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Some Chemicel Characteristics of the Intrusive Rocks of the Bethlehem Porphyry Copper Deposits, B. C., Canada

By

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Abstract

The results of preliminary chemical and optical study of the intrusive rocks of the Bethlehem porphyry copper deposits, B.C., Canada are reported and are compared with similar intrusive rocks of the United States. The intrusive rocks related in time and space to the porphyry copper mineralization in North America seem to have a wide range of composition, but belong to calc-alkalic rock series with two exceptions of sub-alkalic rock series. Of these rocks, the Bethlehem intrusives are characterized by the least potassic and most calcic nature. The propylitic alteration at Bethlehem can be regarded as the lowest grade alteration in the general sense, but the potassium-poor nature of the host intrusive rocks, besides P-T conditions, seems to be an important factor for the absence of potassic silicate assemblages in the alteration zone.

Introduction

The Bethlehem copper deposits, located in Highland Valley in the southern interior of British Columbia, Canada (Figure 1), are generally understood as porphyry copper-type ore deposits. They are composed of four known ore bodies of Huestis, Jersey, East Jersey and Iona, and relatively new Valley Copper. Hirata (1965) pointed out many similarities of intrusive rocks, structural features, and modes of occurrence of sulfide distribution between the Bethlehem copper deposits and the so-called porphyry copper deposits in the United States and South America.

The Bethlehem copper deposits are situated at the center of the Guichon batholith, which as a whole intrudes volcanic rocks of the Upper Triassic Karnic stage and is unconformably overlain by Middle and Upper Jurassic marine sedimentary rocks (Carr, 1966). The K-Ar mineral age is 200±5 m. y. (White and Carter, 1968). At Bethlehem the Guichon batholith is divided into two major units of older quartz diorite and younger quartz diorite (Hirata, 1965). The former is the main phase of the Guichon batholith. The latter consists of stock-like form of the Bethlehem quartz diorite (Figure 2), dike-forming dacite porphyry and crowded porphyry, and intrusive breccia.

Carr (1966) stated that 1) the younger quartz diorite contact, 2) porphyry intrusion and accompanying brecciation, and 3) faults, are important factors to locate both mineralization and alteration. The mineralization is a combination of sulfide vein, stock-work, and dissemination. Chalcopyrite, bornite, molybdenite, and specularite are the major opaque minerals, but pyrite is rather rare. Chloritization, epidotization and argillization are distict. Sericite is also present. Little tourmaline occurs in the matrix of breccia pipe ore bodies (Hirata, 1965).

During a short visit to the Bethlehem mine in 1968, the writer collected a small amount of hand specimens. Four selected specimens were analyzed and a few other specimens microscopically examined.

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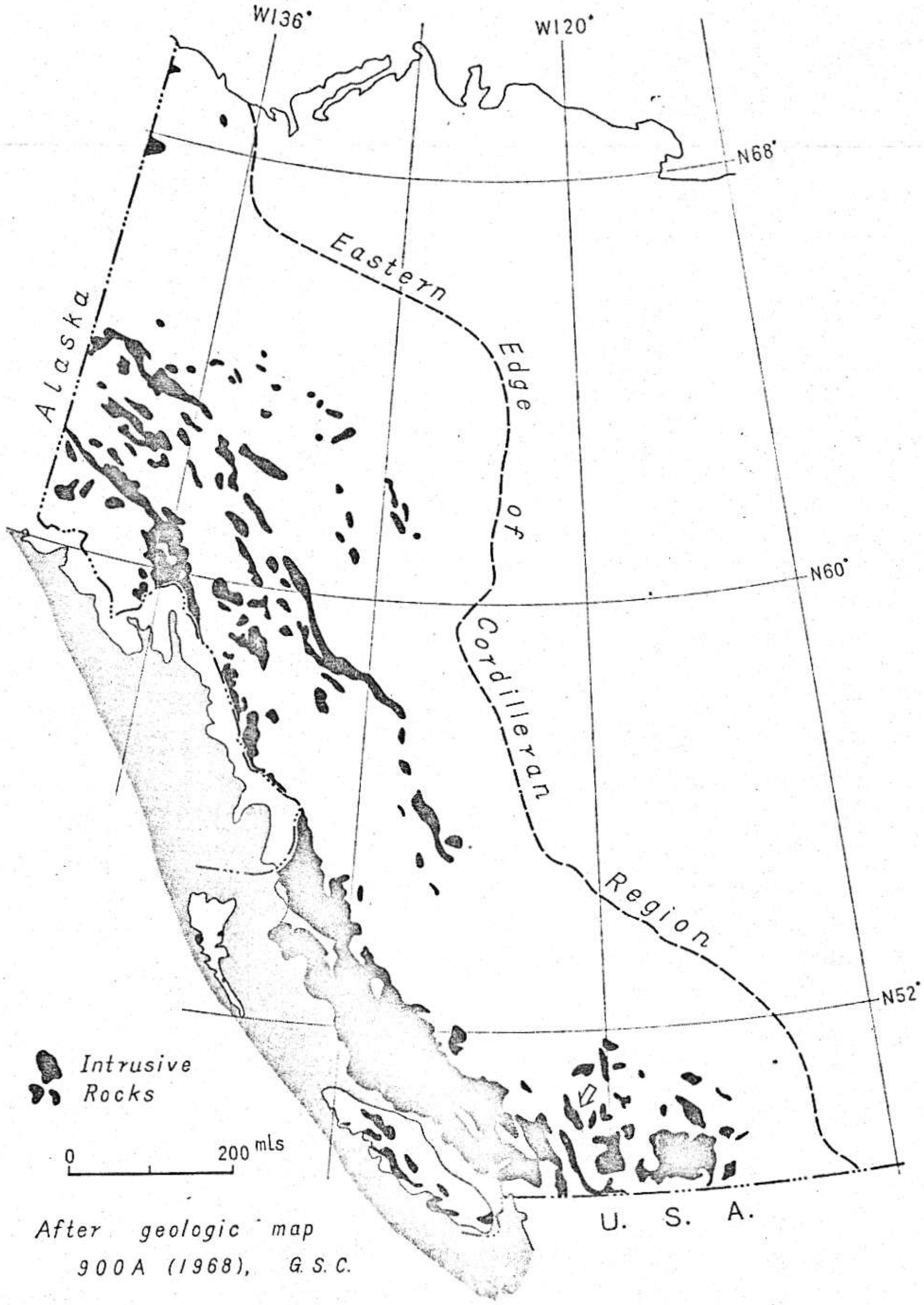

