

Epithermal Gold and Silver Deposits Silver City-De Lamar District, Idaho

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Idaho Geological Survey
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EPITHERMAL GOLD AND SILVER DEPOSITS,
SILVER CITY-DE LAMAR DISTRICT, IDAHO

Bill Bonnichsen¹

ABSTRACT

Since the discovery of precious metals in 1863, the Silver City-De Lamar district in southwestern Idaho has been the source of more than a million ounces of gold and about 32.5 million ounces of silver. Early production was from quartz veins that cut the three major bedrock units in the district: the Silver City granite, the middle Miocene lower basalt-latite unit, and the Silver City rhyolite. Production since 1977 has been from three open pits that constitute the DeLamar Silver Mine.

The silver-gold ores are an example of the shallow-seated epithermal type of mineralization. The principal hypogene silver minerals are naumannite, aguilarite, argentite, and the ruby silver minerals. Common minerals with a probable supergene origin are native silver, cerargyrite, acanthite, and secondary naumannite. Gold occurs as native gold and electrum in both hypogene and supergene ores. The ores are characterized by containing more silver than gold by weight, but the Au:Ag ratio varies as widely as 1:1 to 1:1,000 in various parts of the district. The ores in all of the principal mining operations are selenium rich.

Only one main mineralizing event is recognized to have occurred in the selenium-rich, silver- and gold-bearing central part of the district, and it happened about 16 million years ago, near the end of the volcanism which formed the Silver City rhyolite. It is not clear if antimony-rich silver mineralization in the peripheral parts of the district is the same age or older than the selenium-rich mineralization in the central part. If it is the same age, then the district has an unusual metal zonation pattern; if it is older, then two distinct mineralizing episodes have occurred.

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INTRODUCTION

The Silver City-De Lamar district, located 50 miles southwest of Boise, Idaho, is an east-west trending zone 8 miles long and 2 to 3 miles wide. Gold and silver occur in veins in the De Lamar area in the western part and in the Florida Mountain and War Eagle Mountain areas in the eastern part. The Flint area, about 5 miles to the south, is included in the discussion, although its production is small compared with the main zone.

The district is within the Owyhee Mountains along the southwestern margin of the western Snake River Plain. The mountains are cored by Cretaceous to Miocene plutonic and volcanic rocks and are almost surrounded by Miocene to Pliocene volcanic rocks which erupted during the formation of the Snake River Plain volcanic province.

Placer gold was discovered in the district on May 18, 1863, on Jordan Creek near De Lamar; the first lode discovery was the Oro Fino vein on August 15, 1863, on War Eagle Mountain. Additional discoveries of bonanza silver-gold ore were soon made in the quartz veins cutting the granite on War Eagle Mountain. Most of the production from War Eagle Mountain occurred between 1863 and 1875, and the principal producers were the Poorman Mine operating on the Poorman vein, the Morning Star Mine on the Morning Star-Potosi vein, and the Oro Fino, Ida Elmore, and Golden Chariot mines on the Oro Fino-Golden Chariot vein. The failure of the Bank of California in 1875, and the consequent loss of financial backing, contributed to the closure of the mines. Several were never reopened, and those that were reopened never regained their earlier production levels. The War Eagle Mountain mines produced nearly \$12.5 million of gold and silver from 1863 to 1875 (Lindgren, 1900, p. 111).

Little mining activity took place in the district between 1875 and 1889, but from 1889 to 1914 the two principal underground deposits in the district were mined. These were the De Lamar* Mine, in which several

* De Lamar (spelled with the space) was the surname of Captain J. R. De Lamar who founded the De Lamar Mining Company in the late 1800's, and this was the usage adopted to name De Lamar Mountain and the town. In other usage, DeLamar (spelled as one word, without a space) was adopted by Earth Resources Corporation in the 1970's for the DeLamar Silver Mine.

veins on De Lamar Mountain were mined, and the Trade Dollar Mine, which was developed on the Black Jack-Trade Dollar vein on Florida Mountain. Little mineral production occurred in the district from 1914 to 1977, except for the recovery of placer gold from Jordan Creek between 1934 and 1940. In 1977 the DeLamar Silver Mine, an open-pit operation, was established at the site of the old underground De Lamar Mine on De Lamar Mountain.

In its first century, the Silver City-De Lamar area produced about 1 million ounces of gold (Piper and Laney, 1926; Ross and Carr, 1941; Bergendahl, 1964) and about 25 million ounces of silver (Piper and Laney, 1926). Since its opening in 1977 to December 1981, the DeLamar Silver Mine has added an additional 95,000 ounces of gold and 7.5 million ounces of silver to the district's total.

The first extensive geologic studies of the Silver City-De Lamar area were conducted at the turn of the century by the U. S. Geological Survey (Lindgren, 1900; Lindgren and Drake, 1904). At that time, the Trade Dollar and De Lamar mines were open and permitted detailed observations on the mineralogy and configuration of the veins. However, most of the War Eagle Mountain properties were inaccessible then, so their descriptions have been pieced together from indirect evidence. Several years after the underground mining had ceased, the Idaho Bureau of Mines and Geology released an extensive report (Piper and Laney, 1926) on the region, drawn from field investigations, unpublished mining company reports, the existing literature, and interviews with surviving mining men. Most of the information regarding the ores and veins in the long-abandoned underground mines is from these sources. Later publications with significant amounts of information are those of Asher (1968), Pansze (1975), Bennett and Galbraith (1975), and Ekren and others (1981, 1982). These reports mainly emphasize geologic mapping and descriptions of the rock units.

GEOLOGY OF THE DISTRICT

The three main rock groups in the Silver City-De Lamar district are

the Late Cretaceous Silver City granite, the Miocene basalt and latite flows, and the Miocene Silver City rhyolite (Figure 1). The epithermal silver-gold mineralization formed near the end of the Silver City rhyolite volcanism.

The Silver City granite is predominately a gray, medium- to coarse-grained biotite-muscovite granodiorite which grades to quartz monzonite or albite granite in some areas. Schlieren of mica- and quartz-rich metamorphic rocks and simple pegmatite and aplite dikes occur locally. The Silver City granite is considered to be an outlier of the Idaho batholith. It was intruded by northeast-trending diorite and dacite porphyry dikes during Eocene or Oligocene time; later, it was eroded into a hilly to mountainous topography.

During the middle Miocene, a thick sequence of volcanic rocks was extruded from various sources in the Silver City-De Lamar area. The time span of this volcanic activity was probably between 17 and 16 million years ago (Pansze, 1975; Armstrong, 1975; recalculated for new decay constants using tables of Dalrymple, 1979), although the time at which volcanism started is poorly established. The middle Miocene volcanism started with the extrusion of more than 2,500 feet of basalt onto the Silver City granite, filling many paleovalleys but not entirely covering the area. The basalt changes upwards to basaltic andesite and latite (trachyandesite) flows with 55 to about 64 percent SiO_2 (Ekren and others, 1982; Bonnicksen, unpublished data). These flows are of the same general age as the voluminous early part of the Columbia River Basalt Group. They appear to belong to a widespread group of basaltic to andesitic rocks of the same age in eastern Oregon and northwestern Nevada (Walker, 1977; Stewart and Carlson, 1978) that predates the development of the Snake River Plain volcanic province. The recent discovery (Fitzgerald, 1982) of the Imnaha Basalt unit of the Columbia River Basalt Group as far south as Squaw Butte, only about 70 miles across the Snake River Plain from the Owyhee Mountains, suggests that part or all of the lower basalt sequence in the Silver City-De Lamar district may, in fact, be Imnaha Basalt. The large plagioclase phenocrysts that are common in the lower basalt in the Owyhee Mountains are very similar to those which characterize much of the Imnaha Basalt.

