Poison Mountain porphyry copper-gold-molybdenum deposit, south-central British Columbia

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ABSTRACT

The Poison Mountain Cu-Au-Mo deposit, 90 km north of Lillooet, British Columbia, on the eastern edge of the Coast Plutonic Belt, is jointly hosted by hornfelsed Lower Cretaceous continental arenaceous sedimentary rocks and Late Paleocene stocks and dikes of biotite quartz diorite composition. Concentric zones of sulphide and minor oxide mineralization surround a barren, similar aged, central intrusion of granodiorite. The inner zone, characterized by fracture-controlled and disseminated sulphides and potassic alteration, is surrounded by an outer pyrite halo with magnetite, hematite, and minor phyllic and propylitic alteration.

Six new K-Ar age determinations are presented, together with major and trace element analyses. The latter are compared to results from unaltered rocks outside the deposit, and with potassic alteration zones elsewhere.

Environmental, ore reserve, metallurgical, mining and milling methodologic, and economic studies are summarized, indicating that, at present metal prices, the Poison Mountain deposit is sub-economic.

Introduction

The Poison Mountain Cu-Au-Mo deposit is located 91 km north-northwest of Lillooet, British Columbia, within N.T.S. map 92O/2, at Latitude 51°08′N, and Longitude 122°36′W (Fig. 1). Access from Lillooet is via paved and gravel road to the turnoff at Moha, then by a forest access road up the Yalakom River, into the headwaters of Churn Creek, and to the mineralized area.

The deposit is on the southwest flank of Poison Mountain (Fig. 1), mostly in the drainage basin of Copper Creek, a small, informally named creek flowing westward to Poisonmount Creek. The mineralized system extends northward beyond Fenton Creek, a second, west-flowing, informally named tributary of Poisonmount Creek. Elevations range from 1630 m at the junction of Poisonmount and Churn creeks to 2256 m at the summit of Poison Mountain. The deposit is below the 2000 m treeline elevation. Hill slopes are moderate and outcrop is limited to creek shoulders and ridges. The property is snow free from early June to the end of October.

History

The first published geological information regarding the Poison Mountain area was by MacKenzie (1921). Richmond (1934) recorded that placer gold was discovered at Poisonmount Creek in 1932. Richmond noted that pyrite and gold were found in quartz veins within coarse-grained "bird's eye" porphyry near the headwaters of Poisonmount Creek. Peck (1947) examined the copper showings, hosted by porphyritic quartz diorite containing "a little malachite and, where unweathered, chalcopyrite".

The first serious work began in 1956 (Patterson, 1957) with Granby Consolidated Mining, Smelting and Power Company Ltd. Exploration efforts continued with New Jersey Zinc Exploration Company Ltd. (James, 1960; 1961), American Smelting and Refining Company (Carr, 1962), Copper Giant Mining Corporation Ltd., Homestake Mineral Development Company and Canadian Superior Exploration Ltd. (Waterland, 1967, 1968), Lac Minerals Ltd. (Pegg, 1989; Brown, 1983; So, 1988) and lastly Bethlehem Corp. (Raven, 1993). These companies conducted soil sampling, magnetometer and induced polarization surveys, geological mapping, trenching and road building, and drilling of 137 core holes totalling 19 322 m and 278 percussion holes totalling 21 131 m.

Lac Minerals Ltd. owns the Poison Mountain property subject to a 2% net smelter royalty payable to Homestake and Canadian Superior. Bethlehem Resources Corp. has optioned the property from Lac Minerals Ltd.

Regional Geology

The Poison Mountain deposit lies within the northwest extension of the Methow basin, on the eastern edge of the Coast Plutonic Belt (Fig. 2). The latter consists of Late Paleozoic and Mesozoic sedimentary and volcanic rocks, ophiolite assemblages, and Late Cretaceous to Early Tertiary intrusions (Wheeler et al., 1991). The Methow basin contains Middle Jurassic rocks, correlated with the Ladner Group, together with overlying Lower Cretaceous rocks of the Jackass Mountain Group (Riddell et al., 1993; Glover et al., 1988; Tipper, 1978). The Methow basin strata are divided into the Yalakom Mountain and Churn Creek facies (Schiarizza et al., 1993) both of which occur at Poison Mountain (Fig. 3). Younger, probable Eocene, felsic tuffs, breccias and flows are found 10 km northwest of Poison Mountain in the Red Mountain-Blackdome Mountain area (Tipper, 1978; Archibald et al., 1989).

Structures are dominated by mid- to Late Cretaceous reverse faults and latest Cretaceous-Eocene dextral strike slip faults.

Geology of the Poison Mountain Area

Sedimentary Rocks

Geological mapping in the immediate Poison Mountain area (Fig. 3), compliments that of Tipper (1978) and Glover et al. (1988). Sedimentary rocks underlying Poison Mountain and the area to the east of the Yalakom River include Jackass Mountain Group, Yalakom Mountain facies arkosic sandstone, conglomeratic sandstone, volcanic lithic sandstone, siltstone and shale. Stratigraphic correlation within the Yalakom Mountain facies is difficult due to the limited extent of any distinctive marker horizon and the lack of outcrop.

A local mafic pillow lava, 10 m thick, occurs within these sedimentary rocks 3 km east of Poison Mountain. This volcanic unit, which strikes east-west and dips steeply to the south, has pillows indicating tops to the south. The mafic flow is believed to be conformable although contacts were not observed.

North of Poison Mountain the Churn Creek facies of the Jackass Mountain Group predominates, with units of polymictic boulder to cobble conglomerate, conglomeratic sandstone and sandstone.

