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THE GEOLOGY OF THE GOLDFIELD DISTRICT

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INTRODUCTION

The Goldfield mining district is located in west-central Nevada, about halfway between Reno and Las Vegas on U. S. Highway 95. (Fig. 1). Goldfield is one of the large, bonanza-grade, epithermal precious-metals deposits in Nevada hosted by hydrothermally altered Tertiary volcanic rocks. Goldfield, with production valued at about $100 million, is the third largest of the districts after Comstock and Tonopah. Among epithermal deposits in the Great Basin, Goldfield is unusual for its high gold/silver ratio (3/1), presence of tellurides, and widespread development of advanced argillic alteration, but these characteristics are typical of "enargite-gold" deposits (e.g., Ashley, 1982).

The Goldfield district occupies the central part of the Goldfield Hills, which reach an elevation of 2100 m and are almost completely surrounded by desert basins at elevations of around 1500 m. Over 40 sq km of hydrothermally altered volcanic rocks are present in the Goldfield Hills (Ashley, 1974), but most of the ore production was located in a small (1.3 sq km) area just northeast of the town of Goldfield (Ransome, 1909; Searls, 1948).

Float gold was discovered in the vicinity of Goldfield late in 1902, and the first ore was shipped late in 1903 (Ransome, 1909). In November of 1906, most of the major mines in the district were consolidated as the Goldfield Consolidated Mines Company. Goldfield reached peak production quickly, producing 539,000 oz of gold and 118,000 oz of silver in 1910, after which production steadily declined to below 20,000 oz of gold per year in 1920 (Ashley, 1974). Total production recorded for Goldfield is 4.2 million oz Au, 1.4 million oz Ag, and 7.7 million lb Cu from 4.6 million tons of ore (Schamberger, 1982), for an average grade of nearly one oz Au per ton.

GEOLOGIC SETTING OF THE DISTRICT

The geology of the Goldfield area can be described as a domed uplift, exposing a series of faulted and hydrothermally altered mid-Tertiary volcanic rocks lying unconformably on Paleozoic and Mesozoic basement rocks (Fig. 2). The uplift is flanked by unaltered late Tertiary volcanic and sedimentary rocks that fill the surrounding basins. Most of the mid-Tertiary volcanic rocks were erupted from vents in the Goldfield district (Ashley, 1974).

The oldest rocks exposed in the district, black siliceous shales of the Ordovician Palmetto Formation, are intruded by Jurassic quartz monzonite, a relationship that is well exposed on the south flank of Columbia Mountain, just north of the main district. A sequence of mid- to late Tertiary volcanic rocks, which unconformably overlie the basement rocks, can be divided into three groups on the basis of age and composition. The oldest group consists of flows and tuffs of quartz latite to rhyolite composition, dated at 30-31 Ma (Ashley, 1973). The first group is unconformably overlain by a thick (up to 600 m) sequence of flows and lesser tuffs of andesite to rhyodacite composition, dated at 20-22 Ma (Silberman and Ashley, 1970; Albers and Stewart, 1972). Hydrothermal alteration and ore deposition, dated at 20-21 Ma (Silberman and Ashley, 1970), was closely related to this second period of volcanism. The third group, middle Miocene to early Pliocene units that flank the older Tertiary units, consists of silicic tuffs, basalt flows, and sedimentary rocks with abundant volcanic debris.

Ashley (1974) has identified eight probable vent areas for the pre-mineralization volcanic rocks, forming a ring-shaped pattern that generally coincides with the ring-shaped alteration pattern shown on Figure 1. Ashley (1972, 1974) suggested that collapse of a small caldera may have accompanied eruption of one of the Oligocene units and that the alteration pattern may outline a ring-fracture zone. The postulated ring-fracture system apparently was only a structural conduit for magmas and hydrothermal activity in the early Miocene.

The structural relationships in the district are dominated by three principal features: a zone of N30E trending, east-dipping normal faults in the central part, a N80W trending zone of steeply dipping faults in the southeastern part, and an arcuate fault system in the northwestern part of the district (Fig. 2). Many of these faults localized hydrothermal alteration and now are strongly silicified.

