GEOLOGY AND EVOLUTION OF THE COPPER FLAT PORPHYRY SYSTEM, SIERRA COUNTY, NEW MEXICO

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see related abstracts

ABSTRACT

The Hillsboro district, in central New Mexico, is an example of the typical geologic style of the development of Laramide porphyry copper deposits in southwestern United States. New geochemical, geochronological, and geological data, combined with earlier studies, have provided a refinement of the evolution of mineralization in the district. Past production has been predominantly from the Laramide veins and placer gold deposits, although minor production has occurred from the porphyry copper and carbonate-hosted Pb-Zn and Ag-Mn replacement deposits. The geology of the Hillsboro district is dominated by Cretaceous andesite flows (75.4±3.5 Ma, 40Ar/39Ar), breccias, and volcaniclastic rocks that were erupted from a volcano. The Copper Flat quartz monzonite porphyry (CFQM, 74.93±0.66 Ma, 40Ar/39Ar) intruded the vent of the volcano. The unmineralized Warm Springs quartz monzonite (74.4±2.6 Ma, 40Ar/39Ar) and a third altered, unmineralized quartz monzonite intruded along fracture zones on the flanks of the volcano. Younger latite and quartz latite dikes intruded the andesite and CFQM and radiate outwards from the CFQM. The igneous rocks are part of a differentiated comagmatic suite. Alteration of the igneous rocks consists of locally intense biotite-potassic, potassic, sericitic, phyllic, and argillic alteration. Large jasperoid bodies as well as smaller skarns and marbles have replaced limestones belonging to the El Paso Formation, Fusselman Dolomite and Lake Valley Limestone in the southern part of the district. The porphyry copper deposit is a low-grade hypogene deposit that is concentrated within a breccia pipe in the CQFM stock and contains pyrite, chalcopyrite, chalcocite, molybdenite, azurite, malachite, and cuprite. The CFQM deposit forms the center of the Hillsboro district. Trending outward radially from the CFQM are Laramide Au-Ag-Cu veins hosted by many of the latite/quartz latite dikes. Carbonate-hosted replacement deposits (Ag, Pb, Mn, V, Mo, Zn) are found in the southern and northern parts of the district, distal from the CFQM deposit. Collectively, the evidence suggests that the mineral deposits found in the Hillsboro district were formed by large, convective hydrothermal systems related to the Copper Flat volcanic/intrusive complex. The CFQM porphyry copper deposit exhibits very little supergene alteration and enrichment, in contrast to the extensive supergene alteration and enrichment found in the porphyry copper deposits at Santa Rita and Tyrone, New Mexico and Morenci, Arizona. This is most likely a result of less pyrite (<2%) at Copper Flat and burial of the CFQM deposit from 75 to 24 Ma, preventing any supergene enrichment from occurring.

LOCATION AND MINING HISTORY

EXHIBIT
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The Hillsboro or Las Animas district lies in the Animas Mountains and was discovered in 1877. The town of Hillsboro, first known as Hillsborough, was also established in 1877. A tent city named Gold Dust was founded in 1881 in the district and was home to numerous prospectors looking for placer gold deposits. In 1884, Hillsboro was the Sierra County seat, but by 1938, mining and subsequently, the population of Hillsboro diminished and the county seat was moved to T or C (then known as Hot Springs). Sporadic minor production has occurred since (Table 1).

The first gold production was recovered by arrastras and then by stamp mills in the district prior to 1881 (Burchard, 1881). A 10-stamp mill operated at the Bobtail mine on the Snake vein from about 1881 to 1884 and had a capacity of 20-25 tons per day (Burchard, 1883). Placer deposits in Snake Gulch were also mined by hydraulic mining (Burchard, 1882). Mills operated at the Richmond (1890-1892), Bonanza (1890-1910), Ready Pay/Porter (1898-1913), Snake (1910), and Wicks mines. The copper-matte smelter in the town of Hillsboro was built in 1892 and operated until it closed in the early 1900s. Capacity was approximately 30 tons per day. Manganese was first produced and used in the Hillsboro smelter as flux during the early operation of the Hillsboro smelter (Wells, 1918).

TABLE 1. Metals production from the Hillsboro district, Sierra County (U. S. Geological Survey, 1902-1926; U. S. Bureau of Mines, 1927-1990). *Includes production from Tierra Blanca district in 1939 and from the Caballo district in 1957.

