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Gravity concentration of gold in Nambija - Ecuador: The importance of process analysis for recovery success

G.A. Muñoz[1*], I.C. Pazmiño[2], D.K. Ayala[2], P.A. Espinosa[2], and P.C. Velásquez[2]

[1] Departamento de Ingeniería Química, Universidad San Francisco de Quito (USFQ), Cumbayá, Ecuador.

[2] Instituto Nacional de Investigación Geológico Minero Metalúrgico (INIGEMM), Quito, Ecuador.

[*] Corresponding author: gmunoz@usfq.edu.ec

Abstract

Gold has been recovered from the Nambija mining zone by gravity concentration since the discovery of the deposit in 1982. However, important amounts of the precious metal are lost in the tailings of the artisanal gravity concentration process that is being used to recover the gold. For these reasons, a particle size distribution of the gold in the discharge material from the mills that is fed to the gravity concentration devices was conducted in 12 different operations. It was found that in 8 operations, 45% of the gold was below 44 μm in the discharge material from the mills. This results show that the gold particle size is fine, and explains why gold cannot be recovered efficiently by these artisanal gravity concentration devices. A new gold recovery process is being proposed for the mining district, which includes froth flotation of the tailings after gravity concentration.

INTRODUCTION

Nambija mining zone is located at the Tunantza mountain range in the province of Zamora Chinchipe, in the Southeast region of Ecuador, as shown in Figure 1. Dense jungles, as usual in subtropical regions, surround the mining zone. The climate is hot and humid, with permanent rain during the whole year [1]. Access to the zone is possible through the Zamora-Gualaquiza highway. Once in Namirez town, located at the banks of the Zamora River, the journey continues through a second order road until the San Carlos town. A third order road, to the East, ends in Nambija [2]. Nambija is a Skarn-type sedimentary deposit; thus, it is not possible to find mineralized veins. In fact, mineralization is disseminated around the zone, with a North-East direction. Gold is the most important mineral that is present in the ore. It appears in some cases abundantly, with no sulphides, or in interstitial form together with granate, quartz, potassium feldespates, calcites and plagioclase. Gold is also commonly found together with pyrite in the matrix of calcosilicated rocks, volcanic brechas, or in silicified sediments [1]-[3]-[4]. Mining activity in Nambija started in 1982 with the settlement of informal miners that begun their operations with basic rudimentary tools, such as plows, wheelbarrows, and stamp mills. Initially, gold was found in coarse form, with no associated silver and sometimes with small

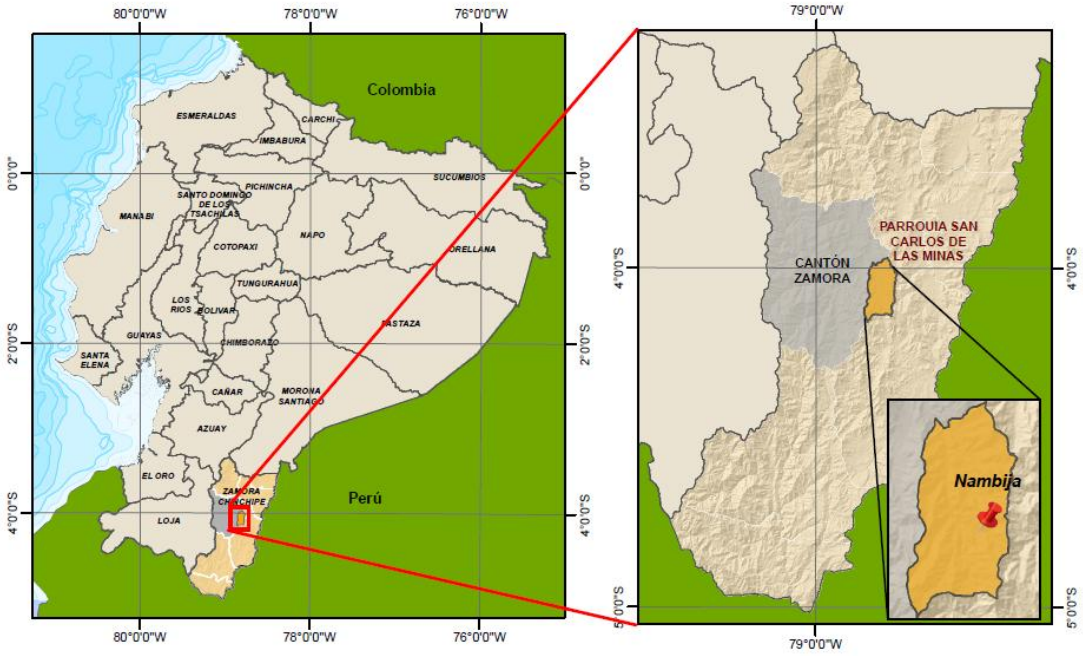

Figure 1. Cartographic map with the location of Nambija.

