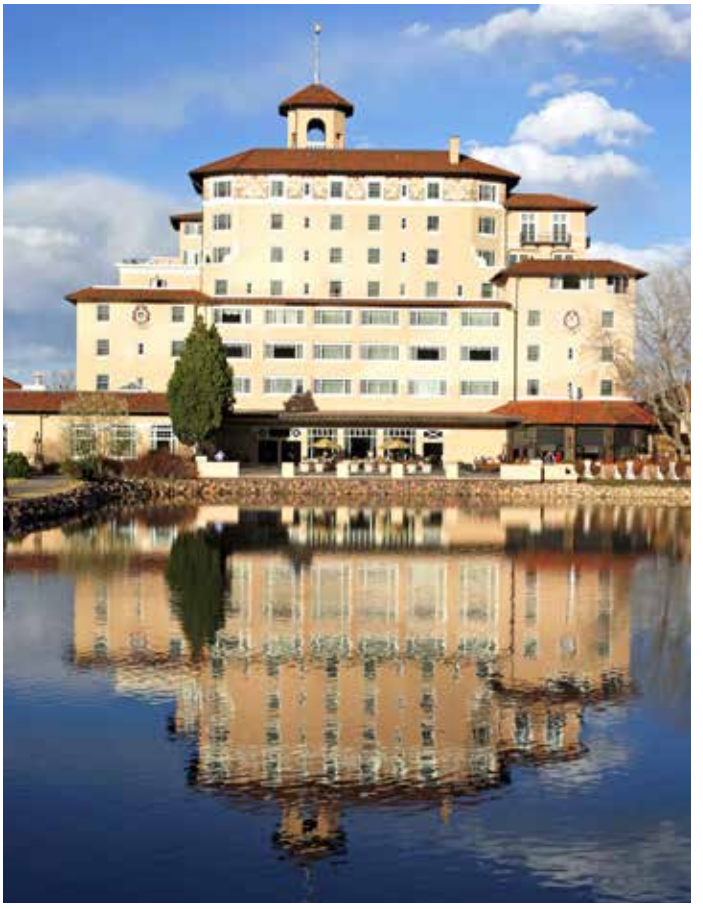
Mineral processors play in the mud while digging deeper for solutions...

by Chee Theng, Managing Technical Editor

Getting minerals out of ores is messy, but mineral processors learn to have fun with it.

Celebrating the innate joys of the industry was the theme of this year's Colorado MPD Conference. At the same time, attendees dug deeper for insights into problems that continue to dog the community, including tailings dam crises, water resource challenges, and a dwindling number of academics to teach and train the workforce (see box).



The 69th Annual Colorado MPD Conference was held April 25-27, 2019, at The Broadmoor in Colorado Springs.

Tailings dam crises

Matt Fuller of Tierra Group International Ltd. brought some of the audience to tears with his impassioned talk on "The Infamous Legacy of Upstream Tailings Dams," which won the conference's Lou Cope award for best paper. The talk was especially poignant coming on the heels of the January tailings dam failure in Vale S.A.'s Córrego do Feijão iron ore mine in Brazil, the latest in a series of catastrophic dam failures over the past decade that includes the Fundão dam failure in 2015.

Noting that the two dams share a common characteristic — both are upstream tailing dams — Fuller explained the three basic dam construction methods and why certain upstream tailing dams are susceptible to failure (Fig. 1). The downstream, centerline and upstream methods denote the direction the centerline of the dam crest moves with each successive raise in elevation of the dam. With the downstream dam, the foundation for future raises is essentially the same as that of the starter dam, he explained. With the centerline dam, half of the dam is constructed on the same foundation as the starter dam, and with the upstream dam, each successive raise is built out over the top of the tailings.

"Downstream dams are expensive to build because each successive raise is bigger, so the sustaining capex to build them keeps growing," Fuller said. Many decades ago, mine owners realized they could construct a starter dam, put their tailings through a hydrocyclone, generate a coarse sand fraction and stack the sand over the top of the tailings to build the next raise. "Then, there is no sustaining capex, it all comes out of operations," Fuller added. The footprint is smaller, and it is a favorable means of retaining the tailings.