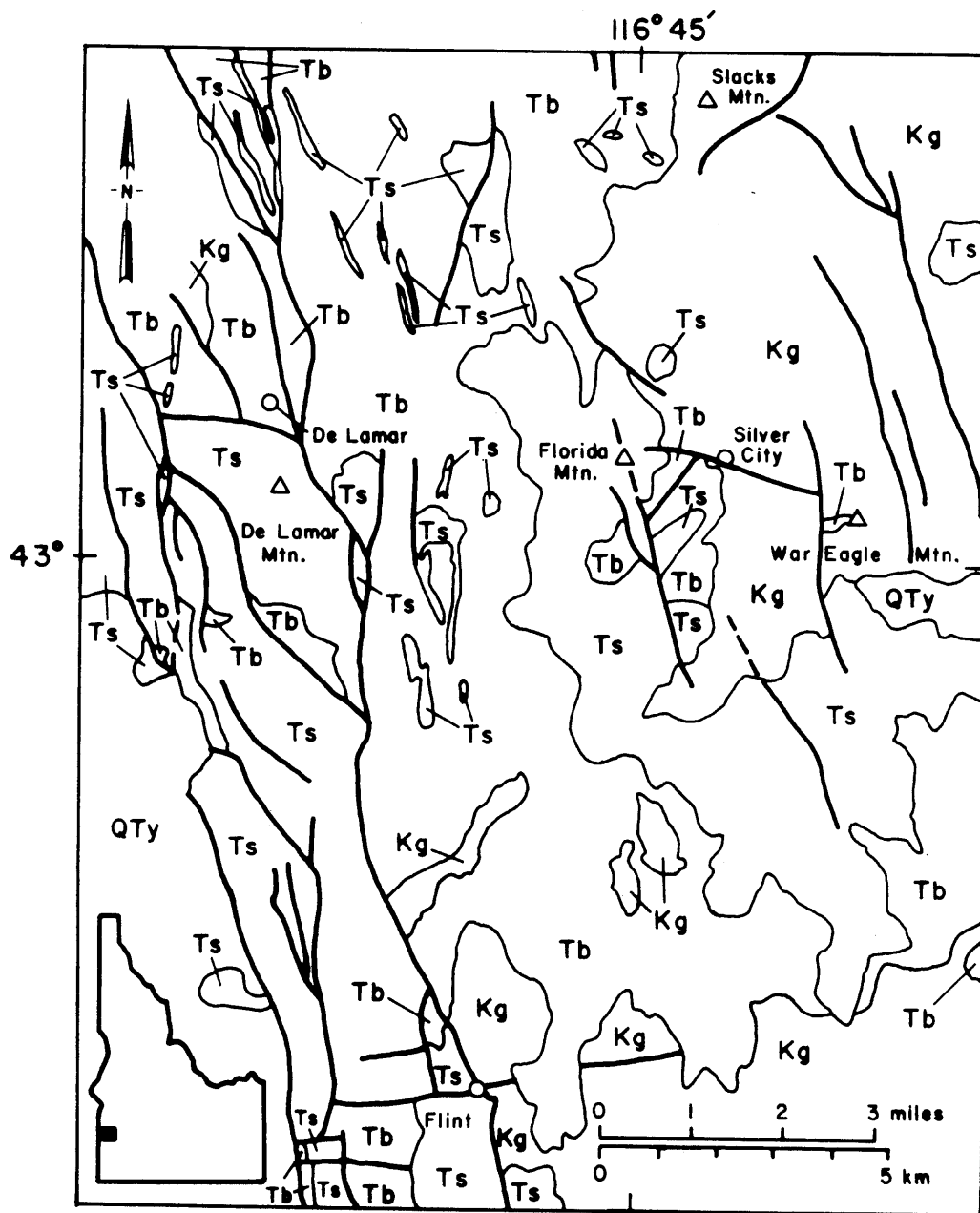


Figure 1. Generalized geologic map of the Silver City-DeLamar district, Owyhee County, Idaho (modified from Ekren and others, 1981). Kg--Silver City granite; Tb--lower basalt-latite unit; Ts--Silver City rhyolite (including dikes); QTy--younger units; fine lines--geological contacts; heavy line--faults.

The middle Miocene volcanism in the Owyhee Mountains ended with the extrusion of rhyolite and quartz latite lava flows and local ash flows that contain more than 73 percent SiO_2 (Ekren and others, 1982; Bonnicksen, unpublished data). Initial strontium isotope ratios (0.7061 in basal vitrophyre, quartz latite phase of Silver City rhyolite dome, Sawpit Peak) suggest that the Silver City rhyolite magmas were formed by the fusion of lower crustal materials (Wilson and others, 1983 in preparation).

Asher (1968) subdivided the Silver City rhyolite into porphyritic and aphanitic varieties, with the aphanitic rocks normally underlying the massive porphyritic rocks. Pansze (1975), who published the most detailed geologic map of the district, recognized that a succession of three units--quartz latite, flow breccia, and upper rhyolite--can be traced through the central part of the district. Both Asher and Pansze recognized numerous volcanic domes and dikes which they regarded as sources of the silicic flows.

More recently, Ekren and others (1981, 1982) have mapped the lower basalt-latite group and Silver City rhyolite from a regional perspective. In the Silver City-De Lamar district, they have divided the lower basalt-latite group into separate basalt and latite units and have divided part of the Silver City rhyolite into the tuff of Flint Creek and the overlying rhyolite of the millsite. Ekren and others (1981) also recognize some of the volcanic dikes and plugs noted previously by Asher and Pansze.

The lack of agreement on stratigraphic subdivisions and map units in the Silver City rhyolite by these authors points out that the Silver City rhyolite is, as yet, poorly understood. The most detailed geologic mapping and stratigraphic investigations of the volcanic rocks in the district have been conducted at the DeLamar Silver Mine, where several units within the Silver City rhyolite are recognized (Table 1; Figure 2).

Several groups of faults have been recognized in the district (Figure 1) by Piper and Laney (1926), Asher (1968), Pansze (1975), and Ekren and others (1981). Most are high-angle normal faults that strike between north and northwest and have small to moderate dip-slip displacements. A few faults have approximately east-west orientations and are probably

contemporaneous with the predominant north- to northwest-trending set; a few others trend northeastward. Asher (1968) suggested the northeast-trending faults may be older because some apparently are offset by the north- to northwest-trending set.

The attitude of the volcanic units generally ranges from subhorizontal to gently dipping, most commonly southwards. It is not clear if all the dips are due to initial deposition on uneven topography, or if some of the units have been rotated. No structural or volcanic rock unit information has come to my attention to suggest that the volcanism or associated epithermal mineralization is related to a large silicic caldera, buried or otherwise, in the Silver City-De Lamar district.

GEOLOGY OF THE ORE DEPOSITS

Nearly all of the gold- and silver-bearing veins in the district strike north to northwest, following the main fault and dike trends, and are thought to be the same age. Piper and Laney (1926), however, considered the mineralization in the Flint area to be older, and Asher (1968) also suggested an earlier episode of silver-antimony mineralization for the northeast-trending veins around Slacks Mountain (Figure 1), about 5 miles north of Silver City.