amounts of pyrite, and its recovery was relatively simple. Soon, Nambija became a town with more than 20 000 miners. Currently, coarse gold on Nambija is rare, and treatment of the ore goes through a traditional process by amalgamation with mercury, as shown in Figure 2. It consists in a crushing and grinding circuit that makes use of a jaw crusher followed by a Chilean mill, a device that uses steel wheels that rotate around a circular track, and fractures the ore mainly through compression forces. The crushed and wet-sieved ore is fed to sluice boxes, where gravity concentration takes place. The concentrate that is collected in the sluice boxes, and the coarse material, included coarse gold, that is trapped by the sieves of the Chilean mill go to amalgamation. Gravity concentration tailings are discarded. Because gravity concentration tailings generally contain recoverable gold, these are treated afterwards in sluice boxes several times. This situation is an indication that gravity concentration in sluice boxes is not an effective way to recover gold from the Nambija mining zone. For these reasons, process analysis, based on the physical, chemical, and mineralogical characteristics of the ore was conducted to try to explain the reasons for low gold recovery with sluice boxes in Nambija.

This work took place in two regions of Nambija mining zone, called North Condominium and South Condominium. The main reason these places were selected was the predisposition of the artisanal miners to work with the technical team in order to improve their gold mining and recovery techniques. Twelve plants in North Condominium, and seven plants South Condominium. In each plant, a representative sample of the Chilean mill discharge was taken for analysis.

