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An investigation of the factors affecting the recovery of molybdenite in the Kennecott Utah Copper bulk flotation circuit

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ABSTRACT

The Bingham Canyon mine and associated Copperton Concentrator operations are a significant copper and molybdenum producer. Molybdenum is present in the deposit as the sulphide mineral molybdenite. In 2004, the price of molybdenum increased 10-fold resulting in a renewed emphasis on production of this metal, including efforts to optimize its flotation recovery. Molybdenite recovery in the bulk flotation circuit is consistently lower than that of the copper sulphides as well as being far more variable. This paper describes the systematic use of size recovery data, quantitative mineralogy and surface analysis to identify the factors contributing to molybdenite recovery relative to copper in the Copperton bulk flotation circuit. Several operational changes have been made to capitalize on the findings of the research these include the separate treatment of an ore type containing problematic silicate minerals and the optimization of the frother to collector ratio to ensure adequate froth stability.

1. Introduction

Kennecott Utah Copper, a wholly owned subsidiary of Rio Tinto, operates the Bingham Canyon Mine, one of the worlds largest open pit copper mines. The mine and associated Copperton Concentrator are located approximately 26 miles South West from Salt Lake City Utah in the eastern foothills of the Oquirrh mountain range near the city of Copperton. Babcock et al. (1997) describe the Bingham Canyon deposit as a classic porphyry copper deposit exhibiting concentric zones of alteration and mineralization. The deposit is notable in its size containing pre-mining reserves of nearly 3 billion tonnes of ore at 0.67% copper. Nested within the copper ore body are overlapping zones of molybdenum, gold and silver containing 0.06% molybdenum, 0.3 g/tonne gold and 1.5 g/tonne silver. Kennecott was the first company to successfully produce molybdenum concentrate as a byproduct from relatively low grade ores and in 1936 produced approximately 1 million pounds of concentrate. The presence of molybdenum in the deposit lead to the inclusion of a copper molybdenum separation plant when the Copperton Concentrator was constructed in 1988.

The Bingham Canyon deposit has been separated into a number of ore types based initially on lithology with further subdivision then based on processing characteristics. The quantity of ore processed through the concentrator each day dictates that several ore types will be treated at once, in a blend. A blend normally consists of 3–5 ore types as shovels work different parts of the mine at once. The processing characteristics of individual ore types have been extensively modeled and these are arithmetically combined to estimate the expected performance of blends in the production planning process. Blending ores arithmetically to determine their overall performance is reliable unless cross contamination takes place. This is the case with the Limestone Skarn ore (LSN) which has been found to reduce the recovery of the ores it is blended with. Understanding the processing of the LSN ore and its effect on molybdenum and copper recovery has been a focus at Copperton for the last two years.

Until recently, molybdenum had been seen as a relatively insignificant byproduct of copper production. This changed in 2004 when the price of the metal increased 10-fold as a result of increased demand from Chinese steel makers. The increase in the price of molybdenum has resulted in a renewed emphasis on the production of the metal, including efforts to optimize its production from mine to product. Therein lies the motivation for the work contained in this paper.

The Copperton Concentrator consists of a grinding circuit and two flotation circuits. Four SAG mills, eight ball mills and an integral pebble crusher, reduce 150,000 tonnes per day of run of mine ore to a nominal P80 of 240 μm. Cyclone overflow is processed through the bulk flotation circuit, consisting of five rows of rougher scavengers with scavenger concentrate regrind and cleaner circuit to produce a 25% copper concentrate containing approximately 2% molybdenum. This bulk concentrate is then processed through a separate molybdenum flotation plant where the copper is

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depressed and a high grade molybdenum concentrate is produced. The copper concentrate is pumped to Kennecott's Garfield smelter for further treatment.

Bulk flotation molybdenum recoveries are consistently lower than that of copper as well as being far more variable. The objective of the work presented in this paper was to determine, and where possible prioritize and address some of the factors that contribute to the molybdenum recovery being lower than copper in the bulk flotation circuit at Kennecott Utah Copper. The factors investigated include the in situ morphology of molybdenite and how this manifests itself in the flotation feed, the size by size recovery and liberation characteristics of the molybdenite, the effect of gangue mineralogy as present in various ore types, the occurrence of precipitate coatings from process water, surface oxidation and the effect of the frother to collector ratio.