Most of the veins are fissures filled with quartz, accompanied by variable amounts of adularia, sericite, or clay. A few have been described as silicified shear zones. The veins are narrow, in most places only a few inches to a few feet wide, but persist laterally and vertically for as much as several thousand feet. Within an individual vein, the gold and silver ore occurs in definite shoots, generally with a moderate rake and somewhat irregular in outline. The localization of ore shoots has commonly been attributed to the presence of cross-fractures, or, in one instance (Trade Dollar Mine), to the intersection of the vein with the granite-basalt contact. Some of the most productive veins in the district follow thin basaltic dikes.

All three major rock units, the Silver City granite, the lower basalt-latite unit, and the Silver City rhyolite, are cut by mineralized

Table 1. Features of the volcanic rock units recognized in the vicinity of the DeLamar Silver Mine.

Unit and symbol	Thickness	Phenocryst and rock fragment data	Description	Mode of emplacement and possible source	Comments
Millsite rhyolite (Tms)	0 to 500+ feet	5% subhedral sanidine and quartz phenocrysts up to 3 mm across	purplish red; flow breccias are common at top and base; massive to flow-banded interior with columnar joints; lithophysae are common	lava flow(s) from NNW-trending dikes at Louse Mountain (sec. 22, T. 5 S., R. 4 W.)	postmineralization; only minor alteration
Banded rhyolite (Tbr)	0 to 300 feet	less than 1% phenocrysts of rounded sanidine and quartz	white, pink, or purplish red; strongly developed folded flow bands; commonly pervasively altered; hydrothermally brecciated and veined by quartz	low-viscosity lava flow or possibly an ash flow, probably from a local vent	50 to 70 feet of basal vitrophyre was altered to form a clay layer that ponded hydrothermal solutions
Porphyritic rhyolite (Tpr)	100 to 850 feet	3% to 8% subhedral to euhedral quartz and sanidine phenocrysts	buff to white; generally homogeneous and massive, less commonly banded; commonly silicified with quartz veins and brecciation in altered zones	a rhyolite dome or thick lava flow lobe from a nearby buried source; it may cover its own vent	one of many rhyolite domes in the region associated with NNW-trending faulting
Tuff breccia (Ttb)	0 to 170 feet	angular fragments of altered T1b and T1 up to 10 cm across in a fine altered matrix	green; predominantly bedded lapilli tuff; beds vary from several inches to several feet thick and are moderately sorted by size but are not graded	near vent outfall from phreatomagmatic explosions that probably culminated in Tpr extrusion	unit is not laterally continuous; pervasive alteration; some fragments replaced by pyrite
Quartz latite (Tql)	0 to 350(?) feet	sparse phenocrysts of quartz, sanidine, and minor andesine and clinopyroxene less than 1 mm across	black to greenish gray; weathers to orange or red; commonly altered to red or white; produces platy fragments and extensive talus on slopes	lava flows mainly from Florida Mountain and Cinnabar Mountain and other sources	a unit of regional extent exposed in the Glen Silver pit and nearby in Louse Creek
Porphyritic latite (Tl)	50 to 200 feet	xenocrysts and xenoliths of quartz, feldspar, granite, and basalt; 3% 1-mm size quartz and feldspar phenocrysts	dark gray to black; weathers to brownish red where massive and to various colors where platy; commonly altered to red or white; commonly has platy structure and red amygdules	mainly vesicular lava flows from Sullivan Knob near De Lamar and Florida Mountain	occurs above T1b at the DeLamar Silver Mine; regional studies indicate T1 is intercalated within upper part of T1b elsewhere
Lower basalt (T1b)	0 to 2,500+ feet	commonly has labradorite laths up to 1 cm long; local olivine phenocrysts	black to gray-green; generally massive but locally scoriaceous, brecciated, palagonitic, and pillowed; commonly has poorly developed columnar jointing	numerous lava flows; probably fissure eruptions from NNW-trending dikes	flows typically are 50 to 150 feet thick and are quite continuous laterally

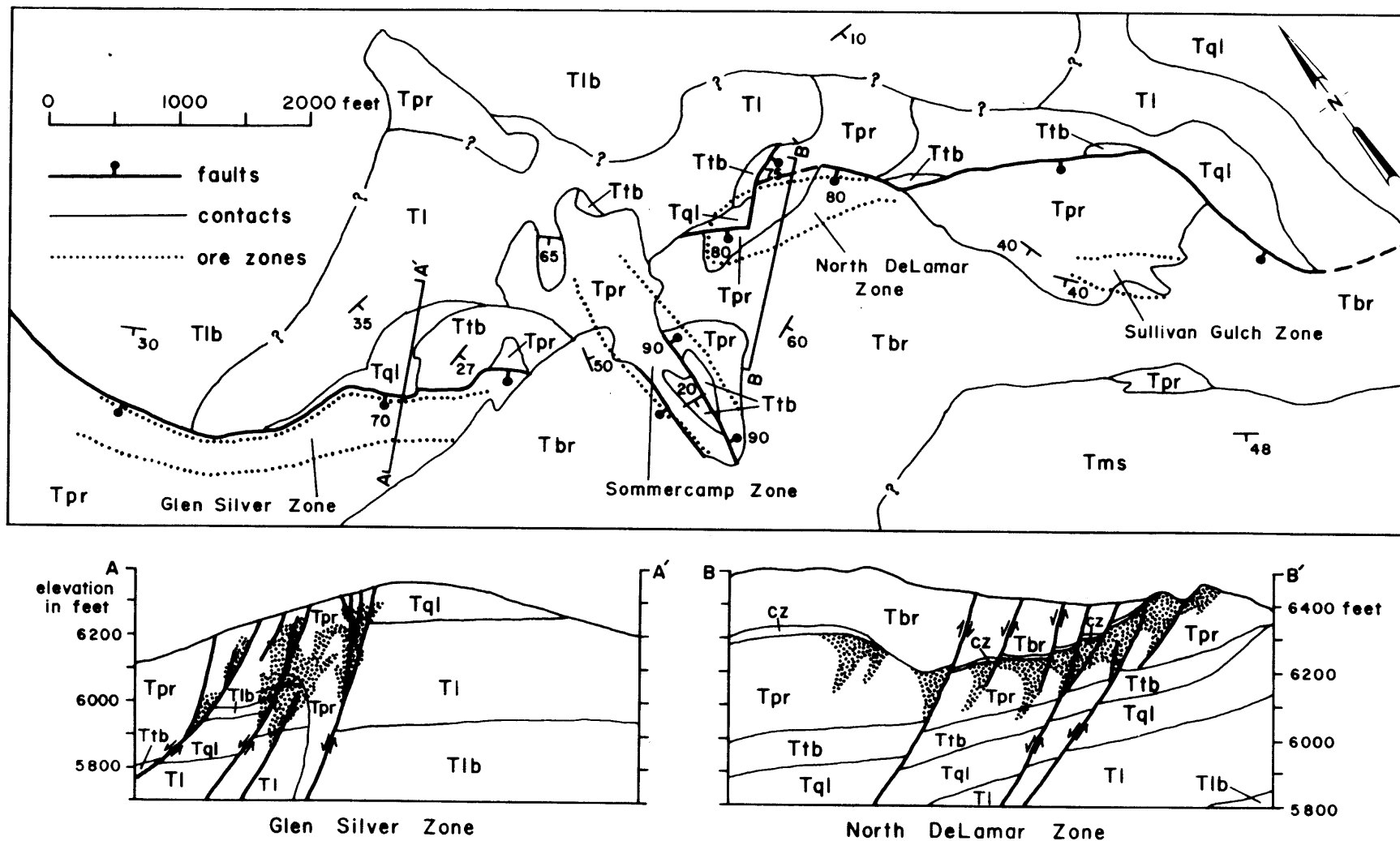


Figure 2. Generalized geologic map and cross-sections of the DeLamar Silver Mine. See Table 1 for identity of geologic units. The ore zones in the cross-sections are shown by stippling and the cz symbol refers to the clay zone at the base of the banded rhyolite (Tbr). Note also that the cross-sections are drawn at an enlarged scale.