Fig. 1 Location of the Bethlehem copper deposits in the Canadian Cordillera.

The following description is based on this preliminary examination.

Analyzed Specimens

Chemical analyses of the four specimens are listed in Table 1. The samples were collected in the Jersey pit, where even rocks with fresh outlook were altered to various degrees. The analyzed specimen

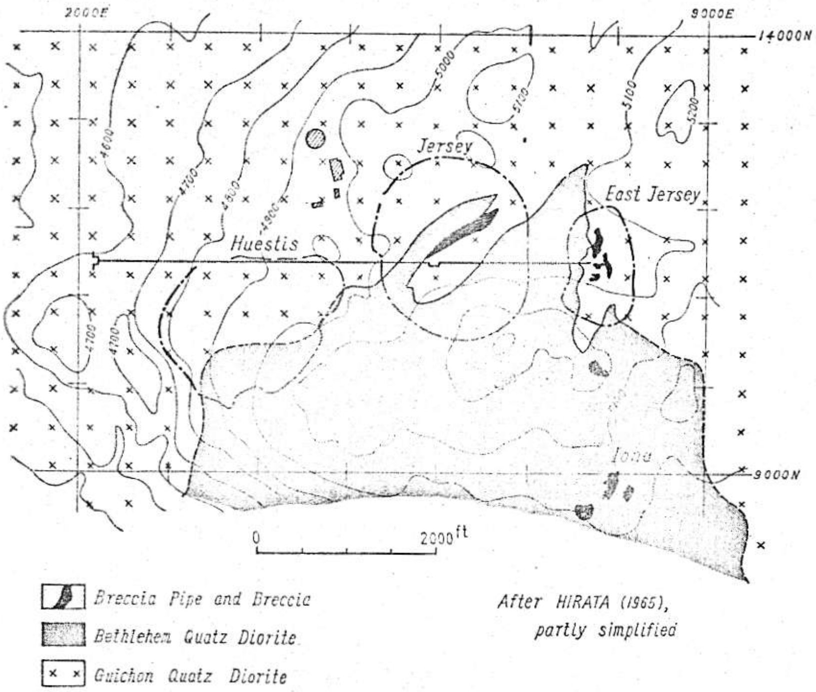

Fig. 2 Location of the four orebodies distributed around the margin of the Bethlehem quartz diorite.

No. 1 of the Guichon batholith is a hollocrystalline medium-grained rock with the IC number (CHAYES, 1956) of 83. The grain size seems to be much finer than that of common granitic rocks exposed in the core of the Circum Pacific belt. The Japanese examples of the granitic rocks show the IC number around 40 (ISHIHARA, 1971). The major constituents are, in order of abundance, plagioclase, mafic minerals, quartz, and potassium feldspars. Potassium feldspars occur in small amount but are distinct in hand specimens because of the slightly reddish brown color. The color is darker than that of ordinary quartz dioritic rocks.

Microscopic observation indicates that plagioclase and mafic minerals are mostly euhedral. The interstices are filled with mainly anhedral quartz. Normative plagioclase composition as the whole is about An_{40} (Table 1). The plagioclase is rarely zoned, and always contains specks of alteration minerals such as sericite, actinolite, albite, and clay minerals. The secondary albite occurs also in the interstices of plagioclase. There are no fresh mafic minerals in the analyzed specimen. The observed minerals are actinolite, chlorite, and epidote. The outline of the pseudomorph indicates biotite and hornblende to be the original minerals.

The analyzed specimen No. 2 of the Bethlehem quartz diorite is very similar to the specimen No. 1, but it is slightly finer (IC number of 114), lighter-colored, and prophyritic due to aggregates of amphiboles. Under the microscope the alteration is weaker than that of No. 1. Plagioclase is more commonly zoned. Normative plagioclase is calculated as An_{35}. Potassium feldspars are subhedral and show microperthitic structures with irregular form of albite lamellae. Amphiboles have been converted to chlorite, opaque minerals and carbonates, but a part of biotite is retained in the chloritization. The biotite has $Y \fallingdotseq Z$ of pale brown, which is often described in hydrothermally altered zones of some ore

Table 1 Chemical analyses of the intrusive rocks from the Jersey pit, Bethlehem copper deposits.

