Gold Recovery

Discrete fracture network modeling in support of in situ leach mining

by Bill Dershowitz

Consider a deep gold orebody with grade of 4 g/t (0.11 oz/st). At the time of this writing, with gold prices at historic highs, it could be a good, but not great, prospect. But if it is a vein deposit, and those veins are 200 g/t (5.8 oz/st), it would be significantly more attractive if there was a way to produce directly from those veins, leaving the rest of the rock in place.

There is a way to do this, in situ leach (ISL) or solution mining. It has been a viable commercial technology for more than five decades.

One way to apply the idea is to drill a pattern of injection and pumping wells targeting these veins, a circulating lixiviant such as cyanide through the orebody. The lixiviant dissolves the gold (or other target resource, such as copper or uranium) present in the orebody, and is then produced through the pumping well. The mineral is removed from the liquid by conventional means, and the same lixiviant can then be recycled and recirculated through the well array to produce additional metal.

In contrast with openpit mining, there is no overburden to remove. Unlike underground mining, there is no need to dig shafts, stopes and other infrastructure to get to the orebody. Aside from the drill cuttings, there is no waste rock to dispose of. There is no need to build a mill to process millions of tons of ore. Personnel issues and subsidence issues are dramatically reduced. There is no need for a tailings impoundment.

Largely because it involves less disturbance of the earth, it could be the greenest form of mining.

So why is ISL not more common?

It is ironic that even though ISL has tremendous “green” potential due to reduced surface impacts and less energy consumed, it is environmental concerns that have been one of the biggest barriers to commercial application. Any project that involves injecting a hazardous liquid such as cyanide or sulfuric acid into the ground is likely to raise substantial opposition. The potential for ground water contamination has attracted the attention of environmental activists and regulators alike.

The lixiviant, as well as being potentially hazardous environmentally, is also costly, emphasizing the importance of good recovery.

Given these issues it is easy to see why ISL has yet to reach its full potential.

Trends brighten the future for ISL

Recent developments in discrete fracture network (DFN) site characterization, analysis, and modeling, have the potential to address both the production efficiency and environmental issue limiting the application of ISL. With improved wellfield design, and more compelling analysis and modeling, ISL has the potential to be an important supplement to conventional mining, targeting high-grade ores and extending the life of existing mines.

Existing ISL mines are primarily in uranium, where very high permeability deposits facilitate conventional hydrogeologic analysis, modeling and permitting. In gold and other vein and heterogeneous deposits, the feasibility of ISL depends on characterization, analysis and stimulation of discrete fractures and veins. This process is considerably more difficult to predict, control, monitor and regulate.

However, DFN technologies developed over the past 20 years to address these same issues in the oil and gas industry can be directly applied to ISL to improve environmental compliance and lixiviant recovery where minerals are concentrated.
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DFN (Discrete Fracture Network) modeling (Fig. 1) aids in understanding the fracture pathways in the orebody and the country rock. This includes the fractures' orientation, reactive surface area and other characteristics so as to understand how the lixiviant will flow in the orebody – and whether it can be recovered after it has absorbed the mineralization.

DFN modeling couples geomechanics and fluid flow in a realistic three-dimensional model of natural fractures and other discrete features and their properties, together with the rock matrix volumes defined by those fractures and, therefore, supports the design of a well-constrained, reliable and productive ISL (In situ leaching) program (Fig. 2). Supported by fractured image logging, core sampling and hydrogeological testing, DFN modeling will determine which fractures are permeable and which are suitable for ISL.

Where the rock itself is highly permeable, and fractures serve only as an unwelcome pathway for lixiviant loss (as in most existing ISL uranium mines), DFN analysis is used to characterize the risk of occurrence of such pathways, and define the best location for monitoring and head control wells to prevent this loss. Where the rock has very low permeability, and the mineral itself is in high permeability veins, DFN analysis supports the design of injection and production wells that optimally access those veins, avoiding pathways for lixiviant loss. Where mineral-containing veins are of lower permeability, DFN analysis provides a tool for evaluating the potential of hydraulic fracturing targeted to improve lixiviant transport through those veins. And, where fractures provide low permeability barriers with a relatively high permeability rock mass, DFN analysis aids the design of coupled injection/pumping wells and monitoring wells to successfully exploit the resulting hydrologic compartmentalization.

Some of the progress in DFN technology has been due to the oil and gas sector’s burgeoning interest in “unconventional” hydrocarbon deposits in tight rocks such as shale. Understanding the fracture network is vital to the success of hydrofracturing or “fracking” to stimulate the flow of hydrocarbons into a well.

Increased focus on ISL parallels the development of heap leach technologies in response to earlier increases in metal prices. When gold hit $9.64/g ($300/oz) a number of years ago, there was a trend to take waste rock and tailings from previous mining operations and run them through a heap-leach process to extract mineralization that was missed the first time. When gold climbed to dizzying heights in recent years, it was economic to put those reworked rocks and tailings through heap-leach a second or even third time.