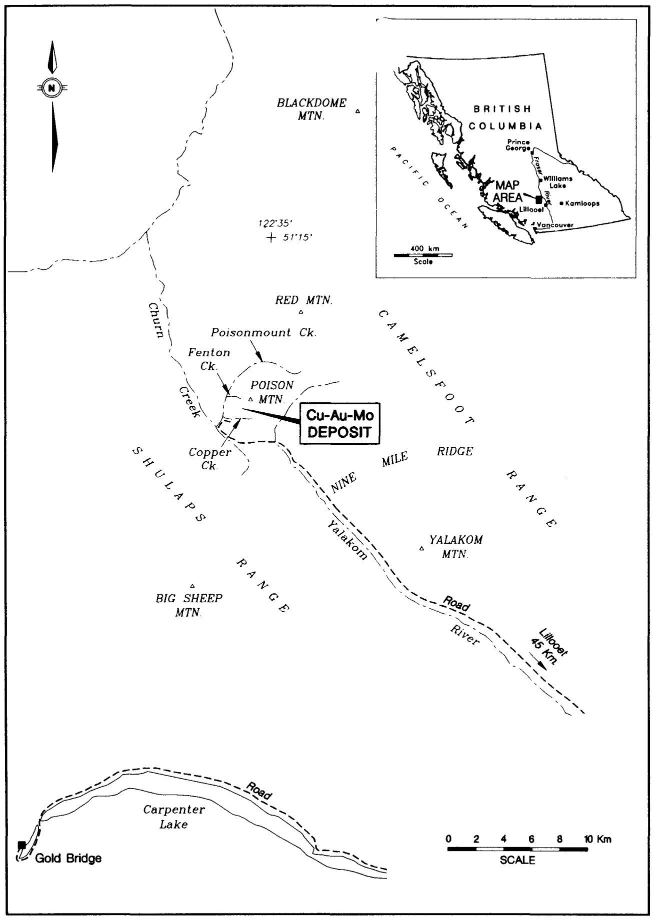

FIGURE 1. Location map, Poison Mountain area.

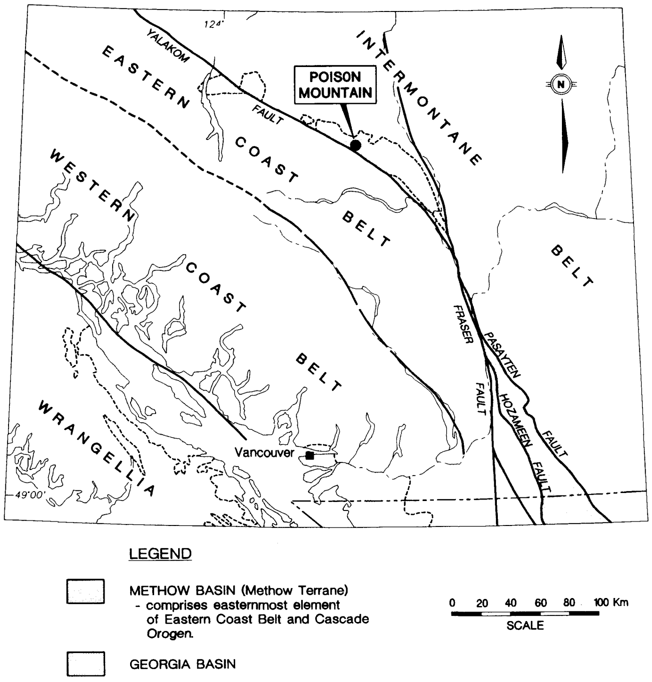

FIGURE 2. Regional tectonics map, Poison Mountain area.

Intrusive Rocks

Several quartz diorite porphyry (QDP) stocks intrude the sedimentary rocks in the Poison Mountain area, including a potasically-altered biotite quartz diorite porphyry (BQDP) with associated dikes, and two elongate granodiorite stocks. The Poison Mountain deposit is hosted by both sandstone and BQDP.

Barren QDP stocks are located immediately east and 2 km east of the Poison Mountain deposit (Fig. 4), and are characterized by phenocrysts of feldspar (up to 12 mm diameter), biotite, and hornblende and by abundant secondary chlorite, epidote and carbonate. The QDP immediately east of the deposit contains up to 20% epidote, 10% chlorite, 10% clay-sericite, 5% Ti-oxide and minor amounts of Fe-oxide and carbonate. Epidote is found in plagioclase phenocrysts, in fan-shaped aggregates and in the matrix. Chlorite is found in plagioclase and pseudomorphing hornblende as plates, stringers and patches. Clay and sericite are also found in plagioclase, and carbonate occurs with quartz or interstitial to epidote grains. Ti-oxide occurs in aggregates with chlorite and epidote.

Structure

Folded strata east of Poison Mountain on Yalakom Creek define an open syncline with a northwest-trending axis. The pillow lava unit on the northeast limb, and cross beds from siltstone on the southwest limb indicate that tops are up.

A right-lateral fault with a horizontal displacement of about 100 m, indicated by the offsets of southward fining and thinning conglomerate beds, parallels Churn Creek and is probably a splay of the Yalakom Creek Fault. Several strong shears exist in the Copper Creek vicinity, where drill holes indicate a strong east-west shear underlying the creek. Four discrete northeast-trending linear topographic lows, north of Copper Creek in the deposit, are considered to be the surface expressions of shears.

Steep dipping northwest trending joints are common throughout the mapped area and within the deposit area. Two sets of steeply-dipping joint planes dominate; one strikes east-northeast and the other strikes north-northwest. Dips are variable depending on rock types and location relative to intrusions (Fig. 5). The northeast-trending fault, shear and joint orientation is probably conjugate and antithetic to the right-lateral displacement along the northwest-trending Yalakom Fault.

Metamorphism

Regionally, the Methow basin rocks are virtually unmetamorphosed. However, the Jackass Mountain Group underlying Poison Mountain, contains variable amounts of carbonate, chlorite and epidote related to the intrusions.

Geology, Petrology and Alteration of the Poison Mountain Deposit

Geology and Petrology

The sedimentary rocks of the Copper Creek area are massive, fine- to medium-grained feldspathic to lithic sandstones (greywacke) with thin bands of intercalated thin shale and pebble conglomerate. In the Fenton Creek area lenses of polymictic boulder conglomerate are interbedded with greywacke and shale that strike north-northwest and dip steeply to the east.

