Occurrence of gold in the Far Southeast porphyry-copper-gold deposit, Luzon, Philippines

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Introduction

The Far Southeast (FSE) copper-gold (Cu-Au) deposit is located in northern Luzon, Philippines (Fig. 1a). The deposit is being explored by Far Southeast Gold Resources Inc., a joint venture of Gold Fields Switzerland Holdings AG, a subsidiary of Gold Fields Ltd., and the Lepanto Consolidated Mining Company. Porphyry Cu systems are large volumes (10 to 100 km³) of hydrothermal altered rock centered on shallow porphyry intrusions; in addition to Cu and Au hosted by intrusions, the systems may also contain epithermal base and precious metal mineralization, and other deposit types (Gillentine, 2010). Porphyry deposits are mainly located in volcanic arcs; they account for about 70% of the world’s Cu production (Gillentine, 2010).

The FSE deposit is among the highest Au grade of porphyry Cu deposits in the world, is related to shallow intrusions formed about 1.4 million years ago (Hedenquist et al., 1998). The top of the ore body is located over 900 m below the present surface (Fig. 1b), at an elevation of 1500 m. The host rocks are the Lepanto mafic-ultramafic unit, the Imbanguila dacite porphyry and the Imbanguila quartz diorite porphyry; the latter two units were intruded shortly before deposit formation. Recent drilling (2010-2011) from the 700 m elevation level (Fig. 1c) determined an inferred resource of 902 million tonnes (Mt) at an average grade of 0.7 g/t Au and 0.5 wt% Cu, equivalent to 13.8 Moz Au and 4.6 Mt Cu (Gadoury et al., 2013).

The main purpose of this study was to determine the sulfide minerals related to visible gold, and relate this to the stockwork of quartz and anhydrite veins.

Methods

Core samples of mineralized rocks were drilled from 700 m elevation (Fig. 1c); over 102,000 m of core were drilled in 38 holes from 2012 to 2013. This core was sampled in January 2014 by J.W. Hedenquist.

Polished thin sections were made from selected core samples at the University of Ottawa.

Samples were analyzed under petrographic microscope, both transmitted and reflected light (10x to 500x magnification):

1. A scanning electron microscope (SEM) was also used for semi-quantitative analysis of sulfide minerals and gold, to help identification and to determine the silver content of the gold.

Results

Veins

After surveying and observing 29 samples under the petrographic microscope, the veins in the samples were separated into different groups. The criteria used were mineralogy and cross-cutting features (Fig. 2). All veins are composed mainly of quartz and anhydrite. Anhydrite is associated with the matrix of the host rock, and is also present in veins where repositioned. The veins were divided into 3 groups, A to C. Group A is composed of Chalcopyrite (cc), Bornite (bn), ± Magnetite (mag)/hematite (hem), locally with bn replaced by Covellite (cv) or Digenite (dg). Chalcocite (cc). Group B veins contain Pyrite (py) ± ep mg/hem. Group C veins are only hem/mag, and commonly reopen older veins. There can be multiple generation of the same vein type.

Mineral assemblages and associations

Several sulfide assemblages (mineral associations) occur in this deposit, inside and outside veins. Minerals such as cc and dg/cc are not part of some assemblages, but typically are a replacement of ln (i.e., an association). dg/cc can be contemporaneous with ln in some assemblages.

Discussion and conclusions

Gold-bearing minerals are bornite and chalcopyrite, with gold typically on grain margins; minor visible gold is also in quartz veins.

Bornite is replaced by both digenite/chalcocite and covellite; the replacement by digenite/chalcocite is more common, whereas covellite is observed at greater depths and on the edges of the deposit. This replacement is caused by cooling (Fig. 7).

Gold grains observed in bornite are likely the product of solution as temperature decreases; bornite and chalcopyrite have a high solubility of gold (up to 2000-4000 ppm) at high temperatures, 700°C, whereas decreasing temperature leads to a lower solubility of gold in these minerals, as low as 300 ppm at 500°C (Frisby and Franks, 2014). In addition, the replacement of bornite by digenite/chalcocite as temperatures decrease (Fig. 7) may also lead to formation of gold blisters from that in solid solution in the bornite.

In some places it appears that pyrite was precipitated earlier than chalcopyrite and bornite.

The magnetite is bothigenous (originally disseminated in the intrusive rocks) and hydrothermal.

The repetitive assemblages and their order (paragenesis) indicate that cooling was episodic, followed by reheatting in pulses (Fig. 7).

References and Acknowledgements

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