



**ISOTOPIC AGES, WALLROCK CHEMISTRY AND FLUID
INCLUSION DATA
FROM THE BRALORNE GOLD VEIN DEPOSIT*
(92J/15W)**

**By C. H. B. Leitch and C. I. Godwin
Department of Geological Sciences,
The University of British Columbia**

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INTRODUCTION

Work aimed at understanding the nature of the ore-forming processes at the Bralorne gold vein deposit continued in 1987. A few days were spent in the Bridge River camp examining key outcrops to assess questions raised by the isotopic age determinations at Bralorne. One further isotopic date, on sericite from the Lucky Gem property in Eldorado Basin north of Gold Bridge (Figure 2-4-1, Table 2-4-1), is in progress. Galena lead isotope data for previous and recently obtained samples from the Bridge River camp have been compiled and interpreted.

Further petrographic and chemical analysis of the rocks immediately surrounding the Bralorne mine suggests that the Pioneer volcanics of the Cadwallader Group are basalts of probable island-arc tholeiite affinity. Detailed chemical analyses of the altered intrusive rocks adjacent to major vein systems were also completed. Gains and losses of mobile elements have been corrected for volume changes accompanying alteration by the methods of Gresens (1967). The ore-forming fluids are further characterized by fluid inclusion studies at several levels from surface to 2000 metres depth in the deposit. Results from sulphur isotope studies confirm the mesothermal character of the mineralization.

GEOCHRONOLOGY OF THE BRIDGE RIVER CAMP

Mineralization at the Bralorne mesothermal gold vein deposit is closely related to a suite of Late Cretaceous or Early Tertiary dykes. Pre-mineral albitite dykes dated at 91.4 ± 1.4 Ma by uranium-lead determinations on zircons, and post-mineral lamprophyre dykes dated at 43.7 ± 1.5 Ma by potassium-argon on biotite, set limits on the time of mineralization. An intra postmineral green hornblende porphyry dyke set, which forms a transitional series to the albitites, dates at 85.7 ± 3.0 Ma and may restrict the age further. Thus mineralization occurred long after and is genetically unrelated to emplacement of the host Bralorne intrusives, which have been dated as Early Permian by uranium-lead on zircons (minimum age of 270 ± 5 Ma) and by potassium-argon on

hornblende (284 ± 10 Ma). Further support for the Early Permian age comes from lithologically similar intrusives 20 kilometres to the north at Gold Bridge, which gave 287 ± 20 Ma by potassium-argon on hornblende, and 320 ± 80 Ma by rubidium-strontium for a whole-rock isochron (Leitch, Van der Heyden, Armstrong, Godwin and Harakal, in preparation).

The Early Permian age of 270 Ma implied by the present work for at least parts of the Cadwallader and Bridge River groups is in conflict with Middle Triassic stratigraphic ages

**TABLE 2-4-1
FORMATIONS IN THE BRIDGE RIVER AREA,
SOUTHWESTERN BRITISH COLUMBIA
(Figure 2-4-1 shows distribution of units)**

UNIT NO.	MAP SYMBOL	DESCRIPTION
EOCENE		
7		Rexmount porphyry
CRETACEOUS-TERTIARY		
6		Coast plutonic complex (and satellite plutons)
JURASSIC-CRETACEOUS		
5		Relay Mountain and Tyaughton Groups
EARLY PERMIAN (OR EARLIER)		
4		Bralorne intrusives
3		Cadwallader Group
2		Bridge River (Fergusson) Group
1		Ultramafic rocks
		Geological contact
		Fault
hk 287		Radiometric date (Ma): h = hornblende; b = biotite; z = zircon; w = whole rock. k = K-Ar, r = Rb-Sr, u = U-Pb.

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British Columbia Ministry of Energy, Mines and Petroleum Resources, Geological Fieldwork, 1987, Paper 1988-1.

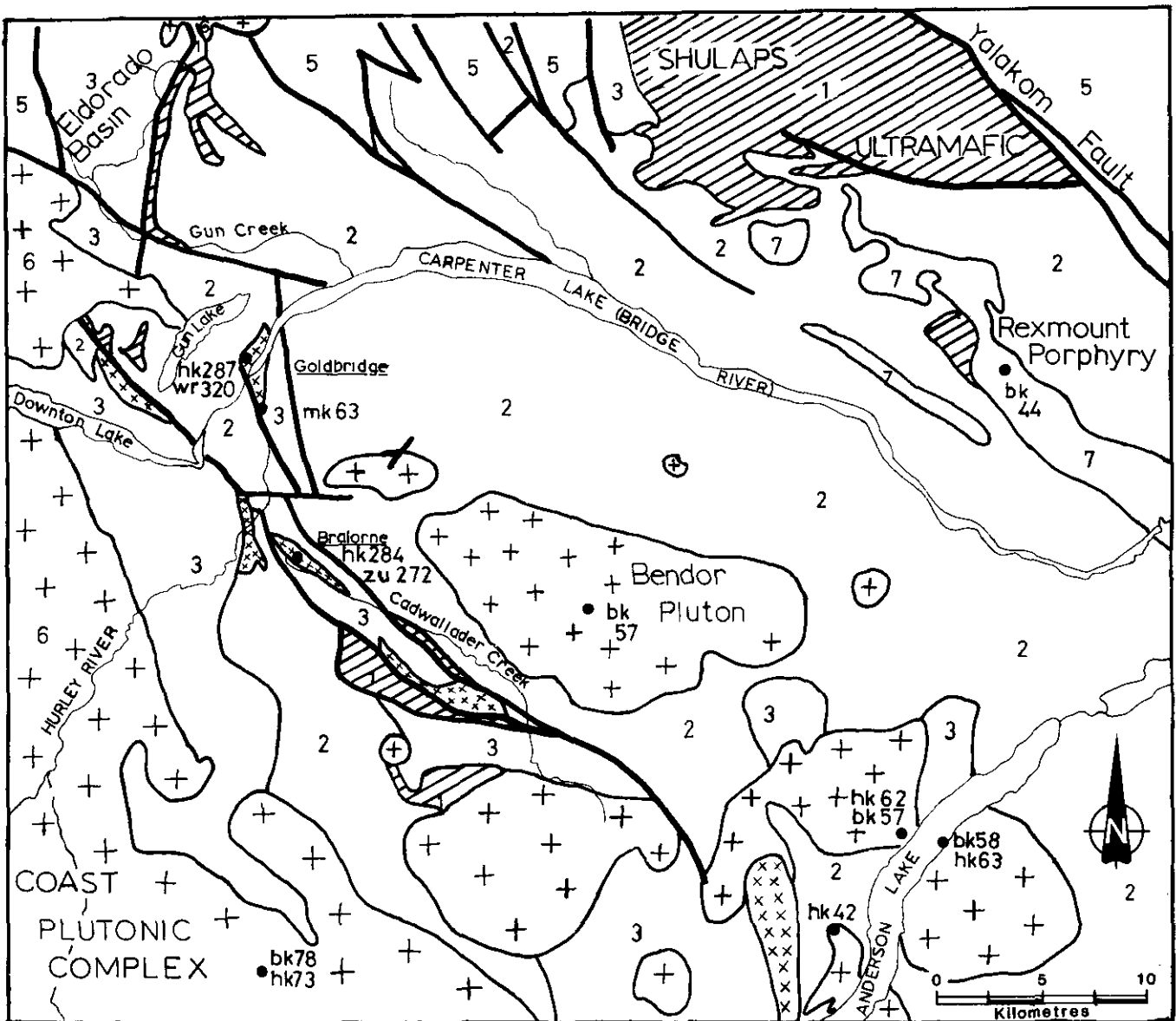


Figure 2-4-1. Regional geology and radiometric ages of the Bridge River area, from Woodsworth (1977), modified after Church (1987) and the results of this study. Units and symbols are defined in Table 2-4-1.

(225 Ma) assigned elsewhere on the basis of paleontologic evidence. This issue is addressed in more detail later in this paper. However, the 45-Ma discrepancy might be explained by combined uncertainty in the isotopic and paleontologic data. Alternatively, rocks of the Cadwallader Group in the Bralorne area could be distinct from and older than the lithologic equivalents 20 to 30 kilometres to the north, or the contact between Bralorne intrusives and stratified rocks might be everywhere faulted.

Geochronology, combined with the lead isotope and fluid inclusion data of this study and stable isotope plus fluid inclusion studies of other workers (Maheux *et al.*, 1987), suggest that there were several pulses of mineralizing activity in the Intermontane Belt adjacent to the Coast plutonic complex. A trend of decreasing temperatures and younger age of mineralization is evident with increasing distance from the Coast plutonic complex, implying that it was the main heat

source responsible for mineralization. The main pulses seem to become progressively younger to the east, from about 90 Ma for relatively high-temperature mesothermal Au + Ag + As ± W ± Mo mineralization at Bralorne near the Coast plutonic complex, to 65 Ma for Ag + Au + Sb + As ± Hg mineralization at the Minto and Congress deposits just north of Gold Bridge (Figure 2-4-1), to about 45 Ma (Faulkner, 1986) for gold-silver epithermal mineralization at the Blackdome deposit (92O/8W), 100 kilometres east of the Coast plutonic complex.

GALENA LEAD ISOTOPE DATA

A compilation of previous and recently obtained lead isotope ratios for the Bridge River camp (Leitch, Dawson and Godwin, in preparation) shows a distinct clustering of data from 17 widespread and apparently diverse deposits that is

interpreted to be the expression of a single, protracted but episodic mineralizing event coinciding with emplacement of the Coast plutonic complex during Late Cretaceous to Early Tertiary time (90 to 45 Ma). This, and the geochronological data presented above, supports the district-wide zoning model proposed by Woodsworth *et al.* (1977).

The tightly clustered lead isotope data define a linear trend that falls between upper crustal model curves and a mantle curve. This trend is interpreted to be a "mixing line isochron" (compare Andrew *et al.*, 1984) that represents the mixing of primitive mantle-type lead and more radiogenic lead (modeled respectively by the "mantle" and "upper crustal" curves of Doe and Zartman, 1979). Such mixing could be between either: (1) two groups of rocks (oceanic volcanics, such as the Bridge River Group basalts, and upper crustal volcanic arc/clastic rocks, such as the Cadwallader Group) by a meteoric thermal system generated by the emplacement of the Coast plutonic complex, or (2) the Bridge River Group primitive oceanic volcanics and introduced fluids with a more radiogenic signature. Lead from cratonal sediments, represented by Godwin and Sinclair's (1982) "shale curve" for lead evolution in Cordilleran miogeoclinal shale-hosted stratiform deposits, apparently is not involved in the proposed mixing model, confirming the allochthonous nature of the host oceanic and arc terranes.

REGIONAL GEOLOGY


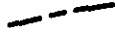
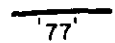
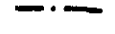

Fieldwork tried to resolve the differences between isotopic and paleontologic ages of the Cadwallader and Bridge River groups referred to above. Detailed work involved the logging of drill core from surface holes on the Bralorne property. This has resulted in revision of the surface geology plan published earlier (Leitch and Godwin, 1986).

AGE OF THE CADWALLADER GROUP

The Early Permian age of 270 ± 5 Ma implied by the present work for those parts of the Cadwallader and Bridge River groups in the Bralorne block is in conflict with Middle Triassic stratigraphic ages (225 Ma) assigned elsewhere on the basis of paleontologic evidence. The Bralorne block is the area bounded by the Fergusson and Cadwallader faults (Figure 2-4-2, Table 2-4-2); stratified rocks within it show lithological similarities to rocks of the Cadwallader Group mapped by Rusmore (1985) in the Eldorado basin 20 kilometres to the northwest (Figure 2-4-1). The age conflict hinges on several key points:

- (1) Paleontologic evidence, all from outside the Bralorne block, dates the Cadwallader and Bridge River groups as younger than the Bralorne intrusives.
- (2) The rocks mapped as Cadwallader and Bridge River within the Bralorne block are lithologically and chemically similar to those mapped elsewhere.
- (3) The Cadwallader and Bridge River rocks appear to be intruded by, not laid on top of, the Bralorne intrusives; however, some contacts are faulted.
- (4) Cadwallader sediments include a conglomerate which contains clasts that resemble soda granite, implying that the soda granite is older than the conglomerate.

TABLE 2-4-2
FORMATIONS IN THE BRALORNE-PIONEER CAMP
(Figure 2-4-2 shows distribution of units)

UNIT NO.	MAP SYMBOL	DESCRIPTION
EOCENE		
10		Lamprophyre dykes
UPPER CRETACEOUS		
9		Green hornblende porphyry dykes
		Major quartz veins (named)
8		Albite dykes
8a		Grey plagioclase porphyry dykes
EARLY PERMIAN BRALORNE INTRUSIVES		
7		Soda granite
6		Diorite
6a		Hornblendite
5		President ultramafics (serpentinite)
PERMO-TRIASSIC (?) CADWALLADER GROUP		
4		Hurley Formation (turbidites, volcaniclastic sediments)
3		Pioneer Formation (basalts, aquagene breccias)
PERMO-JURASSIC (?) BRIDGE RIVER (FERGUSSON) GROUP		
2		Sediments (ribbon chert, argillite)
1		Pillow basalts

- (5) Although the paleontologic dates in the Cadwallader rocks come from a sedimentary unit overlying the basal volcanic unit, the lower parts of the sedimentary unit contain intercalations of volcanics lithologically similar to those of the underlying unit.

The paleontologic age of the Cadwallader Group is limited to the Late Triassic Karnian-Norian boundary at about 230 to 220 Ma, by conodonts found in exposures in the Eldorado basin by Rusmore (1985). Her mapping led her to propose a new subdivision of the Cadwallader Group. She distinguished a lower volcanic unit equivalent to the Pioneer Formation, an upper sedimentary unit equivalent to the Hurley Formation, and a unit transitional between the two. She could find no justification for the formerly defined Noel Formation at the base of the Cadwallader Group and proposed that it be abandoned. On the other hand, Church (1987) in mapping of the Bralorne sheet (92J/15W) retained the threefold division of the Cadwallader Group. However, he put most of the basaltic volcanics in the area into the Pioneer Formation, including those formerly considered (Cairnes, 1937; Stevenson, 1958) as part of the underlying Fergusson (Bridge River) Group.