Greywackes consist predominantly of angular to subrounded clasts of plutonic and volcanic rock, coarse, angular and subrounded grains of hornblende, plagioclase, quartz, potash feldspar, and minor biotite in a quartz-feldspathic matrix. Trace amounts of secondary (?) ilmenite, sphene and apatite are disseminated throughout, with 1% to 10% chlorite, 1% to 20% carbonate, 1% to 5% epidote, 10% to 20% clay-sericite and less than 2% Fe-oxides, hematite and actinolite. Calcite and other carbonate minerals are disseminated in the matrix and have formed overgrowths on plagioclase and hornblende grains. Epidote occurs as both prismatic grains and disseminated patches within the matrix, and also with carbonate as replacments of plagioclase. Sericite-clay replaces plagioclase grains

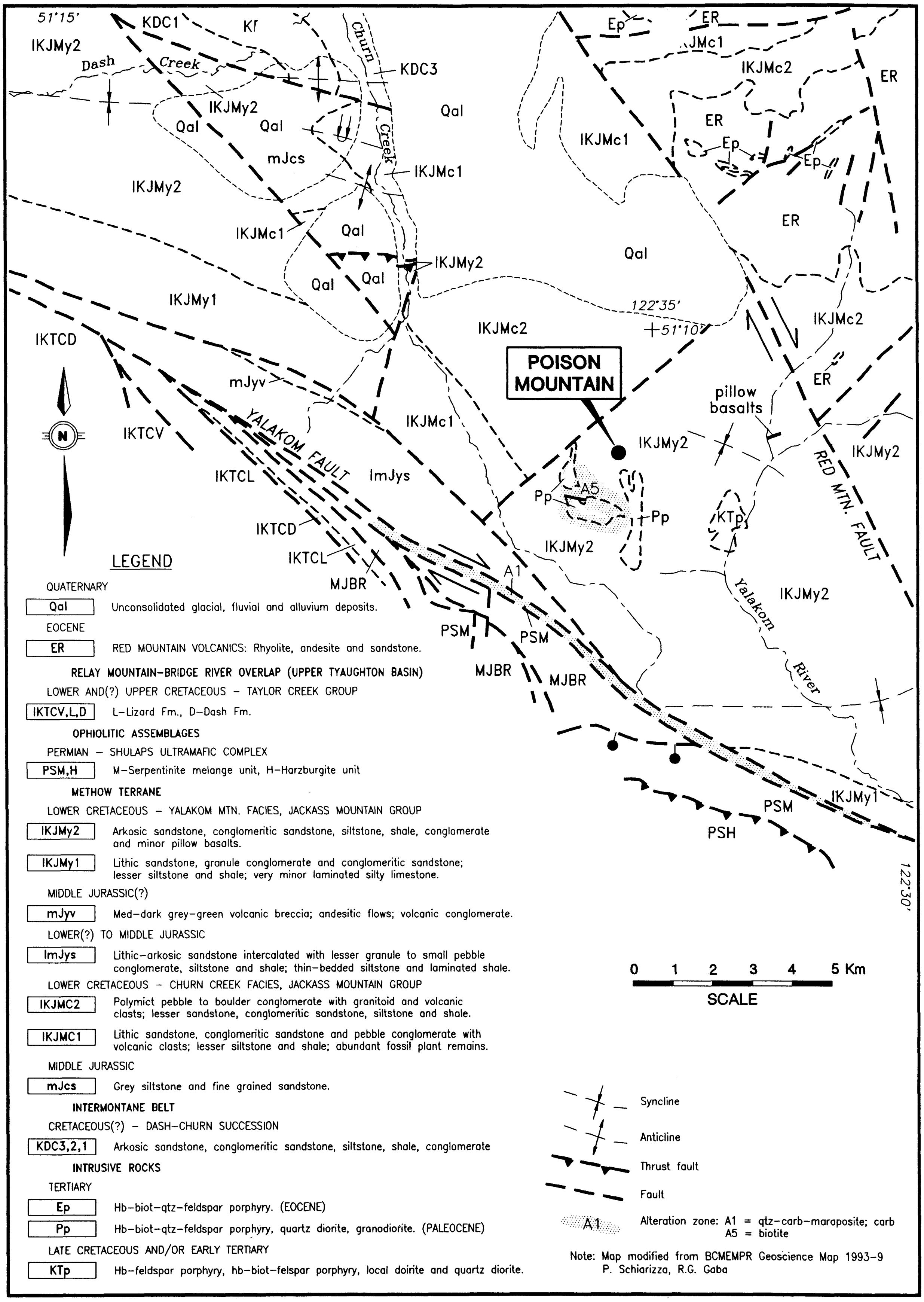

FIGURE 3. Regional geology map, Poison Mountain area.