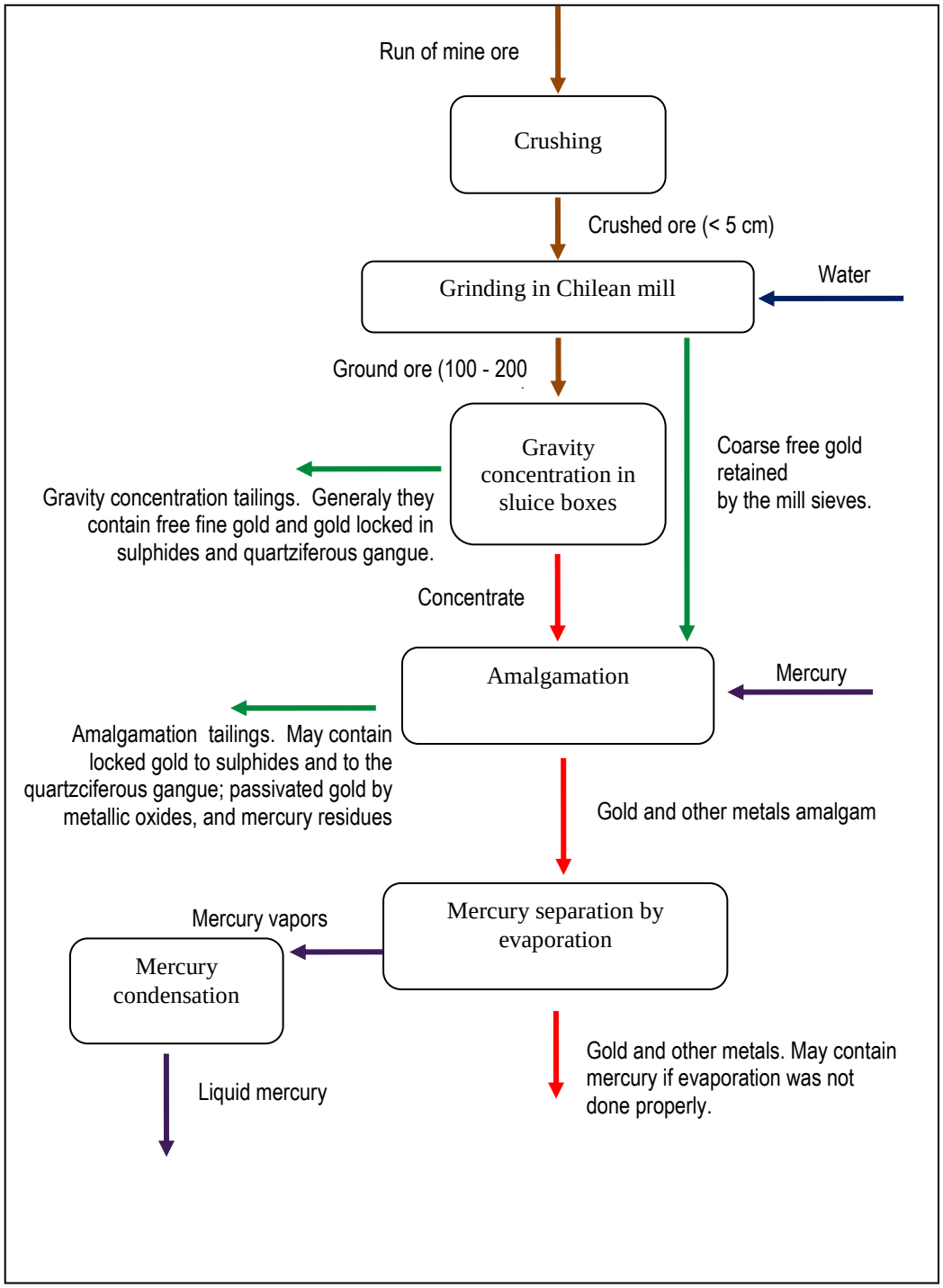

Figure 2. Flowsheet of a traditional process for gold recovery by amalgamation in Nambija.

EXPERIMENTAL PROCEDURES

Field work. Twelve samples of the discharge material from equal number of artisanal processing plants were taken from North Condominium. The same was done with seven artisanal plants in South Condominium Each sample was taken using a 3-litre HDPE container, and transferred to a plastic bag. The sample was allowed to rest for a few minutes, and water was discharged. Each bag with about 1-kg of humid sample was labeled, and samples were shipped to the INIGEMM chemical lab in Quito. In addition, two random samples of run-of-mine (ROM) ore from each Condominium were taken for analysis.

Sample preparation. Each simple was dried in a convection oven for 12 hours at 60 ºC. Dried samples were homogenized and a 500-g sample was separated for particle size analysis.

Samples analyses. Particle size analysis was done using a Perkin-Elmer model 1964 set of sieves of different openings, and a Perkin-Elmer model 1964 sieve shaker. Initial sieving was done using only a # 325 mesh sieve (44 um), in order to eliminate the slimes from the sample. Slime elimination of the original sample was done to avoid distorted particle size distribution curves due to slime adhesion to other particles by electrostatic forces. Afterwards, the +#325 sample was dried, and sieved again using the whole set of sieves. Gold at different size fractions was established by grouping the sieved material in three particle size fractions: a fine fraction (< 44 μm), a medium fraction (44 – 88 μm) and a coarse fraction (88 – 354 μm), and each size fraction was analyzed for gold. Gold analysis was done by fire assay, followed by acid attack of the *doré*, and Au concentration determination in solution by ICP-OES. Gold distribution in each size fraction as a function of comminution time was studied milling a 1-kg sample or run-of-mine material at different times in a lab-scale ball mill. Milled samples were then wet-sieved to obtain a particle size distribution curve, and the sieved material was grouped into the three size fractions described previously, and analyzed for gold.

RESULTS AND DISCUSSION

Table 1 shows the number of plants studied, average processing rate and gold content in each sector: North Condominium (NC) and South Condominium (SC). The current average gold content of the ore is relatively low, compared to the Au content 20 years ago, where was common to find specific places with more than 100 – 200 g/t. Processing equipment in both sectors is very similar in terms of capacity and construction characteristics. However, local artisanal miners recognize that SC material is much harder to break than NC material. As a result, they conclude that, using similar equipment, a higher amount of NC ore is milled, and its particle size is smaller, when compared with SC ore.

Table 1
General Information of the Studied Plants

	North Condominium	South Condominium
Number of plants studied	12	7
Average processing rate (kg/h)	420	206
Average gold content (g/t)	1,74	1,99

Artisanal miner's observations are confirmed when comparing the average particle size distribution (PSD) curves of the mill discharge for North and South Condominium, presented in Figure 1. The PSD curve for NC illustrates a material with smaller particle size that SC. If using the same or similar equipment for comminution processes, these results suggests that NC material is softer than SC ore.