veins. Most of the production at War Eagle Mountain, Florida Mountain, and Flint was from veins in the granite, while at De Lamar all of the production was from the rhyolite. The granite shows only modest hydrothermal alteration; commonly no more than a few feet of alteration is present next to veins. Much of the rhyolite, however, is pervasively altered. A combination of highly silicified or sericitized rock, or a mixture of clays, sericite, and quartz commonly occur tens or even hundreds of feet from veins in rhyolite. Where veins cut the lower basalt, chloritization is typical, and its distribution is quite erratic.

Naumannite (Ag_2Se) is the principal hypogene silver mineral and normally is accompanied by variable but subordinate amounts of aguilarite (Ag_4SeS), argentite, and ruby silver as well as other silver-bearing sulfantimonides and sulfarsenides. Where interpreted to have been reorganized by supergene activity (Lindgren, 1900; Piper and Laney, 1926), the principal silver minerals are native silver, cerargyrite, and some secondary naumannite and acanthite. In both the hypogene and the oxidized and supergene-enriched portions of the veins, the principal gold-bearing minerals are native gold and electrum. Variable amounts of pyrite and marcasite, and minor chalcopyrite, sphalerite, and galena occur in some veins; the base metal-bearing minerals become more abundant at deeper levels.

Quartz is the principal gangue mineral. Much is massive, but some has drusy or comb structure and a lamellar variety is locally abundant. This lamellar (or cellular or pseudomorphic) variety consists of thin plates of quartz set at various angles to one another (see photographs in Lindgren, 1900; Piper and Laney, 1926). Each plate consists of numerous tiny crystals that have grown from either side of a medial plane. Lamellar quartz has been interpreted as the replacement of preexisting calcite (or perhaps barite) crystals. Adularia commonly shows crystal outlines developed as an open-space filling. Piper and Laney (1926) interpreted the textures to mean that the gangue and ore minerals are roughly contemporaneous and from the same source, with most of the ore mineral deposition occurring toward the end of a long period of general mineralization.

The composition of the nonsilicate portion of the ores is known

from three flotation concentrate analyses (Table 2) reported by Piper and Laney (1926). The Flint analysis has much more silver relative to gold and much more antimony relative to arsenic than do the two Silver City area samples. The ores had a predominance of silver over gold by weight, but some of the high-grade oxidized and supergene-enriched near-surface material had about equal amounts of gold and silver. Gold and silver were also nearly equal in the deep levels of the Poorman Mine. At the other extreme, the Au:Ag ratio approached 1:1,000 in ores from Flint and from the very silver-rich material beneath the clay cap zone at De Lamar. In the Poorman Mine the proportion of gold to silver increased with depth, whereas in the nearby Oro Fino-Golden Chariot vein the opposite was reported. The Au:Ag ratio varied widely in the Trade Dollar and old De Lamar mines but in general the Trade Dollar produced much more silver-rich ore than the De Lamar Mine.

DELAMAR SILVER MINE

The old De Lamar Mine, which opened in 1889, had a total production of 402,552 ounces of gold and 5,873,088 ounces of silver, worth approximately \$12.4 million at the time (Piper and Laney, 1926). The mine consisted of the main De Lamar section and the Sommercamp section, and contained about 115,000 feet of underground openings. The mine operated until November 1913, when it closed due to the lack of higher grade ore reserves. Also contributing to its closure was a U. S. government lawsuit to recover the cost of timber used for the operation and to prevent further timber cutting from federal land in the region (Asher, 1968).

The main De Lamar section, at the site of the present-day North DeLamar pit (Figure 2), was 1,300 feet long in a northwest-southeast direction and up to about 300 feet wide, as measured on the No. 4 level (6,240 feet elevation). The section contained the Hamilton-Wilson No. 9 vein striking N. 25° W. and dipping 45°-66° W., and the 77 vein striking N. 62° W. and dipping 35° SW. These were connected by smaller veins and stringers. At lower levels the veins assumed steeper dips, 65 to 80 degrees being common. The 77 vein was the most important producer. The Sommercamp section, at the site of the present-day Sommercamp pit (Figure 2), was a zone about 300 feet across that contained ten interlinked veins

Table 2. Analyses of concentrates of ores from veins in the Silver City and Flint areas.

	<u>A</u>	<u>B</u>	<u>C</u>
Gold	36.20 oz/ton	66.5 oz/ton	0.92 oz/ton
Silver	1,290.0	1,617.0	635.0
Lead	0.8 percent	none	2.4 percent
Zinc	0.2	1.5 percent	2.4
Iron	23.8	29.2	22.8
Copper	0.9	1.2	1.3
Arsenic	0.7	2.4	1.4
Antimony	0.6	2.2	7.6
Sulfur	27.8	24.0	25.6
Lime	0.3	--	--
Insoluble	18.9	33.6	34.4

- A. First class concentrate of Alpine vein ore, levels 11 and 12, Trade Dollar Mine, Florida Mountain area (Piper and Laney, 1926, p. 120).
- B. Flotation concentrate of ore from the Flat and California veins, Never Sweat Mining Company, War Eagle Mountain area (Piper and Laney, 1926, p. 152).
- C. Flotation concentrate of ore from veins in Precious Metals Mines Company's Rising Star-Perseverance Mine, Flint area (Piper and Laney, 1926, p. 157).

striking N. 18° W. and dipping 65°-80° W.

These ore-bearing zones plunged 20 to 30 degrees southward. In both, the southern limit of the ore was a clay zone several feet thick with a shallow dip to the south. These clay zones were known as iron dikes to the miners and were interpreted to be the low-angle De Lamar and Sommercamp faults by Piper and Laney (1926), Asher (1968), and Pansze (1975). However, the excellent exposure in the present-day open-pit mines has shown that these zones really are mainly the thick basal vitrophyric section of the banded rhyolite unit (Tbr) which has been hydrothermally altered. In the underground workings, much of the rich silver ore--the "silver talc"--was extracted where the veins abutted against the base of this clay zone. With its shallow dip, this zone formed the upper as well as the southern limit to mineralization in both sections of the mine.

The present-day DeLamar Silver Mine consists of three operating pits: the Sommercamp, North DeLamar, and Glen Silver zones (Figure 2). Additional mineralization in the Sullivan Gulch zone has yet to be mined. About 24,000 tons of ore and waste are mined per day, 2,100 tons of which are milled in a cyanide leach plant. This is followed by fire-refining to produce 1.5 to 2.0 million ounces of gold-bearing silver bullion per year. The ore reserves, using a cutoff grade of 1 ounce/ton silver equivalent (Ag + 40Au), are about 12 million tons averaging 1.8 ounces/ton silver and 0.023 ounce/ton gold. The ore reserves with a 2 ounce/ton silver equivalent cutoff, which was being used in 1982, are about 7 million tons averaging 2.5 ounces/ton silver and 0.036 ounce/ton gold. Thus, the minimum total amount of recoverable silver initially at De Lamar (production of the old De Lamar Mine, plus production since 1977, plus ore reserves using the 1 ounce/ton silver equivalent cutoff) would be approximately 35 million ounces; for gold it would be about 770,000 ounces.

