Metallurgical Considerations for Modeling the Recovery of Gold from Heap Leach Facilities

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Abstract

Significant efforts have been made in recent heap leach models to improve the accuracy and consistency of gold production forecasts. It starts with breaking the heap leach facility into manageable cells that can be customized based on the operators' level of resolution. The discretized model tracks numerous metallurgically relevant inputs such as ore type, tons and grade, particle size distribution, pad stacking and geometry, leach kinetics, and solution hydrodynamics. Frequently, these criteria are not well defined, or operations are unable to project changes to production based on changing site conditions. It is critical that the metallurgical testing programs are defined well enough upfront to provide a broader array of information, so that an operation is able to adjust based on their actual mining and process conditions. It is often the case that one or many of these steps are skipped, or assumed to be known based on prior experience, because the risk is assumed to be manageable and to keep budgets or timing deadlines intact.

A solid metallurgical test program for a heap leach operation begins with a comprehensive analytical campaign in the exploration stages to identify potential red flags such as the presence of clays, organic carbon, sulfide sulfur, or deleterious metals that may impact operational or closure designs. Small-scale, high throughput cyanide amenability shake leach programs are also important in understanding extractions and identifying problematic areas within a particular geology or ore body. These databases are common to see in one form or another from exploration teams and need to be evaluated on an iterative basis as the database is transferred between operational teams. A thorough database, which can start on RC drill samples, should move towards metallurgical core and include the following tests on samples identified above the assumed cut-off grade:

- geological logging (three-dimensional location, lithology, alteration);
- fire assay – gold and silver;

- cyanide amenability shake leach;
- total carbon and speciation;
- total sulfur and speciation; and
- mineralogy (quantitative XRD/XRF).

It is not necessary to complete these steps initially, but they should be completed as exploration continues and as metallurgical work commences.

After a large enough database has been built, a compositing campaign can then be undertaken to evaluate leach kinetics and potential gold extractions at multiple sizes under bench- and pilot-scale conditions. This should be an exercise involving both geological and metallurgical components to identify key drivers. Leach testing, such as the bottle roll or column leach, provides a basis for the kinetic response under various conditions. However, particularly for larger sizes, diffusion leach testing should be conducted to better understand the tortuosity requirements of a geological alteration as opposed to a pit or mine plan blend.

Throughout this process it is critical to understand the diffusion and deportment of gold. This stage can often be overlooked when leach extractions are favourably projected. In the event of a poorly performing sample, it becomes more difficult to pinpoint the reason for the performance. Often it is assumed to be due to many of the common gold leach pitfalls, such as silica encapsulation, preg-rob, or refractory ore; however, it is a small cost to understand and mitigate the overall risk.

After chemical properties are better understood, ore must then undergo degradation and compaction testing to project initial and future changes to geotechnical and hydrodynamic stability. These conditions are dependent on the overall operating size. Eventually a blasting and fragmentation study should be conducted for potential run-of-mine ores, or to determine a crushing schema for ore that has demonstrated a crush benefit to identify these potential operating size distributions.

Overall, the combination of the chemical and physical properties allows for an optimized operating size distribution based on the heap leach modeling and NPV analysis. It is also feasible, with a large enough database, to provide site-dependent proxy testing that can simplify on-site metallurgical laboratory testing and dictate operational control logic.

The accuracy of these inputs into the heap leach model starts with the metallurgical testing program, which should be evaluated on an iterative basis. The "industry-standard" testing that is utilized must be constantly questioned and tailored towards each site because conditions change, and testing may need to be modified accordingly. The results then directly correlate to the ability to forecast an accurate time-dependent production of gold.

Forte Dynamics (Dynamics) is a consulting and engineering firm based out of Northern Colorado, with a focus on open pit resource and reserve modeling, mine planning, blasting analysis, metallurgy, process design, recovery modeling, detailed engineering, and EPCM services. In conjunction with Forte Analytical (Analytical), a mineral testing laboratory focusing on open pit mine and heap leach facility advancement, the two groups can elaborate on several case studies in which they have provided a broad scope review of greenfield exploration data or brownfield process debottlenecking needs to optimize heap leach operations. This in turn then provides operations with a site-specific and concise estimate of heap leach facility extraction rates, in-heap inventories, and production rates.

