JAMESON CELL TECHNOLOGY PILOT-SCALE TEST FOR ROUGHER APPLICATION : THE AU-CU GOLDEX COMPLEX CASE STUDY

Abstract

The Jameson Cell technology, known for its high efficiency in flotation, was tested in rougher duties for processing Au-Cu ore at the Goldex Complex. With the introduction of ore from the Akasaba West mine, the flotation circuit presented a unique opportunity to further optimize Au/Cu recovery and concentrate grade. An approach using process mineralogy was implemented to unlock this potential, combining flotation stream characterization with a pilot-scale trial of the Jameson Cell Technology. These initiatives were designed to enhance operational efficiency, ensuring that copper recovery and concentrate quality improve, positioning the mine for continued production success. Mineralogical analysis identified copper losses in fine particles, highlighting inefficiencies in the current flotation process. In response to these findings, the Jameson Cell was tested at a pilot scale. Piloting results on the rougher feed stream show that the Jameson Cell was able to closely match the existing copper recovery performance of the entire flotation circuit (≈ 87% Cu recovery) with a significant increase in grade from 3 to 11% Cu. Gold grade-recovery performance was also improved compared to the existing rougher circuit achieving double the current concentrate grade while increasing the recovery by up to 20%. Piloting tests consistently demonstrated superior performance to conventional cells, thus confirming the potential of the Jameson Cell for the roughing duty in the flotation of Au-Cu ores.

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INTRODUCTION

The Jameson Cell Technology was invented in the late 1980s to overcome existing flotation equipment limitations (Lawson, 2016; Young et al., 2006). It has since gained significant recognition for its high efficiency in cleaning coal circuit operations, producing high-grade concentrate while outperforming the results of conventional column cells. Originally developed at Mount Isa Mine, the Jameson Cell technology is a high-efficiency, low-cost, and simple flotation cell installed in 450 operations across thirty countries (Glencore Technology, 2024a). It has historically been used in pre-flotation and cleaning duties but became very competitive in a larger range of applications these last few years with the recent development of full Jameson Concentrator designs (Gurnett et al., 2016). The Jameson Cell has typically implemented in base metals (copper, zinc, and lead) as well as in coal and industrial mineral operations (Clayton et al., 1991; Glencore Technology, 2024b; Pokrajcic et al., 2005; Şahbaz et al., 2024; Young et al., 2006). This study intends to demonstrate the application of the Jameson Cell technology in rougher duties for a Au-Cu ore, exploring new applications.

Industrial Context

Owned by Agnico Eagle Mines Limited, the Goldex Au underground mine and the Akasaba West Cu-Au open pit mine (which began operating in January 2024) make up the Goldex Complex. Both are located on the Cadillac fault in the Abitibi region of Quebec, Canada. Ore processing occurs above ground using a conventional SAB

(SAG/Ball Mill) comminution circuit with pre-classification via hydrocyclones. The ball mill product is processed through a gravity gold circuit leading to production of doré bars, with the gravity tailings returning to the ball milling circuit. The hydrocyclone overflow, with a P80 of 125 µm, reports to sulphide froth flotation. The flotation circuit is shown in Figure 1. It targets recovery of all sulphide minerals. A first mechanical cell constitutes the rougher “circuit” producing around 65% of the final concentrate. Rougher tailings are then processed to maximize recovery in five conventional cells bank which constitute the scavenger circuit. The last cell tailings constitute the final tailings. The five scavenger cell concentrates report to a cleaner column. The column concentrate joins the rougher concentrate to produce the final concentrate while the column tailings are returned to the scavenger circuit.