Sample No.		1	2	3	4
S. G.	Bulk	2.67	2.74	2.70	2.62
	Powder	2.82	2.74	2.75	2.74
SiO_2		60.71	66.19	64.89	67.60
TiO_2		0.68	0.29	0.38	0.39
Al_2O_3		16.94	17.42	17.35	16.79
Fe_2O_3		2.39	1.19	1.20	0.10
FeO		2.66	1.54	2.28	1.47
MnO		0.09	0.03	0.04	0.05
MgO		2.69	1.25	1.51	1.40
CaO		5.55	4.23	4.43	2.32
Na_2O		4.31	4.41	3.77	4.32
K_2O		1.04	1.31	0.52	0.78
P_2O_5		0.24	0.13	0.15	0.14
Cu				tr	0.33
Fe			0.04	0.25	0.63
S		<0.01	0.04	0.29	0.72
SO_3				<0.01	<0.01
$H_2O(+)$		2.16	1.46	2.62	2.40
$H_2O(-)$		0.32	0.16	0.06	0.28
Total		99.78	99.69	99.74	99.70
il		1.29	0.55	0.72	0.74
ap		0.52	0.28	0.33	0.31
mg		3.46	1.73	1.74	0.14
py		tr	0.08	0.54	1.35
or		6.15	7.74	3.07	4.61
ab		36.47	37.32	31.90	36.56
an		23.79	20.24	21.08	10.67
C			1.33	2.86	4.93
wo		0.97			
en		6.70	3.11	3.76	3.49
fs		1.96	1.36	2.64	2.04
qz		15.99	24.31	28.41	31.85
Total		97.30	98.05	97.05	96.69
Femic total		14.90	7.11	9.73	8.07
or+ab+qz		58.61	69.37	63.38	73.02
DI		60.2	70.8	65.2	75.5
an/an+ab × 100		39.5	35.2	39.8	22.6

Analyst: K. OHTA.
No. 1: Guichon quartz diorite, Jersey pit 4,900 ft bench; 2: Bethlehem quartz diorite, 4,900 ft bench; 3: Altered Bethlehem quartz diorite (chilled phase), 4,700 ft bench; 4: Altered and mineralized Bethlehem quartz diorite, 4,700 ft bench.
Fe: equivalent to each sulfur content in the form of FeS_2 subtracted from Fe_2O_3.

deposits occurring in granitic rocks.

The specimen No. 3 is a porphyritic rock with aphanitic matrix. Mafic minerals are the most distinctive phenocrysts. Under the microscope, the rock shows a porphyritic texture with phenocrysts of plagioclase and mafic minerals in the cryptocrystalline groundmass (Figure 3). This is a chilled phase of the Bethlehem quartz diorite having slightly more "basic" composition than the proper phase

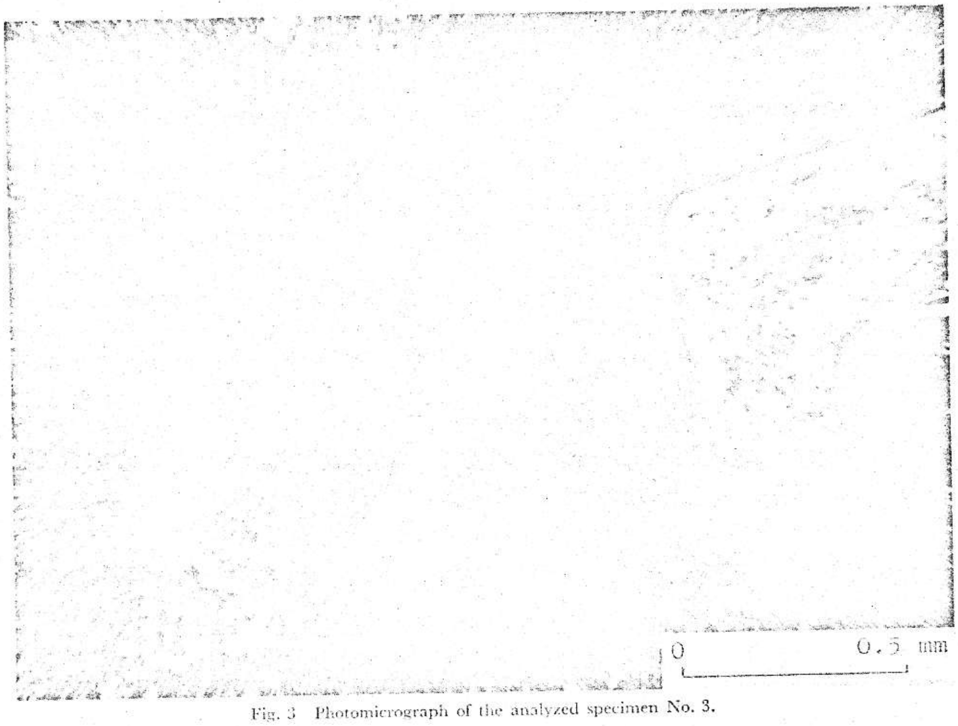

Fig. 3 Photomicrograph of the analyzed specimen No. 3.

