CASE STUDY

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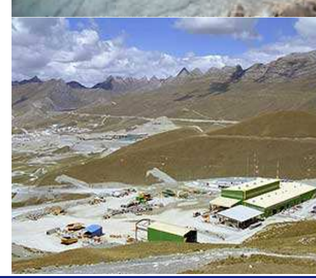
xstrata process support



Process Diagnosis for the Antamina Bornite Zone

The Antamina mining and milling operations, Perú, treat a skarn polymetallic deposit for the recovery of copper, zinc, molybdenum, and lead-bismuth-silver concentrates.

The operation format is entirely by campaign, whereby the concentrator processes one of eight ore types at a time. Each ore type has distinct mineralogical and metallurgical character resulting in varying processing strategies. The main paymetals are Cu and Zn with a variety of minor and deleterious elements, some of which end up in final concentrates. The most important of these elements are As and Bi that can end up in final Cu concentrates and give rise to substantial penalties. During several campaigns of the ore type known as the Bornite Zone, Bi contamination of the Cu concentrate was high enough that concern was raised over the possibility that future concentrates might become unsaleable without the ability to limit the contamination.

In order to develop a strategy which will ensure the recovery of deleterious elements to concentrate is minimised, an understanding of where the elements are located is required. While assay databases can give the geology team an idea of concentrations throughout the orebody, an assessment of mineralogy including Bi and As deportments by mineral and a firm understanding of textures within the host rock are important information required by the metallurgical staff before a rejection strategy can be developed.

The Bornite Zone is relatively small, making up approximately 10% of the resource at Antamina, and is highlighted in Figure 1 as the Wollastonite-Bornite Exoskarn. To assess the Bi and As deportment, 55 core samples from 29 drill holes taken throughout the zone, were collected and prepared as polished thin sections. Each sample was measured with QEMSCAN and EPMA.