Conodonts and radiolaria of similar age to those in the Cadwallader Group have also been found in the Bridge River Group sediments at several locations to the north of Bralorne (Cameron and Monger, 1971). Here the paleontologic ages range from Middle Triassic to Early Jurassic (Potter, 1983).

Volcanic and sedimentary rocks in the Bralorne block have long been considered to belong to the Bridge River and Cadwallader groups, and to be intruded by the Bralorne intrusives (Cairnes, 1937; Stevenson, 1958; Joubin, 1948). In the mine area, both drill core and underground workings show Bralorne intrusives with abundant xenoliths, apparently of Cadwallader rocks, implying an intrusive relationship. A similar complex interfingering relationship between the Cadwallader volcanics and the Bralorne intrusives has been described 5 kilometres north of the mine by Cairnes (1937), who further suggested that the volcanics and intrusives were comagmatic and therefore roughly coeval.

The following evidence suggests that Cadwallader Group rocks are intruded by the Bralorne intrusives:

- (1) From 5 to 20 metres of baking or bleaching of the Cadwallader rocks, that appears to be the product of hornfelsing, occurs in drill holes crossing the northeast contact of the Bralorne intrusive mass, where it is com-

posed mainly of soda granite (Figure 2-4-2). This linear contact is, however, marked by a strong zone of shearing, and is probably an intrusive contact that was later faulted. Such hornfelsing is also evident on the Wayside property 5 kilometres north of Gold Bridge, where the adjacent intrusive, although devoid of the network of quartz-epidote fractures characteristic of the Bralorne diorite, is seen in thin section to be a soda granite, with distinctive symplectic quartz-albite intergrowths identical to those seen in the soda granite at Bralorne and described below.

- (2) Complex interfingering of Bralorne diorite and greenstone occurs on the southwest flank of the intrusive mass. If these greenstones belong to the Cadwallader Group then it would be difficult to propose that each of these small greenstone bodies is in fault contact with the Bralorne diorite. The alternative is that the greenstone bodies are unrelated to the Cadwallader rocks and are simply fragments of an older greenstone terrane. This seems unlikely because the section at Bralorne is lithologically similar to the Cadwallader section established by Rusmore (1985). Both contain volcanic and volcanoclastic rocks and turbidite sequences composed of volcanic detritus.

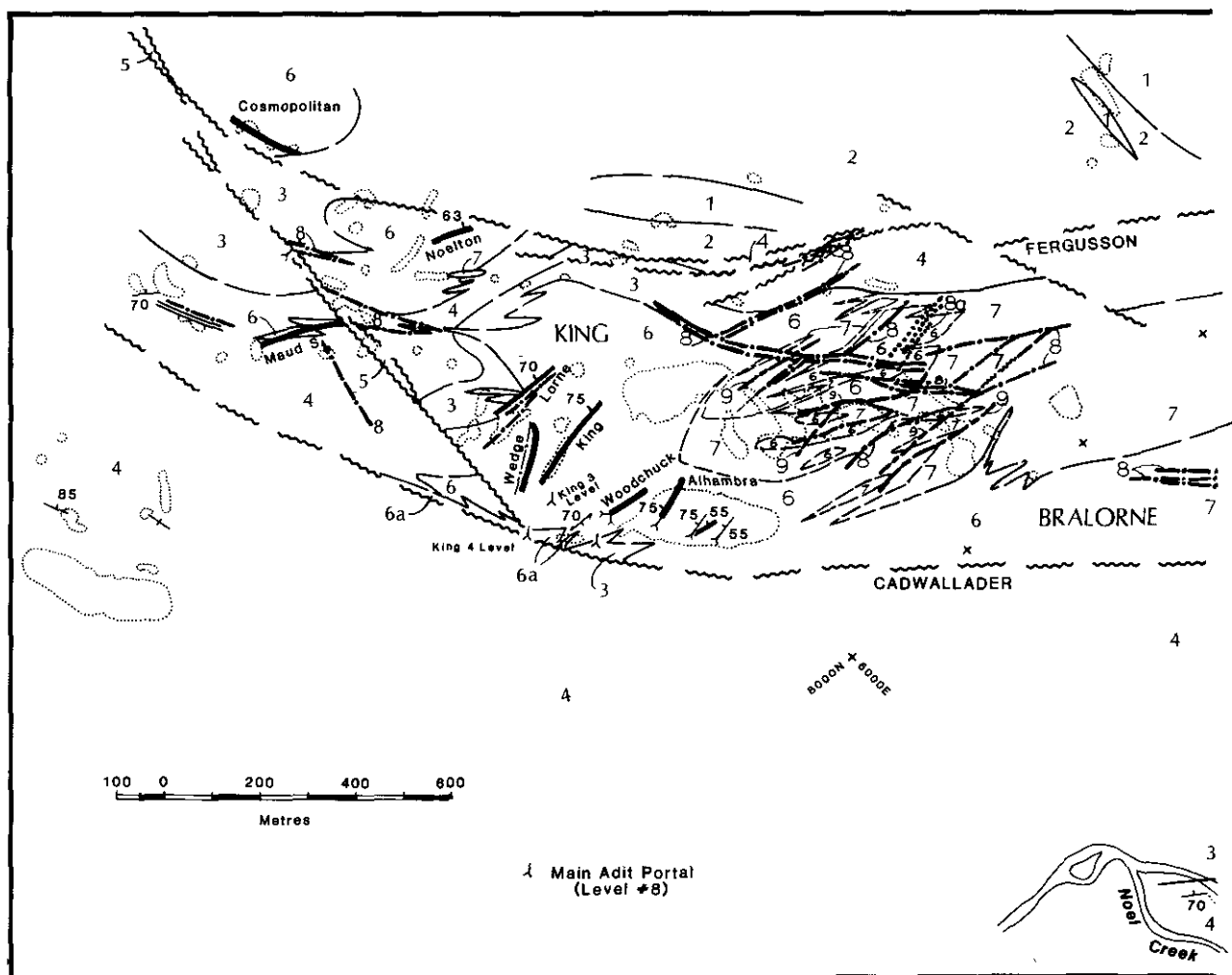


Figure 2-4-2. Surface geology of the Bralorne-Pioneer gold-quartz vein system. Units are defined in Table 2-4-2 (continued on facing page).

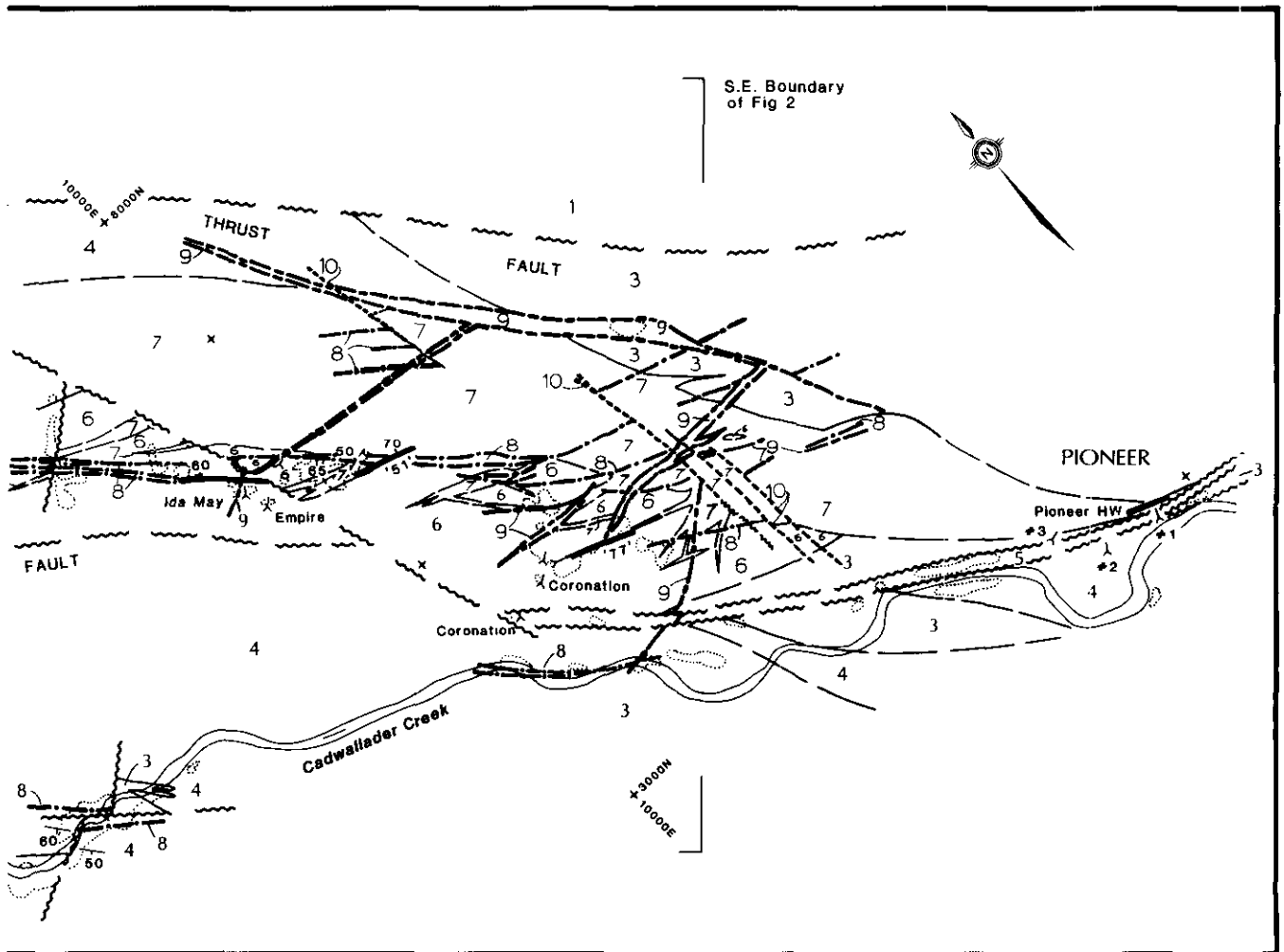
Cadwallader Group sediments at several locations (Wayside property and Eldorado basin) outside the Bralorne block include a conglomerate unit which contains clasts that resemble soda granite in both hand specimen and thin section. One possible interpretation of this relationship is that the transitional and sedimentary units of the Cadwallader are younger than the Bralorne intrusives, while the underlying volcanic unit is older. Unfortunately, both the volcanic and sedimentary parts of the Bralorne section appear to be hornfelsed by the Bralorne intrusives. Also, if the volcanic unit is older than the Bralorne intrusives (that is, >270 Ma), and the sedimentary unit is younger, it implies a volcanic event spanning 40 Ma, since the lower portion of the sedimentary unit contains intercalations of the same volcanics.

OTHER REGIONAL OBSERVATIONS

At the Gold Bridge quarry, Bralorne diorite and soda granite are cut by dykes identical to the albitite dykes in the Bralorne mine. The Lucky Gem prospect in Eldorado basin (Figure 2-4-1), and the Lucky Strike in Taylor basin adjoining to the east, were also visited. Rocks at the Lucky Strike bear a striking resemblance to those at Bralorne. An outcrop of foliated Bralorne diorite is cut by a felsic dyke similar to

albitite (Leitch and Godwin, 1986), and mineralization in the adit is associated with an intensely quartz-carbonate-sericite-altered albitite dyke. Further north and west, however, the abundant felsic dykes are not albitites; instead, they are very similar to Bendor dykes (described below).

Several lines of evidence indicate that the major intrusives hosting the Bralorne deposit could have been emplaced below the sea floor in a zone transitional between an arc and a back-arc basin. First, the petrology of the intrusive suite, which includes serpentinized ultramafite, hornblende diorite and trondjemite or "soda granite" are typical of an ophiolite association. Also, the chemistry of both the Cadwallader and Bridge River basalts is transitional between island-arc tholeiite and mid-ocean-ridge basalts (Rusmore, 1985; Potter, 1983; this study). Secondly, the gradational contact relationships between the hornblende diorite and the intruded Cadwallader Group volcanics suggest that the diorite intruded its own volcanic products. Finally, intrusive contacts of the diorite into the elongate ultramafic bodies seen at Wayside and Bralorne imply that the ultramafics are of Permian or older age and had themselves been emplaced into a higher structural level (that is, thrust up out of their initial mantle environment, by the time of diorite intrusion).



DETAILED GEOLOGY — BRALORNE AREA

Petrography and chemistry of the major units in the Bralorne block have been reported in Leitch and Godwin (1987). Further petrographic and chemical analyses have now been completed to characterize these major units, investigate minor units, and compare the supposed Pioneer volcanics of the Cadwallader Group in the Bralorne block to

volcanics mapped elsewhere as Cadwallader by Rusmore (1985) and Bridge River by Potter (1983).