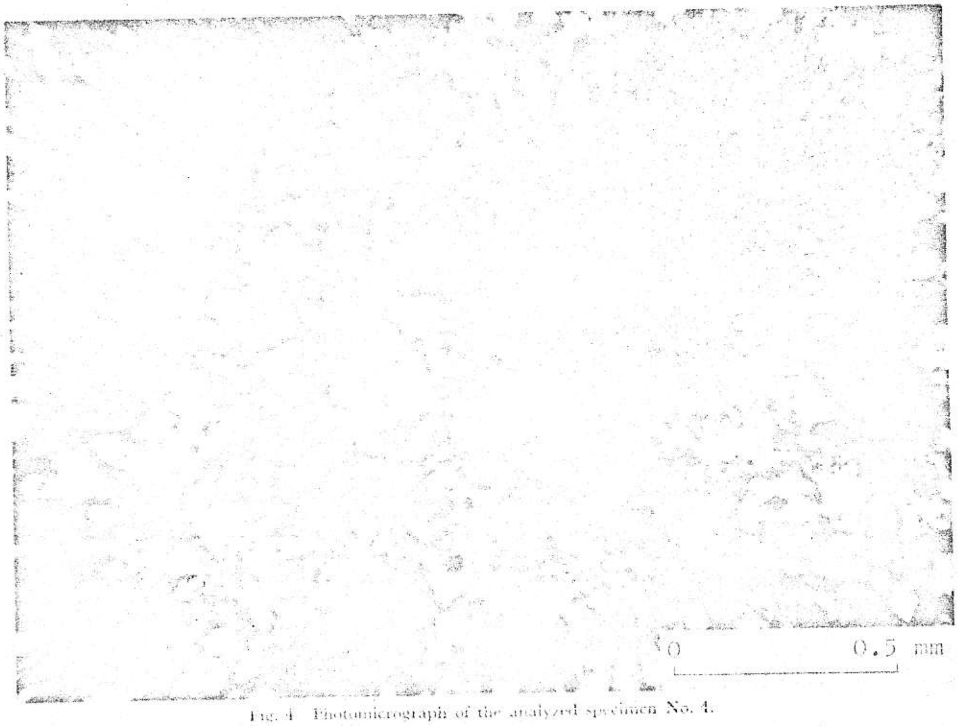

Fig. 4 Photomicrograph of the analyzed specimen No. 4.

of the Bethlehem quartz diorite (Table 1). The rock is also altered moderately in the same manner as the specimens No. 1 and No. 2. Presence of epidote-group minerals, mainly of clinozoisite, is quite prominent in replacing the original mafic minerals. Specks of sericite in plagioclase are much clearer than that of the specimen No. 1. Normative pyrite is about 0.5%. The copper content is not more than 0.05%.

The analyzed specimen of No. 4 is an altered and slightly mineralized rock of the Bethlehem quartz diorite. This rock consists of phenocrystic plagioclase and groundmass of sugar-like aggregates of quartz, plagioclase (albite), and mafic minerals (Figure 4). This groundmass may have been formed through recrystallization process by hydrothermal alteration. The survived plagioclase has been partly sericitized and argillized, as shown by specks of sericite and clay minerals. Larger crystals of flaky sericite are seen in the limited parts of the groundmass. Some sericite flakes constitute a part of chloritized biotite. This sericite must have been converted from biotite. The original mafic minerals in general have been completely altered to chlorite and epidote. Disseminated copper sulfides in most cases occur associated with these mafic alteration products. The assemblage of the altered minerals indicates that the specimen belongs to propyritic alteration of Creasey (1966). More advanced alteration of sericite-quartz assemblage is observed in the restricted parts around molybdenite and/or copper sulfides-bearing quartz veins or fractures at Bethlehem.

Results and Interpretation

Intrusive rocks: The analyzed Bethlehem quartz diorite is relatively fresh, while the Guichon quartz diorite is slightly altered as described in the previous section. However, these specimens may be considered fresh rocks among those from porphyry copper deposits. The two quartz diorites show the feldspar ratio between quartz diorite and granodiorite (Figure 5). The characteristic is the higher contents of quartz and plagioclase. A typical evolution trend of a calc-alkalic rock series on this diagram should be from the plagioclase corner to the quartz-orthoclase side-line. Most of the United States examples follow roughly this trend except for those from the Bingham and Robinson. The Bethlehem intrusive rocks are more

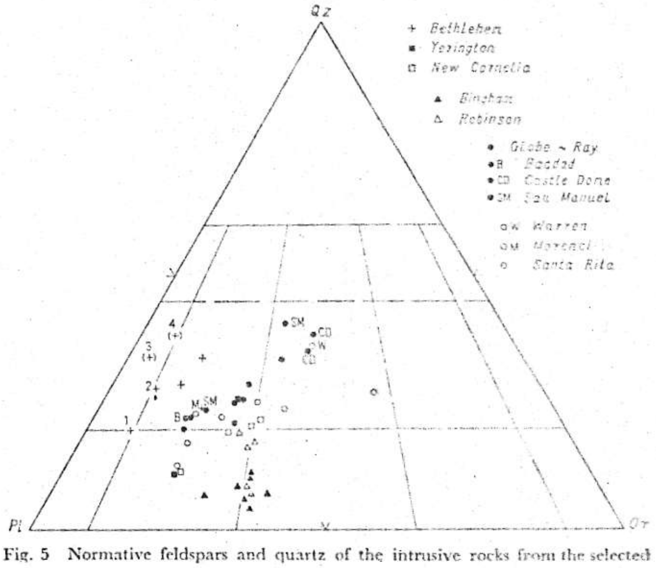

Fig. 5 Normative feldspars and quartz of the intrusive rocks from the selected North American porphyry copper deposits.

Table 2 Additional chemical analyses of the intrusive rocks from the Highland Valley area, collected by T. Tatsumi in 1970.

