Preg-robbing Characteristics of Gold Ores in Ghana

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Abstract

The characteristics of gold ores change with time during exploitation from free-milling to refractory and double refractory gold ores. This prevents extraction of the minerals of interest in sufficient quantities for profitability. The main constituents of the ore that render it refractory and double-refractory are sulphides and carbonaceous matter. Sulphides prevent the lixiviants from contacting the metal of interest during leaching, and thus, reduce recovery. Carbonaceous matter, on the other hand, adsorbs the metal of interest from pregnant solution, and thus, reduces recovery, in a phenomenon referred to as preg-robbing. Recent studies indicate that though most of the Gold Mining Companies in Ghana are known to be treating free-milling or non-refractory gold ores, some of the gold ores contain substantial amount of carbonaceous materials. This motivated a study to assess the preg-robbing characteristics of gold ores in Ghana. The ores were subjected to various investigations including cyanidation with and without carbon, and preg-robbing in standard gold solution. The results indicate that,in six out of the 8 mines studied, the ores exhibited preg-robbing tendencies ranging from mildly (< 50%) to moderately (50-80%) and highly (> 80%) preg-robbing. Two out of the six were in the highly preg-robbing zone with cyanidation recoveries below 85%. Ores from these two mines also adsorbedabout 40 g of gold per tonne of ore in the preg-robbing test using standard gold solution.This study provides the platform to properly document the preg-robbing behaviour of the gold ores treated in Ghana.

1 Introduction

The exploitation of minerals results in exhaustion of mineral resources since they are not renewable. The exploration leads to discovering new deposits, and with time as mining progresses, deeper zones are encountered consisting of new types of ores with changes in characteristics. These changes in ore mineralogy present challenges during processing and extraction. The ore becomes more complex to treat and recover the metal of interest economically. Some of the causes of this complex nature of the ores are the presence of carbonaceous matter and sulphides in the ore.

Carbonaceous matter in gold ores causes two types of difficulties. Firstly, the carbon can lock up a proportion of the gold in the ore and inhibit leaching. The CM therefore acts in a refractory manner since it impedes gold extraction. The ore can also contain "active" carbon that adsorbs gold from the pregnant solution, thusacting as an adsorbent (Rees and Van Deventer, 2000; Amankwah *et al.,* 2005; Yen *et al.,* 2008; Ofori-Sarpong et al, 2010; 2013; Ofori-Sarpong, 2013). The presence of carbonaceous material in ores has been shown to act like activated carbon and adsorb the solubilised gold from the cyanide solution when leaching, and to chemically combine with the soluble gold resulting in loss of gold due to the fineness of the carbon.In metallurgical operations this phenomenon is termed preg-robbing (Zaitseva*et al*., 1973; Jha, 1984; Hausen and Bucknam, 1985; Abotsi and Osseo-Asare, 1986; Quach*et al*., 1993; Ofori-Sarpong et al., 2010).

Preg-robbing may be defined as the phenomenon whereby the gold cyanide complex ($Au(CN)_2^-$) is removed from solution by the constituents of the ore. The main constituents of the ore causing preg-grobbing are the carbonaceous matter present. These constituents may include wood chips, organic carbon and impurities such as elemental carbon. The auro-cyanide complex may also be preg-robbed from solution by the minerals themselves (Rees and Van Deventer, 2000).

In Ghana, most mining companies are sited in areas where the mineralisation zones were originally free-milling. However, continuous and consistent mining of the non-renewable oxide zones have compelled mining companies to surmount mineralised zones that deviate from typical oxides. The changes in characteristics come with challenges in following conventional treatment methods, and these have resulted in lower recoveries and high tailings values. Though many factors may account for this occurrence, one area that has not received adequate attention is the possibility of preg-robbing. This stems from the believe that preg-robbing is associated only with complex/refractory gold ores (Zaitseva*et al*., 1973; Jha, 1984; Hausen and Bucknam, 1985; Abotsi and Osseo-Asare, 1986; Quach*et al*., 1993; Ofori-Sarpong et al., 2010). This paper therefore reports on investigations aimed at assessing the preg-robbing characteristics of gold mineralisations in Ghana so as to create a platform for proper documentation and further study.

Experimental Investigations

Materials

The ores for the study were obtained from various Mining Companies in Ghana, including Adamus Resources Limited, Anglogold Ashanti Limited, Iduapriem and Obuasi Mines, Gold Fields Ghana Limited, Tarkwa andDamang Mines, Golden Star PresteaBogoso Resources, Bogosoand Wassa Mines, Newmont Ghana Gold Limited, Ahafo Mines and Sankofa Mines, Prestea. Standard gold cyanide solution (50 µg/mL in 0.05% NaCN + 0.1 NaOH) was obtained from high-purity standards, whereas sodium cyanide, lime, activated carbon, orbital shaker incubator and all other relevant materials were obtained from the Mineral Engineering Laboratory of the University of Mines and Technology.

