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Geology of the Copper Mountain Alkalic Porphyry Cu-Au Deposit

(excerpted, modified and augmented, with permission, from a preliminary draft of :

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Introduction

Mineral deposits within the Copper Mountain (Similkameen) mining camp are located 15 km south of Princeton, British Columbia and 180 km east of Vancouver (Lat. 49°20', Long. 120°31', N.T.S. 92 H/7E; Fig. 4). The Crows Nest Highway (# 3) provides access to the Ingerbelle Pit, the Ingerbelle East deposit and the concentrator complex on the west side of the camp (west of the Similkameen River). The remainder of the known deposits (Pit 1, Pit 2, Pit 3 and Virginia Pit) and other prospects (Duke of York, Honeysuckle, Oronoco, Alabama, Connector, June Bug, Oriole, Oriole Pits, Voigt, Pit 2 East, Pit 2 West and P4 zones) can be reached from Princeton via the Copper Mountain Road on the east side of the Similkameen River (Figs. 4 and 5). Elevations in the camp range from 1050 to 1300 m; the Similkameen River flows at 770 m elevation northward through a canyon that bisects the mining camp. Topography is moderate across higher altitudes but is rugged through the Similkameen River canyon. Climate is typical of intermontane environments at these elevations, with moderate snowfalls during the winter and cool summers. Precipitation occurs predominantly during the spring and fall. Vegetation consists of grasslands with interspersed ponderosa pine at lower altitudes grading up to dense forests of lodgepole pine, douglas fir and a variety of spruce at higher altitudes.

Exploration and Production History

Copper mineralization has been known to exist in the Copper Mountain area since 1884, but was not seriously prospected until 1892. Several unsuccessful attempts at exploration, development and production were carried out by various companies until 1923, when the Granby Consolidated Mining, Smelting and Power Company (Granby) acquired the property. During 1925-1930 and 1937-1957 (the underground era), Granby extracted 31,547,478 tonnes of ore containing 1.08 % copper (recovered grades of 0.882 % copper, 0.185 g/t gold and 4.322 g/t silver) from the vein orebodies on the east side of the Similkameen River (Table 1). Most of this ore came from glory-hole and underground stopes from an area that is now part of the Pit 3 deposit. However, 1,955,910 tonnes of 0.760 % copper came from several open pits in the Pit 1, Pit 2, Oriole and Oriole Pits areas, mined between 1952 and 1957. Ore was transported from an adit on the east wall of the Similkameen River canyon to the concentrator and smelter complex at Allenby (Fig. 4) via a rail line precariously cut into the side of the Similkameen River canyon. Tailings were dumped into an impoundment at the edge of the Similkameen River just inside the Princeton city limits. Additional information regarding this early exploration, staking, development and production activity is presented in Preto (1972) and Fahrni et al. (1976).

Modern exploration and development activity in the Copper Mountain camp began in 1966 (the open pit era), when Newmont Mining Corporation of Canada (Newmont) optioned a block of Granby claims west of the Similkameen River. Subsequent bulldozer trenching partially delineated a mineralized zone (the Ingerbelle deposit; Fig. 5) under shallow overburden and drilling results indicated sufficient reserves for production. During this time, Granby was delineating open pit reserves through drilling in the old Copper Mountain mine area on the east side of the river. In 1967, Newmont

Table 1 - Copper Mountain Mine Production History (data from T.N. Macauley, written communication; Similco Mines Ltd. internal company and annual reports; Newmont Mining Corp. of Canada annual repor

Year	Pit Mined	Tonnes Mined	Tonnes Milled	Stripping Ratio (Waste/Ore)	% Cu Heads	Production Cu tonnes	Production Au Troy oz	Production Ag Troy oz	Recovered Grade Cu (wt. %)	Recovered Grade Au (gpt)	Recovered Grade Ag (gpt)	Cu Recovery (%)	Cu/Au	Recovered Cu/Ag	Ag/Au
Underground Mining - Granby Consolidated Mining, Smelting and Power Company															
1925-1930; 1937-1957		-----	31,547,478	-----	-----	278,116	187,294	4,384,097	0.882	0.185	4.322	-----	47,741	2,040	23.41
Open Pit Mining - Newmont Mining Corporation of Canada and Similco Mines Ltd.															
1970	Ingerbelle	154,222	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
1971	Ingerbelle	14,808,901	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
1972	Ingerbelle	19,403,797	2,710,671	6.16	0.44	10,300	16,327	72,527	0.380	0.187	0.832	86.4	20,283	4,566	4.44
1973	Ingerbelle	19,250,302	4,859,613	2.96	0.45	18,688	28,100	130,800	0.385	0.180	0.837	85.5	21,382	4,593	4.65
1974	Ingerbelle	21,089,349	4,613,947	3.57	0.48	19,142	29,100	117,800	0.415	0.196	0.794	86.4	21,148	5,224	4.05
1975	Ingerbelle	14,414,275	3,694,061	2.90	0.46	14,787	21,400	86,400	0.400	0.180	0.727	87.0	22,216	5,502	4.04
1976	Ingerbelle	16,229,554	6,355,744	1.55	0.42	23,133	35,600	147,200	0.364	0.174	0.720	86.7	20,892	5,053	4.13
1977	Ingerbelle	14,801,644	7,135,924	1.07	0.37	22,952	35,200	140,000	0.322	0.153	0.610	86.9	20,963	5,271	3.98
1978	Ingerbelle	12,740,518	6,779,400	0.88	0.41	24,766	37,100	139,800	0.365	0.170	0.641	89.1	21,462	5,696	3.77
1979	Ingerbelle	9,903,748	6,899,148	0.44	0.43	26,490	38,100	138,800	0.384	0.172	0.626	89.3	22,353	6,136	3.64
1980	Combined	9,754,062	6,612,477	0.48	0.46	26,304	37,570	156,280	0.398	0.177	0.735	86.5	22,509	5,411	4.16
1980	Ingerbelle	7,664,813	6,508,151	0.18	0.46	25,999	37,331	154,800	0.399	0.178	0.740	86.8	22,391	5,400	4.15
1980	Pit 2	2,089,249	104,326	19.03	0.28	305	239	1,480	0.292	0.071	0.441	104.3	41,004	6,622	6.19
1981	Combined	12,137,239	6,868,304	0.77	0.40	23,147	26,931	145,560	0.337	0.122	0.659	84.3	27,633	5,113	5.40
1981	Ingerbelle	3,890,920	3,561,612	0.09	0.41	12,445	17,288	73,400	0.349	0.151	0.641	85.2	23,144	5,451	4.25
1981	Pit 2	8,246,319	3,306,692	1.49	0.38	10,702	9,643	72,160	0.324	0.091	0.679	85.2	35,681	4,768	7.48
1982	Pit 2	13,027,188	6,704,103	0.94	0.38	22,098	20,048	173,086	0.330	0.093	0.803	86.7	35,438	4,105	8.63
1983	Combined	12,596,275	6,850,160	0.84	0.36	21,577	19,709	182,872	0.315	0.089	0.830	87.5	35,198	3,793	9.28
1983	Pit 2	10,820,005	6,607,034	0.64	0.36	20,878	19,228	167,466	0.316	0.091	0.788	87.8	34,909	4,008	8.71
1983	Pit 3	1,776,270	243,126	6.31	0.36	699	481	15,406	0.288	0.062	1.971	79.9	46,751	1,460	32.03
1984	Combined	12,634,377	6,516,316	0.94	0.39	21,678	15,927	206,898	0.333	0.076	0.988	85.3	43,760	3,369	12.99
1984	Pit 2	7,440,738	5,052,118	0.47	0.39	16,870	14,140	119,972	0.334	0.087	0.739	85.6	38,358	4,521	8.48
1984	Pit 3	5,193,639	1,464,198	2.55	0.40	4,808	1,787	86,926	0.328	0.038	1.847	82.1	86,504	1,778	48.64
1985	Combined	13,078,898	6,881,004	0.90	0.42	23,903	17,352	266,666	0.347	0.078	1.205	82.7	44,268	2,882	15.37
1985	Pit 2	5,789,660	4,555,887	0.27	0.42	16,417	13,057	110,986	0.360	0.089	0.758	85.8	40,425	4,756	8.50
1985	Pit 3	7,289,238	2,325,117	2.13	0.42	7,485	4,295	155,680	0.322	0.057	2.083	76.6	56,031	1,546	36.25
1986	Combined	15,841,279	6,876,469	1.30	0.43	23,665	13,493	386,019	0.344	0.061	1.746	80.0	56,387	1,971	28.61
1986	Pit 2	479,901	351,988	0.36	0.37	1,097	970	8,342	0.312	0.086	0.737	84.2	36,353	4,227	8.60
1986	Pit 3	15,361,377	6,524,480	1.35	0.44	22,568	12,523	377,677	0.346	0.060	1.800	78.6	57,939	1,921	30.16
1987	Pit 3	17,701,010	6,974,535	1.54	0.44	23,804	14,425	397,157	0.341	0.064	1.771	77.6	53,054	1,927	27.53
1988	Combined	18,060,255	7,189,448	1.51	0.48	27,196	16,864	407,863	0.378	0.073	1.765	78.8	51,847	2,144	24.19
1988	Pit 3	18,004,010	7,189,448	1.50	0.48	27,196	16,864	407,863	0.378	0.073	1.765	78.8	51,847	2,144	24.19
1988	Pit 1	56,246	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
1989	Combined	22,422,005	7,508,777	1.99	0.46	26,045	17,277	432,220	0.347	0.072	1.790	75.4	48,467	1,937	25.02
1989	Pit 3	13,813,718	5,381,426	1.57	0.47	20,142	13,532	341,296	0.374	0.078	1.973	79.6	47,856	1,897	25.22
1989	Pit 1	8,608,286	2,127,351	3.05	0.42	5,903	3,745	90,924	0.277	0.055	1.329	66.1	50,677	2,067	24.28
1990	Combined	21,519,355	6,750,370	2.19	0.50	25,590	13,617	317,186	0.379	0.063	1.462	75.8	60,419	2,594	23.29
1990	Pit 3	10,656,712	2,706,135	2.94	0.51	10,828	7,145	181,085	0.400	0.082	2.081	78.5	48,724	1,922	25.34
1990	Pit 1	10,862,643	4,044,234	1.69	0.50	14,762	6,472	136,101	0.365	0.050	1.047	73.0	73,331	3,487	21.03
1991	Combined	8,049,460	3,851,004	1.09	0.48	14,486	7,617	183,354	0.376	0.062	1.481	78.4	61,143	2,540	24.07
1991	Pit 3	2,097,414	1,192,949	0.76	0.55	5,145	3,385	91,871	0.431	0.088	2.395	78.4	48,863	1,800	27.14
1991	Pit 1	5,561,049	2,598,180	1.14	0.45	9,205	4,033	90,613	0.354	0.048	1.085	78.7	73,383	3,266	22.47
1991	Virginia	390,997	59,874	5.53	0.30	136	199	870	0.227	0.103	0.452	75.8	21,985	5,029	4.37
1992	Combined	14,133,048	7,367,256	0.92	0.45	25,704	18,655	308,261	0.349	0.079	1.301	77.5	44,299	2,681	16.52
1992	Pit 3	4,122,252	1,353,521	2.05	0.40	4,381	3,276	87,768	0.324	0.075	2.017	80.9	42,993	1,605	26.79
1992	Pit 1	8,269,906	4,854,351	0.70	0.51	19,160	9,519	211,635	0.395	0.061	1.356	77.4	64,712	2,911	22.23
1992	Virginia	1,740,890	655,895	1.65	0.30	1,205	4,778	2,162	0.184	0.227	0.103	61.2	8,107	17,915	0.45
1992	Pit 2 Stockpile	0	503,488	0.00	0.22	959	1,082	6,696	0.190	0.067	0.414	86.6	28,493	4,604	6.19
1993	Combined	11,312,260	6,120,892	0.85	0.45	21,394	14,202	370,711	0.350	0.072	1.884	77.5	48,432	1,855	26.10
1993	Pit 3	8,819,438	4,858,132	0.82	0.49	18,965	11,880	354,385	0.390	0.076	2.269	80.2	51,324	1,721	29.83
1993	Pit 1	26,006	16,707	0.56	0.51	66	24	805	0.396	0.045	1.499	78.0	88,715	2,645	33.54
1993	Virginia	2,466,815	988,107	1.50	0.33	1,801	1,527	11,951	0.182	0.048	0.376	56.1	37,914	4,844	7.83
1993	Ingerbelle Stockpile	0	257,946	0.00	0.25	562	771	3,580	0.218	0.093	0.432	86.9	23,454	5,051	4.64
Underground		-----	31,547,478	-----	-----	278,116	187,294	4,384,097	0.882	0.185	4.322	-----	47,741	2,040	23.41
Ingerbelle		154,352,043	53,376,216	1.89	0.427	199,264	295,546	1,201,527	0.373	0.173	0.702	87.38	21,620	5,316	4.07
Pit 1		33,384,136	13,640,823	1.45	0.482	49,096	23,793	530,078	0.360	0.054	1.209	74.74	66,341	2,978	22.28
Pit 2		47,893,061	27,185,637	0.76	0.382	89,326	78,407	660,188	0.329	0.090	0.755	86.01	36,628	4,350	8.42
Pit 3		104,835,078	40,213,068	1.61	0.460	146,021	89,593	2,497,114	0.363	0.069	1.931	78.87	52,399	1,880	27.87
Virginia		4,598,702	1,703,876	1.70	0.314	3,142	6,504	14,983	0.184	0.119	0.274	58.63	15,529	6,741	2.30
Open Pit Total		345,063,019	136,119,622	1.53	0.432	486,849	493,843	4,903,890	0.358	0.113	1.121	82.79	31,646	3,190	9.92
Newmont		257,091,744	100,327,479	1.56	0.419	357,765	413,409	3,057,808	0.357	0.141	1.045	85.09	25,241	3,412	7.40
Similco		87,971,276	35,792,143	1.46	0.468	129,084	81,205	1,849,652	0.361	0.078	1.772	76.99	46,363	2,035	22.78
Camp Total		-----	167,667,100	-----	-----	764,964	681,137	9,287,987	0.456	0.127	1.724	-----	36,066	2,647	13.63