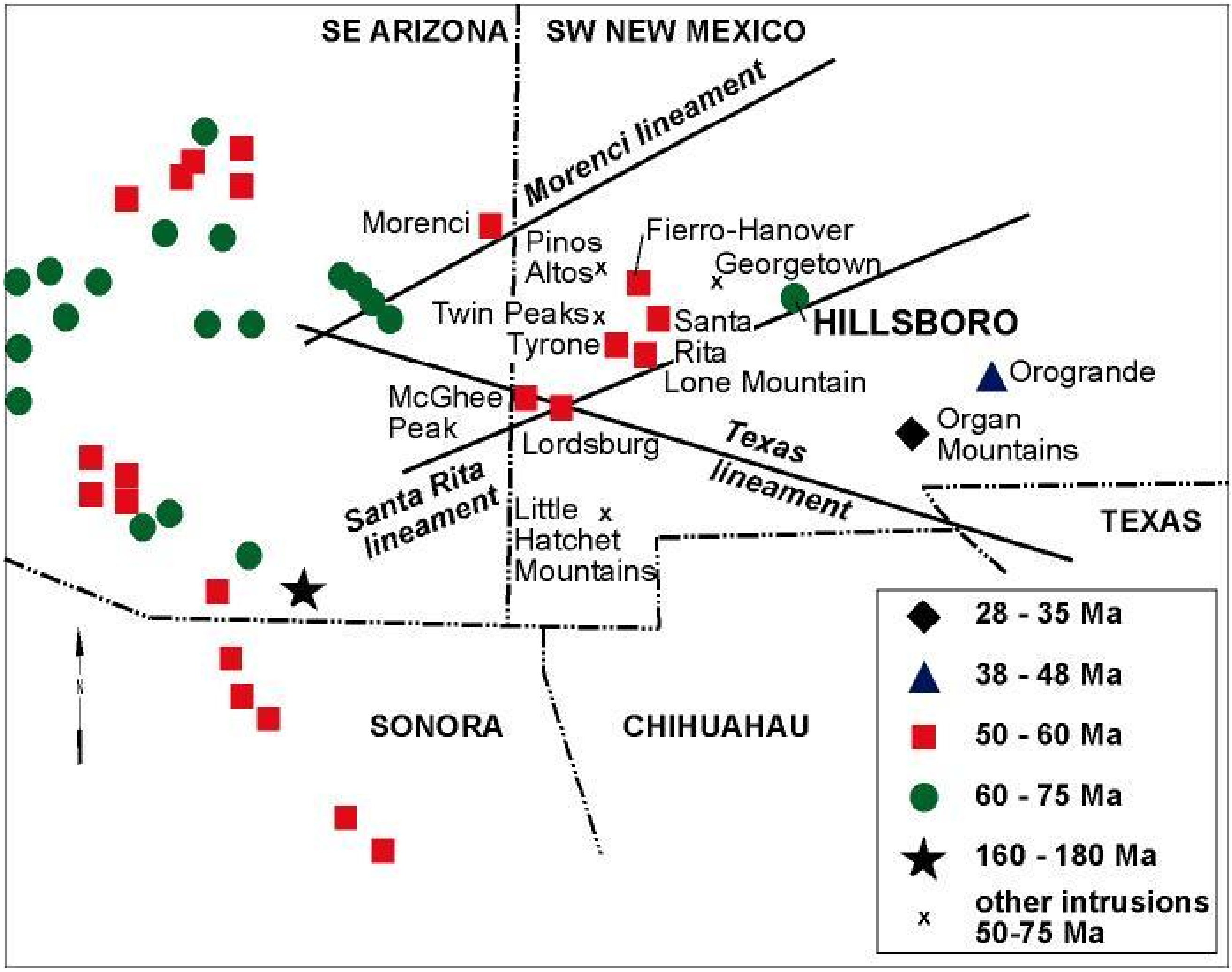
YEAR	ORE (SHORT TONS)	COPPER (lbs)	LODE GOLD (oz)	PLACER GOLD (oz)	SILVER (oz)	LEAD (LBS)	VALUE ($)
1877-1904	—	—	—	—	—	—	6,750,000
1933	272	3,000	239	221	1,277	600	10,177
1934	761	14,100	462	1,139	4,647	700	60,109
1935	666	22,000	1,098	1,761	2,561	18,400	104,481
1936	983	34,980	1,638	1,620	4,571	—	120,788
1937	469	17,400	357	1,234	2,587	—	70,309
1938	268	13,900	425	2,073	2,104	—	90,138
1939*	1,160	29,900	868	2,271	3,427	100	115,306
1940	1,084	25,000	684	1,688	2,219	3,300	87,588
1941	4,581	20,000	432	989	1,562	1,100	53,269
1942	11	—	11	582	79	—	20,811
1943	—	—	—	2	—	—	70
1944	—	—	—	5	—	—	175
1946	12	400	7	—	83	—	377
1948	6	—	4	—	65	—	199
1949	11	1,000	35	—	338	—	1,728
1950	111	3,600	121	—	491	—	5,428
1951	1,214	—	289	—	52	—	0,162
1952	563	—	125	—	30	—	4,402
1953	1,230	—	265	—	51	—	9,426
1955	10	400	2	3	11	—	2,259
1957*	304	3,300	4	58	4	—	1,138

