Gold Deportment in the Far Southeast Porphyry Copper-Gold Deposit, Philippines

Matt Bunce[1], Jeffery Hedenquist[1], Keiko Hattori[1], Simon Jackson[2]
[1]University of Ottawa, Ontario, Canada
[2]Geological Survey of Canada, Ontario, Canada

Introduction

The Far Southeast porphyry copper- gold deposit is located within the Mankayan mineral district of northern Luzon, Philippines (Figure 1). The porphyry is concealed at a depth of ~550 m below surface with mineralization hosted within the Imbanguila diorite –dacite intrusion complex forming at 1.3-1.4 Ma. Far Southeast Gold Resources Inc, a joint venture of Lepanto Consolidated Mining Company and Gold Fields Ltd, recently completed 102 km of underground drilling and confirmed a resource of 892 Mt at 0.7 g/t Au and 0.5 wt% Cu. Previous studies identified native gold as blebs in sulfides, and also proposed the presence of gold micro-inclusions in sulfides. The present study focused on gold deportment using microscopy, SEM with EDS, and LA-ICP-MS. Bornite, chalcopyrite, pyrite, covellite and chalcocite (the latter two replacing bornite) were analyzed in samples that ranged in depth from ~1100 to 1550 m below surface.

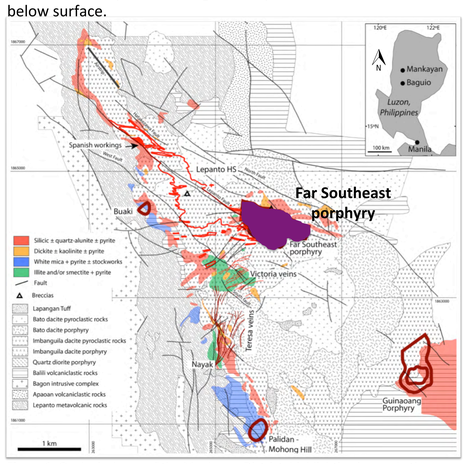


Figure 1. Geological map of the Mankayan District, highlighting in purple the location of the Far Southeast porphyry deposit.

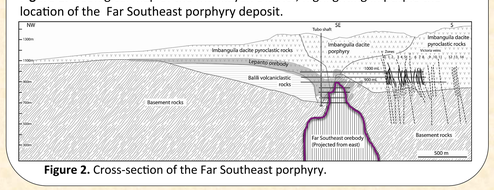


Figure 2. Cross-section of the Far Southeast porphyry.

Analytical Methods

1. Core samples (59 in total) and corresponding rock chips were analyzed from drill core of the deposit using a binocular microscope and hand lens. This included areas of high and low Cu and Au respectively, in search of visible gold. Sulphide occurrences between minerals: pyrite, chalcopyrite, bornite, covellite, digenite and chalcocite were also analyzed.
2. Transmitted and reflected light microscopy was used to analysis thin sections (59 in total) corresponding to the core samples. This was completed in search for visible gold, and to analyze occurrences of minerals. Samples were screened for quality for further analysis in SEM or LA-ICP-MS.
3. A scanning electron microscope (SEM) was completed to obtain back-scattered images in search of ≤10 micrometer inclusions of gold, or other sulfides unidentifiable in microscopy.
4. Laser ablation inductively-coupled plasma mass spectrometry (LA-ICP-MS) was used to analyze gold content within sulfides as well as to determine trace element content in sulfides.

Fig 3 to 5 need scales still, need to scale them later

Sulphide Occurrences

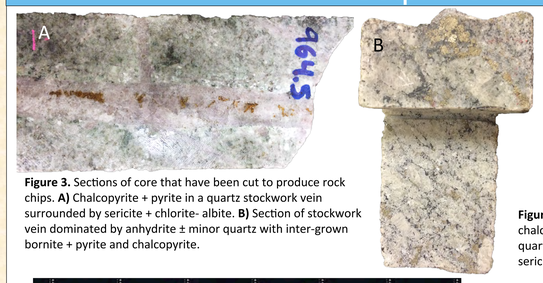


Figure 3. Sections of core that have been cut to produce rock chips. **A)** Chalcopyrite + pyrite in a quartz stockwork vein surrounded by sericite + chlorite- albite. **B)** Section of stockwork vein dominated by anhydrite ± minor quartz with inter-grown bornite + pyrite and chalcopyrite.

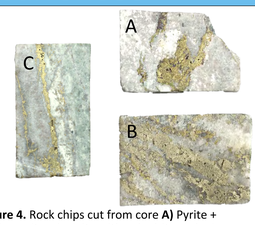


Figure 4. Rock chips cut from core **A)** Pyrite + chalcopyrite + bornite with anhydrite and minor quartz. **B)** Pyrite + anhydrite **C)** Chalcopyrite vein with sericite + chlorite – albite alteration.