Notes :

1970 - Overburden stripping of Ingerbelle Pit commenced in December
1972 - Commenced mining Ingerbelle Pit in April; mill capacity = 13,608 tonnes per day
1975 - Labour strike = 65 Days
1976 - Mill expanded to 19,958 tonnes per day; Cutoff grade was lowered from 0.30 to 0.20 in February
1980 - Overburden stripping of Pits 1, 2 and 3; Commenced mining Pit 2 in February
1981 - Ingerbelle Pit completed in September
1983 - Commenced mining Pit 3 in May
1985 - Pit 2 completed in February
1988 - Mine sold to Similco Mines Ltd. in June
1989 - Commenced mining Pit 1 in August
1991 - Commenced mining Virginia Pit in May; Labour strike = 135 Days
Commenced milling low grade Pit 2 stockpile in December
1992 - Pit 1 completed in December
1993 - Commenced milling Ingerbelle stockpile in February;
Mine closed and placed on standby in November

Tonnes mined in 1970 and 1971 represents overburden stripping of Ingerbelle Pit.
18,180 of tonnes mined in 1980 from Pit 2 represents overburden stripping of Pits 1, 2 and 3 on east side of Similkameen River
Individual company production statistics for 1988 have been pro-rated by month (5/12 for Newmont; 7/12 for Similco)

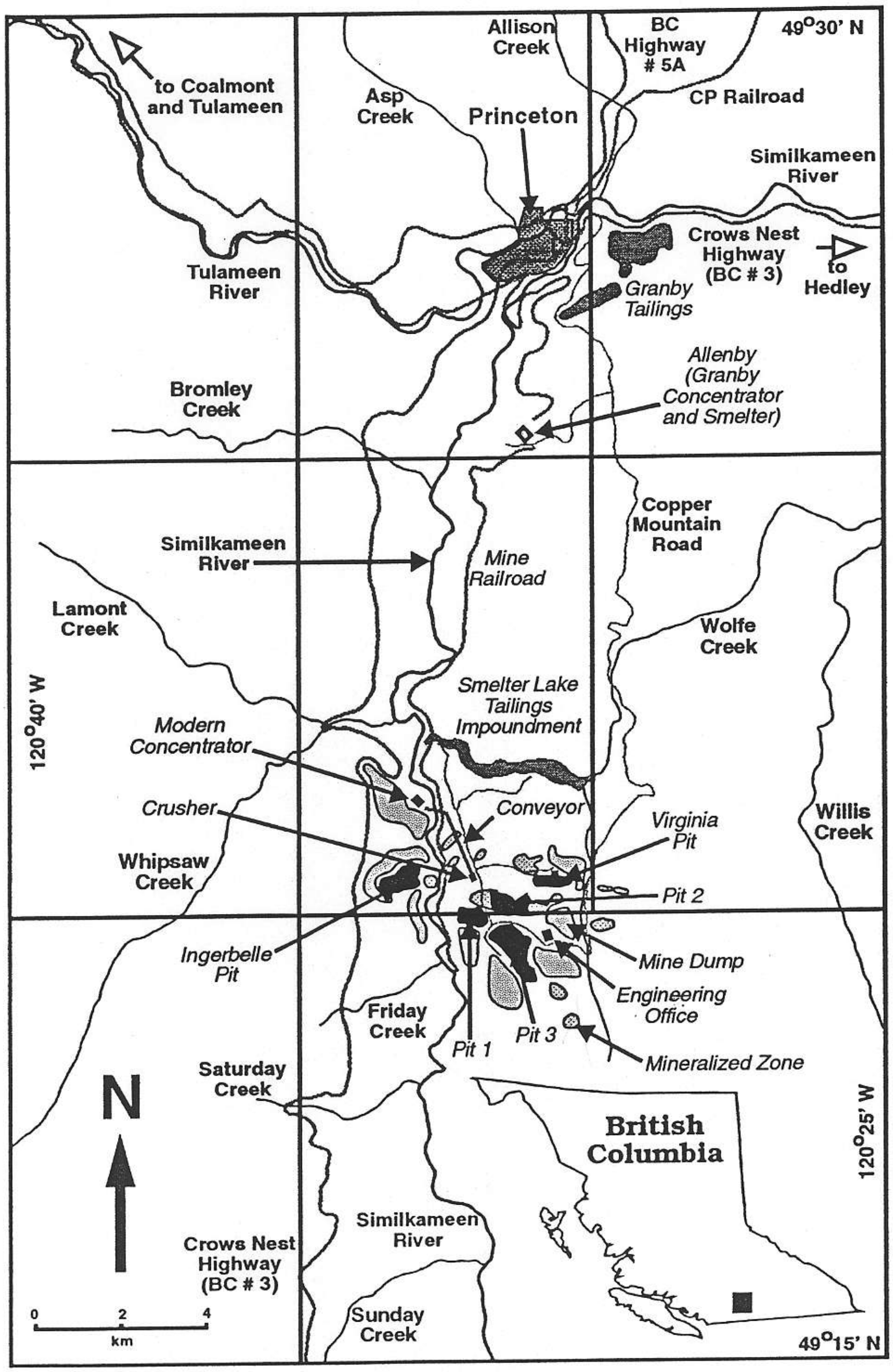

Figure 4 - Copper Mountain (Similkameen) mining camp, southern British Columbia.

ultimate pit

Ingerbelle phase 2 new pit (at river level)

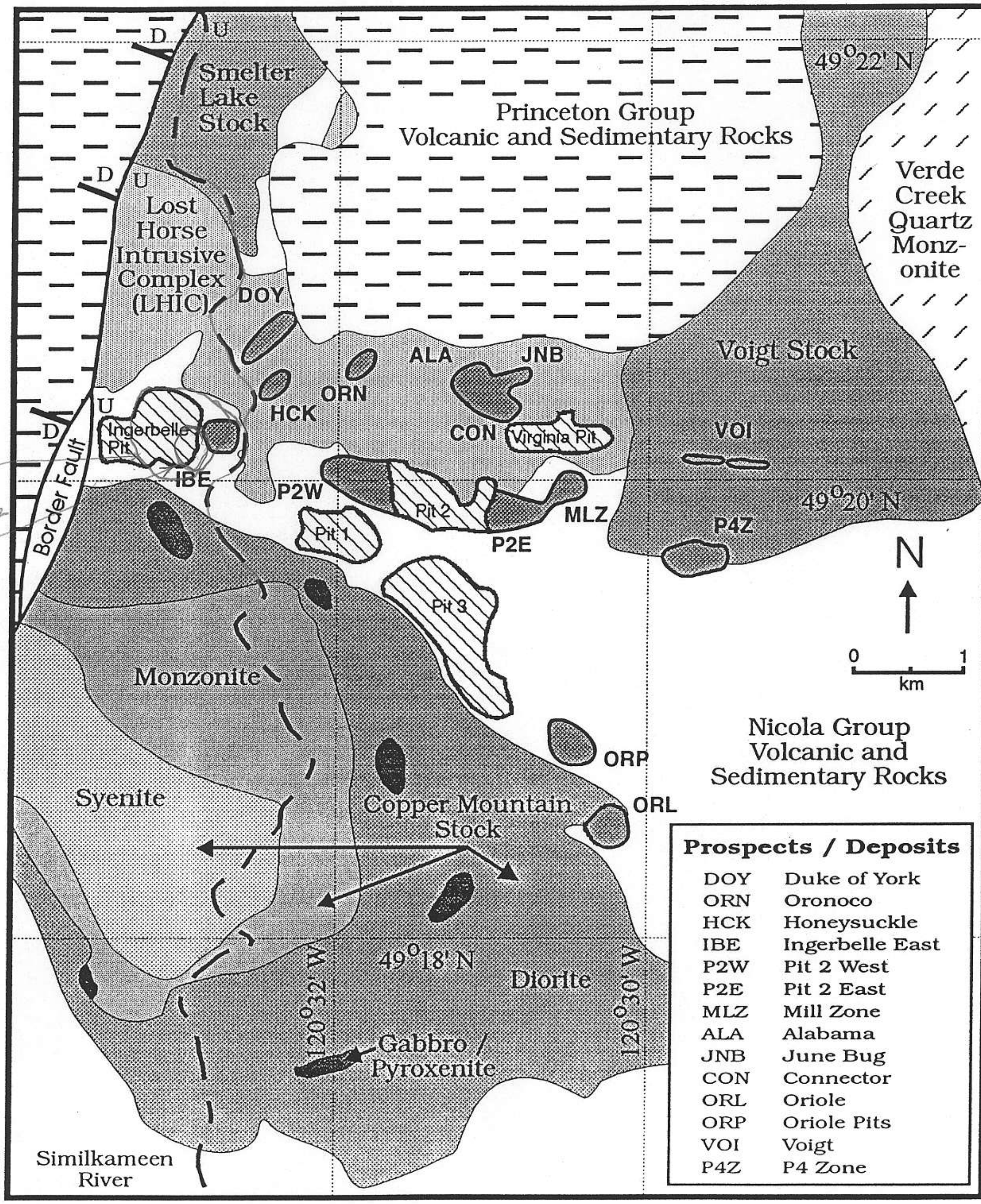

Figure 5 - Generalized geology map of the Copper Mountain alkalic copper-gold camp, Princeton, British Columbia (simplified from Preto, 1972).

purchased Granby's entire mining interest in the district, including a much needed tailings impoundment location (Smelter Lake; Fig. 4) for US $ 800,000 (CDN $ 824,000), plus 40,000 shares of Newmont (at US $ 4 per share). By exercising options on claims west of the river, Newmont consolidated the known orebodies in the district into its wholly owned subsidiary, Similkameen Mining Company (Similkameen). Geophysical surveys, trenching and drilling were continued by Similkameen for another two years before open pit production plans for the Ingerbelle deposit were finalized in 1969 (Fahrni et al. 1976). Capital costs were US $ 73,000,000 (CDN $ 76,212,000). All subsequent mining at Copper Mountain was by open pit methods.