TOTAL 1933 -1957	13,716	188,980	7,066	13,671	26,159	24,200	758,340
SUBTOTAL 1902-1961	34,403	384,042			77,916	153,387	
1982	—	7,000,000	—	—	—	—	—
ESTIMATED TOTAL 1877 -1982	—	24,000,000	150,000	120,000	78,000	153,387	8,500,000

The Copper Flat porphyry-copper deposit in the northern part of the Hillsboro district was discovered in 1975 (Castellano et al., 1977; Dunn, 1982, 1984), although alteration and mineralization in the area suggested to earlier geologists that a porphyry-copper deposit should occur in the district (Kuelmer, 1954). Approximately 200 short tons of copper oxide were mined from the oxide cap in 1911-1931 (Sternberg shaft; Hedlund, 1974). A copper leach plant operated in the mid-1950s, but production figures are unknown. Quintana Minerals Corp. produced approximately 7 million pounds of copper in March through June 1982, prior to closure of the open-pit mine (Ohl and Eveleth, 1984). Alta Gold Co. applied for mining permits to reopen the Copper Flat mine, but the company went bankrupted before the permits were issued. The future of the mine is unknown. Mineable reserves were estimated in 1984 as 60 million short tons of 0.42% Cu (504 million lbs Cu) and 0.012% Mo (14.4 million lbs Mo)(Dunn, 1984). Current reserves of the deposit are estimated as 60 million tons of ore containing 487 million lbs Cu, 251,000 oz Au, 3.2 million oz Ag, and 15.7 million lbs Mo (Dillard, 1995). The gold grade is reported to be 0.004 oz/ton.

GEOLOGIC SETTING

The Hillsboro mining district lies on the eastern edge of the Laramide Arizona-Sonora-New Mexico porphyry copper belt. It is the oldest porphyry copper deposit in the state; although the Piños Altos pluton is ca. 74.4 Ma (McDowell, 1971) and a Georgetown monzonite dike has been dated as ca. 71 Ma (McLemore, 1998), both of which have associated Cu-Au-Ag skarn or Ag carbonate-hosted replacement deposits. The Twin Peaks monzonite porphyry in the Burro Mountains is 72.5 Ma (Hedlund, 1980) and a hornblende andesite in the Hidalgo Formation in the Little Hatchet Mountains is 71.4 Ma (Lawton et al., 1993). Polymetallic veins and alteration suggests that a porphyry may underlie the Lordsburg district (57.4 Ma, McLemore et al., 2000a). Porphyry copper deposits are not known to occur in these areas, but certainly the possibility exists that deposits may occur undiscovered in the subsurface.



