

THE BRALORNE GOLD VEIN DEPOSIT: AN UPDATE*

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INTRODUCTION

Fieldwork on the Bralorne gold vein deposit in 1986 included further logging of core drilled from the surface by Mascot Gold Mines Limited in 1980 to 1984 and revisions to the surface and underground geology. Unfortunately most of the underground core from the days of the Bralorne mine operation was destroyed this summer. The geology of the lower levels of the mine, from 8 to 44, can no longer be studied in detail. However several key intersections of the main 77 and 79 vein systems and their wallrocks, saved in 1985, are available for studies of alteration, ore mineralogy and fluid inclusions. Preliminary potassium-argon dates have also been completed.

REVISED GEOLOGY

The geology of the northeastern flank of the Bralorne intrusive complex is much more complex than was previously suspected from surface mapping of limited outcrops, nevertheless the rock units are as described in Leitch and Godwin (1986) with the minor exceptions noted below.

Soda granite forms a large north-west-trending dyke-like intrusive (3 kilometres long by 200 metres wide) in contact with diorite on the southwest and andesites of the Cadwallader Group on the northeast. This area was previously mapped as underlain by sediments of the Hurley Formation.

Long sections (in the order of hundreds of metres) of apparently volcaniclastic sediments, intercalated with argillite in a turbidite sequence, were cut by drill holes on the northeastern flank of the dyke. Similar sections are exposed in the gorge of Cadwallader Creek immediately east of Bralorne townsite.

All units, including the Bridge River Group cherty sediments, are cut by a large number and variety of dykes. In order of increasing age, these are: lamprophyre; green hornblende porphyry; albitite; and a previously unrecognized grey plagioclase porphyry that is intermediate in texture and time of formation to the soda granite and albitites. It is also apparent from logging the inclined surface drill holes that most structural features (dykes, veins, intrusive contacts) have subparallel dips of about 65 degrees northeast. The only exceptions are very late lamprophyre dykes which appear to dip vertically and strike due north. Dykes of albitite and the sparsely developed grey plagioclase porphyry strike about 115 degrees, parallel to the structural grain of the district. The later green hornblende porphyry dykes fill a set of conjugate fractures with one direction parallel to the strike of the older dykes.

Petrographic study of the dykes and relogging of all dyke intersections in core suggest that rather than two distinctly separate dyke sets (albitite and green hornblende porphyry) there may be considerable overlap between the two. The end members are clearly distinguishable (see chemistry in Tables 2-4-1 and 2-4-2) but there are many examples of fine-grained green dykes which could be either relatively late, unaltered albitites or rather chilled, thin, hornblende porphyry dykes. Ragged chlorite-calcite pseudomorphs after

hornblende phenocrysts are detectable in all of the albitite dyke sections studied. In addition, although the green hornblende porphyry dykes are usually quite unaltered, a dyke with abundant relict hornblende phenocrysts is strongly altered adjacent to the 51 vein (see Figure 47-2, Leitch and Godwin, 1986).

GEOCHRONOLOGY

Distinguishing the relative ages of the dyke sets is important in establishing the chronology of events in the camp. Two potassium-argon dates obtained recently indicate a surprisingly large interval between intrusion of the main quartz diorite mass (about 225 ± 10 million years) and the largely postmineral green hornblende porphyry dyke set (85.7 ± 3 million years). Both dates are on hornblende concentrates that have apparently not been significantly reset by Coast Plutonic Complex activity. Considerable confidence can be placed in the later date, as the hornblende contained 0.14 per cent potassium. The potassium content of the hornblende in the diorite was too low (0.06 per cent) for an accurate age determination to be made. Reduction of the data obtained gives an age of 284 million years, but J. Harakal (personal communication, 1986) feels this is likely a maximum as excess argon commonly has a more noticeable effect in low-potassium rocks. Conodonts show that the Cadwallader Group, intruded by the diorite, is Carnian/Norian in age (225 million years) (Rusmore, 1985) so the diorite is likely 220 to 200 million years.