Stripping of the Ingerbelle deposit commenced in December 1970 and mining began in April 1972. In February 1976, the cut-off ore grade was reduced from 0.30 % to 0.20 % copper and the mill capacity was expanded, at a cost of US $ 6,000,000 (CDN $ 6,102,000) from 13,608 tonnes per day to 19,958 tonnes per day to accommodate the resulting increase in ore extraction rate. In 1979, a primary crusher and conveyor were installed, at a cost of CDN $ 23,400,000, on the east side of the Similkameen River (Fig. 4) to allow mining of the additional reserves located there. In February 1980, mining of Pit 2, on the east side of the river, commenced. The Ingerbelle Pit was completed in September 1981 and in May 1983 production from Pit 3, also on the east side of the river, commenced. Pit 2 was completed in February 1985.

The entire Copper Mountain property was sold by Newmont to Cassiar Mining Corporation (Cassiar) in June 1988 for US $ 10,000,000 (CDN $ 12,310,000) in an effort to reduce debt incurred through a US $ 33 per share Newmont dividend to shareholders (the Newmont share price at the time was US $ 54.75 per share) in a successful effort to counter a hostile takeover bid of Newmont Mining Corporation by Ivanhoe Partners, a junk bond syndicate headed by T. Boone Pickens. Cassiar later became Princeton Mining Corporation and has controlled and mined the property as Similco Mines Ltd. (Similco) since that time.

Open pit production from Pit 1 and the Virginia Pit, both on the east side of the river, commenced in August 1989 and May 1991, respectively. In December 1991, milling of a low grade stockpile, largely from Pit 2, on the east side of the river commenced, and in December 1992, Pit 1 was completed. Finally, in February 1993, milling of the low grade Ingerbelle stockpile on the west side of the river was initiated.

In November 1993, due to low metal prices, low grade reserves and high stripping ratios, the Copper Mountain mine and mill complex ceased production and were placed on stand-by. Exploration by Similco continues across the property, and has recently focused on : i) the Alabama zone (on the Alabama, June Bug and Diamond Dot claims), where drilling on 400 ft sections has added significant tonnes to the camp's mineable reserve, and ii) the Ingerbelle East Zone, where known mineralization is currently being assessed further. Additional mineralized zones within the camp have significant potential for ore, including the Oriole zone.

A detailed production history of open pit mining operations at Copper Mountain is presented in Table 1. These data allow calculation of a camp wide open pit stripping ratio (waste/ore) of 1.53. The individual grade and tonnes production data from each pit allow calculation of the mean open pit recovered grades of 0.358 % copper, 0.113 g/t gold and 1.121 g/t silver.

Gold and silver recoveries in the concentrate are not precisely known because they are not routinely analyzed in the heads. However, historic check assays of gold and silver in the heads and tails, along with the generally high gold and silver grades in the copper concentrate, have indicated that recoveries are similar to that of copper (approximately 80 % for each). Exploration drill core and production blast hole assays exhibit a strong correlation between copper and gold in the Ingerbelle Pit (Fig. 6A), and between copper and gold, and copper and silver in the Virginia zone (Figs. 6B and 6C),

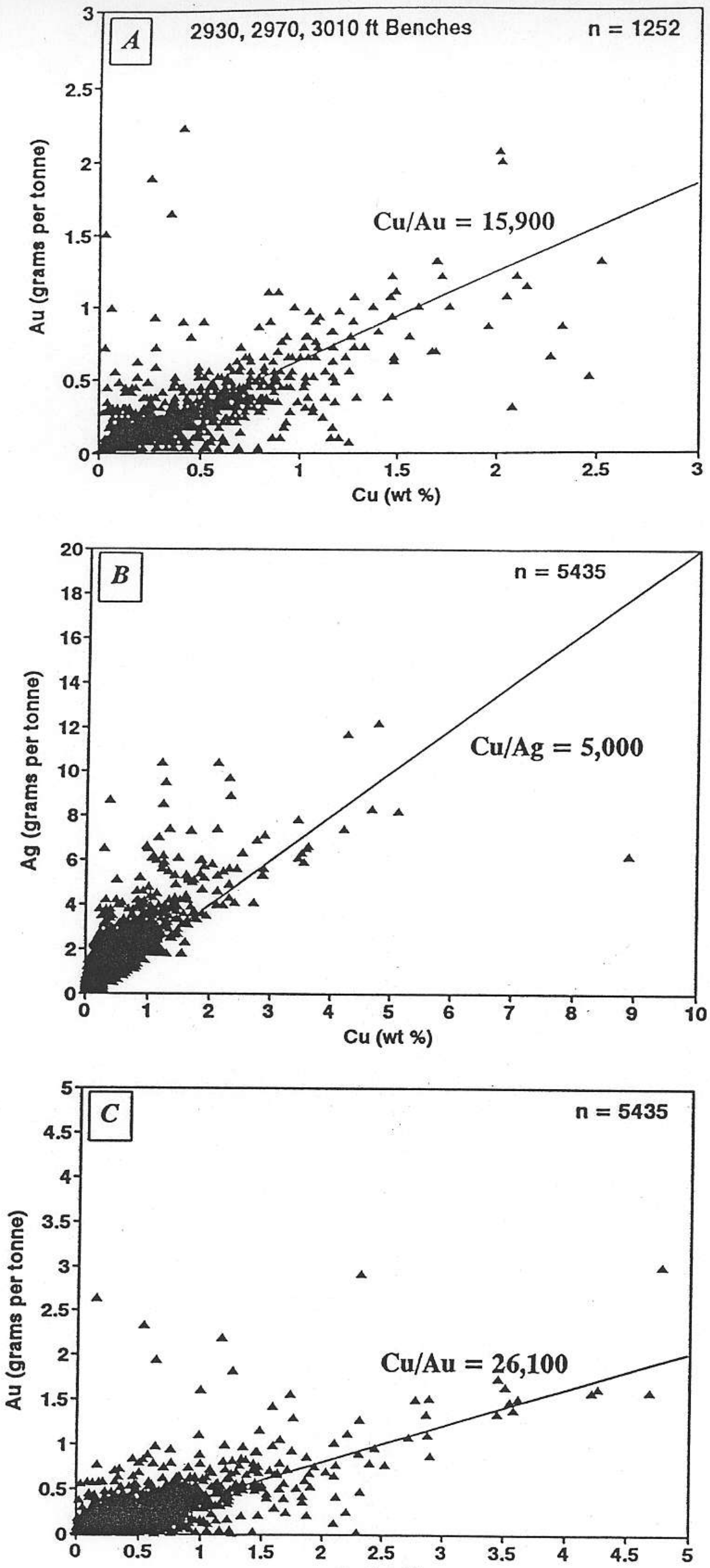

Figure 6 - Scatterplots of : (A) production blast hole copper and gold assays from the 2930, 2970 and 3010 ft benches in the Ingerbelle Pit, (B) copper and silver assays from exploration drill core samples through the Virginia Zone, and (C) copper and gold assay from exploration drill core samples through the Virginia Zone. The sloped lines have been visually fit through the modal ratio of the data.

suggesting a strong mineralogical association for these elements (Stanley, 1992). Approximately 83 % of the revenue from open pit mining came from copper, with the remaining revenue from by-product gold and silver, paid as credits to the copper concentrate (T. Macauley, written communication).

Reserves

Ore reserves for the camp, as of January 1, 1994, can be divided into 'stockpile', 'low stripping ratio', 'high stripping ratio' and 'geological' categories. These are summarized in Table 2. Low grade stockpile reserves total 9.404 million tonnes of 0.270 % copper, 0.227 g/t gold and 2.209 g/t silver, whereas low stripping ratio reserves total 1.578 million tonnes of 0.426 % copper, 0.178 g/t gold and 3.084 g/t silver with a bulk stripping ratio of 1.20, and high stripping ratio reserves total 82.933 million tonnes grading 0.413 % copper, 0.111 g/t gold and 3.798 g/t silver with a bulk stripping ratio of 2.26. Geological reserves from the Alabama and Ingerbelle East zones total 38.737 million tonnes grading 0.331 % copper.

Table 2 - Summary of Mined, Mineable and Geological Reserves in the Copper Mountain Camp (Aug. 1, 1994).

Deposit	**Tonnes ($\times 10^6$)**	**Cu (%)**	**Au (g/t)**	**Ag (g/t)**	**Stripping Ratio**
Low Grade Stockpile Reserves					
Stockpiles	9.404	0.270	0.227	2.209	-----
Low Stripping Ratio Mineable Reserves					
Pit 3 - Phase 1	0.272	0.455	0.097	5.100	0.41
Virginia Pit	1.305	0.420	0.195	2.664	1.37
High Stripping Ratio Mineable Reserves					
Pit 3 - Phase 2 ('L' Cut)	9.553	0.462	0.097	5.100	1.91
Pit 3 - Phase 3 ('Q' Cut)	38.000	0.479	0.097	5.100	2.60
Pit 2 - Extension	35.380	0.330	0.130	2.047	1.78
Geological Reserves					
Alabama	19.595	0.312	0.160		~ 0.80
Ingerbelle East	19.142	0.350			~ 1.66

(Note : reserves for these deposits were originally calculated in English units, but have been converted to metric units for the purposes of this report; significant digits have been retained to allow re-calculation back to the original English units.)

Local Geology

The Copper Mountain alkalic porphyry copper-gold camp occurs in the eastern volcanic belt of the Nicola Group (Monger, 1989b). Within the camp, Nicola Group rocks include, massive and rarely pillowed mafic and intermediate flows and flow breccia, coarse volcanic breccia with rounded clasts (agglomerate), sometimes containing characteristic 'stubby' hornblende-phyric monzodiorite clasts, felsic and intermediate water-lain tuff and tuff breccia, and volcanic siltstone, sandstone and conglomerate, and minor limestone (Dolmage, 1934; Preto, 1972, 1979). These are exposed in a northwesterly-oriented belt 1100 m wide by 4300 m long (Fig. 5). Bedded units exhibit easterly to southeasterly strikes and dips are generally steep (all greater than 45° in both northeast or southwest directions; Preto, 1972). Compositions of the volcanic rocks range from basalt to rhyolite, but are predominantly andesitic (Preto, 1972).