PIONEER VOLCANICS

Six samples of Pioneer volcanics (Table 2-4-3) were selected to show as great a range of composition as possible for chemical analysis and rubidium-strontium dating. They range from intermediate to felsic in appearance, but thin

TABLE 2-4-3
CHEMISTRY OF PIONEER VOLCANICS

Location	Bralorne Block						Bonanza Basin Carpenter Lake		Average Basalts (Hughes, 1982)			
Sample No. (N)	C095 (4)	C096A (1)	C096B (1)	C096C (5)	C098A (1)	C098D (1)	AVGCAD1 (3;10)3	AVBRIV2 (3)	CALK (>3)	MORB (100)	OIB (>14)	IAT (10)
Major Elements (%)												
SiO ₂	47.34	44.8	45.9	63.96	48.6	52.9	50.64	48.4	51.0	49.3	50.0	51.2
Al ₂ O ₃	13.71	11.0	14.8	13.49	14.8	14.2	15.26	13.6	18.7	16.5	13	18.1
TiO ₂	1.01	0.15	0.72	0.33	1.38	0.50	(1.22)	2.05	0.90	1.5	2.7	0.8
Fe ₂ O ₃	10.32	8.40	11.5	4.46	10.9	7.8	12.17	11.1	8.9	10.0	11.5	10.1
MgO	12.41	14.7	15.5	8.07	10.1	11.7	5.57	5.20	4.8	7.5	10	6.2
CaO	9.03	9.0	5.9	3.13	6.8	6.0	6.24	10.7	10.7	11.0	10	11.0
Na ₂ O	1.50	0.00	0.59	3.57	3.6	4.1	4.90	3.31	2.9	2.8	2.5	2.0
K ₂ O	0.04	0.00	0.03	0.05	0.59	0.24	(0.71)	0.36	0.6	0.2	0.5	0.3
MnO	0.26	0.15	0.25	0.11	0.18	0.16	(0.16)	0.15	0.17	0.18	0.18	0.2
P ₂ O ₅	0.11	0.03	0.06	0.06	0.20	0.05	(0.17)	0.31	0.13	0.10	0.3	0.1
LOI	4.58	11.92	4.90	3.16	2.88	2.50	2.58	4.60	1.0	—	0.5	0.7
TOTAL	100.31	(100)	(100)	100.39	(100)	(100)	99.65	99.8	99.80	99.1	101.2	100.4
Specific Gravity	2.90	2.72	2.83	2.74	2.87	2.84						
Minor Elements (ppm)												
As	14	15	4	0	0	0						
Ba	50	52	53	62	72	83	220		160	14	200	75
Cl	26	—	—	—	—	—	—					
Co	30	64	54	25	46	52	39			55		
Cr ^a	275	1185	495	117	191	348	115	130	90	330	140	50
Cu	75	58	135	8	2	4	95					
Mo	1	—	—	—	—	—	(Li = 22)					
Nb	3	3	3	1	8	1	<10	20				
Ni	70	465	195	34	75	135	61		70	175	75	30
Pb	6	15	8	11	18	12	—					
Rb	2	0.0	0.5	0.1	5.0	1.9	—	10	12	3	5	5
S	745	305	530	220	575	540						
Sb	3	0	4	2	0	0	(Sc = 37)					
Sr	270	50	196	240	163	110	310	210	400	150	400	200
V ^a	270	54	235	57	395	140	340	340	255			270
Y	22	8	25	12	35	16	24	33		45		
Zn	105	61	200	66	91	83	91					
Zr	63	41	48	65	139	52	49	150	65	110	100	
Normative Minerals (%)												
Quartz		1.1		23.4				2.0	1.3		1.0	3.4
Corundum				2.2								
Orthoclase	0.2		0.2	0.3	3.6	1.5	3.2	2.1	3.5	1.2	3.0	1.8
Albite	13.8		5.3	30.4	32.1	36.5	43.1	29.5	24.5	23.5	19.0	16.9
Anorthite	35.6	34.5	31.2	15.8	23.5	20.0	18.8	25.0	31.2	32.4	24.0	39.5
Diopside	7.0	12.9		8.7	8.8		9.9	23.5	13.1	19.2	20.6	11.8
Hypersthene	29.4	49.4	54.4	26.2	4.2	15.8	5.8	8.0	14.8	10.3	22.0	21.8
Olivine	9.3		1.7		22.5	14.7	12.4	2.5		7.1	4.0	
Magnetite	2.2	1.9	2.4	0.9	2.2	1.6	2.8	3.5	3.2	3.0	2.8	3.9
Ilmenite	2.2	0.3	1.5	0.7	2.7	1.0	3.1	2.8	1.7	2.9	4.9	1.5
Apatite	0.3	0.05	0.1	0.1	0.5	0.1	0.5	0.7	0.3	0.3	0.6	0.3
Diff'n Index	14	1	5	54	36	38	37	25	29	25	27	22
Modes (Estimated Volume %)												
Quartz	10	8	10	10		5	2					
Albite (andesine)	(40)	(44)	(30)	68	(50)	(40)	(60)	(75)				
Mafic: H'blende												
(Cpyrox)	(55)	(46)				(54)	(35)	(20)				
Ilmenite (Rut), Sph	(3)	(2)	2		5	(1)	(3)	(5)				
Pyrite (Py/Po)	2	tr										
(No. of Samples)	(1)	(1)	(1)			(1)	(3)	(3)				

1 - Rusmore, 1985; 2 - Potter, 1983; 3 - bracketted figures are averages of 10 analyses; 4 - adjusted to allow for known contamination due to grinding in Cr-steel Teel Tema mill, by comparison to same samples ground in W-carbide mill.

section and chemical analyses show that they are, with one exception, basalts composed principally of relict plagioclase (albite, An_{0-5} , replacing andesine, An_{30}), and hornblende or clinopyroxene phenocrysts in a felted mat of plagioclase microlites and interstitial chlorite and actinolite. Small but significant amounts of quartz, iron and titanium oxides and sphene are present, and quartz-epidote-chlorite amygdules are common. Magnesia contents (8 to 15 per cent) are unusually high – enough to justify calling them high-magnesia basalts (Hughes, 1982). Potash contents range from not detectable to average (0.6 per cent) as is typical of all the volcanics in the Bridge River district that were analysed in this study or by Rusmore (1985) or Potter (1983). Soda contents fall into two categories with either normal low (0 to 1.5 per cent) or high (3.5 to 4 per cent) values that are characteristic of spilitized basalts produced by low-grade alteration on the sea floor (Carmichael *et al.*, 1974). Titania values are low to very low compared to average basalts. Less mobile trace elements (vanadium, titanium, yttrium, niobium, zirconium, chromium) in diagrams proposed by Pearce and Norry (1979), Shervais (1982), and Garcia (1978) indicate that these Pioneer volcanics are transitional between island-arc tholeiites and mid-ocean-ridge basalts. A similar conclusion was reached by Rusmore (1985) for the volcanics of the Eldorado basin.

The one sample at Bralorne that is not a basalt is C096C (Table 2-4-3, 64 per cent SiO_2 , 3.6 per cent Na_2O). This rock is a quartz keratophyre (Carmichael *et al.*, 1974), which is commonly associated with spilitized basalts.

MINOR UNITS

Further analysis of minor units (Table 2-4-4) was carried out on the dykes at Bralorne because isotopic dating had shown that mineralization was closely related to them spatially and temporally. The dyke sets, from oldest to youngest are: aplite, grey plagioclase porphyry, albitite, green hornblende porphyry, Bendor porphyry and lamprophyre.

Aplite dykes are merely fine-grained equivalents of the soda granites. They lack the porphyritic character and aphanitic groundmass that characterize all the following dykes. They are probably final differentiates of the diorite – soda granite system and as such are Early Permian in age (no radiometric dating or chemical analyses are available).

Grey plagioclase porphyry dykes contain striking symplectic quartz-albite intergrowths which are also present in highly altered “quartz core” areas of the soda granite and albitite dykes. The grey plagioclase porphyry may be more closely related to the time of mineralization, and essentially a precursor to the albitites. Chemically it is very similar to the albitite dykes (Table 2-4-4) in all respects except the soda, barium and strontium contents, which are closer to those of the soda granite.

Albitite and green hornblende porphyry dykes appear to form a spectrum which spans the pre to post-mineral range (91 to 86 Ma). They are characterized by varying proportions of quartz, plagioclase and hornblende phenocrysts. Albite and quartz phenocrysts with rare hornblende are typical of the albitites, while the other end-member, green hornblende porphyry, is typified by lesser albite, major hornblende and a lack of quartz phenocrysts. As the name albitite implies,

these rocks are rich in soda (7 per cent). They would be classified as extremely fractionated (differentiation indexes are 75 to 90; Hughes, 1982), calcalkaline dacites to rhyolites of potash-deficient subalkaline character (Irvine and Baragar, 1971). The other end-member, green hornblende porphyry, is much less differentiated (differentiation index is 30) and far more mafic (Table 2-4-4).

Bendor dykes are not well represented at Bralorne, but are more common throughout the Bridge River camp. Although initially mapped as albitite, these dykes have several distinctive petrographic features that set them apart. As these features are also found in the nearby Bendor batholith (Cairnes 1937), it seems appropriate to call them Bendor dykes. These rocks are characterized by hornblende with relict augite cores, and calcic plagioclase with sharp oscillatory zoning. This zoning (oligoclase, An_{17} , to andesine, An_{42}), and the more calcic composition are not observed in any of the earlier intrusive rocks; zoning presumably has been obliterated by the homogenizing effects of greenschist metamorphism associated with intrusion of the Coast Complex. Available isotopic dates support this conclusion, as the earlier dykes (90 to 85 Ma) pre-date the bulk of Coast Complex intrusion at 85 to 70 Ma (Woodsworth, 1977), and the Bendor plutons are younger than the Coast plutonic complex at 63 to 57 Ma (Wanless *et al.*, 1977). Dykes at the Congress mine, 15 kilometres north of Bralorne, are also younger than the Coast Complex at 67 Ma (Harrop and Sinclair, 1986). They contain 30 per cent oscillatory zoned intermediate plagioclase, and similar amounts of chloritized hornblende phenocrysts, as in the Bendor dykes.

Lamprophyre dykes (43.7 ± 1.5 Ma), dated in this study by potassium-argon on biotite, distinctly crosscut mineralized veins and are oriented roughly perpendicular to the veins and earlier dykes. They are ultramafic rocks, classed as kersantites (Hughes, 1982) that contain biotite, clinopyroxene and apatite phenocrysts in a finer grained groundmass of the same minerals plus glass. They are distinct chemically from all other intrusive rocks in the area, containing more abundant barium, strontium, phosphorus pentoxide, potash and titania (Table 2-4-4). They are the same age as the Rexmount porphyry (Figure 2-4-1; Woodsworth, 1977), and perhaps the same age as mineralization at Blackdome (Faulkner, 1986).

Restites, or dark-coloured masses, in the Bralorne intrusives suggest that at the present level of exposure the Bralorne soda granite may have been derived from the diorite by partial melting, as the two show migmatitic contact relationships (compare Leitch and Godwin, 1987). To test this hypothesis, areas of darker coloured material in the migmatite (the restite or neosome) presumably derived from diorite by extraction of the felsic material that formed the lighter coloured soda granite (leucosome) were analysed (C043 and C085 in Table 2-4-4). These analyses do not correspond well with the calculated restite compositions (Leitch and Godwin, 1987; reproduced here as RESTI, Table 2-4-4). They are depleted in silica and considerably enriched in alumina, titania and iron compared to the calculated restite composition. They also have normative olivine, which the calculated restite does not. Except for higher iron they correspond most closely to analyses of Pioneer basalts (C095,

C096, C098, Table 2-4-3) which supports field observations that suggest the restites are merely xenoliths of the volcanics initially intruded by the diorite and then both intruded by the soda granite.

Hornblendite at Bralorne (Unit 6a on Figure 2-4-2) is probably an ultramafic derivative, formed by intrusion of the diorite into ultramafite as described in Leitch and Godwin (1987). The texture of the original ultramafic rock is strongly modified to a net of coarse dark hornblendes poikilitically

enclosing pyroxene remnants. This is also seen on the Wayside property, again on the west flank of the diorite where it is in contact with the ultramafite. One analysis (Table 2-4-4) shows the low alumina, titania, soda, potash, phosphorus, and higher magnesia and lime contents expected of an ultramafic derivative. A comparison of the analyses of the hornblendite and the President ultramafics (Cairnes, 1937) also shows this strong modification, with the peridotite or serpentinite containing much higher magnesia and much lower silica and alumina than the hornblendite.