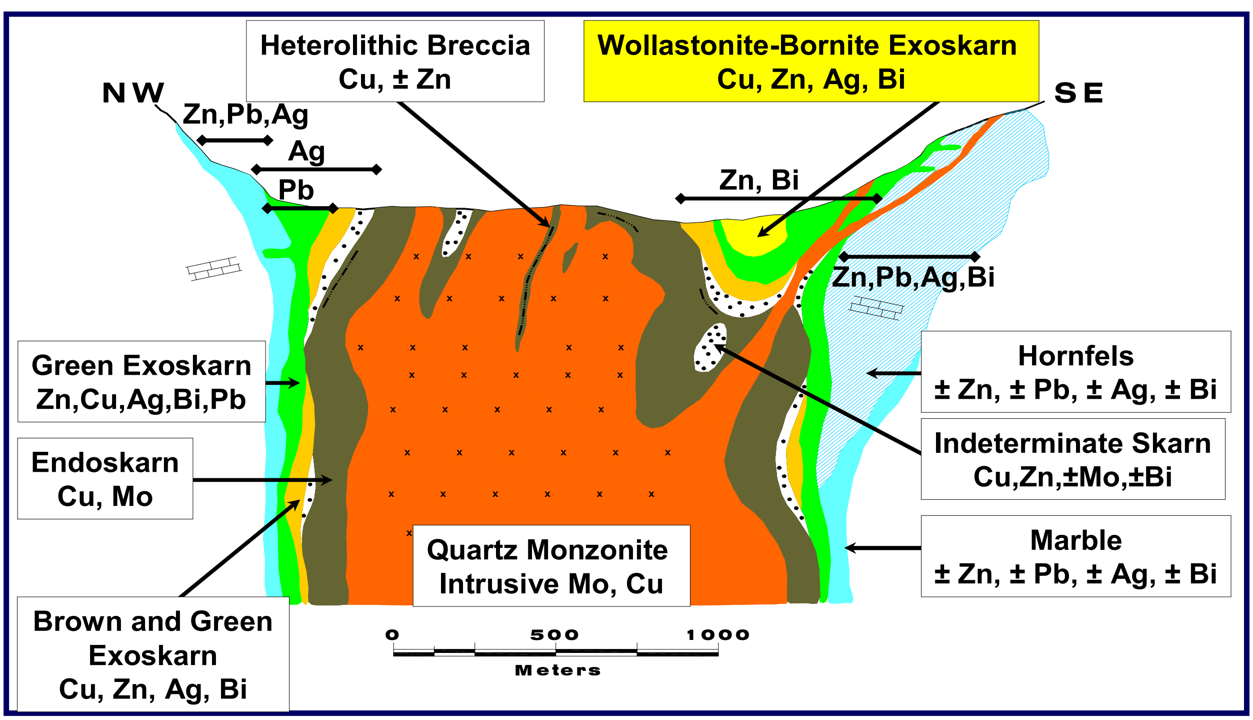


Figure 1: Schematic Cross Section, Antamina, Looking Northeast (Lipten and Pacheco, 2004)

Bismuth Mineralogy

Two bismuth-bearing minerals, wittichenite (Cu_3BiS_3) and aikinite ($PbCuBiS_3$) were identified. Of particular importance however, were the results of EPMA which showed significant amounts of Bi in solid solution within the atomic structure of bornite (Cu_5FeS_4). Furthermore, in one area of the deposit, an unusual mottled texture, was identified where two bornites with different bismuth levels are intergrown in a single grain (Figure 2). The field of view in the image is approximately 500 µm x 500 µm.

The bornite with the brighter backscatter intensity contains an average of 6.5% Bi, an amount which would contribute heavily to Bi contamination if this texture was present in significant quantities in the concentrate.

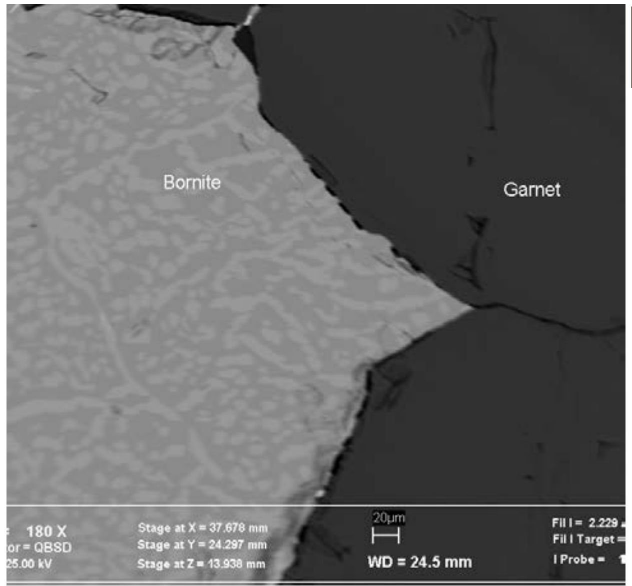


Figure 2: Backscattered Electron Image of Mottled Bornite

Microprobe analysis of normal bornite and the two bornites making up mottled bornite was completed. Bismuth levels within bornite as well as in wittichenite and aikenite are presented in Table 1.

Table 1: Bismuth content in Bornite, Wittichenite and Aikenite within Antamina's Bornite Zone by EPMA.

Mineral	%Bi	Number of Analyses
Bright phase in Mottled Bornite	6.54	37
Dark phase in Mottled Bornite	0.8	220
Normal Bornite	0.61	189
Witttichenite	35.1	2
Aikenite	35.75	15

Bismuth Deportment

Bismuth deportment has been quantified by calculating the percentage of bismuth contributed to each sample by various bismuth bearing minerals. Samples were separated into two categories; those containing mottled bornite and those containing normal bornite. Figure 3 summarises the results. Based on the results of the deportment analysis, the probability that significant bismuth can be rejected is low. This conclusion is based on measurements that show the majority of bismuth in the Bornite Zone samples occurs as a solid solution component within bornite itself. Wittichenite and aikenite, two discrete bismuth-bearing minerals were also identified in the samples. Wittichenite occurs within bornite or chalcocite and is often very fine grained (5µm). Aikinite is associated with galena or chalcopyrite-quartz-calcite veins, and has been observed as fine to medium grained. The unusual mottled bornite texture, containing up to 6.5% Bi, will have a strong impact on bismuth contamination when processing ores from this zone. An exercise to map the location of these mottled bornite samples revealed that the majority of them occur at depth within the Bornite Zone. It is likely that as mine development proceeds and this high bismuth mineral is mined as an important Cu mineral, the bismuth contamination levels in copper concentrate will actually increase. A mining plan designed to dilute Cu ore from this zone with other Cu ores, or blending of the Cu concentrate with Cu concentrates with low levels of Bi were recommended to mitigate this risk. The use of quantitative mineralogy to define the Bi deportment has avoided significant effort in metallurgical investigations aimed at rejecting Bi from concentrate.