Four predominant rock types are observed in the open pits. These consist of (in decreasing order of abundance) :

1.) coarse agglomerates that are poorly sorted. Both matrix- and clast-supported varieties occur. The matrix of this fragmental is andesitic and its clasts consist of subrounded andesite, a characteristic 'stubby' hornblende-phyric monzodiorite with aligned phenocrysts and rare black mudstone. This unit occurs within the Ingerbelle and Virginia Pits, as well as Pits 1, 2 and 3;

2.) fine-grained, aphyric to sparsely plagioclase-porphyritic andesite flows of dark green to black colour. The plagioclase phenocrysts are normally zoned and the unit is observed in all open pits;

3.) thinly bedded, felsic tuffaceous epiclastic sedimentary rocks, which consist of cherty and reworked, fine-grained (ash) tuffs of light grey, pale blue, buff, tan and banded green and black colours. These typically fracture readily without preferred orientation and is also observed in all open pits; and

4.) clast supported slump breccia with a medium grey mudstone matrix and clasts of felsic tuffaceous epiclastic sedimentary rocks (above). These occur only within Pit 2 and the Virginia Pit.

The volcanic and sedimentary facies of these rocks indicates that the depositional environment for the Nicola Group in the Copper Mountain area was probably tectonically active, shallow and subaqueous, possibly on the margin of an emergent or submergent island arc volcano. These Nicola Group rocks are bounded on the north and south by several intrusive bodies of Jurassic age and are cut by later, steeply dipping, north-trending dikes.

Copper Mountain Intrusions

Jurassic intrusions in the Copper Mountain camp have a silica-saturated alkalic affinity (Lang et al., 1992, in press). As such, they contain neither primary igneous quartz nor feldspathoid minerals and exhibit a typical equigranular-to-porphyritic texture. These intrusions consist of two general types.

The first type is diorite-to-monzonite and syenite of the Copper Mountain, Voigt and Smelter Lake stocks (Montgomery, 1968). The Copper Mountain stock bounds the belt of Nicola Group rocks on the south and is concentrically zoned (Fig. 5). The outer margin of the stock is flow-foliated and dominated by equigranular-to-subporphyritic, medium-grained diorite-to-monzodiorite composed of subequal amounts of augite and plagioclase, lesser poikilitic biotite, magnetite, poikilitic potassium feldspar and apatite, and accessory zircon and titanite (Montgomery, 1968). In places, this border phase hosts medium-to-coarse grained monzodiorite dikes that contain up to 10 % quartz (Lang, 1993). It also hosts several small bodies of gabbro and pyroxenite (Montgomery, 1968; Preto, 1972; Fahrni et al., 1976). The border phase grades inward to an intermediate phase of monzonite that differs from the margin primarily by its higher plagioclase/augite ratio, higher concentrations of potassium feldspar, the presence of hornblende rims on augite, greater concentrations of apatite and titanite, and a coarser grain size (Lang, 1993). Approximately 2/3 of the way laterally into the intrusion, this intermediate phase yields abruptly to a core of non-magnetic, pegmatoidally-textured, leucocratic perthitic syenite. This contact is interpreted as a normal consequence of *in situ* fractionation processes, rather than evidence of multiple intrusion (Montgomery, 1968). This is because of : i) the symmetry of the zoning of intrusive units within the intrusion, ii) the symmetry and pattern of magnetic, electromagnetic and radiometric geophysical signatures within the intrusion, and iii) the lack of chilled margins and other cross-cutting relationships along this contact. The Copper Mountain stock is not known to host significant mineralization, but does contain minor zones of alteration with traces of sulfide minerals in its syenite core.

The Voigt and Smelter Lake stocks occur north of the belt of Nicola Group rocks (Fig. 5). They are smaller in plan than the Copper Mountain stock and do not exhibit any discernible concentric zonation, bnt are petrologically similar both to each other and to the marginal monzodiorite phase of the Copper Mountain stock (Montgomery, 1968). These bodies are equigranular to weakly subporphyritic, fine- to medium-grained monzodiorites that contain subequal amounts of augite and plagioclase, lesser poikilitic potassium feldspar, shreddy-to-poikilitic biotite that is commonly chloritized, magnetite and local accessory titanite and zircon (Lang, 1993). Minor hornblende also occurs in the Voigt Stock, which in places takes on a more evolved monzonite composition. In the Smelter Lake stock, augite is significantly coarser than plagioclase. Both stocks have been locally subjected to minor amounts of potassium feldspar alteration and traces of disseminated pyrite, but are not known to host significant copper-gold mineralization.

In the Copper Mountain, Voigt and Smelter Lake stocks, augite is generally euhedral and is thus interpreted to be the first major phase to crystallize within these melts. All three of these intrusions are interpreted to be pre-mineral, locally hosting minor copper mineralization.

Lost Horse Intrusive Complex

To the north of the belt of Nicola Group rocks lies the Lost Horse intrusive complex (LHIC), a multi-phase suite of diorite-to-monzonite and minor syenite intrusions consisting predominantly of dikes and less common intrusive plugs, sills and other irregular intrusions (Preto, 1972). These intrude Nicola Group rocks (Fig. 5), but are interpreted to have been emplaced after the Copper Mountain, Smelter Lake and Voigt stocks because : i) clasts from these stocks are recognizable in LHIC intrusions, and ii) a small LHIC dike intrudes the Smelter Lake stock (Montgomery, 1968; Preto, 1972). In places within the complex, these dikes comprise only one third of the rock volume, the other two thirds consisting of Nicola Group rocks. On the whole, petrographic variation among these intrusions is great, and a number of petrographically, texturally and chronologically distinct phases can be identified (Preto, 1972). However, three main intrusive types comprise the majority of the dikes within the complex (LH1g, LH1b and LH2). Most of these occur as steeply dipping dikes (Preto, 1972; Stanley and Lang, 1993; Lang, 1993).

Intrusions that were emplaced prior to main-stage alteration and mineralization include the LH1g and LH1b subtypes. The LH1g dikes comprise the oldest phase of the complex. They are diorites and have a mineral assemblage similar to the Copper Mountain, Smelter Lake and Voigt stock monzodiorites described above, but lack the poikilitic potassium feldspar and biotite textures of these earlier units. The LH1b dikes comprise a younger monzodiorite, but are fine-grained and strongly porphyritic, with phenocrysts of biotite, apatite, plagioclase, augite, and variable amounts of hornblende. The LH2 dikes are the youngest intrusions and have an overall monzonite composition (Stanley and Lang, 1993; Lang, 1993). They are notable for their significant concentrations of accessory titanite, and relatively coarse plagioclase phenocrysts, which in some LH2 dikes have a characteristic hiatal (bimodal) or seriate (continuous) size distribution.

The LHIC intrusions vary in other ways. Specifically, the predominant orientations of the different dike types vary. LH1g and LH1b dikes strike predominantly easterly and northeasterly, whereas LH2 dikes strike northeasterly and northerly. In addition, the locus of intrusion of these dikes appears to have changed over time, with LH1g and LH1b dikes being more prevalent on the east side of the complex (on the east side of the river) and LH2 dikes being more prevalent on the west side of the complex (in the Similkameen River canyon and on the west side of the river).

However, regardless of the type of LHIC intrusion, both plagioclase and clinopyroxene are consistently euhedral and thus are interpreted to be the first major minerals to crystallize in the Lost Horse intrusions. Furthermore, all types of the

LHIC intrusions exhibit a close spatial relationship with mineralization. LH1g intrusions are typically pre-mineral; LH1b intrusions are pre-and near syn-mineral; LH2 intrusions are clearly syn- to post-mineral and are most closely associated with mineralization.

Other Intrusions

Predominantly within the eastern part of the Copper Mountain camp, post-mineral intrusions occur as steeply dipping, north-trending dikes of probable Eocene age. Both massive, aphyric mafic and flow-banded, quartz- and hornblende-phyric felsic dikes occur, and these fed the Princeton Group volcanic rocks that, along with associated sedimentary rocks, filled extensional grabens during Eocene time (Monger et al., 1992). These volcanic and sedimentary rocks consist of rhyolite flow, dome and tuff complexes, basalt and 'needle' hornblende dacite flows underlying and sometimes interbedded with immature sandstones, siltstones and coal deposits. They are in fault and unconformity contact with and cover the north edge of the LHIC.

Finally, to the northeast of the camp is a large equant stock of calc-alkalic Verde Creek quartz monzonite / granodiorite of Cretaceous age that cuts the Voigt stock.

The west side of the Copper Mountain camp is bounded by the Border Fault, a moderate-to-steeply west dipping, north-trending normal fault that, with a number of splays, juxtaposes Eocene Princeton Group sedimentary and volcanic rocks on the west against Late Triassic Nicola Group volcanic rocks and Early Jurassic intrusions on the east. This fault is one of several north- and northwest-trending faults that extend through the central and eastern volcanic facies of Quesnellia and that appear to have controlled the locus of numerous smaller diorite, monzonite and syenite intrusions during the Jurassic (Preto, 1977, 1979; Monger, 1989b). It was probably active both during intrusion and mineralization in the Copper Mountain camp, and afterward, (during Jurassic obduction of Quesnellia onto the North American cratonic margin (Ghosh, submitted) and during subsequent Eocene extension) because it truncates the Copper Mountain stock and mineralization in the Ingerbelle zone.

Rocks in the Copper Mountain camp exhibit little evidence of metamorphism. With the exception of albite-epidote hornfels in contact aureoles about the intrusions, rocks exhibit zeolite, prehnite-pumpellyite, and lower greenschist grades of metamorphism (Preto, 1972; Lefebure, 1976). In the contact aureoles at Copper Mountain, diopside- or biotite-plagioclase-magnetite hornfels facies predominate (Preto, 1972).

Hypogene Alteration

Hypogene alteration in the Copper Mountain camp consists of both (selectively) pervasive and structurally controlled styles (as defined by Titley, 1983). Some of these are described below in approximate chronological order; all are summarized in Tables 3, 4 and 5.