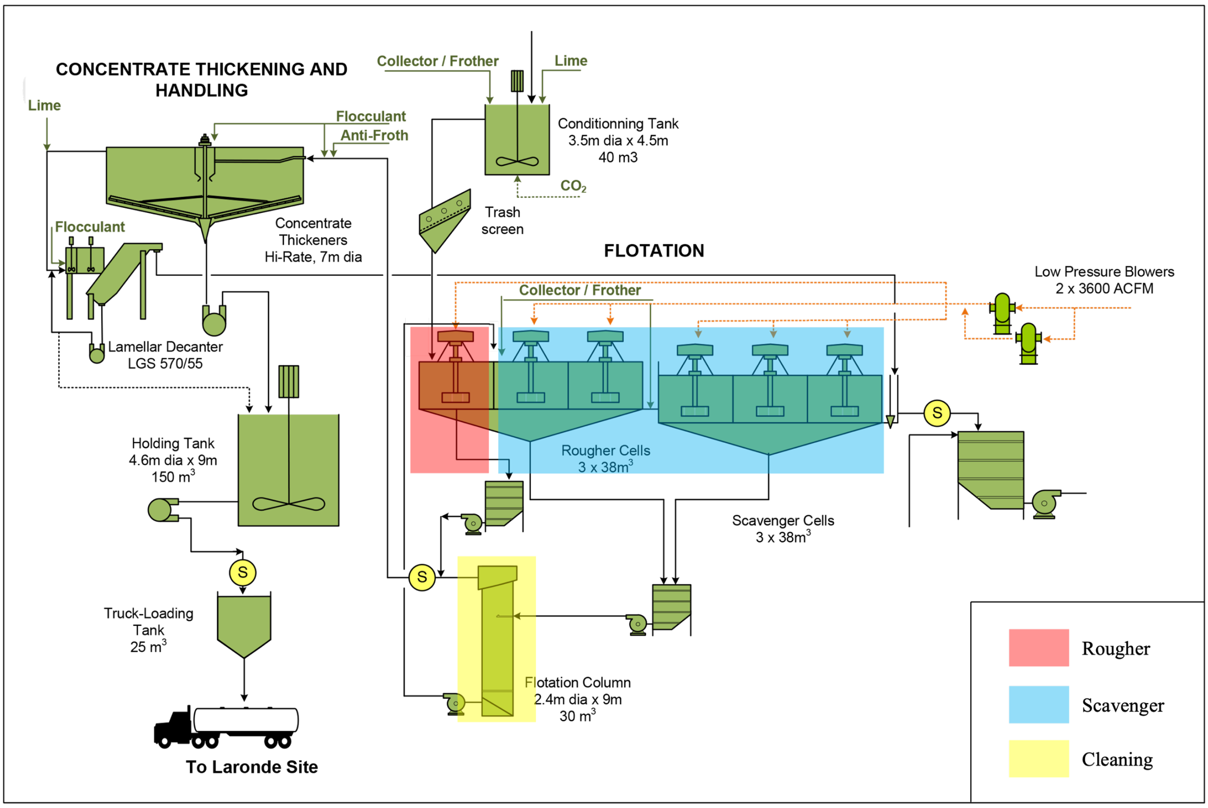

Figure 1: Goldex Flotation Circuit Flowsheet

The current ratio for the Goldex Mill feed is 20% of Akasaba West ore and 80% of Goldex Mine ore. Average flotation performance data since the beginning of Akasaba production in January 2024 are presented in Table 1. The data represent the daily averages for periods with significant proportions of Akasaba ore.

Table 1: Average flotation circuit performances calculated with daily production data from January to May 2024 for significant Akasaba ore contributions

	Feed Grade		Concentrate Grade		Flotation Recovery		Mass Pull
	Au [g/t]	Cu [%]	Au [g/t]	Cu [%]	Au [g/t]	Cu [%]	[%]
Average	0.69	0.074	14.1	1.85	71.1	87.1	3.5

During the first five months of Akasaba West production, the mine identified an opportunity to optimize copper recovery and concentrate grade. While gold recovery remained stable and unaffected by the introduction of ore from the new deposit, efforts were made to further enhance copper recovery performance.

An approach using process mineralogy was investigated to improve the recovery and reach the production objectives. Process mineralogy is a field of applied mineralogy that addresses challenges in ore processing using mineralogy. It involves the practical study of streams mineralogy to optimize metallurgical flow sheets (Henley, 1983). This study presents the results of this approach from the flotation streams characterization to the Jameson Cell Technology pilot-scale test results. On-site piloting operational challenges are also discussed in this study, aiming to facilitate site involvement in R&D optimization projects.

MATERIAL AND METHODS

Jameson Cell Technology and Pilot Scale Equipment

The Jameson Cell technology is a pneumatic flotation device divided in three main parts: the downcomer, the tank froth zone, and the tank pulp zone (Figure 2 (b)). It has been amply described in the literature since Jameson, 1988. Feed slurry is injected into the downcomer through an orifice plate, generating a high-pressure jet. The downcomer serves as the primary zone for bubble-particle interaction. The plunging jet of liquid entrains and then shears air, which is naturally aspirated, into very fine bubbles around 300 to 500 µm. This increases the probability of positive bubble-particles collision thanks to a large interfacial area. These small bubbles improve the flotation kinetics, decreasing the residence time. Moving to the pulp zone, secondary bubble-particle interactions occur, and bubbles disengage from the pulp. The separation tank facilitates the separation of hydrophilic particles from the particle-laden bubbles. The velocity difference between the mixture and the remaining pulp leads to recirculating stream. The tailings recycling aims to reduce feedrate variations to the cell so the downcomer can operate at a stable feed pressure and flow rate. Lastly, froth overflows from the froth zone. Wash water can be added during this operation to remove entrained gangue minerals. (Atkinson, 1993; Harbort et al., 2003; Niedoba et al., 2021; Pokrajcic et al., 2005; Shean et al., 2017; Young et al., 2006).The scale up of the equipment is direct and guaranteed by Glencore Technology. The Jameson Cell Technology is sized to accommodate the design flow rate by adjusting the number of downcomers (Glencore Technology, 2024b).