Figure 2 presents gold distribution in each size fraction of the discharge material of the milled ore. For North Condominium, it is clear that more than 50% of the gold is in the fine fraction (< 44 μm), and about 24% of the gold in in the medium fraction (44 – 88 μm). For the case of South Condominium, gold distribution is different. Only 14% of the gold is in the fine fraction, and close to 35% of the gold is located in the medium fraction.

Figure 3 shows the range of application of separators. Is can be seen that for the case of wet sluices, its use is recommended for particle sizes above 80 μm. Analysis of Figure, together with the results presented in Figure 2 may explain poor gold recoveries using sluices boxes in Nambija. North Condominium has about 23,5% of the gold in the coarse fraction (> 88 um), which is the range size recommended for sluice box utilization. The same analysis may be done for SC. These results suggests that, under ideal conditions, no more than 23,5% of the gold from NC, and no more than 51,3% of the gold from SC may be recovered by sluice boxes.

Comminution tests revealed that time required to achieve a d_{80} of 74 μm for NC and SC was 18 and 28 min, respectively. These results confirm artisanal miner's observations regarding the softer nature of NC ore, when compared to SC ore. Figures 5 and 6 illustrate gold distribution in size fraction as a function of time for NC and SC, respectively. It is evident that as milling time increases, the amount of gold that is reported in the fine and medium fraction increases, until a maximum is reached in the case of SC.

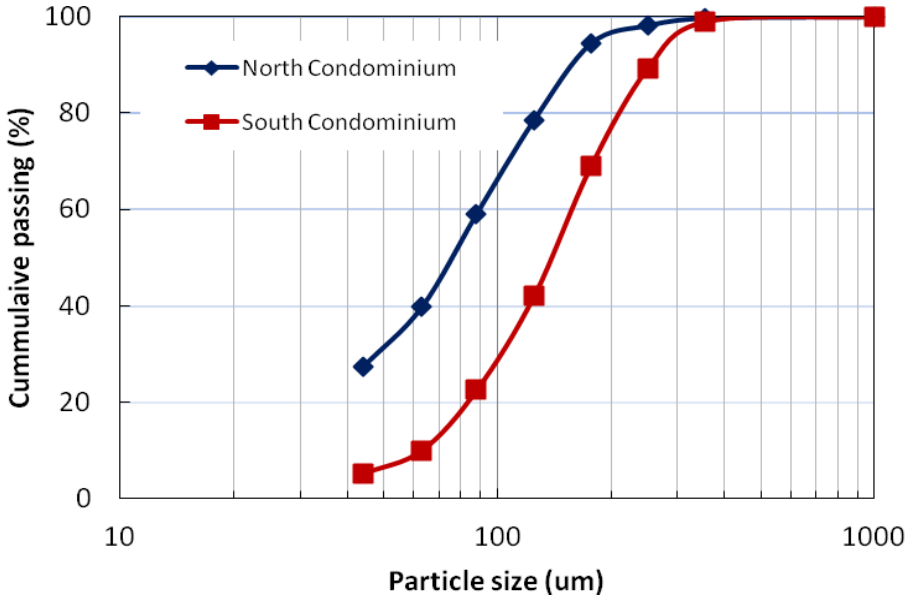

Figure 1. Average particle size distribution curves of the mill discharge for North and South Condominium.

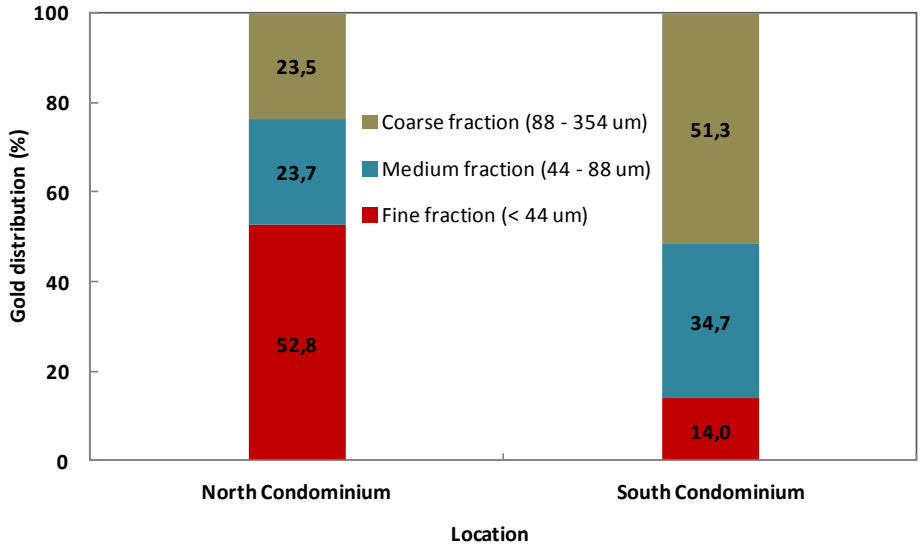

Figure 2. Gold distribution in each size fraction of the discharge material of the milled ore.