		1401	1411	1501
	SiO_2	67.17	63.27	71.68
	TiO_2	0.27	0.36	0.18
	Al_2O_3	17.10	16.77	15.66
	Fe_2O_3	1.16	1.16	0.68
	FeO	1.26	1.26	0.68
	MnO	0.06	0.06	0.04
	MgO	1.07	1.12	0.47
	CaO	3.98	4.76	2.46
	Na_2O	4.15	3.46	4.53
	K_2O	1.77	2.62	2.03
	P_2O_5	0.14	0.15	0.08
	CO_2	0.03	2.06	
	S	0.02	0.01	
	$H_2O(+)$	1.10	2.60	1.15
	$H_2O(-)$	0.28	0.22	0.20
	Total	99.56	99.88	99.84
Normative Constituents	il	0.51	0.68	0.34
	ap	0.31	0.33	0.17
	mg	1.68	1.68	0.99
	or	10.46	15.48	12.00
	ab	35.12	29.28	38.33
	an	18.90	22.48	11.76
	C	1.42		1.70
	wo		0.10	
	en	2.66	2.79	1.17
	fs	1.03	0.88	0.46
	qz	26.04	21.28	31.57
	Total	98.13	94.98	98.49
	Femic total	6.19	6.46	3.13
	qz+ab+or	71.62	66.04	81.90
	DI	73.0	69.5	83.2
	an/an+ab×100	35.0	43.4	23.5

Analyst: K. OHTA

1401: Bethlehem quartz diorite at Lornex. This specimen is actually coarse-grained actinolite-biotite granodiorite, and some plagioclase has been strongly sericitized and argillized. 1411: "Porphyrite" at Jersey pit, Bethlehem. This specimen can be called altered dacite porphyry. Sericitization and carbonatization are distinct; while epidotization and chloritization are moderate. 1501: Bethsaide granodiorite at southwest of the Valley Copper orebody (ca. 2,000'). This is coarse-grained hornblende(?)-biotite granodiorite. Epidotization is rather obvious.

calcic and silicic than those of the United States. In addition to the Bethlehem quartz diorite, there are many porphyries of dacitic composition related to copper mineralization in time and space at Bethlehem. These porphyries must be more potassic than the Bethlehem quartz diorite (e. g. 1411, Table 2). However, it seems to be true that the Bethlehem copper mineralization is related to more calcic intrusive rocks than those of the United States.

The alkali-lime index by Peacock (1931) also indicates calcic character of the intrusive rocks at Bethlehem. Although the number of the analyses is limited, the following figures can be given for the rocks from the North American porphyry copper deposits.

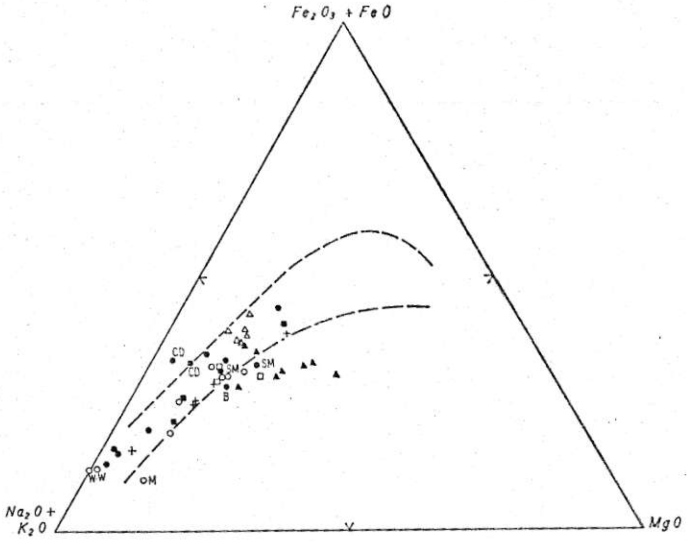

Fig. 6 M-F-A diagram of the intrusive rocks from the selected North American porphyry copper deposits.

About 61:	Bethlehem, Globe-Ray area (Castle Dome), Santa Rita.
59:	New Cornelia
58:	Yerington
56:	Bingham, Robinson.

According to this index, these rocks fall into the range of calc-alkalic suite. The Bethlehem is in the most calcic side, while the Robinson and Bingham in the most alkalic side. In the M–F–A diagram, most of the rocks are plotted in the zone of calc-alkalic series rock. Those of the Last Chance and Bingham stocks occupy a distinctively different field and show a different trend (Figure 6). The term calc-alkalic is designated in many ways (Kuno, 1969), so that it is needed to examine other characters after having more chemical data. In the Harker's diagram (Figure 7) a distinctive difference between intrusive rocks of the Bethlehem and United States porphyry copper deposits is seen in K_2O whose content is low at Bethlehem.

Table 3 Chemical exchange between the unaltered and altered Bethlehem quartz diorite (mg/cc).

	No. 2	No. 4	Losses & gains
SiO_2	1813.6	1771.1	− 42.5
TiO_2	8.0	10.2	+ 2.2
Al_2O_3	477.3	439.9	− 37.4
Fe_2O_3	32.6	2.6	− 30.0
FeO	42.2	38.5	− 3.7
MgO	34.3	36.7	+ 2.4
CaO	115.9	60.8	− 55.1
Na_2O	120.8	113.2	− 7.6
K_2O	32.1	20.4	− 11.7
Cu		8.7	+ 8.7
FeS_2	2.2	35.4	+ 33.2
$H_2O(+)$	40.0	62.9	+ 22.9