LOCAL GEOLOGY

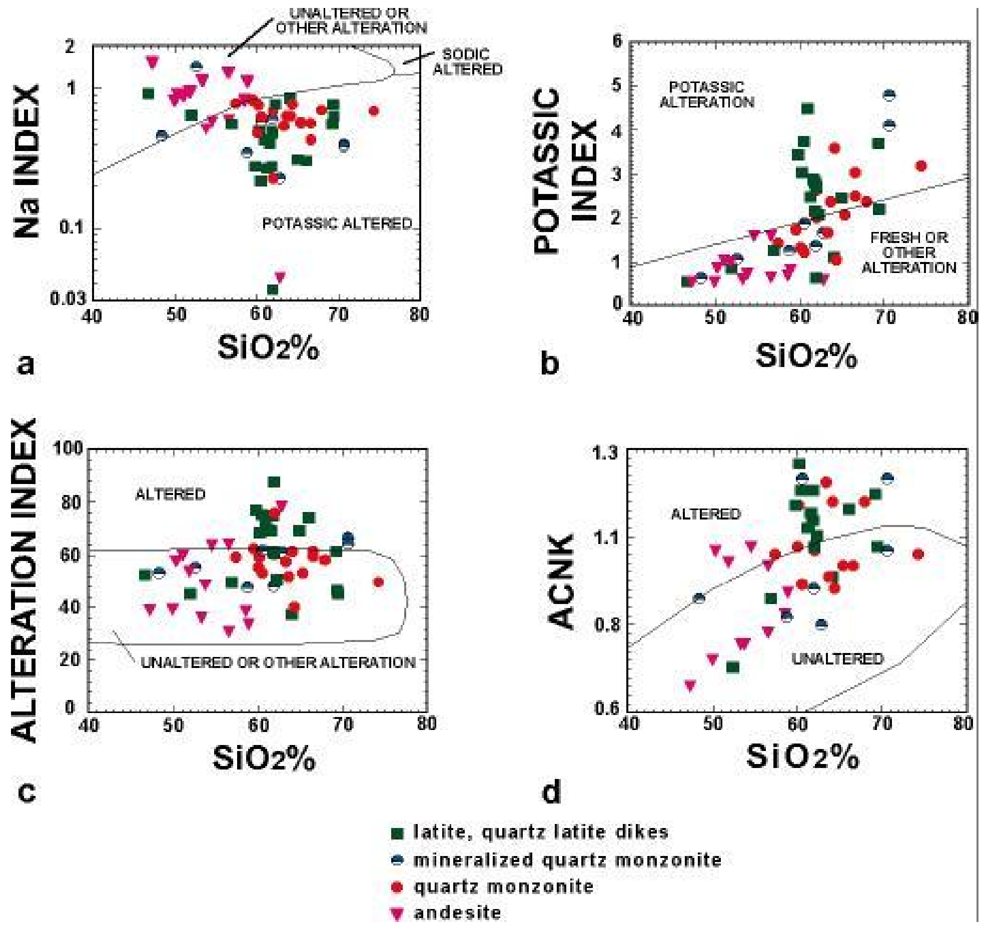
The Hillsboro district is dominated by Cretaceous andesite flows, breccias, and volcaniclastic rocks that were erupted from an andesite volcano. The Copper Flat quartz monzonite porphyry intruded the vent of the volcano. The unmineralized Warm Springs quartz monzonite and a third altered, unmineralized quartz monzonite intruded along fracture zones on the flanks of the volcano. Latite and quartz latite dikes intruded the andesite and Copper Flat porphyry and radiate outwards from the porphyry; the vein deposits are associated with these dikes.

AGE OF IGNEOUS ROCKS

The relatively high uncertainty of the ages does not permit resolution of individual intrusive events, but it appears that the andesite (HILL 5, 75.4±3.5 Ma), Copper Flat quartz monzonite (HILL 15, 19; 74.93±0.66 Ma), and Warm Springs quartz monzonite (HILL 11, 74.4±2.6 Ma) are all about 75 Ma. Since the quartz monzonite intruded the andesite, the andesite cannot be younger than 74.93±0.66 Ma.

CHEMISTRY OF IGNEOUS ROCKS

The igneous rocks are part of a differentiated comagmatic suite. The andesites are metaluminous and alkaline; the quartz monzonites and latites are metaluminous to peraluminous and alkaline to subalkaline.The samples exhibit varying degrees of alteration, as shown in the data scatter in various element plots. However, despite the alteration, the linear variation in Nb/Zr, Zr/TiO2, V/ TiO2, and various major elements suggests that the igneous rocks are comagmatic. The near linear trend in the Nb/Zr plot suggests that removal of Nb and Zr from the magma occurred as a result of crystallization of magnetite, sphene, and zircon. Pearce element plots of Na/Zr vs. Al/Zr and (K + Na)/Mg vs. Al/Mg (molar concentrations) indicate that differentiation can be explained by feldspar fractionation. These plots also indicate that the quartz latite dikes are closely related to the intrusion of the quartz monzonite porphyry.



TYPES OF MINERAL DEPOSITS

PORPHYRY COPPER DEPOSIT

- Consists of Cu, Au, Mo, and Ag disseminated in a quartz-monzonite stock and in thin quartz veins (Schilling, 1965; Dunn, 1982, 1984).
- Predominant minerals include pyrite, chalcopyrite, chalcocite, azurite, malachite, and cuprite. Minor amounts of molybdenite, galena, bornite, tetrahedrite, sphalerite, and fluorite are also present.
- Unlike the Santa Rita, Tyrone, and Morenci deposits, there is only a minor supergene enrichment zone at Copper Flat; Copper Flat is a low-grade hypogene deposit with a low pyrite content.

