

Mineralogy of Bornite-Au Zones in the Bolivar district

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Executive Summary

Bornite-chalcocite in the Bolivar district is typical of skarns in general, occurring near the marble front in the Fernandez zone and in magnesian skarn in the Bolivar Sur zone. Although the marble front occurrence of bornite-chalcocite can result in locally high grades, abundance is limited and this is not likely to be an important economic factor at Bolivar. In contrast, the Mg skarn occurrence of bornite-chalcocite at Bolivar Sur is likely to be widespread and will result in higher Cu grades than occur elsewhere in the Bolivar district. This may have metallurgical implications if Bolivar Sur ore becomes a major mill feed. High Au assays in the Fernandez zone appear to be structurally controlled and are not directly related to the occurrence of bornite-chalcocite.

Introduction

This report summarizes observations about the mineralogy of bornite-Au rich zones at the Bolivar deposit based upon 12 samples collected during a December 15-19, 2005 field visit. Observations and recommendations from that visit were summarized in a previous report dated 20 December, 2005 and will not be repeated here. As required by Canadian Investment Regulations, Dia Bras has my permission to use this report for their own purposes, for their website, and for release to the public. Features described in this report are illustrated in a PowerPoint presentation (Fig. 1) that can be downloaded at: <http://www.science.smith.edu/~lmeinert/BolivarMeinertBorniteAuPhotos.ppt> This PowerPoint presentation will be removed from the server once Dia Bras has downloaded it for their purposes.

Sample Descriptions

Fernandez Zone

DDH 61	Section 7
0-70	Drill log lists mostly andesite.
70-90	Drill log lists mixed marble and skarn.
90-95	Pale green garnet-wollastonite-pyroxene
95-97	Pale punky green garnet-pyroxene-sphalerite.
97-99	Green-brown garnet-chalcopyrite>sphalerite
99-105	Yellow-green garnet with bornite>chalcopyrite-sphalerite and wollastonite-bornite at marble contact
105-165	Drill log says mostly marble.
165-170	Zoned skarn from green pyroxene>garnet to brown garnet-sphalerite to green garnet-sphalerite-chalcopyrite-bornite at contact with marble
170.5-216	Drill log says mostly marble.
216-248	Drill log says mostly skarn.

Thin Section #	Description
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61-96.5	Globular euhedral garnet in “sea” of sphalerite with chalcopyrite inclusions (Fig. 2). Minor epidote-calcite-quartz filling fractures and brecciated zones. No obvious reaction of garnet with sphalerite, thus indicating approximate equilibrium.
61-97.9	Vugs of chalcopyrite in corroded euhedral, isotropic garnet (Fig. 3). Calcite present in vugs and at garnet-chalcopyrite contacts but no strong retrograde alteration of garnet.
61-100.5	Vugs of bornite-chalcocite-chalcopyrite in euhedral, isotropic garnet (Fig. 4). No obvious reaction of garnet with bornite-chalcocite-chalcopyrite, thus indicating approximate equilibrium. Distribution of chalcocite and chalcopyrite in bornite suggests an unmixing texture from an original high-temperature intermediate solid solution (ISS). Sequential deposition of sulfide minerals also is suggested by replacement textures of chalcopyrite after pyrite (Fig. 5) and large grains of gold replacing CuFe sulfides (Fig. 6).
61-105	Vugs of bornite-chalcocite-chalcopyrite in sheared isotropic, green garnet (Fig. 7). No evidence of shear in sulfide clot, indicating at least some recrystallization or deposition after shearing.
61-105.3	Clots of sphalerite and bornite-chalcocite in garnet-wollastonite skarn at marble contact (Fig. 8).
61-169	Brown garnet skarn with complex optical zonation and birefringence (Fig. 9). Vugs in garnet skarn are filled with either calcite (remnant?) or fine-grained, felted, green chlorite (Figs. 10, 11).

61-171 Massive sphalerite-bornite-chalcocite at marble contact (Fig. 12). Sulfide deposition is localized by marble contact and garnet is resorbed during sulfide deposition (Fig. 13). Locally, the garnet is rutiled, caused by the “exsolution” of rutile needles out of relatively high-Ti garnet (Fig. 14).

Breccia Linda area

DDH 91 Drilled through Breccia Linda West on Section 13

0-20 Drill log lists mostly marble.
20-29 Brown garnet > blue-green pyroxene skarn
29-31 Tan pyroxene > garnet skarn
31-39 Tan pyroxene > green garnet-chalcopyrite-sphalerite with patches of quartz-amphibole retrograde alteration
39-41 Outer breccia pipe ring of massive chalcopyrite-sphalerite
41-46 Calcite-chlorite-amphibole retrograde overprint of skarn in breccia core.
46-52 Breccia fragments of chalcopyrite-sphalerite cemented by calcite-chlorite
52-54 Calcite-chlorite-amphibole retrograde overprint of skarn in breccia core.
54-93 Drill log lists calcite-chlorite-quartz altered skarn.
93-97.5 Pale brown garnetite
97.5-116 Bolivar Granodiorite, fine-grained near margin

Thin Section # Description

91-37 Sphalerite with chalcopyrite inclusions filling vug and replacing zoned birefringent garnet (Fig. 15). Garnet has numerous inclusions of earlier granular pyroxene and some patches of pyroxene skarn are preserved (Fig. 16). Pyroxene contains numerous high salinity fluid inclusions (Fig. 17).