Mineralization in the Sommercamp zone covers an area approximately 1,000 feet by 600 feet, in the North DeLamar zone about 1,100 by 500 feet, and in the Glen Silver zone roughly 1,800 by 400 feet (Figure 2). Most of the economic mineralization in these areas bottoms 300 to 400 feet below the surface. The undeveloped Sullivan Gulch zone is approximately

1,000 feet long and 300 feet wide. Its top is about 200 feet below the surface, and the mineralized section is 300 to 400 feet thick. Sufficient gold and silver occur in the veins and enclosing altered rhyolite to permit open-pit mining. However, the ore grade is highly variable, so assays spaced only a few feet apart are needed to properly assign mine rock to the ore or waste categories.

Economic mineralization occurs in the latites (Tl, Tlq), in the tuff breccia unit (Ttb), in the porphyritic rhyolite unit (Tpr), and at the base of the altered lower vitrophyre of the banded rhyolite (Tbr) unit (clay cap zone). The greatest concentration of mineralization is in the well-fractured, silicified, upper part of the porphyritic rhyolite unit. The overlying millsite rhyolite unit (Tms) is neither mineralized nor significantly altered, indicating that it was emplaced later.

Mineralization and veining occurred mainly in fractures, but locally ore stringers formed along flow bands and other layering in the host rhyolite. The dominant vein trends in the Sommercamp zone are N. 20° W., 70° S. to vertical, and N. 45° W., 85° N. to vertical; in the North DeLamar zone N. 60° W., 30°-40° S.; and in the Glen Silver zone N. 40°-50° W., 70° S. to vertical. The more intense mineralization occurs at vein intersections and where fracture density is greatest. Mineralization is most continuous just below the largely impermeable clay layer at the base of the banded rhyolite unit, with more restricted feeder veins extending downward, so that the ore zones generally become narrower downwards in a wedgelike fashion (Figure 2).

Ore emplacement at DeLamar probably started immediately after the formation of the porphyritic rhyolite unit and continued through the emplacement of the banded rhyolite. It probably occurred at about the same time as the vein formed at War Eagle Mountain and Florida Mountain. Conformable contacts, the lack of evidence for erosion, the truncation of some veins by the banded rhyolite unit, and the local presence of hot spring sinter deposits, both between the porphyritic rhyolite and banded rhyolite and on top of the banded rhyolite, suggest that only a short time may have elapsed between the formation of these two units.

Naumannite and aguilarite are the most important hypogene silver minerals, accounting for 50-70 percent of the silver, and are accompanied

by acanthite (mainly inverted from argentite) which accounts for 30-50 percent of the silver. Other hypogene minerals include pyrargyrite, miargyrite, argentopyrite (AgFe_2S_3) (Thomason, 1982), native gold and electrum, pyrite, marcasite, and traces of chalcopyrite, sphalerite, galena, and jamesonite(?). Minerals interpreted to be of supergene origin include native silver, cerargyrite, iodyrite (AgI), argentojarosite ($\text{AgFe}_3(\text{SO}_4)_2(\text{OH})_6$), covellite, native copper, goethite, hematite, lepidocrocite, psilomelane, jarosite, mandarinoite ($\text{Fe}_2\text{Se}_2\text{O}_4 \cdot 4\text{H}_2\text{O}$) (Lasmanis and others, 1981), and traces of eucairite (AgCuSe) exsolved at low temperature from umangite (Cu_3Se_2). Quartz is the principal gangue constituent; it occurs primarily in a massive form, but locally in the comb, drusy, and lamellar forms. Sericite and kaolinite are common gangue and alteration minerals, and are locally accompanied by zeolites, chlorite, barite, jarosite, and alunite.

Rodgers and others (1980) report that 65 percent of the argentite, naumannite, and aguilarite grains average 65 microns in diameter and occur as anhedral blebs in silicified rhyolite rocks, that the other 35 percent occur as blebs averaging 200 microns across within the quartz veinlets, and that argentite locally occurs as grains and masses up to 2 millimeters across. Gold occurs as anhedral blebs in quartz, in fractures, enclosed within or deposited on naumannite, and in solid solution with naumannite.

Rodgers and others (1980) and Thomason (1982) note that ore deposition began with the formation of quartz and sericite. Disseminated pyrite cubes formed near the end of the sericitization, and colloform pyrite formed in veins and on quartz. Slightly later, and probably at a lower temperature, marcasite encrustations were deposited on the colloform pyrite and as small laths in quartz. Argentite (now acanthite, but with cubic morphology) formed after marcasite and was followed by naumannite. Naumannite occurs as tiny anhedral grains, as replacement rims on argentite, and locally as euhedral grains with a cubic, or less commonly a hexagonal, habit. Gold, for the most part, is texturally later than naumannite, and probably was one of the final hypogene minerals deposited, along with pyrargyrite.

Pervasive hydrothermal alteration, consisting generally of sequential

zones of kaolinitization, sericitization, and silicification approaching the veins, is a characteristic of the DeLamar deposit. The alteration pattern is complex, however, because the formation of many zones overlapped one another in time and space adjacent to the closely spaced veins. Alunite, which is strongly developed near the surface along the fault at the west side of the Sommercamp pit and weakly developed at about the same level elsewhere, indicates that low pH, sulfate ion-bearing solutions locally were present. These may have been generated by boiling of the hydrothermal solutions. This agrees with the interpretation that the DeLamar deposit formed within a few hundred feet of the surface and is in good accord with the occurrence (W. B. Strowd, personal communication, 1982) of siliceous hot spring deposits between the porphyritic (Tpr) and banded (Tbr) rhyolite units. The clay zone was formed by the alteration of the basal vitrophyre layer of the banded rhyolite unit and evidently acted as an impermeable cap to the rising hydrothermal solutions, localizing the high-grade silver ore at that level.

Ratios of Au:Ag at the North DeLamar pit commonly are 1:50 or closer, whereas at the Sommercamp pit they are typically 1:100 to 1:250. This suggests that the North DeLamar mineralization formed at a shallower level, or farther from the underlying hydrothermal feeder system, than did the Sommercamp mineralization, following White's (1981) interpretation of the Steamboat Springs, Nevada, and Broadlands, New Zealand, geothermal systems. On the whole, the DeLamar mineralization is characterized more by its locally erratic ratios than by any specific trend except that as the silver grade increases the abundance of silver relative to gold also generally increases.

Interpretation of the detailed Au:Ag ratio variations is complicated by three or more cross-cutting, vein-forming events that occurred during the general period of mineralization. Production records from the old De Lamar Mine (Piper and Laney, 1926) show that the overall Au:Ag ratio was about 1:15. This was more gold-rich than the present-day ore, and since the early mining was concentrated in the larger veins, the variation in ratios suggests that silver was more widely dispersed than gold around and away from the fissures. This is also suggested by the Au:Ag ratio of 1:951 (Piper and Laney, 1926) in the direct shipping ore taken

from the base of the clay cap zone. Caution must be used when calculating Au:Ag ratios for the deposit since portions of the orebodies were essentially high-graded early in their history, which perhaps biases the ratios toward higher silver in the present operation.