TABLE 2-4-4
CHEMISTRY OF MINOR UNITS

Description	Grey dyke	Albitite Dykes			Green dyke	Lamp. dyke	Restites			Hornblendite
Sample No.	C193	C038	C022	C4141	C083	C1033	C043	C085	RESTI	UM/HBITE
(No. of Analyses)	(2)	(4)	(2)	(2)	(5)	(2)	(2)	(2)	(Calculated)	(2)
Major Elements (%)										
SiO ₂	70.9	63.31	65.5	73.2	51.40	50.7	49.5	48.4	56.1	54.6
Al ₂ O ₃	12.7	16.76	16.5	13.2	14.76	14.0	15.2	14.7	10.6	4.84
TiO ₂	.24	0.40	0.25	0.16	0.80	2.40	0.97	0.72	0.3	0.22
Fe ₂ O ₃ (Total Fe)	2.7	4.00	2.85	1.65	10.24	7.10	13.6	13.2	9.0	7.20
MgO	1.35	1.47	1.32	0.64	6.48	5.82	7.04	9.22	10.2	15.9
CaO	2.64	3.47	2.70	1.65	8.47	7.81	7.25	8.81	8.4	14.9
Na ₂ O	5.72	7.08	6.50	6.95	3.10	2.84	4.08	2.82	3.4	0.58
K ₂ O	0.32	0.86	0.62	0.38	0.25	3.55	0.19	0.05	0.0	0.04
MnO	0.07	0.09	0.09	0.06	0.18	0.09	0.20	0.24	0.2	0.18
P ₂ O ₅	0.06	0.17	0.13	0.10	0.19	1.25	0.08	0.05	0.0	0.02
LOI	3.24	2.71	3.54	2.03	2.72	4.57	1.97	2.54	1.8	1.55
TOTAL	(100)	100.32	(100)	(100)	99.50	(100)	(100)	(100)	100	(100)
Specific Gravity	2.68	2.63	2.67	2.62	2.91	2.62	2.84	2.96	—	3.01
Minor Elements (ppm)										
As	ND	ND	1	2	3	15	ND	ND		26
Ba	60	275	260	140	245	2200	75	60		70
Co	34	14	12	52	35	34	41	38		75
Cr(*)	11	7	7	15	135	100	90	160		3800
Cu	4	6	4	1	36	130	10	3		55
Nb	2	4	2	2	1	17	2	4		ND
Ni	4	7	2	3	36	110	55	77		195
Pb	12	12	14	15	4	27	11	10		35
Rb	8	16	14	9	5	47	3	ND		ND
S	2000	3700	1400	570	310	6800	320	180		360
Sb	ND	ND	ND	4	1	6	ND	3		ND
Sr	88	280	200	205	350	3200	300	300		25
V(*)	27	55	25	12	230	300	290	210		80
Y	15	24	13	9	22	19	25	25		10
Zn	36	70	57	53	100	130	78	120		52
Zr	91	110	84	120	61	430	42	21		18
Normative Minerals										
Quartz	29.6	7.3	17.9	29.0	4.5	0.3			5.4	4.3
Orthoclase	2.0	5.3	3.7	2.1	1.5	21.3	1.1	0.3		0.2
Albite	49.7	63.6	56.0	58.5	26.2	26.0	35.5	25.3	28.8	5.0
Anorthite	8.6	8.7	13.3	4.6	25.8	15.5	23.5	27.3	13.6	10.5
Diopside	4.0	8.7		2.8	13.1	13.4	10.9	15.0	22.4	51.7
Hypersthene	4.8	4.4	7.1	2.1	19.6	14.0	11.5	15.0	23.1	26.3
Olivine							12.8	13.0		
Magnetite	0.6	0.8	0.6	0.3	4.3	1.5	2.7	2.6	4.3	1.5
Ilmenite	0.5	0.7	0.5	0.3	1.5	4.7	1.9	1.4	0.6	0.4
Apatite	0.1	0.4	0.3	0.2	0.5	3.3	0.2	0.1	0.02	0.05
Diff'n Index	81	76	78	90	32	48	37	26	34	10
Modes (Estimated Volume %)										
Quartz	34	15	20	10	8	(Glass 15)		3		1
Albite (Andesine)	56	60	70	85	54		35	40		20
Mafic: Hornblende	10	19	7	5	36	(Biotite 33)	60	53		62
Clinopyx						45			15	
Ilmenite (Rutile)	tr	3	1	tr		2	5	3		2
Sulphide (Py/Po)	tr	3	2	tr	2	(Apatite 5)		1		1
(No. of Thin Sections)	(2)	(1)	(1)	(1)	(8)	(1)	(1)	(2)	(6)	

Totals in brackets (100) indicate pressed powder analysis, normalized to 100%. Otherwise analysis is by fused disk.

* Cr, V contents are adjusted for known contamination introduced during grinding in Cr-steel ring mill.

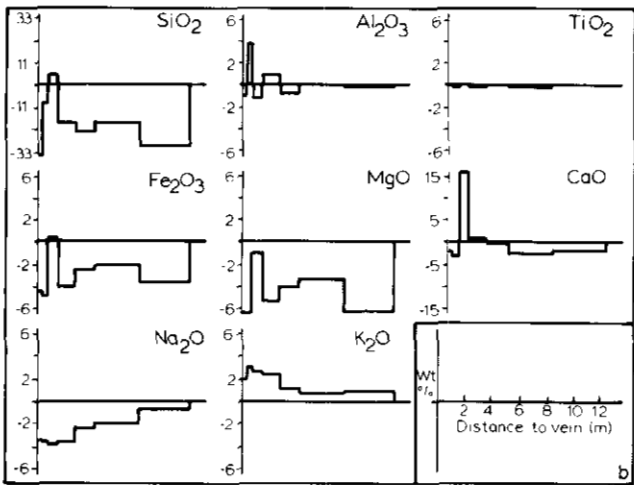
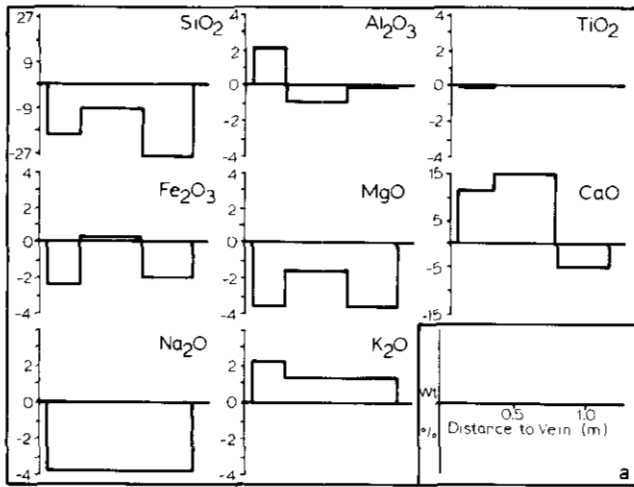


Figure 2-4-3. (a) Gresens plot of weight per cent loss/gain of oxides, plotted versus distance from the vein. Hangingwall of 51 vein, 8 level, near Empire shaft, Bralorne mine, compared to sample C093, the least altered diorite host, from DDH UB-81-17 at 350-400'. Volume factor based on Al_2O_3 and TiO_2 . (b) Same details as (a) but in footwall of 51 vein, 15 level, near Crown shaft, Bralorne mine.

WALLROCK ALTERATION

PETROGRAPHY

Detailed thin-section examination of altered wallrocks at Bralorne has been completed. The common arrangement of alteration minerals around a vein is from an outer green chlorite-epidote zone through a buff carbonate-albite zone to a foliated cream quartz-sericite \pm carbonate zone.

Biotite alteration distributed along fractures, and therefore hydrothermal, has also now been recognized at Bralorne. It occurs both near the surface around the 51 vein and at depth around the 77 vein (see Figure 2-4-2 for locations). It is much more common to the southeast on the Pioneer (Joubin, 1948) and P.E. Gold (Nordine, 1983) properties. The Pioneer greenstones on these two properties seem to alter more readily to biotite, as do the green hornblende porphyry dykes near the 51 vein on 4 level at Bralorne. Otherwise, biotite is only seen below 40 level (1700-metre depth) at Bralorne

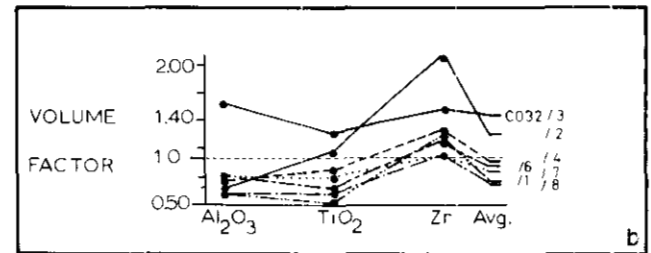
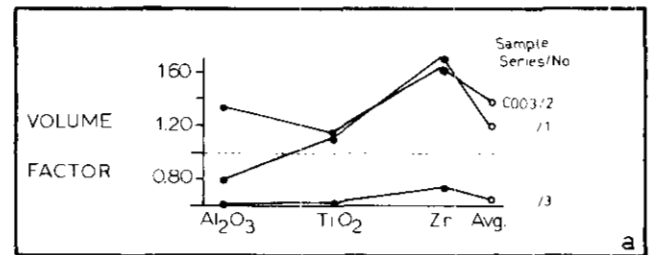


Figure 2-4-4. (a) Volume factor plot for the sample series in Figure 2-4-3(a). (b) Volume factor plot for the sample series in Figure 2-4-3(b).

when the altered host rock is diorite. This may be similar to the Sigma mine in Quebec (Robert and Brown, 1986) where biotite only becomes prominent as an alteration mineral in the lower levels, suggesting that the Pioneer and P.E. Gold properties expose deeper levels of the vein system than seen at Bralorne. Unfortunately the biotite is always intimately intergrown with chlorite and sericite and is not suitable for isotopic dating.

Cream-coloured carbonate alteration at Bralorne is almost always iron-calcite close to the veins, with calcite away from the veins. The iron-calcite does not react to cold dilute hydrochloric acid, and because of its characteristic orangey brown weathering, it has often been misidentified as ankerite. However, even in rocks showing strong carbonate alteration, X-ray diffraction peaks for ankerite and dolomite are very weak or completely absent. This implies a lack of magnesium in the hydrothermal system, which is borne out by the results of chemical analysis (see below).

Two other unusual alteration facies in Pioneer volcanics were found in specimens collected from the Pioneer mine by Joubin, which are now in The University of British Columbia Economic Geology Collection. These are garnet-quartz-calcite-pyrite and quartz-tourmaline (schorl) facies. Neither is common, but the presence of borosilicate is significant; it is common in analogous systems in the Precambrian Shield. (for example, Sigma; Robert and Brown, 1986), but apparently rare at Bralorne.

Albite alteration around the Bralorne veins is stronger and much more widespread than was previously reported (Leitch and Godwin, 1987). It is difficult to recognize due to its superposition on a background of albite from greenschist metamorphism, and the ubiquitous presence of albite in soda granite and albitite dykes. However when examined carefully in thin section it becomes clear that much of the original albite, even in these sodic rocks, has been pervasively altered to "patchwork", "chessboard" and "irregular" albite (Battay, 1951; Leitch, 1981) in proximity to major vein



Plate 2-4-1(a). Primary igneous phenocryst of plagioclase in a grey plagioclase porphyry being replaced by a symplectic overgrowth of quartz and albite. (b) Primary texture of soda granite being replaced by symplectic overgrowths of quartz and albite in a radiating pseudo-hexagonal pattern.

systems. The textural evidence thus supports a hydrothermal origin for the albite found in veinlets, as well as much of that in envelopes surrounding larger quartz veins.

Silica flooding forms an unusual alteration facies and is found in the central portions of the large dyke-like mass of soda granite lying northeast of the diorite (Figure 2-4-2). These sections are exposed in diamond-drill core, in which the typical silica crackling or stockworking by hairline quartz-pyrite veinlets in the soda granite becomes increasingly strong. This leads eventually to a rock composed almost entirely of quartz and albite, with some sericite developed after albite, and pyrite after mafics. In thin section, this intense silicification takes several forms, the most striking being a symplectic intergrowth of quartz and albite that locally completely replaces primary igneous textures (Plate 2-4-1). The texture nucleates in clots which have a radial pattern and pseudo-hexagonal outline, implying quartz grains growing outwards. These textures are restricted to the the most siliceous intrusive phases: soda granite, albitite dykes, and the grey plagioclase porphyry dykes.

A distinctive black calcium carbonate alteration is occasionally present; it also develops along hairline fractures and eventually replaces the whole rock, turning it black and

almost opaque in thin section. The black coloration is caused by myriads of extremely fine (1 to 2 microns) opaque inclusions which may be carbon or, more likely, pyrrhotite. This alteration crosscuts, and is clearly later than, the main-stage alteration associated with mineralization.

ALTERATION CHEMISTRY

A preliminary report in Leitch and Godwin (1987) outlined general trends in alteration chemistry. Further chemical analyses of 10 detailed traverses across altered foot and hangingwall rocks of major veins are in Table 2-4-5. Traverses in diorite host rock cover a vertical range of 1200 metres from surface down to 26 level on the 51 vein system, and 2000 metres from surface down to 44 level on the related 77 and 79 vein systems. In soda granite, which is a less important ore host (Campbell, undated; James and Weeks, 1961), only two traverses were sampled, at 8 and 26 levels on the 51 vein system. All chemical data were reduced to percent losses and gains relative to the appropriate fresh host rock. Volume changes were corrected for by the method of Gresens (1967), as modified by Sketchley and Sinclair (1987), with a computer program developed for the purpose (Leitch and Day, in preparation).

**TABLE 2-4-5
CHEMISTRY OF ALTERED HOST ROCKS, BRALORNE MINE**

Location	Surface:	-51 Vein (in diorite)			-77 Vein (granite)	
	FW	HW				
Sample No.	C1027F1	WC1027F1	C1027H1	C1027H2	C1027H3	C048HW
Distance to Vein (m)	0.1	0.2	0.1	0.3	2.3	1.0
(No. of Analyses)	(2)	(2)	(2)	(2)	(2)	(2)
Major Elements (%)						
SiO ₂	59.5	57.4	52.6	41.6	50.4	70.0
Al ₂ O ₃	13.4	12.5	19.1	19.6	15.1	12.9
TiO ₂	0.23	0.22	0.36	0.58	0.48	0.26
Fe ₂ O ₃						
(Total Fe)	7.42	6.52	8.21	9.52	11.2	5.22
MgO	2.72	3.29	3.69	4.80	5.59	1.77
CaO	4.60	6.36	6.29	11.3	8.51	3.28
Na ₂ O	0.65	0.70	0.21	0.50	1.71	4.00
K ₂ O	2.40	2.14	3.32	2.90	0.65	1.10
MnO	0.13	0.13	0.11	0.17	0.14	0.07
P ₂ O ₅	0.03	0.03	0.05	0.04	0.04	0.12
LOI	9.05	10.74	6.07	9.08	6.31	3.65
TOTAL	(100)	(100)	(100)	(100)	(100)	(100)
Specific Gravity	2.59	—	2.81	2.83	2.80	2.65
Minor Elements (ppm)						
As	180	100	410	1610	19	4
Ba	220	185	265	240	95	350
Co	38	50	24	33	32	10
Cr	210	90	96	25	103	13
Cu	53	47	80	140	39	12
Nb	0	0	2	2	2	ND
Ni	60	42	3	8	16	6
Pb	17	14	10	10	11	20
Rb	45	37	62	60	16	12
S	665	670	2.76%	2.37%	2080	620
Sb	7	12	0	0	0	ND
Sr	90	110	100	150	280	90
V	76	66	80	150	220	30
Y	16	13	7	14	16	6
Zn	72	60	43	72	60	32
Zr	65	57	65	21	48	27

NOTE: Alteration types for Table 2-4-5 are as follows: Q = quartz, A = albite, S = sericite, C = carbonate, X = chlorite, E = epidote, F = fuchsite, Sx = sulfide, B = biotite. Totals given to 2 decimal places include at least one analysis by fused glass disk. All others, listed as (100), are by pressed powder pellet only and have no significance, having been normalized to 100%.

