

ROASTING OF CARBONACEOUS AURIFEROUS PYRITE AND ARSENOPYRITE FLOTATION CONCENTRATE

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ABSTRACT

The roasting conditions for gold ore flotation concentrate from two sources have been studied. Temperatures from 450 to 850°C were employed for one-stage roasting in air for 6 hours. Two-stage roasting was also carried out employing 550°C followed by 750°C for a total time of 2, 4, and 6 hours. The surface areas of the calcines were measured using the B.E.T. nitrogen adsorption technique; the calcine were then leached for gold in 0.1% NaCN solution over a 24 hour period. Results showed that for the one-stage process gold extraction was maximum at 650-700°C for both sample A and B respectively. The surface area was found to decrease with increasing roasting temperature and this was believed to be the cause of the low gold extraction obtained above 700°C. At the lower temperatures below 650°C the low extraction was ascribed to the presence of uneliminated C, S, and As. Two-stage roasting of sample B for 6 hours yielded calcines with higher surface area and consequently a higher gold extraction.

KEYWORDS: Roasting, gold, temperature, leaching, surface area

INTRODUCTION

Ghana is endowed with a number of mineral deposits; notable among these is gold ore [1]. Although all the minerals being exploited contribute measurably to the country's economy, the greater proportion of the revenue is derived from gold. Ores containing gold is found in most parts of Ghana. Three main gold ores may be identified. These are free milling gold as occurs in the reefs at the Tarkwa Goldfields and in alluvial workings as found in the Dunkwa Goldfields, refractory gold ores which contain substantial amounts of sulphur, carbon and arsenic as found at the Ashanti Goldfields, Billiton Bogosu Gold etc., and recently rediscovered oxidized ores at places such as Bibiani, Teberebie and Ashanti goldfields, which are low grade but are amenable to modern extraction methods such as heap leaching.

Of all the gold deposits the refractory ores account for over 50%. Since these ores are usually of high

grade more tonnages are utilised despite the difficulty encountered with the extraction of gold from such ores. The problem with this type of ore is that about 30-70% of the gold is believed to be occluded in the matrix of carbon, sulphur, and arsenic which are the elements that cause these ores to be refractory. In addition to the likelihood of these elements occluding the gold particles, they also consume reagents that are necessary for the gold extraction.

Conventionally these refractory ores are treated by the well-known process of roasting followed by leaching. In recent times new methods have been introduced which do not involve roasting. These are modern methods still in the experimental stage and includes: Pressure leaching (oxidation) [2], the lime-oxygen hydromet process [3] and bacterial leaching [4].

The main objection to the roasting process has been the lack of proper control over emissions into the environment in spite of its effectiveness in the removal of the undesirable elements. These days however, perhaps owing to environmental pressure, the process is being redesigned to make it more environmentally acceptable. Innovations in Ghana include introduction of scrubbers to remove harmful gases from gaseous effluents and the introduction of the fluid-bed roaster. It seems, therefore, that the roasting process will continue to be used into the future.

Roasting of gold ores has been studied by several workers notably Arriagada and Osseo-Asare [5], Carter and Samis [6], Afenya [7] and Norwood [8]. Although these were mainly one-stage roasting processes they have contributed a lot to the understanding of an otherwise complex process. These studies have shown that although low temperatures are inadequate for roasting high temperatures are detrimental owing to sintering that takes place. Sintering causes the gold to be occluded in dense iron oxide mass and this hinders the leaching process. Some of these studies have also indicated that the intermediate temperatures recommended for roasting are usually not adequate for the effective removal of the elements. It appears that low temperatures favour the removal of some elements while for other elements higher temperatures may be preferable. Also, the partial pressure of oxygen which largely determines whether the roasting condition is reducing or oxidizing is known to control the structure of the calcines obtained and hence the amount of gold extracted.

The Fe-S-O and the Fe-As-S-O equilibrium systems have been found to be very useful in this regard and



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support the contention that multistage roasting leads to better gold recovery than one-stage operations. Not much fundamental work seems to have been done in this area of multistage roasting, although commercial roasting operations that involve the use of multistage processes are being practised. Many of these are however in the developmental stage. In Ghana fluidised-bed roasting has been introduced and flat-bed processes are being reappraised. This work is to support not only the continuing development of these innovations but also to support work on the appraisal of existing roasting facilities. The roasting characteristics of flotation concentrates of refractory ores from two mines would be studied to optimise the roasting parameters for maximum gold extraction.

EXPERIMENTAL PROCEDURE

About 28 g of flotation concentrate was used for each roasting test. The first series of tests involved one-stage roasting of ores from two different mines (i.e. ore sample A and ore Sample B).

Prior to carrying out the roasting tests, each of the samples were analysed to determine the chemical as well as the mineralogical constituents. The Philips X-Ray Diffractometer and the ICP (Plasma Emission Spectrometer) were employed in these analysis. Carbon was determined using CO₂ coulometer.

Roasting was carried out in a fixed-bed reactor on samples in air under isothermal conditions at temperatures from 450-850°C for 6 hours. 10 g of the calcine was leached in 0.1% NaCN solution for 24 hours at a pH of 10.6-11.0 at about 10% solids. The leach solution was analysed for gold and the calcines analysed for S, C, and As. The surface area of the calcine was measured using the BET nitrogen adsorption technique.