TRADE DOLLAR CONSOLIDATED MINING COMPANY

The Black Jack-Trade Dollar vein and branching Empire State and Alpine veins on Florida Mountain (Figure 3) were mined principally from 1883 to 1910 and produced about \$12,850,000 worth of silver and gold. At first, the vein was worked from three mines: the Booneville on the north, the Black Jack in the middle, and the Trade Dollar on the south. By 1903 all had been taken into the Trade Dollar Consolidated Mining Company. More than 60,000 feet of development work was established, and about 2 million square feet of vein area was stoped to produce 15,421,700 ounces of silver and 132,580 ounces of gold (Piper and Laney, 1926).

The Black Jack-Trade Dollar vein has been followed at the surface for about $1\frac{1}{2}$ miles (Figure 3). Mining was concentrated principally in a zone about 6,000 feet long and carried to 1,700 feet below the vein apex. The vein is slightly curved, varying from north-northwest-trending at its south end to a north-south strike at its north end. It dips mainly 75° - 80° W., but locally is vertical or steeply inclined eastward. It cuts the Silver City granite and the overlying basalt and rhyolite flows (Figure 4), and follows a normal fault with 40-125 feet of oblique to horizontal displacement (Lindgren, 1900).

In the lower part of the mine where the wallrock is granite, the vein generally follows a 2-inch-wide to 4-foot-wide basalt dike. Lindgren (1900) and Piper and Laney (1926) indicate this dike does not extend into the overlying rhyolite and suggest it was a feeder for some of the lower basalt unit flows. In the granite the quartz-filled vein ranges from a few inches to about $2\frac{1}{2}$ feet in width and follows one or both contacts of the basalt dike. It is tightly frozen to the granite but is separated from the dike by a thin clay seam. In the lower basalt unit the vein generally is a single, sharp-walled, filled fissure 6 inches or less wide, or a quartz- and adularia-cemented breccia containing chloritized basalt fragments as much as 3 feet wide. In the rhyolite the vein

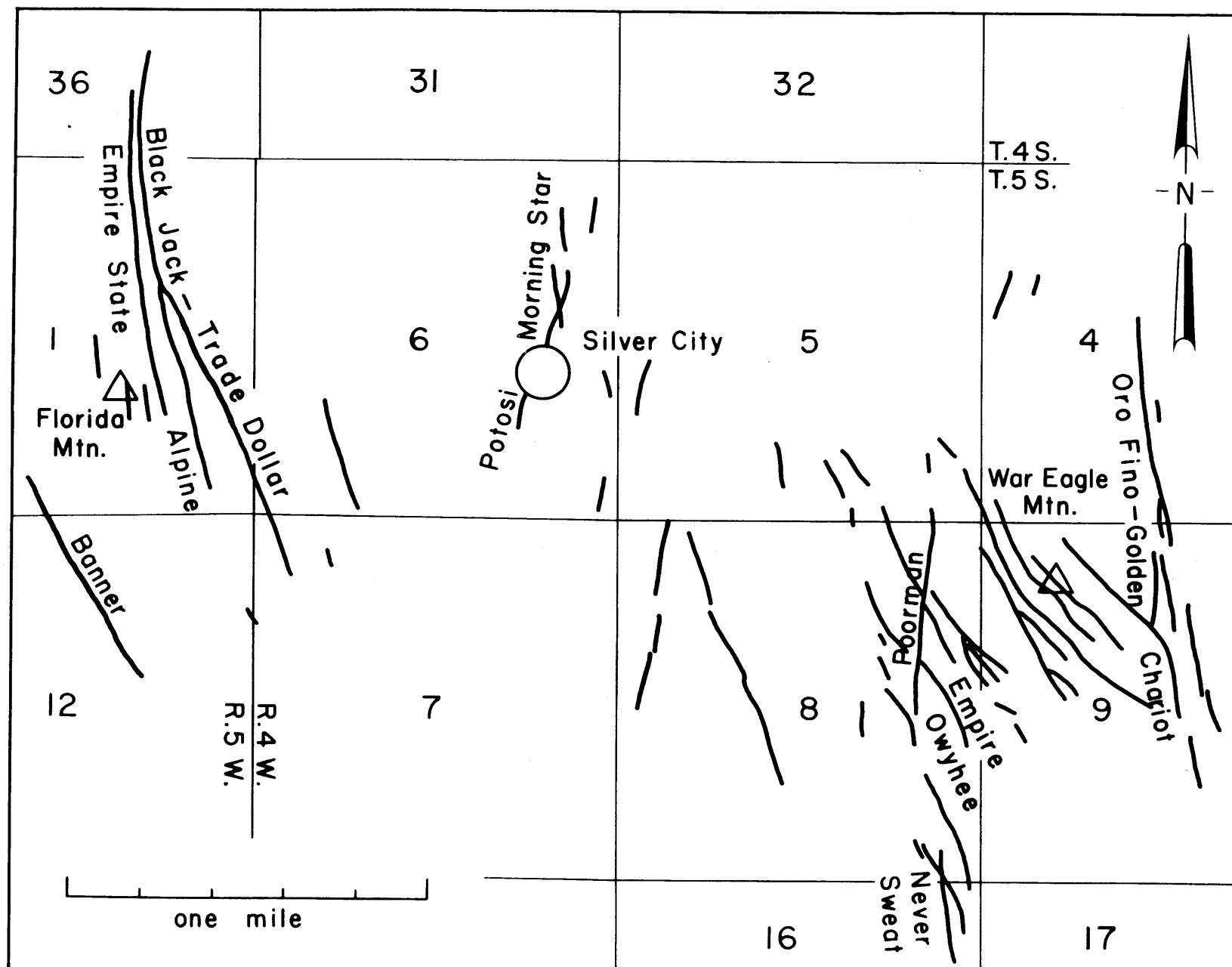


Figure 3. Veins in the Florida Mountain-War Eagle Mountain area (modified from Piper and Laney, 1926, Plate II).

ranges from 3 to 16 feet in width and averages 4 feet. It consists of highly altered rhyolite cut by numerous quartz and adularia stringers; the entire vein width constituted medium-grade ore and the walls varied from sharp to gradational.

Piper and Laney (1926) suggest, on the basis of the stope distribution, (Figure 4) that one large ore shoot near the center of the workings, and three smaller ones, each pitching southward about 45 degrees, occur in the vein. They also note that the best ore occurred in the granite, but that some high-grade bodies were found in the basalt. Very little workable ore occurred in the lower 100 feet of the rhyolite, but above this the orebodies were wider and of uniform but medium grade.

Quartz is the dominant gangue mineral; in most places it is massive, but occurs locally with a lamellar or comb structure. Adularia (especially near the southern end of the vein) and sericitic clay are locally abundant; epidote, chlorite, fluorite, and vivianite are minor to sparse gangue constituents (Piper and Laney, 1926). Ore minerals include native silver and gold, cerargyrite, argentite, naumannite, proustite, pyragyrite, polybasite, and stephanite(?); other metallic minerals reported are pyrite, chalcopyrite (and its oxidation products), sphalerite, galena, jamesonite(?), and clausthalite (PbSe).