Location	8 Level -51 Vein (in diorite)						
	FW			HW			
Sample No.	CO02F1	C002F2	WC002F3	C002F4	C003H1	C003H2	C003H3
Distance to Vein (m)	0.1	0.4	1.5	3.5	0.1	0.5	1.0
(No. of Analyses)	(2)	(3)	(2)	(2)	(2)	(1)	(2)
Major Elements (%)							
SiO ₂	49.7	54.0	54.8	53.0	42.6	40.6	51.7
Al ₂ O ₃	6.5	14.8	14.6	14.9	14.1	8.3	18.0
TiO ₂	0.12	0.21	0.24	0.20	0.21	0.21	0.39
Fe ₂ O ₃ (Total Fe)	4.3	6.7	5.9	6.1	5.7	6.6	9.6
MgO	4.6	3.0	3.3	4.8	2.2	5.0	5.9
CaO	16.7	10.0	9.0	7.8	19.5	17.7	4.0
Na ₂ O	0.09	0.29	1.88	1.36	0.13	0.08	0.38
K ₂ O	1.35	2.85	1.70	1.59	2.49	1.16	2.37
MnO	0.18	0.11	0.12	0.10	0.20	0.26	0.11
P ₂ O ₅	0.02	0.02	0.05	0.01	0.04	0.02	0.02
LOI	16.41	8.07	8.38	10.18	12.79	19.89	7.65
TOTAL	(100)	(100)	(100)	(100)	(100)	(100)	(100)

TABLE 2-4-5: CONTINUED

Sample No.	C002F1	C002F2	WC002F3	C002F4	C003H1	C003H2	C003H3
Specific Gravity	2.80	2.88	2.70	2.73	2.82	2.84	2.77
Minor Elements (ppm)							
As	4000	1835	17	47	4950	21	28
Ba	120	160	145	170	150	140	200
Co	15	37	32	31	29	15	27
Cr	360	160	21	110	17	140	62
Cu	8	28	26	5	7	15	32
Nb	0	0	0	1	1	2	1
Ni	88	60	11	38	12	24	21
Pb	9	8	9	7	7	14	12
Rb	27	89	39	33	47	25	45
S	1.05%	2.75%	4780	1340	2.03%	1050	875
Sb	14	4	0	0	25	20	0
Sr	195	185	110	140	135	200	46
V	35	90	80	80	75	70	170
Y	10	14	11	12	15	34	13
Zn	47	47	50	56	29	46	95
Zr	30	120	93	48	29	29	67

Location	8 Level - 51B FW Vein (in soda granite)					
	FW			HW		
Sample No.	C111-1	C111-2/3	C111-4/8	C111-29	C111-30	C111-31
Distance to Vein (m)	1.0	0.3	0.1	0.5	1.0	3.5
(No. of Analyses)	(2)	(2)	(2)	(2)	(2)	(2)
Major Elements (%)						
SiO ₂	72.5	73.1	68.5	71.8	75.2	73.6
Al ₂ O ₃	13.4	14.5	17.7	17.9	15.4	13.6
TiO ₂	0.19	0.16	0.16	0.21	0.17	0.13
Fe ₂ O ₃ (Total Fe)	2.56	1.56	2.20	1.48	1.38	2.33
MgO	1.17	0.54	0.49	0.60	0.45	0.87
CaO	2.47	3.18	4.04	0.62	0.91	2.39
Na ₂ O	1.69	0.53	0.27	0.32	0.23	2.41
K ₂ O	2.49	2.87	3.37	3.72	3.22	1.80
MnO	0.09	0.04	0.04	0.01	0.01	0.09
P ₂ O ₅	0.04	0.05	0.04	0.04	0.03	0.03
LOI	3.31	3.48	3.17	3.35	2.98	2.74
TOTAL	(100)	(100)	(100)	(100)	(100)	(100)
Specific Gravity	2.70	2.70	2.74	2.71	2.73	2.70
Minor Elements (ppm)						
As	20	1500	1940	2100	3280	9
Ba	185	190	225	255	220	170
Co	3	42	55	4	5	5
Cr	12	11	11	12	13	13
Cu	65	18	4	2	5	125
Nb	3	2	2	2	1	5
Ni	5	3	2	4	3	4
Pb	15	12	13	12	10	14
Rb	40	47	52	63	54	32
S	5020	7940	1.67%	8960	7560	3380
Sb	12	2	13	14	13	4
Sr	55	49	76	22	18	64
V	34	27	30	40	23	29
Y	18	15	13	17	13	27
Zn	300	220	170	100	130	340
Zr	98	70	84	102	75	110
Alteration Type	A-Q-C	Q-S-A-C	Q-C-S	Q-S-C	Q-S-C	Q-A-X
Modal Mineralogy (% Estimated from thin section)						
Quartz	37	50	50	47	60	45
Albite	40	17		6		40
Sericite	7	20	15	35	30	4
Calcite	10	7	25	7	7	3
Ankerite (Fe-carbonate)		2	5			
Chlorite	3					6
Sulphides	py	py,po,as3	py,sl,as5	py,as3	py,sl,as3	po1
Oxides	ru1	ru1	ru<1	ru2	ru<1	ru2

TABLE 2-4-5 : CONTINUED

Location	15 Level - 51 Vein (in diorite)						
	FOOTWALL						
Sample No.	C032-1	C032-2	C032-3	C032-4	C032-5/6	C032-7	C032-8
Distance from Vein (m)	0.1	0.5	1.0	2.0	3.5	5.0	10.0
(No. of Analyses)	(1)	(1)	(1)	(1)	(1)	(1)	(2)
Major Elements (%)							
SiO ₂	45.15	60.15	45.25	53.01	49.02	53.66	48.38
Al ₂ O ₃	18.85	17.75	7.06	15.47	14.12	14.66	18.20
TiO ₂	0.46	0.22	0.18	0.27	0.34	0.30	0.33
Fe ₂ O ₃ (Total Fe)	6.14	3.46	5.72	4.93	7.15	7.65	7.11
MgO	3.24	2.07	5.03	3.51	5.57	6.33	3.35
CaO	9.22	4.93	16.26	9.82	8.97	6.13	8.49
Na ₂ O	0.76	0.24	0.03	0.24	2.21	2.57	5.04
K ₂ O	3.69	3.70	1.80	3.01	1.73	1.14	1.56
MnO	0.12	0.08	0.19	0.12	0.14	0.14	0.08
P ₂ O ₅	0.04	0.06	0.05	0.04	0.04	0.05	0.02
LOI	12.26	7.55	18.82	10.04	11.01	7.28	6.39
TOTAL	99.94	100.21	100.38	100.46	100.29	99.89	99.00
Specific Gravity	2.76	2.75	2.82	2.74	2.75	2.73	2.72
Minor Elements							
Ag	ND	ND	ND	ND	ND	ND	ND
As	4700	150	714	673	45	23	8
Ba	240	200	81	179	132	106	137
Cl	26	31	45	75	50	30	31
Co	20	ND	31	14	16	25	15
Cr	60	154	1835	165	74	86	35
Cu	25	36	35	30	43	29	47
Mo	2	2	1	1	1	1	1
Nb	ND	ND	1	ND	ND	ND	2
Ni	17	6	494	33	38	20	8
Pb	4	3	1	10	5	4	5
Rb	50	48	25	43	25	20	27
S	1.43%	4550	4971	6844	1292	336	3166
Sb	22	8	27	18	4	3	ND
Sr	170	78	157	113	83	125	68
V	110	43	79	140	151	167	272
W	12	5	ND	ND	4	ND	ND
Y	13	8	7	8	14	12	6
Zn	75	31	43	38	44	50	30
Zr	41	24	32	38	43	49	49
Alteration Type	C-S-A (Bxa)	Q-C-S (Schist)	C-S-Q (Schist)	C-A-Q-S	A-S-X-C	A-C-X-S	A-X-C
Modal Mineralogy (% Estimated from thin section)							
Quartz	5	40	13	20	7	10	2
Albite	10			25	43	25	55
Sericite (+ Fuchsite)	35	24	20	13	18	20	
Calcite	40	20	65	35	12	25	15
Ankerite (Fe-carbonate)	5	15			5		
Chlorite				5	13	20	25
Sulphides	py,as3	py1	pol	py1	py1	po,py1	
Oxides	ru2		ctf	ru1	ru1	ru<1	ru2

Location	15 Level - 51 Vein (in diorite)						
	HANGING WALL						
Sample No.	C033/1-2	C033/3-4	C033/5-6	C033/7	C033/8	C033/9	C033/10
Distance to Vein (m)	0.3	1.5	3.5	5.0	8.0	9.0	10.0
(No. of Analyses)	(2)	(1)	(2)	(1)	(1)	(1)	(3)
Major Elements (%)							
SiO ₂	63.66	57.56	54.81	50.58	55.52	57.03	51.71
Al ₂ O ₃	6.89	14.54	17.23	15.02	13.12	9.29	15.19
TiO ₂	0.12	0.22	0.31	0.34	0.28	0.19	0.49
Fe ₂ O ₃ (Total Fe)	3.34	4.79	7.71	9.56	6.96	7.53	10.54
MgO	2.72	2.83	3.85	5.01	3.46	11.12	6.40
CaO	11.59	7.67	4.97	6.54	9.95	8.14	7.51
Na ₂ O	0.13	0.60	1.07	2.86	2.97	2.09	3.04
K ₂ O	1.38	2.69	2.51	1.18	0.21	0.04	0.03
MnO	0.10	0.11	0.09	0.17	0.14	0.19	0.20
P ₂ O ₅	0.03	0.05	0.04	0.03	0.02	0.02	0.07
LOI	10.46	9.34	7.62	8.60	6.43	4.14	3.14
TOTAL	100.42	100.39	100.21	99.89	99.07	99.78	98.33

TABLE 2-4-5: CONTINUED

Sample No.	C033/1-2	C033/3-4	C033/5-6	C033/7	C033/8	C033/9	C033/10
Specific Gravity	2.83	2.74	2.78	2.76	2.80	2.92	2.84
Minor Elements (ppm)							
Ag	ND	ND	ND	ND	ND	ND	ND
As	4340	86	1310	34	12	9	18
Ba	62	179	207	141	58	26	51
Cl	53	24	17	25	26	65	50
Co	33	10	26	32	20	35	30
Cr	972	95	52	10	25	620	50
Cu	26	24	80	128	56	20	70
Mo	2	2	ND	ND	2	ND	ND
Nb	1	ND	1	1	ND	ND	1
Ni	312	7	22	15	11	69	17
Pb	10	8	7	6	4	6	6
Rb	20	40	40	19	7	2	3
S	9580	6123	5625	2095	2497	217	6520
Sb	71	8	9	2	6	9	1
Sr	130	120	81	101	192	58	109
V	63	80	263	324	186	129	236
W	ND	2	ND	ND	ND	ND	ND
Y	6	9	10	13	13	17	17
Zn	45	41	55	54	46	55	80
Zr	27	73	33	42	35	28	43
Alteration Type	Q-C-S-F (Schist)	Q-C-S (Schist)	C-Q-S-A-X	A-X-C-Q	A-X-C	FRESH	A-E
Modal Mineralogy (% Estimated from thin section)							
Quartz	40	25	15	10	8	5	5
Albite		8	20	40	45	35	50
Sericite (+ Fuchsite)	8	25	20	8	3		
Calcite	35	15	27	15	10	3	4
Ankerite (Fe-carbonate)	5	20					
Epidote (+ Zoisite)					2	5	33
Chlorite		5	16	25	30	2	5
Hornblende (+ Actinolite)						50	
Sulphides	py,as11	py,po2	po2	py2	py1		po2
Oxides	ct1				ru1	ru<1	ru1

Location	19 Level -51 Vein (in diorite)					
	FW			HW		
Sample No.	1951F1	1951F2	1951F3	1951F4	1951H1	1951H2
Distance from Vein (m)	0.1	0.8	1.5	3.0	0.1	0.5
(No. of Analyses)	(3)	(1)	(2)	(2)	(1)	(1)
Major Elements (%)						
SiO ₂	50.11	68.5	45.0	56.9	49.8	53.7
Al ₂ O ₃	13.05	11.9	15.3	13.7	13.6	14.5
TiO ₂	0.15	0.20	0.32	0.39	0.23	0.38
Fe ₂ O ₃ (Total Fe)	3.59	1.83	9.90	9.25	5.46	7.77
MgO	2.98	1.40	6.82	7.39	6.02	6.55
CaO	12.85	6.63	9.63	6.63	12.6	7.05
Na ₂ O	0.53	1.33	2.04	2.46	0.30	1.03
K ₂ O	2.86	2.28	1.08	0.04	2.25	1.81
MnO	0.13	0.04	0.14	0.15	0.10	0.11
P ₂ O ₅	0.04	0.03	0.02	0.02	0.03	0.14
LOI	13.94	5.84	9.83	3.19	9.70	7.08
TOTAL	100.23	(100)	(100)	(100)	(100)	(100)