The earliest alteration assemblages have, in general, a pervasive style that is not recognizably controlled by specific structures. Where incipient or weak, this alteration is truly selectively pervasive; where strong, this alteration totally replaces the protolith and is texturally destructive. Structurally controlled alteration dominates later stages of the paragenesis. It is associated with veins ranging from fractures lacking any filling mineral assemblage, through veinlets and veins with small amounts of vein fill and envelopes of variable width, to large dilatant veins with very wide, multiple envelopes. This change in alteration style from pervasive to structurally controlled through time may reflect the evolution of

Table 3 - Summary of Alteration Styles at Copper Mountain

Alteration Type	Structural Style ; Spatial Association	Vein Fill	Selvage; *Envelope(s)*	Width (Vein ; Envelope)
Biotite Hornfels	*Pervasive ; Adjacent to Copper Mountain Stock, LHIC Dikes & Felsic Dikes*	----	---- ; BT+MT+PL±(PY) or DI+MT+PL±(PY)	---- ; 20 - 100 m
Pervasive Propylitic	*Pervasive ; Occur Across Camp But Most Abundant in Distal Parts of Camp*	----	---- ; CH+ACT+EP+CC+AB+ (PY)+(HM)	---- ; 2 - 10 m
Pervasive Sodic	*Pervasive ; Within & Adjacent to LHIC Dikes*	----	---- ;AB+EP+(CH)+(CC)±DI	---- ; 2 - 50 m
Pervasive Potassics	*Pervasive ; Within & Adjacent to LHIC Dikes*	----	---- ; KS+BT+MT+EP±CH	---- ; 2 - 50 m
Pervasive Argillic	*Pervasive ; Restricted to Sodic Alteration Zones*	----	---- ; KA+SE+PY+ (QZ)+(CH)+(EP)	---- ; 2 - 50 m
Pervasive SCC	*Pervasive ; Occurs Loacally Across Camp*	----	---- ; SE+CH+CY+CC	---- ; 2 - 10 m
AB Vein Envelopes	*Empty Fractures ; Occur at Margins of Pervasive Sodic Alteration Zones*	----	---- ; AB+EP±DI	---- ; 2 cm - 1 m
KS Vein Envelopes	*Empty Fractures ; Occur at Margins of Pervasive Sodic Alteration Zones*	----	---- ; KS+EP+(AB)	---- ; 2 cm - 1 m
MT Stringers	*Irregular Veinlets ; Occur Locally Across Camp*	MT	---- ; ±(KS)	< 5 mm ; < 2 mm
BT Stringers	*Wispy Veinlets ; Occur Locally Across Camp*	BT→CH+(KS)+(CC)+(PY)	BT→CH ; ----	< 5 mm ; < 1 mm
KS Veins	*Planar Veins ; Occur Across Camp*	KS+(CH)+(CC)+((BT))+((PY))+ ((MT))±((CP))±((QZ))	---- ; KS+AB+(CC)+(EP) +((MT))+((AP))+((TI))	2 mm - 2 cm ; < 2 mm
Pegm.-Text. Barren Veins	*Dilatant Veins ; Occur Locally Across Camp*	KS+CC+BT+(AP)+(MT)+(AB)+ (EP)+((GN))±((QZ))	---- ; KS±(BT)→(CH)	<1 - 100 cm ; < 5 cm
Pegm.-Text. BN-CP Veins	*Dilatant Veins ; Occur in Proximal Ore Zones*	KS+CC+BT+BN+CP+(AP)+(MT)+ (AB))+(EP)+((GN))±((QZ))	---- ; KS±(BT)→(CH)	<1 - 100 cm ; < 5 cm
Pegm.-Text. CP-PY Veins	*Dilatant Veins ; Occur Peripheral to Pegm.-Text. BN-CP Veins in Proximal Ore Zones*	KS+CC+BT+CY+PY+(AP)+(MT)+ (AB)+(EP)+((GN))±((QZ))	---- ; KS±(BT)→(CH)	<1 - 100 cm ; < 5 cm
BN-CP Veins	*Irregular Veinlets ; Occur Branching From and Peripheral to Pegm.-Text. BN-CP Veins*	BN+CP+(BT)+(CC)	---- ; ----	< 5 mm ; ----
CP Stringers	*Irregular Veinlets ; Occur Across Camp Outside of Zones with BN-CP Veins*	CP+(PY)+(MT)+(KS)+(AB)+ (BT)+(CH)	---- ; CH±(KS)+(AB)	< 5 mm ; < 2 mm
MT-SX Veins	*Dilatant Veins ; Occur in Distal Parts of Camp*	MT+PY+CP+CC+(HM)	---- ; KS+EP+(BT)+(MT)±(CH)	1 - 100 cm ; < 2 cm
HM-SX Veins	*Dilatant Veins ; Occur at Margins of Camp*	HM+PY+CP+CC+(MT)	---- ; KS+EP+(BT)±(CH)	1 - 20 cm ; < 2 cm
KS-EP Veins	*Irregular Veinlets ; Occur Across Camp in Linear Zones*	KS+EP+(CH)±((MT))	---- ; KS+EP+(CH)	< 5 mm ; < 2 mm
CH Veins	*Discontinuous, Sinuous Fractures-to-Planar Veins*	CH+(CC)+(EP)+((MT))+((HM))+ ((PY))+((CP))	CH ; CH+PY+CP+(MT)	< 2 mm ; < 5 mm
CH-SX-CC Veins	*Veins ; Occur in Distal Parts of Camp*	CH+CC+(EP)+(PY)+(CP)+(MT)	EP ; KS	< 2 mm ; < 5 mm
EP Veins	*Planar Veins ; Occur Across Camp But Are Most Abundant in Distal Parts of Camp*	EP±(CH)±(CC)±(KS)± (PY)±(CP)	---- ; KS±(AB)	1 mm - 1 cm ; < 5 mm
AB-KS-SC Veins	*Planar Veins ; Occur Locally Across Camp But Most Abundant at Ingerbelle*	SC+KS+AB+CC±(EP)	SC+KS+AB ; SC+KS+AB	< 1 cm - 10 cm ; < 1 cm
SE Veins	*Planar Veins ; Occur Loacally in Pit 2*	QZ+SE+PY	SE ; SE	< 2 cm ; < 1 mm
QZ Veins	*Planar Veins ; Occur Locally Across Camp*	QZ+CC+((PY))+((CP))	---- ; ----	1 - 3 mm ; ----
ZE Veins	*Irregular Stockwork Veins ; Abundant at Ingerbelle*	ZE	---- ; ----	1 - 5 mm ; ----
Green Clay Veins	*Planar-to-Irregular Veins ; Occur Locally in Pits 1, 3 and in Virginia Pit*	CY	---- ; ----	1 - 3 mm ; ----
CC Veins	*Planar, Continuous Veins ; Occur Across Camp Except for HM-Bearing Types, Which Occur at Camp Margins*	CC; CC±(PY)±(CP)±((CH)); CC+HM+((CH))	---- ; HM±KS±AB	< 1 mm - 5 cm ; < 3 cm

Abbreviations : ( ) = minor ; (( )) = trace ; → = 'replaced by'

QZ	quartz	KS	potassium feldspar	AB	albite (oligoclase)	BT	biotite	DI	diopside		
SC	scapolite	HM	hematite	EP	epidote	ACT	actinolite	CH	chlorite		
ZE	zeolite	CY	green clay	PY	pyrite	CP	chalcopyrite	BN	bornite		
SX	sulfide	CC	calcite	SE	sericite	KA	kaolinite	PL	plagioclase		
DI	diopside	MT	magnetite								

(decreasing) temperature, (increasing) fluid pressure and/or (increasing) strain conditions that occurred during hydrothermal alteration at Copper Mountain.

In contrast to typical calc-alkalic porphyry copper deposits, calcite, instead of quartz, is the dominant gangue mineral in the early pervasive alteration vein assemblages; calcite and, in places, magnetite are the dominant gangue minerals in the later structurally controlled alteration assemblages at Copper Mountain. Quartz is present in minor amounts within several, usually late, vein types; however, the vast majority of veins contain no quartz. The scarcity of quartz may reflect the silica-saturated (but quartz absent) character of the alkalic Jurassic intrusions in the camp and/or the lack of hydrothermal reactions that produce SiO_2. The magma chemistry probably influenced (buffered) the hydrothermal fluids such that they were also probably nearly silica-saturated but did not precipitate significant quartz. Likewise, the abundance of magnetite and relative scarcity of pyrite may reflect the low sulfur fugacities of the hydrothermal fluids responsible for alteration at Copper Mountain. In contrast, the abundance of calcite may result from a combination of higher CO_2 fugacities in the hydrothermal fluid, as well as the more calcium-rich nature of the host rocks and (possibly LH2) causative intrusions relative to calc-alkalic porphyry systems.

Assignment of the pervasive and structurally controlled alteration assemblages at Copper Mountain to the traditional calc-alkalic alteration assemblages of potassic, propylitic, argillic, and phyllic types is difficult, partly because the alteration assemblages observed at Copper Mountain are not identical to those observed in calc-alkalic porphyry systems (Lowell and Guilbert, 1970; Sillitoe, 1973). Nevertheless, an attempt to classify the various vein assemblages observed at Copper Mountain has been made, and explicit definition of the mineral assemblages characterizing these alteration styles are described to prevent ambiguity.

Pervasive Alteration Styles

Six different assemblages of pervasive alteration occur within the Copper Mountain camp : i) hornfels, ii) sodic, iii) potassic, iv) propylitic, v) argillic and vi) 'SCC' alteration (sericite-chlorite-clay). The first four of these are described below. Pervasive sodic and potassic alteration are described together because of their intimate temporal, chemical and geological similarities across the camp.

Hornfels

Pervasive hornfels alteration of Nicola Group volcanic rocks occurs in the northwesterly-oriented belt between the Copper Mountain stock and LHIC in proximity to the Copper Mountain stock, LHIC dikes (Preto, 1972) and felsic dikes (Stanley and Lang, 1993). As a result, hornfels is developed across much of the mineralized portion of the camp. It consists of the recrystallization of mafic and intermediate volcanic rocks (predominantly andesite flows and coarse fragmental volcanic rocks) to a competent, dark purple, dark grey or black, chonchoidally fracturing, fine-grained matte of diopside (proximal to the more mafic parts of the Copper Mountain stock) or biotite, plagioclase and magnetite (Preto, 1972). Recrystallization is generally restricted to the andesite matrix, andesite clasts, and small rims on the margins of 'stubby' hornblende-phyric monzodiorite clasts in these rocks. As a result, hornfels can make these coarse fragmental volcanic protoliths easier or more difficult to identify. In general, hornfelsed andesite contains significantly lower sodium, higher ferric iron, and, in the biotite facies, slightly higher potassium concentrations than those in equivalent non-hornfelsed rocks, based on a small suite of rocks collected to assess any compositional differences. As a result, at least some metasomatism accompanied hornfels recrystallization.

Other rock types within the Nicola Group do not 'appear' to be hornfelsed, possibly because of compositional controls; however, the thinly bedded, felsic tuffaceous sediments are generally recrystallized to fine-grained quartz, plagioclase and potassium feldspar. This recrystallization may be a manifestation of hornfels in these rocks; however, because no significant change in mineralogy accompanied this recrystallization, it probably did not involve significant metasomatism.

Adjacent to post-mineral felsic dikes, hornfelsed intermediate volcanic rocks contain up to 2 %, 1-2 mm, disseminated pyrite cubes. These probably were produced by a later hornfels and metasomatic event associated with the intrusion of the felsic dikes that overprinted an earlier hornfels produced by the Copper Mountain stock of LHIC dikes.

A spatial relationship between hornfels alteration and subsequent veining is apparent across the Copper Mountain camp. Hornfelsed rocks typically fractured more readily than their un-recrystallized equivalents, making them more susceptible hosts to later structurally controlled mineralization (Fahrni, 1951). Hornfels preceded all other alteration events at Copper Mountain; the recrystallization and associated minor metasomatism are interpreted to be caused by the heat introduced by the cooling intrusions within the thermal aureole and reaction with hydrothermal fluids migrating about the Copper Mountain, Voigt and Smelter Lake stocks.

Pervasive Propylitic Alteration

Pervasive propylitic alteration occurs locally throughout the camp, but is generally not well developed. It is generally light or pale green, selective-pervasive, and not textarally-destructive. Pervasive propylitic alteration is characterized by the stability of chlorite, actinolite, epidote and calcite after mafic minerals, and oligoclase/albite, epidote and calcite after feldspar. Pyrite and (specular) hematite or subordinate magnetite are also important alteration minerals. It can be differentiated from incipient sodic alteration (see below) by the presence of actinolite, although these two alteration assemblages may be gradational.

