, and andesite were emplaced as coalescing flows, exogeneous domes, and necks. A porphyritic rhyolite is the most widespread unit in the mine area.

Epithermal silver and gold mineralization at DeLamar is most commonly concentrated in the well-fractured, silicified, upper part of the porphyritic rhyolite. The most continuous mineralization is below the clay-altered base of an overlying fine-grained banded rhyolite.

Mineralogy of the deposit is dominated by sulfides and selenides. Naumannite is the dominant silver mineral commonly occurring as small disseminated grains in quartz. Other silver bearing minerals include; acanthite, argentopyrite, and pyrargyrite. Fine-grained free gold is highly disseminated in the gangue. Pyrite is the most dominant and widespread sulfide of the deposit followed in abundance by marcasite.

The gangue consists almost entirely of quartz. Several varieties occur including lamellar quartz; white, gray, and black common vein quartz; and well formed crystalline quartz. Hydrothermal alteration minerals at DeLamar include sericite, secondary quartz, kaolinite, alunite, chlorite, and zeolites.

Mineralogy of the veins and alteration at DeLamar suggests that hydrothermal solutions were probably at temperatures 100 to 300°C. These solutions are believed to have been highly diluted sodium-chloride waters closely related to the rhyolitic volcanism.

VOLCANIC STRATIGRAPHY AND EPITHERMAL MINERALIZATION OF THE DELAMAR SILVER MINE, OWYHEE COUNTY, IDAHO

by

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VOLCANIC STRATIGRAPHY AND EPITHERMAL MINERALIZATION OF THE DELAMAR SILVER MINE, OWYHEE COUNTY, IDAHO

INTRODUCTION

The geologic study of the DeLamar Silver Mine area, Owyhee County, Idaho, was undertaken as part of a graduate program for the M.S. degree in geology at Oregon State University. The major objectives of the study were to: (1) provide an updated and detailed geologic map of the mine site and immediately adjacent areas; and (2) develop a model for hydrothermal mineralization based on structural relations, mineralogy and distribution of ore, gangue, and wall rock alteration.

As a mine geologist working at the DeLamar Silver Mine from 1978 to 1980, I had the opportunity to study the geology of the mine area and district. Work on the thesis project began with field mapping during the summer of 1981. Mapping was conducted on topographic maps prepared from aerial photographs by Air Photo Services and Global Engineering Inc., Grand Junction, Colorado. Further study during 1981 and 1982 included analysis of representative samples by techniques including ore microscopy, petrography, and X-ray diffraction.

GEOGRAPHIC SETTING

The DeLamar Silver Mine study area encompasses approximately 7.5 square miles in the Owyhee Mountains of southwest Idaho. The Owyhee Mountains are a north-trending range roughly 45 miles long and 15 miles wide. The thesis area is 50 miles southwest of Boise, Idaho, and 10 miles east of the Idaho-Oregon border (Figure 1).

The area is accessible by gravel road from the Idaho-Oregon border east of Jordan Valley, Oregon. The road is maintained year round by the DeLamar Silver Mine. Access is also seasonally possible from the east by the Silver City road via Murphy, Idaho.

Topography in the study area varies from 5,115 feet to 6,486 feet at the summit of DeLamar Mountain. Two regionally important streams flow through the area, Jordan Creek and Louse Creek.

The climate in this region is semiarid with an average rainfall of 10 to 20 inches per year (Asher, 1968, p. 6). Most of the precipitation is in the form of snow.

The semiarid slopes of the Owyhee range are typically vegetated by grasses, sagebrush, and juniper trees. Slopes at higher elevations have various mountain brushes as well as alpine and Douglas fir. Grassy areas are used for stock grazing during the summer.

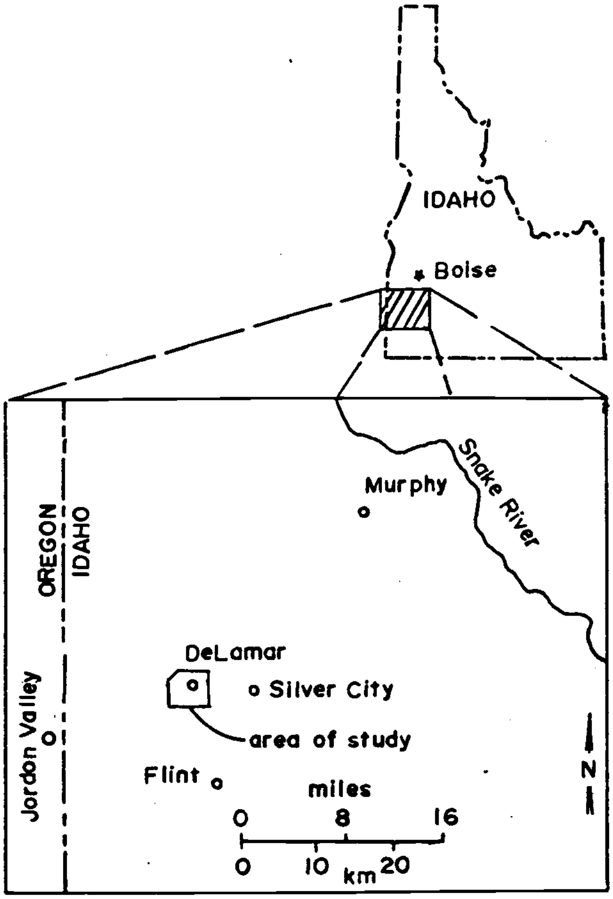


Figure 1. Location of area studied.

Figure 2. Aerial view of the DeLamar Silver Mine looking north into the Sommercamp Pit.

REGIONAL PHYSIOGRAPHIC PROVINCES

The DeLamar Silver Mine area, part of the Silver City region of southwest Idaho, is included in the Basin and Range physiographic province. Surrounding provinces include the High Lava Plains, Snake River Plain, Columbia Plateau, and the Idaho Batholith (Figure 3). The development, general characteristics, and interrelations of these provinces are discussed in the following sections.

Basin and Range

High-angle faulting extends throughout much of the western Cordillera of North America (Figure 4). Basin-range structure consists of a highly complex system of normal faults along which displacement has resulted in the relative uplift of linear segments of the crust to form mountains and the relative sinking of adjacent areas to form valleys. Strike-slip faulting is locally important. In detail, the patterns of mountains and valleys are highly complex. This type structure is developed best in the Basin and Range physiographic province extending from southern Oregon and Idaho through most of Nevada and part of California, Utah, Arizona and New Mexico (Stewart, 1978, p. 2) a total distance of more than 1,000 miles.

During early and middle Cenozoic time, the tectonics of western North America was dominated by events related to a subduction system along the margin of the continent. In middle Cenozoic time, about 29 m.y. ago, a notable change in the tectonic and igneous

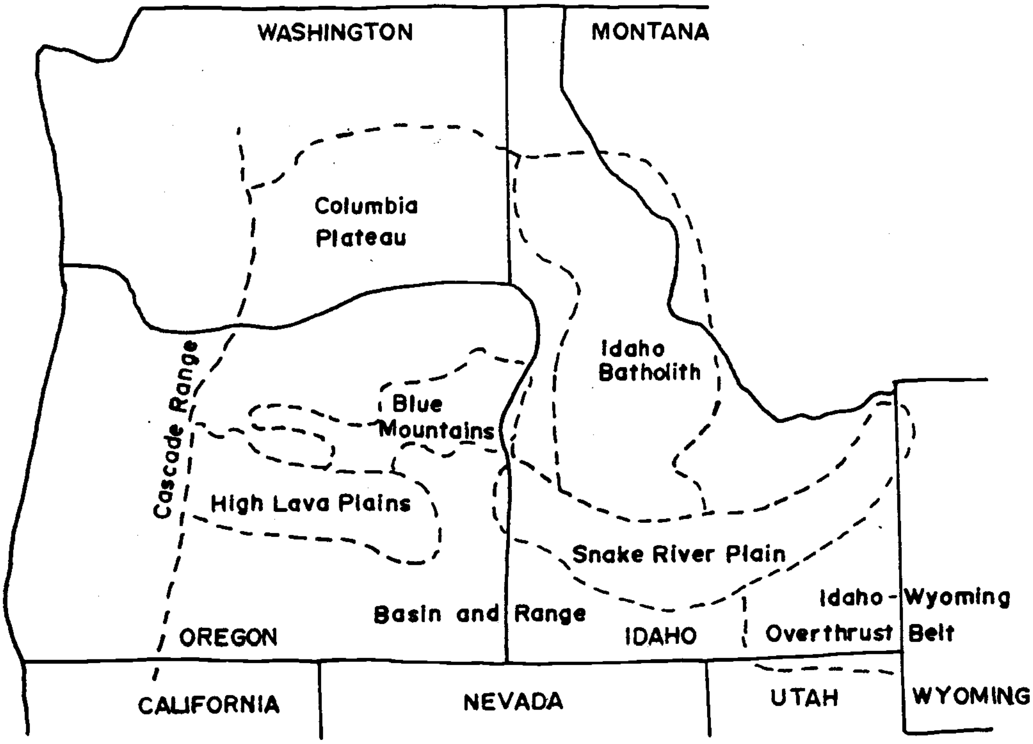


Figure 3. Physiographic provinces surrounding the Silver City region.

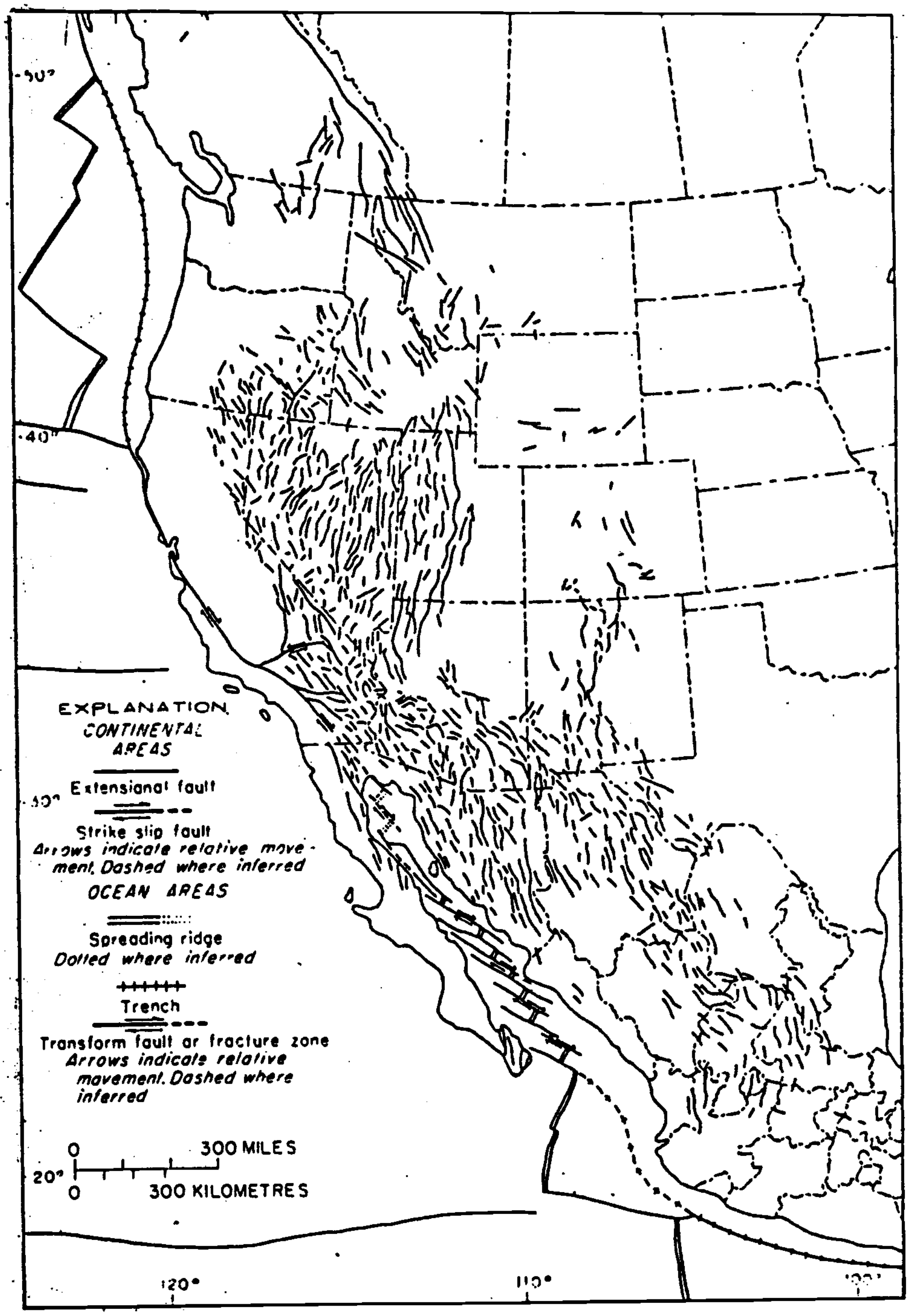


Figure 4. Distribution of late Cenozoic extensional faults and a few major strike-slip faults in western North America and present-day lithospheric boundaries (from Stewart, 1978, p. 3).

history of this system occurred when the East Pacific Rise (spreading ridge) intersected the subduction zone. This caused a change in plate geometry and the development of a transform fault system along parts of the western margin of North America (Noble, 1972, p. 146; Stewart, 1978, p. 10).

Mainly calc-alkaline volcanism dominated the region during early and middle Tertiary time. Inception of bimodal basalt-rhyolite volcanism 16-17 m.y. ago coincides closely with the beginning of normal faulting over much of the Basin and Range (Noble, 1972, p. 145), but may have started slightly earlier in southern Arizona and New Mexico (Stewart, 1978, p. 10).

Stewart (1978, p. 22-26) grouped current theories on the origin of basin-range structure into four main categories: wrench faulting, back-arc-spreading, subduction of the East Pacific Rise, and mantle plumes. The wrench faulting concept relates the development of basin-range structure to oblique tensional fragmentation within a broad belt of right-lateral movement along the western side of the North American lithospheric plate. Back-arc-spreading theory relates the structure to mantle upwelling and associated spreading above a subduction zone. Basin-range structure has been related to convection currents and lateral spreading on the flanks of the East Pacific Rise, which according to this theory, extends under western North America. Deep-mantle convection in the form of narrow rising plumes has been considered to play a major role in the late Cenozoic history of the western United States.

Physical characteristics of the Basin and Range province include: (1) low seismic velocity of the upper mantle, indicative of partial melting (Smith, 1978, p. 140), (2) high heat flow, (3) thin crust, (4) regional uplift and extension (Thompson and Burke, 1974, p. 213-217), and (5) widespread bimodal volcanism in middle Cenozoic time (Noble, 1972, p. 145; Synder and others, 1976, p. 99). Considering these characteristics and other constraints imposed on the models, the concept of back-arc-spreading seems to fit best (Thompson and Burke, 1974, p. 234; Snyder and others, 1976, p. 99; Stewart, 1978, p. 26).

High Lava Plains

The High Lava Plains province is a middle and late Cenozoic volcanic upland approximately 160 miles long and 50 miles wide. The province is contiguous with and graditional into the Basin and Range province to the south. Structurally the province is dominated by a series of discontinuous en echelon normal faults trending about N40°W, commonly called the Brothers fault zone, that are seen on satellite imagery, aerial photography and in the field (Lawrence, 1976, p. 846). Less abundant faults trend about N30°E. Lawrence (1976, p. 850) observed that this pattern is the same as that of strike-slip shear zones on many scales. He further hypothesized that the Basin and Range province terminates in a series of right-lateral strike-slip fault zones along which the total extension and extensional strain rates decrease progressively northward with extension essentially ceasing at the northern edge of the High Lava Plains province. Eruptive centers for both rhyolitic and basaltic volcanic rocks are concentrated in the zones of faulting (Walker and

Nolf, 1981, p. 105).

The High Lava Plains are separated by a relatively sharp boundary from the Blue Mountain province to the north, where older Cenozoic and pre-Cenozoic rocks have been exposed by the Blue Mountain-Ochoco Mountain uplift (Walker and Nolf, 1981, p. 105).

Snake River Plain

The Snake River Plain extends from easternmost Oregon through Idaho in an arc to the Yellowstone Plateau at the northwest tip of Wyoming (Figure 3). The Snake River Plain differs from adjacent regions to the north and south by relatively lower elevations and surface relief. It is covered mainly by late Cenozoic volcanic rocks and sediments.

The western Snake River Plain is probably a large graben, perhaps related to the parallel system of NW-SW trending faults in central and eastern Oregon (Bonnichsen and others, 1975, p. 590). The eastern Snake River Plain probably manifests the regional downdropping that followed the time-transgressive linear volcanism which progressed from extreme southwest Idaho or northwest Nevada to Yellowstone Park (Armstrong and others, 1975, p. 225). In southwest Idaho a second, primarily rhyolitic, trend extends from near the center of the Snake River Plain westward to the Brothers fault zone in central Oregon and to the Newberry volcano (Walker and McLeod, 1977, p. 1215).

Columbia Plateau

The Columbia Plateau physiographic province is dominated by tholeiitic flood-basalt of the Columbia River Basalt Group. The group is the youngest assemblage of flood basalt known, with an age range from about 16.5 m.y. to about 6 m.y. based on potassium-argon age dating and the age of vertebrate fossils in an interbedded formation (Swanson and others, 1979, p. G-5). The basalt flows emerged as fissure eruptions and generally advanced as sheet floods forming thick cooling units composed of one or more flows. High-rate eruptions took place from long fissure systems. The feeders are grouped in huge dike swarms mainly concentrated near the southern and western margins of the lava field (Waters, 1961, p. 586).

Idaho Batholith

The Idaho batholith is a composite pluton which has been described by Ross (1963, p. 47) as being largely quartz monzonite enclosed in a broad shell of gneissic rocks, mostly quartz diorite and granodiorite. The batholith is bisected by older rocks into two distinct lobes, the Atlanta lobe in the south and the Bitterroot lobe in the north. Isotope age dating indicates that the Atlanta lobe is probably 70 to 100 m.y. old. The Bitterroot lobe may not be significantly older than 80 m.y. (Armstrong, 1975, p. 45).

HISTORICAL BACKGROUND AND PRODUCTION

The following discussion of the historical background and mineral production from the Silver City region is largely taken from Piper and Laney (1926, p. 51-56). The Silver City region, as used in this report, refers to an area of indefinite boundaries surrounding the inactive mining camp of Silver City, Idaho.

Significant mineral discovery in the Silver City region dates from May 18, 1863. That day a party of men, led by Michael Jordan, found placer gold at Discovery Bar on what was later called Jordan Creek, just above the present site of DeLamar. The report of rich placer gold deposits spread quickly and precipitated a rush of gold seekers to the area. During 1863 the placer gravels were traced up Jordan Creek, and its tributaries, to lode deposits at their heads on War Eagle Mountain, east of the present site of Silver City. By 1865 the major placer deposits had been worked over and were largely abandoned, except by the Chinese who continued operations on a small scale for many years.

The discovery and development of the Oro Fino and the Morning Star began the lode mining era on War Eagle Mountain, and provided the district's first important production. Near surface stopes in some of these mines, such as the Poorman, yielded shipments of bonanza ore of silver chloride and ruby silver valued at $4,000 per ton and milling ore returning $300 in bullion. As the zone of primary ore was developed values dropped to around $30 per ton.

In 1876, after the mines had been actively worked for 11 years, the financial backing for many of the enterprises collapsed with the failure of the Bank of California. Due to higher operating costs and lower grade ore at depth, coupled with financial problems, many of the mines were closed and have never been reopened. Precious metal production valued at $12,500,000 was reported by Piper and Laney (1926, p. 53) for this period of activity. Later sporadic production from War Eagle Mountain was not significant.

While the activity on War Eagle Mountain was declining, discoveries were made on Florida and DeLamar Mountains during the 1870's and 80's. In 1881 production is reported from the seventy-nine vein in DeLamar Mountain. Production from Florida Mountain mines including the Empire State, Black Jack, and Starlight started in 1883.

In 1889 rich ore bodies of the Black Jack mine on Florida Mountain and the DeLamar mine on DeLamar Mountain were found and developed underground. Two years later the Trade Dollar mine on Florida Mountain encountered the southern extension of the Black Jack vein. After production was started on these mines they were acquired by well-capitalized incorporated companies. The Black Jack and Trade Dollar mines, which had been competitors, were consolidated in 1903. Captain J. W. DeLamar, who was largely responsible for development of the DeLamar mine, sold out in 1901 to the DeLamar Mining Company, Ltd., of London. These better managed companies developed mining on a scale which was large for that day.