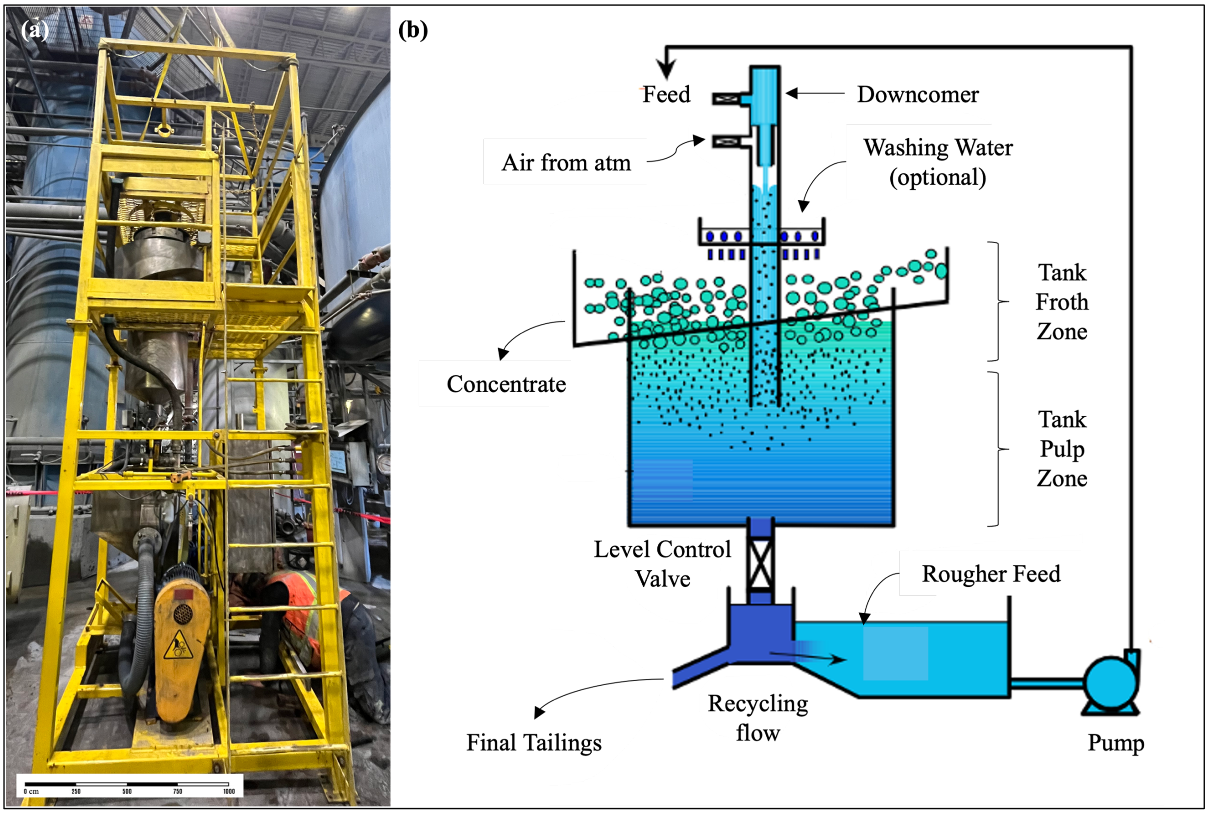

Figure 2 : (a) L500 Jameson Cell Rig; (b) Jameson Cell Technology scheme indicating the different operational zones adapted from Glencore Technology, 2024

Pilot-scale tests were conducted using an L500 Jameson Cell supplied by Glencore Technology (Figure 2 (a)). The entire rig diameter is 500 mm with a 100 mm downcomer. A 16 mm orifice plate was used for air supply. Downcomer pressure was maintained between 175 kPa and 180 kPa using a diaphragm pump at a constant frequency of 45 Hz.

Design of Experiment

The Jameson Cell Technology has different operation parameters presented in Table 2. To obtain a grade-recovery curve and evaluate the performance of the Jameson Cell, a full experimental design of experiments (DOE) was first performed using only air flow rates, washing water and froth depth as factors representing a total of 18 tests. The addition of a frother was also tested. The different levels tested are summarized in Table 2. These levels were adjusted during the pilot-scale test due to operation constraints which makes the theoretical DOE modelling analysis difficult. Minitab software was used to make the DOE analysis.

Table 2: Jameson Cell operating parameters tested during the pilot-scale test

Parameter	Units	Min Level	Max Level	Number of levels (DOE)
Air Flow rate	m^3/h	6	11	3
Washing Water	m3/h	0	0.5	2
Froth Depth	mm	50	200	3
Frother	mL/min	0	5	2

Feed flow rate and feed solids content are also parameters which can impact Jameson Cell performances. These two variables were not monitored precisely during this pilot-scale test and considered constant. These two variables were not monitored precisely during this pilot-scale test and considered constant respectively 13 m^3/h and 40%.

On-site Pilot Plant Installation

The rig was on-site for two weeks and a half weeks and was installed within two days. The location of the Jameson Cell rig was chosen considering the floor area and height requirement with access to compressed air, power, process and tap water. The location was near to a sump pump to reintegrate the Jameson Cell streams in the circuit. To fill the rig, a flexible hose, connected to a diaphragm pump, was submerged into the rougher cell Figure 3(b)(c)). The modified flowsheet is presented in Figure 3 (a).

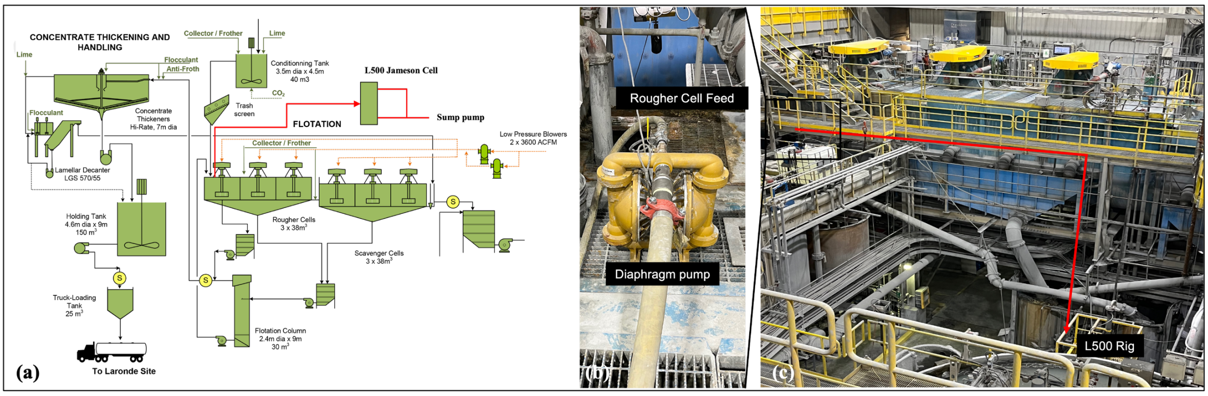

Figure 3 : (a) Modified flotation circuit flowsheet; (b)(c) On-site set-up photos to fill the rig using a diaphragm pump

Pilot-Scale Test Data Acquisition and Analysis

Sampling

Sampling involved the collection of feed, tailings and concentrate from the pilot plant. Each collection consisted of two cuts from each stream. Feed, concentrate and tailings collection times were used to estimate flow rates .