Case study 1

In the first case study, Dynamics and Analytical evaluated a clay issue within a deposit to provide the operator with operational conditions around solution percolation. The site had identified a region of high clay content, estimated at up to 35% passing 200M (74 µm) material within the mining schedule, and had an agglomeration circuit in their process design. Forte assisted in developing a test program that consisted of compacted permeability testing of various blends of pits from the site.

After a review of the ore characteristics and permeability testing, it was determined that solution percolation could be maintained through a modified application rate and blending program to remove the agglomeration circuit from the design. Changes to the solution dynamics and overall process were easily incorporated into the Forte heap leach model.

Case study 2

The second case study comes from an internationally based brownfield site that did not fully understand the preg-rob nature of the ore they were stacking. Grade-control had been based on a visual identification of organic carbon, which was best described as “black is bad, everything else is good.” This has been a frequently noted issue with operations, and unfortunately is not unique to the case study in question.

However, not all organic carbons can be visually identified and not all organic carbons are made the same. It is common to see 0.1 to 0.2% organic carbon in samples, that do not present visually, which then can show extreme levels of “preg-rob”. As Dynamics and Analytical have experienced, the “industry-standard” preg-rob test is run differently by almost every laboratory and does not provide any interpretation on what, if any, levels of preg rob can be accepted. Preg rob tends to be less of an issue at coarser crush sizes; however, it must still be accounted for in the overall model.

Depending on the testing conducted, or the results produced, it is common to see a cut-off value of 10 to 20% preg rob for what should be considered ore, but these values do not truly identify the overall potential for gold loss and must be evaluated further. For this operator, Analytical was able to elaborate on the preg-rob extent of the material on-site, relative to the organic carbon content, and determine an overall grade of both organic carbon and total carbon that was operationally acceptable.

Case study 3

The final case study considered the progression of a detailed and thorough greenfield metallurgical program that was rescoped at numerous steps along the way based on a collaboration between geological and metallurgical leads, and collaborations between Analytical and the site project team. The Gold Rock Project (GRP), outside of Eureka, Nevada was previously developed by Fiore Gold and recently purchased by the Calibre Mining Corporation (Calibre). The GRP 2020 metallurgical drilling program consisted of 15 PQ core holes, representing approximately 1,300 intervals. Each interval was rigorously logged for geological alteration and lithology, according to a four-digit code rock code, specific gravity, fire assay (in triplicate), cyanide amenability shake (in triplicate), and carbon and sulfur speciation. Ore grade samples were then sent for additional mineralogical XRD analysis.

After a statistical review of the interval-based data, Dynamics, Analytical, and the geological team from Calibre re-evaluated the logging to build a small interval composite program for bottle roll leach testing. Results from this stage then fed to a larger composite bottle roll leach, column leach and diffusion leach testing program. Specific refractory materials were identified and underwent additional evaluation including gold deportment to understand the refractory nature. While the result was a metallurgical extraction estimate, by four-digit rock code, which could then be incorporated into the Forte heap leach model, the test program also highlighted the need to modify particular testing procedures to accurately identify extraction rates. The database Analytical generated from the PQ core program was then expanded to the rest of the drilling database, and will provide the site with initial operating based on site-based grade control testing.

The end goal

Whether it is to optimize or improve upon current operations or to develop the necessary testing towards feasibility study, the end goal should always be a better understanding of a deposit to best model the production and make the appropriate NPV determinations. This logic is typically well used when determining process options of higher-grade milled deposits; however, heap leach operations are not often as well designed. Operations typically proceed based on assumptions and limited data, only to find that the assumptions do not hold up under operating circumstances. It is not inappropriate at any stage to step back and re-evaluate a process design based on new information to determine all of the production drivers. There is no definitive checklist that will work for every operation, as deposits vary widely, but the modeling provided by Dynamics and Analytical is focused on providing better answers to the operators before running in to situations such as case studies 1 and 2, among many others.