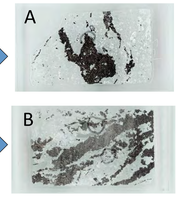


Figure 5. Thick sections cut from the rock chips used for microscopy analysis.

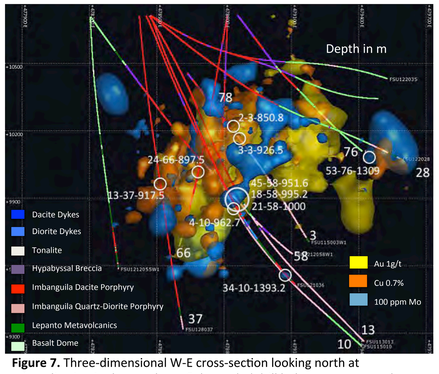


Figure 7. Three-dimensional W-E cross-section looking north at mineralization in the porphyry. Color-coded drill holes represent geology. All photomicrographs and LA-ICP-MS results present on the poster are projected on this cross section in the following manor: sample number – drill hole – interval (m).

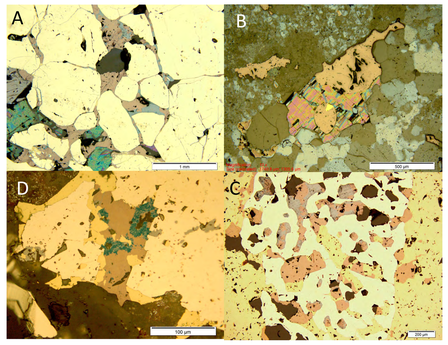
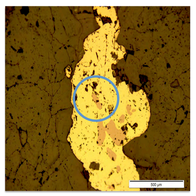


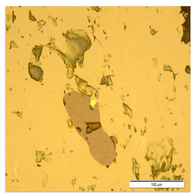
Figure 6. Photomicrographs in reflected light; **A)** ISS pyrite with anhydrite where fractures are being filled with later cooler fluid that results in bornite and covellite-digenite-chalcocite sulfide replacement (4-10-962.7). **B)** Bornite in equilibrium with anhydrite where bornite has replaced almost all of the original chalcopyrite. Located in stockwork quartz vein (19-58-996.2). **C)** "Swiss cheese" pyrite with chalcopyrite and evolved copper sulfides bornite and digenite (24-66-897.5). **D)** ISS pyrite surrounded by chalcopyrite with late bornite replacement. Bornite is being replaced by covellite-chalcocite (34-10-1393.2).

Visible Gold

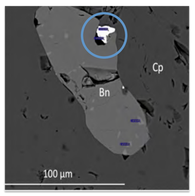
Figure 8. Gold Bleb (3-3-926.5)



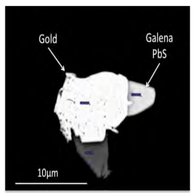
A) Photomicrograph of chalcopyrite vein, assessing mineral assemblages and searching for gold.



B) Analyzing at an increased magnification indicates the bleb is very likely gold.

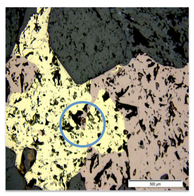


C) SEM was used to produce a backscatter image and allow for weight percentage to be taken.

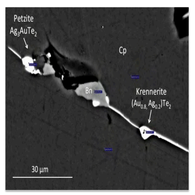


D) Enhanced magnification of SEM on the location to complete a spot analysis. The spot analysis recorded 86.3 wt% Au and 8.6% Ag, confirming it as a gold bleb.

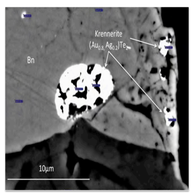
Figure 9. Gold Tellurides



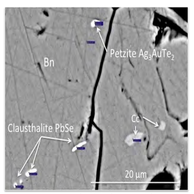
9.A) Chalcopyrite being replaced by bornite on what appears to be a fracture indicated by the circle (53-76-1309)



9.B) SEM analysis on the fracture where bornite has crystalized with tellurides Petzite and Krennerite (53-76-1309).



9.2 On the crystal boundary of bornite, blebs of krennerite with the largest centered in the image range in size from ~7 µm to 1-2µm (53-76-1309).