Sample Preparation for Analysis

Each collected sample was weighed, then filtered before being dried in the oven. The dried sample was weighed to calculate the solids fraction. Next, a division was performed to obtain a representative 300 g sample for chemical analysis, concluding the preparation. Size-by-size chemical distribution analyses were also performed on selected samples to document the Jameson Cell Technology fines particles recovery performances.

Analytical Methods

Characterization of flotation products aimed to understand the copper and gold losses in the flotation circuit. Automated mineralogy analysis was conducted, with three size fractions analyzed using Particle Mineral Analysis (PMA) via QEMSCAN. Chemical assaying including a Whole Rock Analysis (WRA) by a multi-element XRF and ICP scan was compared against QEMSCAN results for quality control. Each sample was analyzed with inductively coupled plasma (ICP) scan and three gold determinations by fire assays. These analyses provide the chemical composition of the metals of interest for data analysis, namely Au, Cu, Ag, S, and Fe. If the sample mass was insufficient, only one or two gold determinations were performed. Size-by-size chemical distributions were performed on flotation tailings samples.

Data Reconciliation

Once the samples were analyzed, experimental results from the pilot-plant test were mass-balanced using weighted non-negative least squares (NNLS) in HSC Chemistry.

RESULTS AND DISCUSSIONS

Existing Flotation Circuit Streams Characterization

Mineral abundance QEMSCAN analysis results for flotation feed and tailings are summarized in Figure 4. The flotation feed is mostly plagioclase (wt. 42.3%), quartz (wt. 19.1%), and amphibole (wt. 9.8%). These three silicates are typical of both deposits and are the main non-sulphide gangue minerals. Tourmaline is commonly found in the Goldex deposit, particularly in mineralized tourmaline veins. Sericite, biotite, and chlorite are classified as alteration minerals in both deposits. The Fe-sulphides are pyrite and pyrrhotite, which are often associated with gold in the Goldex deposit. In the Akasaba deposit, the copper-bearing minerals in the flotation feed consist mainly of chalcopyrite, with a small amount of bornite. Other copper sulphides are covellite, chalcocite, azurite, and malachite in the mineralogical analysis. The combined feed comprises 1 % of sulphides, targeted by flotation. (Daver et al., 2020; Genest et al., 2012; Meng et al., 2020). The tailing sample has a similar composition to the feed but with a lower concentration of sulphide minerals, as expected.

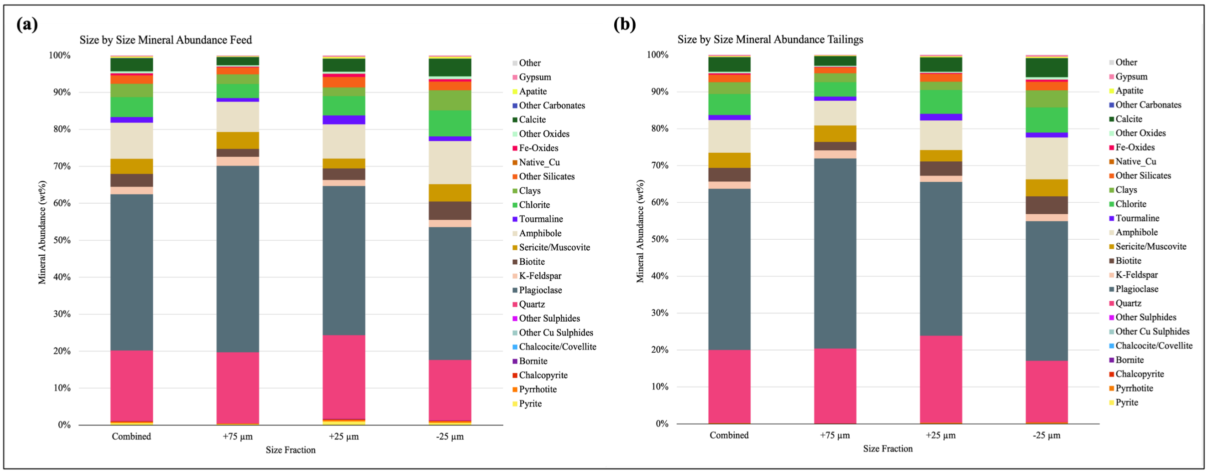

Figure 4 : QEMSCAN Size-by-size mineral abundance bar chart; (a) feed sample; (b) tailing sample

The particle size distribution is similar in both feed and tailings and copper is mainly found in particles smaller than 75 µm in the feed (Figure 4). In the tailings, copper is slightly more prevalent in the largest (>75 µm) and smallest (<25 µm) fractions, with chalcopyrite and bornite being the main copper-bearing minerals lost (Figure 4, Figure 5 (b)). For particles larger than 75 µm, copper losses are likely due to poor liberation, as most remain locked (Figure 6). In fine particles, where most are liberated, the losses may be due to other factors, such as insufficient residence time in the scavenger circuit and/or inadequacy of the flotation column for these particles (Figure 6 (b)). To characterize gold losses, QEMSCAN cannot be used given the low concentrations. Fe-sulphides can be used as a proxy and conclusions remain the same. Pyrite and pyrrhotite are the two mains Fe-sulphide minerals in the tailings, present in each fraction. They are more than 80% liberated in < 75 µm fractions (Figure 5 (a), Figure 6 (a)), indicating that liberation is not the cause for insufficient recovery.