In 1910, the Black Jack and Trade Dollar mines closed because of uneconomic low grade ore at depth. With the grade of workable ore decreasing the DeLamar Company, Ltd., installed a new cyanide mill which greatly reduced milling cost. Even with the new milling procedures the operation was only initiated to recover the cost of timber that had been cut for the operation from government land sections (Bell, 1913, p. 137-138). Future timber use restrictions combined with lower-grade ore caused the mine to close in 1914.

Mining industry in the district during this second period of activity produced precious metals valued at nearly $23,000,000 as calculated at prevailing metal prices at the time of production (Piper and Laney, 1926, p. 56). Thereafter, minor production was periodical. In 1938 a 200 ton flotation mill was constructed to process the DeLamar dumps for their metal content but this mill ceased operation in 1942 (Campbell, 1943, p. 182).

In 1969 a joint venture designed to search for large tonnage, low-grade silver deposits acquired the principal properties on DeLamar Mountain. Preliminary surface sampling, trenching, and airtrack drilling in that year indicated the possible occurrence of a substantial low-grade silver-gold reserve. Serious exploration efforts were initiated in 1970 and pursued at varying rates, dependent somewhat on the price of silver. A feasibility study was completed in late 1974 and the decision made to place the property in production.

Open pit mining was started in 1977 by Earth Resources Company (controlling interest), the Superior Oil Company, and Canadian Superior Mining (U.S.) Ltd. In 1981 Earth Resources Company was acquired by MAPCO. The DeLamar Silver Mine became part of MAPCO Minerals Corporation.

From start up in 1977 to December 1981, 21,721,000 tons of ore and waste have been mined, producing 7,500,000 ounces of silver and 95,000 ounces of gold. Mine production currently averages 24,000 tons per day with the mill processing 2,100 tons per day. Total ore reserves with a 2 ounce per ton silver equivalent [Ag + (Au x 40)] cutoff are around 7,000,000 tons with an average grade of 2.5 oz/ton silver and 0.036 oz/ton gold. Total ore reserves with a one ounce per ton silver equivalent cutoff are approximately 12,000,000 tons having an average grade of 1.8 oz/ton silver and 0.023 oz/ton gold.

PREVIOUS WORK

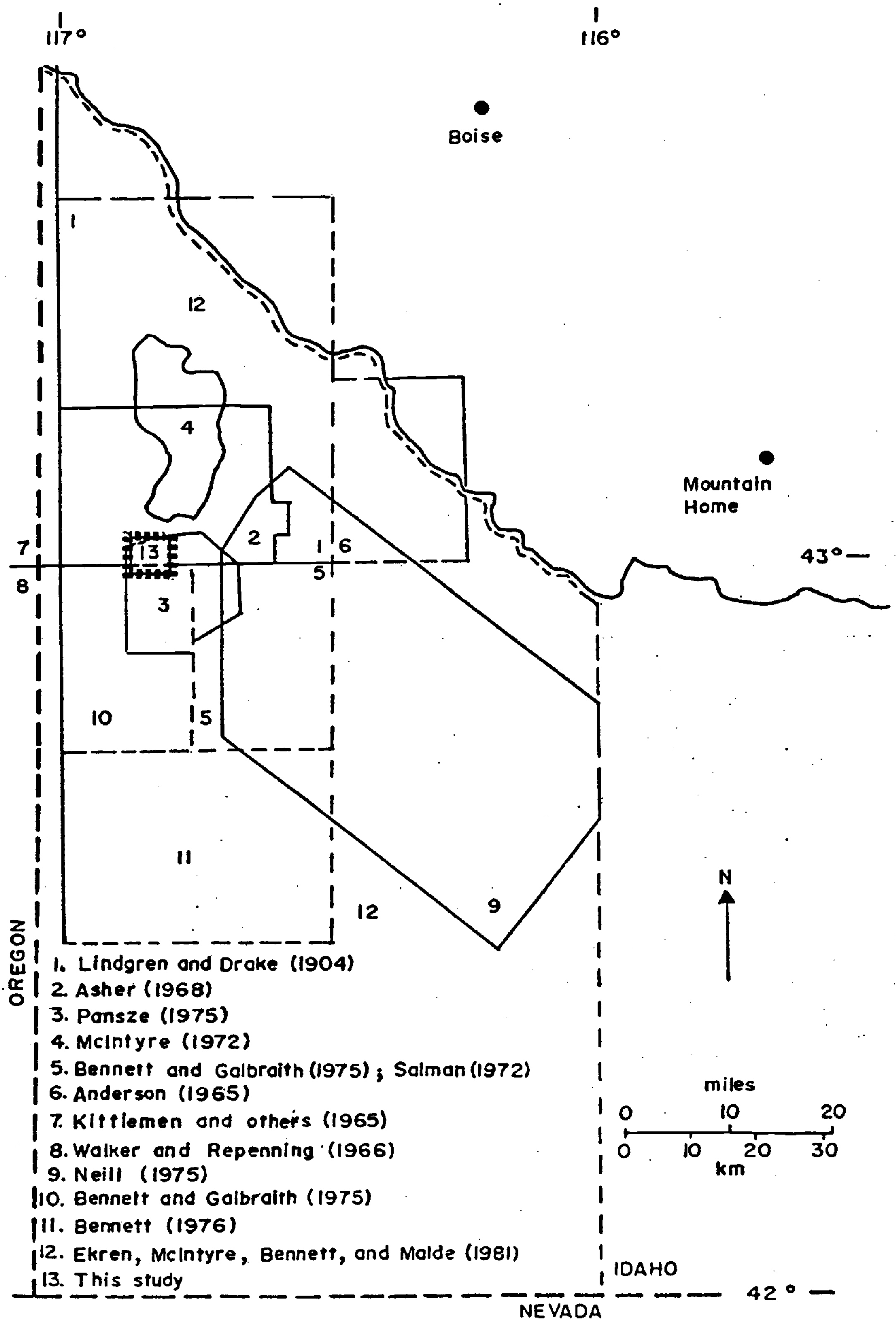
Eldridge (1894) conducted a geologic reconnaissance across central Idaho and made a cursory examination of the Silver City region. Lindgren studied the gold and silver deposits of west and central Idaho in 1897 and reported on them in the Twentieth Annual Report of the U.S. Geological Survey (1900). Somewhat later, Lindgren and Drake (1904) published a large-scale folio of the Silver City quadrangle. Piper and Laney (1926), who relied heavily on Lindgren's (1900) work, reported on the mines of the region around Silver City.

More recent published work includes reconnaissance mapping of about 300 square miles in the Silver City region by Asher (1968). McIntyre (1972) reported on the Cenozoic geology of the Reynolds Creek watershed north of Silver City. Pansze (1975) studied the general geology of the Silver City region with particular concentration on the volcanic stratigraphy. A study by Bennett and Galbraith (1975) analyzed various trace elements in association with mineralization in the district. Ekren, McIntyre, Bennett, and Malde (1981) published a reconnaissance map of Owyhee County, Idaho, west of longitude 116°W at a scale of 1:125,000.

During the development of the DeLamar Silver Mine property numerous individuals contributed to the understanding of the local geology. Knox and Weitz summarized preliminary investigations in a paper presented at the Northwest Mining Association convention in 1976. Notably this included recognition of the complex volcanic stratigraphy. An updated paper by Rodgers, Moss and Thomason presented in 1980 at the Northwest Mining Association convention further defined the geology of the mine area and introduced some of the problems that this thesis attempts to answer.

The area of this study is overlapped by the large-scale reconnaissance mapping of Lindgren (1900), Lindgren and Drake (1904), Piper and Laney (1926), Asher (1968), and Ekren, McIntyre, Bennett, and Malde (1981). It is overlapped on the south by the mapping of Pansze (1975). Figure 5 shows the areas covered by these previous studies.

Figure 5. Index map to previous geologic investigations.


117°
116°
Boise
Mountain Home
43°
42°
OREGON
IDAHO
NEVADA
N
miles
0 10 20
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1. Lindgren and Drake (1904)
2. Asher (1968)
3. Pansze (1975)
4. McIntyre (1972)
5. Bennett and Galbraith (1975); Salman (1972)
6. Anderson (1965)
7. Kittlemen and others (1965)
8. Walker and Repenning (1966)
9. Neill (1975)
10. Bennett and Galbraith (1975)
11. Bennett (1976)
12. Ekren, McIntyre, Bennett, and Malde (1981)
13. This study

Figure 5.

GENERAL GEOLOGY OF THE SILVER CITY REGION

The lithologic units in the Silver City region, surrounding the DeLamar Silver Mine, may be divided into three major groups: Cretaceous granitic rocks with metamorphosed inclusions, Miocene volcanic rocks, and post-volcanic deposits. The volcanic rocks predominate in aerial extent. The informal names used in this discussion are from a generalized synthesis of previous work in the region. The aerial distribution of these generalized regional units, major fault zones, and major precious metal vein trends are shown on Figure 6.

Granitic Rocks

Upper Cretaceous granitic rocks crop out along the crest and eastern flank of the Owyhee Range. The composition of these intrusives ranges from granodiorite to granite, with granodiorite being the most common. The granitic rocks form distinctive, moderately-jointed outcrops, which weather to a sandy grus.

Potassium argon age determinations of muscovite from three rocks provide ages of 62 m.y. to 67 m.y. (Pansze, 1972, p. 2). These ages bracket the Cretaceous-Paleocene boundary of 65 million years.

Metamorphic rocks are present as inclusions or pendants in scattered outcrops of the granitic rocks. Contacts between the granitic and metamorphic rocks are gradational. The metamorphic rocks are older than the granitic rocks, but their age is

Figure 6. Generalized geologic map of the Silver City region, Owyhee County, Idaho. Geology partly from Pansze (1975); and Ekren, McIntyre, Bennett, and Maulde (1981).

EXPLANATION

Lithologic units

QUAT.		Qls	LANDSLIDE DEPOSITS
QUAT. / TERTIARY		QTg	UNDIVIDED TERRACE GRAVELS
			unconformity
TERTIARY	MIOCENE	Tsr	TUFF of SWISHER MOUNTAIN
TERTIARY	MIOCENE	Tsc	SILVER CITY RHYOLITE
TERTIARY	MIOCENE	Tl	LATITE and QUARTZ LATITE
TERTIARY	MIOCENE	Tlb	BASALT
			unconformity
CRET.		Kg	GRANITIC ROCKS

Lithologic contacts

Faults

Principal epithermal gold-silver veins

Figure 6.

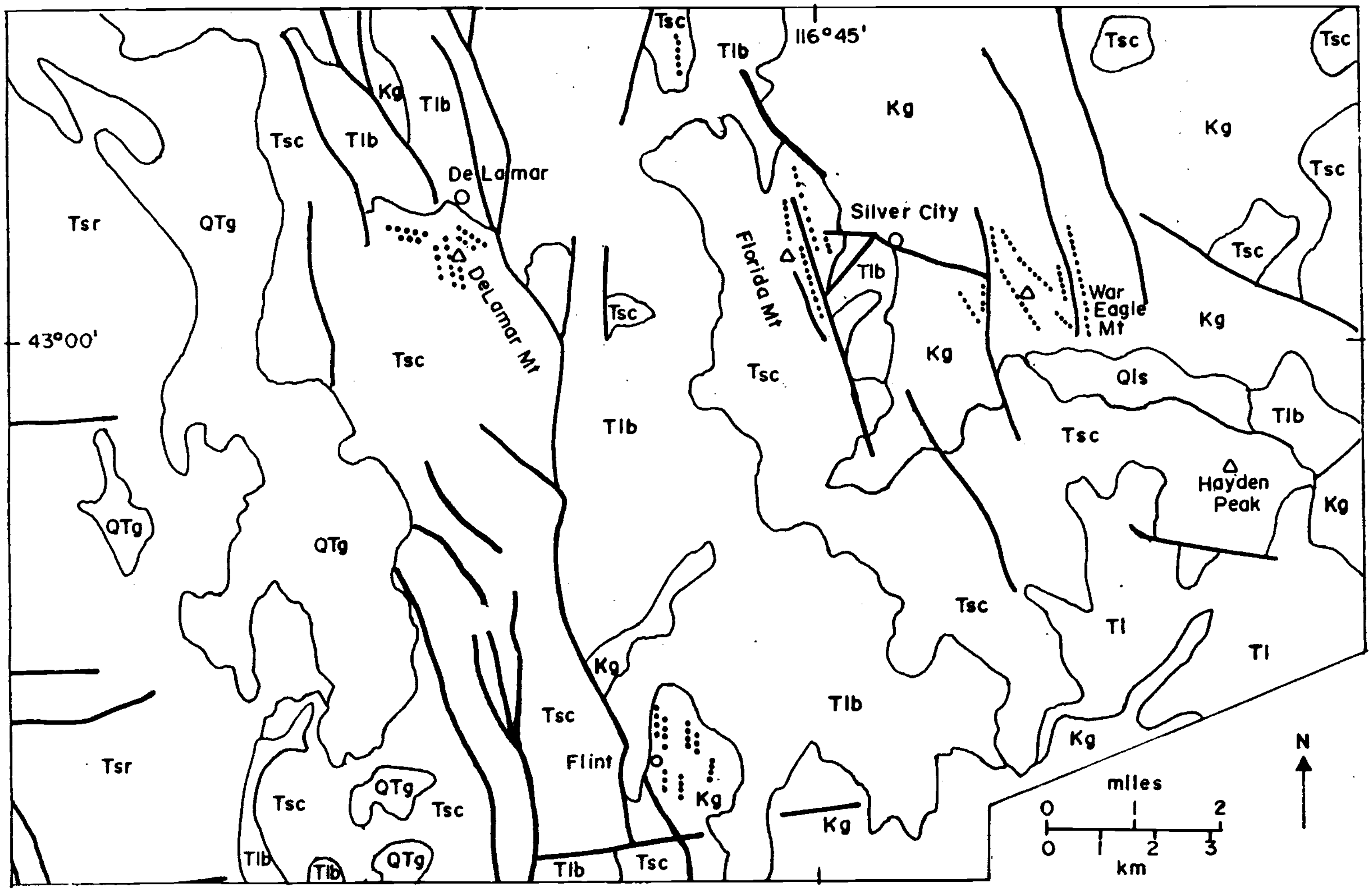

116°45'
43°00'
Tsc
Tlb
Kg
Tsr
QTg
De Lamar
DeLamar Mt
Florida Mt
Silver City
War Eagle Mt
Qls
Hayden Peak
Tl
Flint
miles
0
1
2
0
1
2
3
km
N

Figure 6.

undetermined. The metamorphic rock type most commonly observed is quartz-muscovite-biotite schist, with gneisses occurring less frequently. The rocks appear to have been sedimentary units (Lindgren, 1900, p. 118; Piper and Laney, 1926, p. 113-114) which were metamorphosed during intrusion of the granitic rocks.

The contact between the granitic rocks and the overlying rocks is unconformable. Flows of basalt terminate against slopes of granitic rocks, which indicates the presence of an erosion surface of moderate relief before extrusion of the basalt. Granitic rubble is found in this contact zone at some places.

Taubeneck (1971, p. 1899) correlated granitic rocks of southwest Idaho with the Idaho batholith primarily by the location and trend of gneissic border rocks on either side of the Snake River Plain. A deep drill hole beneath the western Snake River Plain that bottomed in granitic rocks tends to confirm this interpretation (McIntyre, 1979). Gross mineralogical characteristics of granitic rocks in southwest Idaho also closely resemble those in the western part of the batholith just north of the Snake River Plain (Taubeneck, 1971, p. 1899).

Volcanic Rocks

Numerous volcanic units have been identified by the various workers in the region surrounding the DeLamar Silver Mine (Figure 6). More than one-half of these are local in extent. The volcanic units discussed in this summary are those of regional extent that have been described by Asher (1968), Pansze (1975), and Ekren and others (1981). These units are (1) basalt, (2) latite, (3) Silver City rhyolite, and (4) tuff of Swisher Mountain.

Basalt

Basalt is exposed along a wide band that trends north-northwest through the center of the region. This unit is composed of an undetermined number of conformable flows of alkali olivine basalt. The general thickness of individual flows ranges from around 50 to 150 feet. The total thickness of the basalt is probably more than 2500 feet (Asher, 1968, p. 34). The basalt forms dense black outcrops which are usually massive and have closely-spaced irregular joints. Outcrops of basalt usually form rounded hills with step-like benches tracing individual flows. Age determinations (Pansze, 1972, p. 2) date the basalt at approximately 16.6 million years.

Latite

Latite and quartz latite are exposed over a moderate area in the southwest part of the region. The latite is a flow rock which overlies basalt in most places, but also locally rests on granitic rocks. It is generally black or gray, dense, and aphanitic with less than ten percent quartz phenocrysts. The maximum exposed thickness is around 1800 feet near Hayden Peak (Pansze, 1975, p. 24).

Silver City Rhyolite

The Silver City rhyolite consists of an undetermined number of separate and often coalescing cooling units of rhyolite that were locally derived from various dikes and vents. Silver City rhyolite covers the tops of Florida Mountain and DeLamar Mountain and crops out between DeLamar and Flint. Fresh exposures of the rhyolite are pink, reddish-gray, and reddish brown. Where altered it is white or light gray. The unit varies from generally aphyric to locally porphyritic, with the proportion of phenocrysts varying widely. It is commonly dense and fissile, the partings have well developed Leisengang banding. Some of the cooling units are probably welded ash-flow tuffs which were mostly remobilized to liquids prior to final consolidation (Ekren and McIntyre, 1978, p. 215). The unit's composite thickness may be over 1500 feet. Potassium-argon age determinations of the Silver City rhyolite (Panseze, 1972, p. 3) indicate an age of 15.6 million years.

Tuff of Swisher Mountain

The tuff of Swisher Mountain is exposed in a north-northwest trending belt across the western edge of the region. It is mostly a compound cooling unit of densely welded medium gray or reddish gray rhyolite tuff. The tuff is commonly flow layered from base to top with vitrophyres locally being flow brecciated. In places the unit is over 650 feet thick. The source of the tuff of Swisher Mountain is a buried vent complex centered near Juniper Mountain, in the southwest part of Owyhee County (Ekren and others, 1981). The unit is the same as the rhyolite of Poison Creek of Neill (1975), who reported two potassium-argon dates of 13.1 m.y. and 13.8 m.y. on sanidine.

Post Volcanic Deposits

Terrace gravels cover large areas in the western part of the region. The gravels consist of rounded pebbles, cobbles, and boulders of local volcanic and granitic units. Landslide and talus slopes commonly form on steep hillsides. Landslide deposits are particularly thick on slopes in an area southeast of War Eagle Mountain.

MINERAL DEPOSITS OF THE SILVER CITY REGION

The mineral deposits of the Silver City region occur mostly as epithermal vein fillings of faults and fractures. The size and extent of the different veins and vein systems have been described in detail by Lindgren (1900, p. 122-163), Piper and Laney (1926, p. 93-162), and Asher (1968, p. 75-97).

Mineralogy

The ore minerals of these deposits are those characteristic of epithermal deposits in the modified Lindgren classification of ore deposits (Ridge, 1972, p. 676). Mineralogy of the ore is dominated by sulfides of silver, arsenic, and antimony. According to Piper and Laney (1926, p. 73-81) the principal ore minerals are native gold and silver, acanthite, proustite, pyrargyrite, polybasite, miargyrite, and naumannite. These precious metal-bearing minerals are accompanied by sulfides such as pyrite, chalcopyrite, galena, sphalerite, and jamesonite. Principal gangue minerals in the veins are adularia and quartz with lesser amounts of calcite, barite, fluorite, siderite, and vivianite.

Controls of Ore Deposition

The veins of the Silver City region have been localized along fault structures. The predominant trend of the veins is north-northwest (Figure 6). The more intensely mineralized areas of DeLamar Mountain, Flint, Florida Mountain, and War Eagle Mountain occupy zones at the intersections of two regional fault trends. These zones have a relatively greater number of fractures, which thereby provided structurally favorable sites for the localization of ore. They form two broadly defined belts with a structurally unfavorable zone between them.

The mineralized veins cut most of the lithologic units in the region. Ore has been produced from the granitic rocks, basalt, latite, and the rhyolite. The mineralization seems to be localized primarily by structure.

However, the local extent of the mineralization and the style of veining does vary with lithology. Mineralization in the granitic rocks is generally in discrete veins with little metallization or alteration in the host rock outside of the vein. The rhyolite is generally intensely fractured where mineralized, developing small veinlets and boxworks.

GEOLOGY OF THE DELAMAR SILVER MINE

Lithologic Units of the DeLamar Silver Mine Area

The lithologic units of the DeLamar Silver Mine area are described in the following sections. Phenocryst percentages are by visual estimation. Colors given are those from the Geological Society of America rock-color chart.

Lower Basalt

Basalt is exposed on the slopes above Jordan Creek in the northern part of the map area (Plate 1). The unit is composed of an undetermined number of conformable flows of alkali olivine basalt. The general thickness of individual basalt flows ranges from around 50 to 150 feet. A thickness of over 850 feet is exposed in the map area.