Most of the productive mines are located along or near the arcuate fault system in the northwestern part of the district (compare Fig. 1 and 2). The most continuous fault in the district, the Columbia Mountain fault, is the main element in the system. It can be traced north from the main district for about 3.2 km, then it bends northeasterly and splits into several discontinuous faults. The Columbia Mountain fault dips moderately (20-55) to the east and shows normal displacement of over 100 m (Ransome, 1909).

HYDROTHERMAL ALTERATION

Hydrothermally altered rocks cover over 40 sq km in the Goldfield district (Fig. 1). Four alteration types have been identified, three of which consistently form zoned envelopes of advanced argillic and intermediate argillic alteration alteration adjacent to the faults and fractures that guided flow of hydrothermal fluids (Harvey and Vitaliano, 1964; Ashley and Albers, 1975; Ashley and Keith, 1976). In and adjacent to the fracture is (1) a zone of strong silicification that is composed dominantly of fine-grained (0.002-0.02 mm) silica, with lesser alunite, kaolinite, pyrite, and trace amounts of diaspore and pyrophyllite. The

bonanza

many silicified zones are only weakly anomalous to barren of gold. Gold deposition probably postdates development of most quartz and alunite, but fine-grained quartz and plates of alunite occur with native gold and other opaque minerals. These "silica ledges", which form craggy, resistant outcrops, are bordered by (2) abundant quartz and alunite, with kaolinite, sericite, pyrite, and local opal. Farther from the structure is (3) a wide, poorly exposed zone of intermediate argillic alteration that can be divided into two subzones on the basis of montmorillonite versus kaolinite content (Harvey and Vitaliano, 1964). In the inner subzone, kaolinite is the dominant (up to 90%) clay mineral (assemblage: quartz + illite + kaolinite + pyrite, with local adularia and opal). The inner subzone is gradational with an outer subzone in which montmorillonite is present (assemblage: quartz + montmorillonite + kaolinite + illite + pyrite). Widths of alteration zones vary considerably within the district, and widths of the outer zones do not appear to bear a direct relationship to the width of the silicified zone. Intermediate argillic zones extend as much as 100 m on each side of the silica ledge, and intermediate argillic zones related to adjacent veins commonly overlap and coalesce. The intermediate argillic zone may abut against fresh rocks or may pass into widespread (4) propylitic alteration, which contains calcite and chlorite and is sulfide-poor (Ashley and Keith, 1976). Because propylitization is not concentrically zoned about the silicified zones, propylitic alteration may have occurred prior to advanced argillic and intermediate argillic alteration, perhaps associated with Oligocene or early Miocene magmatism (Ashley, 1974).

Surface oxidation extends to at least 10 m in argillized rocks and 60 to 300 m down the more permeable silicified zones. Oxidation of iron-rich minerals (principally pyrite) has produced a variety of iron oxides, which impart pastel to rust colors to the altered and silicified rocks. Supergene jarosite and gypsum veinlets are locally present in the altered rocks. Sulfur isotope studies of alunite samples collected in and adjacent to the silicified zones verify that the "replacement alunite" is of hypogene origin, but thin alunite veins are of supergene origin (Jensen et al., 1971).

ORE DEPOSITS

The ore-bearing areas of the Goldfield district are shown on Figure 1. Over 95% of the gold produced has come from the "main district" (Fig. 3). The most detailed descriptions of the mines are by Ransome (1909), with later developments described by Locke (1912) and Searls (1948). The basement rocks of shale and quartz monzonite are overlain by quartz latite flows, which are overlain by porphyritic rhyodacite to the north and "Milltown" andesite to the south. Ashley (1974) interprets the porphyritic rhyodacite mass, which hosts most of the bonanza orebodies, to be an intrusive flow-dome complex.