In the lower levels of the mine naumannite was the dominant silver mineral, whereas in the upper levels, where oxidation and supergene enrichment had largely reorganized the ore, native silver and argentite were the principal ore minerals. The downward extent of supergene activity is not known. A small amount of ore from early near-surface workings carried a large gold content, but the silver content relative to gold increased downward in the upper levels. At greater depths, in normal hypogene ore, silver was much more abundant relative to gold, although the ratio was somewhat variable. On the basis of total production, the gold to silver ratio for the mine was 1:138.6, which is more silver-rich than other mines in the district (Piper and Laney, 1926).

ORO FINO-GOLDEN CHARIOT VEIN

The Oro Fino-Golden Chariot vein (Figure 3) was the most productive on War Eagle Mountain, being the source of about \$7 million worth of

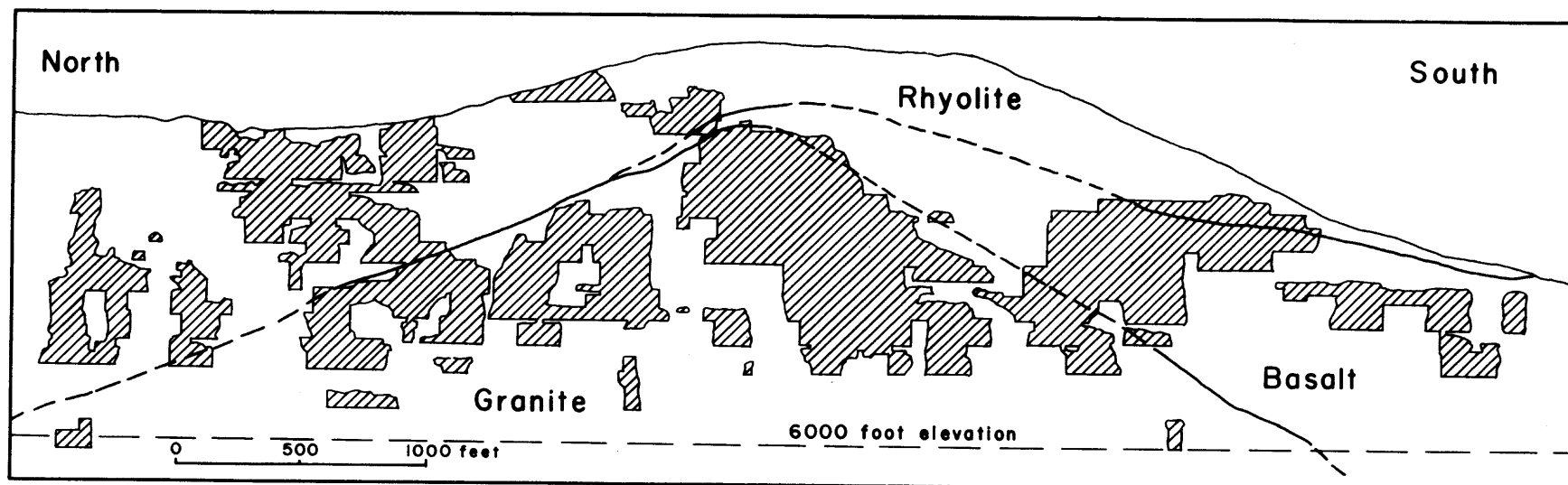


Figure 4. Longitudinal section of the Black Jack-Trade Dollar vein showing the stoped areas (modified from Piper and Laney, 1926, Plate XIII).

gold and silver from a main ore zone about 3,600 feet long and extending 1,100 feet below the surface. The Oro Fino (\$2 million), Golden Chariot (\$2 million), and Ida Elmore (\$1.3 million) mines had the greatest production; other mines include the Minnesota, South Chariot, and Mahogany. Very little mining has occurred since 1876; thus few details of the geology are known.

The vein strikes N. 4° W. and generally dips 80 to 90 degrees eastward, to cut the Silver City granite and the early Tertiary diorite and dacite porphyry dikes. Mining was conducted through a vertical extent of about 1,500 feet. The vein was also intersected more than 2,000 feet below its apex on War Eagle Mountain by the Sinker tunnel in 1902. It generally is about 3 feet wide. The vein is discontinuous at the surface and probably has suffered minor fault displacements. The main ore zone occurred where the vein is intersected by numerous secondary vein fissures, suggesting that ore deposition was controlled by their presence. Altogether, the vein was traced a total of 1½ miles, to include the Afterthought Mine south of the main ore zone.

From observations of surface exposures and waste dumps, Piper and Laney (1926) concluded that the vein is a quartz-cemented granodiorite and basalt breccia. The quartz varies from massive to drusy or lamellar and locally is accompanied by calcite.

Gold exceeded silver in value overall, but only in some of the oxidized surface ores did it predominate by weight. In the Oro Fino Mine the Au:Ag ratio was 1:1.1 near the surface and was 1:7.3 at 220 feet. Piper and Laney (1926) attribute the increase of silver relative to gold with increasing depth to a decrease in supergene enrichment intensity and suggest that enrichment did not extend much below 300 feet.

POORMAN MINE

The Poorman Mine, located 2,000 feet west of War Eagle Mountain summit, opened in 1863 on the Poorman vein. By 1890, when most mining activity ceased, about \$3 million of gold and silver had been produced. The vein is nearly vertical and strikes N. 2°-4° E. This vein is traceable for 0.7 mile on the surface, and Piper and Laney (1926) suggest that it may continue to the south as the Never Sweat vein, for a total

of 1.4 miles. The vein was discontinuously mined to a depth of 950 feet along 1,800 feet of strike length. Nearly all ore came from a single ore shoot which rakes northward at about 45 degrees. This shoot varied from 300 to 800 feet of strike length in its upper part to about 100 feet at the lowest mining level. Piper and Laney (1926) suggest that it was localized by the intersection of the Poorman vein with the north-northwest-trending Empire vein, which dips 60 degrees eastward. Below 600 feet the Poorman vein changes attitude to dip 45°-50° E., leading Piper and Laney to suggest that mining may actually have followed the north-northwest-trending, eastward-dipping Owyhee vein below this level.

The Poorman vein is a silicified shear zone, varying from a single 4- to 5-inch-wide, quartz-filled fissure to a zone of altered granite traversed by several 1½- to 3-inch-wide quartz stringers, for an aggregate width of as much as 4½ feet. Most of the quartz is massive, but is accompanied locally by comb-structure quartz.

Hypogene metallic minerals reported are gold, pyrrargyrite, proustite, polybasite, stephanite, owyheeite, and argentite or naumannite (or both). Small amounts of pyrite, marcasite(?), galena, sphalerite, and chalcopyrite occur in the lower levels of the mine. Gangue minerals other than quartz include minor amounts of calcite, epidote, chlorite, sericite, clay, and probably siderite.

Bonanza ores, worth thousands of dollars per ton, occurred in the upper 300 to 400 feet of the deposit. This material was the product of oxidation and supergene enrichment and consisted largely of cerargyrite in thin plates as much as a foot across accompanied by native silver in a soft mixture of clay and quartz. Of interest was a mass of proustite, perhaps a single crystal, weighing more than 500 pounds, recovered from 100 feet below the surface. Ores from the upper level bonanza stopes are reported to have had an Au:Ag ratio of 1:37.5, whereas ore from intermediate levels had a 1:5.6 ratio, and that from the lowest level had a 1:1.1 ratio (Piper and Laney, 1926).