Pervasive propylitic alteration is most abundant at the margins of the camp but, based on textural and petrographic evidence, appears to also have been present at its centre (the region bordering the northern margin of the Copper Mountain stock adjacent to Pits 1 and 3; Fig. 5), having been subsequently overprinted and destroyed there by later feldspathic alteration. As such, it may have been abundant everywhere across the camp, at least during the early stages of hydrothermal activity at Copper Mountain.

Cross-cutting relationships suggest that pervasive propylitic alteration occurred at different locations in the camp at different times. It occurred across the camp during the early and middle stages of hydrothermal activity and at the camp margin during middle-to-later stages; subsequent fracture-controlled propylitic alteration (in chlorite, chlorite-sulphide-calcite and epidote veins; see below) clearly cuts this earlier pervasive alteration and exhibits a converse time and spatial relationship, occurring at the camp margin first during the middle-to-late stages of hydrothermal activity and across the camp during the latest stage.

Pervasive Sodic and Potassic Alteration

Two feldspar-dominated pervasive alteration assemblages (sodic and potassic) are observed within the Copper Mountain camp. Both are early, affect large volumes of intrusive rocks and lesser volumes of volcanic rocks, and probably resulted from interactions between host rocks and magmatic-hydrothermal waters at high temperatures, low strain rates and low fluid pressures. They are not generally structurally controlled; however, at their margins, both pervasive alteration assemblages grade into wide alteration envelopes about unfilled fractures (see below), indicating that the pervasive alteration style may have been produced by coalescing fracture envelopes or that fluids diffusing along grain boundaries coalesced into fractures at the margins of these zones.

Bleaching caused by sodic alteration (Na metasomatism) changes LHIC dikes and relatively fresh or hornfelsed mafic and intermediate volcanic rocks to a pale greyish-green or mottled white and grey. Analogous metasomatism caused by potassic alteration (K metasomatism) turns similar rocks a salmon or orangish-pink (Preto, 1972). Oligoclase/albite after plagioclase is the most abundant mineral in sodically altered rocks, although minor amounts of epidote, diopside and calcite, largely after ferromagnesian silicates, also occur; magnetite is destroyed and sulfides, with the exception of minor pyrite, are generally lacking. Destruction of magnetite and ferromagnesian silicate minerals produces an iron-deficient alteration assemblage (Gunton, 1974).

Incipient Na metasomatism involves the albitization of feldspar, the chloritization of ferromagnesian minerals, and the partial destruction of magnetite. Minor epidote also replaces ferromagnesian minerals. Where very intense, particularly in fragmental volcanic units, Na metasomatism is texturally destructive, and altered rocks take on a fine sucrosic texture. Some of these sodically altered zones are overprinted by incipient potassic alteration that imparts a light pink colour. This contains subordinate amounts of potassium feldspar, but rarely contains biotite. In outcrop scale, these pink zones commonly occur interior to a halo of less intense pale greyish-green-to-white sodic alteration (Huyck, 1992a). This style of alteration typically occurs within Lost Horse dikes and the immediately adjacent hornfelsed zones on their margins, as well as the eastern end of Pit 3 and the Oriole Pits zone.

Pervasive potassic alteration appears to generally crosscut zones of earlier pervasive sodic alteration. This alteration produces a pink colour and in non-sodically altered rocks replaces plagioclase with potassium feldspar, ferromagnesian minerals with biotite, epidote and calcite, and contains minor chlorite (both after biotite and replacing original mafic minerals). Magnetite has been observed to be both stable and unstable in this assemblage, the latter generally where alteration is more intense. The assemblage generally contains no sulfides, but where present, pyrite is the sole sulfide mineral.

Intense, pervasive potassic alteration is texturally destrnctive; rocks take on a coarse sucrosic texture. Nevertheless, the coarsest phenocrysts remain identifiable. Pervasive potassic alteration is generally restricted to the interiors of Lost Horse dikes, and results in a salmon pink colour. Where incipient potassic alteration has taken place, potassium feldspar replaces plagioclase in the groundmass (phenocrysts are only affected where more intense), but mafic minerals are generally fresh or replaced only by epidote.

Not all pink zones intrepreted to be potassically altered obtain their color from potassium feldspar. Some are composed of hematite-stained oligoclase/albite, possibly produced by the liberation of ferric iron during the destruction of magnetite. These pink sodically altered zones are common on the west side of the Similkameen River, but are rare on the east side.

Where the protolith of pervasive sodically or potassically altered rocks is difficult to ascertoin, the rocks at Copper Mountain are referred to as Na- or K-metasomatites, respectively, in order to reflect their hydrothermal origin (within the camp they have also been referred to as 'albitite' and 'microsyenite', respectively).

In general, pervasive potassic alteration affected a larger volume of rock than sodic alteration, although sodically-altered zones tend to be larger and more continuous. Both sodic and potassic styles of pervasive alteration are similar in that they are characterized by feldspar flooding and the replacement of mafic igneous minerals. Similarly, both alteration assemblages are largely crosscut by sulfide-bearing veins and generally occur within and immediately adjacent to LHIC dikes that intrude the Nicola Group volcanic rocks north of the Copper Mountain stock.

Where present, pervasive sodic alteration more commonly acts as a host for later veins, possibly because, like the hornfels, it produces a more brittle altered rock that fractures readily during subsequent hydrothermal activity. In contrast, rocks affected by potassic alteration, with their abundance of biotite and chlorite, are softer and less brittle, making them more difficult to fracture. The abundance of iron within intense pervasive potassic alteration, and its relative scarcity in intense pervasive sodic alteration, may exert some influence on the resulting vein mineralogy because later veins cutting potassically altered rocks tend to have higher concentrations of copper-iron sulphides (and thus higher copper grades) than those cutting sodically altered rocks. Rocks exhibiting less intense feldspathic alteration do not exhibit this grade distinction.

Within the south-central part of the Copper Mountain camp, the dominant pervasive alteration is sodic. This alteration affects large portions of Pits 1 and 3, and smaller portions of Pit 2, the Oriole Pits zone and the Ingerbelle Pit (Fig. 7). As such, development of sodic alteration is most common along the northern margin of the Copper Mountain stock in the central portions of the camp. Local, irregular patches occur in the northwest corner of Pit 2, in the Lost Horse Gulch area and the Huckleberry, Ingerbelle East and Oriole zones, where is it clearly controlled by structures of variable orientation (Fig. 7) These zones of sodic alteration, whereas commonly mineralized, generally are not hosts to the highest copper grades. This may be because the sodic alteration has leached out the iron necessary to stabilize chalcopyrite precipitation.

On a camp scale, pervasive potassic alteration generally cross-cuts sodic alteration zones. It forms generally less continuous volumes and is more structurally controlled, although still pervasive. However, zones of pervasive potassic alteration do extend far beyond the volumes affected by pervasive sodic alteration; it represents the predominant pervasive alteration assemblage in the northern half of Pit 2, the Virginia Pit, parts of the Ingerbelle Pit, the Oriole zone (Huyck, 1992a), the Voigt zone, Lost Horse Gulch and other prospects hosted by the LHIC. As such, a crude, early pervasive alteration zoning is evident across the camp (Fig. 7) defined by an 'inner' zone of sodic alteration and an 'outer' (as well as overlapping) zone of potassic alteration.

Structurally Controlled Alteration

The second important alteration style in the Copper Mountain camp is structurally controlled by fractures with variable amounts of fill (from closed fractures, through wispy stringer and irregular veinlets, to widely dilatant planar veins). These and their associated alteration envelopes can be divided temporally into early, intermediate and late stage varieties; however, because of mutually cross-cutting relationships and poorly constrained chronological relationships between veins in different areas within the camp, a general, camp-wide paragenesis is difficult to define. Nevertheless, substantial confidence can be assigned to specific paragenetic sequences in given areas within the camp (generally within individual open pits).

Generally pre-mineral veins within the Copper Mountain camp consist of sodic feldspar and potassium feldspar vein envelopes, magnetite stringers, biotite stringers, potassium feldspar veins and barren pegmatite-textured veins. Post-mineral veins consist of potassium feldspar-epidote, chlorite, epidote, feldspar-scapolite, sericite, quartz, zeolite, green clay and calcite veins. Veins containing significant amounts of mineralization within the Copper Mountain camp are described below, as well as in Tables 3, 4 and 5.

Pegmatite-Textured Veins

The 'pegmatite-textured veins' are so called because they may contain fine-to-coarse-grained vein selvages and very coarse euhedral minerals that filled open spaces within the vein. Large (up to 5 cm across) phlogopite books are characteristic of these veins are . Whereas their historical name implies a magmatic origin, these veins are clearly formed by hydrothermal processes and the current usage of 'pegmatite' in their name refers only to the textural form of minerals within these veins. The veins vary in sulfide concentration from zero to 50 percent.