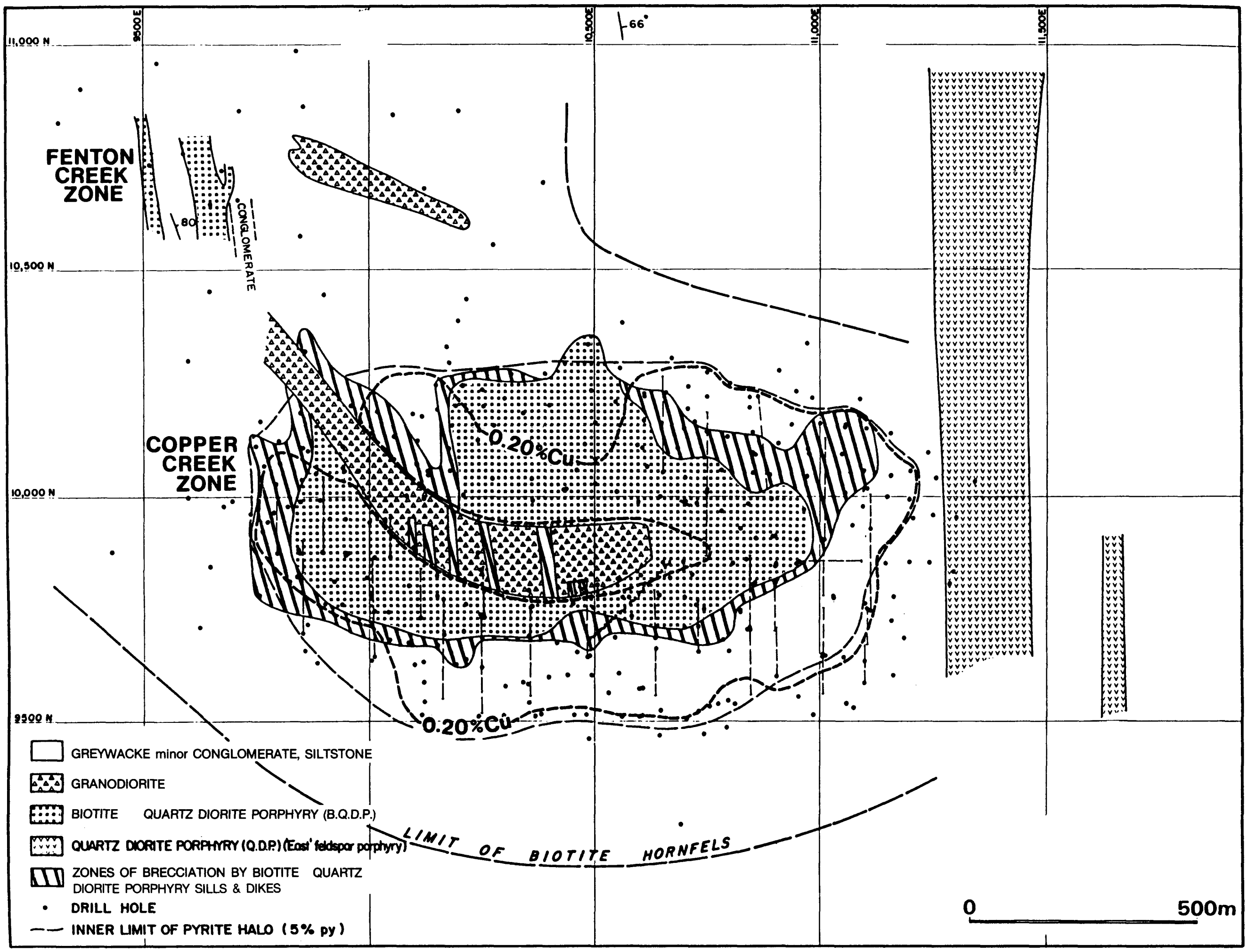

FIGURE 4. Geology map, Poison Mountain.

and some biotite. Chlorite occurs as disseminated flakes in the matrix, and also as overgrowths of biotite and hornblende grains.

A large aureole of hornfelsed greywacke surrounds the BQDP and granodiorite on Copper Creek and Fenton Creek (Fig. 4). The hornfels is characterized by its massive texture, pyrite-magnetite-hematite content, quartz veins and dark grey black colour due to abundant biotite. The hornfels retains sedimentary textures except in the brecciated contact areas with the BQDP. It is divided into an inner mineralized zone (>0.2 % Cu) and an outer pyrite halo.

Hornfelsed greywackes contain from 15% to 25% fine-grained felted biotite, which occurs throughout the matrix and replaces lithic clasts. They are recrystallized with a quartz feldspathic matrix. Potash feldspar, amounting to 1% to 2% of the rock, forms selvages to quartz veins. Magnetite, hematite and ilmenite occur as disseminations, as aggregates with sulphides, in quartz veins or as veinlets comprising up to 1% of the rock. Carbonate forms a trace to 3%, and sericite forms a trace to 10% due to replacement of plagioclase. Trace amounts of chlorite replace biotite and occasionally are found in K-feldspar-quartz veinlets. At depth, gypsum forms late stage cross-cutting veins in both BQDP and hornfelsed greywackes.

The BQDP-hornfels contact forms an arcuate zone of brecciation (>50% BQDP) 50 m wide, marked by extensive BQDP diking (<50 % diorite). Due to a paucity of outcrop the areal extent of hornfels is defined by induced polarization and magnetometer surveys (Seraphim and Rainboth, 1976).

The BQDP, a 500 m by 1000 m horseshoe-shaped intrusion, hosts 50% of the ore. It is characterized by a dark grey, biotite-rich matrix and a cataclastic texture. Feldspar phenocrysts are less than 6 mm long, although two sub-types exist: one with feldspar phenocrysts up to 6 mm in length, and the other with feldspar phenocrysts up to 10 mm in length. Minor hornblende and biotite phenocrysts occur in the BQDP.

The BQDP contains plagioclase An_{30-40}, hornblende and lesser biotite phenocrysts in a fine-grained matrix of plagioclase, quartz, minor potash feldspar and trace apatite. The matrix is made up of 50% to 60% recrystallized quartz, producing a granoblastic texture. Biotite and hornblende phenocrysts and matrix are partially replaced by minute flakes of biotite. Several samples exhibit a weak foliation due to biotite wrapping around plagioclase phenocrysts. In brecciated areas plagioclase phenocrysts are broken and have a cataclastic texture. The BQDP contains 1% to 2 % quartz veins. Minor amounts of K-feldspar form veinlets and selvages in quartz veins. Trace amounts of magnetite, hematite and ilmenite occur as disseminations or accompany the quartz and K-feldspar veins. Sericite, carbonate, chlorite and epidote replace plagioclase and biotite phenocrysts and comprise less than 2% of the rock.

A pale-green granodiorite stock 150 m wide by 1000 m long is centrally located within the hornfelsed greywacke and BQDP. It consists of euhedral grains of plagioclase and hornblende up to 7 mm long with interstitial grains of quartz, plagioclase, K-feldspar and trace amounts of apatite. The granodiorite displays a massive to slightly porphyritic texture and its green colouration is due to minor chlorite, epidote, actinolite and carbonate alteration of hornblende, plagioclase and groundmass. The granodiorite is generally barren of mineralization, but locally contains up to 0.5% pyrite. Drill core displays local K-feldspar and pyrite in minor quartz veins.