Fresh outcrops of basalt are black and weather to brownish gray, The basalt forms dark, rubbly slopes and terraces, with particularly resistant flows forming short cliffs. Weathered basalt slopes are commonly covered by reddish to yellow-brown soil. Most flows are dense and massive with irregular jointing. Crude columnar jointing is developed in a few flows. Different flows may vary considerably in texture from aphanitic to porphyritic with conspicuous plagioclase phenocrysts, or vesicular. In the DeLamar Silver Mine area the well exposed basalt is commonly black, dense, and fine grained. Age determinations (Pansze, 1972, p. 2) date the basalt regionally at approximately 16.6 million years.

Chemical analyses of basalt collected in the Silver City region (Pansze, 1975, p. 19) show the unit is an alkali olivine basalt. The average chemical analysis of 12 samples (Pansze, 1975, p. 22) is given in Table 1.

In thin section textures of the basalt are highly variable including subophitic, hyaloophitic to intergranular, interstitial, and porphyritic. Mineral percentages are also highly variable. The groundmass is composed of black glass and microlites of plagioclase, clinopyroxene, and magnetite. Microphenocrysts consist of forsteritic olivine, magnetite, clinopyroxene, and labradorite.

Locally the basalt is propylitically altered and characterized by various combinations of chlorite, calcite, zeolites, pyrite, and iron oxides. The propylitically altered rocks are commonly dull green. Vesicle fillings contain calcite, chlorite, zeolites, and crystalline or amorphous silica.

Regional flows of lower basalt are believed to have come from fissure eruptions (Pansze, 1975, p. 23). A few feeder dikes have been found; most are probably still concealed.

Arkosic Sedimentary Rocks

Arkosic sedimentary rocks are present in the extreme east central part of the map area. These rocks have been found in only one small (approximately 300 feet in diameter) outcrop where the unit is about 15 to 20 feet thick, lying on the basalt.

On fresh surfaces the rock is dusky yellow weathering to grayish brown. It is well indurated having crude bedding commonly one-half to two inches thick. The coarser grained beds have subangular

Correlative unit(s), this study	Unit from Pansze (1971, 1975)	SiO_2	K_2O	Na_2O	CaO (%)
Lower basalt	Lower basalt[1] average of 12 samples	45.4	0.49	3.41	8.30
Porphyritic latite	Latite porphyry[2]	69.2	4.75	3.43	1.19
Quartz latite	Quartz latite[2] average of 2 samples	71.9	4.45	3.29	0.97
Lower rhyolite Green rhyolite tuff breccia Porphyritic rhyolite Banded rhyolite Millsite rhyolite	Upper rhyolite[2] average of 9 samples	76.1	4.56	2.78	0.49
Louse Creek andesite	Upper basalt[1]	60.6	2.7	3.6	4.2

Table 1. Chemical analyses for regionally correlative units in the Silver City region. 1-from Pansze, 1975, p. 22. 2-from Pansze, 1971, p. 151.

to subrounded, 1-3 mm, grains of feldspar and quartz in a fine grained yellow-brown matrix of feldspar, quartz, biotite, and rock fragments. Finer grained beds apparently are composed mostly of rounded grains and rock fragments.

This unit was probably deposited in a paleostream channel on the basalt. The coarse grained constituents are from the granitic basement rock of the region. This indicates that the granitic rocks were exposed with enough relief to be weathered, broken down, and transported after the basalt flows were emplaced but before the silicic volcanism. The unit is probably present elsewhere but due to its low-relief weathering characteristics is not well exposed.

Porphyritic Latite

Porphyritic latite occurs in the extreme south-central part of the map area where it is dissected by Louse Creek. Due to its limited exposure, thickness is difficult to estimate, but it is probably at least 100 feet. Within the map area the porphyritic latite is overlain by quartz latite. The base of the unit is not exposed.

The top of the unit is a flow breccia with a large amount of glassy scoriaceous clasts exposed on both sides of Louse Creek at about 5325 feet of elevation. The fragments in the flow-top breccia vary from sub-rounded to sub-angular and range in average size from 2 to 6 inches. The lower, more massive, part of the unit displays irregular jointing. Attitudes of flow structures on the west edge of the outcrop area dip approximately 70° to the west.

Fresh outcrops of porphyritic latite are dusky brown. The flow-top breccia commonly weathers to dark rounded knobs 6 inches to 2 feet in diameter. The more massive lower part weathers dark grayish red purple.

In hand specimen the lower massive section is dominantly a mottled brick-red and black groundmass with colorless to white phenocrysts of potassium-feldspar and plagioclase averaging 1 to 2 mm. Altered, rounded xenoliths of granitic rock and basalt averaging 3 to 5 mm are occasionally found within the unit.

Microscopically the rock is composed dominantly of very-fine-grained felsic groundmass. The unit contains about 20 percent total phenocrysts; composed of sanidine (75 percent), labradorite (5-10 percent), and a small amount of biotite and magnetite. The sanidine phenocrysts are commonly 0.8 to 1.5 mm in length and subhedral to anhedral in shape. Subhedral plagioclase phenocrysts average 0.5 mm in diameter. A few microspherulites, formed by devitrification, are present. Pansze (1975, p. 151) reported a chemical analysis for correlative latite porphyry which is given in Table 1.

Due to its limited exposure postulations on the source area of the porphyritic latite are tentative. Characteristics such as the top breccia and steeply dipping layering in places implies that it was emplaced as a highly viscous lava flow.

Quartz Latite

Quartz latite is exposed in the south-center of the map area. The quartz latite rests on the porphyritic latite and is over lain by porphyritic rhyolite, and on the east by Louse Creek andesite. Both the upper and lower contacts are unconformable. In the map area the unit has an apparent thickness of around 300 to 500 feet.

In fresh exposures the rock is dense, aphanitic, and light to medium gray. Weathered surfaces are pale brown to grayish orange pink. Thin platy jointing (1 to 3 inches) is common. Weathered fragments form steep hillsides with talus covered slopes.

Hand specimens show a few percent of small phenocrysts of quartz and feldspar in an aphanitic groundmass. Microscope study of the quartz latite shows 85 to 90 percent of the rock to be felsic groundmass. Rounded phenocrysts of quartz (0.5 mm) make up about 5 percent of the rock. Sanidine (0.5 to 1 mm) and andesine (0.5 mm) comprise most of the other phenocrysts with a trace of clinopyroxene and biotite present. Phenocrysts are commonly rounded and embayed, having reaction rims with the groundmass. A chemical analysis (Pansze, 1971, p. 151) of a regionally correlative quartz latite is given in Table 1.

The source of the quartz latite may have been an exogeneous volcanic dome. Pansze (1975, p. 26) considered domes to be the sources of other quartz latites mapped in the Silver City region. Flow-layering of the quartz latite in the study area dips generally to the north, indicating a possible source to the south.

Pole Creek Rhyolite

The Pole Creek rhyolite has a small outcrop area, approximately 200 feet in diameter, in the northeast corner of the map area. The rhyolite, which lies on basalt, is probably the remnant of a larger flow. In the exposed outcrop the unit is around 20 feet thick.

On a fresh surface the rhyolite is mottled grayish red purple whereas weathered surfaces are moderate brown to pale reddish brown. Hand specimens are dominated by a pale red purple groundmass with a few percent of indistinct feldspar and quartz phenocrysts. A most notable characteristic of the rock is the presence of biotite (approximately 2%) up to 1 mm. Microscopically the fine grained groundmass is highly spherulitic. All phenocrysts appear to have been partly resorbed and reacted with by the spherulitic groundmass.

The Pole Creek rhyolite does not seem to correlate with other rhyolites in the study area. It may be more related to rhyolites occurring north of the area (Figure 6) along a northwest trend.

Lower Rhyolite

The lower rhyolite occurs in a northwest trending belt from the east central edge of the study area. Drilling intersected the lower rhyolite beneath the Sommercamp and North DeLamar Pits. The unit is 50 to 200 feet thick in the pit areas. It may be thicker in its easternmost exposures.

Relatively unaltered lower rhyolite is a finely banded pale red-purple rock. Unaltered exposures weather to a grayish red purple. The top of the unit is marked by a scoriaceous flow-top breccia with subrounded clasts in a dense matrix. In places the vesicles have been flattened giving the top a streaked appearance.

Unaltered hand specimens have conspicuous banding and approximately 3 percent rounded quartz phenocrysts (0.5 to 1 mm) in a mottled matrix. The lower rhyolite is commonly fissile, breaking into 1 to 4 centimeter thick plates. Microscopically the groundmass is composed of alternating bands (2 to 6 mm) of glass and devitrification spherulites. Total phenocryst content is about 5 percent; mostly quartz but also some biotite and sanidine.

The lower rhyolite, close to the mineralized areas, is commonly hydrothermally altered to varying degrees. Where least altered it is pinkish gray. In more strongly altered areas it is medium light gray to white. Banding in the rock is destroyed in some strongly altered areas. Most commonly the groundmass and feldspars are partly altered to kaolinite and lesser amounts of sericite.

The lower rhyolite was probably emplaced as a lava flow, based on characteristics such as the scoriaceous flow-top breccia, and its conspicuous flow banding. The most likely source is the roughly domal shaped Sullivan knob, just off the east-central area of the map, which is largely composed of lower rhyolite.

Green Rhyolite Tuff Breccia

A distinctive green rhyolite tuff breccia is exposed around the northern flanks of DeLamar Mountain, the northwest trending Glen Silver ridge, and at depth in the Sommercamp and North DeLamar zones. Where penetrated by drilling the unit's maximum thickness is about 150 feet. The green rhyolite is always found overlying the lower rhyolite.

All known outcrops of the green rhyolite have been hydrothermally altered to varying degrees. Exposures of the least altered rock are pale green but with increasing alteration the unit is commonly lighter being very pale green. Weathered surfaces are dusky yellow green, often pockmarked by differential weathering of

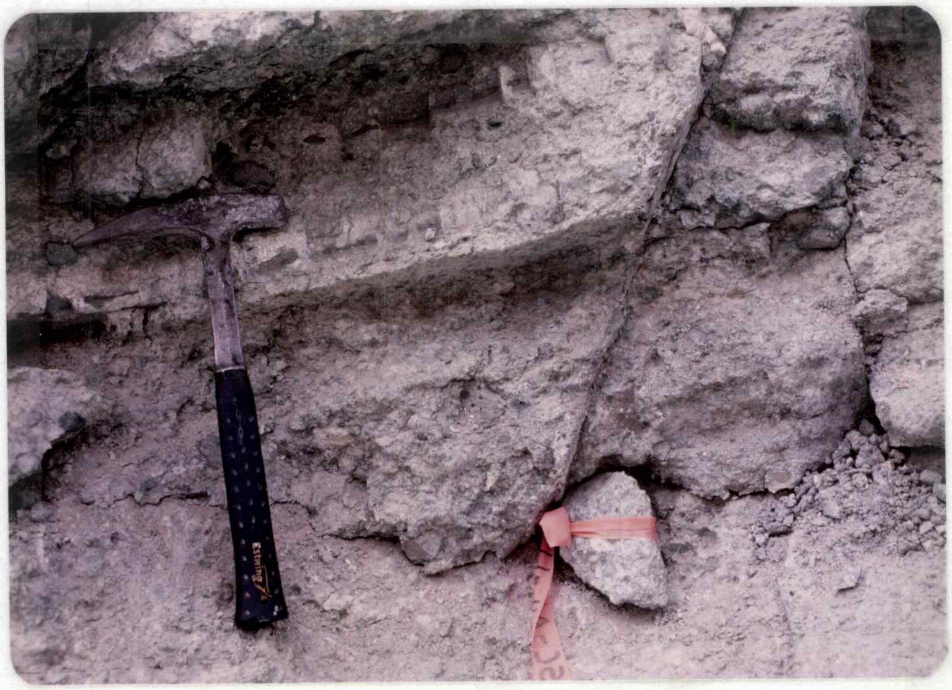


Figure 7. Green rhyolite tuff breccia, exposed in the Sommercamp Pit, exhibiting crude layering.

inclusions. In areas of greater iron oxide staining the weathered surface is light brown to very dusky red.

In some areas the upper few feet of the green rhyolite has been reworked forming fine- to coarse-grained, poorly sorted sandstones and conglomerates composed of lithic fragments and volcanic ash. The reworked section often exhibits graded bedding on a small scale.

The bulk of the unit is a poorly sorted to unsorted lithic-rich tuff breccia with crude layers ranging from inches to several feet in thickness. The green rhyolite commonly contains 5 to 20 percent subrounded to rounded lithic fragments in a fine-grained groundmass. Fragments are dominantly altered basalt with lesser amounts of lower rhyolite. Most clasts are 2 to 4 mm in diameter with some ranging up to several centimeters. The lithic fragments are commonly altered very light gray to white or light brown. Mafic lithic fragments are commonly pervasively replaced by pyrite in strongly altered zones.

Microscopically, the matrix of the green rhyolite tuff breccia contains about 5 percent rounded and broken quartz phenocrysts (0.3-0.6 mm), 7 to 10 percent highly altered feldspar phenocrysts, and a trace of biotite in a fine-grained devitrified groundmass. The groundmass and some lithic fragments are altered dominantly to chlorite group minerals as well as some kaolinite and sericite.

In cross-section and on the geologic map it can be seen that the green rhyolite tuff breccia is always either beneath or flanking the later porphyritic rhyolite. The green rhyolite may be the product of initial explosive eruptions from the same feeder zone for part of the porphyritic rhyolite. The thickness of green rhyolite tuff breccia, as shown on cross-section C-C' (Plate 3), is greatest around the porphyritic rhyolite feeder zone. From study of core samples and exposures in the Sommercamp Pit it has been determined that the amount of green rhyolite inclusions in the porphyritic rhyolite increases with closer proximity to the feeder zone.

Rhyolite Dike

A gray phenocryst poor rhyolite dike is exposed in a roadcut of the main access road just east of the bridge crossing Jordan Creek. The 15 foot wide dike, with a light brown weathered surface, cuts basalt and has an attitude of approximately N10°W 75°S. Along the edge of the contact rounded and stretched inclusions of basalt are present in the rhyolite dike. Microscopically, the dike is composed dominantly of glass and microlites, with around 2 percent phenocrysts (0.3-0.6 mm) of rounded quartz and feldspar.

The strike length of the dike has not been determined, as it shows no relief on the weathered slopes above and below the roadcut. It is possible that it extends a greater distance than is shown on the geologic map. The attitude and mineralogical characteristics suggest that it may have been a feeder for porphyritic rhyolite.

Porphyritic Rhyolite

Porphyritic rhyolite is the most widespread and extensive unit in the DeLamar Silver Mine study area. Economically, the unit is important as the major host rock for epithermal silver and gold mineralization. The rhyolite is exposed in two subparallel zones trending northwest and also along the north-trending Henrietta Ridge. Porphyritic rhyolite commonly forms bold ridges with steep resistant slopes. The unit disconformably overlies green rhyolite tuff breccia, lower rhyolite, quartz latite, and lower basalt. A postassium-argon age determination of porphyritic rhyolite from the north end of Henrietta Ridge dates the rhyolite at approximately 15.7 million years (Pansze, 1975, Plate 1).

The porphyritic rhyolite is a composite unit made up of different phases of closely related rock from coalescing flows, exogeneous domes, and necks. Locally the unit may be highly variable, especially in color and texture. Fresh outcrops are commonly white to very light gray but may also range from pale red purple to grayish orange pink. On weathered surfaces the colors are darker with the rock commonly mottled by black and gray lichens on the surface.

Within a single outcrop area the unit is generally massive and homogeneous with textural variations largely due to the presence or lack of lithophysae. Banding is well developed in some places but is not ubiquitous.

Typically fresh prophyritic rhyolite contains 5 to 10 percent anhedral to subhedral quartz (0.5-1.5 mm) and sanidine (1-3 mm) phenocrysts, with a trace of biotite. The fine-grained hypocrystalline groundmass sometimes displays spherulitic or lithophysal texture. Some phases of the rhyolite, especially those exposed west of Jordan Creek, contain cracked and shattered phenocrysts in a glassy matrix. This may be the result of pyroclastic activity accompanying eruption of the flows.

Figure 8. Outcrop of porphyritic rhyolite forming the south end of Henrietta Ridge; view to the west.

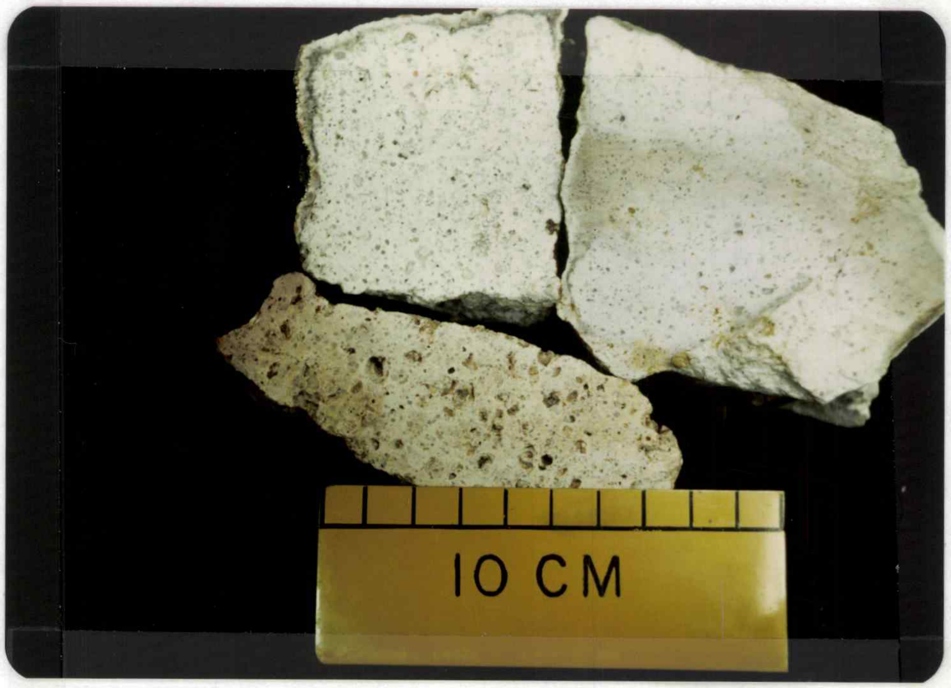


Figure 9. Hand specimens of fresh porphyritic rhyolite.

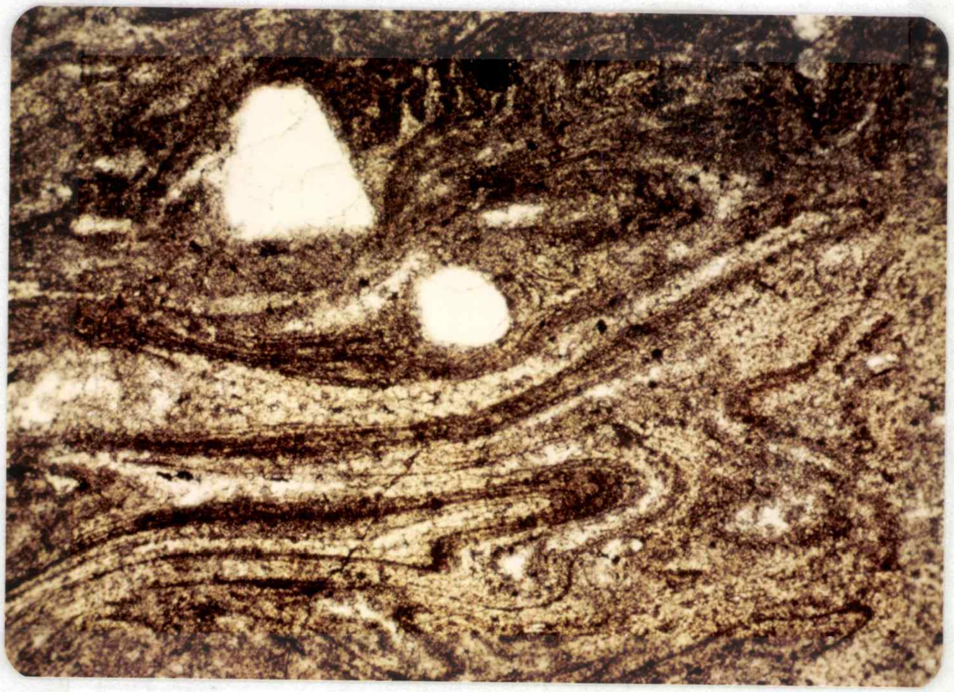


Figure 10. Thin section of fresh porphyritic rhyolite; plain light, approximate field of view 4.5 mm.