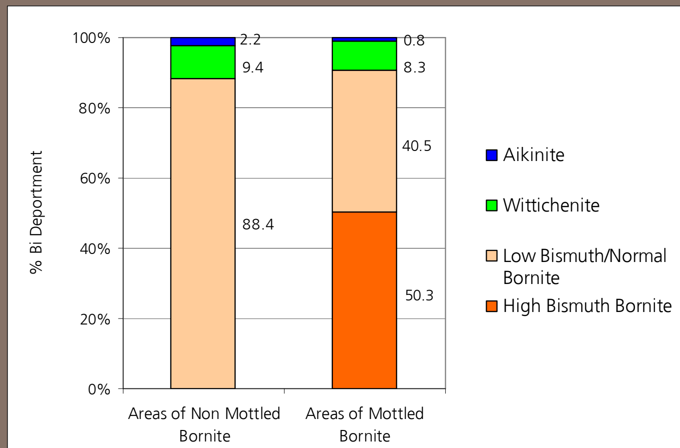


Figure 3: Bi Deportment in the Antamina Bornite Zone

Arsenic Mineralogy

Arsenic is present in several zones within the Antamina orebody. In the Bornite Zone, the main arsenic carriers are tennantite $(Cu,Ag,Zn,Fe)_{12}(As,Sb)_4S_{13}$ and enargite Cu_3AsS_4. While these two minerals can be a challenge to differentiate with QEMSCAN, they are easily distinguished by EPMA. Table 2 summarises the As content in the two minerals as determined by EPMA.

Using a combination of the two instruments, it was shown that tennantite occurs as coarse massive to semi-massive veins, several millimeters in size, associated with quartz and calcite. Enargite is less common and most often occurs as rims, 30 µm to 60 µm in size, surrounding chalcopyrite (Figure 4).