Contacts between granodiorite and BQDP and between granodi-

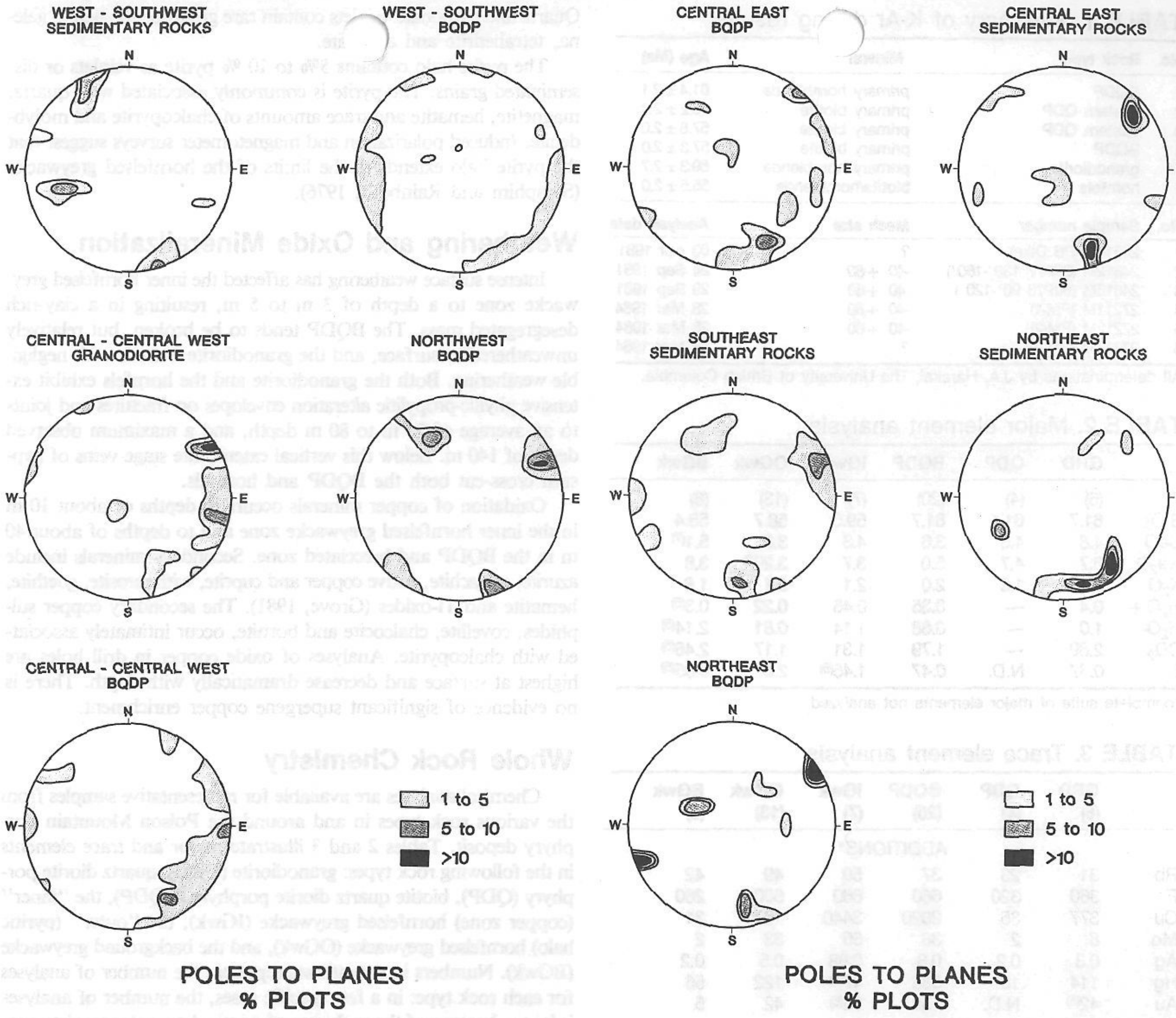

FIGURE 5. Major joint planes.

orite and the hornfelsed sedimentary rocks are sharp, bleached, and lack brecciation, where intersected in drill core. Surface mapping disclosed several QDP dikes cross-cutting the granodiorite.

Alteration

Mineralization at Poison Mountain is hosted equally by BQDP and hornfelsed greywacke. Four overlapping phases of alteration are indicated by thin section studies: in order of importance, these are potassic, minor phyllic, propylitic, and supergene. Major and trace element analyses show consistent patterns with those of Oyarzan (1974) where potassic alteration is outlined.

Potassic alteration is defined by biotite alteration of the host greywacke and diorite, together with quartz-K-feldspar veining and with sulphide and oxide mineralization. Near the diorite contact the granodiorite is cut by quartz and K-feldspar veins. Sulphide mineralization is intimately associated with the potassic alteration as indicated by quartz-biotite-sulphide segregations, sulphide-quartz-K-feldspar veining and magnetite-sulphide veinlets and blebs in both greywacke and BQDP.

Phyllic alteration of greywacke consists of sericite-carbonate ± chlorite-epidote formed within clastic plagioclase and its surrounding matrix. The same phyllic assemblage envelopes quartz and K-feldspar veins in BQDP. Phyllic alteration also occurs in bleached zones around sericite-carbonate ± clay (gouge), epidote and chlorite composed fractures or shears.

Propylitic alteration in the deposit area may be retrograde in nature, since the granodiorite, diorites and hornfelsed greywacke show minor amounts of carbonate, chlorite and epidote with trace amounts of actinolite, sericite and clay.

Geochronometry

Six rock samples, representing various intrusive rocks and biotite hornfelsed sedimentary rocks, were dated by the K-Ar method at The University of British Columbia. The results, tabulated below (Table 1), show that the intrusive events were fairly closely clustered around approximately 58 Ma or Late Paleocene. The date of 55.5 Ma ± 2.0 Ma on the mixed biotite/hornblende from the hornfelsed sedimentary rock seems somewhat young, given the presumed geological sequence of events.

Economic Geology

Copper-Gold-Molybdenum Mineralization

Sulphide mineralization straddles the arcuate contact between BQDP and hornfelsed greywacke. The principal sulphide minerals are pyrite, chalcopyrite, molybdenite and bornite. The highest copper

TABLE 1. Summary of K-Ar dating results

No.	Rock type	Mineral	Age (Ma)
1	BQDP	primary hornblende	61.4 ± 2.1
2	eastern QDP	primary biotite	58.2 ± 2.0
3	eastern QDP	primary biotite	57.8 ± 2.0
4	BQDP	primary biotite	57.3 ± 2.0
5	granodiorite	primary hornblende	59.3 ± 2.7
6	hornfels	biotite/hornblende	55.5 ± 2.0

No.	Sample number	Mesh size	Analysis date
1	24610 (PPB Dike)	?	03 Apr 1981
2	24612M (80P77 130′-160′)	-40 +80	24 Sep 1981
3	24613M (80P78 90′-120′)	-40 +60	29 Sep 1981
4	27211M (PM-1)	-40 +80	28 Mar 1984
5	27212M (PM-2)	-40 +60	28 Mar 1984
6	27213M (PM-4)	?	28 Mar 1984

All determinations by J.A. Harakal, The University of British Columbia.