Hydrothermal alteration has extensively affected the porphyritic rhyolite of DeLamar Mountain. Where altered the rock is usually white to light gray or light greenish gray. The intensity of alteration is commonly dependent on the spatial relation of the rock to epithermal vein systems. The most common alteration minerals are quartz and sericite, with the proportions increasing with the intensity of alteration. A quartz-alunite assemblage is developed in a few localized occurrences, usually near the surface. Where affected by extreme "quartz flooding" the highly altered rock may have a fresh glassy appearance in hand specimen. Lithophysae may be partly filled by amorphous SiO_2, as is especially common in exposures north of the Sullivan Gulch zone.

Sources for the porphyritic rhyolite flows are local dikes, plugs, and exogeneous volcanic domes which exploited areas of structural weakness along northwest - and north - trending zones. In the area of greatest study and information, the Sommercamp zone, the porphyritic rhyolite vented along a north-trending fracture. As the rhyolite erupted it formed a thickened dome above the vent area and thinner flows marginally. Study of exposures and drill core samples from near the edge of the postulated vent area shows an increase of rounded inclusions of basalt and older rhyolites with depth. In the north end of the Sommercamp Pit, at the lower levels, the porphyritic rhyolite has rounded inclusions averaging 2 to 5 centimeters diameter and up to 20 cm long. The inclusions appear to be mostly basalt altered to green clays and fine disseminated pyrite.

The lower basalt-porphyritic rhyolite contact northwest of the West Glenn Silver zone, exposed in a roadcut, shows the rhyolite's intrusive nature. The contact is gradational over approximately 100 feet from fresh basalt through a zone of rounded bleached basalt fragments in a porphyritic rhyolite matrix to rhyolite with no inclusions. In earlier studies (Asher, 1968; Pansze, 1975), the rhyolite-basalt contact was considered to be a normal fault. The evidence from well exposed contacts and the detailed geometry of the porphyritic rhyolite gained by drilling clearly shows its intrusive nature. It should be considered that some displacement may have occurred along the feeder zones.

Banded Rhyolite

Banded rhyolite caps DeLamar Mountain and covers an irregular northwest trending zone in the center of the study area. The unit has been penetrated by drilling in thicknesses up to 480 feet. More commonly it is 200 to 300 feet thick. Banded rhyolite overlies porphyritic rhyolite, green rhyolite tuff breccia, and lower basalt, but is in fault contact with basalt in the east-central part of the area. In most places the banded rhyolite forms smooth commonly talus covered slopes. Steep cliffs of banded rhyolite occur in exposures north of Louse Creek.

Fresh exposures of the rhyolite consist of alternating grayish pink and pale red purple bands (1-5 mm) of fine-grained felsic minerals with less than one percent phenocrysts. The banding is commonly contorted and folded. A black vitrophyre 10 to 50 feet thick is often present at the base. Weathered surfaces are pinkish gray to pale brown. The banded rock tends to weather to thin plates.

Figure 11. Hand specimen from the lower basalt-porphyritic rhyolite contact northwest of the West Glen Silver zone. Rounded, bleached basalt fragments are in a matrix of intrusive rhyolite.

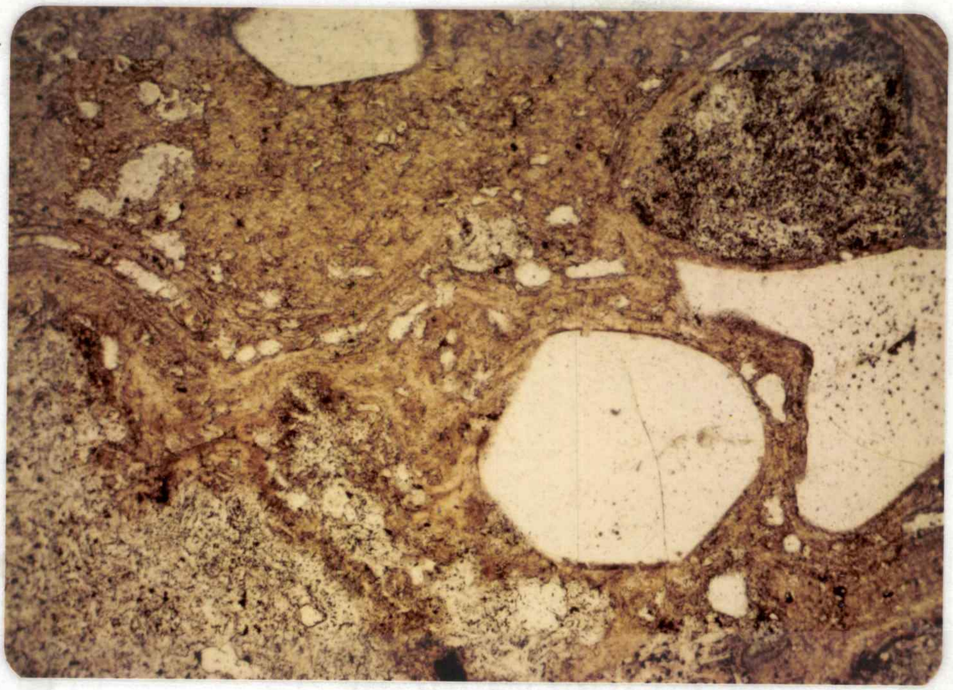


Figure 12. Thin section of the lower basalt - porphyritic rhyolite contact northwest of the West Glen Silver zone. Rounded fragments of basalt are in the upper right and lower left; plain light, approximate field of view 4.5 mm.

Where hydrothermally altered, commonly with varying amounts of kaolinite and quartz, the banded rhyolite is very light gray to white. The altered basal vitrophyre is pale yellowish brown grading to a grayish yellow green to pale blue green where intensely altered to clay. This alteration "clay zone" was considered by many early workers in the area to be a fault, based on its similarity to fault gouge. This point is discussed in greater detail in the section on hydrothermal alteration.

Microscopically, the banded rhyolite is dominantly glass and microlites alternating with bands of devitrified spherulites. Rounded phenocrysts (0.5-1 mm) make up less than one percent of the rock. The dominant phenocryst is quartz with lesser amounts of feldspar. The basal vitrophyre is only slightly devitrified and commonly has a perlitic texture.

Flow azimuth, the absolute direction of movement at any point on a flow, was determined for one oriented thin section of basal vitrophyre using the methods of Elston and Smith (1970). Results from this sample indicate a source area to the south. Study of additional samples would be necessary to verify this conclusively.

The emplacement mechanism of the banded rhyolite is debatable. The unit's gross characteristics seem to be those of lava flows. Some features of the rhyolite suggest that it may be a welded ash-flow tuff that reverted almost entirely to a viscous liquid shortly after emplacement and before the parent ash-flow mass had come to rest. Structures indicative of viscous laminar flowage, such as lineations, crenulations and folds, ramp structures, extremely flattened and stretched fragments, and zones of flattened glass shards are

Figure 13. Banded rhyolite showing folded flow layering; exposed in cliffs north of Louse Creek.

Figure 14. Millsite rhyolite exhibiting columnar jointing; north of Louse Creek.

observed in the banded rhyolite. Ash-flow tuffs which developed laminar flowage have been described in the Canary Islands (Schmincke and Swanson, 1967), and in southeast Oregon (Walker and Swanson, 1968). Regional studies of flow-layered and flow-folded welded ash-flow tuffs by Ekren, McIntyre, and Bennett (1978, p. 215) in Owyhee County, Idaho suggest that some have reverted to high-viscosity liquids with the obliteration of primary pyroclastic features.

Conditions which may contribute to a transition from ash flow to viscous liquids include: chemical compositions which cause the glass to have lower viscosity, high temperatures, and volatile retention. The most prevalent cause may be eruption at high temperatures near the liquidus.

Millsite Rhyolite

Millsite rhyolite covers most of the southeast corner of the study area. It is well-exposed along the steep slopes of Sullivan Gulch and the north-south trending ridge south of the DeLamar Silver Mine mill. The unit unconformably overlies porphyritic rhyolite and banded rhyolite. Drilling in the area has penetrated up to 440 feet of millsite rhyolite; its greatest thickness probably exceeds 500 feet.

The millsite rhyolite is a resistant unit commonly forming ridges bounded by steep slopes and short cliffs. Fresh exposures are most commonly grayish purple to grayish red purple. Weathered surfaces are reddish brown to dark yellowish brown commonly mottled by dark

Figure 15. Basal breccia of millsite rhyolite incorporating "ripped up" fragments of the black vitrophyre forming the bottom of the unit.

lichens which cover much of the surface.

Most of the unit contains between 7 and 10 percent phenocrysts in a glassy and microspherulitic groundmass. Phenocrysts are typically comprised of about 50 percent quartz (0.5 mm), 40 percent sanidine (avg. 1-1.5 mm, up to 4 mm), 0-10 percent plagioclase, and a trace to 2 percent of altered biotite and pyroxene. The lower part of the millsite rhyolite generally has fewer, and smaller, phenocrysts in a dominantly glass matrix.

The top of the unit in places exhibits a breccia with angular to subangular grayish red purple clasts in a pale pink matrix. Most clasts are less than 5 cm but some are up to 50 cm in diameter. This breccia is well exposed on the ridge top south of the mine office. Microscopic study of the breccia shows that the clasts are strongly iron-oxide-altered phenocryst-rich rhyolite in a matrix of glass and broken phenocrysts. This is interpreted to be a flow breccia.

Portions of the unit have well developed lithophysae commonly up to 10 cm in diameter. A massive central zone has well-developed columnar jointing exposed on the south-facing cliffs approximately one-half mile due south of the millsite of the DeLamar Silver Mine. A basal breccia and black, sometimes reddish, vitrophyre form the bottom of the unit.

The millsite rhyolite is probably a lava flow or flows. The source of the rhyolite was not determined. It may have erupted from vents now concealed in the study area or vents farther to the south.

Thermal Spring Deposits

Siliceous thermal spring deposits form resistant caprocks on two hills near the center of the study area. Small deposits of siliceous sinter are also exposed by the Henrietta workings, in the eastern part of the Ohio zone, and southeast of the Sullivan Gulch zone. The two larger deposits are approximately 75 to 100 feet thick and unconformably overly porphyritic rhyolite, banded rhyolite, and millsite rhyolite. The deposits are dominantly a vuggy white siliceous rock. Some vugs or vesicles form elongate pipes having roughly vertical orientations. Microscopically, the vuggy rock is composed almost entirely of microcrystalline quartz cut by microveinlets of quartz.

Knobs of siliceous breccia occur in the eastern part of the Ohio zone. This breccia has a gray to white fine-grained siliceous matrix containing subangular to rounded clasts of rhyolite and basalt averaging 5 to 20 mm in diameter. A similar breccia, which has now been excavated, was previously exposed in the North DeLamar zone. The deposits may be the products of volatile-rich near surface breccia pipes associated with hot spring activity.

Louse Creek Andesite

Louse Creek andesite crops out in the southeast edge of the study area. It unconformably overlies quartz latite, porphyritic rhyolite, banded rhyolite, and millsite rhyolite. The maximum thickness of the unit is about 300 feet.

Fresh exposures are medium gray, aphanitic, and massive, with platy jointing developed in places. The rock weathers to a brownish gray. The top part of the unit is a flow breccia of grayish-red scoriaceous fragments in a dense matrix. Microscopically the unit is

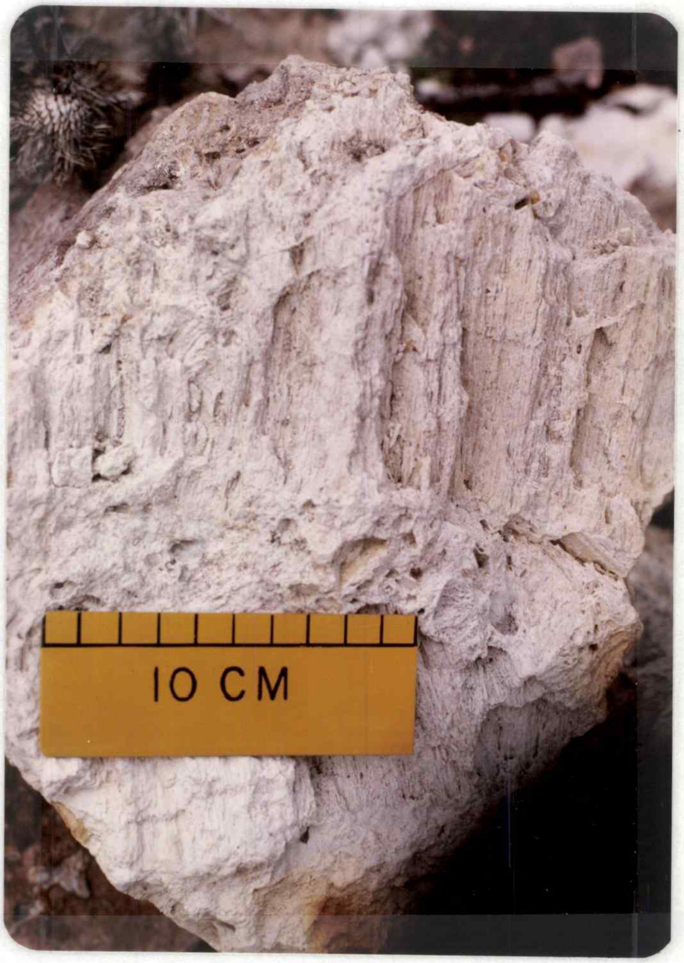


Figure 16. Siliceous thermal spring deposits with some vugs forming elongate pipes having roughly vertical orientations.

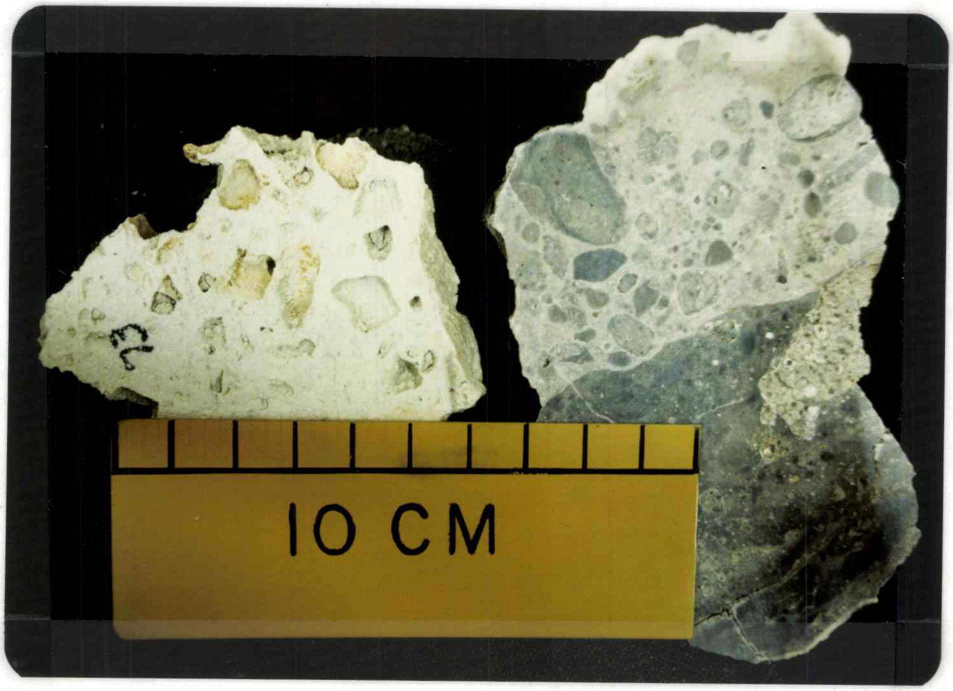


Figure 17. Thermal spring deposits. On the left, white vuggy sinter; on the right, siliceous breccia.

dominantly (90-95%) a hypocrystalline groundmass probably containing microlites of pyroxene, feldspar, and magnetite. Most phenocrysts (80-95%) are twinned and zoned andesine (0.5-1.5 mm). Less than 10 percent of the phenocrysts are rounded and embayed quartz (0.2 mm). A single chemical analysis of the unit (Pansze, 1975, p. 22) shows 60.6 weight percent SiO_2 (Table 1) which, together with the mineralogy, classifies the rock as andesite.

The andesite was emplaced as a lava flow but its origin and exact age relations are not known. Field evidence indicates that it was emplaced later than the rhyolitic sequence, possibly as an intracanyon flow.

Undivided Gravels and Placer Gravels

Quaternary and Tertiary terrace gravels cover older lithologies in the southwest part of the study area. These gravels are composed of pebbles, cobbles, and boulders of locally-derived volcanic and granitic rocks. The thickness of these gravels was not determined.

Placer gravels along Jordan Creek were intensely worked and largely depleted of gold soon after mining commenced in the region. Gold remaining in the placer gravels is typically very-fine grained "flour gold." Recent attempts to rework the placer deposits in the area have had poor results.

<table>
<tr><th>This thesis 1982</th><th>Pansze 1975</th><th>Asher 1968</th><th>Lindgren and Drake, 1904</th></tr>
<tr><td>Louse Creek andesite</td><td>Upper basalt</td><td></td><td></td></tr>
<tr><td>Thermal spring deposits</td><td rowspan="8">Upper rhyolite</td><td>Silver City rhyolite</td><td rowspan="10">Rhyolite</td></tr>
<tr><td>Millsite rhyolite</td><td>Welded tuff</td></tr>
<tr><td>Banded rhyolite</td><td rowspan="6">Silver City rhyolite</td></tr>
<tr><td>Porphyritic rhyolite</td></tr>
<tr><td>Rhyolite dike</td></tr>
<tr><td>Green rhyolite tuff breccia</td></tr>
<tr><td>Lower rhyolite</td></tr>
<tr><td>Pole Creek rhyolite</td></tr>
<tr><td>Quartz latite</td><td rowspan="2">Quartz latite</td><td rowspan="2"></td></tr>
<tr><td>Porphyritic latite</td></tr>
<tr><td>Lower basalt</td><td>Lower basalt</td><td>Basalt-latite</td><td>Basalt</td></tr>
</table>

Figure 18. Generalized lithologic correlation chart. Diagonal lines indicate units absent or not exposed.

STRUCTURAL GEOLOGY

Regional structure is dominated by a set of N10-20°W trending oblique-slip, high-angle faults and a less pronounced set trending N75°W. Large fault blocks are progressively downdropped to the west of the axis of the Owyhee Range. These faults may be related to crustal extension in the Basin and Range province (Christiansen and Lipman, 1972, p. 255) and to rifting in the Snake River Plain (Thompson, 1966, p. 284).

Faults and fractures in the DeLamar Silver Mine area follow the dominant regional trends. These structurally weak zones were exploited during rhyolitic volcanism and later epithermal mineralization.

One of the more important faults cutting DeLamar Mountain is the West Fault,which on the western edge of the Sommercamp Pit, strikes N5°W and dips 70°W. Normal displacement along the fault downdrops the west side at least 450 feet as seen on cross section C-C'. The center of the Sommercamp zone seems to have been downdropped around 200 feet relative to the North DeLamar zone. This is based on offset of the contact between green rhyolite tuff breccia and lower rhyolite. Fault displacement may have taken place simultaneously with the venting of the porphyritic rhyolite.

A fault in the Glen Silver zone trending N60°W downdrops the south side about 180 feet. The relations in this zone are similar to the main DeLamar Mountain area. The fault zone(s) seems to have developed prior to or during emplacement of the porphyritic rhyolite.

In the east central part of the study area, lower basalt appears to have been uplifted as a block displacing younger rhyolitic rocks. Slickensides have been found in places along this contact. This fault can be traced trending N 15° W as a linear on aerial photographs.

The poles for many attitudes of fractures and epithermal veins in the Sommercamp Pit were plotted on equal area projection stereonets (Figures 19, 20). Attitudes of the veins show two major trends: (1) N 20° W 70°S-vertical, and (2) N 45° W 85°N-vertical. Fracture attitudes have three major trends: (1) N 20° W 70°S-vertical, (2) N 40° W 85°N-vertical, and (3) N 35° E 75°N-vertical. Comparison of these plots shows that the major vein trends and most of the major fracture trends are the same. It is of interest to note that one of the fracture trends, N 35° E 75°N-vertical, has not hosted epithermal veins. It may be tentatively concluded that this fracture set was post-ore.