Table 3: Size-by-size weight and copper distribution

	Feed	Tailing	Feed	Tailing	Feed	Tailing	Feed	Tailing
	Combined		+75 µm		+25 µm		-25 µm	
Wt. Dist. [%]	100.0	100.0	35.6	35.5	27.1	25.7	37.3	38.8
Cu Dist. QEMSCAN [%]	100.0	100.0	12	36	42	25	46	39
Cu Dist. Chemical [%] *	-	100.0	-	31.3	-	14.8	-	53.9

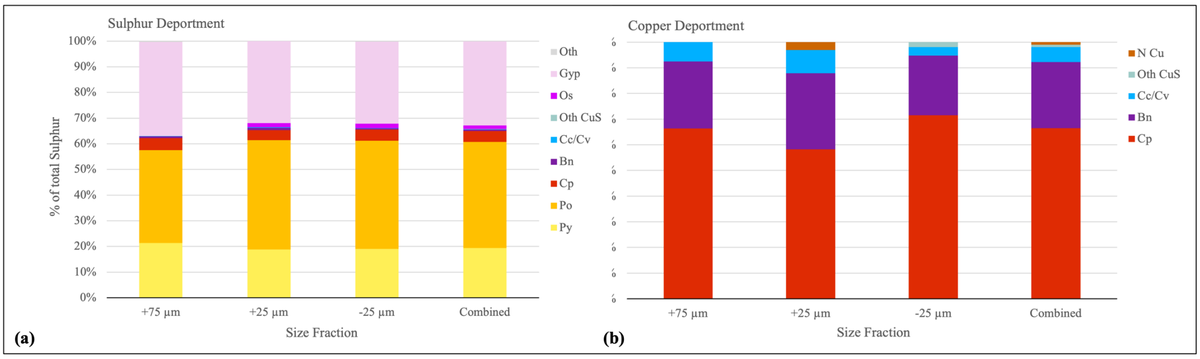

Figure 5 : Tailing sulphur (a) and copper (b) deportment. Oth: Other; Gyp: Gypsum; Os: Other sulphurs; Oth Cus: Other copper sulphurs; Cc: Chalcocite; Cv: Covellite; Bn: Bornite; Cp: Chalcopyrite; Po: Pyrrhotite; Py: Pyrite

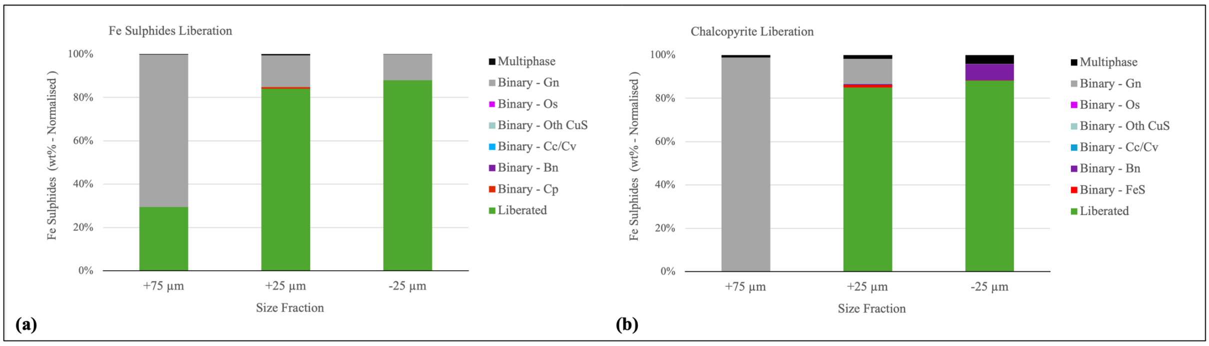

Figure 6 : Tailing Fe-sulphides (a) and Chalcopyrite (b) liberation. Gn: Galena; Os: Other sulphides; Oth Cus: Other copper sulphides; Cc: Chalcocite; Cv: Covellite; Bn: Bornite; Cp: Chalcopyrite; FeS: Fe-sulphides

This characterization justify the need to optimize the flotation circuit and consider using Jameson Cell technology as it has been proved that the cell hydrodynamics can improve small particles recovery (Taşdemir et al., 2007).

Jameson Cell Pilot-Scale Test

Overall Results

Au and Cu grade-recovery, when using Jameson cell in rougher duty, have a well-defined scatter plot across several operating conditions (Figure 7). The performance of the cell shows a capacity to produce very high copper grades within a narrow recovery range (70 - 90%). An inflection point at 11% Cu is observable, indicating that it may be difficult to produce concentrates with higher copper content. The highest copper recovery achieved in the pilot plant was 94%. For the gold, recovery results range is more spread (30 – 80% recovery).