Methods

Cyanidation of gold

The ores were prepared prior to leaching by drying, followed by crushing and ball milling to 80% passing 106 µm.Three sets of samples weighing 1 kg each of the ores from the various mineswere prepared at 50% pulp density. The pulp for each sample was then conditioned with lime to a pH of 10.5-11.5, and leached with 1 kg/t cyanide strength in rolling bottles for 24 hours. For the first set of samples prepared, activated carbon was introduced into the leaching bottles. For the second set of samples leached, no activated carbon was introduced. Kinetic leaching studies was conducted on the third set of samples without carbon addition.Each of the leaching studies detailed above was conducted in duplicates. For the kinetic studies, solution samples were taken for gold analysis after every 1, 2, 4, 8, 16 and 24 hour(s). For the carbon in leach studies, solution samples and activated carbon were taken at the end of the leaching studies for gold analysis. Tailing samples were taken from each of the bottles and fire assayed to determine the residual gold.

Preg-robbing test

Dried ores were taken through crushing and ball milling to 80% passing 106 µm prior topreg-robbing test. Duplicates of each sample weighing 10 g were used to contact 25 ml of 16 µg/mL gold solution and agitated at 200 rpm in an orbital shaker incubator for 24 hours. Each pulp was then filtered and the filtrate analysed for the gold content at the end of the contact time. The Preg-robbing Effect of Carbon(PEC) in the various ores was estimated with respect to the amount of ore used for the adsorption test based on Equation 1, modified after Ofori-Sarpong et al. (2011).

$$PEC\left(in\ \frac{gram\,of\ gold}{tonne\,of\ ore}\right)=V_S\ mL\ x\left(\left(IC_{Au}-FC_{Au}\right)^{\mu g}\!/_{mL}\right)\left(\frac{1}{W_{Ore}\ g}\right)$$

[1]

In Equation 1, IC_{Au} and FC_{Au} are the initial and final concentrations of gold in solution, W_{Ore} is the weight of the ore used in the adsorption test and V_S is the volume of gold solution used.

Results and Discussions

This paper assessed the variation in preg-robbing characteristics of various gold mineralised zones in Ghana. The following sections present and discuss the results obtained from duplicate experiments. For the sake of confidentiality, the names of the mining companies have been dissociated with the results and dummy-named Mine 1 – X.

Recovery of gold from direct cyanidationas a function of leaching time

Fig. 1 depicts the average results of the kinetics of gold recovery from ores obtained from various mining companies in Ghana. The ores were leached in duplicates with I kg/t of cyanide for up to 24 hours in rolling bottles.

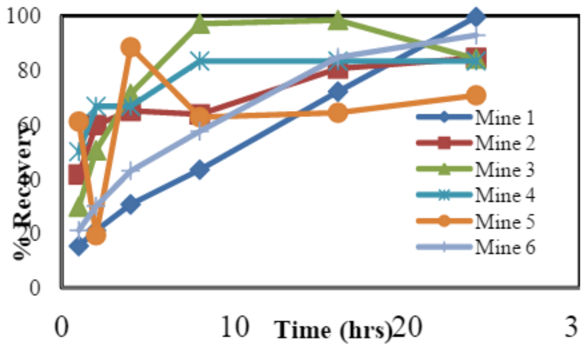

Fig. 1 Comparison of gold recovery fromores in Ghana as a function of leaching time

For Mine 1, percentage recovery increased continuously and linearly, starting from 15% at 1 hour leaching to a maximum of 99% at the 24thhour. The ore from this mine is considered free-milling andcontains no active refractory components, and hence exhibited no preg-robbing behaviour. This agrees with the work of Rees and Van Deventer (2000), who concluded that most of the oxide minerals used were not preg-robbing. Mine 6 depicted a similar trend as Mine 1 as the percentage recovery upsurged continuously from an initial value of 21.07% at 1 hour leaching to a peak of 92.79% at the 24th hour. Preg-robbing effect was generally not observed. Preg-robbing occurs when the ore contains active carbons that adsorb gold from pregnant solution thus acting like activated carbon (Hausen and Bucknam, 1984; Osseo-Asare et al., 1984; Ofori-Sarpong et al., 2010).

The recovery for Mine 2 increased from 41% at 1 hour leaching to about 66% at the 4th hour, followed by a slight decline to 63% at the 8th hour beyond which leaching rate was slow, ending at 83% at the 24th hour. This decrease at the 8th hour could be due to the presence of preg-robbers, which adsorbed part of the leached gold whiles gold leaching continued. During the first four hours of leaching the carbonaceous matter CM) in the ore was probably undergoing conditioning (Marsden and House, 2006; Ofori-Sarpong and Amankwah, 2012), cleaning the passivated pores on the CM and thereby exposing the pores to gold cyanide complex for adsorption. Since adsorption is a surface phenomenon, the adsorbed gold cyanide complex could go back into the solution as agitation takes place or the adsorption sites on the CM could be saturated and therefore lead to subsequent increase in recovery associated with 16 and 24 hours of leaching. The maximum gold recovery of 94% was attained at the 24th hour.