- Proven and probable reserves (December 31, 1997) of 56,549,000 tons of ore at an average grade of 0.432% Cu, 0.004 oz/ton Au, 0.064 oz/ton Ag and 0.014% Mo.
- Enriched in Cu and Mo and depleted in Ag, As, Pb, Zn, Ba, Bi, Mn, and V relative to the vein and replacement deposits (McLemore et al., 1999).

LARAMIDE (POLYMETALLIC) VEINS

- As much as 1,500 m long and 0.8-3 m wide
- Typically en echelon and pinch and swell.
- Consist of quartz, pyrite, clay, iron oxides, barite, malachite, chrysocolla, chalcopyrite, bornite, free gold, galena, and several additional sulfide minerals
- Enriched in Au, Ag, Cu, As, Bi, and depleted in Mo relative to the porphyry-copper and carbonate-hosted replacement deposits

CARBONATE-HOSTED REPLACEMENT DEPOSITS

- Small replacement pods of Ag-Mn and Pb-Zn, small Pb-Zn skarns, and veins in Paleozoic limestones and dolomites
- Typically Ag-Mn or Pb-Zn dominant
- Breccia fragments of jasperoid within the deposits indicate that an early deposition of jasperoid preceded metals deposition
- Enriched in Pb, Zn, Ba, V, and depleted in Au and Cu relative to the vein and porphyry-copper deposits

PLACER GOLD DEPOSITS

- The second most productive of all placer districts in New Mexico
- The best deposits were found in drainages and gulches radiating from the Copper Flat area
- Total production from placer deposits estimated as 120,000 oz Au and accounts for most of the gold production in the district
- Are found in four gravel units ranging in age from latest Miocene to Holocene
- Small and amenable to small-scale placer operations

SUMMARY OF FLUID INCLUSION DATA

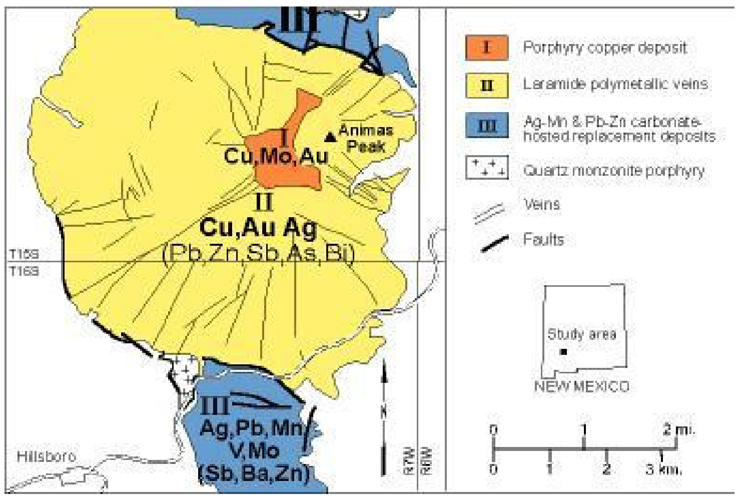
(Fowler, 1982; Norman et al., 1989)

- Homogenization temperatures averaged 320-360°C for majority of the inclusions within the porphyry copper breccia zone with salinities of 7-45 eq. wt.% NaCl.
- Formed at pressures of 127-166 bars at a depth of 1-2 km.
- Veins had higher homogenization temperatures of 226-388°C with salinities of 5.7-33.7 eq. wt% NaCl.
- The similarity in chemical composition of fluids from both the veins and breccia deposits indicate that a similar fluid source with different chemical depositional processes produced the ore deposits, not differences in fluid composition.

DISTRICT ZONING

Many workers in the district have recognized district zoning (Harley, 1934; Fowler, 1982; Hedlund, 1985; McLemore et al., 1999, 2000). The CFQM porphyry-copper deposit forms the center of mineralization and is characterized by Cu, Mo, and minor Au (McLemore et al., 1999) and depleted in Ag, As, Pb, Zn, Ba, Bi, Mn, and V. Trending outward radially from the CFQM are Laramide Au-Ag-Cu veins hosted by many of the latite and quartz latite dikes. The veins are variable in chemical composition, but consist predominantly of Cu, Au, and Ag with relatively high values of Pb, Zn, Sb, As, and Bi (McLemore et al., 1999, table 3). Carbonate-hosted replacement deposits are found in the southern and northern parts of the district, distal from the center and contain Ag, Pb, Mn, V, and Mo and relatively high values of Sb, Ba, and Zn (McLemore et al., 1999, table 3). They are lower in Au and Cu concentration relative to the CFQM and vein deposits. Placer gold deposits were formed by erosion of the Laramide polymetallic veins and occur in the drainages and alluvial fans emanating from the Laramide vein deposits.