Unfortunately no hornblende or biotite is available from the andesites, soda granite, grey plagioclase porphyry, or albitite, but biotite phenocrysts in the lamprophyre will be dated. Zircons for uranium-lead dating were not recovered from two large samples of the Pioneer andesites. However a rubidium-strontium treatment of the Bralorne intrusive suite and the andesites is in progress. Zircons were recovered from each of two samples of the diorite and the soda granite and from one sample of the albitite dykes, but these are awaiting analysis. When available, these dates will help to elucidate the timing of intrusion and mineralization. An unsuccessful attempt has been made to date limestone lenses in the Hurley Formation cored by Normine Resources Ltd. on the P.E. Gold prospect adjoining the Pioneer mine. Samples analysed by the Geological Survey of Canada are barren of conodonts.

PETROLOGY

Preliminary chemical data for a limited suite of major rock units is set out in Table 2-4-1. A noteworthy feature in the major element chemistry is the extremely low K_2O in all igneous rocks of the Bralorne area, ranging from 0.08 per cent in the diorite to 0.69 per cent in soda granite (the only exception is 2.5 per cent K_2O in a sericite-altered albitite dyke). The relatively high Na_2O (up to almost 6 per cent) is also of interest and corroborates the albitic plagioclase (An_{0-10} , rarely to An_{15}) which is present in all units, including even the hornblendites, pyroxenites, and Pioneer andesites. This albite may be a reflection of regional greenschist metamorphism (widespread chlorite and actinolite, especially in the

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andesites, also suggest this), or may be due to widespread hydrothermal alteration. Obvious albitization textures (Leitch, 1981) indicative of hydrothermal alteration are limited to margins of some veins and are rarely pervasive. However, it is possible that the much more obvious feldspar-destructive alteration (epidote, chlorite, carbonate, sericite and quartz, moving progressively closer to the vein) has obscured earlier alteration. Altered rocks show a strong increase in CaO and loss-on-ignition toward the vein, corroborating the carbonate alteration; increases of K₂O to 2 to 3 per cent probably correlate with the sericitic alteration, while the drop in Na₂O (to near zero) and Fe₂O₃ (by half) indicates the destruction of original albite and hornblende.

The relationship of diorite intruding ultramafics, postulated last year (Leitch and Godwin, 1986) has been confirmed. The gradual transition from normal diorite (about 40 per cent mafics) to hornblende (60 to 80 per cent mafics) to relict pyroxenite/peridotite with hornblende mantling clino and orthopyroxene is suggestive of border phase contamination of the diorite by the ultramafic to produce much of the hornblende commonly seen along its southwestern flank (modes estimated from thin-section studies,

Table 2-4-2). Dyking of both diorite and soda granite into hornblende and serpentinite supports this conclusion.

The relationship between diorite and soda granite is not as clear. Partial melting or differentiation of the diorite have been proposed as alternative mechanisms for the formation of the soda granite. They cannot be distinguished petrologically using addition-subtraction diagrams of Bowen (1956) or a plot of normative Qz-Or-Ab. However a few observations may be made. The temperature required to partially melt a rock of diorite composition, which lies far from the granite minimum, would be 1050°C if no volatiles were present, or perhaps as low as 750°C in the presence of abundant H₂O and HCl (Mehnert, 1971). This is far above the 400 to 410°C (Winkler, 1967) attested to by the adjacent lower greenschist facies rocks. Also, although it is clear that the contact zone between diorite and soda granite is unquestionably a migmatite (variety agmatite, Mehnert, 1971) the texture is due to injection of soda granite into diorite. The relationship is partly obscured by dark andesite xenoliths included in diorite prior to intrusion of the soda granite, and is therefore not clear in drill core, but can clearly be seen in an excellent outcrop near the bridge at Goldbridge. It is possible that

