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"Research Note"

RECOVERY OF GOLD FROM A FREE-MILLING ORE BY CENTRIFUGAL GRAVITY SEPARATOR*

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Abstract– In this study, the technical viability of the application of a Falcon Centrifugal Concentrator for the recovery of gold from ore was reported. The results of mineralogical analysis have revealed that gold with a size of 1-300 μm particles occurs predominantly in native form in association with quartz as free particles, and with sulphide minerals as inclusions and growths located in the grain boundaries. The results of gravity tests have indicated that 81% of the gold from the ground ore (-74 μm) can be recovered into a concentrate (Con.1) with a grade of 262 g/t Au at a 7.2% yield. A clean concentrate containing 1760 g/t Au at 33.8% recovery was found to be produced by the further enrichment of Con.1 via hand panning. Final tails assaying 2.5 g/t Au obtained after three recovery stages corresponded to a gold "loss" of 8.0% and a feed mass of 73.8%. These findings demonstrate the amenability of Mastra ore to gravity recovery using a Falcon Concentrator, probably as a pretreatment step ahead of cyanidation.

Keywords– Gold recovery, ore mineralogy, gravity concentration, centrifugal separator

1. INTRODUCTION

Aqueous cyanidation processes are traditionally used to treat ores in which gold is present as fine particles, while gravity separation can be utilized to recover free and coarse gold from ores [1]. In particular, the gravity recovery of coarse gold ahead of flotation and/or cyanidation can be an attractive option with the possibility of maximizing the net smelter return and improving the overall gold recovery. The use of centrifugal gravity separators to efficiently recover even fine gold particles has further expanded the scope of gravity applications in the gold milling practice [2-3].

The application of centrifugal force has proved an effective technique for the recovery of fine heavy minerals in recent years. The centrifugal force acting on a particle can be equal to or even higher than 50 times the force of gravity, significantly increasing the settling rate of a particle. The size of particles that can be captured becomes finer as the intensity of centrifugal forces generated is increased [3-4].

The Falcon Concentrator (Fig. 1a) [5] is an enhanced gravity device that generates a high gradient centrifugal field whereby the deposition and stratification of fine particles occur inside a smooth centrifugal wall [4]. Feed slurry is introduced into a rotating rotor bowl and accelerated by an impeller as it flows on the inner wall of the rotor. The lower part of the rotor is inclined at a slight angle to provide a migration zone, while the cylindrical upper part acts as the retention zone (Fig. 1b). The strong centrifugal forces, normal to the wall, lead to the hindered settling and stratification of particles in the migration zone. The weak driving force, parallel to the inclined rotor surface, moves the stratified particles up towards the top. The lighter particles, on the outside of the bed, migrate out of the rotor assembly due to their lower

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specific gravity or small size. Heavy particles are retained in the concentrating (retention) zone where the concentrate is cleaned by fluidization water.

The Mastra ore deposit, located in Gümüşhane-Turkey, offers an estimated resource of 808,000 tonnes of ore, containing, on average, 8 g/t Au [6, 7]. The ore body is currently under development and a cyanidation plant is expected to be in operation at the end of 2007. The mineralogical, alteration and fluid inclusion characteristics of the Mastra Au deposit can be characterized by those of an adularia-sericite type epithermal deposit. Gold is present as particles ranging from a few microns to 100 μm in size and mostly encapsulated in quartz [6]. Previous studies have shown that Mastra ore is amenable to cyanide leaching with gold recoveries of >90% over 24-48 h of leaching periods [7-9]. The relatively long leaching times required for high gold recoveries were probably due to the presence of coarse gold particles in the ore. In this study, the ore mineralogy and the potential application of gravity separation as a pretreatment step using the Falcon concentrators were evaluated.