The silicified zones that host the ore deposits can be divided into three systems based on their geometry (Fig. 3). The most productive system is represented by one principal zone (the "main vein") that strikes north and dips moderately (20-50 degrees) to the east. The main vein is present from the Red Top mine on the north to near the sharp bend in the vein near the January-Combination open cut on the south. The Mohawk mine, near the center of this trend, was the most productive in the district. The second most productive system is a series of northeast trending veins that dip steeply east. The principal vein in this group connects with the main vein through the bend at the January-Combination open cut and extends southeast to the Florence mine. Other structures of this group include the Jumbo, Clermont, and Velvet veins, which are in the hanging wall of the main vein system. A third, minor set of vein structures trend northeast and only locally are ore bearing, north of the Florence and in the vicinity of the Merger mine. In general, the veins become more lode-like and tabular with depth. As the veins approach the surface, they horsetail and become more irregular in form.

Most of the silicified material in the veins of the main district carries anomalous gold values (Ashley and Albers, 1975), but high-grade bonanza ore was confined to ore shoots, where previously silicified rock had been fractured or brecciated before hydrothermal activity ceased.

The ore shoots tend to form sheet-like masses but in detail are quite irregular in shape (Ransome, 1909; Locke, 1912). Ore-grade versus low-grade material is not defined by any sharp structure and commonly can be determined only by assay (Ransome, 1909). In the main district, about 15 individual orebodies can be classified as "bonanzas", and they have average dimensions of 60-130 m along strike, 60-100 m down dip, and 7 m wide and average 100,000 tons grading 1 to 5 oz Au per ton. The richest ore shoot mined, from the Mohawk mine, contained 12,500 tons averaging 20 oz Au per ton (Ransome, 1909).

The texture of the Goldfield ores varies from finely crystalline with disseminated ore minerals, to brecciated or vuggy types where ore minerals form crusts around breccia fragments or line vugs, to massive "sooty" types that are practically solid ore minerals (Tolman and Ambrose, 1934). Typical unoxidized ore contains pyrite, bismuthinite, famatinite, and fine native gold in a dark gray quartz gangue (Tolman and Ambrose, 1934). Famatinite belongs to the tetragonal series luzonite-famatinite, and the material from Goldfield has an As:Sb ratio of nearly 1:1 (stibioluzonite) and contains tin (Ransome, 1909; Ashley and Albers, 1975). Marcasite, sphalerite, tetrahedrite-tennantite (commonly associated with bismuthinite and enclosed in famatinite), and chalcopyrite are locally present in subordinate amounts (Tolman and Ambrose, 1934; Ashley and Albers, 1975). Goldfieldite (Cu6Sb2(S,Te)9) was first identified and named by

Ransome (1909) and is characteristic of the rich "sooty" ores of the Mohawk mine, which are a mixture of fine native gold and goldfieldite, closely associated with marcasite. The gold-silver tellurides petzite ($(Au, Ag)_2Te$), hessite (Ag_2Te), and sylvanite ($AgAuTe_4$) occur in small amounts closely associated with goldfieldite or bismuthinite (Tolman and Ambrose, 1934), and calaverite ($AuTe_2$) is reported by Searls (1948). Alunite and kaolinite are generally present as soft white substances in the quartz gangue.

The best ores characteristically exhibit concentric shells of ore minerals and quartz around silicified and pyritized breccia fragments. The sequence of ore minerals is variable, and gold can be on an inner shell, an outer shell, or two shells. Detailed petrographic work by Tolman and Ambrose (1934) has defined a paragenetic sequence (Fig. 4). Native gold was one of the last minerals deposited and commonly replaced earlier formed ore minerals on inner shells.

The character of the ores changes with depth, showing a gradual decrease in ore grade, decreasing development of silicification, decreasing abundances of tellurides, bismuthinite, and famatinite, and an increasing abundance of pyrite. Ore mined from the deepest workings, where the vein occupied the pre-volcanic unconformity, was much richer in silver (5 oz/ton) and copper (4%) than the shallower ores (Searls, 1948). The main vein system was mined to a maximum depth of 410 m.