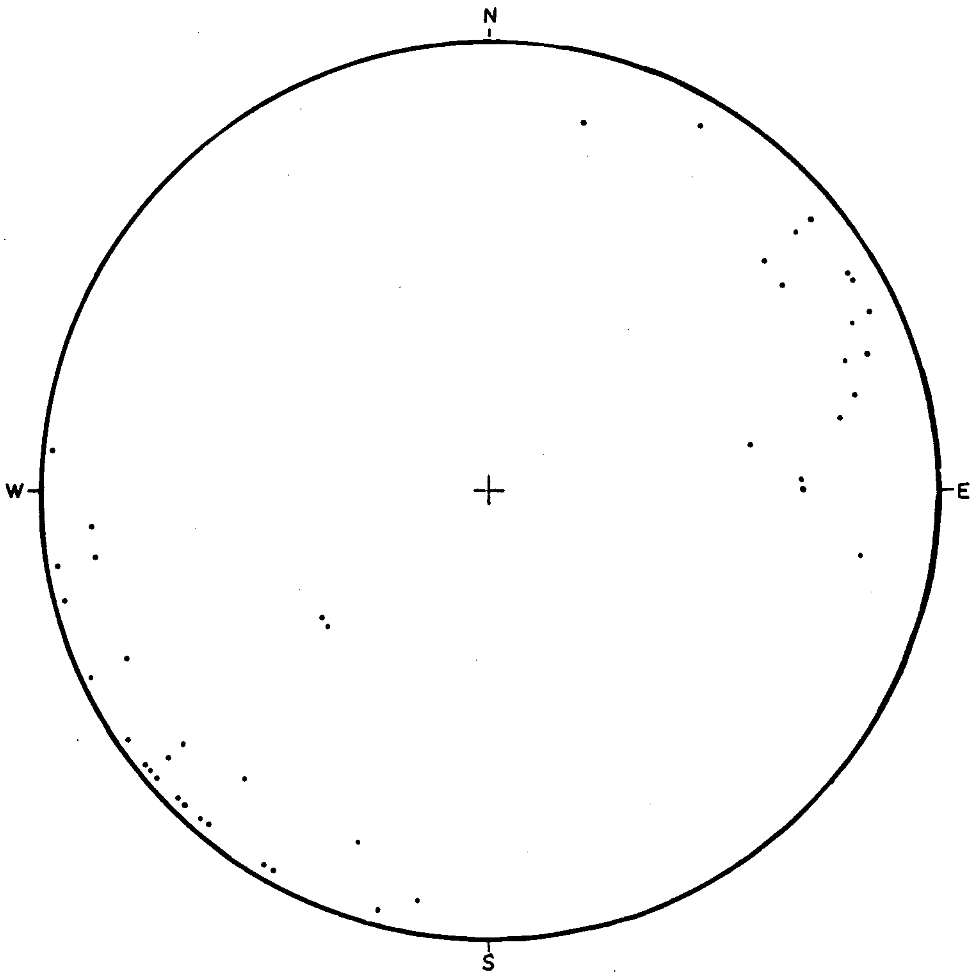


Figure 19. Diagram showing poles of veins in the Sommercamp Pit plotted on equal area projection. DeLamar Silver Mine, Owyhee County, Idaho.

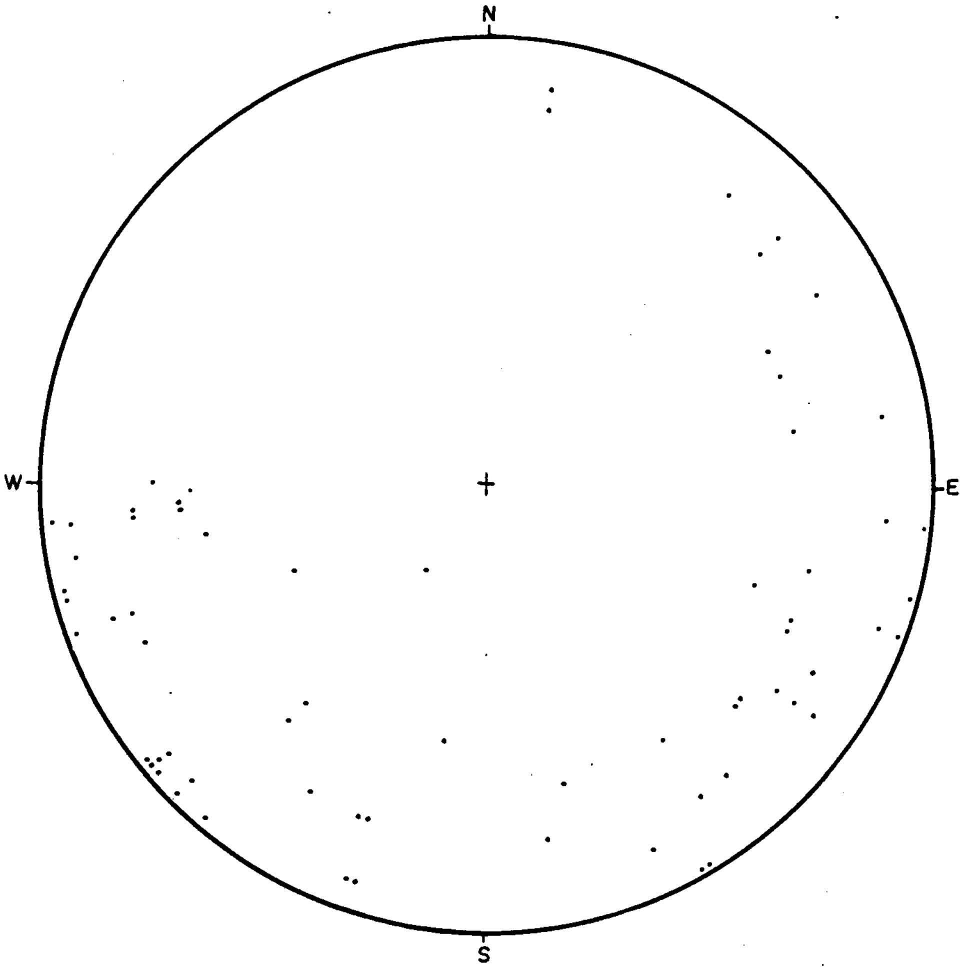


Figure 20. Diagram showing poles of fractures in the Sommercamp Pit plotted on equal area projection. DeLamar Silver Mine, Owyhee County, Idaho.

GENERAL CHARACTERISTICS OF EPITHERMAL AG-AU DEPOSITS

The term epithermal was proposed by Lindgren (1933, p. 203-212) implying an origin at low temperature (50-200°C) and shallow depth (500-3000 feet). White (1981, p. 408) updated Nolan's (1933) earlier subdivision of epithermal silver-gold ore deposits into silver-dominated and gold-dominated. The silver-dominated group commonly contains a variety of silver minerals (electrum, acanthite, sulfosalts, and selenides), pyrite, and base metal sulfides. Quartz is the main gangue mineral. Some quartz occurs in lamellar plates, which are pseudomorphic after lamellar calcite. Wall rocks adjacent to veins are generally altered to mixtures of quartz, sericite, and adularia.

The gold-dominated group consists of two intergradational subgroups. The first of these is characterized by veins of comb quartz, pyrite, and free gold. The other subgroup is mineralogically more complex with tellurides being common and stibnite and cinnabar occurring in many deposits. Quartz is the most abundant vein material; adularia is locally present. According to Nolan (White, 1981, p. 408), wall rocks of the gold-dominated deposits are commonly unaltered except adjacent to veins, contrasting with the highly altered wall rocks of the silver-gold deposits.

White (1981, p. 408) correlates the gold-dominated deposits with the shallow parts of active geothermal systems such as the Broadlands, New Zealand, and Steamboat Springs, Nevada. The silver-dominated ore deposits may be more similar to the deep base metal sulfide zone of Broadlands.

FORMS OF THE DELAMAR ORE BODIES

Most mineralization at DeLamar is localized in three zones: the Sommercamp, North DeLamar, and Glen Silver (Figure 21). Mineralization in the Sommercamp zone covers an area approximately 1,000 feet long and 600 feet wide; the North DeLamar zone is about 1,100 by 500 feet; the Glen Silver mineralized area is roughly 1,800 feet long and 400 feet wide. Most economic mineralization in the three areas bottoms 300 to 400 feet below the surface. The Sullivan Gulch zone is approxomately 1,000 feet long and 300 feet wide. The top of this ore zone is about 200 feet below the surface, with the mineralized section being 300 to 400 feet thick.

Mineralization is most commonly concentrated in the well-fractured, silicified, upper part of the porphyritic rhyolite. As shown on cross section C-C' (Plate 3) the ore zones generally have wedge-like or cone-like flare upward. Mineralization and veining are mostly controlled by fractures, but locally veining may be influenced by flow banding and layering in the rhyolites. Dominant vein trends in the Sommercamp zone are N20°W 70°S to vertical, and N45°W 85°N to vertical; in the North DeLamar zone N60°W 30° to 40°S; and in the Glen Silver zone N40° to 50°W 70°S to vertical.

The entire vein structures are not uniformly mineralized. More intense mineralization occurs at vein intersections and where fracture density is greatest. The largely impermeable clay alteration zone at the base of the banded rhyolite had a "ponding" effect on the rising mineralizing fluids. Mineralization is most continuous

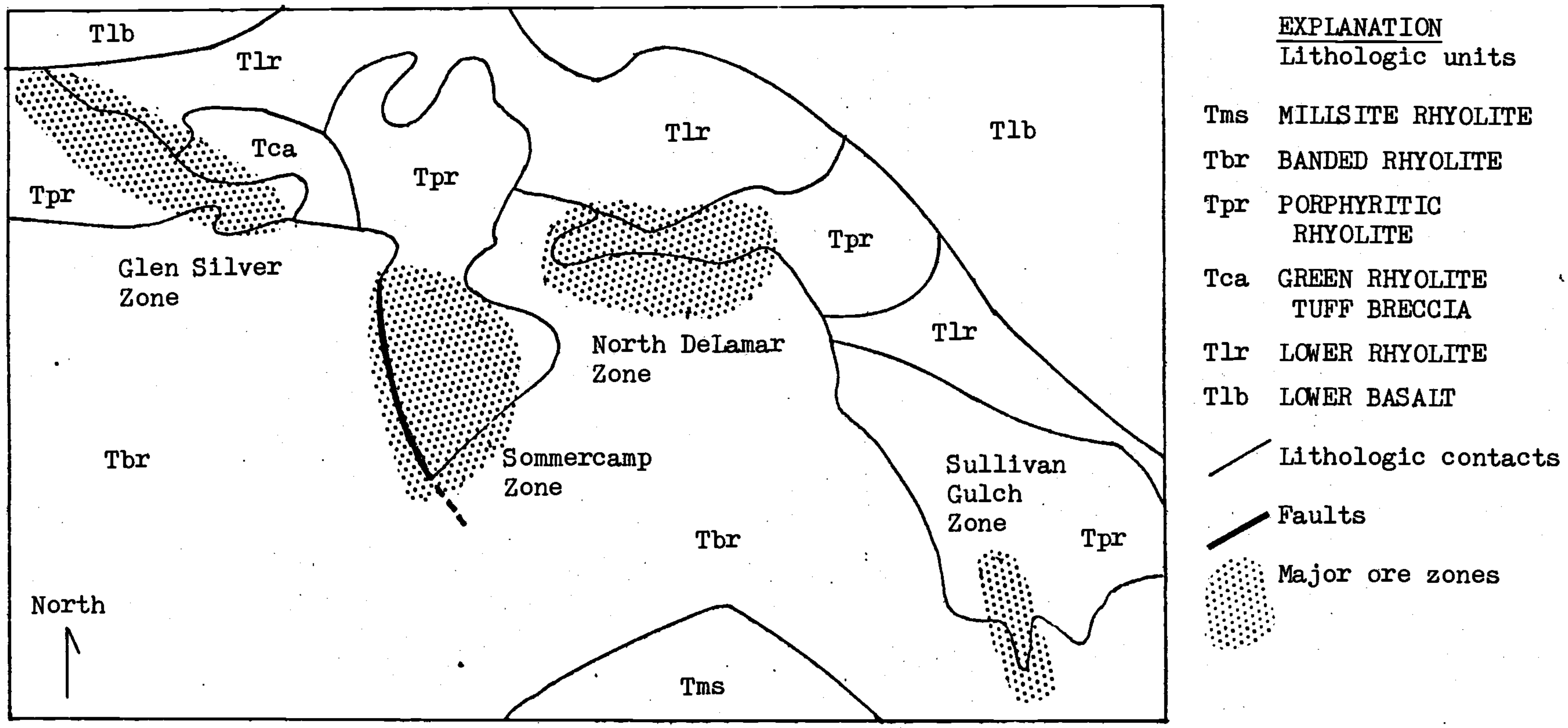
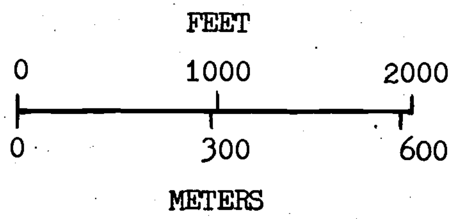


Figure 21. Major ore zones and generalized geologic map of the DeLamar Silver Mine, Owyhee County, Idaho.



immediately below this zone, with more restricted feeder veins extending downward.

METAL RATIOS--AG/AU

Silver-gold ratios from the Sommercamp and North DeLamar areas were studied using assays from development drill hole samples taken at 5 foot intervals. Areas with consistent ratios were grouped into zones, shown on cross section C-C' (Plate 3).

Overall the Sommercamp area has higher silver-gold ratios, commonly 100-249/1 whereas ratios in the North DeLamar area are lower, 50/1. In general as silver grade increases the ratio of silver to gold also increases. The distribution of ratio values demonstrates the erratic nature of the mineralization. In places areas of consistent ratios roughly coincide with vein trends and the trend of the restricted feeder zones at depth.

Interpretation of the silver-gold ratios may be complicated by multiple and overlapping periods of mineralization. The controlling factors are difficult to determine without specific chemical and thermodynamic data. A comparison may be made with the Broadlands geothermal system, New Zealand, where the ratio of Ag/Au modestly exceeds 1/1 in most surface formed deposits and high level core but increases greatly downward to around 1,0000/1 near the bottom of the hole (White, 1981, p. 407). The low ratios of the North DeLamar mineralization may indicate that it formed farther from the feeder zone than the Sommercamp and/or at a higher level in the system.

ORE MINERALOGY

Ore minerals at DeLamar are characteristic of epithermal deposits. Mineralogy of the deposit is dominated by sulfides and selenides. The gangue consists almost entirely of quartz.

Ore mineralogy was determined in part by conventional methods including hand specimen study and observation of polished sections with reflected light microscopy. Various X-ray diffraction methods proved useful due to the small grain size of many ore minerals and the difficulty of optically determining some of the silver bearing minerals. Conventional X-ray diffraction techniques were used to determine ore minerals separated with tetrabromoethane (s.g. 2.96) from crushed samples.

A more unconventional X-ray diffraction technique was used to identify small mineral grains and to differentiate between similar appearing minerals. A needle with a very sharp point mounted in a plastic handle was used to "drill" the sample by rotating the needle. The product of such drilling is a fine powder that piles up beside the hole. The sample powder is then mounted on a glass capillary tube using high-vacuum silicon grease. By this procedure very small grains in both hand specimens and polished sections can be sampled. The mounted samples were exposed in a 57.3 mm Debye-Scherrer X-ray camera for between 30 to 45 minutes. The diffraction patterns proved useful in identification of both single crystals and mixtures.

In the following sections the dominant ore and gangue minerals are discussed.

Naumannite (Ag_2Se)

Naumannite is the dominant silver mineral at the DeLamar Silver Mine. Theoretically naumannite is 73.15 weight percent silver and 26.85 weight percent selenium. Shannon (1920, p. 604) reported the first identification of naumannite in the United States from a sample collected at DeLamar by Eldredge (who labeled it argentite) in 1893. The sample described by Shannon weighed 475 grams and came from the underside of the "iron dike" (intense clay alteration zone) in the "silver stopes" where unusually rich ore occurred.

Reported world occurrences of naumannite are rare. Notable localities include the Republic district, Ferry County, Washington; Tilkerode, Harz Mountains, Germany; Cerro de Cacheuta, Mendoza, Argentina (Roberts, Rapp, and Weber, 1974, p. 431); Jarbridge, Elko County, Nevada; and Guanajuato, Mexico (Davidson, 1960, p. 5)

In the Silver City district naumannite has almost the same physical properties as acanthite. Both minerals are dark blue-gray, sectile, slightly malleable, and present the same forms. Below 133°C naumannite crystallizes in the hexagonal system. Above 133°C it crystallizes in the isometric system, but internally the crystals revert to hexagonal with cooling (Palache and others, 1944, p. 179). X-ray diffraction analysis of soft gray metallic minerals at DeLamar indicated more than 80 percent to be naumannite, with the remainder being mostly acanthite.

Naumannite commonly occurs as small grains disseminated in quartz and in some fractures. It is also found as crystal aggregates growing on drusy quartz that lines vugs. Most of the crystals are

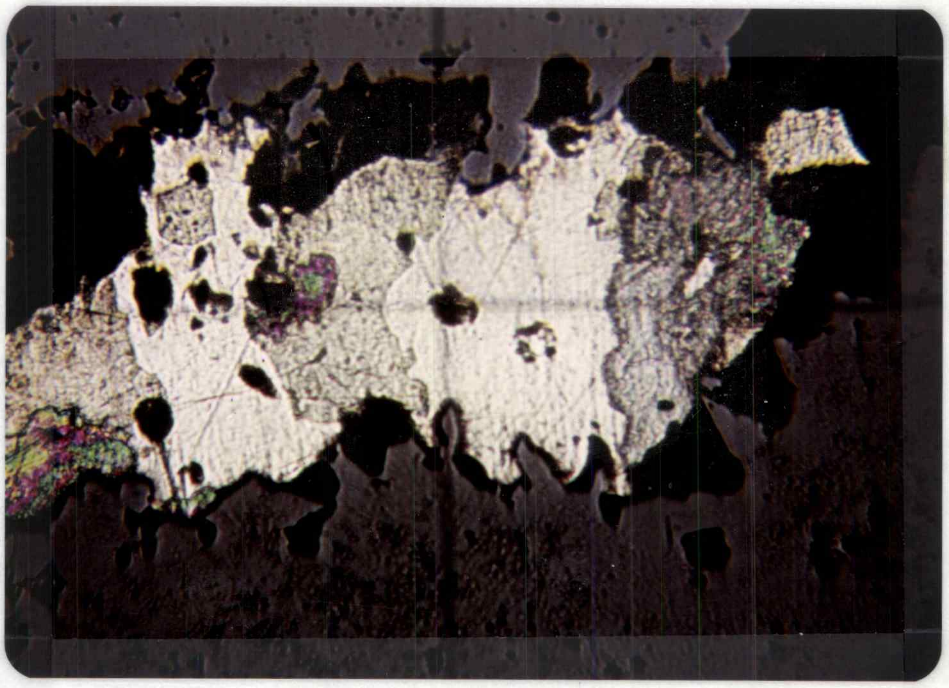


Figure 22. Polished section of naumannite (light gray) and pyrite (white); field of view approximately 0.3 mm. Iridescent colors on naumannite are tarnish.

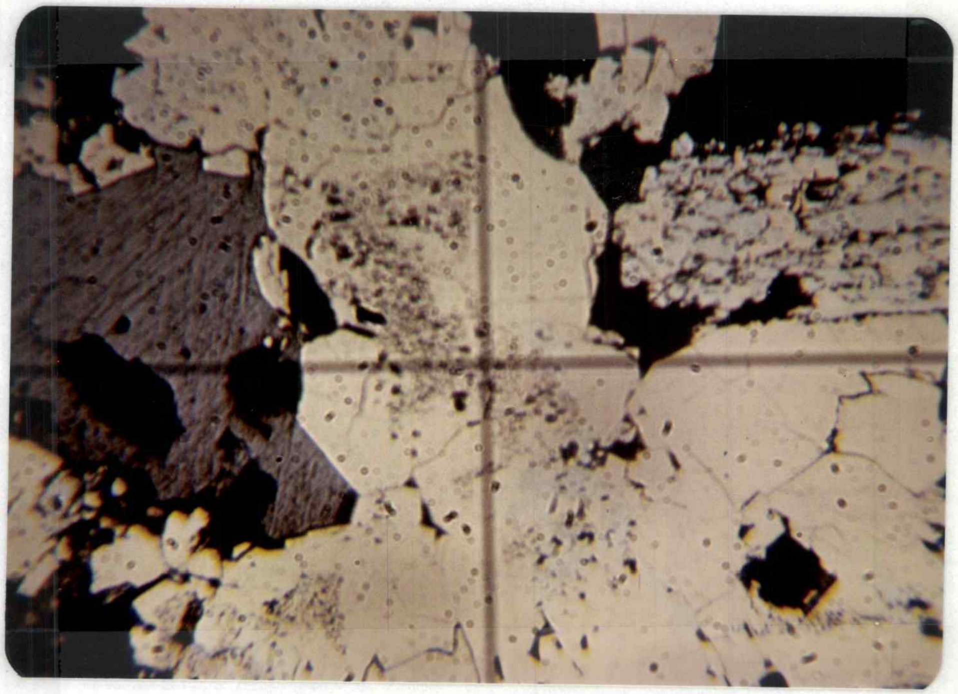


Figure 23. Polished section of naumannite (dark gray), pyrite (grayish yellow), and lath shaped marcasite in the upper right exhibiting steel blue polarization colors; field of view approximately 0.3 mm.

crudely formed or anhedral but occasionally crystals display well-developed morphology. Cubic shaped naumannite crystals are recognized in veins and in some vugs. The presence of cubic habit naumannite ore specimens indicates minimum temperatures of formation above 133°C. Although uncommon, some vugs contain well-formed hexagonal plates of naumannite, indicating that in those areas the latest crystallization of naumannite was below 133°C.