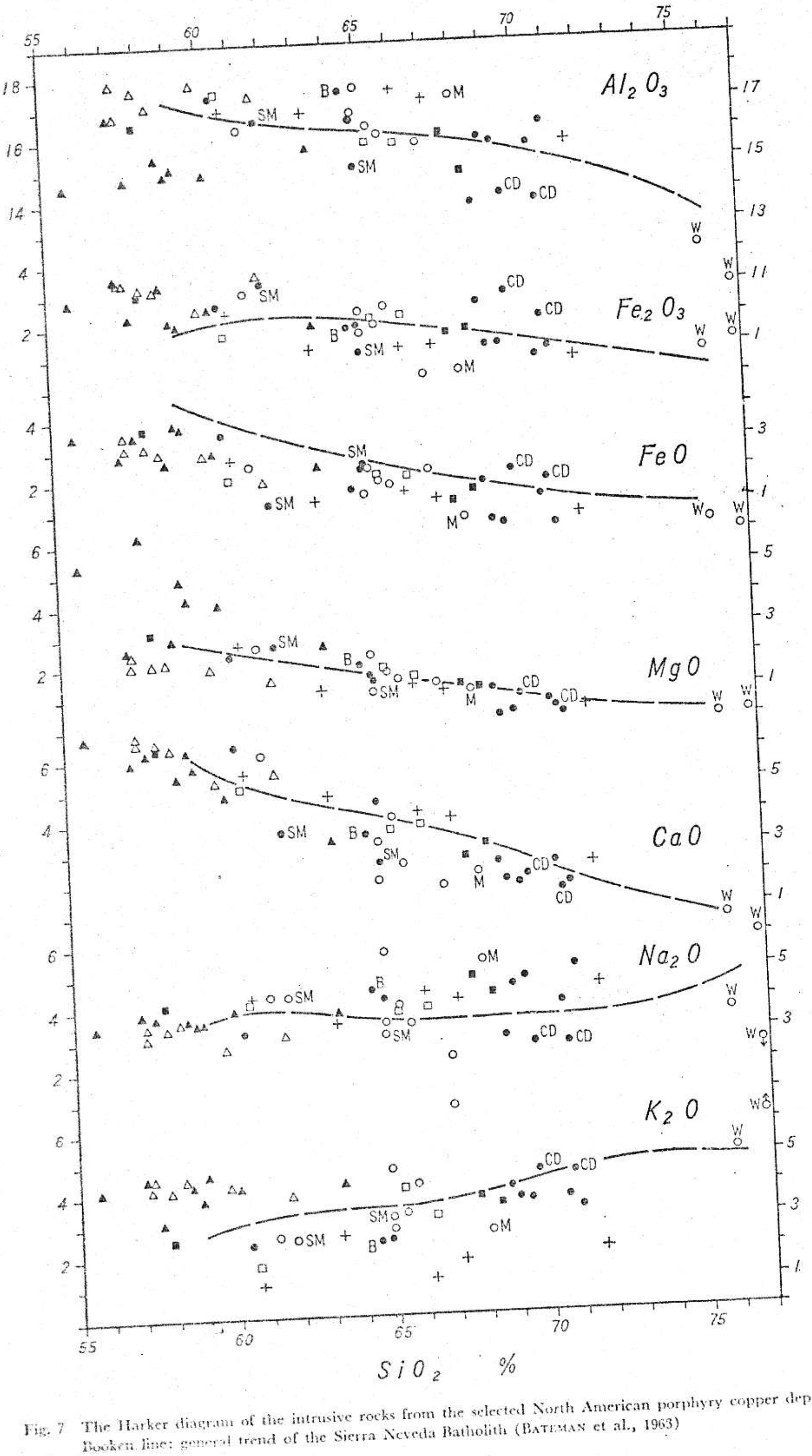

Fig. 7 The Harker diagram of the intrusive rocks from the selected North American porphyry copper deposits. Booken line: general trend of the Sierra Neveda Batholith (BATEMAN et al., 1963)

Chemical changes during alteration: Each component of the specimens No. 2 and No. 4 was calculated in milligram per cubic centimeter and compared to each other in order to know the losses and gains during the propyritic alteration (Table 3). This comparison is debatable because the original composition of the specimen No. 4 must be different from that of the specimen No. 2 owing to heterogeneity of the Bethlehem quartz diorite. Nevertheless, there are coincident losses and gains to the mineralogical changes observed under the microscope. The loss in CaO, Na_2O, and K_2O agress to decomposition of feldspars. No considerable changes are seen on mafic elements as the whole. SiO_2 and Al_2O_3 decrease slightly.

Conclusive Remarks

1) The intrusive rocks at Bethlehem belong to a calc-alkalic suite. They are an example of the commonest intrusive rocks in British Columbia of saturated series of Brown (1969, p. 34). Intrusive rocks of diorite-monzonite-syenite series reported by Brown (1969) are not observed among the area of the porphyry copper deposits examined in this paper. Some intrusive rocks in the Robinson area are normatively undersaturated ones, but they seem to become saturated rocks continuously during the fractional crystallization.

2) The most related rocks to porphyry copper mineralization are classified as granodiorite to quartz monzonite in North America (Titley and Hicks edit., 1966; Ridge edit., 1968; Wilson, 1963; Gillerman, 1964; Brown, 1969). The Bethlehem examples are quartz diorite to granodiorite. This means that the intrusive rocks are characterized by low content of K_2O, as compared with those of the United States. The reason is perhaps because the Bethlehem copper deposits are located close to the core of the Cordillera Orogeny.

3) The mineral assemblage of the altered intrusive rocks at Bethlehem can be regarded as that of the fringe alteration zones of the United States examples, which have no commercial copper contents. Low content of potassic silicates at Bethlehem, however, could be consistent with the less potassic nature of the host intrusive rocks.

4) The mineral assemblage may also be related to the low content of the total sulfides, which could have been an important catalyzer for some mineral-pars during the silicate reaction.