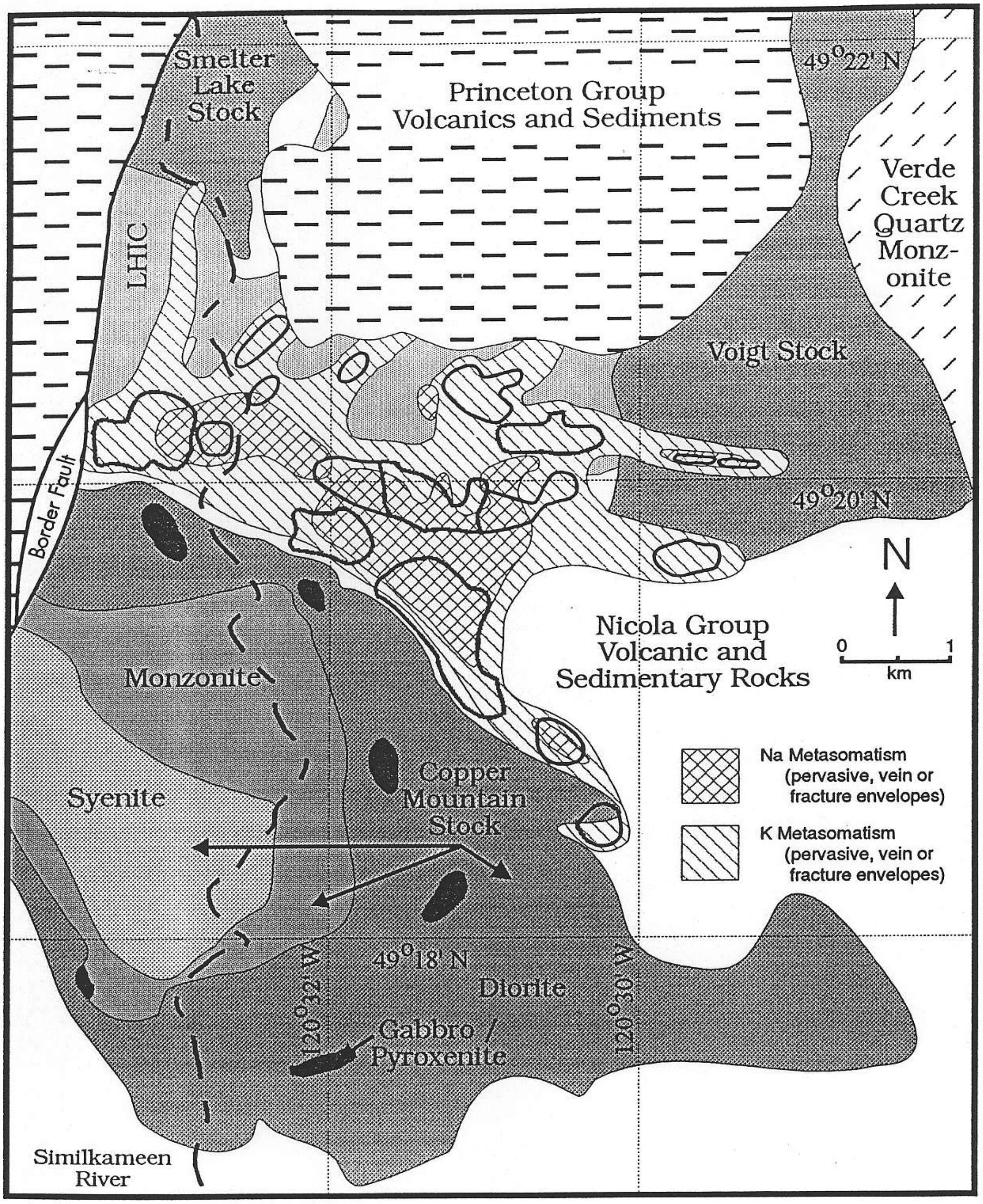

Figure 7 - Generalized geology map of the Copper Mountain alkalic copper-gold camp, Princeton, British Columbia (modified from Preto, 1972) with zones of predominantly sodic and potassic alteration indicated. These alteration zones include both pervasive (early) and structurally controlled (late) styles. Propylitic alteration occurs across the camp and (in its pervasive form) is cut by and (in its structurally controlled form) crosscuts both types of earlier feldspathic alteration.

Pegmatite-textured veins are either barren of sulfides, or contain chalcopyrite with either bornite or, less commonly, pyrite. As such, they can be subdivided into several groups, based upon mineralogy: i) barren veins, ii) bornite-chalcopyrite stable veins, and iii) chalcopyrite-pyrite stable veins. Sulphide-absent pegmatite-textured veins occur locally across the Copper Mountain camp. In contrast, the distribution of the sulfide-bearing pegmatite-textured veins defines an 'inner' (south-central) bornite-chalcopyrite stable zone and an 'outer' (marginal), chalcopyrite-pyrite stable zone (Fig. 8). The inner zone is located along the contact between the Copper Mountain stock and the Nicola Group in the vicinity of Pits 1 and 3; these veins typically do not penetrate more than one metre into the Copper Mountain stock.

Bornite-chalcopyrite stable veins formed the ore of the old Granby mine stopes. They occur mainly in the north and central portions of Pit 3, locally in Pit 2, and sparsely in Pit 1 and the Ingerbelle Pit. In Pits 1 and 2, retrograde alteration has replaeed biotite with chlorite and, locally, magnetite with hematite. In the Granby stopes, bornite and chalcopyrite in the veins have locally been replaced on their margins by bladed specular hematite, digenite, chalcocite, and epidote. These replacements are interpreted to be late hydrothermal (propylitic) overprints on the bornite-chalcopyrite stable veins, possibly during collapse and cooling of the hydrothermal system.

Pyrite-chalcopyrite stable veins formed peripherally to, and locally cut, the bornite-chalcopyrite stable veins. They occur locally in Pits 1, 2 and 3, the Virginia and Ingerbelle Pits, and in the Oriole Zone. Propylitic alteration has also overprinted these veins in many locations, replacing biotite with chlorite and, less commonly, magnetite with hematite.

Magnetite-Sulphide Veins

These veins occur primarily in the Virginia Pit and within prospects hosted by the LHIC, and carry high gold grades (Huyck, 1986, 1990a, 1990b, 1991a, 1991b, 1992b) relative to other zones in the eastern part of the Copper Mountain camp. They are commonly dilatant, planar and occur in 'sheeted' parallel clusters, but in some cases form crackle zones a few metres wide. In larger veins, magnetite on the vein margin commonly exhibits a coarse-grained, bladed habit, but toward the centre of the vein exhibits a more equant habit. Hematite commonly occurs in the cores of the magnetite blades, and the bladed magnetite is interpreted to represent original specular hematite blades that have been replaced or overgrown by later magnetite (Huyck, 1992b). Pyrite and chalcopyrite are less abundant than magnetite; chalcopyrite precipitated after pyrite and magnetite. Native gold has been observed associated with chalcopyrite overgrown by pyrite. Gangue calcite, is typically interstitial to magnetite and sulfides. Chlorite in the alteration envelopes replaces primary igneous biotite.

These veins may be equivalent or geochemicall related to chalcopyrite-pyrite stable pegmatite-textured veins. They are distinguished by their lower abundance of biotite, higher abundance of magnetite and finer-grained texture. As such, they may comprise another sulphide oxide assemblage within the Copper Mountain vein zoning relationships presented in Figure 8. These veins are the principal contributor to ore in the Virginia Pit.

Hematite-Sulphide Veins

In the Voigt and Alabama zones, veins similar to the magnetite-sulfide veins occur, but these contain variable but generally subordinate amounts of magnetite and an abundance of hematite. These veins also exhibit paragenetic relationships suggesting the minor replacement of early specular hematite by magnetite (Huyck, 1992b). Chalcopyrite and gold mineralization is restricted to veins where this overprint has occurred (Huyck, 1992b). The distribution of this vein type defines the fourth sulfide-oxide vein assemblage that exhibits zonation across the Copper Moumtain camp. It occurs to the northeast in the outer-most portions of the camp (the Voigt and Alabama zones).

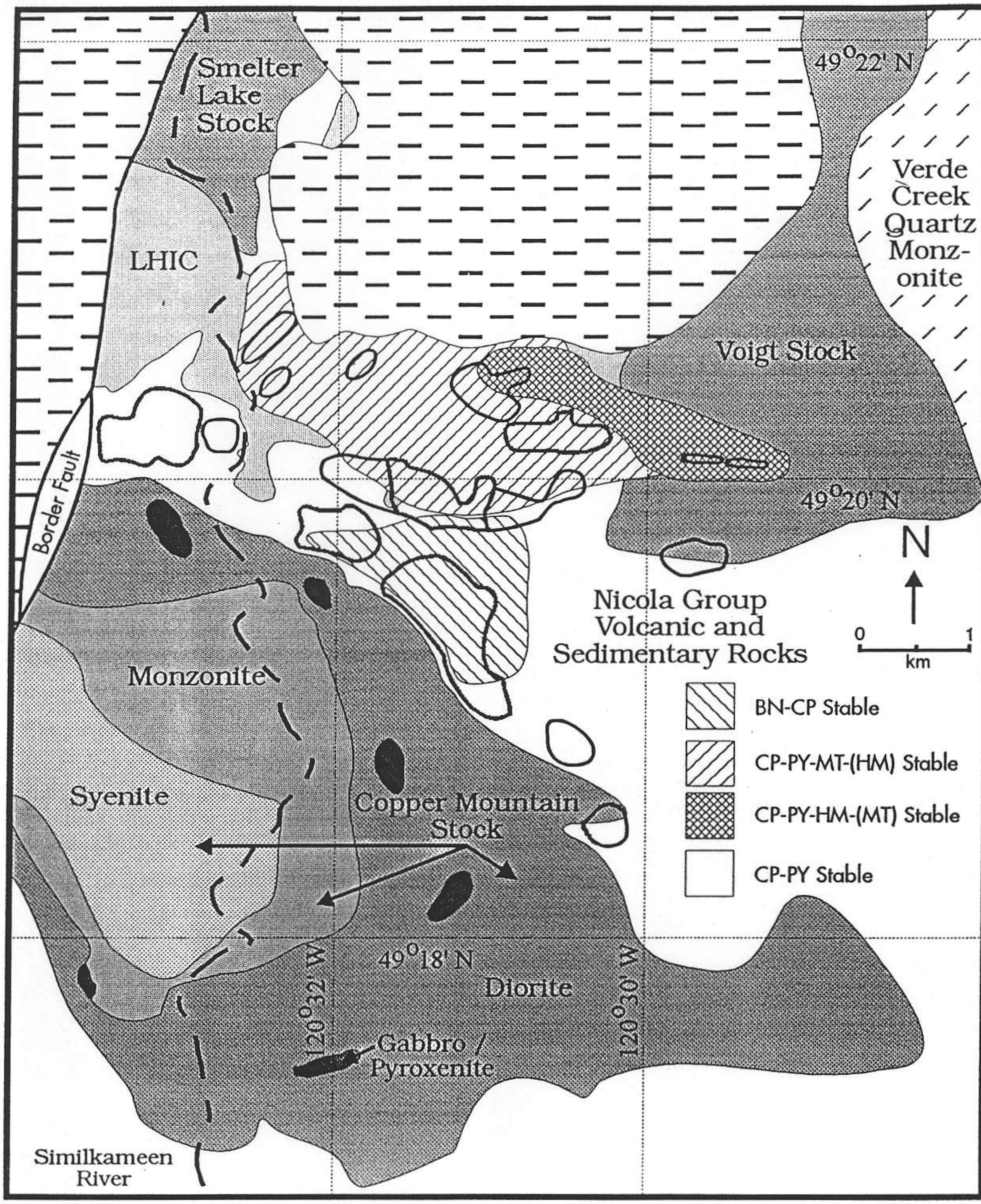

Figure 8 - Generalized geology map of the Copper Mountain alkalic copper-gold camp, Princeton, British Columbia (modified from Preto, 1972) with zones of major sulfide-oxide ore assemblages indicated. Areas not hatched contain a pyrite-chalcopyrite assemblage. In general, these assemblages zone outward from bornite-chalcopyrite, to magnetite-pyrite-chalcopyrite, to hematite-pyrite-chalcopyrite or pyrite chalcopyrite.

Table 4 - Crosscutting Relationships Between Alteration Assemblages in the Copper Mountain Camp (for abbreviations, see Table 3).

			Posterior																											
Alteration Type			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Biotite Hornfels		1	1																											
Pervasive Propylitic		2	R	2							R		R	R	R	R			R											
Pervasive Sodic		3	R	R	3																									
Pervasive Potassic		4	R	R		4																								
Pervasive Argillic		5			R		5																							
Pervasive SCC		6	R	R		R		6		R			R					R	R	R	R	R	R	R					R	
AB Vein Envelopes		7	C	C	G				7																					
KS Vein Envelopes		8	C	C	C	G				8																				
MT Stringers		9	C	C	C	C			C	C	9																			
BT Stringers		10	C	C	C	C			C			10		C	C	C														
KS Veins		11	C	C	C	C			C	C	C		11	M					C	C	M			M						
Pegm.-Text. Barren Veins	P	12	C	C	C	C			C	C			M	12	S	S			S	S	M									
Pegm.-Text. BN-CP Veins	r	13	C	C	C	C			C	C				S	13	B	M		B	B	S									
Pegm.-Text.CP-PY Veins	i	14	C	C	C	C			C	C				S	B	14		M	B	B	S									
BN-CP Veins	o	15	C	C	C	C			C	C		C	C		M		15	B												
CP Stringers	r	16	C	C	C	C			C	C	C	C	C			M	B	16												
MT-SX Veins		17	C	C	C	C			C	C	C	C	C	S	B	B			17	B	S									
HM-SX Veins		18	C	C	C	C			C	C			C	S	B	B			B	18	S									
KS-EP Veins		19	C	C	C	C			C	C	C	C	M	M	S	S	C	C	S	S	19			M						
CH Veins		20	C	C		C				C	C	C	C	C	C	C	C	C	C	C	C	20	M							
CH-SX-CC Veins		21	C	C	C	C			C	C	C	C	C	C		C		C	C		C	M	21							
EP Veins		22	C	C	C	C			C	C	C	C	M	C	C	C	C	C	C		M	C	C	22			C			
AB-KS-SC Veins		23	C	C	C	C			C	C	C		C				C	C							23					
SE Veins		24			C				C		C	C	C			C		C	C		C					24				
QZ Veins		25	C	C	C	C			C	C	C		C	C			C		C	C		C	C	C	C	C	25			
ZE Veins		26	C	C	C	C			C	C	C	C	C				C	C			C	C	C	C	C			26		
Green Clay Veins		27	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C				27	
CC Veins		28	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	28

Shaded cells indicate contemporaneous alteration styles, based on mineralogical, structural and/or mutually crosscutting relationships.