Two-stage roasting was carried out on sample B using a combination of reducing and oxidizing roasting for total times of 2, 4 and 6 hours. Reducing conditions were employed at 550°C for half of the total time in order to remove as much As as possible. Roasting at 750°C followed immediately under oxidizing conditions in order to get out as much sulphur as possible. The calcines obtained in these tests were leached as usual. They were also analysed for S and As, and the surface areas were determined.

RESULTS AND DISCUSSION

Results of the chemical analysis are shown in Table 1. The main constituents are C, S, As, Fe and Si; contents with varying roasting temperature for sample A is shown in Fig. 1 for one-stage roasting. The curves show that the amount of element eliminated increases much more rapidly up to about 550°C after which only a gradual increase in losses are observed with increasing roasting temperature. Generally however the extent of removal of these elements appear to be favoured by the higher temperatures (above 550°C), C removal being more efficient than the removal of S and As. In the case of S and As it seems that below

TABLE 1: Chemical analysis of the flotation concentrates.

Element	% Composition	
	Sample A	Sample B
C	9.43	2.12
S	10.11	22.55
As	10.00	3.59
Fe	15.67	12.35
Si	13.10	-
Al	5.96	-
Ca	0.78	-
K	0.80	-

about 700°C more As is eliminated than S while the opposite is the case above this temperature. This observation was confirmed in sample B as shown in Fig. 2. The curves for the two samples indicate that calcine produced at about 550°C contain more S than As (ie. about 2.7% S and 2.0% As in sample A, and about 1.0% S and 0.5% As in sample B) whereas calcines produced at about 850°C contain more As than S (ie. about 2.9% As and 1.5% S in sample A, and about 0.5% As and 0.2% S in sample B). The work of Arriagada and Osseo-Asare [5] reports a similar general trend where up to the highest temperature of 750°C, As elimination was higher than S elimination. X-ray diffractograms showed that with increasing temperature there was a decrease in the pyrite and arsenopyrite content and a concurrent growth of Fe₂O₃.

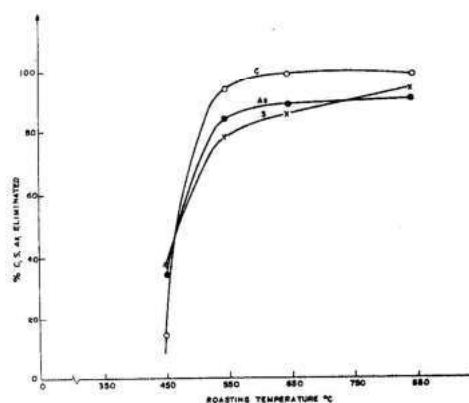


Fig. 1: Progress of Elimination of C,S, As from Sample

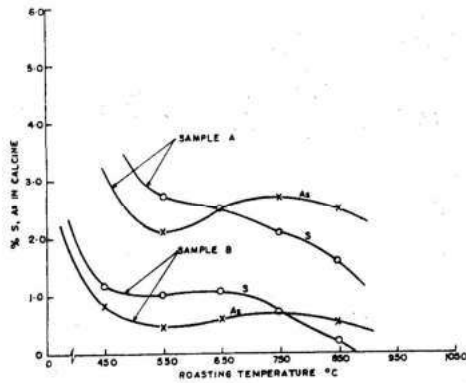


Fig. 2: % S, As in Calcine Vs Roasting Temperature

The amounts of gold leached out of the various calcines after 6 hours one-stage roasting in air are shown in Fig.3. For both samples, the gold leached out seems to increase to a maximum between 650 and 700°C and thereafter decreases with an increase in the roast-

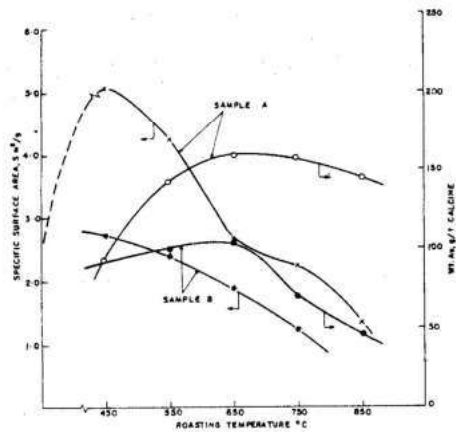


Fig. 3: Variation in Surface Area of Calcine and Gold Extraction with Roasting Temperature

ing temperature. The trend in gold extraction at the lower temperatures is attributed to the presence of uneliminated arsenic, sulphur and carbon compounds which would either occlude the gold or consume reagents thus decreasing the efficiency of extraction. The difference in the maximum extraction obtained for the two samples (about 160 g/t calcine for sample A and about 100 g/t calcine for sample B) arises from the different grades of the two flotation concentrates employed.