5) The low content of the total sulfides seems to be the prime agent for lack of chalcocite blanket at Bethlehem, as pointed out also by Hirata (1965), among various causes such as glacial truncation, climate condition, rather abundant carbonates, and others. But the content was enough to form secondary oxide ores with no enrichment (e. g. Iona orebody).

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(The original manscript completed in January 1970)

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カナダ，ブリティシュコロンビア州，ベスレヘム斑岩銅鉱床に関係する貫入岩の化学的性質

石原 舜三

要 旨

ベスレヘム鉱床の花崗岩質岩石が予察的に調べられた。この貫入岩はカルク・アルカリ岩系の石灰質な種類に属する。銅鉱化作用ともっとも密接な貫入岩の岩質は，ノルム鉱物で石英閃緑岩～花崗閃緑岩であって，アメリカ合衆国の同種鉱床の場合より斜長石に富む。

ベスレヘム鉱床でもっとも普遍的な変質作用は CREASEY (1966) の分類によるプロピライト化変質に属するものである。これは合衆国ではもっとも低度の周縁変質相である。しかし，ベスレヘム鉱床のプロピライト化変質の原因は，カリウムに乏しい原岩の性質および硫化物総量が少ないなどの，原岩と鉱液の化学的性質にも由来するものと思われ，温度圧力条件によって一義的に規制されたものではないらしい。

550.835 : 550.822

^{137}Cs による坑井内の散乱ガンマ線エネルギー分布の測定

中井 順二*

Measurement of Energy Distribution of Gamma Ray from ^{137}Cs in the Borehole

By

Junji Nakai

Abstract

The response of a $1\frac{3}{4}$ inch in diameter by 2 inch long sodium-iodide scintillator to isotropic incident gamma rays has been studied and presented as a 14 by 14 matrix for the energy range

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Appendix List of the chemical analyses used in this paper of the intrusive rocks related to the porphyry copper deposits in the United States

Localities and rock names	Bingham, Last Chance and Bingham stock							
	1 Bt-Px Mz	2 Bt-Px Mz	3 Bt-Px Qm	4 Bt-Px Mz	5 Bt-Px Mz	6 Bt-Px Mz	7 Mz	8 Mz
SiO_2	55.7	57.6	60.1	59.1	58.9	63.4	58.64	57.16
TiO_2	0.87	0.87	0.81	0.86	0.86	0.69	0.83	0.87
Al_2O_3	14.5	14.7	14.8	15.0	14.8	15.6	15.35	16.69
Fe_2O_3	2.8	2.3	2.5	2.0	2.1	1.9	3.25	3.47
FeO	3.5	3.5	2.9	3.7	3.8	2.4	2.54	2.76
MnO	0.12	0.15	0.15	0.15	0.11	0.04	tr	tr
MgO	5.3	6.2	4.0	4.2	4.8	2.6	2.84	2.47
CaO	6.7	6.2	4.8	5.7	6.2	3.3	5.37	5.86
Na_2O	3.4	3.7	3.9	3.5	3.5	3.8	3.60	3.82
K_2O	4.1	3.1	4.2	4.6	3.8	4.3	4.23	4.49
P_2O_5	0.63	0.52	0.46	0.49	0.49	0.32	0.02	0.41
S							0.05	
CO_2	0.55	0.12	0.15	<0.05	<0.05	0.10		
$H_2O(+)$	1.1	0.64	0.38	0.49	0.38	0.77	1.50	1.06
$H_2O(-)$	0.31	0.30	0.20	0.25	0.09	0.53	0.86	0.83
Total	100	100	100	100	100	100	99.08	99.89
Source	Moore et al. (1968)						Butler et al. (1920)	

Localities and rock names	Robinson, monzonite and monzonite porphyry						Yerington			Bagdad
	Liberty monzonite			Weary Flat stock		14 Lane Valley sill	15 Gd	16 Qm	17 Qm	18 Qm
	9	10	11	12	13					
SiO_2	57.30	57.95	58.36	57.26	61.69	59.79	57.90	68.35	67.70	64.49
TiO_2	0.71	0.73	0.67	0.71	n.d.	n.d.	1.12	0.57	0.23	0.46
Al_2O_3	16.69	17.52	16.96	17.79	17.26	17.70	16.38	14.71	15.95	17.43
Fe_2O_3	3.37	3.14	3.11	3.39	3.53	2.42	3.02	1.69	1.53	1.84
FeO	3.08	3.07	2.87	3.45	1.91	2.76	3.66	1.47	1.14	1.65
MnO	0.17	0.17	0.17	0.29	0.09	0.09	0.09	0.04	n.d.	0.09
MgO	2.34	2.05	2.07	2.02	1.45	1.92	3.13	1.11	1.23	1.93
CaO	6.71	6.46	6.35	6.58	5.49	5.22	6.33	3.11	2.70	3.47
Na_2O	3.41	3.34	3.52	3.06	3.05	2.64	4.10	4.28	4.83	4.48
K_2O	4.52	4.08	4.46	4.15	3.88	4.19	2.52	3.54	3.74	2.38
P_2O_5	0.42	0.42	0.36	0.21	0.34	0.37	0.42	0.20	n.d.	0.19
S	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.				
CO_2	0.26	0.16	0.11	0.04	n.d.	n.d.	0.08	0.14		0.12
$H_2O(+)$	0.50	0.48	0.47	0.55	0.73	2.00	0.89	0.46	0.36	0.90
$H_2O(-)$							0.18	0.31	0.19	0.44
Total	99.48	99.59	99.48	99.50	99.42	99.10	99.82	99.98	99.60	99.87
Source	Bauer, Jr. et al. (1966)						Knopf (1918)			Anderson et al. (1955)