9.3 SEM analysis also produced inclusions of clausthasite that occur in lamellae orientations. A small petzite grain and replacement of bornie with chalcocite are also occurring (45-58-951.6)

Gold Micro-Inclusions and Trace Elements in Sulphides

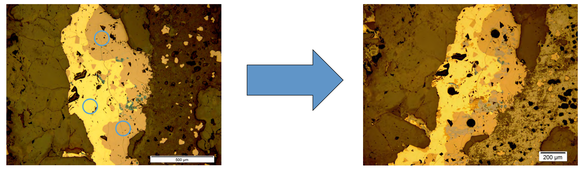
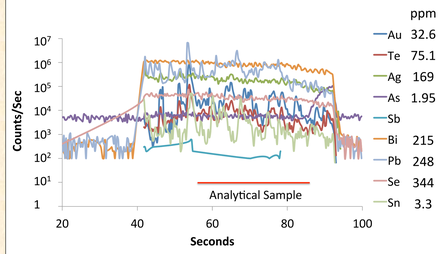


Figure 10. Two photomicrograph showing pre (A.) and post (B.) laser ablation. Whole sulphides free of inclusions were targeted to ensure the best analysis of the respective sulfide. Image shows three LA-ICP-MS holes with one in chalcopyrite and two in bornite. (2-3-850.8).



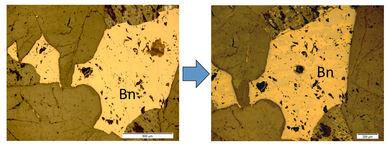
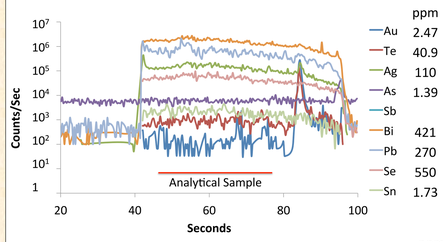


Figure 11. LA-ICP-MS results of ablated bornite shown by the photomicrograph above. This sample shows strong correlation between gold and tellurium, indicating multiple micro-inclusions are intersecting the laser as it ablates the target (13-58-917.5).



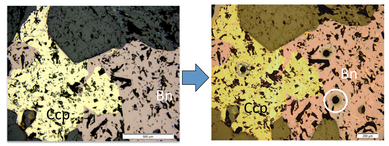
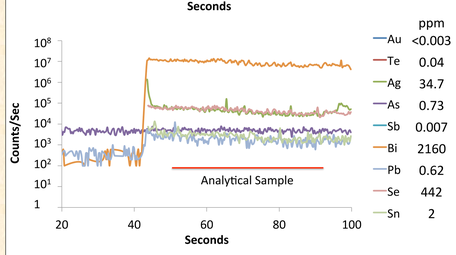


Figure 12. LA-ICP-MS results of ablated bornite shown in white by the photomicrograph above. A gold-telluride inclusion is clearly visible at ~83 seconds on the graph, with very low gold content occurring in the bornite itself. Very high amounts of Bi, Pb, and Ag are occurring in bornite (53-76-1309).



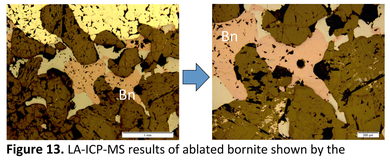
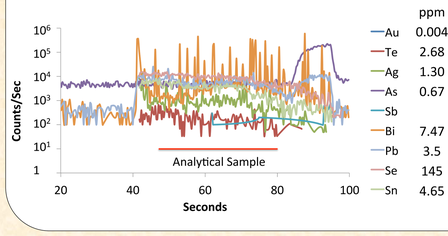


Figure 13. LA-ICP-MS results of ablated bornite shown by the photomicrograph above. Gold content is beneath detection limit with the sample containing high Bi(2160 ppm) and Se (442 ppm). This sample best represents the trace element results observed in bornite samples; gold is negligible and Bi, Se, and Ag are consistently high (21-58-1000).



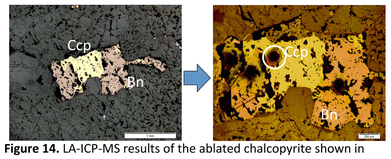


Figure 14. LA-ICP-MS results of the ablated chalcopyrite shown in white by the images above. Small peaks of Bi indicate the presence of a Bi mineral inclusion. Note the high Se (145) and low gold content (13-37-917.5).

Summary

1. Gold content is primarily found as blebs mostly 10 µm to 2 µm in size as gold, and Au-tellurides.
2. LA-ICP-MS determined that invisible gold content in sulfides is low, with bornite having the highest content at ≤ 8pp within its crystal structure.
3. High values of Bi (2160 ppm), Se (680 ppm), and Pb (640 ppm) are found in all sulfides analyzed. As values are ≤ 2 ppm.
4. ?

Acknowledgments
I would like to thank George Mrazek (uOttawa) for the excellent quality thin sections , Glenn Poirier (uOttawa) for assistance using SEM, Zhaoping Yang (GSC) for her assistance completing LA-ICP-MS and data compilation at the GSC, and Zhaoshan Chang for letting me adapt Figures 1 and 2.