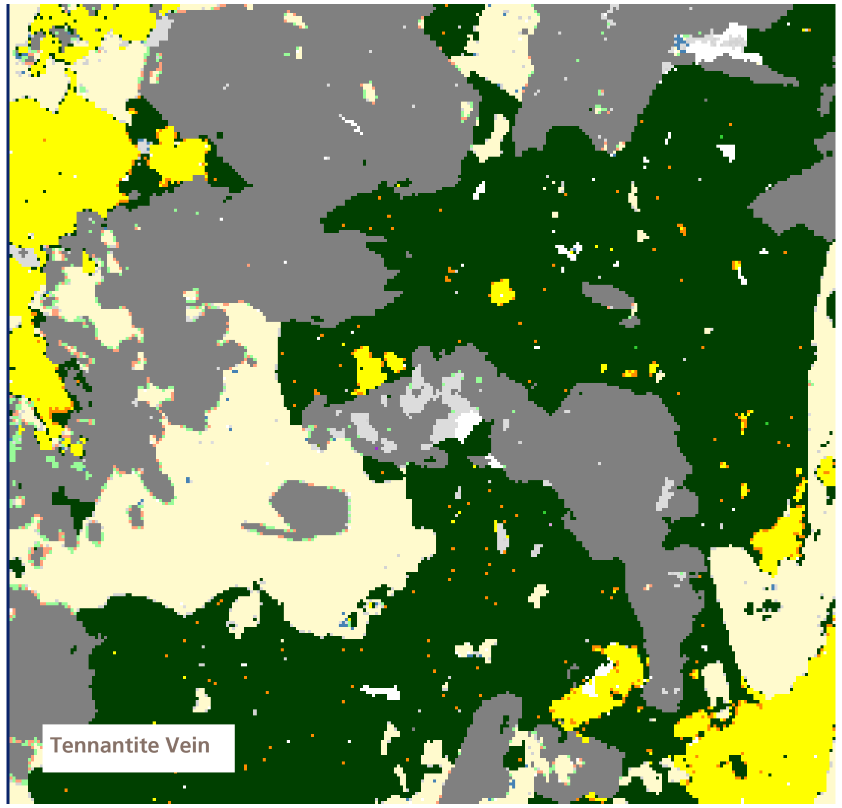


Table 2: Arsenic Content within Enargite and Tennantite.

Mineral	%As	Number of Analyses
Enargite	19.38	36
Tennantite	11.48	160

Liberation and separation of tennantite in the flotation circuit is possible based on textures documented in the study. Finer enargite textures will require finer grinding to adequately liberate.

Laboratory scale flotation and plant piloting of an As depression strategy has confirmed that separation of As from the Cu concentrate is possible. Antamina has also managed the problem through blending of ores and concentrates, and through the commercial terms that they negotiate. The use of quantitative mineralogy was fundamental in development of the mineral processing strategy by defining As deportment in discrete, coarse grained, easily liberated minerals.

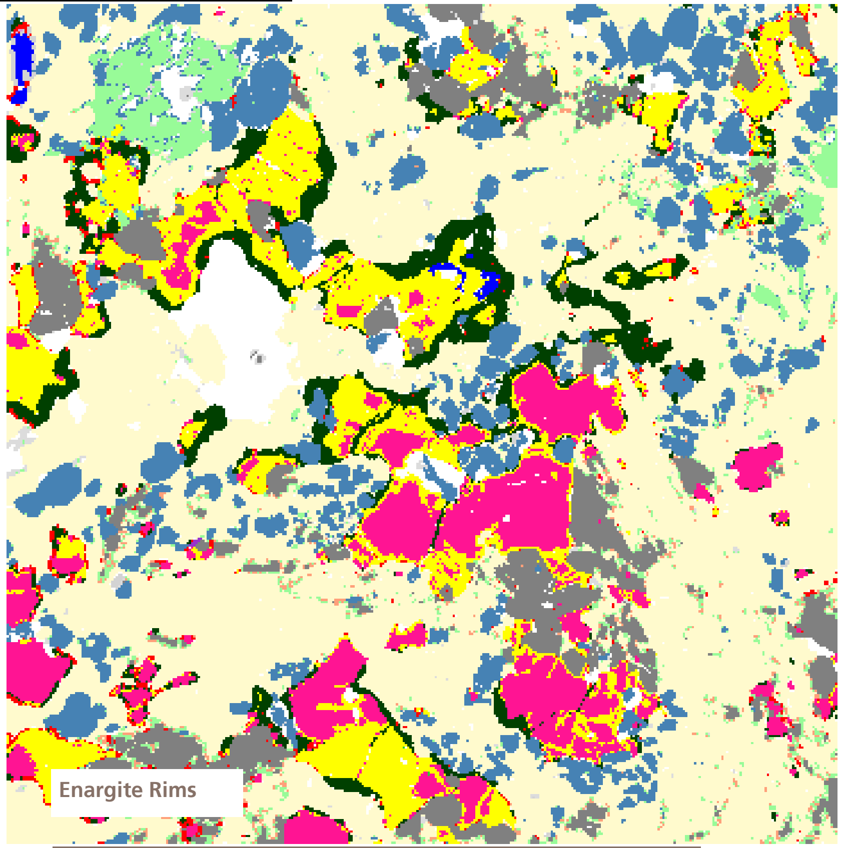


Figure 4: QEMSCAN Images of Tennantite and Enargite Textures in the Antamina Bornite Zone.

Process Mineralogy Group

XPS Process Mineralogy is part of Xstrata Process Support, and independent consulting service, consisting of a blend of skilled mineral processing and mineral science personnel. Process Mineralogy utilizes mineral processing, quantitative mineralogy, sampling and statistics at the XPS Centre in Sudbury, Ontario.

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