Acanthite (Ag_2S)

The second most abundant silver mineral at DeLamar is acanthite. In pure form acanthite is 87.06 weight percent silver and 12.94 weight percent sulfur. It has almost the same physical properties as naumannite, being blue-gray to black, sectile, and somewhat malleable. A polished surface of acanthite is darkened on exposure to a strong light faster than naumannite. Acanthite, a monoclinic form of Ag_2S, is the stable form at room temperature. Argentite, the cubic variety of Ag_2S, is stable only above 179°C (Palache and others, 1944, p. 177). In nature the material usually called argentite exhibits gross cubic external morphology but is in fact the monoclinic acanthite.

At DeLamar, acanthite is found in quartz gangue with naumannite as anhedral blebs. Also it commonly occurs as a late stage mineral coating drusy quartz in vugs. Some of these late stage minerals have well-developed crystal habit proving that at least some represent hypogene mineralization. Perry (1971, p. 9) observed grains of acanthite displaying coarse lamellar inversion twinning, which shows that at least a portion of this mineral was deposited at higher

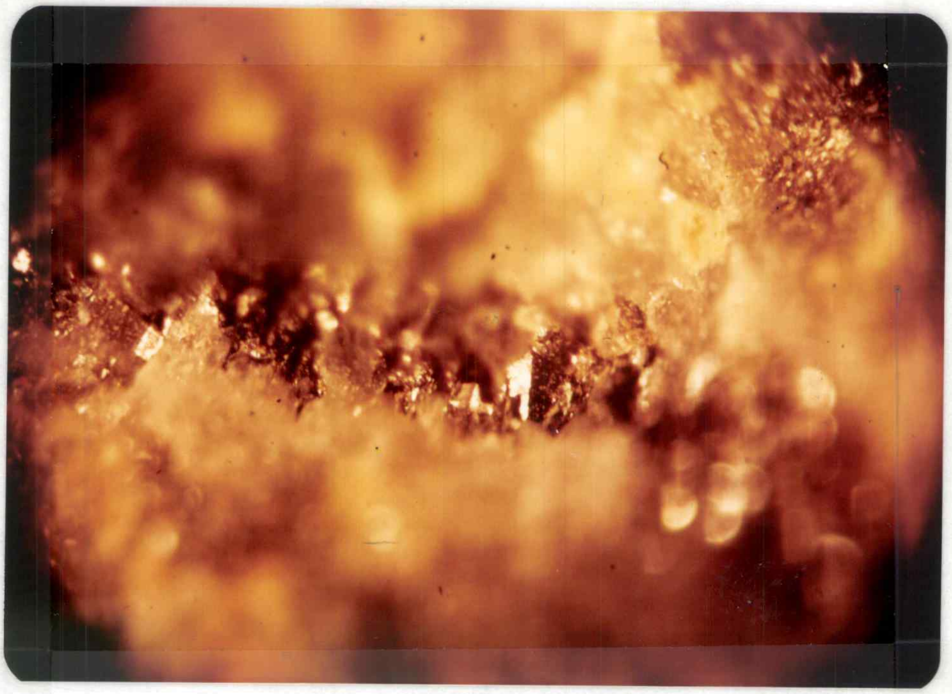


Figure 24. Isometric crystals of naumannite indicating crystallization above 133°C; approximate field of view 3 mm.

Figure 25. Hexagonal crystals of naumannite in vug with drusy quartz indicating crystallization below 133°C; approximate field of view 3 mm.

temperatures than its isometric-monoclinic inversion point at 179°C.

Pyrite (FeS_2)

Pyrite is the most widespread and dominant metallic mineral of the DeLamar deposit. Most pyrite occurs as disseminated cubic crystals and anhedral grains. It appears as one of the earliest deposited minerals, but it also occurs as coatings on some of the younger minerals. The intensely clay-altered zone, at the base of the banded rhyolite is in places heavily impregnated with pyrite crystals; some up to 10 mm across. Lath shaped crystals of pyrite less than 2 mm long found along the edges of veins and in altered county rocks may be pseudomorphic after a zeolite. Pyrite with poor crystalline form associated with marcasite may have inverted from earlier marcasite.

The colloform variety of pyrite, melnikovite, occurs in some zones at DeLamar. This colloform texture is well preserved in some pyrite clots up to 20 mm in diameter in the upper levels of the West Fault mineralized zone. Melnikovite pyrite results from the crystallization of colloidal gels of FeS_2 at low temperature (Ramdohr, 1969, p. 784).

Marcasite (FeS_2)

Marcasite is a widespread sulfide at DeLamar, second only to pyrite in abundance. It occurs in close association with pyrite in almost all zones. Marcasite is common as lath shaped crystals and as anhedral aggregates surrounding pyrite. In the West Fault mineralized zone marcasite is intimately intergrown in irregular clots with

Figure 26. Polished section of medium gray naumannite (central right) surrounded by grayish-yellow pyrite and lath shaped pyrite and marcasite intergrowths; approximate field of view 0.9 mm.

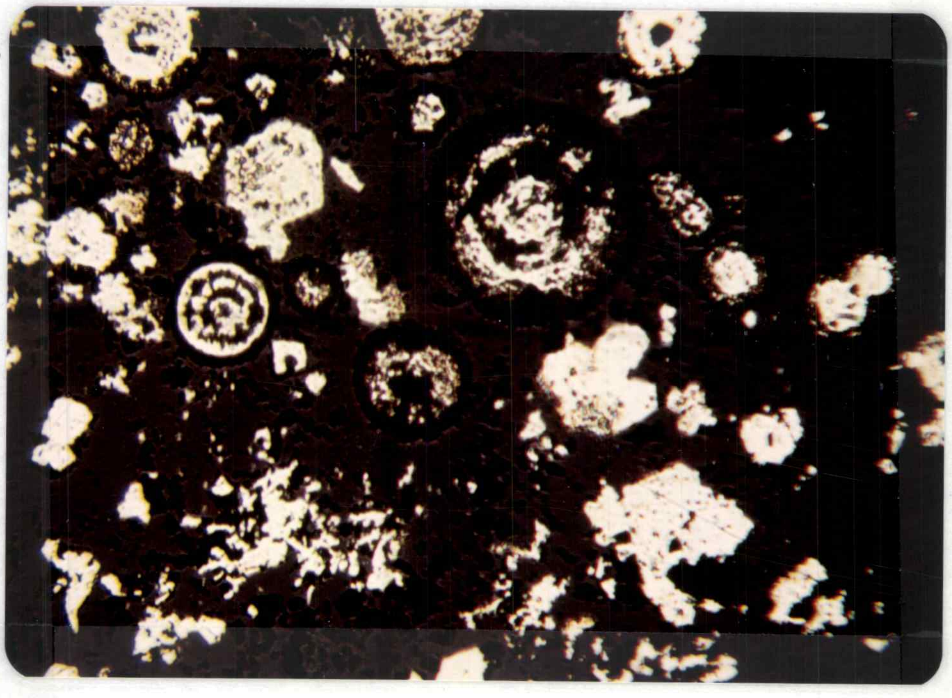


Figure 27. Polished section of melnikovite pyrite with colloform texture; field of view approximately 0.9 mm.

pyrite and melnikovite pyrite of poor cyrstalline form.

Marcasite in veins and quartz matrix breccias is probably hypogene. Some marcasite found as small anhedral crystals in open fractures appears to be supergene. Marcasite occurs mostly in surface and near-surface deposits where it formed at low temperatures and from acid solutions (Ramdohr, 1969, p. 831).

Argentopyrite ($AgFe_2S_2$)

Argentopyrite was found in a polished section of a sulfide-rich banded quartz vein associated with the West Fault mineralized zone in the Sommercamp Pit. This is the first reported occurrence of the mineral in the Silver City region. In polished section the mineral is very distinctive being yellow to brown (darker than pyrite) with strong to very intense anisotropy. Polarization colors are vivid shades of blue-gray, very deep blue, grayish-white, and reddish. The optical identification was confirmed by X-ray diffraction studies.

Argentopyrite at DeLamar forms intricate intergrowths with pyrite and marcasite. Its textural relation with other crystals suggests that it formed early. In hand specimen the argentopyrite in the intergrowths can not be differentiated from pyrite and marcasite.

Heating experiments show that argentopyrite is unstable at temperatures above 150°C. Czamanske (1969, p. 461) reasoned that the infrequent and minor occurrence of argentopyrite results from the fact that its formation requires sulfur fugacities near those associated with pyrite-pyrrhotite equilibrium, whereas geologic environments seldom provide such low values for sulfur fugasities at

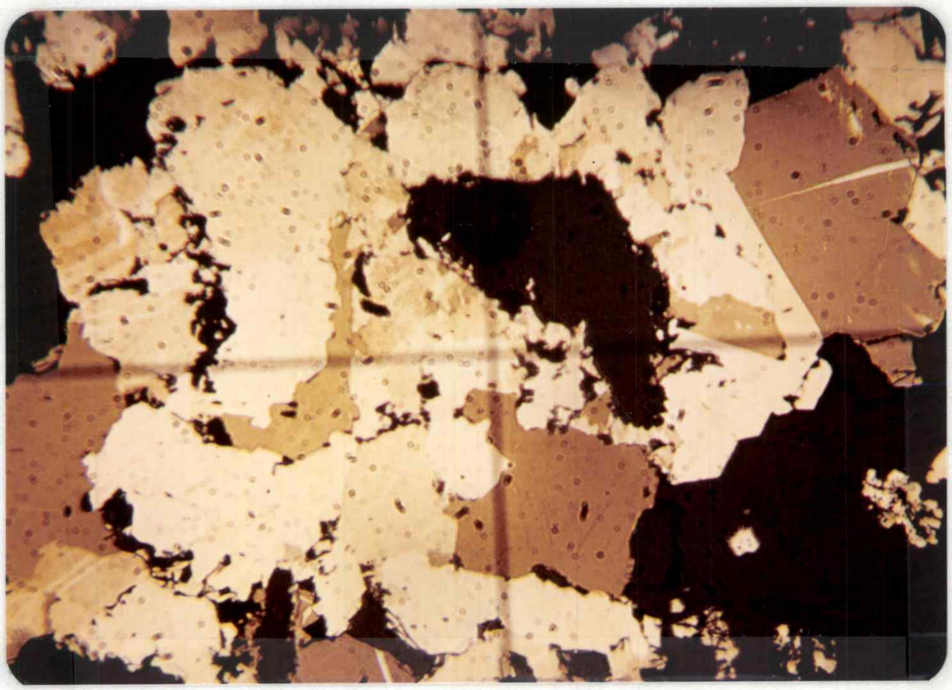


Figure 28. Polished section of argentopyrite (moderate brown to dusky yellow) and pyrite (grayish yellow); approximate field of view 0.9 mm.

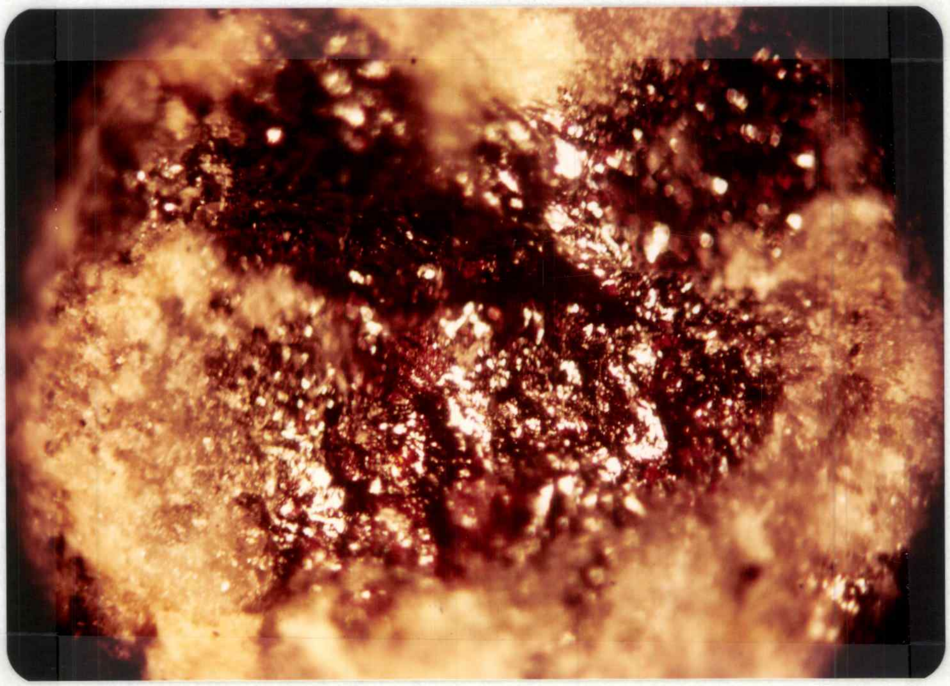


Figure 29. Pyrargyrite, dark ruby silver, on quartz; approximate field of view 3 mm.

low temperatures with an availability of abundant silver.

Pyrargyrite (Ag_3SbS)

Pyrargyrite, the dark ruby silver, was found in a two foot thick north-south trending quartz vein in the northwest part of the Sommercamp zone. This vein crosscuts other veins and appears to be relatively younger. Pyrargyrite, with gray black adamantine to metallic luster, occurs as aggregates of irregular grains and as anhedral crystals in open spaces. Its characteristic red internal color is generally visible. The pyrargyrite probably formed at low temperatures as one of the last silver minerals to crystallize in the sequence of primary deposition.

Native Gold (Au)

Native gold is very rarely seen in hand specimens or microscopically at DeLamar. Gold blebs rarely exceed five microns with most being smaller. Although highly variable, high gold values are often found in white lamellar quartz veins. Commonly these richer gold veins are very soft and crumbly being stained reddish orange. These veins crosscut other veins in places suggesting that at least one period of higher gold deposition occurred in the middle to later stages of mineralization. Practically all the native gold in the region occurs as an alloy of gold and some silver, which is known as electrum (Piper and Laney, 1926, p. 75).

Native Silver (Ag)

Most of the native silver at DeLamar is probably of supergene

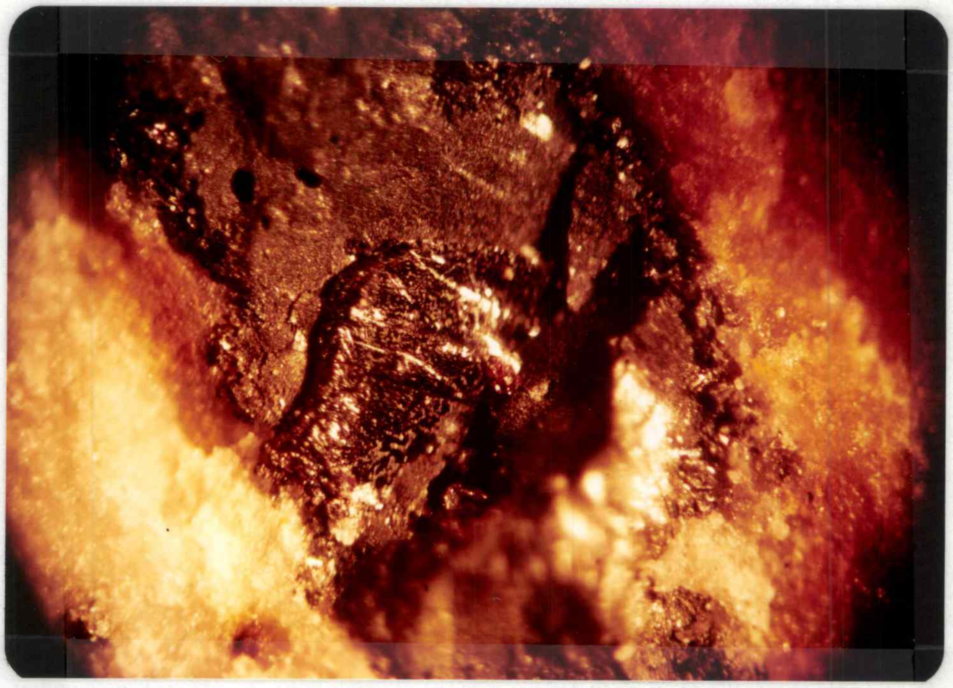


Figure 30. Pyrargyrite (center) with alteration rim of native silver; field of view approximately 3 mm.

origin. Usually bright white with a creamy tint the native silver is found in fractures and as alteration rims around silver bearing minerals. It probably accounts for a very minor percentage of total silver in the deposit.

Cerargyrite (AgCl)

Cerargyrite is a supergene mineral that is most abundant in the upper oxidized zones. It is very sectile and ductile, colorless when fresh, turning violet-brown to gray on exposure to light. Cerargyrite commonly occurs as coatings or as platy fracture fillings.

Umangite (Cu_3Se_2) Eucairite (AgCuSe)

A trace of the rare selenides umangite and eucairite was found in DeLamar core samples (Perry, 1971, p. 9). The two minerals occur as myrmekitic intergrowths apparently resulting from exsolution of umangite from eucairite.

Chalcopyrite ($CuFeS_2$) Galena (PbS)

Very small amounts of chalcopyrite occur as anhedral blebs in and partly replaced by naumannite. A trace of galena (?) occurs as small isolated anhedral grains. Possibly the galena-appearing grains are actually clausthalite (PbSe) in view of the relatively high selenium content of the deposit (Perry, 1971, p. 8).

GANGUE

The gangue material at DeLamar consists almost totally of quartz. Several varieties occur including a peculiar type of lamellar quartz; white, gray, and black, common vein quartz; and well formed crystalline quartz.

Much of the quartz present as gangue has a laminated structure. These quartz veins which,may be up to several feet wide are made up of thin lamellae crossing one another at various angles. This structure indicates that the quartz has replaced another mineral, probably calcite or barite, which formerly constituted the gangue.

These white lamellar quartz veins are also a common gangue in deposits on Florida and War Eagle Mountains of the Silver City region. The Owyhee vein on War Eagle Mountain carries calcite in tabular form on siderite and quartz. It also has "chopped" quartz considered to be pseudomorphic after calcite (Lindgren, 1900, p. 173). No calcite associated with veining has been found at DeLamar.

In some occurrences the lamellae of the pseudomorphic quartz are coated thickly with small drusy quartz crystals. Microscopic study of the lamellar plates reveals that they are composed of small quartz grains arranged along the sides of a very straight median line.

If the lamellar quartz veins are pseudomorphic the fissures must have first been filled with calcite or possibly barite that was later replaced. Any ore metals that were deposited with this initial gangue were either taken into solution and redeposited or removed.

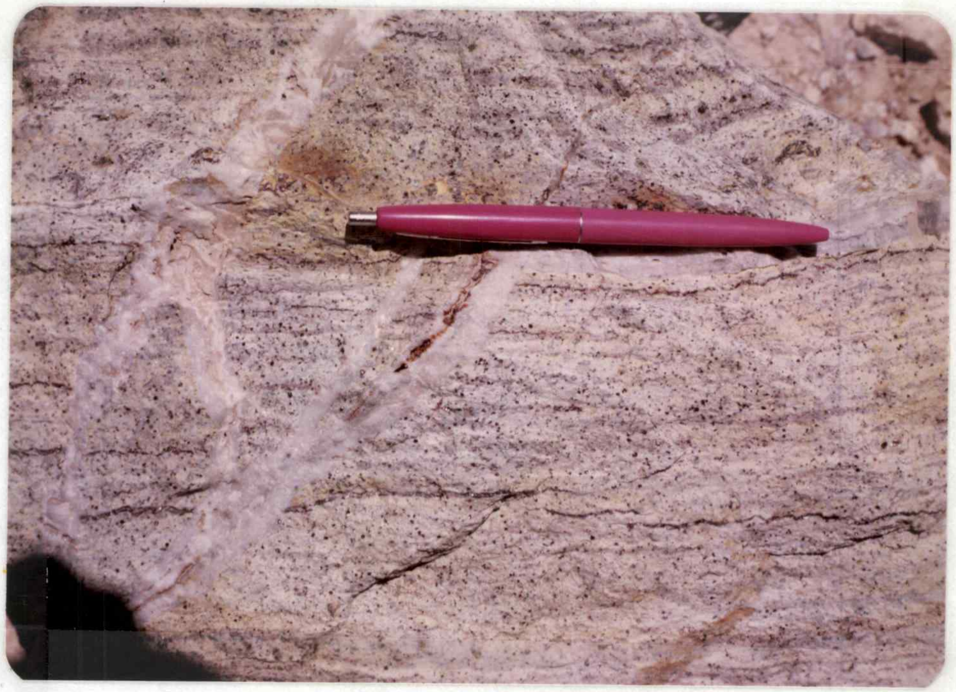


Figure 31. Flow banded porphyritic rhyolite cut by quartz veins in the North DeLamar Pit.