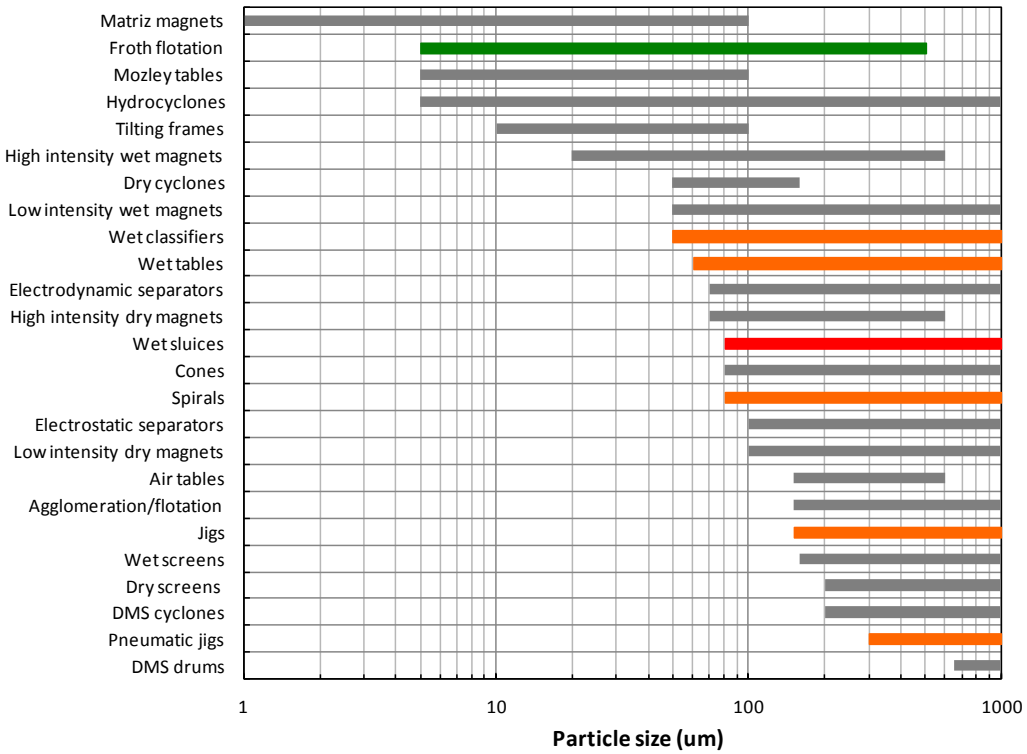

Figure 3. Range of application of separators (Adapted from [5]).

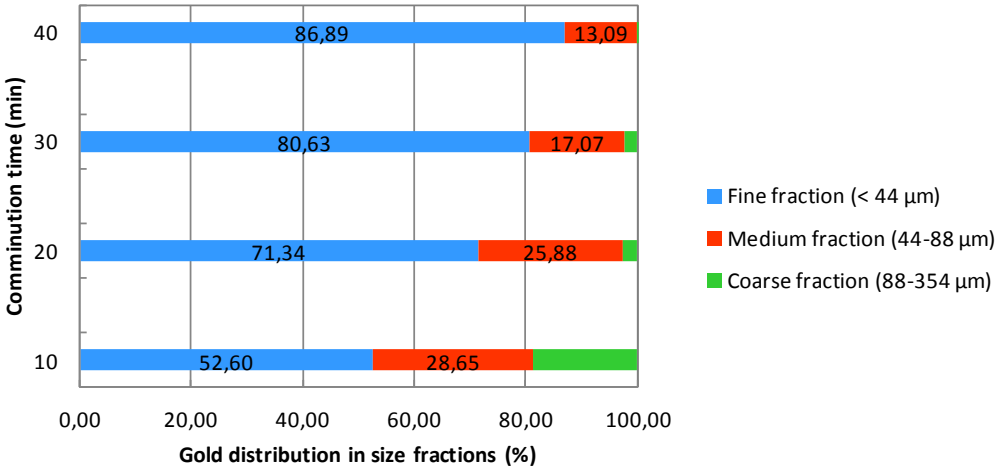

Figure 4. Gold distribution in size fraction as a function of time for North Condominium.