At higher roasting temperatures (>700°C), the gold extraction decreases. This is attributed to the sintering of the hematite and hence the difficulty in leaching out the gold. The densification of the calcine (which results in a decrease in the surface area) was observed under the scanning electron microscope. Fig.3 also shows the trend in the surface areas of the calcines and these are seen to decrease with increasing roasting temperature. The curves show that the surface area for sample A calcines decrease from about 5.0 m²/g obtained at 450°C to about 1.4 m²/g obtained at 850°C. The corresponding trend for sample B is from about 2.7 m²/g obtained at 450°C to about 1.2 m²/g obtained at about 750°C. The differences in the surface areas for the two samples may be due to differences in the particle size of the flotation concentrates. However the results show the same trend and agree with results obtained by other workers [5].

Fig.4 and 5 show results obtained for two-stage roasting tests on sample B. These tests were designed to improve on the results obtained in the one-stage process by taking advantage of the various favourable conditions observed. By doing part of the roasting at 550°C in the presence of C and S (in a limited supply of air) would result in a reducing condition. This would

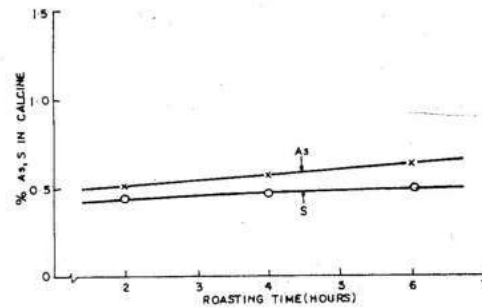


Fig. 4: Amount of As, S in Calcine Vs Roasting Time For Two Stage Roasting

ensure the formation of mainly volatile arsenic oxides such as As_2O_3 , As_2O_5 etc. at the low temperature. It was expected to obtain adequate elimination of the S and the As, especially, the As together with a reasonably porous calcine. Continuation of the roasting at $750^\circ C$ under oxidizing conditions was expected to further reduce the levels of the elements especially C, and S but without excessive reduction in the surface areas of the calcines.

Fig.4 shows the amounts of As and S eliminated for total roasting time of 2, 4 and 6 hours. There is no significant difference between the values all of which lie between 0.4 and 0.6%. These values agree with those obtained for As at $550^\circ C$ and for S at $750^\circ C$ as obtained in the one-stage process. The surface area of the calcine, as shown in Fig.5, increase with increasing time of roasting from about $1.5 m^2/g$ after a total time of 2 hours to about $3.5 m^2/g$ after 6 hours. Compared with the values of $2.4 m^2/g$ and $1.2 m^2/g$ obtained at $550^\circ C$ and $750^\circ C$ respectively for one-stage roasting, the $3.5 m^2/g$ obtained in the two-stage roasting is quite significant. Fig.5 also shows that the amount of gold leached out of the calcines increases from about 85 g/t after 2 hours to about 120 g/t after 6 hours. This shows a significant increase in the gold extraction of about 100 g/t obtained for one-stage roasting.

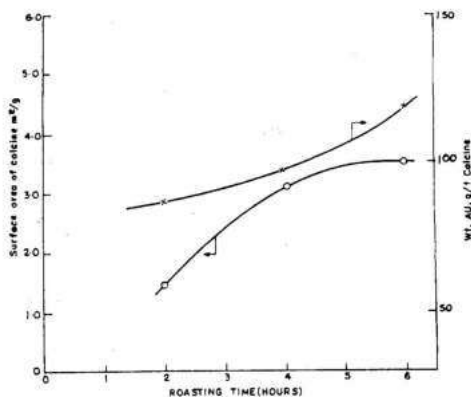


Fig. 5: Wt. of Gold Extracted and Surface Area of Calcine Vs Roasting Time for Two Stage Roasting

CONCLUSION

In this work the roasting characteristics of carbonaceous auriferous pyrite and arsenopyrite flotation concentrate (refractory gold ore) from two gold mines in Ghana have been studied. The results show that

1. temperatures between $650 - 700^\circ C$ give the best roasting conditions for maximum gold extraction when applying one-stage roasting. The maximum extraction obtained was about 150 g/t for sample A and about 100 g/t for sample B.
2. The low extraction obtained at temperatures below the optimum was ascribed to the presence of unroasted compounds of C, As and S in the calcine.
3. Above the optimum temperature sintering of the calcine with the resultant decrease in the surface area was believed to have caused the low yield in gold extraction. These would lead to the occlusion of the gold particles either in the unroasted compounds or in the dense calcine. The results agree generally with that obtained by other workers [5,6,7].
4. Two-stage roasting carried out on sample B indicated that employing $550^\circ C$ for 3 hours under reducing condition followed by oxidizing roasting at $750^\circ C$ for a further 3 hours produced calcines with low S and As contents. Also this process yielded a surface area of about $3.5 m^2/g$ which was much higher than the maximum of $2.5 m^2/g$ obtained for one-stage roasting at $450^\circ C$.
5. The two-stage process yielded gold extraction of about 120 g/t as against the maximum of 100 g/t obtained for the one-stage process.
6. The results obtained in this work show that high yields are possible in multistage roasting processes. More work of this nature is recommended to provide data to support commercial developments in this area that should benefit the gold mines in Ghana that use refractory ores.

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