TABLE 2-4-1
CHEMISTRY OF MAJOR UNITS IN THE BRALORNE-PIONEER AREA

Sample No. (N)	CO95 (3)	CO93 (3)	CO82B (2)	AVGDI (8)	CO94 (3)	CO82A (2)	AVGSG (5)	CO92 (3)	CO83 (3)	RESTI (CALC)
Major Elements (%)										
SiO ₂	47.50	59.35	55.52	55.32	71.83	66.10	68.90	64.54	52.25	56.1
Al ₂ O ₃	12.95	11.22	13.60	13.12	13.68	14.27	13.97	17.76	14.56	10.6
TiO ₂	0.95	0.23	0.50	0.40	0.19	0.20	0.20	0.20	0.77	0.3
Fe ₂ O ₃ (Total Fe)	10.55	7.80	9.65	9.28	3.07	4.74	3.88	2.83	10.24	9.0
MgO	12.54	8.12	5.07	7.00	0.44	1.61	1.03	1.11	6.48	10.2
CaO	9.36	7.06	5.89	7.02	2.10	4.00	3.06	3.76	8.69	8.4
Na ₂ O	1.47	3.88	4.71	3.60	5.60	6.00	5.78	1.98	3.10	3.4
K ₂ O	0.04	0.14	0.10	0.08	0.69	0.12	0.41	2.67	0.25	0.0
MnO	0.28	0.16	0.18	0.20	0.08	0.09	0.08	0.11	0.19	0.2
P ₂ O ₅	0.11	0.02	0.02	0.03	0.05	0.11	0.07	0.12	0.19	0.0
LOI	4.71	1.82	3.96	2.71	2.47	2.30	2.40	4.73	2.78	1.6
Total	99.96	99.80	99.20	98.76	100.20	99.54	99.78	99.81	99.50	99.8
Minor Elements (ppm)										
As	14	1	6	8	12	8	10	11	3	
Ba	50	47	120	63	102	120	110	706	245	
Cl	26	74	53	52	28	33	30	14	57	n
Co	30	32	24	30	4	16	13	9	35	o
Cr	275	160	35	86	10	26	17	12	135	t
Cu	75	62	69	60	11	18	14	6	36	
Mo	1	0	2	1	1	2	1	1	2	a
Nb	3	1	2	1	2	0	1	2	1	n
Ni	70	69	17	43	3	4	3	2	36	a
Pb	6	6	8	8	6	7	7	9	4	l
Rb	2	3	4	3	14	3	9	39	5	y
S	745	430	6000	375	760	4160	760	950	310	s
Sb	3	2	0	2	2	3	2	2	1	e
Sr	270	110	190	125	80	235	80	110	350	d
V	270	145	200	180	14	58	30	29	230	
Y	22	16	20	17	17	6	12	10	22	
Zn	105	56	65	64	36	54	43	52	100	
Zr	63	49	34	40	86	24	60	69	61	

(N) is number of analyses; 5 separate rocks for average diorite, 2 for soda granite.

Sample identifications: CO95 = Pioneer andesite; CO93 = Bralorne quartz diorite; CO82B = same; AVGDI = average of five diorites, 16 Level to surface; CO94 = soda granite; CO82A = same; AVGSG = average of two soda granites; CO92 = albitite dyke, sericite-carbonate altered; CO83 = green hornblende porphyry dyke; RESTI = calculated restite composition.

TABLE 2-4-2
CIPW NORMS AND ESTIMATED MODES OF MAJOR UNITS FROM THE BRALORNE-PIONEER AREA

Sample No.	CO95	CO93	CO82B	AVGDI	CO94	CO82A	AVGSG	CO92	CO83	RESTI	HBITE	AVGAB	AVGGHO	LAMP
Normative Minerals														
Quartz		10.5	7.1	8.1	30.4	19.7	25.0	32.8	4.5	5.4				
Corundum					0.02			5.1						
Orthoclase	0.2	0.8	0.6	0.5	4.1	0.7	2.4	15.8	1.5	0.0				
Albite	12.4	32.8	39.9	30.5	47.4	50.8	48.9	16.8	26.2	28.8				(no
Anorthite	28.6	12.8	15.7	19.4	10.1	11.6	11.0	17.9	25.8	13.6				analyses
Diopside	13.7	17.8	10.9	12.3		6.2	3.1		13.1	22.4				available)
Hypersthene	32.5	19.0	14.7	20.0	3.8	5.2	4.5	4.0	19.6	23.1				
Olivine	2.0													
Magnetite	3.7	3.8	5.4	4.5	1.5	2.3	1.9	2.1	4.3	4.3				
Ilmenite	1.8	0.4	0.9	0.8	0.4	0.4	0.4	0.4	1.5	0.6				
Apatite	0.3	0.04	0.04	0.1	0.1	0.3	0.2	0.3	0.5	0.02				
Differentiation														
Index	13	44	47	39	82	71	76	65	32	34				
Modes (Estimated Volume %)														
Quartz	10	10	6	11	40	20	37	40	10	0	1	26	8	0
Albite	40	40	60	55	50	70	52	55*	52	35	20	59	54	0
Mafic: (Hblend) ..		48	30	33	8	7	11	3	35	60	62	13	36	(BI=2.5)
(Cpx)	55*										15			35
Ilmenite (Rut)	3	2	1	1	1	1	tr	1	3	5	2	1	2	2
Pyrite (Py/Po)	2	tr	3	tr	1	2	1	1	0	0	1	1	0	(AP=3)
(No. of Samples)	(1)	(1)	(1)	(10)	(1)	(1)	(10)	(1)	(1)	(1)	(6)	(13)	(8)	(1)