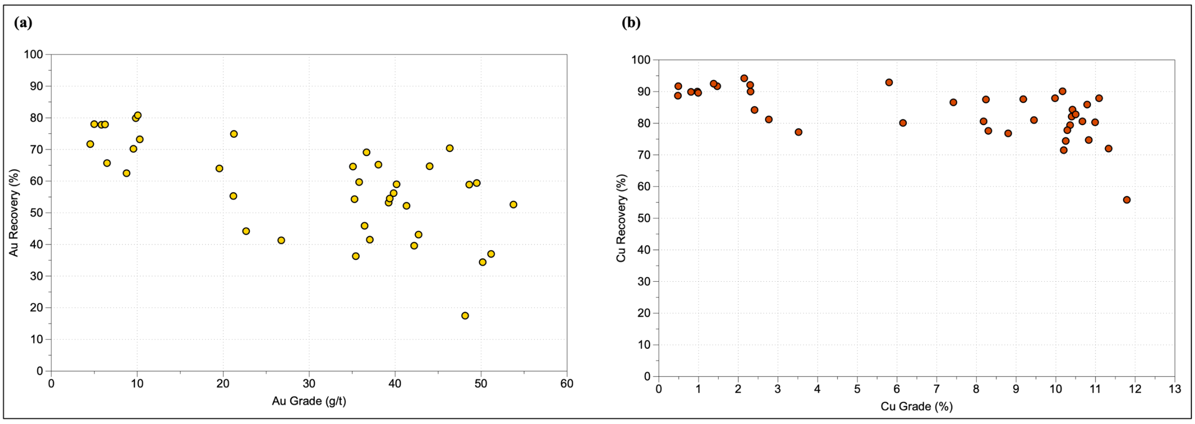

Figure 7 : Au (a) and Cu (b) grade-recovery scatter plots

Figure 8 presents the Cu-Au, Cu-S and Au-S selectivity. No selectivity between two elements is represented by the 1:1 diagonal line. To the right of this line, the process has a better selectivity for x-axis element. The results demonstrate a clear selectivity for copper compared to gold and sulphur. The Jameson also tends to be more selective for gold than for sulphur. It shows that the Jameson cell could achieve acceptable performances in this rougher duty, with a high degree of selectivity between the rougher feed's valuable Cu/Au and non-valuable S elements.

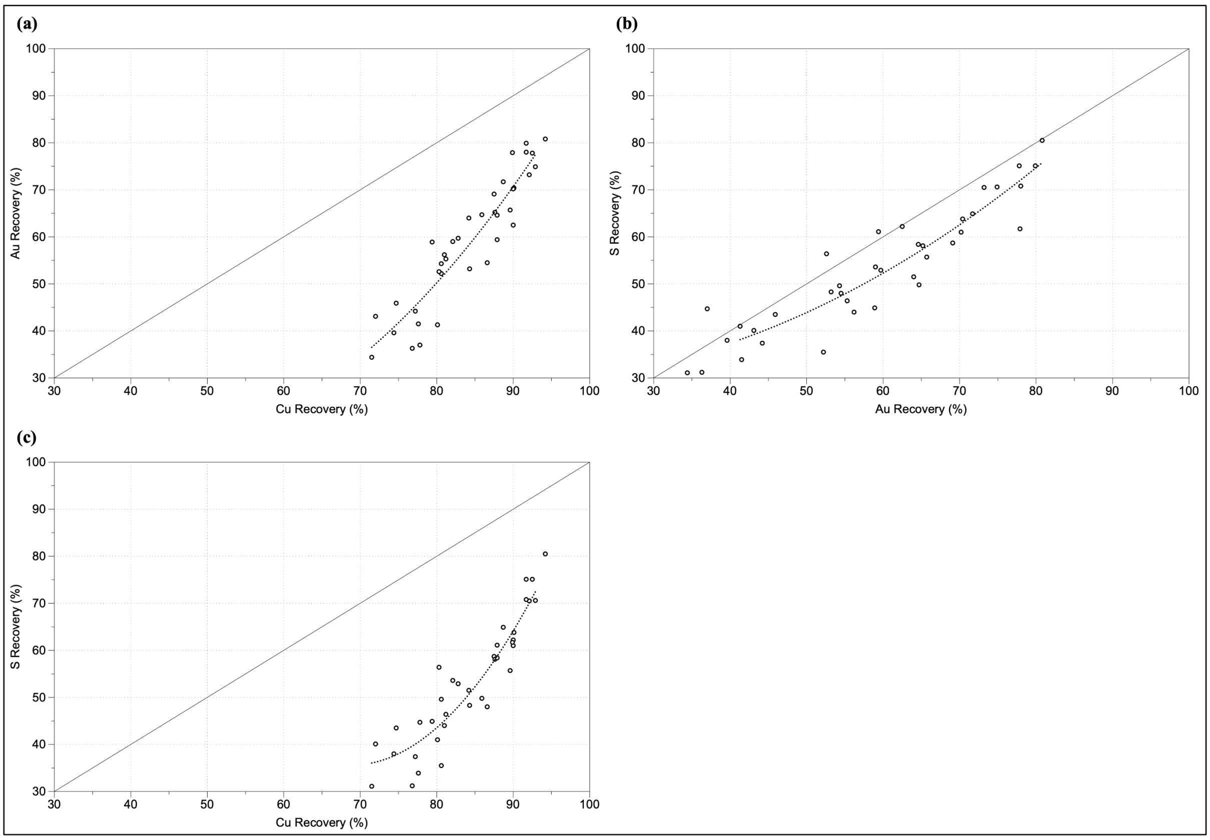

Figure 8 : Selectivity scatter plot copper and gold between (a); gold and sulphurs (b); and copper and sulphurs (c)

Operating Parameters Effects Study

The influence of operational parameters on flotation performance using the Jameson Cell was evaluated through DOE analysis. Due to operational challenges, the tests were not conducted at single values for each level. Instead, a range of values was incorporated into the DOE analysis. Corresponding parameter ranges are detailed in Table 4.