TABLE 2-4-5: CONTINUED

Sample No.	1951F1	1951F2	1951F3	1951F4	1951H1	1951H2
Specific Gravity	2.77	2.71	2.76	2.84	2.77	2.73
Minor Elements (ppm)						
As	1200	19	31	9	55	ND
Ba	240	160	100	60	180	150
Co	4	4	38	45	34	35
Cr(*)	120	200	42	75	160	48
Cu	10	ND	70	62	47	48
Nb	ND	ND	2	1	2	3
Ni	18	2	26	18	49	23
Pb	22	8	9	11	6	12
Rb	71	46	23	ND	48	36
S	8000	7400	4300	7900	8800	5500
Sb	ND	ND	5	ND	ND	ND
Sr	400	80	75	62	90	45
V(*)	50	30	120	150	70	130
Y	7	4	9	16	14	15
Zn	47	26	76	77	52	61
Zr	9	16	27	29	46	39
Alteration Type	Q-S-C-A	Q-S-C-A	C-A-X-S	A-C-E-X	Q-C-S-X	Q-C-A-X
Modal Mineralogy (% Estimated from thin section)						
Quartz	30	55	10	5	35	30
Albite	20	10	25	50	5	25
Sericite	20	18	15		15	8
Calcite	20	12	27	5	30	25
Epidote (+ Zoisite)				5		
Chlorite		1	20	3	12	10
Hornblende (+ Actinolite)				30		
Sulphides	as2.py3	py4	py1	po2	py3	po2
Oxides		ru<1	ru2	rutr		

Location	20 Level - 77 Vein							
	FW				HW			
Sample No.	W2077F0	2077F1	2077F2	2077H3	2077H5	2077H1	2077H2	2077H4
Distance to Vein (m)	0.1	0.2	0.5	0.1	0.5	1.0	2.0	5.0
(No. of Analyses)	(1)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
Major Elements (%)								
SiO ₂	50.8	46.7	53.1	42.0	41.6	46.7	42.2	40.3
Al ₂ O ₃	22.3	17.0	15.2	18.0	16.9	17.6	16.0	15.7
TiO ₂	0.45	0.79	0.97	0.27	0.46	0.44	0.54	0.45
Fe ₂ O ₃ (Total Fe)	7.06	6.50	7.31	9.33	14.4	11.0	14.8	11.6
MgO	1.65	5.35	8.07	6.97	7.55	6.05	7.30	10.5
CaO	6.69	9.13	6.43	9.15	7.90	5.87	7.51	8.65
Na ₂ O	0.18	0.48	2.94	1.03	1.44	2.02	2.24	1.88
K ₂ O	3.77	2.51	0.18	1.97	1.01	0.63	0.29	0.13
MnO	0.07	0.11	0.10	0.12	0.15	0.13	0.15	0.15
P ₂ O ₅	0.05	0.16	0.18	0.01	0.04	0.02	0.02	0.01
LOI	7.03	11.67	5.61	11.63	9.14	9.89	9.10	0.61
TOTAL	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)
Specific Gravity	2.89	2.78	2.79	2.81	2.68	2.79	2.81	2.78
Minor Elements (ppm)								
As	5900	1120	ND	64	30	71	40	48
Ba	450	350	160	450	120	220	130	60
Co	45	37	40	45	53	52	57	52
Cr (*)	20	140	130	40	35	25	30	220
Cu	71	46	67	26	100	81	110	90
Nb	ND	1	2	ND	ND	ND	ND	1
Ni	14	35	45	27	23	24	21	70
Pb	15	16	16	11	13	20	12	10
Rb	71	62	ND	43	19	17	5	2
S	2.13%	3800	940	2500	3300	2500	3400	910
Sb	15	ND	3	ND	ND	2	ND	ND
Sr	125	170	600	150	125	160	320	160
V (*)	210	190	220	150	250	200	260	170
Y	13	16	17	7	4	9	10	8
Zn	75	93	100	56	75	68	73	83
Zr	41	80	78	14	19	20	15	19

TABLE 2-4-5: CONTINUED

Location	26 Level - 85 Vein (soda granite)				32 Level - 79 Vein (diorite)			
	FW		HW		FW		HW	
Sample No.	C118/1-4	C118	C118/16	C118/17	WC117/1	WC117	C117/9	C117/11
Distance to Vein (m)	0.7	3.0	1.5	3.0	0.1	1.2	0.1	1.2
(No. of Analyses)	(1)	(2)	(1)	(1)	(5)	(2)	(2)	(2)
Major Elements (%)								
SiO ₂	75.2	76.7	74.6	75.1	40.04	45.6	45.4	40.1
Al ₂ O ₃	14.5	12.1	12.6	11.9	16.69	12.2	14.1	15.3
TiO ₂	0.15	0.18	0.21	0.22	0.82	0.75	0.75	1.20
Fe ₂ O ₃ (Total Fe)	2.14	2.03	2.30	2.11	16.97	14.2	12.9	19.0
MgO	0.43	0.57	0.66	0.36	8.82	10.1	11.2	8.55
CaO	1.37	1.41	2.14	2.42	7.26	11.1	8.50	11.7
Na ₂ O	2.03	4.39	4.55	4.50	1.60	2.25	1.55	1.31
K ₂ O	2.17	1.04	0.87	0.80	0.25	0.13	0.22	0.08
MnO	0.02	0.03	0.05	0.04	0.18	0.19	0.13	0.17
P ₂ O ₅	0.02	0.01	0.03	0.07	0.02	0.02	0.05	0.04
LOI	1.95	1.44	2.06	2.47	7.97	3.47	5.35	3.62
TOTAL	(100)	(100)	(100)	(100)	100.62	(100)	(100)	(100)
Specific Gravity	2.68	2.67	2.59	2.67	2.91	3.02	2.91	3.15
Minor Elements (ppm)								
As	1300	16	ND	1	23	13	17	ND
Ba	190	120	88	94	100	90	77	27
Co	3	4	37	9	50	60	56	49
Cr	20	18	12	19	43	65	470	200
Cu	43	5	54	67	82	54	38	22
Nb	3	ND	2	3	ND	1	1	2
Ni	6	3	3	7	12	50	190	65
Pb	15	12	8	12	11	15	15	14
Rb	41	20	16	16	2	3	3	ND
S	6700	6300	3100	1800	2050	320	260	1800
Sb	7	ND	4	ND	6	ND	3	2
Sr	63	65	72	75	210	170	180	150
V	30	35	40	45	350	280	250	200
Y	31	5	7	23	8	28	17	11
Zn	19	31	31	31	100	67	59	75
Zr	185	210	130	30	11	22	21	18
Alteration Type	Q-S-A	Q-A-S	Q-A-S	A-Q-X	C-X-A-E	A-E-C	C-X-E-A	A-X-E-C
Modal Mineralogy (Estimated from thin section, %)								
Quartz	50	40	50	40	5	tr	3	tr
Albite	15	40	35	45	10	30	10	40
Sericite	25	10	5	2				
Calcite		5	4	3	35	5	5	10
Ankerite	5		1				25	
Epidote (+ Zoisite)					10	10	15	10
Chlorite	2	2	3	8	30	tr	20	10
Clinopyroxene						20		10
Hornblende (+ Actinolite)					5	35	20	10
Sulphide (Py,Po)	3	3	2	1	<1			
Rutile	<1	<1	<1	1	5	<1	2	10

Location	41 Level - 79 Vein (in diorite)						
	FW			HW			
Sample No.	C116	C116/18	C116/19	C116/20	C116/21	C116/22	C116/23
Distance to Vein (m)	0.1	0.3	1.0	2.0	3.0	5.0	10.0
(No. of Analyses)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
Major Elements (%)							
SiO ₂	38.0	44.7	50.5	41.1	37.1	46.4	39.0
Al ₂ O ₃	17.2	20.4	20.7	15.3	13.7	20.8	15.6
TiO ₂	0.75	1.55	0.23	0.78	0.97	1.18	0.76
Fe ₂ O ₃ (Total Fe)	12.8	12.4	5.13	11.1	16.3	12.8	14.5
MgO	7.95	5.93	3.69	7.70	7.30	7.07	8.48
CaO	13.1	5.29	6.40	10.2	12.5	3.30	9.79
Na ₂ O	0.34	2.52	2.35	0.30	1.05	0.94	1.31
K ₂ O	1.93	1.71	3.05	1.51	0.56	2.32	0.07
MnO	0.18	0.11	0.22	0.17	0.17	0.11	0.22
P ₂ O ₅	0.04	0.17	0.11	0.06	0.07	0.13	0.25
LOI	8.32	4.77	7.66	11.96	10.29	5.09	10.19
TOTAL	(100)	(100)	(100)	(100)	(100)	(100)	(100)
Specific Gravity	2.88	2.83	2.76	2.80	2.84	2.80	2.84

TABLE 2-4-5: CONTINUED

Sample No.	C116	C116/18	C116/19	C116/20	C116/21	C116/22	C116/23
Minor Elements (ppm)							
As	5400	6100	39	37	57	66	2
Ba	230	200	450	220	120	230	61
Co	39	34	18	34	92	23	33
Cr	100	25	40	95	30	80	40
Cu	220	38	ND	ND	190	39	2
Nb	ND	1	ND	4	1	2	ND
Ni	24	18	15	64	47	46	67
Pb	20	21	12	17	20	16	15
Rb	37	31	61	30	14	46	ND
S	2.12%	2.05%	1800	245	1.27%	9500	230
Sb	43	2	ND	ND	ND	ND	ND
Sr	230	190	200	105	130	120	230
V	260	340	70	250	280	290	200
Y	14	16	8	27	26	21	15
Zn	100	90	40	66	80	75	86
Zr	13	24	11	24	42	18	15
Alteration Type	C-Q-S-Sx	C-S-A-X	C-S-X-Q	C-S-X-E	C-A-S-X	S-X-C-Q	A-X-C-S
Modal Mineralogy (% Estimated from thin section)							
Quartz	10	2	10	tr	2	15	5
Albite		15	7		30	5	40
Sericite	10	30	25	25	10	40	10
Calcite	40	30	30	30	35	10	20
Ankerite (Fe-carbonate)		5	5		3	5	
Epidote				20			
Chlorite	30	12	20	20	10	20	23
Sulphides	po6,as2	as4,po1	py,po1		po6,cp1	po3	
Oxides, Phosphates	ru2	ru1	ru2	ap3,ru2	ru3	ru2	ru2

Location

44 Level - 77 Vein (in diorite)

Sample No.	FW				HW				
	C128/21	C128/23	C128/24	C128/5	C128/4	C128/3	C128/2	C128/1	WC128
Distance to Vein (m)	0.1	1.0	2.0	0.1	1.0	2.0	3.0	4.0	5.0
(No. of Analyses)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
Major Elements (%)									
SiO ₂	28.5	56.2	55.8	41.1	42.1	39.1	42.3	40.7	39.6
Al ₂ O ₃	9.28	17.1	16.2	16.5	18.6	18.3	20.6	19.5	14.7
TiO ₂	0.38	0.68	0.66	0.78	0.75	0.74	0.70	0.60	0.72
Fe ₂ O ₃ (Total Fe)	6.63	7.91	8.76	12.4	16.7	16.3	14.0	13.8	12.0
MgO	9.24	5.80	5.17	8.82	10.1	9.21	6.08	6.90	13.4
CaO	24.8	2.91	4.67	8.63	4.40	6.43	5.71	9.38	12.2
Na ₂ O	0.16	3.80	4.88	1.41	1.85	1.17	2.63	2.13	1.44
K ₂ O	0.42	1.13	0.15	0.78	0.38	0.27	1.55	0.20	0.17
MnO	0.14	0.10	0.16	0.16	0.18	0.19	0.14	0.23	0.17
P ₂ O ₅	0.03	0.21	0.22	0.08	0.03	0.02	0.20	0.23	0.03
LOI	20.97	4.31	3.33	9.43	4.74	8.35	6.08	6.39	9.21
TOTAL	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)
Specific Gravity	2.77	2.74	2.80	2.80	2.89	2.84	2.84	2.88	2.88
Minor Elements (ppm)									
As	425	3	ND	14	ND	1	110	ND	3
Ba	110	240	110	190	80	68	200	70	75
Co	49	32	35	44	45	32	35	23	23
Cr	600	31	58	150	36	34	61	22	220
Cu	33	20	58	65	130	120	140	120	26
Nb	ND	3	4	2	ND	ND	1	ND	1
Ni	170	11	11	39	14	12	28	11	105
Pb	14	9	12	15	13	9	20	18	17
Rb	6	21	3	17	12	9	38	4	5
S	2800	5100	2000	2200	1.06%	3200	1.04%	1170	840
Sb	1	ND	ND	ND	ND	9	6	ND	ND
Sr	200	250	360	125	270	230	190	400	260
V	140	160	155	260	310	230	230	200	220
Y	17	23	23	13	6	7	8	7	12
Zn	56	110	100	110	95	60	51	70	90
Zr	10	81	79	34	5	9	8	5	9
Alteration Type	X-C-A	A-C-X	A-C-X-E	X-A-S-C	A-X-B	X-A-E-C	S-X-A-C	A-X-C-E	E-C-X-A

TABLE 2-4-5: CONTINUED

Sample No.	C128/21	C128/23	C128/24	C128/5	C128/4	C128/3	C128/2	C128/1	WC128
Modal Mineralogy (% Estimated from thin section)									
Quartz	tr	tr	5	4		5	5		3
Albite	10	50	60	25	40	20	15	30	10
Sericite		10	1	17	5	3	40	5	
Calcite	25	20	10	10	5	15	10	20	20
Ankerite (Fe-carbonate)				8					
Epidote (+ Zoisite)			10	2		20		20	40
Chlorite	55	15	10	27	25	25	20	20	15
Biotite					15	5			
Hornblende (+ Actinolite)									10
Sulphides	po3,cp1,as	po,cp2	po1	po.py.as.cp2	po4,cp1	py·1	po2,cp1	po1	po·1
Oxides	ru6,ap1	ru3	ru3	ru5	ru5	ru7	ru7	ru4	ru2

A few representative examples of the chemical changes adjacent to the major veins are provided in Figure 2-4-3 (a and b). The more obvious changes on approaching the vein, with mineralogical explanations, are:

- (1) Loss of Na₂O and increase in K₂O, due to destruction of albite and replacement by sericite.
- (2) Loss of MgO and Fe₂O₃, due to destruction of mafic minerals (hornblende) and replacement by sericite and carbonate.
- (3) Increase in loss on ignition (LOI) and calcium content due to development of carbonate (calcite and iron-calcite or ankerite). This is variable, depending on composition of the original host rock. Often, even where strong carbonate replacement is seen in thin section, there is a net loss of calcium because quartz and sericite become prominent near the vein and calcite is replaced by iron-calcite or ankeritic carbonate.
- (4) There is a net loss of SiO₂ in the vein envelope that is variable due to the inclusion of thin quartz veinlets in some samples near the vein.