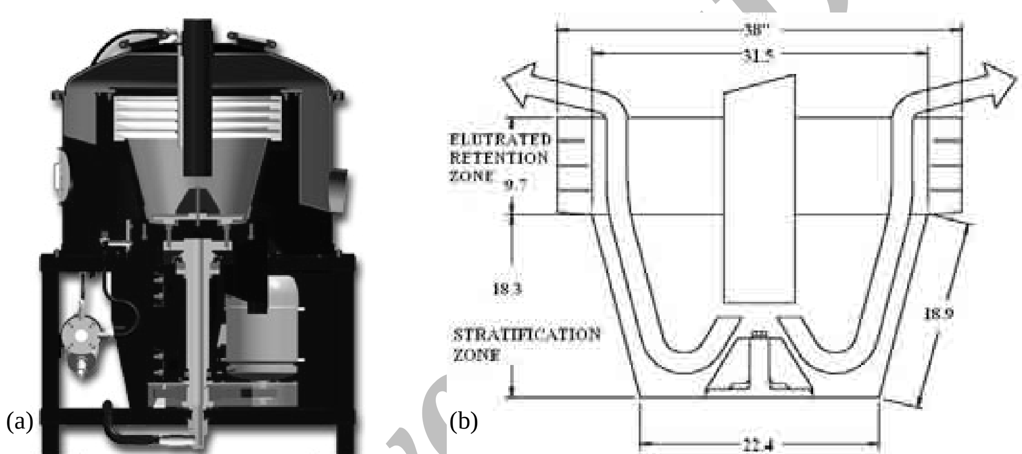

Fig. 1. a) A view of a Falcon Concentrator (FC), b) Stratification and retention zones in the bowl [5]

2. MATERIALS AND METHODS

A total amount of 150 kg ore sample was obtained from the veins of the Mastra (Gümüşhane-Turkey) gold deposit. Representative sub-samples of 2 kg each were prepared by riffling of the bulk sample (-4 mm) after crushing. These were then milled to -74 µm (Fig. 2a) in a laboratory rod mill.

The polished sections prepared from a number of hand-picked pieces of the ore were examined under an ore microscope (Leitz Wetzlar 1432) and, the size distribution of the gold particles within the ore sample was obtained (Fig. 2b). The chemical (Table 1) and mineralogical analysis of the sample indicated that the ore consisted of predominantly quartz, and to a lesser extent, silicates and sulphides (4.32% S) of Pb, Fe, Zn and Cu. The ore sample was determined to contain 23.3 g/t Au and 8.6 g/t Ag (Table 1).

Table 1. The chemical analysis of the head sample

SiO_2	Al_2O_3	Fe_2O_3	CaO	ΣS	Cu	Pb	Zn	As	LOI	Au	Ag
%	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	g/t	g/t
86.12	3.36	5.47	0.33	4.32	0.52	0.38	0.26	0.08	3.40	23.3	8.6

The gravity recovery tests involved three recovery stage scoping tests on the ground ore to evaluate the gravity recoverable gold content of the ore. A laboratory type SB40 Falcon Concentrator (diameter of rotor 10.2 cm) was used in these experiments and operated under the conditions as 20% solids by weight, 0.5 psi water pressure, 28º bowl angle, 1325 rpm (200 G) spin rate. The concentrate produced in the first and second recovery stages was hand-panned to upgrade their gold content. The tails from the first recovery stage were processed in the second recovery stage and the tails were further treated in the third stage to scavenge the gold contained and to produce final tails.

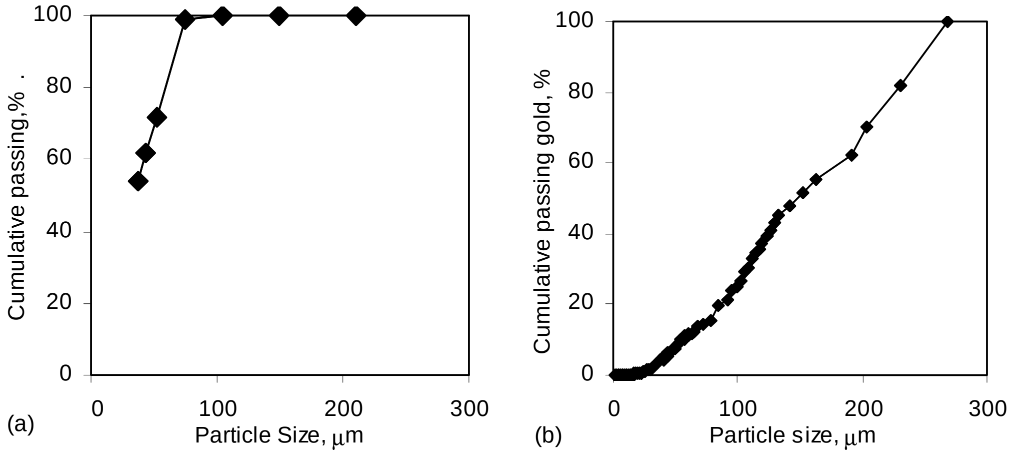

Fig. 2. a) Size distribution of the ore sample used in the gravity tests, b) and of gold particles in the ore

3. RESULTS AND DISCUSSION

Microscopic examination of the polished sections revealed that quartz was the most abundant mineral in the ore (Fig. 3a, 3d). Pyrite, chalcopyrite, sphalerite and galena were identified as the sulphide phases, which were present as associated with each other in a cataclastic texture (Fig. 3b- 3d). Pyrite was observed to occur mainly as euhedral particles (Fig. 3b, 3d). Gold was identified to occur predominantly in the native form and, to a lesser extent, as electrum.