The fine fraction, called slimes, which is deposited on the upstream side, self-classifies as it flows away from the dam, leaving a coarser layer at the base of the raises that dries more quickly and presents a dry foundation upon which to build the next raise. A decant structure, basically a concrete sewer drain, is used to flow water off the water pool, take it down the valley, under the starter dam, and discharge it downstream. These facilities are almost never lined, so there is a reliance on seepage of the water entrained in the tailings into the underlying foundation.

"This is great if you have a permeable foundation, but in many places around the world, especially in the tropics and Brazil, the foundations are not permeable, and they don't just

drain out. Aside from evaporation, the extent of the ability to dewater these dams is through small holes in the decant structure. This particular arrangement is prolific throughout Mexico and the south," Fuller said.

"Then, once the dam is built up to the full height of the valley, they say, 'What do we do? Well, let's just build another one.' So they go and build another upstream dam on the downstream side of the previous one," he added.

With static or dynamic (earthquake) increased pore pressure, water-saturated tailings are transformed from a semi-solid state into a fluid state in a naturally occurring phenomenon called tailings liquefaction, thereby compromising the integrity of the dam, which is a possible cause of the Fundão dam failure.

Fuller concluded by listing some of the challenges facing tailings management, of which one of the biggest is the prevalent attitude of "Because that's the way we've always done it."

Water in mining

In his talk titled "Waste Rock Risk Mitigation," Jacob Croall of Newmont Goldcorp gave an overview of what Newmont Goldcorp is doing on water management, and how and why the company is doing it.

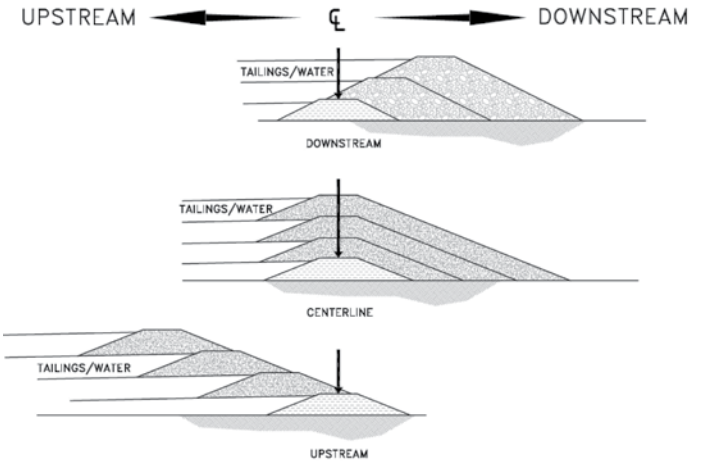
Water management is getting harder, he said, driven by rising social, political and media concern over poor water performance; water scarcity or surplus leading to increased treatment costs and production constraints; and increasingly stringent regulations. Understanding water management at the regional and watershed scale can reduce risks, develop opportunities and decrease financial exposure at closure. As companies mature in water management, they progress through several phases: a developing phase characterized by reactivity, an opportunistic "emerging" phase with simple metrics, a strategic phase where companies take a managed approach, and an industry-leading phase where companies are proactive.

Croall stressed the value behind predicting versus reacting in Newmont Goldcorp's solution development model (Fig. 2). "Reactivity based on 'you can't control what you don't measure' limits mitigation or control options and increases costs," he said. "If you can predict it in the early stages, you open up all these opportunities for managing the risk and engineering solutions before you get to the high-cost treatment." Front-loading projects with questions and data generation incurs short-term costs but is financially rewarding in the long term.

Croall illustrated the steps in the solution development model with an acid rock drainage example. He concluded by noting that the industry is shifting and that focus and diligence are required to integrate solutions early. Companies that fail to develop technical capability and incentivize long-term thinking will incur high costs and reputation loss over the long term.

Figure 1

Three dam construction methods: downstream, centerline and upstream. (Graphic courtesy of Tierra Group International Ltd.)