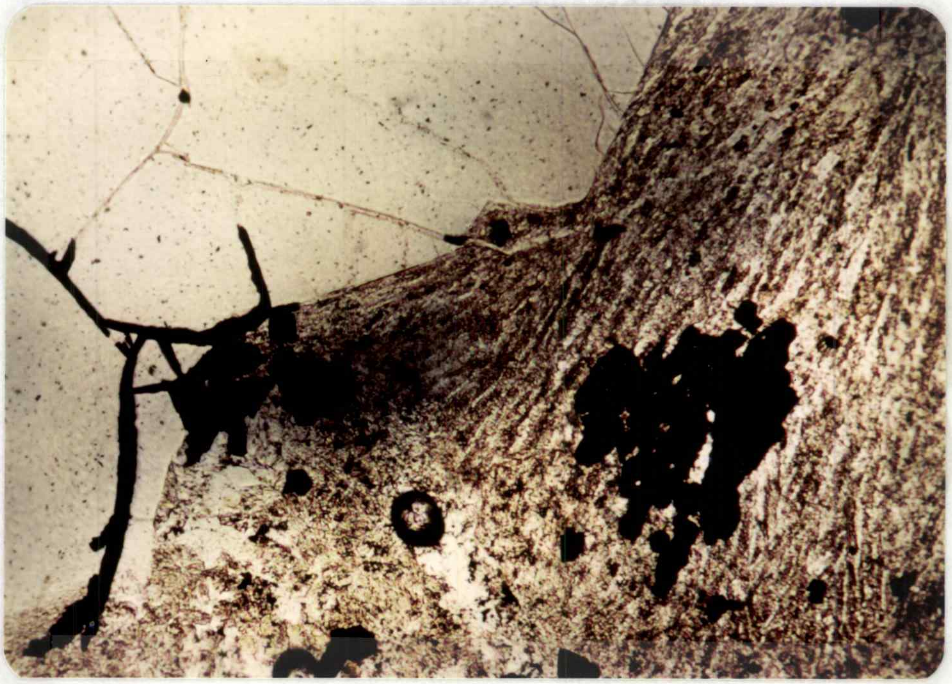


Figure 32. Thin section of disseminated mineralization in porphyritic rhyolite; plain light, approximate field of view 1.5 mm.

Massive cloudy white, gray, and black quartz veins are also common at DeLamar. These veins may either be composed of one type or of alternating bands which may or may not be symmetrical on both walls of the vein. These massive veins are composed of small grains of microcrystalline quartz.

Well-formed crystalline quartz occurs in vugs, cavities, and some fissures. These quartz crystals seldom exceed 5 mm in length. Most are small and may best be called drusy quartz. Late stage ore minerals are sometimes found coating these small quartz crystals in vugs.

Fragments of the country rock in breccia veins are cemented by both massive and lamellar quartz. Dark gray massive quartz is one of the most common matrix materials of breccia veins.

In several thin sections from the Sommercamp and North DeLamar zones lath-shaped barite crystals (0.3-0.7 mm) are partly to totally replaced by opaque minerals. The opaque minerals commonly have a cubic habit suggestive of pyrite. Lath-shaped pyrite and marcasite in the deposit may be pseudomorphic after earlier barite. Barite is found in the east-central part of the Sommercamp zone as clear well-formed crystals up to 12 mm diameter in porphyritic rhyolite lithophysae cavities. The crystal habit of some lamellar quartz is similar to that of the barite.

Figure 33. White lamellar quartz vein in porphyritic rhyolite.

Figure 34. Banded quartz vein containing naumannite and sulfides.

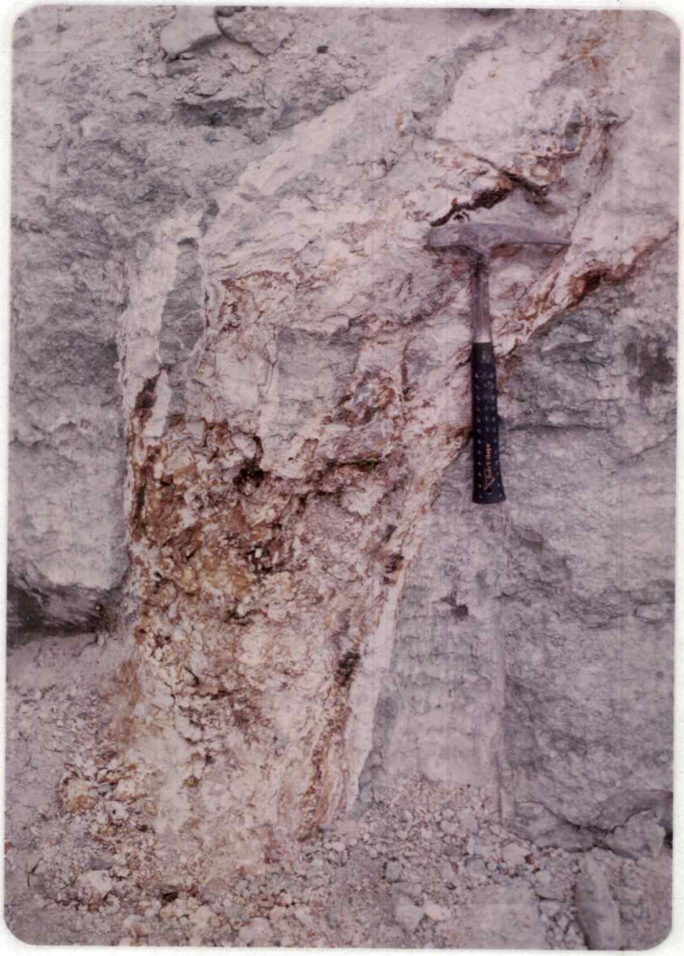


Figure 35. Anastomosing vein cutting green rhyolite tuff breccia; north Sommercamp Pit.

Figure 36. Open space in brecciated porphyritic rhyolite partly filled by lamellar quartz vein; West Glen Silver zone.

Figure 37. Silicified, sulfide rich breccia of the West Fault; Sommercamp Pit.

Figure 38. Breccia vein in banded rhyolite; southwest Sommercamp Pit.

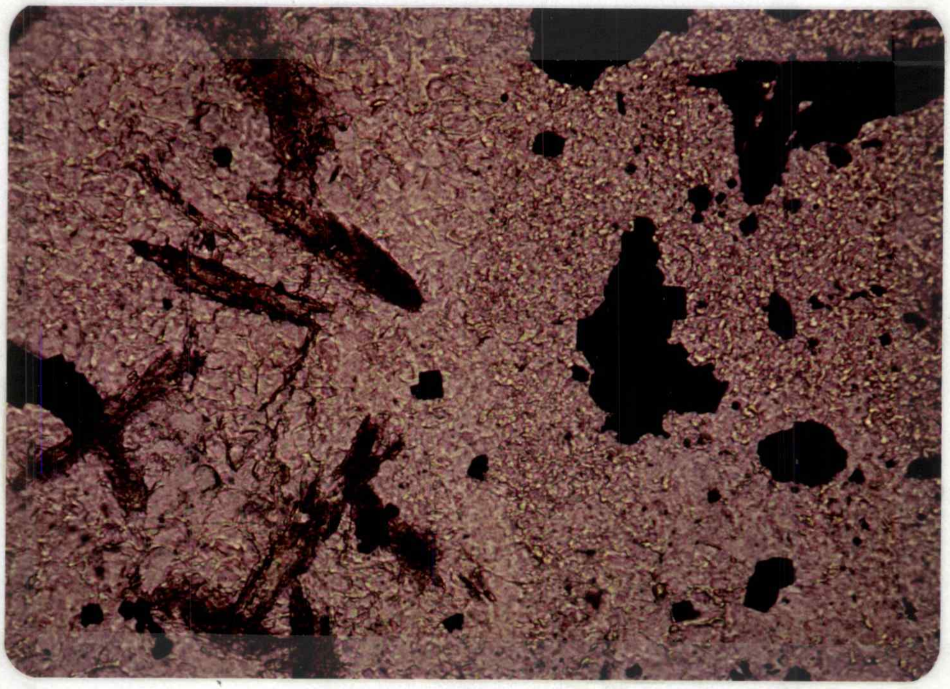


Figure 39. Thin section of lath-shaped barite crystals partly to totally replaced by opaque minerals; field of view approximately 1.5 mm.

PARAGENESIS

The generalized paragenesis of ore minerals at DeLamar is shown in Figure 40. Age relations were determined from the textural and spatial relations of mineral grains in samples dominantly from the Sommercamp zone. In other areas of the deposit or on a very local scale these relations may be somewhat different.

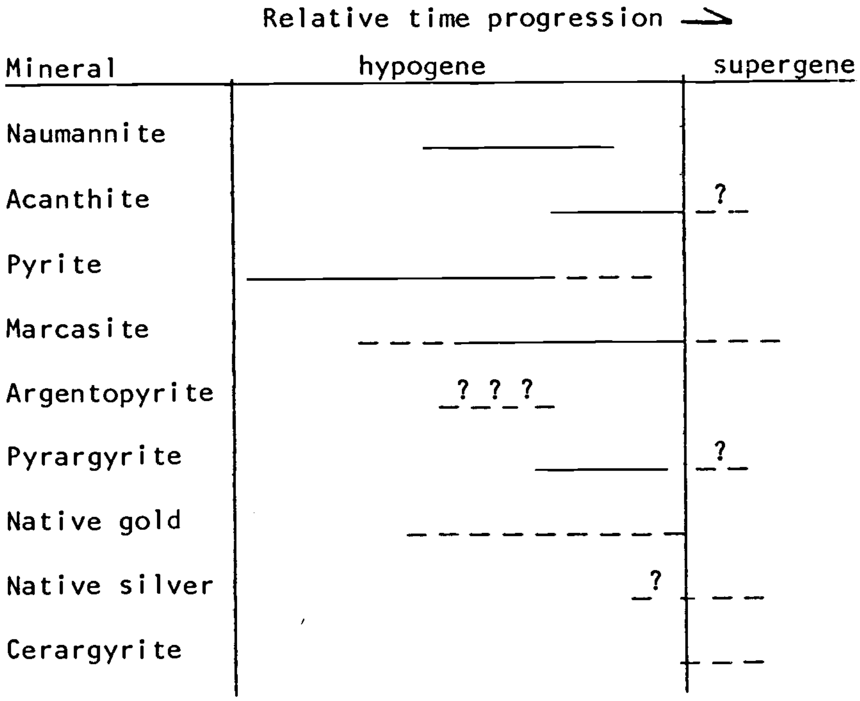


Figure 40. Generalized paragenetic sequence of mineralization, DeLamar Silver Mine, Owyhee County, Idaho. Relative progression of time from left to right.

HYDROTHERMAL ALTERATION

Hydrothermal alteration of the Sommercamp zone was studied in greatest detail and to a lesser extent alteration associated with the North DeLamar zone. Data was obtained from diamond drill core and samples collected during mapping. Over 50 thin sections were examined in evaluation of alteration in the Sommercamp zone. Optical identifications of each alteration assemblage were aided and verified by X-ray diffraction. Major zones were defined by the relative abundance and types of alteration minerals.

Diagnostic alteration minerals at DeLamar include sericite, secondary quartz, kaolinite, alunite, chlorite, and zeolites. The distribution and intensity of alteration seems dependent on the proximity to fluid conduits and upon the primary minerals in the rocks. In general the more intense alteration produced lighter colored "bleached" appearing rocks. Zones of alteration are somewhat gradational but may change rapidly in places. Major alteration assemblages for the Sommercamp and North DeLamar zones are shown in cross section C-C' (Plate 3).

The porphyritic rhyolite is the major ore host at DeLamar. It contains about 10 percent quartz and potassium-feldspar (sanidine) phenocrysts. Along with alteration of the groundmass the type and amount of alteration of the potassium-feldspar is diagnostic. In the upper less intensely mineralized parts of the porphyritic rhyolite, alteration of sanidine phenocrysts ranges from a few percent up to about 15 percent. Rims of these phenocrysts are typically altered to

Figure 41. East side of the Sommercamp Pit; mineralized porphyritic rhyolite is exposed in the lower left; mostly barren banded rhyolite in the upper right. The clay altered base of the banded rhyolite is diagonal across the view.

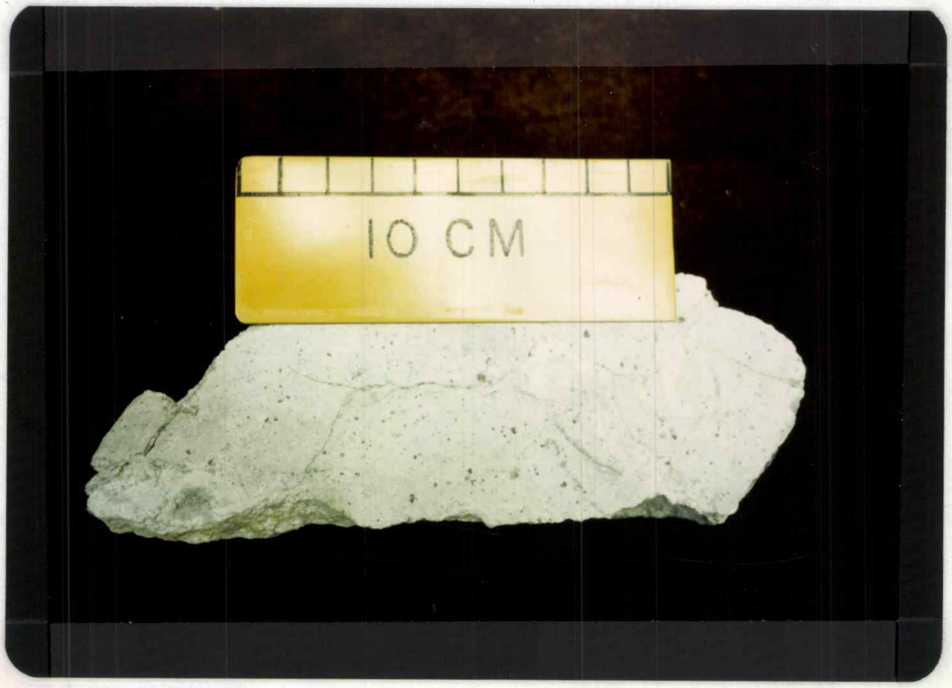


Figure 42. Altered porphyritic rhyolite from the ore zone in the Sommercamp Pit.

quartz and sericite. In the more intensely mineralized areas alteration of the groundmass and sanidine progressively increases until the feldspar is totally replaced by quartz and sericite.

A strong quartz-alunite assemblage is developed in porphyritic rhyolite along the upper part of the West Fault breccia zone. The alunite is hypogene, having well developed crystal form and giving good X-ray diffraction patterns. A weaker zone of quartz-alunite is found in a less mineralized area of porphyritic rhyolite in the upper levels of the Sommercamp zone just below banded rhyolite. The quartz-alunite assemblages are at approximately the same level in the deposit.

Fine grained, banded rhyolite with few phenocrysts overlies porphyritic rhyolite in the mineralized area. The banded rhyolite is usually barren or weakly mineralized. It is moderately to strongly mineralized along the West Fault and in near-vertical breccia veins in the southeast Sommercamp zone.

The base of the banded rhyolite is mostly a perlitic vitrophyre approximately 10 to 50 feet thick. In the mineralized areas this basal section of the banded rhyolite is intensely altered to a dense grayish-yellow green to pale blue green clay. This "clay zone" is mostly fine-grained sericite with sparse quartz phenocrysts. The intensity of this clay zone alteration increases with depth. In the strongly mineralized areas the zone is highly pyritiferous.

It seems that the perlitic vitrophyre provided a favorable pathway for initial alteration fluids. As fluids progressively altered this particularly susceptible zone self-sealing occurred by formation of the less permeable clay minerals. Little mineralization is present in this clay zone suggesting that these early fluids either contained only small amounts of gold and silver or precipitated them at other levels. Later metal-rich fluids were largely unable to penetrate this highly impermeable zone.

This clay zone was called the "iron dike" by early miners due to its high content of pyrite. It was considered by many previous workers to be a fault, based on its similarity to fault gouge. Lindgren (1900, p. 125) interpreted the feature as a zone of intensely altered and crushed rhyolite. Piper and Laney (1926, p. 43-45) considered the clay zone to be a post-mineralization strike-slip fault with a small normal movement. Asher (1966, p. 66-67) thought that there appeared to be strike-slip movement along the zone, but that reverse dip-slip movement was greatest. This was based on the amount of lateral movement estimated from offset along contacts of aphanitic and porphyritic rhyolites. The aphanitic rhyolite was considered to be stratigraphically lower. A close inspection of Asher's map and cross section of the DeLamar area in light of more detailed mapping shows a possible reason for this interpretation. Asher grouped both the lower rhyolite and banded rhyolite of this study as aphanitic rhyolite. But, these are not the same unit. They are stratigraphically separated by porphyritic rhyolite. During the 1970's early development study of the DeLamar deposit retained the idea that the fine-grained rhyolites are stratigraphically lower than porphyritic rhyolite. Ideas regarding the feature fluctuated back and forth from normal fault to thrust fault. Pansze (1975, p. 47) did not believe that the aphanitic rhyolite was always stratigraphically lower, but considered the clay zone to be a

Figure 43. Intense clay alteration of the basal section of the banded rhyolite in the Sommercamp Pit. Bench height is 15 feet.

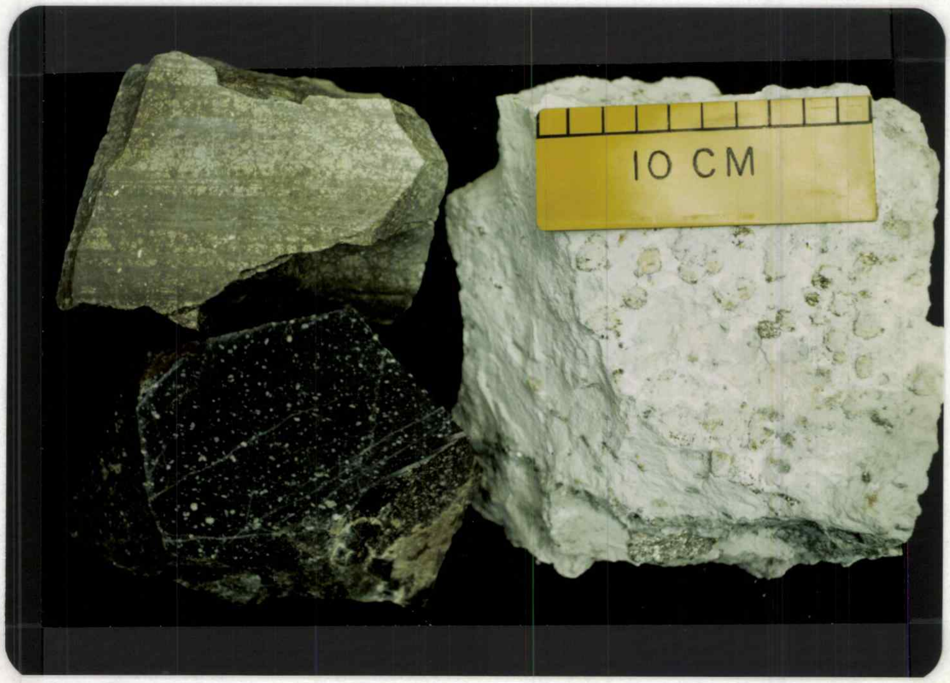


Figure 44. Perlitic basal vitrophyre of banded rhyolite. Lower left hand specimen is fresh; upper left is a bleached fragment found in "clay zone"; specimen on right is extremely altered to pyritiferous clay.

low-angle normal fault.

Evidence that the clay zone is an alteration feature and not a fault includes:

1) study of the banded rhyolite outside of the mineralized areas show it to have a perlitic basal section approximately the same thickness as the clay zone, and fragments of bleached perlitic vitrophyre have been found in the clay zone;

2) southeast of the North DeLamar zone, clay alteration can be traced into unaltered perlitic vitrophyre;

3) layering in the banded rhyolite above the clay zone is not extremely offset and disturbed as might be expected if nearby to a major fault, and relict flow banding and layering is preserved in many areas of the altered zone;

4) thin section study of the clay zone shows it to have the same percentage and size of quartz phenocrysts as unaltered banded rhyolite; and

5) the geometry of the clay zone contact is not planar but convoluted with the rocks being essentially locked in place.