91-53 In core of breccia zone most skarn has been replaced by coarse-grained calcite, quartz, sphalerite, and chalcopyrite with fine-grained patches of chlorite replacing some garnet while other garnet crystal are unaffected, perhaps due to a compositional difference (Fig. 18). Where most intense this alteration obliterates the previous skarn and only pseudomorphs of the previous garnet shapes remain (Fig. 19).

91-96 Garnet-pyroxene skarn away from breccia zone preserves fresh garnet and pyroxene textures (Fig. 20). Chalcopyrite appears to coexist stably with pyroxene (Fig. 21) and pyroxene typically is full of high-salinity fluid inclusions (Fig. 22).

Bolivar Sur

DDH 135	Drilled -50° at the northern end of the Bolivar Sur zone and intersected both the upper calcic ore horizon (Zn rich) and the lower dolomitic ore horizon (Cu rich).
0-23.6	Drill log lists mostly marble and wollastonite skarnoid.
23.6-26	Pale wollastonite-tan garnet skarn.
26-38	Andesite dike with skarn along both contacts. This would be a good sample to date as it clearly is pre- or syn-skarn formation unlike other andesite dikes which cut and therefore postdate skarn. One box of core from this 12 m andesite intersection should be sufficient to yield dateable zircons
38-46	Tan garnet at contact of andesite dike with patches of sphalerite-bornite-chalcopyrite and a sharp contact of tan garnet with marble
44-53	marble
53-58	20-80% sphalerite in green-tan garnet-pyroxene skarn Contact with marble is sharp
58-63.5	Zoned skarn sequence from green-tan garnet-pyroxene sphalerite to red-brown garnet-pyroxene-chalcopyrite to green garnet-pyroxene-sphalerite to sharp contact of sphalerite with marble. Zonation of skarn and associated sulfide mineralogy is fairly consistent throughout the Bolivar deposit.
63.5-69.5	Marble
69.5-71.4	Yellow-green garnet and 5-10% bornite
71.4-83	Drill log lists mostly marble.
83-163	Drill log lists marble, skarn, hornfels, and andesite dike.
163-165	Green garnet skarn
165-167	Brown garnet-chalcopyrite±magnetite Some high grade core with 5-10% visible chalcopyrite was not split
167-170	Green garnet-magnetite-chalcopyrite
170-177	Green garnet and tan magnesian skarn
177-200	Drill log lists hornfels and andesite dikes
200-218	Bolivar Granodiorite

Thin Section # Description

135-69.5 Unlike the Fernandez zone, bornite and chalcocite (Fig. 23) occur in magnesian skarn with minerals like phlogopite (Fig. 24) and no evidence of shearing or introduction of gold.

Discussion of Bolivar Bornite-Au zone mineralogy

Bornite samples were selected from three different areas, Fernandez, Breccia Linda, and Bolivar Sur. Of these only the Fernandez zone also contains high Au. The occurrence of Au with bornite is not well understood and as a first step I asked Jacques Marchand to re-analyze drill core pulps from these zones in Drill Hole 61 with the Chemex multi-element package (Table 1). The high gold intervals also contain high Ag, As, Bi, and Sb and are low in B. No other analyzed elements appear to be different between the high and low Au samples. The thin section from the highest grade interval 100-101' (6.59 g/t Au) has visible gold and is close to a sample at 105' in the same drill hole that contains abundant shearing of garnet. This suggests that there may be a structural control on the gold distribution at Bolivar and that gold is not directly related to bornite. The association of gold with shearing of skarn also is important in the Nambija district in Ecuador. However, Nambija is a Au skarn with no Cu or other sulfides and thus not greatly similar to Bolivar.

The occurrence of bornite, or more accurately bornite-chalcocite as these two minerals always occur together, is different in the three zones examined, Fernandez, Breccia Linda, and Bolivar Sur. In the Fernandez zone bornite-chalcocite occurs at the marble front and filling vugs interstitial to euhedral garnet. Both occurrences are typical of Cu-Zn skarns. The Breccia Linda occurrence of bornite is quite minor and mostly the mineralization in this zone is linked with intense chemical brecciation, as described in previous reports. The bornite-chalcocite in the Bolivar Sur zone is directly related to the dolomitic protolith and resulting magnesian skarn. This is clearly seen in the occurrence of magnesian minerals such as olivine and phlogopite and the intimate intergrowth of phlogopite with bornite-chalcocite in 135-69.5 (Fig. 24).