The graph for Mine 3 indicates that the percentage recovery increased from the initial 46% recovery at 1 hour leaching to a peak of 98% at 16 hours of leaching, and then dipped to 84% at 24 hours of leaching. Possible preg-robbling of the gold cyanide complex occurred between the 16th hour and the 24th hour of leaching as observed in the drop of gold recovery from 98 to 84%. According to Rees and Van Deventer (2000), the drop in recovery after the 16th hour can be attributed to adsorption by the carbonaceous matter or adsorption onto the ore minerals themselves, and this may occur by a physical adsorption process, or by the reduction of auro-cyanide at the mineral surface (Marsden and House, 2006). This ore contain pyrites, arsenopyrites, and clay minerals and thus has the potential to preg-rob (Hausen and Buckman, 1984).

Results for Mine 4 showed an increase in the percentage recovery from an initial value of 50% to a maximum of 83%. The percentage recoveries for the 2nd and 4th hours of leaching were the same at 67%. This value increased to 83% at the 8th hour and remained at that value up to the 24th hour of leaching. This observation means that, preg-robbing was taking place simultaneously with leaching. In addition, there could be cyanicides in the ore which consumed leaching reagent in wasteful reactions (Marsden and House, 2006).

The observation for Mine 5 was that, the recovery fell sharply from 61% at 1 hour leaching to a minimum of 19% at the 2ndhour and then rose to 88% atthe 4thhour of leaching. The sharp drop and rise in gold recovery could be due to the effect of a combination ofpreg-robbing and preg-borrowing associated with CM and other minerals, with the preg-borrower releasing part of the gold taken (Rees and Van Deventer, 2000). Beyond the 4th hour, recovery reduced to 63% at the 8th hour and finally ended at 70% after 24 hours of leaching possibly due to continuous leaching and preg-robbing.

In general, it was observed that, Mine1 started with the lowest recovery of 15.31% at 1 hour leaching and ended with the highest recovery of 99.49% at the 24th hour of leaching. However, Mine 3 had 97.11% and 98.43% recovery for 8 and 16 hours of leaching respectively, representing the highest recoveries for the respective leaching times while Mine 5 recorded the highest values of 61.09% and 88.42% for the 1st and 4th hours of leaching respectively. Mine 4 recovered the highest value of 66.67% for the 2nd hour of leaching.The summary here is that the ores from different mines have different leaching behaviours, and exhibit different degrees of preg-robbing characteristics.

Direct preg-robbing behaviour of the ores

The Preg-robbing Effect of Carbon (PEC) in oresused in this study was estimated with respect to the amount of ore used for the adsorption experiment as shown in Equation 1, and the results are presented in Fig. 2.

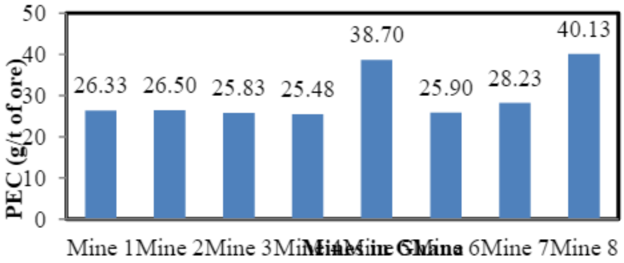

Fig.2Preg-robbing effect of gold ores used in Ghana mines

From Fig. 2, the average gold adsorbed in grams per tonne of most of the oresused was around 26. However, Mines 5 and 8 recordedhigh values of 39 and 40 g/t respectively. The ore from Mine 8, which had the highest preg-robbing is associated with pyrites, arsenopyrites and carbonaceous matter and was classified as double refractory (DRGO). Mines 5 and 8 robbed more than 90% of gold in the standard gold solution used for the adsorption test. Per the results obtained, a classification scheme was established (Table 1) to categorize the ores based on the percentage of the gold that was robbed. This classification puts about half of the ores analysed in the moderately to highly preg-robbing classes.

Table 1 Classification of preg-robbing characteristics of gold ores inGhana

% Robbed	*Classification*
Above 80%	*Highly Preg-robbing*
50-80%	*Moderately Preg-robbing*
Less than 50%	*Mildly Preg-robbing*

5.0 Conclusions

This paper reports on investigations aimed at assessing the preg-robbing characteristics of gold mineralisations in Ghana. The kinetics of leaching study reveals that, with the exception of two mines, all the mines showed preg-robbing characteristics. Also, from the preg-robbing test, it can be inferred thatMine 8 had the highest preg-robbing followed by Mine 5, with 99.32% and 95.79% robbed respectively. These mines are classified as highly preg-robbing using the classification scheme in Table 3.1. The others were classified as either mildly or moderately preg-robbing. In general, about 75% of the ores studied showed various degrees of preg-robbing. These results set a platform for further studies to map out all the gold ores treated in Ghana and properly document the preg-robbing characteristics.

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