Table 4: Corresponding parameter ranges for DOE levels

Parameter	Units	Level 1	Level 2	Level 3
Air Flow rate	m^3/h	4-6	7-8	9-11
Washing Water	m3/h	0	0.4-0.5	-
Froth Depth	mm	50-90	100	200
Frother	mL/min	0	4-5	-

Figure 9 illustrates the mean gold grade in the concentrate, gold recovery, copper grade in the concentrate, and copper recovery for each level of each factor. The models developed are statistically acceptable and not detailed in this study. They allow key observation to be made and that detailed analysis is forthcoming.

Airflow rates exhibited a significant influence on all the responses analyzed. It was positively correlated with recovery, while negatively affecting grades, as has been documented in previous studies (Rahman et al., 2015). Washing water demonstrated an inverse effect, reducing recovery while improving concentrate grade. Even if the impact of washing water in flotation is still discussed today, the Jameson Cell Technology ability to produce high quality concentrate without targeting high recovery using washing water was proved (Wills and Finch, 2016). Our study shows the same conclusion. The impact of froth depth was less clear; an optimal point may exist depending on whether the main objective is to maximize concentrate grades or recovery. These results can be explained by the manual measurements which were not very accurate. For frother addition, results revealed an increase in recovery, but also a negative effect on grades. This phenomenon can be explained by the fact that higher recovery shifts the performance along the grade-recovery curve, which typically involves a trade-off between recovery and grade.

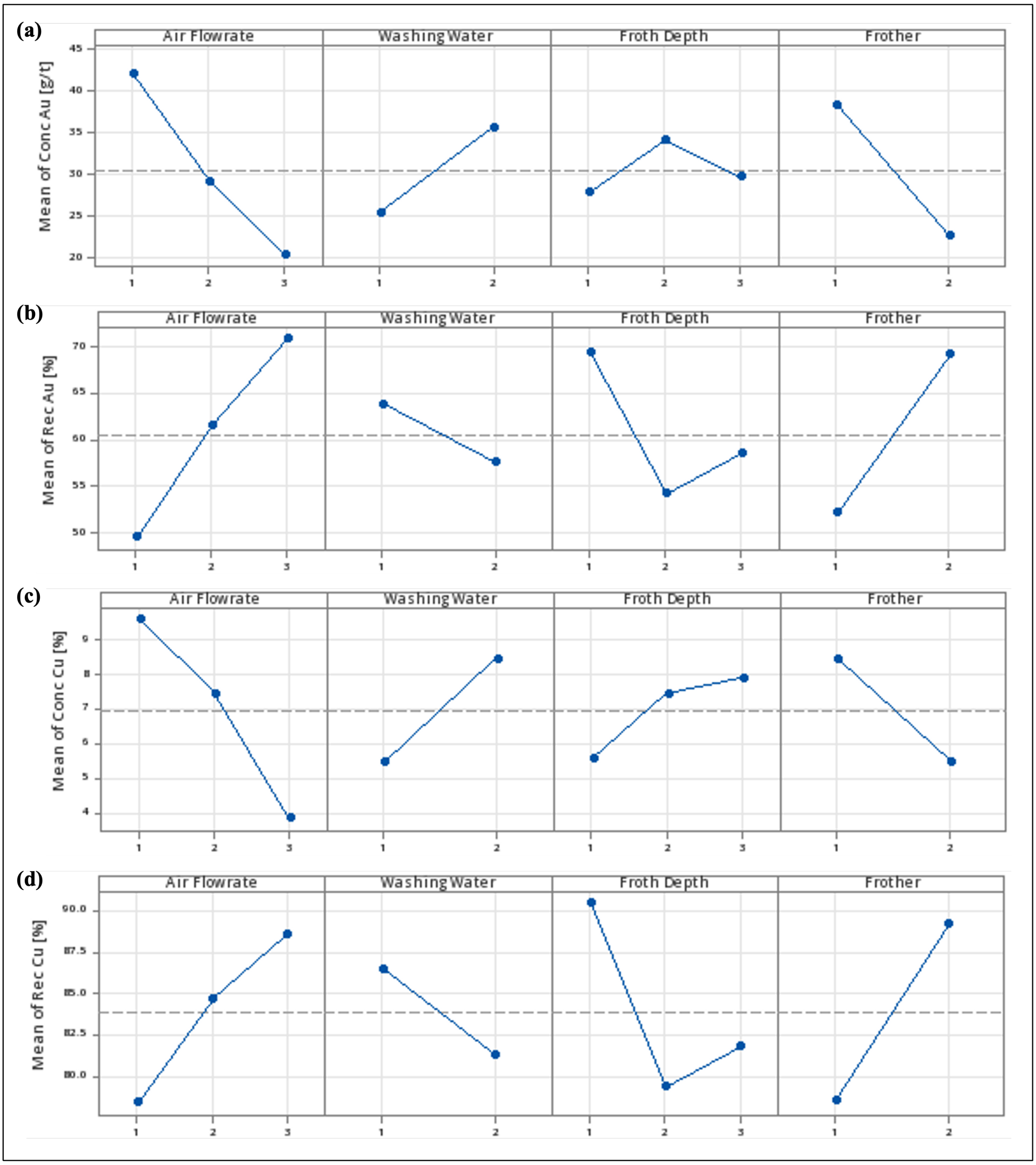

Figure 9 : Mean concentrate Au grade (a), Au recovery (b), concentrate Cu grade (c) and Cu recovery for each level of each factor

Size-by-Size Chemical Distribution

Size-by-size chemical distribution is currently being processed. Results are expected to gain a better understanding of Jameson Cell Technology fine particle recovery.