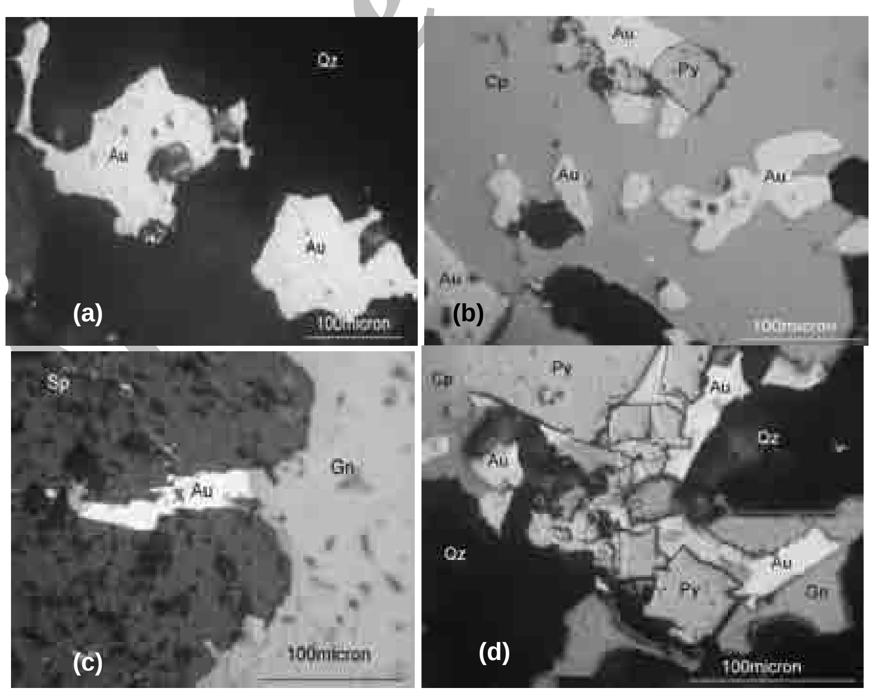

Fig. 3. The occurrence of gold in the ore, a) gold particles in quartz matrix, b) gold particles associated with chalcopyrite and pyrite, c) gold particle associated with galena and sphalerite, d) gold particles associated with galena, pyrite and chalcopyrite in quartz, (Au: gold; Cp: Chalcopyrite; Gn: Galena Py: Pyrite; Sp: Sphalerite, Qz: Quartz) (Oil immersion, ×25)

Gold particles were observed to be associated with quartz as particles (Fig. 3a) and with sulphide minerals as inclusions and growths within the grain boundaries (Fig. 3b-d). Half of the gold particles appeared to be ≤20μm in size (Fig. 2b), while the volumetric distribution of gold indicated that the gold particles of ≤150μm in size constituted only 50% of the total gold present in the ore. These findings agreed with the cyanide leaching data [7-9] that excessively high contact times were required to achieve high gold extractions (>90%). The current results also suggested that the coarse gold particles could be potentially recovered by gravity methods.

The results of the gravity recovery tests and the general flow sheet for the three-stage gravity tests are shown in Fig. 4. In the first recovery stage 81% of the gold present in the ore was recovered into the concentrate (Con. 1), which was then upgraded by panning to obtain a clean concentrate (Pan Con. 1) with a grade of 1760 g/t Au with 33.8% recovery and 0.4% mass yield. These findings could be interpreted as an indication of the likely performance of the Falcon Concentrator in batch or continuous operation. In this regard, approximately one-third of the gold could be recovered as a high grade concentrate using a batch-type Falcon Concentrator, while a gold concentrate (~262 g/t Au) containing the majority of gold (~81%) only as a small fraction of feed mass (~%7.2) could be produced using a continuously operated Falcon Concentrator.