The hypogene mineral assemblages at Goldfield formed from fluids of low pH, high sulfate activity, probably at temperatures in the range of 200-300 degrees C, and at paleodepths to the top of ore estimated to be 100-400 m (Hemley et al., 1969; Knight, 1977). Oxygen isotope data suggests that the fluids were dominated by meteoric water (Taylor, 1973), but sulfides have sulfur isotopic values characteristic of magmatic sulfur (Jensen et al, 1971). Mass-balance arguments (Ashley, 1979) indicate that gold and sulfur were added to the hydrothermal system from a deeper source, perhaps from a Miocene, epizonal pluton that geophysical and geologic evidence suggests may exist at shallow depths on the eastern side of the district (Ashley, 1979).

Oxidized ores, in which the principal ore mineral is native gold, occur within 30-50 m of the surface. Ashley and Albers (1975) have shown that the distribution of gold in the veins is not strongly affected by surface oxidation.

Recent work in the district includes the search for new bonanza orebodies in the outlying parts of the district, heap leaching of old mine dumps and mill tailings, and attempts to block out shallow, oxidized, low-grade ore adjacent to the old workings in the heart of the district. In 1980, a joint venture between Noranda Exploration, Inc. and Pacific Gold and Uranium, Inc. announced geologic reserves of 550,000 tons at an average grade of 0.07 oz Au per ton, but subsequent owners have not announced any plans to begin mining.

FIGURE CAPTIONS

Fig. 1. Generalized distribution of altered and mineralized rocks in the Goldfield mining district, west-central Nevada.

Fig. 2. Generalized geologic map of the Goldfield mining district, based on ------.

Fig. 3. Geologic map and cross section showing the geometry of ore-bearing veins.

Fig. 4. Paragenesis of gangue and ore minerals.

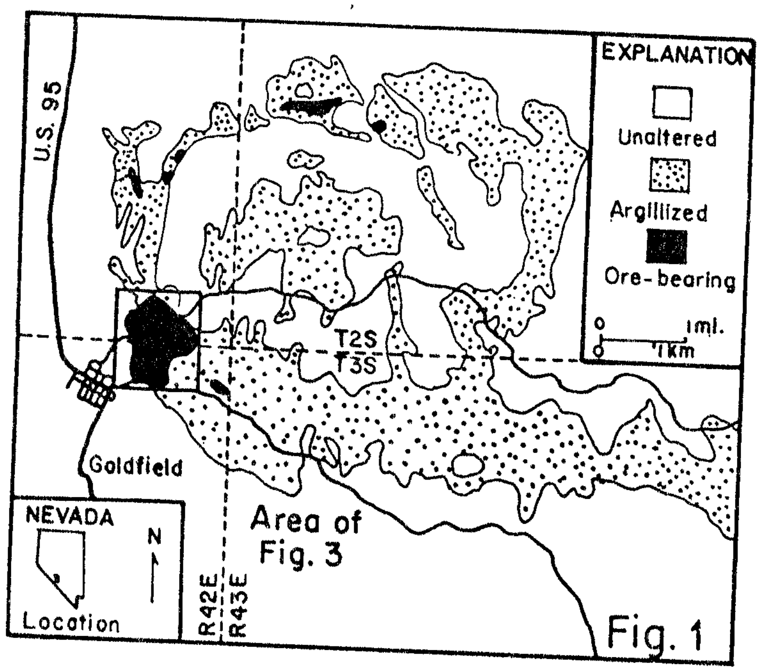

EXPLANATION
Unaltered
Argillized
Ore-bearing
0 1mi.
0 1Km
U.S. 95
T2S
T3S
Goldfield
NEVADA
N
Location
Area of
Fig. 3
R42E
R43E