There is no major change in alteration chemistry from the surface to the 2000-metre depth; thin-section examination indicates that similar alteration assemblages (with the possible exception of biotite) are present on 44 level and at surface. Differences between the way diorite and soda granite react to alteration are slight. There is a less noticeable loss of Fe₂O₃ and MgO in the altered soda granite, as there are only minor mafics to destroy; there is a greater loss of Na₂O, as albite is more abundant. Changes in calcium are often less noticeable, again as most of the calcium is in mafic minerals in both soda granite and diorite, and the soda granite is considerably less mafic.

The diagrams of losses and gains (Figure 2-4-3) show relatively little change in Al₂O₃ and TiO₂, since these components and zirconium are used as approximations to immobility in order to estimate volume changes. Of course, per cent changes in Al₂O₃ are larger than those in TiO₂ as alumina is far more abundant in unaltered rocks. An example of the volume changes or volume factor involved in alteration is given in Figure 2-4-4a. In this case there is an initial volume decrease (C003/3), possibly due to destruction of albite and hornblende. This is followed by an increase in volume (C003/1, 2) immediately adjacent to the vein, caused by strong carbonate alteration as shown by the correlated increases in LOI and calcium content (Table 2-4-5). Also shown in Figure 2-4-4b is the typical agreement between

Al₂O₃ and TiO₂ in estimation of the volume factor, and strong over estimation of volume factor by zirconium. In this case, zircon was rejected from the computation of the average volume factor used in making the profiles of loss/gain.

FLUID INCLUSIONS

Vein quartz at Bralorne is full of both primary and secondary fluid inclusions. Indisputably primary inclusions are abundant and arranged in prominent growth zones conforming to the crystal outlines, but they are all too small for inclusion studies. The rest of the inclusions may be divided into two main groups, or possibly three, on the basis of their homogenization temperatures.

Inclusions of the first group are often in clusters not obviously related to any fracture plane or growth zone. They may be primary (Roedder, 1984) and are so labelled in Table 2-4-6 and Figures 2-4-5 to 2-4-7. Some of them are visibly three-phase; they have an aqueous liquid phase, an inner carbon dioxide liquid phase and an innermost carbon dioxide vapour bubble. The presence of another component, probably methane, is indicated by the depression of the melting point of carbon dioxide by about 0.5 to 1.0°C from -56.6°C. Historically this is supported by a methane explosion in 1947 (Patterson, 1979) on the P.E. Gold property. Most, however, appear to be simple two-phase inclusions of aqueous liquid with a vapour bubble with no detectable carbon dioxide component. It is possible that these inclusions do contain a small amount of carbon dioxide rimming the vapour bubble, that is simply too small to see. They are grouped with the primary inclusions because of their similar homogenization temperatures.

The second group of inclusions are probably secondary (Roedder, 1984). They are arranged along myriads of tiny fractures that criss-cross the quartz grains with a brush or wispy texture which, together with the presence of the primary three-phase inclusions, indicates a mesothermal environment (J.T. Reynolds, personal communication, 1987). Many of this second group may be pseudosecondary inclusions (Roedder, 1984) as the fractures containing them do not cross some grain boundaries. They are referred to as secondary for simplicity in the discussion that follows.

Data from fluid inclusions are summarized in Table 2-4-6 and Figures 2-4-5, 2-4-6 and 2-4-7. Given the equipment limitations (the instrument used was a Chaixmeca stage on a Leitz Laborlux microscope with poor optics compared to current models), the approach followed was to gather as

TABLE 2-4-6
SUMMARY OF FLUID INCLUSION DATA, BRALORNE GOLD-QUARTZ VEIN SYSTEM
 (Summarized from Figures 2-4-5 and 2-4-6)

Level (vein) Depth (m)	Sample No.	Primary	Tm (ice) Psuedosec	Secondary	Primary	Th Psuedosec	Secondary
Surface (Lorne) (Cosmopolitan) 0	C1018 C1002		-2.0		295 + 15 280 + 20	230 + 30	
3 (Woodchuck) 130	C1024		-1.5		235 + 25	195 + 25	
8 (51B FW) (51B Bxa) 270	8-51B(FW) 8-51B	-7.0	-2.0 -2.5		310 + 60	225 + 15	140 + 20
15 (51) 580	15-51(C)		-2.5		260 + 20	190 + 20	
16 (51) 630	16-51FW(E)		-2.5 (-1.5)	-0.5	225 + 10	190 + 20 (215 + 25)	160 + 20
Additional Data: Te = -21 (-26)							
26 (85) 1100	C118-11		-1.6 + 0.6		290 + 40	225 + 25	
Additional Data: Tmc = +11.5 + 0.5; Te = -22.5 + 1							
32 (79) 1400	C117-7	-4.0 + 1	-1.5 (-2.0 + 1)		350 + 80	190 + 30 (205 + 35)	
Additional Data: Te = -20.5 (-24)							
	C117-5	-3.5	-1.5		270 + 40	180 + 30	
Additional Data: Tmc = +8.7 + 2.0; Te = (-21.5 + 0.5)							
41 (79) 1800	C116-14	-3.5		-0.5	?265 + 15	215 + 20	?150
44 (77) 2000	C128-20 C128-19	-5.0 -5.0	-1.5 -1.5		280 + 50 330 + 60	190 + 40 200 + 40	

Figures given in brackets are measured in calcite; all others from quartz. Tm ice (melting point of ice) figures can only be regarded as crude (order of magnitude) estimates. Th = homogenization temperatures; Tmc = melting point of clathrates; Te = eutectic point (first melting temperature).

much data as possible and plot histograms to illustrate salient features. The clustering of homogenization temperatures, coupled with relatively constant liquid/volume ratios (about 15 ± 5 per cent) within groups of inclusions in a single sample, and even from sample to sample, implies that necking has not been a serious problem. The primary/secondary separation, made largely on the dual populations seen in the histograms, appears to be valid, but further work is required to verify this.

The few fluid inclusions that were measured in calcite were generally three-phase (carbon dioxide bearing), as would be expected. It was impossible to determine if they were primary or secondary, but their homogenization temperatures are similar to the secondary inclusions in quartz. As the calcite is always paragenetically late, it is reasonable to postulate that the inclusions in calcite and the secondary inclusions in quartz both represent a phase of later, lower temperature fluids.

HOMOGENIZATION TEMPERATURES

Primary inclusions of the first group have optically determined final homogenization temperatures that increase with depth in the deposit, with a maximum range from 120 to 440°C (Figure 2-4-5). Homogenization temperatures for carbon dioxide range from 6 to 27°C. Most inclusions homogenize to the liquid phase, but a few homogenize to the vapour

phase. Although this may be due to necking down, this seems unlikely because the temperatures for homogenization to both liquid and to vapour are similar. This was hard to measure with certainty because the carbon dioxide bearing inclusions commonly decrepitated.

Decrepitation studies on samples submitted to Mitsubishi Metal Corporation in Japan (Sugiyama, 1986) provide a better indication of an increase in homogenization temperature with depth (Figure 2-4-7). The decrepitation method suffers from difficulties relating data to specific fluid inclusion types, significant overshoot of homogenization temperature to produce decrepitation, and variable overshoot depending on size of inclusions (small inclusions may be able to withstand much higher pressures). However the advantages are that data may be obtained from inclusions too small to measure optically and more rapidly than by optical means. In the present study a suite of samples from surface to 2000 metres, which had been studied optically, shows general agreement between decrepitation temperatures and the optically determined data. The gradient suggested by the decrepitation data is about 30°C per kilometre, which corresponds to a reasonable geothermal gradient. So far, this is the most pronounced vertical zonation found in the deposit.

It may be significant that the lower temperature group of fluid inclusions (psuedosecondary or secondary) shows little or no increase in temperature with depth. This suggests that they represent late fluids circulating after the deposit had

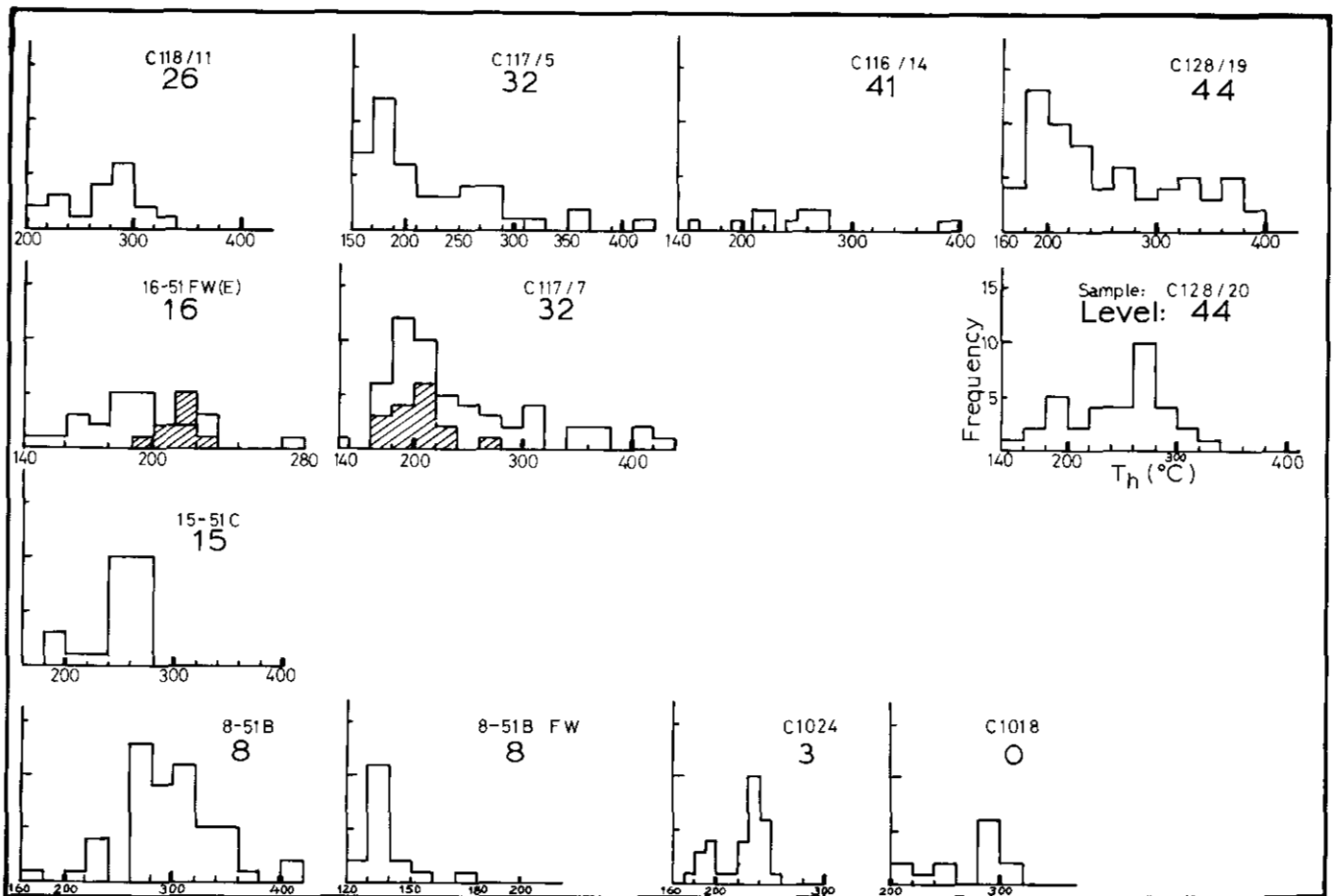


Figure 2-4-5. Histograms of homogenization temperatures (T_h) for various levels in the Bralorne mine. Mean values are summarized in Table 2-4-6 and plotted on Figure 2-4-7. All inclusions measured in quartz except those shown hachured, which are in calcite.

TABLE 2-4-7
SULPHUR ISOTOPE DATA FOR SEVERAL DEPOSITS OF THE BRIDGE RIVER CAMP

DEPOSIT (Sample No.)	Measured $\delta^{34}S$ for minerals:					Delta sl-gn	T (C)	
	gn	sl	tt	py	cp			po
Bralorne-Pioneer (E73.004.048)	+2.35	+4.13	+2.15			1.78	370	
Bralorne Mines (Suite #60)	-6.48 (-6.32)	-3.35				3.03	260	
Bralorne (41 Level, 79 Vein) (C116-14)	+5.95	+4.68		+8.99	+6.42	+4.17	reversed	—
Bralorne (Surface, Ida May) (E73.004.047)	+2.36		+4.53			—	—	
Pioneer (14th Level) (E3519)	-5.30	-2.63				2.67	295	
Pioneer (5th Level) (Joubin)	+1.94	+1.00 (+1.14)				reversed	—	
P.E. Gold (P-85-03/450.5 m)	-0.08	+1.78 (+1.78)		+2.85	+2.02	1.86	360	
BRX Arizona (unlocated)	-7.50	-4.22		-4.92	-5.76	3.28	240	
Blackdome (unlocated)	+0.64					—	—	

Legend: gn = galena, sl = sphalerite, tt = tetrahedrite, py = pyrite, cp = chalcopyrite, po = pyrrhotite.

Figures in brackets are repeat measurements. Sulphur isotope ratios and temperature estimates by H. Roy Krouse, Department of Physics, University of Calgary.