FLINT AREA

Between 1865 and 1924, \$800,000 worth of silver and gold were produced at Flint from the Rising Star and Perseverance mines of the

Precious Metals Mines Company (Figure 1). Most of the values were in silver (1.5 million ounces) from the Rising Star vein; the rest were from the Perseverance vein. Piper and Laney (1926) report that six fairly evenly spaced quartz veins, striking N. 10° W. to N. 10° E. and dipping 65°-85° E., occur in a 2,000-foot-wide zone in the Silver City granite near Flint. Other generally north-trending quartz veins cut the granite elsewhere in the area. The Rising Star vein, the most prominent of the group, was traced for 1,100 feet at the surface and mined to about 600 feet. It generally is 10-20 feet wide, but the other veins of the group are 1-5 feet wide. The quartz generally is massive, but locally contains vugs and in many places has been shattered and coated by a minor late-stage generation of quartz. The quartz gangue is accompanied by sparse calcite, muscovite, sericite, clay, and graphite.

The silver-bearing minerals include miargyrite, pyrargyrite, polybasite, stephanite, proustite, argentiferous tetrahedrite, argentiferous jamesonite(?), and minor xanthoconite, argentite, naumannite(?), and stromeyerite(?). Other hypogene minerals are stibnite, chalcopryite, galena, sphalerite, arsenopyrite, and pyrite. It is not known in what form the gold occurs. Pyrite was not particularly abundant in the ore shoots, but it is quite abundant in other parts of the veins and, according to Piper and Laney (1926), is not accompanied by silver or gold. In the lower part of the Rising Star Mine, which was the part mined in the later years of production, the ore assayed 20 to 30 ounces of silver per ton. The Flint area ores are characterized by a smaller proportion of gold compared with silver than are those at Silver City and De Lamar. For example, the Flint concentrate analysis (Table 2) has an Au:Ag ratio of 1:690. It also is notably richer in antimony than the others.

A basalt dike follows the Rising Star vein throughout most of the mine. This dike is completely fresh and follows a fault that offsets the vein for a short distance, indicating that it is younger than the vein. This, in conjunction with the observations that nowhere in the Flint area has a vein been observed to cut either the lower basalt or rhyolite units and that north-northwest-trending faults offset the north-trending veins, led Piper and Laney (1926) to conclude that the Flint silver- and antimony-rich mineralization is older than the silver-gold mineralization at Silver City and De Lamar.

DISCUSSIONS AND CONCLUSIONS

Based on the mineralogy and general nature of the veins and their close association with Miocene silicic volcanism and hot springs deposits, the gold and silver deposits at DeLamar clearly are of the shallow-seated epithermal type. For the veins on War Eagle and Florida Mountains, the potassium-argon ages of 15.2, 15.6, and 16.6 million years for vein adularia and of about 16 million years for the Silver City rhyolite (Pansze, 1975; Armstrong, 1975, p. 9-10; recalculated for new decay constants using the tables of Dalrymple, 1979) also affirm that the veins formed during the waning stages of volcanism. The mineralogy, physical similarity, and high selenium content of the veins, as well as their relatively simple internal nature, suggest that the main part of the district underwent only one general mineralizing episode. This is consistent with essentially all of the veins having moderate to steep dips and north to northwest trends. The differences in the vein wallrock types and their extent of alteration, along with the increase of copper, lead, and zinc abundance at lower levels at Florida and War Eagle Mountains, suggest that the DeLamar deposits have not been eroded as deeply as the others and perhaps are more nearly localized over the volcanic conduits which provided heat and perhaps hydrothermal fluids.

The local occurrence of alunite at DeLamar, which may have formed because of boiling, also suggests that DeLamar is more shallow. The upwards-flaring nature of the mineralization nodes at DeLamar, as well as the clay cap at the top of the mineralization, indicates that the fluids there moved upwards and outwards during ore deposition. At War Eagle and Florida Mountains, however, the lateral offset of the veins from nearby volcanic domes suggests that fluid movement during deposition may have been obliquely upwards or even horizontal from nearby volcanic centers.

The sequence of mineral formation is about the same throughout the district. Based on its limited occurrence, calcite probably was the first mineral formed in many veins. Much of it was later replaced by lamellar quartz. This event merged into the deposition of the main vein filling of massive quartz, and the formation of the local drusy and comb

structure types. Quartz deposition was accompanied by the formation of adularia, sericite, or clay; it overlaps in time the deposition of the gold- and silver-bearing minerals and the deposition of local pyrite and base metal sulfides at depth. Pansze (1975) interpreted the replacement of calcite by lamellar quartz as resulting from the cooling of the ore solutions with time or increased distance from their source. He notes that calcite is relatively insoluble above 225°C regardless of the partial pressure of CO₂, but that its solubility increases markedly at lower temperatures, whereas the solubility of quartz decreases at lower temperatures.

The more common isometric argentite form of Ag₂S rather than the hexagonal acanthite form suggests that much of the silver deposition occurred above 177°C (Craig and Scott, 1974). The occurrence of some hexagonal naumannite (Rodgers and others, 1980; Thomason, 1982), however, reveals that ore deposition persisted to temperatures below 133°C.

It is not clear why the silver-gold ores of the Silver City-De Lamar district have the high selenium content by which they are characterized. Most likely the hydrothermal solutions from which the ores were deposited were unusually rich in selenium, but they probably were not particularly impoverished in sulfur, judging by the presence of the various sulfide minerals. It is interesting to note that the Silver City-De Lamar district is one of three such Tertiary, selenium-rich, epithermal, precious metal districts in the northwestern United States, the other districts being Jarbidge, Nevada, and Republic, Washington (Davidson, 1960).

The veins at Flint differ from those at Silver City and De Lamar by being richer in silver compared with gold and much richer in antimony. This is shown by the analyses in Table 2, and by the vein minerals, as stibnite occurs only at Flint. As noted above, Piper and Laney (1926) considered the Flint mineralization to be older than that in the centrally located Silver City-De Lamar part of the district. Similarly, Asher (1968) considered the stibnite-rich, silver-bearing mineralization in granitic rocks at Slacks Mountain (Figure 1) and other localities a few miles north of the main part of the district to be older, since those veins occupy northeast-trending fractures which he believed had formed earlier.

Piper and Laney's (1926) most compelling evidence of age relations at Flint is the postmineralization basalt dike that follows the Rising Star vein. It would constrain the Flint mineralization to an age older than that at Silver City and De Lamar only if it is approximately the same age as the basalt dikes at the Trade Dollar Mine and along the Oro Fino-Golden Chariot vein. The age of the Rising Star dike is not known, however. If it is younger than the rhyolitic volcanism in the area--and this certainly is feasible considering the vast quantities of younger basalt which occur on all sides of the Silver City Range--the silver-antimony veins at Flint quite conceivably are the same age as those at Silver City and De Lamar. Similarly, the silver-antimony mineralization described by Asher (1968) at Slacks Mountain and other localities north of Silver City may also be the same age as the mineralization in the central part of the district, and may simply occupy fractures that formed earlier. Consequently, it is not presently known if one or two distinct episodes of precious metal mineralization have occurred in the district. If it is only one episode, the district could have an overall metal zoning pattern consisting of relatively higher gold and selenium in the Silver City-De Lamar core region, and relatively higher silver, antimony, and base metal abundances in the outlying areas. Conversely, if two episodes occurred, then no district-wide zoning relationships are evident. If there really are two episodes, then the earlier one responsible for the silver-antimony mineralization probably is related to the northeast-trending Eocene- or Oligocene-age diorite and dacite porphyry dikes (Piper and Laney, 1926; Pansze, 1975; Ekren and others, 1981) that cut the Silver City granite.

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