TABLE 2. Major element analysis

*	GRD	QDP	BQDP	IGwk	OGwk	BGwk
	(6)	(4)	(20)	(7)	(13)	(8)
SiO_2	61.7	61.1	61.7	59.5	58.7	58.4
CaO	4.8	4.6	3.6	4.3	3.8	$5.1^{(7)}$
Na_2O	5.7	4.7	5.0	3.7	$3.2^{(12)}$	3.8
K_2O	2.1	1.8	2.0	2.1	2.1	1.8
H_2O+	0.4	—	0.35	0.45	0.22	$0.3^{(5)}$
H_2O-	1.0	—	0.68	1.14	0.81	$2.14^{(5)}$
CO_2	2.89	—	1.79	1.31	1.17	$2.46^{(5)}$
S	0.37	N.D.	0.47	$1.45^{(6)}$	2.0	$0.05^{(5)}$

*complete suite of major elements not analyzed.

TABLE 3. Trace element analysis

	GRD (6)	QDP (4)	BQDP (20)	IGwk (7)	OGwk (13)	BGwk (8)
			ADDITIONS*			
Rb	31	23	37	50	49	42
F	360	320	660	660	500	260
Cu	377	35	2020	3440	1070	31
Mo	8	2	36	65	33	2
Ag	0.3	0.2	0.8	0.88	0.5	0.2
Hg	114	18	336	$47^{(6)}$	122	56
Au	$42^{(5)}$	N.D.	159	$86^{(6)}$	42	5
*values in ppm except Au and Hg in ppb						
			LOSSES**			
Sr	730	845	630	375	380	$360^{(7)}$
Ba	610	780	660	500	485	750
As	7	6	8	12	10	18
Sb	<3	N.D.	<6	<5	<5	8
Pb	$6^{(5)}$	4	$8^{(19)}$	<6	3	$24^{(7)}$
Zn	25	85	33	35	$35^{(12)}$	86
**values in ppm						

grades are within BQDP and adjacent brecciated hornfels; the highest gold grades are within BQDP. Molybdenite is concentrated, albeit at low levels, within hornfels at the outer edge of the copper-gold zone.

The BQDP contains 0.5% to 1.0% pyrite as disseminated grains and fracture fillings, within quartz and K-feldspar veins, or in association with other sulphides, magnetite and hematite. The BQDP also contains 0.5% to 2.0% chalcopyrite, which is intergrown with <0.5% bornite. Trace amounts of molybdenite are found in quartz veins and along fractures.

The hornfelsed greywacke is subdivided into an inner copper zone, defined by the 0.20% Cu contour (Fig. 4), and an outer pyritic halo. Sulphide mineralization is similar to that hosted by BQDP, but quantities differ. The inner zone contains 0.5% to 2.0% pyrite and 0.5% to 2.0 % chalcopyrite, minor amounts of molybdenite, and traces of bornite. Chalcopyrite and pyrite are most often found on fractures or in veins of magnetite-hematite or quartz. The abundance of chalcopyrite decreases as the pyrite halo is approached. Quartz and carbonate veinlets contain rare grains of sphalerite, galena, tetrahedrite and a[illegible]ite.

The pyrite halo contains 5% to 10 % pyrite as veinlets or disseminated grains. The pyrite is commonly associated with quartz, magnetite, hematite and trace amounts of chalcopyrite and molybdenite. Induced polarization and magnetometer surveys suggest that the pyrite halo extends to the limits of the hornfelsed greywacke (Seraphim and Rainboth, 1976).

Weathering and Oxide Mineralization

Intense surface weathering has affected the inner hornfelsed greywacke zone to a depth of 3 m to 5 m, resulting in a clay-rich desegregated mass. The BQDP tends to be broken, but relatively unweathered at surface, and the granodiorite is fresh with negligible weathering. Both the granodiorite and the hornfels exhibit extensive phyllic-propylitic alteration envelopes on fractures and joints to an average of 70 m to 80 m depth, and a maximum observed depth of 140 m. Below this vertical extent, late stage veins of gypsum cross-cut both the BQDP and hornfels.

Oxidation of copper minerals occurs to depths of about 10 m in the inner hornfelsed greywacke zone and to depths of about 40 m in the BQDP and brecciated zone. Secondary minerals include azurite, malachite, native copper and cuprite, with jarosite, goethite, hematite and Ti-oxides (Grove, 1981). The secondary copper sulphides, covellite, chalcocite and bornite, occur intimately associated with chalcopyrite. Analyses of oxide copper in drill holes are highest at surface and decrease dramatically with depth. There is no evidence of significant supergene copper enrichment.

Whole Rock Chemistry

Chemical analyses are available for representative samples from the various rock types in and around the Poison Mountain porphyry deposit. Tables 2 and 3 illustrate major and trace elements in the following rock types: granodiorite (GRD), quartz diorite porphyry (QDP), biotite quartz diorite porphyry (BQDP), the "inner" (copper zone) hornfelsed greywacke (IGwk), the "outer" (pyritic halo) hornfelsed greywacke (OGwk), and the background greywacke (BGwk). Numbers in parentheses represent the number of analyses for each rock type: in a few specific cases, the number of analyses is lower, because of the exclusion of erratic data or incomplete analyses. More details of the analytical results are presented in Appendix I.

The major element analyses (Table 2) generally show that there is little variation between mineralized and unmineralized rocks. In the greywacke, there appears to be a very slight increase in SiO_2, reflecting silicification, and slight decreases in CaO and CO_2, reflecting possible destruction of carbonate minerals. The marked increase in sulphur in the outer hornfels zone reflects the pyrite halo around the copper zone.