C = Crosscuts ; R = Replaces ; M = Mineralogically Related ; S = Structurally Related ; B = Both Mineralogicially and Structurally Related

Table 5 - Alteration Paragenesis of the Copper Mountain Porphyry Copper-Gold Camp (for abbreviations, see Table 3).

Alteration Type	*Ingerbelle Pit*	*Pit 3*	*Pit 1*	*Pit 2*	*Virginia Pit*
	time →	**time →**	**time →**	**time →**	**time →**
Biotite Hornfels	▬	▬	▬	—	—
Pervasive Propylitic	—	—	—	—	—
Pervasive Sodic	—	▬	▬	▬	
Pervasive Potassic	▬	▬	▬	▬	▬
Pervasive Argillic			—	—	
Pervasive SCC					—
AB Vein Envelopes	—	▬	▬	▬	
KS Vein Envelopes	▬	▬	▬	▬	▬
MT Stringers	—	—	—	—	—
BT Stringers	—	—	—	—	—
KS Veins	▬	—	—	▬	▬
Pegm.-Text. Barren Veins	—	—	—	—	
Pegm.-Text. BN-CP Veins	▬	▬	▬	—	
Pegm.-Text. CP-PY Veins	▬			▬	
BN-CP Veins	▬	▬	▬	—	
CP Stringers	▬			▬	▬
MT-SX Veins					▬
HM-SX Veins					—
KS-EP Veins	▬	▬	▬	▬	▬
CH Veins				—	▬
CH-SX-CC Veins	▬			—	▬
EP Veins	▬	▬	▬	▬	▬
AB-KS-SC Veins	▬			—	
SE Veins				—	
QZ Veins	—	—	—	—	—
ZE Veins	▬				
Green Clay Veins	—	—	—	—	—
CC Veins	▬	▬	▬	▬	▬

Bornite-Chalcopyrite Veins

Small, irregular bornite-chalcopyrite veins occur among and peripheral to bornite-chalcopyrite pegmatite-textured veins. Bornite concentrations generally exceed those of chalcopyrite. Veins lacking the biotie and calcite gangue are significantly more common in volcanic rocks that have been previously partially bleached by early sodic alteration, than in hornfelsed, biotite-rich volcanic rocks. These veins may be non-dilatant equivalents to the pegmatite-textured bornite-chalcopyrite veins described above.

Chalcopyrite Stringer Veins

Small, irregular veinlets of chalcopyrite, less than 5 mm wide, generally occur in the peripheral portions the camp where bornite-chalcopyrite stable pegmatite-textured veins are lacking. These veins form ore only where they develop in concentrated networks. They may be non-dilatant equivalents to the chalcopyrite-pyrite pegmatite-textured veins and are common in the bottom of Pit 3.

In general, the mineralogical expression of some styles of hypogene alteration is partially controlled by host rock composition and the presence of pre-existing alteration types. Table 4 summarizes the cross-cutting relationships observed between different alteration assemblages. Table 5 compares the alteration paragenesis at several locations in the camp, and illustrates both the control of pre-existing alteration on the alteration assemblage and the alteration zoning observed across the camp.

Alteration Paragenesis and Zoning

In general, early forms of alteration at Copper Mountain are pervasive, whereas later forms are fracture-controlled. Similarly, early fracture-controlled veins are irregular, wispy or ill-defined, whereas later veins are strongly planar.

Early hornfels alteration was followed by slightly later pervasive propylitic and then sodic and potassic alteration. The pervasive sodic alteration is restricted to the central portions of the camp, whereas the pervasive potassic alteration overprints the earlier sodic alteration, is more structurally controlled and is distributed across the camp. Both of these feldspathic alteration assemblages are intimately spatially associated with late LHIC (LH2) dikes, and thus are considered to be a result of a magmatic-hydrothermal fluid evolved from these magmas and reacting with already solid portions of the intrusions and adjacent country rocks.

Pervasive propylitic alteration generally occurs in the periphery of the camp; it probably did occur abundantly in the centre of the camp, but has been subsequently overprinted by later feldspathic alteration. Structurally controlled propylitic alteration assemblages occur across the camp and overprint earlier alteration styles. Both magnetite- and hematite-stable forms of propylitic alteration occur. This alteration is probably responsible for the chloritization of hydrothermal and igneous biotite, (specular) hematization of magnetite, and replacement of chalcopyrite and bornite by digenite, covellite and chalcocite. Argillic alteration is restricted to zones that were already sodically altered, and probably resulted more from hydrothermal alteration of rocks that were already devoid of iron, magnesium and calcium due to earlier sodic alteration (and thus lacked significant buffering capacity), than from reaction with highly acid fluids.

Sulphide-bearing veins also exhibit a spatial variability across Copper Mountain. Bornite-chalcopyrite-stable veins generally occur in the central portions of the camp, whereas pyrite-chalcopyrite, pyrite-chalcopyrite-magnetite and pyrite-chalcopyrite-magnetite-hematite veins generally occur in zones outward toward the east, north and west periphery. These veins control the spatial zoning of precious metals within the camp. High silver grades are associated with bornite-chalcopyrite veins in the core of the hydrothermal system whereas high gold grades occur in chalcopyrite-pyrite-magnetite ± hematite veins at the margins of the system. Production data from the various open pits reflect this metal zonation (Table 1).

Evolution of the silicate-bearing veins through time, from potassium feldspar (potassic) to potassium feldspar-epidote to epidote (propylitic) veins, suggests changing hydrothermal conditions during the period that these veins formed. This is further reflected in the spatial distribution of both the pervasive and structurally controlled propylitic alteration, which may record the expansion and heating up of the hydrothermal system and aureole (in the pervasive propylitic alteration), and then its subsequent collapse and cooling down (in the structurally controlled propylitic assemblage veins).

Late stage veins exhibit a diverse mineralogy and are generally widespread. Some of these vein types may have been produced by the waning stages of hydrothermal activity at Copper Mountain (scapolite, quartz and zeolite veins), but others appear to have been produced regionally, possibly by other magmatic events in the area (calcite and green clay veins).

Summary

The Copper Mountain porphyry copper-gold deposit is hosted by relatively fine-grained and equigranular-to-subporphyritic, quartz-absent diorites-to-monzonites and a package of augite-phyric intermediate volcanic flows, fragmentals and sediments of the alkalic eastern volcanic belt of the Nicola Group (Monger, 1989b), that these intrude. Alteration styles in the camp consist predominantly of sodic, potassic and propylitic assemblages. Argillic and phyllic alteration assemblages, quartz gangue and molybdenite are rare to absent. Magnetite and calcite are the primary gangue minerals. Copper, gold, and to a lesser extent silver, exhibit relatively constant ratios in each mineralized zone. The combination of these mineralization, alteration and geological characteristics indicate that the Copper Mountain ores most closely resemble in the silica-saturated alkalic porphyry copper-gold deposit model of Lang et al. (1992, in press).

The overall pervasive and fracture-controlled alteration mineral assemblage modes observed at Copper Mountain are consistent with the alteration of a relatively unevolved, quartz-absent host rock mineral assemblage rich in iron, magnesium and calcium (alkalic diorites and andesites). Hydrothermal reaction processes and/or environmental conditions significantly different from those observed in calc-alkalic porphyry copper-molybdenum deposits need not be invoked to explain the observed differences in alteration mineralogy. Nevertheless, the relative absence of anhydrite and the low pyrite concentrations in the ore may suggest that the hydrothermal system at Copper Mountain was sulphur (S_2-SO_4) poor relative to calc-alkalic systems. Similarly, the presence of calcite in most alteration assemblages and the abundance of late scapolite veins in the deposit may suggest that the hydrothermal fluid was CO_2-rich relative to calc-alkalic systems (late stage quartz veins do contain visible CO_2 in their fluid inclusions). Finally, the importance of epidote, actinolite, calcite, biotite and chlorite in the alteration at Copper Mountain may suggest that the hydrothermal fluids had a near-neutral pH and were calcium-, magnesium- and iron-rich relative to typical calc-alkalic porphyry systems, features that might be expected in a hydrothermal fluid that evolved from a less evolved, calcium-, magnesium- and iron-rich melt.

Strong structural alignment of mineralization typifies the control on mineralization at Copper Mountain. In the eastern part of the camp, these structures have a predominant easterly-orientation and are spaced at signifieant distances of up to 150 m. Therefore, whereas the Copper Mountain deposit has traditionally been considered to be a porphyry deposit, the style of mineralization at Copper Mountain ranges from more classic porphyry style mineralization in the Ingerbelle Pit, where structures in multiple orientations at high densities (typically less than a 5 m spacing) control mineralization, to more of a sheeted vein style deposit in Pits 1, 2, and 3 and the Virginia Pit, where strong alignment of widely spaced structures controls mineralization. These sheeted veins still retain enough grade continuity to be bulk-tonnage mineable, just like a more classic porphyry deposit. Furthermore, this spatial variation in controls on mineralization may suggest that the intrusive centre and core of the structural conduit system of this porphyry deposit may be located in the Ingerbelle Pit near the largest mass of late LHIC (LH2) dikes thought to be the causative intrusions. Mineralization on the east side of the Similkameen River may thus have been telescoped upward, along the Copper Mountain stock contact, and outward by a high structural permeability (fractures) that was imposed by regional tectonic forces at the time of fluid flow.

Further information regarding the geology of the Copper Mountain (Similkameen) porphyry Cu-Au camp can be found in the following publications, reprinted with permission in Appendix A.

Fahrni, K.C., Macauley, T.N. and Preto, V.A.G., 1976: Copper Mountain and Ingerbelle. in 'Porphyry Deposits of the Canadian Cordillera', ed. by Sutherland-Brown, A., Canadian Institute of Mining and Metallurgy, Special Volume No. 15, pp. 368-375.

Stanley, C.R. and Lang, J.R., 1993: Geology, Geochemistry, Hydrothermal Alteration and Mineralization in the Virginia Zone, Copper Mountain Copper-Gold Camp, Princeton, British Columbia (19H/7). in 'Geological Fieldwork 1992', ed. by Grant, B. and Newell, C., British Columbia Ministry of Energy, Mines and Petroleum Resources, Paper 1993-1, pp. 259-268.