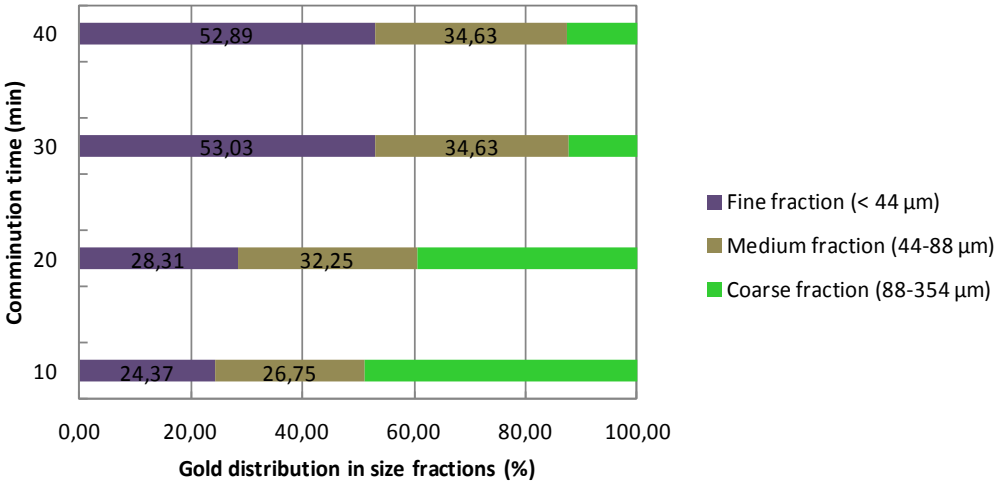

Figure 5. Gold distribution in size fraction as a function of time for South Condominium.

Results presented in Figures 4 and 5, suggest that when ore from the Nambija zone is ground enough to reach a d_{80} of 74 µm, most of the gold falls in the fine o fine-medium fraction; thus, gravity concentration by sluice boxes, or other concentration devises such as wet classifiers, wet tables, spirals, or jigs, are not an option for processing this type of ore, as presented in Figure 3. The best option for this type of material may be froth flotation; however, further analysis is recommended.

CONCLUSIONS

Gold distribution in each one of the three size fractions of the discharge material of the milled ore for North Condominium, showed that more than 50% of the gold is in the fine fraction (< 44 μm), and about 24% of the gold in in the medium fraction (44 – 88 μm). For the case of South Condominium, gold distribution is different. Only 14% of the gold is in the fine fraction, and close to 35% of the gold is located in the medium fraction. These results suggest that gold in Nambija is fine, and may explain poor recoveries of the precious metals through gravity concentration devices, such as sluice boxes.

Comminution tests suggest that increasing milling time helps gold to fall in the fine o fine-medium fraction; thus, gravity concentration by sluice boxes, or other concentration devises such as wet classifiers, wet tables, spirals, or jigs, are not an option for processing this type of ore. The characteristics of gold in the deposit: basically free of silver and sulphides, with the exception of pyrite, suggest that the best option for this type of material may be froth flotation; however, further analysis is recommended.

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REFERENCES

[1]. Minería Ecuatoriana (1988). Lo que no se ha dicho de Nambija, Quito, 49-51.

[2]. Munoz G., & Avila M., The Gold Mining Industry in Ecuador - Current Technology and Potential Investment Opportunities, 29th International Precious Metals Conference, June 11-14, 2005, Orlando, Florida.

[3]. Mc Kelvey, G., y Hammerstrom, J. (1991). A reconnaissance study of gold mineralization associated with garnet skarn at Nambija, Zamora Province, Ecuador, USGS Research on Mineral Resources, USGS Circular 1062, U.S. Printing Office, Washington, D.C.

[4]. MIS (1993). Gold and silver in may, U.S. Department of the Interior Bureau of Mines, Washington D.C.

[5]. Wills, B.A., & Napier-Munn T.J., MINERAL PROCESSING TECHNOLOGY, Seventh Edition, Elsevier Science & Technology Books, London, United Kingdom, 2006, 444 pp.