The trace element analyses (Table 3) are divided into two groups. The first includes those elements that typically are more abundant within the copper zone. The second includes those elements that commonly are depleted within the copper zone, or that show no real trend.

The granodiorite, which cannot be directly compared to the BQDP due to its compositional differences, has distinctive major element values, with the exception of SiO_2 which is the same as the BQDP at 61.7%. Elevated trace element values in the granodiorite include Cu at 377 ppm, Mo at 8 ppm, Au at 85 ppb and Hg at 114 ppb.

Quoting Chilean porphyry copper deposits, Oyarzan (1974) observed that during the process of potassium metasomatism K_2O is enriched in biotite, sericite, alunite and K-feldspar at the expense of Na_2O and CaO. The elements Rb and Sr ionically substitute for K_2O and CaO and are more sensitive to hydrothermal reactions, giving increases in absolute Rb, K and Rb/Sr, Ca/Sr, and decreases in Sr, Ca and K/Rb. Oyarzan observed intense metasomatism which obliterated original rock type changes.

Major and trace element analyses at Poison Mountain show decreasing abundances of CaO and Sr, increasing abundances of K_2O, Rb and larger K_2O/CaO and Rb/Sr (Appendix I), both from QDP to BQDP and from background greywacke to hornfelsed greywacke. The BQDP and hornfelsed greywacke have distinctly more Cu, Mo, Ag, Au, F and Hg and less Ba and Zn than their unmineralized equivalents.

At Poison Mountain the petrology, and major and trace element analyses do not show the intensity of potassic alteration demonstrated by Chilean deposits (Oyarzun, 1974), Highland Valley deposits (Olade and Fletcher, 1975) and the Panguna porphyry (Papua New Guinea) deposit (Ford, 1978). The Poison Mountain system is more akin to the Granisle porphyry copper deposit, British Columbia, a biotite-rich system with an extensive sulphur anomaly (hydrothermal pyrite) (Jambor, 1974).

Economics

Ore Reserves

In-situ geological ore reserves at a 0.15% Cu sulphide (S) cutoff from block modelling (Nunn, 1982) were calculated at:

(1) Oxide Zone 40 211 000 tonnes
grading Cu (S) = 0.228%, Au = 0.127 g/t, Mo = 0.007%
Cu oxide (O) = 0.15%

(2) Sulphide Zone 768 315 000 tonnes
grading Cu (S) = 0.232%, Au = 0.122 g/t, Mo = 0.007%

Ore reserves at a 0.15% Cu (S) cutoff adequate for a 20-year mining plan (Nunn, 1982) were calculated at:

Ore 412 175 000 tonnes
Waste 143 994 000 tonnes
Strip Ratio = 0.35 : 1
Cu (S) = 0.24%, Au = 0.14 g/t, Mo = 0.007%

A higher grade core (Hogan, 1987) centred in the above ore reserves has been calculated at:

Higher Grade 4 140 000 tonnes
Cu (S) = 0.33%, Au = 0.34 g/t

Mining Methods

Preliminary mine feasibility studies by Kilborn Engineering (1982) considered an escalating 20 000 (years 1-5), 40 000 (years 6-10) and 60 000 (years 11-20) tonnes of ore per day open pit operation. It would be similar in operation to other British Columbia open pit copper mines using 10 m^3 shovels, 120 ton trucks and large diameter rotary blast hole drills.

Metallurgical Testwork

During 1980-1981, two extensive laboratory test programs were carried out, using drill core composite samples. The first was designed to develop a suitable bulk flotation process and to determine the work index of the feed. The second was to investigate flotation responses as a function of possible variations with depth on several vertical blocks. Material from the inner hornfelsed greywacke zone and the BQDP displayed similar responses to the test condition and variables. The average work index was determined to be 11.5.

The flotation test work involved a "locked cycle test" scheme, with initial grinding to 67% minus 200 mesh followed by a rougher flotation and three cleaner flotation stages. All tailings were recycled: first cleaner back to rougher after regrinding to 100% minus 200 mesh; second cleaner back to rougher; and third cleaner back to first cleaner. Rougher flotation tails went through scavenger flotation, whence concentrates were also reground to 100% minus 200 mesh and returned to rougher flotation. The scavenger tails represented the final tailings product; the final product was the third cleaner flotation bulk concentrate.

The arithmetic average of the test results on the seven blocks suggest a final product could be a bulk concentrate assaying 25.21% Cu, 0.405% Mo, with 11.42 g/t Au and 64.78 g/t Ag. The recoveries averaged 92.5% for copper, 87.5% for molybdenum, 67.5% for gold and 39.7% for silver.

Environmental Impact

Four baseline studies initiated by Lac Minerals Ltd. between 1981 and 1983, were carried out by Envirocon Limited. The programs which constitute Stage One environmental impact studies, were as follows: hydrology, surface water hydrology, atmospheric environment, and distribution of California bighorn sheep in the Poison Mountain area.

Regional hydrogeological mapping (Vogwill, 1981) indicates low rock permeability and excellent ground water quality. Highly variable rock permeability is associated with the fractured rocks of the deposit. A surface water hydrology monitoring program (Boyle, 1983) was carried out over a one year period in the Yalakom Creek and Churn Creek drainages, in order to determine runoff and water balance. Figures for the year were computed to be: precipitation, 574 mm; runoff, 135 mm; and evapotranspiration, 439 mm.

A wide-ranging study (Boyle, 1982), covering Churn Creek, Red Mountain, Nine Mile Ridge, Yalakom Mountain, the northern Shulaps Range and the Poison Mountain area (Fig. 1) was designed to quantify the movements and distribution of various populations of California bighorn sheep. The southern subpopulation would potentially be affected by an improved access road and increased traffic along Yalakom Creek.

Economic Analysis

Calculations were made by Kilborn Engineering (1982) and Hogan (1988) using a milling rate of 40 000 tonnes per day, and various metal prices. Using the 1982 prices of $0.90 per pound copper, $500 per ounce gold and $4.50 per pound molybdenum the Net Cash Flow and Net Present Value (at a 15% discount rate) of the deposit was insufficient to proceed with the project. Price combinations used were: copper at $0.90, $1.50, and $2.00 per pound with gold at $500 per ounce; and, copper at $0.90 per pound with gold at $1,000 per ounce. Molybdenum was calculated at $4.50 per pound. Smelting and refining charges used were 25% of the copper price for copper, 9% of the gold price for gold, and 9.0% of the silver price for silver. All prices are quoted in Canadian dollars.