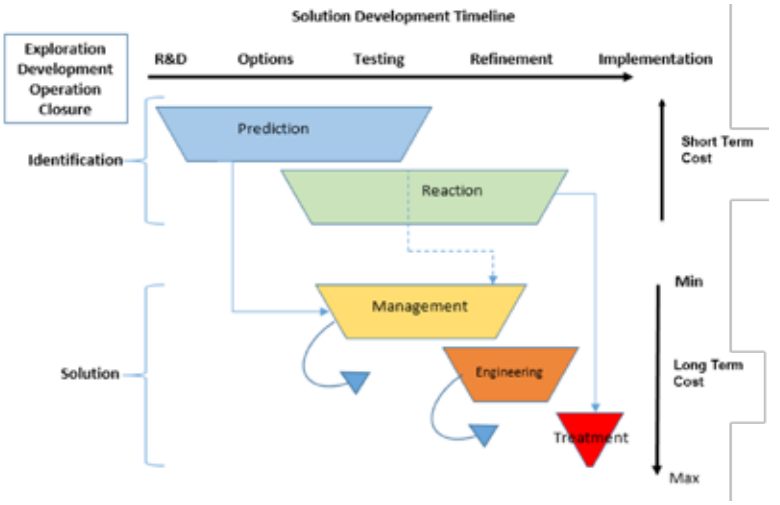
Sulfides water treatment

Taking the discourse on water into the realm of operations, Scott Shuey of Newmont Goldcorp spoke on "First Stage Yanacocha Sulfides Water Treatment, aka Development of YaS Cu SX/EW."

"Modern hydrometallurgical plants must manage the use of water with the same attention given to costly reagents or final products," Shuey observed. "Water itself is a costly reagent, whether it is obtained in arid or coastal environments, or treated and discharged in wet environ-

Figure 2

Solution development model. (Graphic courtesy of Newmont Goldcorp)



ments. In the development of the Yanacocha sulfides copper solvent extraction/electrowinning (SX/EW) plant, focusing on water as a co-product, with SX/EW as the final step in copper production and the first step in clean water production has been critical in the project's success."

Designing the plant to operate at the intersection of these two goals reduces potential difficulties for operations and helps ensure water stewardship for decades to come at Yanacocha, Shuey said.

Diagnostic leach testing

Deepak Malhotra, president of ProSolv Consulting, spoke on "Diagnostic Leaching: A Practical Approach for Assessing Refractory Ore." "New discoveries are almost all refractory ores," he said. "While new minerological tools can sometimes identify the deportation of gold, the process is expensive and not always successful. For process development, it is desirable to complement minerological methods with a diagnostic leach test."

Malhotra showed that the diagnostic leach process — consisting of a series of leaches, each more aggressive than the previous one, combined with interstage cyanidation — in conjunction with traditional minerology can be a powerful tool in aiding metallurgists to minimize testwork for new property development and to optimize existing gold plants. As a standard process will not characterize all types of refractory ores, customization based on preliminary mineralogy, head elemental analyses and X-ray diffraction/X-ray fluorescence analyses is necessary, and cyanidation and carbon-in-leach bottle roll tests need to be run.

Biooxidation

Gold production from refractory ores rose from 5 percent to more than 10 percent from 1994 to 2009 and is projected to climb to 20 percent in 2050, Jaeheon Lee, associate professor at the University of Arizona, said in his talk on "Biooxidation — Tank or Heap... Anything Else?"

Lee reported the results of a study comparing ultrafine grinding, flotation and gravity, roasting, pressure oxidation, tank biooxidation and sand farming to evaluate alternatives for the processing of refractory ores with 30 to 35 percent cyanidation. Two sulfidic refractory composite sample ores were tested, one with high gold, copper and arsenic concentrations and the other a more common ore with low gold grade and some copper and arsenic content.

Biohydrometallurgy uses microorganisms for the oxidation of sulfide minerals to assist in the leaching of metals from concentrates and low-grade ores, or in the breakdown of refractory ores and has the advantages of regenerating the leach agent in the process, meaning less chemical addition, an environmental benefit, and providing routes to handle low-grade materials and materials containing harmful elements such as arsenic. Sand farming is a new biooxidation process in which whole ore is agglomerated with microorganisms in solution.

The study showed 80 and 92 percent gold extractions for sand farming after 44 and 83 days of biooxidation, respectively, and considerably lower capital and operating costs, indicating sand farming can be a niche market process.

Cobalt concentrator in Idaho

Darby Stacey, of Formation Capital Corp., and Cameron Wolf, of Samuel Engineering Inc., teamed up to speak on "Expanding the Idaho Cobalt Concentrator."

Owned by Formation Capital, a wholly owned subsidiary of eCobalt, the Idaho Cobalt Project promises to provide a safe, secure, transparent and ethical supply of cobalt. It has the highest cobalt grades in North America, significant project investment to date, from exploration to preconstruction, derisking project execution, and is the only near-term primary cobalt mine in the United States, with an approved plan of operations and fully permitted mine and mill, Stacey said.