Fig. 1

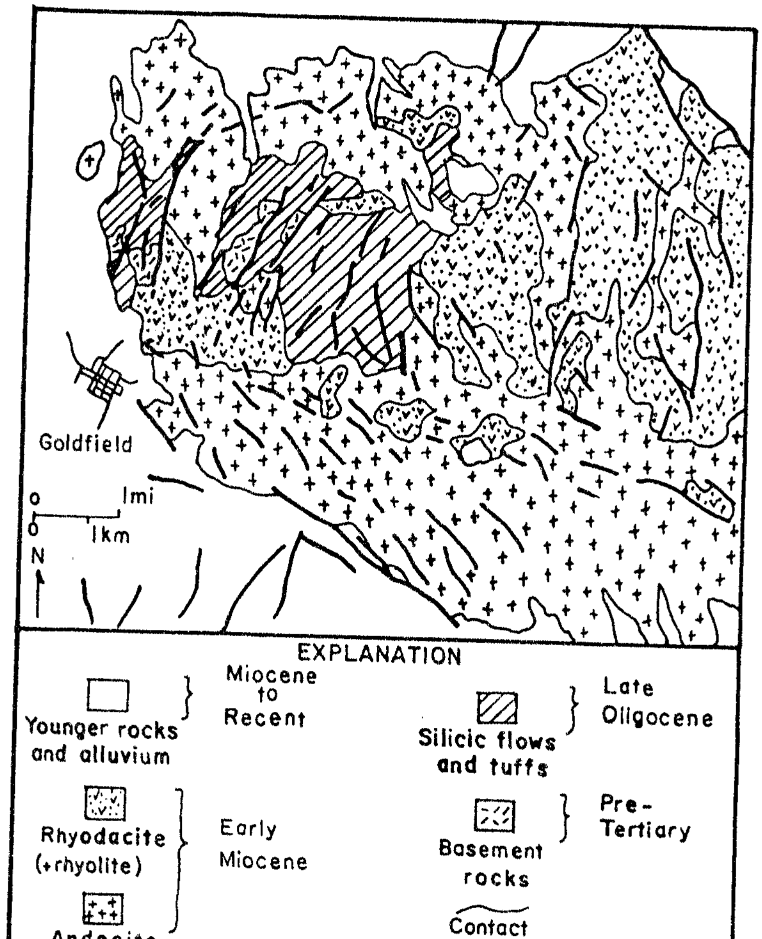
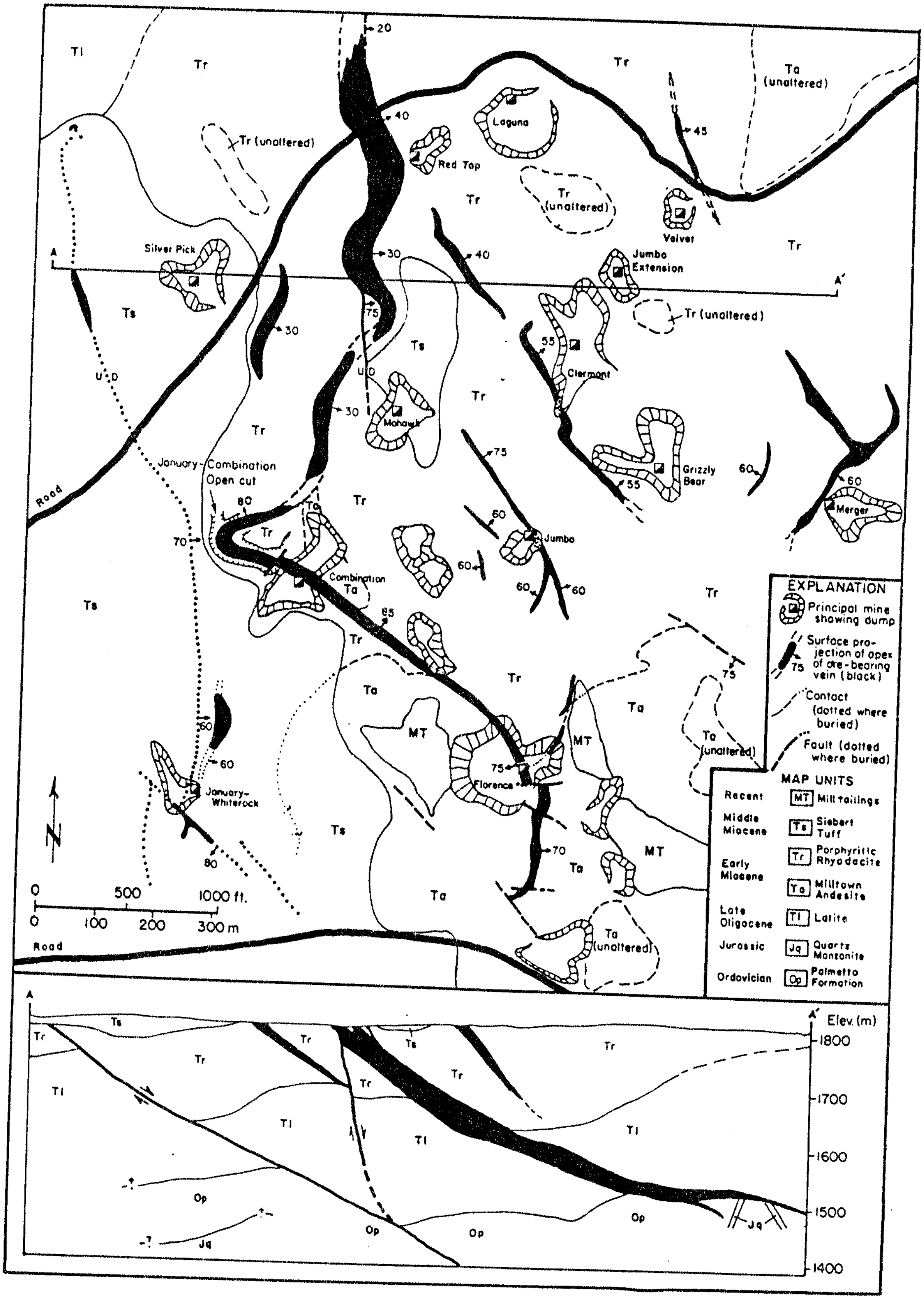
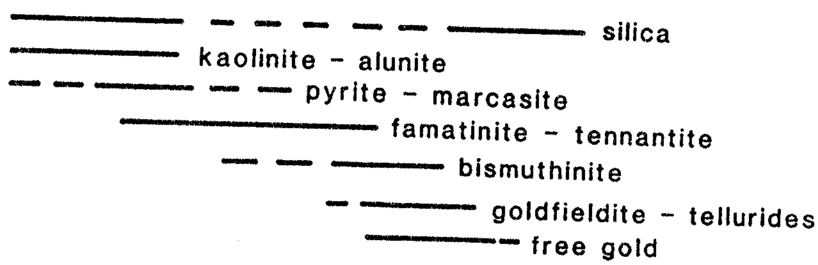

Goldfield
0 1mi
0 1km
N
EXPLANATION
Younger rocks and alluvium
Miocene to Recent
Silicic flows and tuffs
Late Oligocene
Rhyodacite (+rhyolite)
Andesite
Early Miocene
Basement rocks
Pre-Tertiary
Contact
Fault

Fig. 2



EXPLANATION
Principal mine showing dump
Surface projection of apex of ore-bearing vein (black)
Contact (dotted where buried)
Fault (dotted where buried)
MAP UNITS
Recent MT Mill tailings
Middle Miocene Ts Siebert Tuff
Early Miocene Tr Porphyritic Rhyodacite
Ta Milltown Andesite
Late Oligocene Tl Latite
Jurassic Jq Quartz Monzonite
Ordovician Op Palmetto Formation
Silver Pick
Laguna
Red Top
Velvet
Jumbo Extension
Clermont
Mohawk
Grizzly Bear
Merger
Jumbo
Combination
January-Combination Open cut
January-Whiterock
Florence
Tr (unaltered)
Ta (unaltered)
Road
0 500 1000 ft.
0 100 200 300 m
Elev. (m)
1800
1700
1600
1500
1400

GENERALIZED PARAGENESIS



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