* Sum of alteration products (chl, ep, carb for mafics; ser, carb for plagioclase). Sample identifications are as listed in Table 2-4-1, with the addition of HBITE (average hornblende), AVGAB (average albitite dyke), AVGGHO (average green hornblende porphyry), and LAMP (lamprophyre dyke). Norms calculated with a BASIC program (FeO/Fe₂O₃ estimated for each rock).

the soda granite was derived from partial melting of the diorite at depth during a younger thermal event, but this hypothesis is only tenable if supported by zircon dating.

VEIN MINERALOGY

Very little sulphide, often only 1 to 3 per cent, is present in the veins. Altered wallrocks usually contain up to 5 or even 10 per cent sulphides over widths of a few centimetres to several metres. However the sulphide assemblage is similar in both veins and wallrocks with the exception of a few more diverse assemblages (see following) in veins with rich gold values. Arsenopyrite with lesser pyrite is ubiquitous. Occasionally pyrrhotite, almost always with chalcopyrite, is as abundant as the arsenopyrite. The high arsenic content of the system is noteworthy.

It is likely that rutile, also ubiquitous, is the product of hydrothermal alteration of ilmenite originally present in the intrusive host; this may indicate formation of some of the vein material by *in situ* replacement of wallrock.

Septae of wallrock within the veins are strongly replaced by sulphides and form thin dark bands parallel to the contacts, giving the veins their characteristic ribboned appearance. Usually the septae are strongly sheared and slickensided, but occasionally they are stylolitic, suggesting pressure solution. Textures in the vein quartz are strongly outlined by myriads of inclusions arranged in crystallographic growth zones. Quartz grains grew perpendicular to the walls of the veins, while sulphides are restricted to a "breccia network" of other gangue minerals interstitial to the quartz.

Free gold is relatively common in the polished sections studied, occurring as blebs 2 to 10 microns across and often in or associated with pyrite, tetrahedrite or arsenopyrite. Larger gold blebs (15 to 50 microns) are found in more diverse sulphide assemblages which may include galena, sphalerite, tetrahedrite, chalcopyrite, and possibly bournonite. Wherever fuchsite is found in the altered wallrock,

a few grains of chromite are always present. The chrome is likely derived from picotite in inclusions of ultramafic material. Oxidation has produced limonite in some specimens.

Gold selenides and tellurides, stibnite, and marcasite, reported by Dolmage (1934) and Cairnes (1937), were not seen in this study. Dolmage's observations were confined to the Pioneer vein system which is no longer accessible.

FLUID INCLUSIONS

Preliminary fluid inclusion data (at levels 15 and 44 only and uncorrected for pressure) indicate a tendency toward higher homogenization temperatures and possibly higher salinities at depth. At both levels there appear to be primary and pseudo-secondary inclusions. Table 2-4-3 summarizes the data (n = number of measurements).

TABLE 2-4-3
FLUID INCLUSION DATA FROM BRALORNE MINE
(in °C)

	Pseudosecondary		Primary	
	T melt	T hom	T melt	T hom
Level 15	-2	190	-3.5	260
(-500 m)	(n=4)	(n=5)	(n=5)	(n=20)
Level 44	-2	200	-5	315
(-1750 m)	(n=24)	(n=37)	(n=8)	(n=30)

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