2. Factors contributing to lower molybdenum recovery

In the published literature, lower molybdenum recoveries have been attributed to various sources. Many of the factors identified are generic issues that are not specific to molybdenum flotation. Based on the performance characteristics of a number of porphyry copper molybdenum plants, Shirley and Sutulov (1985) and Hernlund (1961) summarized some of the factors that may affect the floatability of molybdenum from porphyry ores at industrial scale; these are (1) mineralogy of ore deposits, (2) slime coatings, (3) optimizing copper metallurgy at the expense of molybdenum, (4) grinding and liberation and (5) flotation reagents. While most of these issues are generic, what becomes important when considering the poor performance of molybdenum relative to copper is the extent and relative contribution from each mechanism.

Bulatovic et al. (1999) studied the effect of clay slimes on copper and molybdenum flotation from porphyry ores. While they were able to qualitatively identify bad actors as well as noting the effects on coarse and fine particle recovery, the work was empirical and difficult to extrapolate to other ore types.

The fundamental research of Chander and Fuerstenau (1972), Hoover (1980) and Raghavan and Hsu (1984) have focused primarily on those factors contributing the hydrophobicity of molybdenite. The approaches taken have tended to focus on one mechanism at a time. This work was often done under conditions not seen in an industrial scale porphyry copper molybdenum plant.

There is a need for the published fundamental work to be viewed in the context of an industrial scale operation where any number of competing factors can be contributing to the behavior of molybdenum.

2.1. Molybdenite structure and morphology

Molybdenite comprises hexagonal crystals in which each molybdenum atom is surrounded by six sulphur atoms. The crys-

a

b

Fig. 1. Examples of vein controlled molybdenite. Example (a) shows a 20 mm wide quartz vein lined on both sides with 2–3 mm molybdenite crystals. Example (b) is a piece of drill core that broke along a thin fracture to reveal a thin layer of smeared molybdenite. The smearing appears to take place in situ.

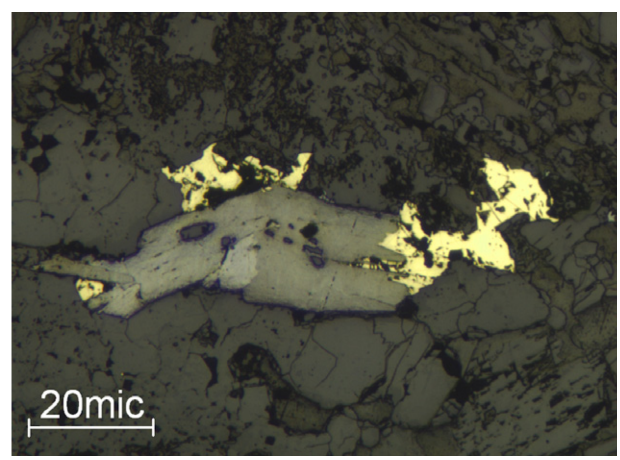

Fig. 2. An example of disseminated molybdenite contained in host rock. The molybdenite is in contact with chalcopyrite.

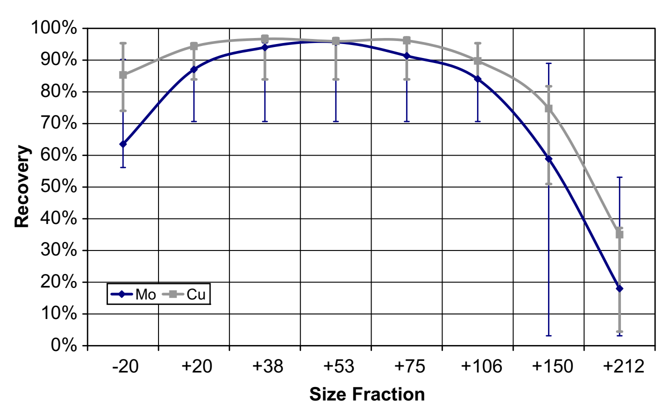

Fig. 3. Average size by size molybdenum and copper recovery for the 18 months from April 2005 until October 2006. The curve is calculated based on analysis of weekly composites of feed and tails. Error bars are included representing the range that occurs around these average values.