Conclusions

Overall, the occurrence of bornite-chalcocite in the Bolivar district is typical of its occurrence in skarns in general. It is well known that bornite occurs in otherwise chalcopyrite-dominant skarns near the marble front and this is the dominant occurrence in the Fernandez zone. The other major occurrence of bornite-chalcocite at Bolivar and in most skarn deposits is in magnesian skarn resulting from metasomatism of a dolomitic protolith. This is the dominant occurrence in the Bolivar Sur zone. In short, there is nothing unusual about either of these occurrences at Bolivar and similar occurrences should be predictable. Although the marble front occurrence of bornite-chalcocite can result in locally high grades, the abundance is limited and this is not likely to be an important economic factor at Bolivar. In contrast, the Mg skarn occurrence of bornite-chalcocite at Bolivar Sur is likely to be widespread and result in higher Cu grades than occur elsewhere in the Bolivar district, as indeed has been the case to date. The Bolivar Sur occurrence of bornite-chalcocite also may have metallurgical implications as bornite-chalcocite will respond differently to flotation than chalcopyrite. This may require adjustments in the mill when the Bolivar Sur ore becomes a major mill feed.

Even though bornite-chalcocite is spatially associated with high Au assays in the Fernandez zone, it does not appear that the two are related. The gold appears to be structurally controlled and other than the fact that major structures likely will channel all hydrothermal fluids in the region, the gold appears to be distinctly later than the main sulfide minerals sphalerite and chalcopyrite.

Geochemical analyses of 1' intervals from drill hole #61

Sample #	230480	230481	230482	230483	230484	230485	230486	230487	230488	230489	230490	230491	230492	230493
interval	95-96	96-97	97-98	98-99	99-100	100-101	101-102	102-103	103-104	104-105	105-106	106-107	158-159	159-160
Cu%	0.0427	0.344	4.86	4.95	4.02	6.12	2.17	4.22	2.13	4.08	1.01	0.114	0.0247	0.0164
Zn%	3.45	6.07	1.73	0.683	1.24	0.161	0.111	0.571	1.35	0.381	0.609	0.0233	0.207	0.0482
Ag	3.5	3.1	23.8	298	381	572	198	344	176	348	103	10.6	1.6	1
Au	0.056	0.043	0.151	2.38	3.64	6.59	2.13	4.57	1.955	2.63	0.883	0.025	0.017	0.005
Al	1.36	1.88	1.22	1.23	1.5	1.35	1.56	1.42	1.62	1.74	0.27	0.05	2.23	1.58
As	114	285	174	831	1925	534	1240	4080	1360	3090	1635	85	65	62
B	870	4840	1100	530	50	30	30	40	30	10	6940	1000	690	420
Ba	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	10	<10
Be	1.1	1.2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Bi	40	42	174	956	952	1530	925	2130	1000	860	266	23	6	9
Ca	9.31	10.15	9.01	11.15	13.15	12.85	15.7	14.6	16.4	16.1	>25.0	>25.0	20.9	10.35
Cd	156.5	263	71.7	36	58.1	9.9	7.7	38.8	67	26.1	34.4	0.9	12.1	3.2
Co	60	108	51	28	24	8	16	31	32	27	16	1	9	3
Cr	16	16	5	3	1	<1	2	1	2	<1	1	1	3	13
Fe	2.24	3.35	8.06	6.71	7.68	7.17	7.43	7.42	7.72	9.46	1.5	0.22	0.45	2.06
Ga	<10	<10	<10	<10	<10	<10	<10	<10	<10	10	<10	<10	<10	<10
Hg	1	2	<1	1	<1	<1	1	<1	1	2	1	<1	<1	<1
K	0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.04	0.02
La	10	10	<10	<10	<10	<10	10	10	10	<10	<10	<10	<10	<10
Mg	0.55	1.01	0.58	0.55	0.34	0.34	0.54	0.44	0.54	0.19	0.55	0.08	0.32	0.4
Mn	1185	1500	1280	1265	1530	1500	1665	1500	1700	1760	705	386	537	1210
Mo	<1	<1	<1	1	1	1	1	1	1	1	5	5	9	10
Na	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.19	0.01
Ni	3	14	28	13	10	8	21	39	25	32	7	<1	10	7
P	320	390	350	320	230	60	80	280	330	80	60	20	280	350
Pb	11	13	10	38	37	58	32	46	73	60	52	33	9	29
S	1.84	3.5	5.33	3.74	3.26	2.8	1.4	2.92	2.17	2.9	<0.01	<0.01	<0.01	0.05
Sb	39	81	14	111	1455	117	100	24	105	267	10	7	5	6
Sc	2	3	3	2	2	1	<1	1	<1	1	<1	<1	<1	2
Sr	49	13	11	20	16	22	26	26	24	13	200	292	741	211
Ti	0.09	0.09	0.05	0.04	0.03	0.02	0.01	0.01	0.01	0.01	<0.01	<0.01	0.05	0.09
Tl	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
U	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
V	18	23	28	29	29	25	27	29	32	31	14	1	4	16
W	10	<10	<10	<10	<10	10	<10	<10	<10	<10	<10	<10	<10	10