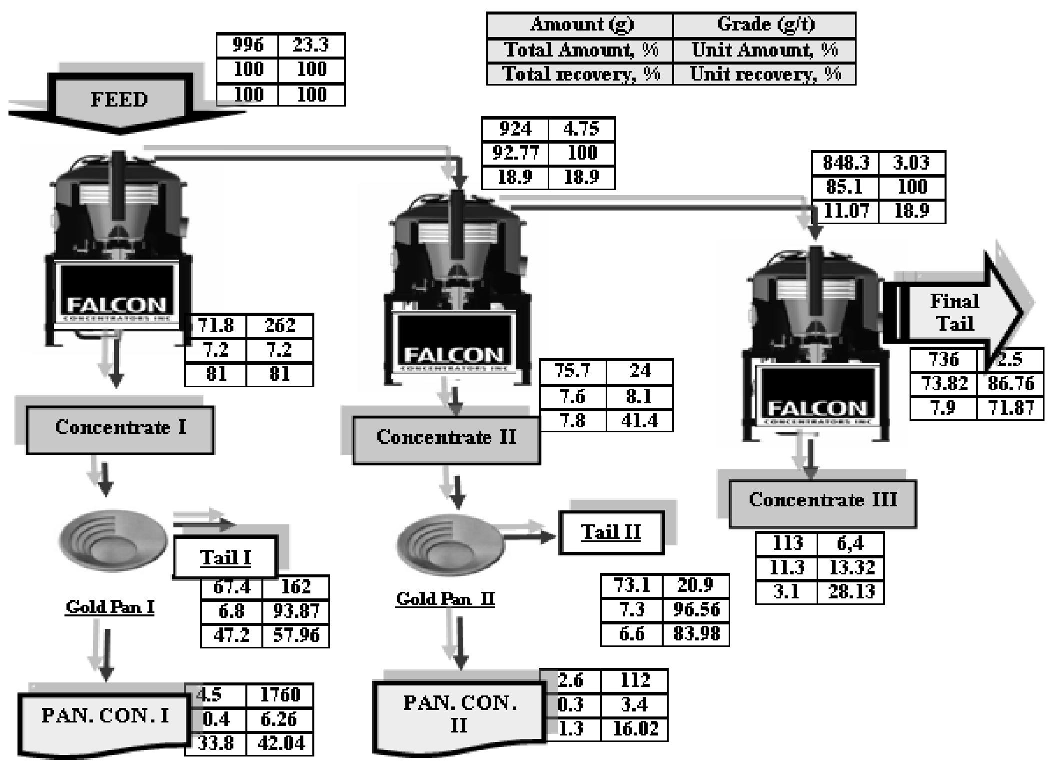

Fig. 4. The flowsheet for gravity recovery tests using a Falcon concentrator and the summary of results

The findings also showed that approximately 74% of the feed was produced as final tails, which contained 2.5 g/t Au corresponding to a 7.9% of the total gold present in the ore. This indicated that ~92% of the gold was recovered in a three-stage gravity process. The gold reported to the concentrates (Pan Con.1 and 2) could be regarded as an indication of the gravity recoverable gold present in the ore. High panning losses with 58% and 84% for Con.1 and 2 respectively could be attributed presumably to the finer gold distribution of the ground ore compared with that of the as-received ore. It may also be relevant to note that grinding could produce flaky gold particles, which respond poorly to centrifugal gravity separation [10].

4. CONCLUSION

The mineralogical analysis of the Mastra gold ore has shown that gold occurs as associated with quartz and sulphide minerals, and as particles of 1-300 μm in size. The gold particles, having a size of ≥150 μm, were estimated to be 50% of the gold present in the ore, indicating its potential for gravity recovery. The scoping recovery tests on the ground ore (-74 μm) using a Falcon Concentrator have shown that 81% of the gold present in the ore can be recovered at a mass yield of 7.2%. The upgraded concentrate by panning was found to contain 1760 g/t Au. The panned concentrates would probably be an indication of the gravity recoverable gold. However, the recoverable gold content of the ore could have been underestimated, probably due to over grinding considering the size distribution of gold particles in the as-received ore. Further staged tests using progressively ground ore (e.g. GRG test) are probably required to determine the true GRG content of the ore.

This study has shown that Mastra ore is amenable to the gravity recovery of the contained gold using a centrifugal separator appropriately as a pretreatment method ahead of cyanidation.

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