Discussion and Conclusions

Porphyry copper-molybdenum-gold mineralization at Poison Mountain is intimately associated with potasically-altered BQDP and hornfelsed Lower Cretaceous Jackass Mountain Group arenaceous sedimentary rocks.

Although there are numerous QDP intrusions in the area, only those coincident with granodiorite at Poison Mountain and Fenton Creek have potassic alteration and mineralization. Geological and age dating evidence suggests that the QDP and granodiorite were components of a Paleocene intrusion at Poison Mountain. The QDP and sedimentary rocks have been altered and mineralized in concentric zones around the granodiorite. These include biotite-altered QDP and hornfelsed greywacke, copper-gold-molybdenum mineralization, and a pyritic halo. The BQDP has been cataclastically deformed, probably, by the intrusion of the massive granodiorite. Field observation and petrographic inconsistencies, such as a QDP dike in the granodiorite and granodiorite fragments in BQDP, support a contemporaneous QDP and granodiorite intrusive event.

Comprehensive studies of the site environment, ore reserves, metallurgy, mining and milling methods, and economics have been completed, without encountering technical obstacles. Economic analysis indicates that the deposit will not support bulk mining at present metal prices.

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Appendix I. Major and trace element analyses

Elements background (Number of analysis)	Granodiorite (6)	Biotitized Q.D. porphyry (20)	Quartz diorite porphyry (4)	>0.25% Cu equiv. hornfelsed greywacke (7)	Pyrite Halo hornfelsed greywacke (13)	Greywacke (8)
SiO_2%	61.7 (55.0-62.0)	61.7 (59.-63.5)	60.1 (59.5-60.5)	59.5 (57.5-61.0)	58.7 (55.0-63.0)	58.4 (50.5-61.5)
CaO%	4.8 (3.6-5.7)	3.6 (2.1-7.0)	4.6 (4.6-4.7)	4.3 (2.45-6.0)	3.8 (2.75-4.8)	(5.1) 6.0 (4.3-12.3*)
Na_2O%	5.7 (5.0-6.1)	5.0 (3.2-5.8)	4.7 (4.6-5.8)	3.7 (3.3-4.5)	3.2(12) (2.5-5.3)	3.8 (3.0-4.4)
K_2O%	2.1 (1.8-2.5)	2.0 (1.6-2.7)	1.8 (1.7-1.8)	2.1 (1.8-2.6)	2.1 (1.8-2.5)	1.8 (1.5-2.5)
S%	0.37 (0.21-0.47)	0.47 (0.08-1.44)	N.D.	1.45 (6) (1.27-1.59)	2.0 (0.64-3.26)	0.05(5) (0.02-0.11)
$H_2O(+)$% @105°C	0.40 (<0.2-0.55)	0.35 (0.15-0.55)		0.45 (0.15-0.80)	0.22 (0.14-0.38)	0.3(5) (0.2-0.5)
$H_2O(-)$% @950°C	1.0 (<0.02-3.1)	0.68 (<0.05-2.65)		1.14 (0.7-2.6)	0.81 (<0.05-3.35)	2.14 (5) (0.75-4.6)
CO_2%	2.89 (1.19-3.95)	1.79 (0.7-3.0)		1.31 (0.1-2.7)	1.17 (0.4-2.8)	2.46 (5) (0.45-6.15*)
Rb ppm	31 (16-46)	37 (19-54)	23 (21-25)	50 (40-66)	49 (36-66)	42 (35-49)
Sr ppm	730 (520-970)	630 (480-960)	845 (815-865)	375 (275-470)	380 (285-590)	(360)420 (280-845*)
Ba ppm	610 (540-690)	660 (440-800)	780 (710-800)	500 (360-660)	485 (320-735)	750 (400-1430)
F ppm	360 (230-520)	650 (440-860)	320 (110-430)	660 (440-860)	500 (330-590)	260 (190-360)
As ppm	7 (3-13)	8 (2-18)	6 (3-11)	12 (2-60)	10 (2-32)	18 (3-55)
Sb ppm	<3 (<2-6)	<6 (<2-30)	N.D.	<5 (<2-<5)	<5 (<2-<5)	8 (N.D.-36)
Cu ppm	377 (107-595)	2020 (940-4100)	35 (32-42)	3440 (1900-4900)	1070 (210-1900)	31 (17-74)
Pb ppm	(6) 16 (2-68*)	(8) 14 (<2-132*)	4 (2-4)	<6 (<2-24)	3 (<2-7)	(24) 39 (2-144*)
Zn ppm	25 (15-38)	33 (18-89)	85 (55-123)	35 (26-42)	(35) 66 (35) (23-440*)	86 (48-187)
Mo ppm	8 (15-38)	36 (3-87)	2 (1-2)	65 (31-100)	33 (11-91)	2 (2-3)
Ag ppm	0.3 (0.2-0.5)	0.8 (0.2-1.9)	0.2 (0.2-0.2)	0.8 (0.4-1.4)	0.5 (0.2-1.4)	0.2 (0.2-0.4)
Au ppb	(42) 85 (25-300*)	159 (55-500)	N.D.	(86) 134 (75-420*)	42 (13-127)	5 (N.D.-15)
Hg ppb	114 (30-250)	336 (20-900)	18 (15-20)	(47) 88 (20-287*)	122 (30-510)	56 (30-90)
K_2 O/Rb × 100	6.8	5.4	7.7	4.2	4.3	4.3
Ca O/Sr × 100	0.7	0.6	0.5	1.1	1.0	1.4
Rb/Sr	0.04	0.06	0.03	0.13	0.13	0.10
K_2O/CaO	0.44	0.56	0.39	0.49	0.55	0.3

(57.7) 61.7 (5)
(55.0-62.0*)
*Erratic High Value
(57.7) Average if One Erratic High Value Removed
61.7 Average value
(5) Number of Analysis
(55.0-62.0) Range