Benchmark

To evaluate whether the Jameson cell might be a potential solution to increase the rougher circuit performance, we compared its performance with the current circuit. Performance data from the rougher circuit and from the overall flotation circuit are integrated into the experimental scatter plots, where data are grouped by mass pulls (Figure 10).

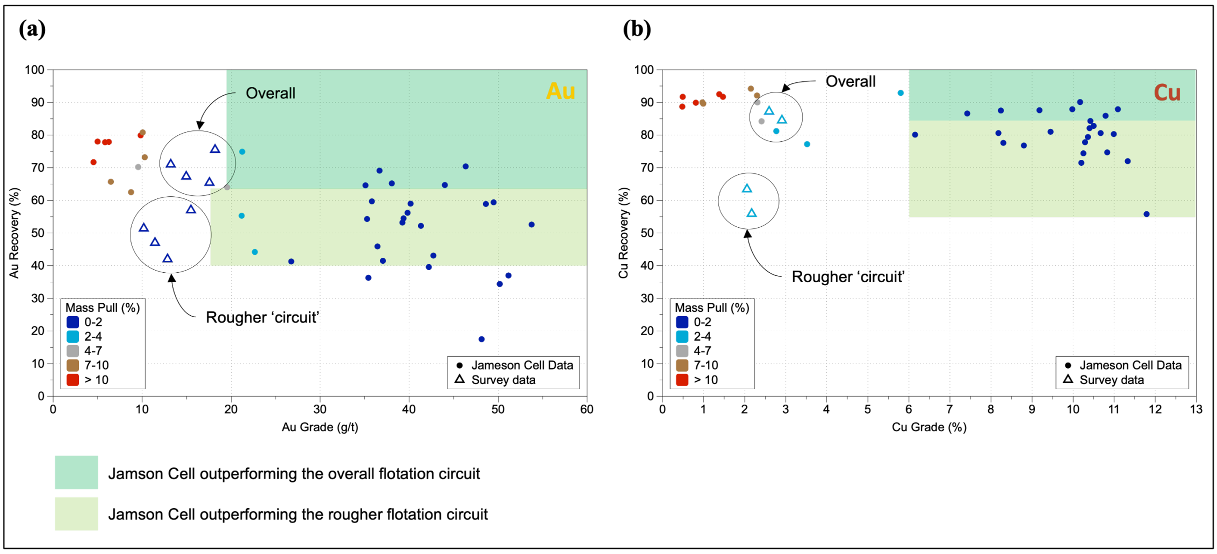

Figure 10: Table 6: Benchmark for Au (a) and Cu (b) Jameson Cell Technology performances compared to the rougher "circuit" and the overall flotation circuit

The Jameson Cell Technology outperformed the rougher circuit for Au with a majority of points in the light-green zone. The recovery was similar or improved compared to the existing rougher circuit, while the grade almost doubled. While the recovery is slightly lower than the overall circuit, the much higher grade means that simply sending some feed material to the concentrate could achieve a higher recovery. The variability compared to the overall flotation performance may be attributed to the fact that the JC setup used relied on a single pass, in contrast to the complete circuit, which incorporates the recirculation of tailings from the flotation column.

For copper, the Jameson Cell consistently outperformed the rougher circuit, and even the overall flotation circuit, when considering grade at a similar recovery. The pilot plant results are promising for copper recovery, showing a strong potential to significantly increase the grade of the copper concentrate while reducing the mass pull to concentrate. This is a crucial development as it suggests that the existing circuit could be optimized to achieve a higher quality copper concentrate, leading to an improved operational efficiency. The pilot plant has consistently performed above the target copper concentrate grade while maintaining or even improving recovery rates. This consistency is a positive indicator of the JC's ability to help meet production targets. Thus, JC Technology performance is generally promising, particularly in relation to copper concentration. However, the variability in gold recovery suggests that further optimization is needed, along with a better understanding of the flotation recovery of Au bearing species. The combination of using a Jameson Cell in both the rougher and cleaner stages could maintain the overall mass pull to concentrate while achieving a higher overall recovery rate.

CONCLUSION

The approach using process mineralogy played a crucial role in identifying optimization opportunities in the flotation circuit, particularly the copper losses in fine particles. By integrating mineralogical analysis with flotation stream characterization, the approach provided valuable insights that informed the pilot scale testing of the Jameson Cell.

The results of the pilot tests are promising, showing that the Jameson Cell significantly improved copper concentrate grade while maintaining comparable recovery rates to the entire flotation circuit. In addition, gold recovery and grade were also enhanced compared to the existing rougher circuit. The effects of each parameter were evaluated, with air flow rate being the main driver of performance. Washing water is not recommended as the grade is already high without it and its addition comes with lower recovery. Frother addition is still recommended for the next piloting phase. Froth depth does not seem a crucial parameter in this study. The Jameson Cell technology shows the ability to increase copper and gold grade while maintaining recovery and confirms it as a highly efficient tool for improving flotation circuit performance. The next step will be a second phase of piloting with the objective of confirming good performance with optimized parameters and lab-scale tests to float the tailings produced by the Jameson Cell, in order to simulate a circuit. Results from size-by-size chemical distribution analysis will also help the preparation of the next phase.

This study also serves as a strong example of how R&D and innovation require active site involvement. Pilot scale testing demands robust logistics and a dedicated workforce to carry it out effectively, even while production is going on.

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