Localities and rock names	New Cornelia			Globe-Ray region						
	19 Bt Qd	20 Hb-bt Qm	21 Hb-bt Qm	22 Schultze Gr	23 Gp	24 Gp (dike)	25 Gr Mtn Qmp	26 Lost G. Qm	27 Gd	28 Qd
SiO_2	60.59	65.29	66.23	70.95	69.35	68.95	70.52	68.63	64.84	60.42
TiO_2	0.61	0.54	0.47	0.23	0.19	0.22	0.27	0.69	0.50	0.83
Al_2O_3	17.39	15.74	15.71	16.30	15.71	15.84	15.54	13.68	16.49	17.27
Fe_2O_3	1.60	2.05	2.20	1.01	1.18	1.14	0.77	2.53	1.87	2.60
FeO	1.98	2.03	1.98	0.36	0.43	0.56	1.31	1.81	2.28	3.47
MnO	0.08	0.07	0.08	tr	tr	tr	0.02	0.15	0.06	0.13
MgO	2.38	1.84	1.58	0.23	0.36	0.24	0.66	1.10	1.58	2.30
CaO	5.06	3.66	3.78	1.85	1.79	1.96	2.49	2.51	4.54	6.36
Na_2O	4.09	3.77	3.89	5.16	4.78	4.56	3.96	2.94	4.18	3.14
K_2O	1.63	4.11	3.22	3.34	3.63	3.69	3.72	4.04	2.46	2.34
P_2O_5	0.36	0.24	0.24	tr	0.08	0.08	0.09	0.24	0.19	0.20
S				tr	tr	0.00	tr	(FeS_2) 0.11	0.00	0.05
CO_2							0.00		tr	0.00
$H_2O(+)$	3.29	0.62	0.67	0.37	0.97	1.49	0.88	0.87	0.98	0.86
$H_2O(-)$	0.78	0.14	0.03	0.26	1.17	0.86	0.36	0.70	0.19	0.40
Total	99.84	100.10	100.08	100.06	99.64	99.59	100.59	100.00	100.16	100.37
Source	Gilluly (1946)			Peterson (1962)						

Localities and rock names	Castle Dome		San Manuel		Warren		Morenci
	29 Qmp	30 Qmp	31 Gdp	32 Gdp	33 Alk Gr	34 Gp (sill)	35 Qmp
SiO_2	69.60	70.68	61.8	64.88	75.86	76.81	68.04
TiO_2	0.62	0.55	0.62	0.56	0.21	0.13	0.41
Al_2O_3	13.99	13.82	16.5	15.01	12.17	10.96	17.20
Fe_2O_3	1.82	2.03	3.3	1.06	0.85	1.18	0.34
FeO	2.15	1.83	1.2	2.42	0.36	0.08	0.67
MnO	0.13	0.11		0.04			0.06
MgO	0.86	0.44	2.6	1.44		0.14	1.05
CaO	2.12	1.61	3.6	2.59	0.62		2.21
Na_2O	2.66	2.64	4.3	3.02	3.60	0.26	5.33
K_2O	4.56	4.48	2.5	3.14	5.04	8.50	2.65
P_2O_5	0.23	0.19	0.22	0.19	tr	tr	0.12
S	(FeS_2) 0.02	(FeS_2) 0.05		$(SO_3 1.04)$ 0.00			
CO_2			1.0	1.35			
$H_2O(+)$	1.00	1.26	1.9	2.03	0.72	1.17	1.23
$H_2O(-)$	0.14	0.14	0.5	0.37	0.27	0.48	0.60
Total	99.90	99.83	100.04	99.14	99.70	99.71	99.91
Source	Peterson et al. (1951)		Creasey (1965)		Ransome (1904)		Lindgren (1905)

Localities and rock names	Santa Rita					
	Hanover-Fierro		Santa Rita stock			
	36 Gd	37 Gdp	38 Qmp	39 Qmp	40 Qmp	41 Qmp
SiO_2	61.26	65.36	65.7	64.87	64.90	66.93
TiO_2	0.52	0.45	0.42			0.37
Al_2O_3	16.22	16.29	16.0	16.63	17.55	15.74
Fe_2O_3	3.0	1.94	2.5	2.36	1.63	0.23
FeO	2.38	1.88	1.8	2.35	1.50	2.23
MnO	0.08	0.04	0.04			0.02
MgO	2.57	1.75	1.5	2.27	1.10	1.36
CaO	6.12	4.05	2.5	3.24	2.05	1.78
Na_2O	4.34	3.90	3.4	5.71	3.40	2.24
K_2O	2.61	3.29	4.2	2.79	4.70	6.70
P_2O_5	0.48	0.24	0.31			0.17
S	0.05		n.d.	0.22	0.17	1.17
CO_2	0.09	0.06	0.06	0.08		0.01
$H_2O(+)$	0.20	0.52	1.3	0.15	0.87	0.93
$H_2O(-)$	0.15	0.20	n.d.	n.d.	0.03	0.27
Total	100.07	99.98	100	100.67	97.92	100.17
Source	Jones et al. (1967)					

Abbreviations Qd: quartz diorite, Gd: granodiorite, Gdp: granodiorite porphyry, Qm: quatz monzonite Gr: granite Gp: granite porphyry, Mz: monzonite Px: augite, Hb: hornblende, Bt: biotite