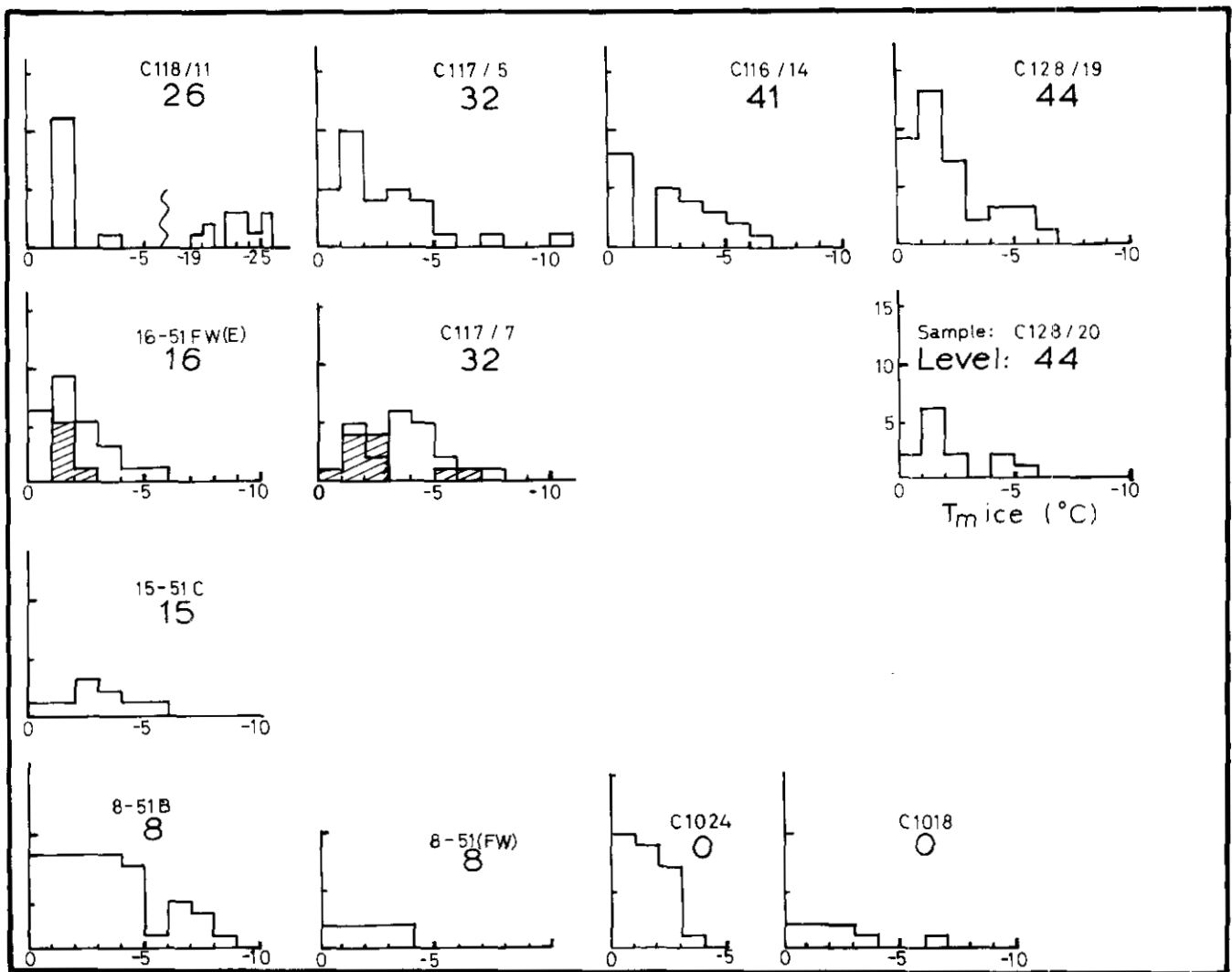


Figure 2-4-6. Histograms of ice melting temperatures (T_m) for various levels in the Bralorne mine. Mean values are summarized in Table 2-4-6. All inclusions measured in quartz except those shown hachured, which are in calcite.

been partially unroofed and the temperature gradients had been reduced.

Pressure corrections to temperature data to obtain trapping temperatures can be estimated by comparison of fluid inclusion homogenization temperatures to temperatures estimated from sulphur isotope equilibrium pairs. Sulphur isotope temperatures (*see below*) fall into two groups at around 250 and 350°C, which, if assumed to be trapping temperatures, may correspond to the two groups of homogenization temperatures at 200 and 280°C. If so, the pressure correction would be about 70°C for primary fluid inclusions and about 50°C for secondary inclusions. These would indicate pressures of approximately 1.0 kilobar for primary fluids and 0.5 kilobar for later fluids (Roedder, 1984, page 262), or depths of about 4 kilometres and 2 kilometres respectively, if lithostatic load conditions applied.

SALINITIES

Salinities of fluid inclusions are usually estimated by observing the last melting point of ice crystals after supercool-

ing. This method can only be confidently applied to the two-phase secondary inclusions at Bralorne, which show last melting of around -0.5 to -1°C . This is because the presence of carbon dioxide in the primary inclusions causes the formation of clathrate (CO_2 hydrate) compounds that do not melt until $+8$ to $+12^\circ\text{C}$ and thus obscure the melting of ice; the presence of methane in the carbon dioxide bearing inclusions has the opposite effect (Collins, 1979). Thus it is impossible to estimate the salinities of the Bralorne inclusions by using the last melting point of clathrate compounds. Nevertheless the last melting of ice in inclusions with no observable carbon dioxide appears to fall in the range -2 to -5°C (Figure 2-4-6). Because of these complications, all that can reliably be said about the salinities at Bralorne is that the ore fluids were dilute, certainly less than 10 weight per cent and probably less than 5 weight per cent NaCl equivalent. This is typical of gold quartz veins of mesothermal character (Taylor, 1987) and has also been observed in Bralorne samples by Maheux *et al.* (1987).

Vaguely detectable eutectic temperatures of about -20.5 to -22.5°C in some samples indicate that the dissolved salts

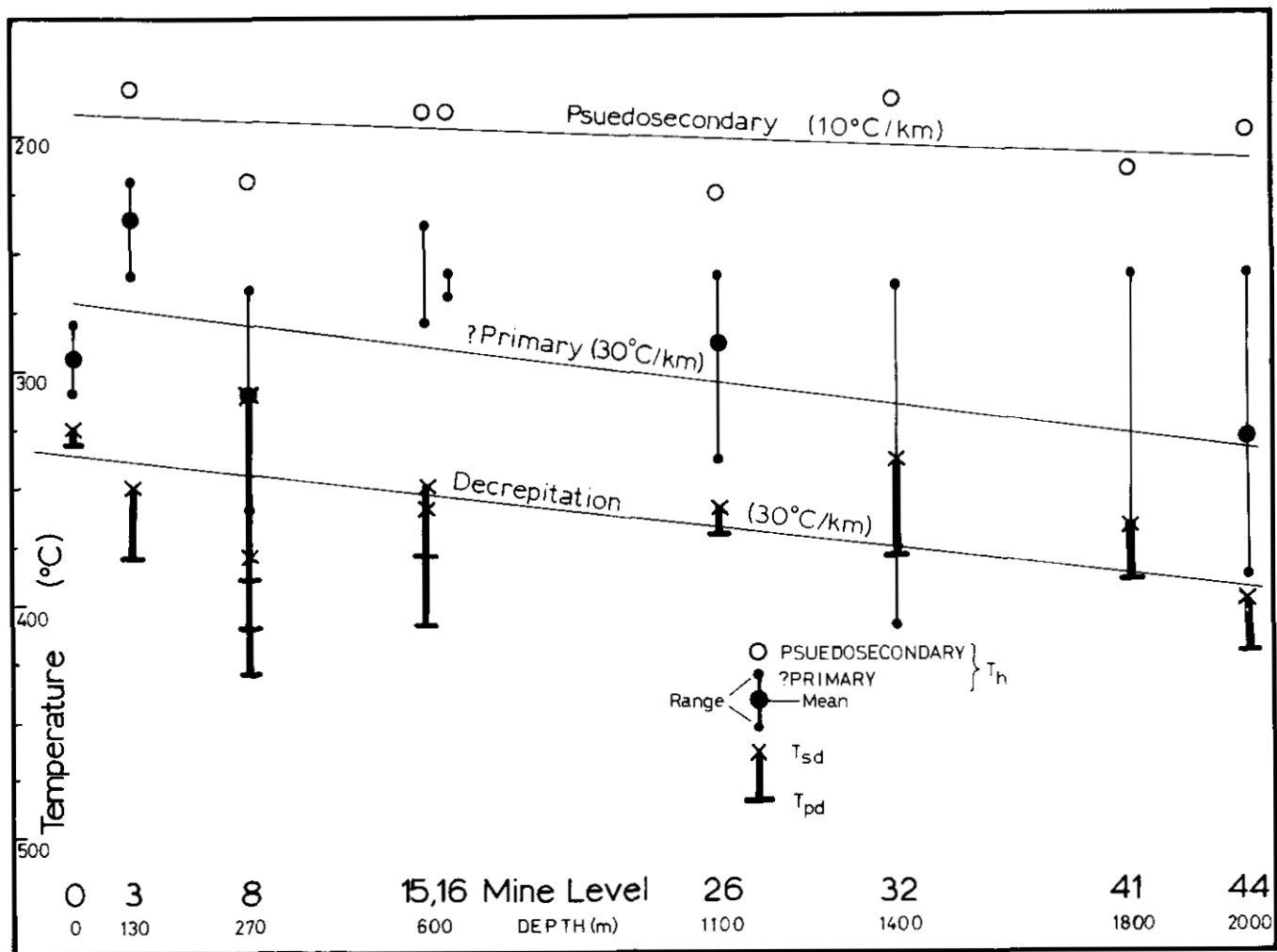


Figure 2-4-7. Plot of variation with depth for optically determined homogenization temperatures (T_h), for presumed pseudosecondary and primary fluid inclusions. Also shown are decrepitation temperatures versus depth in the mine (T_{sd} = start of decrepitation, T_{pd} = peak of decrepitation). Note the two populations of temperatures for samples from 8 and 15 levels. All inclusions measured in quartz.

are probably mostly NaCl and KCl (Roedder, 1984). The destruction of albite and its replacement by sericite in wallrock alteration envelopes indicates that KCl may be dominant. In some calcite specimens, however, a lower eutectic temperature of -24 to -26°C may indicate the presence of some other salt.

SULPHUR ISOTOPES

Sulphur isotopes were analysed in hand-picked (99 per cent pure) galena, spalerite, pyrite, pyrrhotite, chalcopyrite and tetrahedrite from samples at different levels of the mine, and from nearby deposits in the Bralorne area (Pioneer, P.E. Gold, BRX). Table 2-4-7 gives the isotopic data and the temperatures calculated from them using formulae from Ohmoto and Rye (1979). Temperatures calculated using data from minerals other than galena and sphalerite are erratic and unrealistically high. This is common (Godwin *et al.*, 1986) as pyrite typically does not equilibrate as well as galena and sphalerite. Furthermore pyrrhotite, chalcopyrite and pyrite

have a much more widespread distribution than sphalerite and galena and probably represent several phases of ore formation. Tetrahedrite is much more limited in distribution and appears to be in equilibrium with sphalerite and galena, but no experimental curves for tetrahedrite are available. Sphalerite and galena, on the other hand, appear to have formed contemporaneously and are therefore probably generally in equilibrium.

The sphalerite and galena pairs give temperatures of formation ranging from 240 to 370°C . Unfortunately this cannot be compared directly with fluid inclusion homogenization data as the only sample for which sulphur isotope and fluid inclusion data has been determined (C116-14) shows reversed $\delta^{34}\text{S}$ values indicating the galena and sphalerite could not have equilibrated in this case. However, two polarities are apparent in the data, one around 250°C and the other near 350°C . If these two clusters correspond to the secondary or lower temperature and primary or higher temperature groups of fluid inclusions, then substantial pressure corrections need to be applied to the homogenization temperatures.

CONCLUSIONS

The inferences that can be drawn about Bralorne ore fluids are as follows: primary fluids, presumed to be responsible for gold mineralization, were dilute solutions containing 5 weight per cent $KCl \pm NaCl$, 10 per cent carbon dioxide and minor methane at temperatures of around 350°C and pressures of 1 kilobar. Later secondary fluids were perhaps even more dilute, 1 to 3 weight per cent $NaCl \pm KCl$ but without detectable carbon dioxide or methane, at temperatures of about 250°C and pressures of 0.5 kilobar. Sulphur isotopic ratios of sulphides associated with the gold mineralization cluster around 0 parts per mil, with a range of -7 to +9.

Neither the primary nor secondary inclusions show any direct observable relationship to gold mineralization, so it is equally possible that the gold-bearing fluids were the early high-temperature or the later lower temperature type. Microscopically, gold occurrence is restricted to sulphides which occur only with patches of alteration minerals in altered wallrock slivers included in the veins, never in the quartz itself.

Earlier workers (Dolmage, 1934; Cairnes, 1937) have stressed the paragenetically late occurrence of gold, which fills fractures in sulphides. However, this could easily be the result of remobilization of the relatively soft gold into fractures in brittle minerals such as pyrite and arsenopyrite. Macroscopically, visible gold is usually present as fine smears or paint on slickensided surfaces, where it is accompanied by pyrite. These layers are part of the thin dark septae of altered rock that give the Bralorne veins their ribboned appearance.

The available evidence suggests that gold was deposited with sulphides wherever reactive host rock was present, principally inside the vein conduit. Low gold values are reported in the wallrock, dropping off rapidly to background values over less than a metre (Bellamy and Saleken, 1983). Also, there is no gold associated with the calcite veining, which has homogenization temperatures similar to the secondary inclusions. Thus deposition was probably from the earlier higher temperature fluids of which the primary fluid inclusions reported here are the most representative.

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