- I—porphyry-copper deposit forms the center of mineralization (Cu, Mo, Au)
- II—propagating outward radially from the Copper Flat quartz monzonite are Laramide Au-Ag-Cu veins (Pb, Zn, Sb, As, and Bi) hosted by many of the latite and quartz latite dikes
- III—carbonate-hosted replacement deposits in the southern and northern parts of the district, distal from the center (Ag, Pb, Mn, V, Mo Sb, Ba, Zn)



ENVIRONMENTAL GEOLOGY

Munroe et al. (2000; Munroe, 1999) examined the mine waste piles in the Hillsboro district. Their work concluded that the minerals in the Laramide veins were more reactive relative to the carboanate-hosted replacement samples, probably because more pyrite is found in the veins. Pyrite is the predominant mineral that causes acid rock drainage. Munroe et al. (2000) also concluded that secondary oxidation rinds may "armor" sulfides (such as galena coated by angelsite) from further oxidation and release of metals into the environment. Acid rock drainage is found in some areas of the district, but the lack of intense rainfall minimizes the effect to ground and surface waters (Munroe, 1999).

Water in the Copper Flat pit varies from acidic to neutral; ground water is neutral to alkaline (Table 2). Chemical composition also varies (Table 2; U. S. Bureau of Land Management, 1996; Castellano et al., 1977; Munroe, 1999). Mining at Copper Flat was expected to have no or minimal adverse effects on water quality in the area.

TABLE 2. Range of chemical analyses of selected metals in water collected from the Copper Flat open-pit and ground water in the Hillsboro district, in mg/L (from U. S. Bureau of Land Management, 1996). 1 From National Research Council (1980).

ELEMENT	RANGE IN PIT WATER	RANGE IN GROUND WATER	TOLERABLE LEVELS FOR DOMESTIC LIVESTOCK1
pH	1.9-7.8	7.0-9.5	—
F	1.46-8.10	<0.3-4.77	40
Cu	<0.01-684	<0.01-3.21	25
Mn	<0.01-142	<0.02-4.90	400
Zn	<0.03-51	<0.01-2.41	300
Ni	<0.01-0.03	<0.01	50
Cd	<0.005-0.035	<0.005-0.030	0.5
Al	<0.01-2.0	<0.01-2.00	200
As	<0.004-.010	<0.005-0.010	—

CONCLUSIONS

- Geochemical and geochronological data indicate the igneous rocks are comagmatic and related to a Laramide andesite volcanic complex that formed at about 75 Ma.
- Collectively, the data indicates that the mineral deposits were formed by large, convective hydrothermal systems (depths of 1-2 km) related to the Copper Flat andesite volcanic complex and subsequent intrusion of the quartz monzonite and latite-quartz latite dikes.
- The Copper Flat porphyry copper deposit also exhibits very little supergene alteration and enrichment, in contrast to the extensive supergene alteration and enrichment found at Santa Rita and Tyrone.
- One possible explanation for this is that the Copper Flat deposit contains less than 2% pyrite and the more productive deposits contain higher concentrations of pyrite and more importantly, higher pyrite:chalcopyrite ratios than found at Copper Flat (Titley and Marozas, 1995).
- Another explanation for this difference is that the Copper Flat porphyry remained buried in the subsurface until uplift at about 21 Ma (Kelley and Chapin, 1997), whereas the Santa Rita and Tyrone deposits were exposed to multiple periods of surface erosion, alteration, and supergene enrichments. At Santa Rita and Tyrone, extensive erosion of the overlying andesite volcano and supergene enrichment of the porphyry-copper deposit occurred during the Eocene, prior to Oligocene volcanic activity.
- In contrast very little of the Copper Flat volcano eroded during the Eocene; much of the erosion occurred during after uplift at 21 Ma forming the alluvial deposits and placer gold deposits.
- Acid rock drainage is found in some areas of the district, but the lack of intense rainfall minimizes the effect to ground and surface waters.
- Secondary oxidation rinds may "armor" sulfides (such as galena coated by angelsite) from further oxidation and release of metals into the environment.

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