Above the clay zone the banded rhyolite is mostly altered to kaolinite and quartz. The secondary quartz is present in the groundmass and as crosscutting microveinlets. Zeolite is found in the uppermost levels of banded rhyolite above the mineralized zone. The zeolite occurs preferentially in certain bands of the rhyolite. Some zeolite forms euhedral crystals that appear to have developed prior to or contemporaneously with quartz. Other zeolite crystals are reacted with and embayed by quartz of a later stage.

The green rhyolite tuff breccia contains 5 to 20 percent lithic

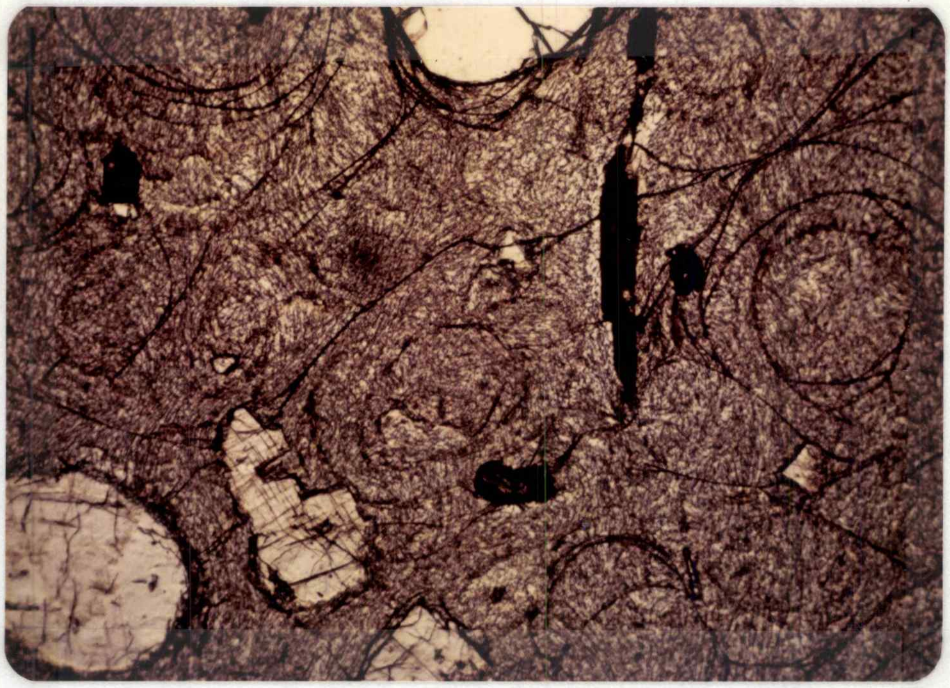


Figure 45. Thin section of fresh perlitic basal vitrophyre of banded rhyolite; plain light, field of view approximately 4.5 mm.

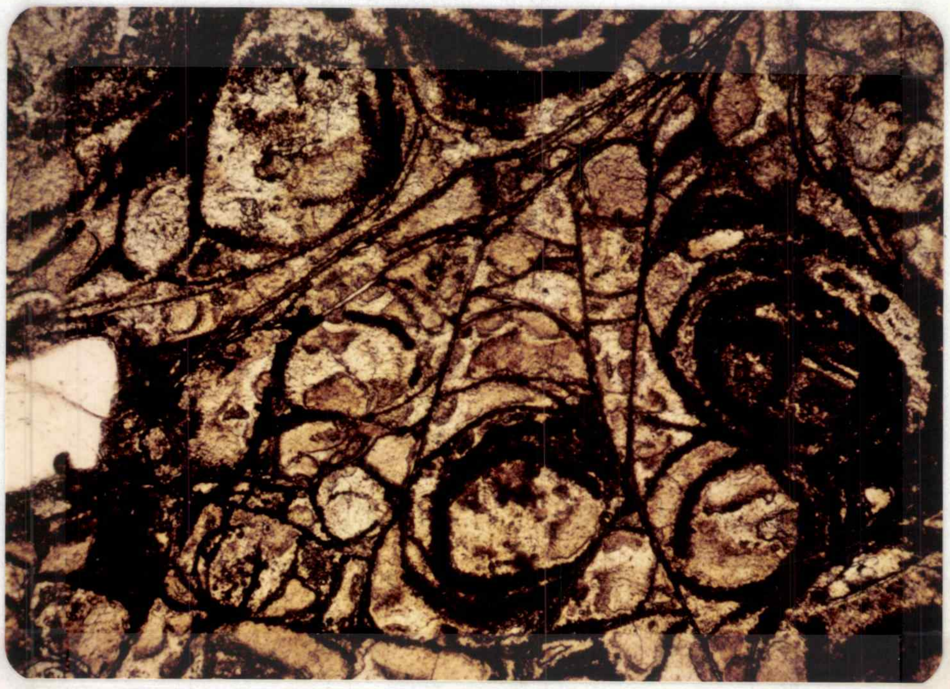


Figure 46. Thin section of bleached fragment of perlitic basal vitrophyre of banded rhyolite found in the "clay zone"; plain light, field of view approximately 4.5 mm.

fragments, dominantly basalt, in a fine-grained groundmass. The groundmass and some lithic fragments are altered mostly to chlorite group minerals as well as to some kaolinite, sericite, and quartz. Mafic lithic fragments are commonly pervasively replaced by pyrite in zones of strong alteration. The presence of chlorite may be due to the availability of iron and magnesium from the inclusions of basalt.

The lower rhyolite near mineralized areas is bleached to a medium light gray to white color. Most commonly the groundmass and feldspars are partly altered to kaolinite and lesser amounts of sericite. The lower rhyolite in the deeper levels of the Sommercamp zone is locally strongly pyritized along flow banding.

Development and Chemistry of Hydrothermal Alteration

The following discussion of the environment of hydrothermal alteration in hot spring environments and epithermal ore deposits is partly from information summarized by Rose and Burt (1979, p. 195-207).

Mineral assemblages developed during hydrothermal alteration are dependent upon temperature, pressure, chemical composition of the hydrothermal fluid, chemical and mineralogical composition of the parent rock, and the time available for equilibration. The stability fields of feldspars, micas, and clays are commonly controlled by hydrolysis, in which K^+, Na^+, Mg^{2+}, and other cations are transfered from the minerals to solution, and H^+ enters the solid phase. The stability of potassium-feldspar and muscovite at temperatures below about 300°C is limited by the following reactions:

$$3KAlSi_3O_8 + 2H^+ = KAl_3Si_3O_{10}(OH)_2 + 6SiO_2 + 2K^+$$

(potassium-feldspar) (muscovite) (quartz)

$$2KAl_3Si_3O_{10}(OH)_2 + 2H^+ + 3H_2O = 3Al_2Si_2O_5(OH)_4 + 2K^+$$

(muscovite) (kaolinite)

At least two distinct types of alteration are present in the epithermal system. One occurs beneath the water table where the hydrothermal fluid is usually near neutral or weakly alkaline, with chloride as the major anion. In the other type near-surface fluids are acid, have high SO_4^{2-}/Cl^-, iron, magnesium, calcium, and aluminum, and relatively low sodium and potassium.

As deep hot water approaches the surface, three main processes may change the character of alteration and mineral deposition: cooling, boiling, and condensation (Rose and Burt, 1979, p. 206). Simple cooling is of importance primarily for minerals with prograde solubility such as quartz (Holland and Malinin, 1979, p. 500). In the higher temperature range there is a tendency to form additional muscovite from feldspars. At temperatures below about 150°C, montmorillonite, illite, and mordenite may form as the result of cooling.

With time the wall rocks in a hydrothermal system will be at approximately the same temperature as the fluids. This creates a buffering effect keeping the fluids warm as they continue to rise toward the paleo-surface. The fluids will begin to boil when the hydrostatic head is insufficient to prevent it. Co_2, H_2S, and other volatile compounds are then selectively partitioned into the vapor

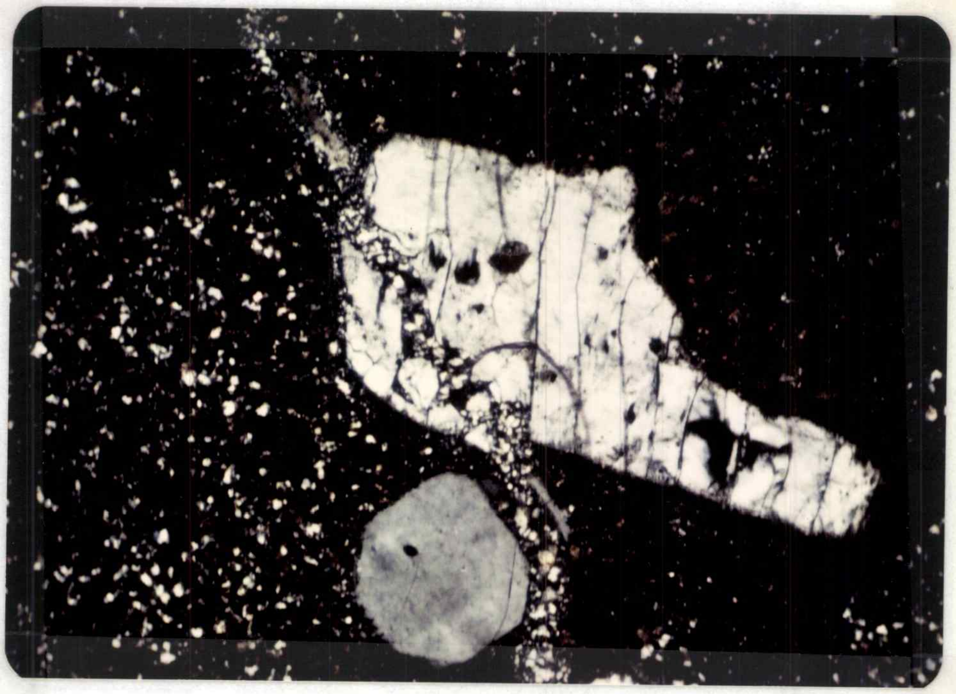


Figure 47. Thin section of porphyritic rhyolite from the upper, less altered, areas of the Sommercamp zone; crossed polars, approximate field of view 4.5 mm. Sanidine phenocryst (center) is cut by quartz microveinlet.

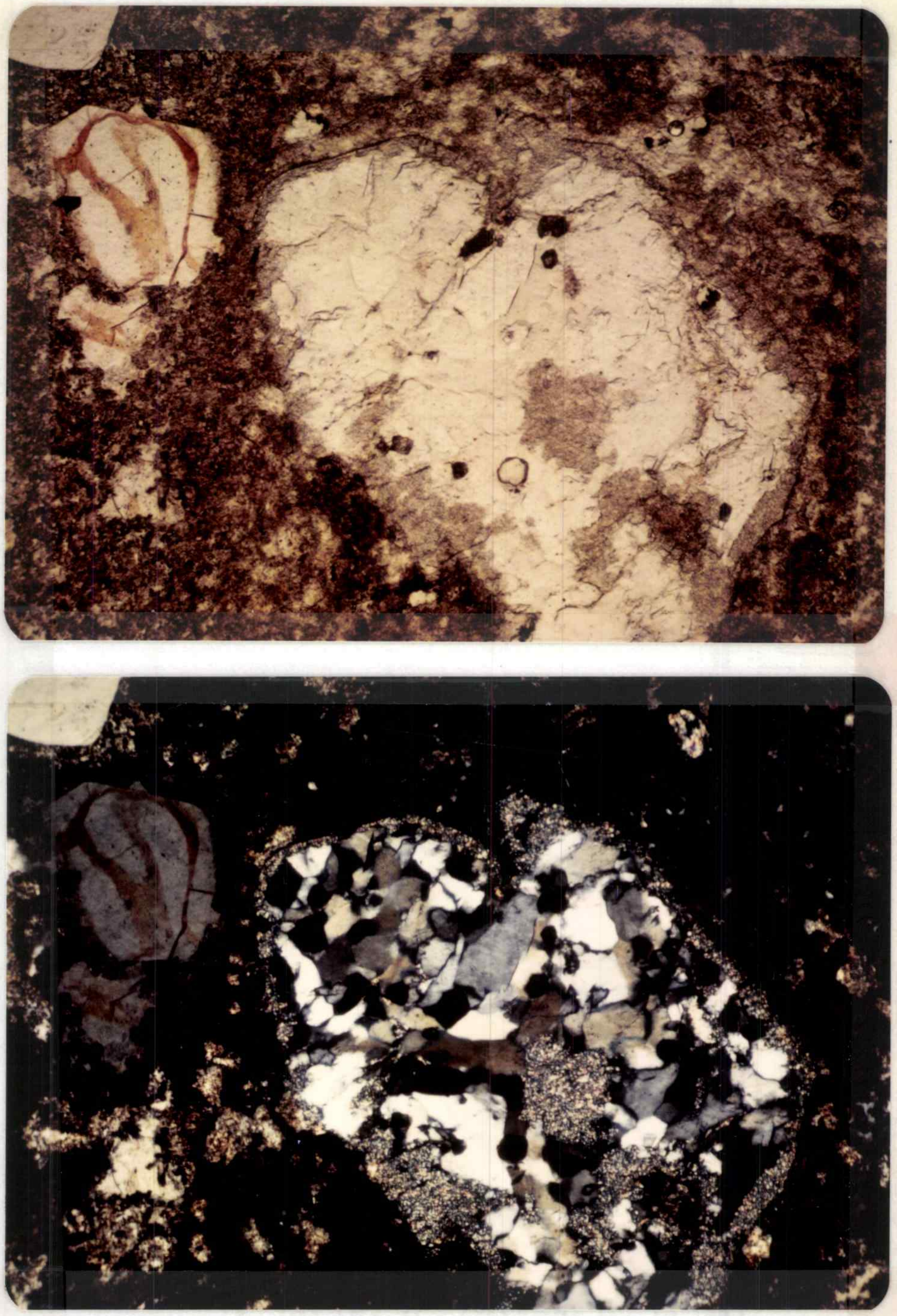


Figure 48. Thin section of porphyritic rhyolite from the central highly altered part of the Sommercamp zone; approximate field of view 4.5 mm. Top photo is view in plain light; bottom is view with polars crossed. The larger (central) sanidine phenocryst has been altered to a mosiac of quartz and sericite. The smaller quartz phenocrysts remain relatively unaltered.

phase, thereby increasing the pH and K/H of the remaining solution.

In the upper vapor-dominated part of the hydrothermal system sulfuric acid forms from hydrogen sulfide in the oxidizing environment. The overall reaction is:

$$H_2S + 2O_2 = H_2SO_4$$

Alunite is a characteristic mineral produced under conditions of acid-sulfate alteration of silicate rocks. The mineral assemblages produced in such environments contain alunite, a silicate phase, and commonly one or more of the minerals kaolinite, sericite or pyrophyllite. Such assemblages are indicative of extreme cation leaching (Hemley and others, 1969, p. 599). The following reactions may form alunite from muscovite, kaolinite or potassium-feldspar:

$$\underset{\text{(muscovite)}}{KAlSi_3O_{10}(OH)_2} + 4H^+ + 2SO_4 = \underset{\text{(alunite)}}{KAl_3(SO_4)_2(OH)_6} + \underset{\text{(quartz)}}{3SiO_2}$$

$$\underset{\text{(kaolinite)}}{3Al_2Si_2O_5(OH)_4} + 2K^+ + 6H^+ + 4SO_4 =$$

$$\underset{\text{(alunite)}}{2KAl_3(SO_4)_3(OH)_6} + \underset{\text{(quartz)}}{6SiO_2} + 3H_2O$$

$$\underset{\text{(potassium-feldspar)}}{3KAlSi_3O_8} + 6H^+ + 2SO_4 = \underset{\text{(alunite)}}{KAl_3(SO_4)_3(OH)_6} + 2K^+ + \underset{\text{(quartz)}}{9SiO_2}$$

SOURCE AND CHARACTERISTICS OF THE ORE-FORMING MEDIUM

Mineralogy of the veins and alteration at DeLamar suggest that the hydrothermal solutions were probably at temperatures between 100 to 300°C. These solutions are believed to have been highly diluted sodium-chloride waters closely related to the silicic rhyolite volcanism. An age date of porphyritic rhyolite, the main ore host, is approximately 15.7 million years. Potassium-argon age dates, for adularia, from similar mineralized zones on nearby Florida and War Eagle Mountains are about 15 million years (Pansze, 1975, p. 57).

Fluid inclusion studies of several epithermal gold-producing districts in Nevada show them to have low salinities, commonly below 2.1 weight percent NaCl equivalent (Nash, 1972, p. C17). Fluid-inclusion homogenization temperatures for these deposits range from 160 to 330°C.

O'Neil and Silberman (1974, p. 904) studied the stable isotope relations of epithermal gold-silver deposits of the Great Basin. Analyses of the hydrogen isotope compositions of the fluid inclusions were made for 14 deposits. The deviation per mil D range observed for the inclusions are -90 to -139. This similarity in range of deviation per mil D between the hydrothermal fluids demonstrates that the dominant component of fluids sampled from these deposits was meteoric in origin. Most of the per mil ^{18}O values of epithermal vein minerals are negative and, in general, relatively isotopically light. This confirms that isotopically light ground water has played a large role in the process of vein and ore deposition in most of these deposits.

White (1981, p. 409) compared the chemical interrelations of epithermal precious metal deposits and active geothermal systems like Broadlands, New Zealand, and Steamboat Springs, Nevada. The model assumes: (1) As, Sb, Hg, Tl, B, and Au selectively precipitated in near surface areas; (2) deposits relatively high in Ag and base metals but with some Au and complex sulfosalts formed at greater depths, higher temperatures, and possible higher salinities than those of group (1); (3) base metals (and Ag?) transported dominantly as metal-chloride complexes that became unstable with decreasing temperature, decreasing salinity from meteoric dilution, and increasing pH (from loss of CO_2, boiling, and reaction with wall rocks); (4) chloride complexes of As, Sb, Hg, Tl, and Au either not significant, or became less important as sulfide complexes became more important.

Data suggest that sulfide complexes of gold in hydrothermal solutions are stable in deposits formed both at less than about 300°C and where mineralogy indicates reducing conditions (Barnes, 1979, p. 453). Evidence for silver deposition implies that at lower temperature, sulfide complexes are also more important, but that above 300°C chloride complexes become dominant. In precipitation from sulfide complexes cooling, oxidation, and decreasing pH may all be involved. Banding of ore and gangue minerals may be due to episodic boiling of the system.

SUMMARY AND CONCLUSIONS

The oldest Cenozoic unit exposed in the DeLamar Silver Mine area is a Miocene alkali olivine basalt. It was emplaced as numerous conformable flows on Cretaceous granitic rocks. These flows are believed to have come from fissure eruptions.

The development of a prominent north-northwest fracture system created structurally weak zones which were exploited by silicic volcanism. Rhyolites were emplaced as flows and exogeneous domes from local dikes and vents. The inception of this bimodal basalt-rhyolite volcanism coincides closely with the beginning of normal faulting throughout much of the Basin and Range. The rhyolites may also be related to the time-transgressive linear volcanism which progressed from southwest Idaho to Yellowstone Park, and westward into central Oregon.

Continued north to northwest trending fracturing and faulting differentially affected the complex pile of silicic volcanic rocks. In some units, such as the brittle porphyritic rhyolite, intense fracturing created an interconnecting network of open space.

In the waning stages of rhyolitic volcanism a hydrothermal system of highly diluted magmatic fluids developed. As these solutions ascended along favorable structures they altered surrounding rocks and initially precipitated lamellar calcite or barite in veins. These were later replaced by metal-rich quartz veins. With continued fracturing and fluid circulation multiple generations of banded and breccia silver-gold-quartz veins formed. Siliceous sinter deposits accumulated where thermal springs reached the surface.

Terrace gravel deposits were formed by the erosion and deposition of regional rock units. Gold eroded from lode veins concentrated in some gravels forming placer deposits.

Ore deposits of the DeLamar Silver Mine are of the silver-dominated epithermal type. The mineralization displays many features in common with epithermal districts reviewed by Schmitt (1950, p. 192-193) and Eimon (1981, p. 3-4). These characteristics include:

1) occurrence in Tertiary volcanic rocks. The ore host is rhyolite;

2) associated with vertical tectonics. The extensional structural regime is favored to create the needed open spaces;

3) occurrence close to the surface (moderate to low temperature and pressure conditions);

4) increasing fissure complexity upward, in places having the form of a wedge-like or cone-like flare upward. The entire vein structure is almost never uniformly mineralized;

5) the ore mineralogy suggests temperatures of formation less than 200°C; and

6) gangue is principally quartz of multiple generations. Veins exhibit lamellar and crustified textures, drusy cavities, and breccia with vein cement.

The close association of mineralization with the silicic volcanism suggests that the two processes were related. The magmatic component of the hydrothermal fluids may have evolved as late stage volatiles from a high-level magma chamber. Alternatively the volcanic activity possibly acted as a "heat engine" mobilizing fluids and metals from other sources at depth or nearby.

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