One side effect of this has been improvements in leaching technology that can be applied to in situ leaching.

Other improvements in leaching technology have come by applying it to existing underground mines – particularly those that are too deep, too hot or in other ways too problematic for continued mining even though there is still mineralization present. A stope wash, in which lixiviant is passed through the mine’s workings, can help with resource recovery.

ISL can help extract mineralization from pillars in a worked-out mine without the safety and surface-impact risks often associated with robbing pillars.

In using ISL to maximize recoveries from exhausted underground workings, it is important to make sure that the flow and transport pathways are well understood, and that lixiviant flow is controlled.

Better understanding of ISL applications also comes from the more than 50 mines worldwide that have safely and successfully produced uranium using this technology. The keys to success of these mines include the high permeability and relative homogeneity of these formations. In uranium ISL, fractures and, particularly, injection-induced hydraulic fractures are avoided, as they provide potential transport pathways that can interfere with lixiviant recovery and efficiency.

When using ISL for lower permeability, more fractured gold ore bodies, careful site characterization is needed to positively identify vein deposits to be produced, and potential fractures and faults that could provide escape routes for lixiviant.
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Recent advances in hydraulic testing, including hydrophysical flow logging, osmotic transport monitoring cells and geophysical characterization of in situ fracturing all support improved resolution of this necessary DFN mine model.

Global experience in ISL has also led to better understanding of hydraulic cage control of lixiviant to ensure that all lixiviant fluids are captured and recycled. The hydraulic cage concept maintains a consistent, well-documented gradient from injection to pumping wells. In fractured rock, hydraulic cage performance can potentially be degraded where discrete fractures bypass the head control and monitoring well. Recent advances in fracture logging in wells, and in characterization of fracture transmissivities using hydrophysical flow logs, supports the development of discrete fracture network models that minimize the risk of lixiviant escape.

Pilot tests support feasibility studies

Once DFN characterization, analysis and modeling have been carried out to demonstrate that ISL has the potential to provide a viable mining technology for a particular orebody, the next stage may be a pilot test, likely consisting of a few wells drilled into the target formation for injection monitoring and testing. A test liquid – possibly, a fluorescent dye that can be easily tracked – is pumped into one well to see how much of the fluid can be recovered through the others.

If this test is successful, a larger pilot test might be performed – perhaps a ring of several pumping wells with a recovery well in the center, again to test recovery rates. This test will help determine the economic feasibility of ISL in this case – and also provide information on the environmental risks from fugitive lixiviant. This information then forms part of the regulatory review documentation.

There are many hurdles facing greater application of ISL. But it seems likely that the trends are in its favor. For a variety of technical, safety and economic reasons, much of the gold and other minerals in undeveloped deposits, and in existing open pit and underground mines cannot be economically produced by conventional mining methods.

As the environmental and technical challenges of ISL continue to be resolved, this technology is starting to look more attractive by comparison. Discrete fracture network mine characterization, analysis and modeling can be a significant part of this development.

Siemens extends motion controllers; New generation of multi-axis controllers has new features

SIEMENS INDUSTRY, Inc. announced the extension of the upper performance range of its Simotion D motion controllers. The new generation of Simotion D445-2 multi-axis controllers has new features such as onboard Profinet interfaces and high-speed I/O. With three-times the performance, a single controller can support up to 128 axes of motion.

Simotion D motion control systems are the ideal solution for production machines covering all levels of performance — from simple single-axis positioning tasks to complex synchronous applications — with extremely short cycle times on a large numbers of axes. Thanks to its scalability, Simotion D offers users a high degree of flexibility for the ever-changing demands on machine automation. The Simotion D drive-based multi-axis control system not only offers PLC, motion control and advanced technology functions, but also an integrated drive control based upon Siemens Sinamics S120 drives.

With the new Simotion D445-2 DP/PN and D455-2 DP/PN versions, the performance range has been extended even higher. Compared to the previous generation, the maximum quantity has been doubled to 128 axes and the memory capacity significantly expanded. This has increased the PLC and motion control performance by a factor of three. With Simotion D445-2 DP/PN and D455-2 DP/PN, the previously optional Profinet I/O interface has now been integrated on the modules as standard. This frees up the option slot for other expansion cards. The onboard interface is equipped with an integrated three-port switch and facilitates different network topologies such as line, star or tree structures, without the need for additional external switches. The interface not only supports real-time (RT), but also isochronous real-time (IRT) data exchange and can be operated as a controller and / or device of another controller.

In addition to the Profinet interface, Simotion D445-2 DP/PN and D455-2 DP/PN also have two Profibus and two Ethernet interfaces, as well as 28 digital I/Os, of which 16 can be used for technology tasks such as output cams and measuring inputs with micro-second resolution.

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