In a cobalt market that is growing but characterized by violent price swings, the decision was made to scale up the plant by 50 percent to 1.1 kt/d (1,200 stpd). The design challenge was to upscale the mill design, use as much existing equipment as possible, use knowledge gained from past construction, design out operating bottlenecks, stay on the existing footprint, and do all of the above fast. By working with Samuel Engineering, this was accomplished. The task was started in December 2018 and completed by Valentine's Day.

Wolf took over to describe the nine project items, from changing the ore tram to ore haulage to expanding the new concentrate loadout building. Stacey shared the values of using the historic engineering team at Samuel Engineering, involving construction experts, the criticality of a flexible and capable layout designer, and having regular team interaction and working meetings.

Eagle gold project in Yukon

In his talk titled "Valley Leaching in the Yukon," Nick Gow of Forte Dynamics Inc. spoke on the Eagle gold project, which is the flagship deposit of gold exploration and development company Victoria Gold Corp. in the Tintina Gold Belt of Yukon, Canada. The deposit has shown proven and probable reserves of 84 t (2.7 million oz) of gold, and several nearby promising exploration targets, putting it on track to be the largest gold mine in Yukon history. Operations consist of a conventional openpit mine

with a three-stage crushing plant, valley-fill heap leach and standard gold recovery circuit.

Due to the remote location and cold climate, there have been numerous logistical considerations to overcome, including cold climate stacking and leaching operations, water management, and electrical grid supply risk. To assist in several of these areas, Forte Dynamics, an engineering consulting firm with a focus on heap leach operations, provided recommendations for optimal design and operations.

The mine is on the verge of starting operation. Construction and commissioning are close to completion, with plans to begin placing ore onto the heap leach pad this summer. Once in full production, the project will employ 350 to 400 people.

Colorado MPD conference

James Metsa, regional director of sales and technical support at Weir Minerals, received the 2019 Daman Lifetime Achievement award, and three students won financial assistance: Grant Colligan of the Colorado School of Mines, who also won the best student presentation award with his paper on "Importance of Mineral Processing on Rare Earth Hydrometallurgical Extraction," Melinda Ravnaas of the South Dakota School of Mines and Technology, and Marc "Freddy" Sime of Montana Technological University.

The conference also saw presentations on the Mining and Metallurgical Society of America by Amy Jacobsen, the SME Foundation by Mary Korpi and the National Mining Hall of Fame and Museum by Stephen Whittington.

The 69th Annual Colorado MPD Conference, held April 25-27, 2019, in Colorado Springs was chaired by Jaye Pickarts, principal engineer at Tetra Tech. For information on next year's conference, go to www.coloradompd.com or send an email to chair@coloradompd.com. ■

...and pausing to consider the future of minerals education

In a survey of 16 universities offering degrees in mining engineering and mineral processing/extractive metallurgy (MP/EM) conducted by SME at the end of 2018 to assess demand for faculty employment, the universities reported three current and approved positions for department heads or chairs, five tenure/tenure-track positions for mining engineering, and four such positions for MP/EM.

Furthermore, looking ahead to anticipated faculty openings over the next five years, the numbers were four for department chairs or heads, 21 to 28 for mining engineering and 17 to 19 for MP/EM, said Hugh Miller, 2019 SME President, who gave the keynote address at the 69th Annual Colorado MPD Conference.

In his address on "The Future of Minerals Education — Landmines and Opportunities," Miller pointed to a falling trend in the academic sector for both mining and mineral engineering. Accredited U.S. mining engineering departments have gone from 25 in 1982 to 14 currently, and tenure/tenure-track mining faculty staff had shrunk 42 percent since 1984 to 76 in 2015. The numbers are similarly dismal for the mineral community. "Excluding China, India and Iran, the global number of B.S. graduates in mineral engineering has continued to decline for the last five years and is believed to be well below the current industry attrition rate due to retirement," Miller said.

Only six U.S. academic programs in extractive metallurgy currently remain, with another five in mineral processing embedded in other academic departments such as materials, physical metallurgy, mining and chemical engineering. The six extractive-metallurgy degree programs have approximately 22 tenured/tenure-track faculty, of whom an estimated 10 will be eligible for employment by 2022.

Downtrends are also apparent in other western countries. Enrollment in Australia's eight mining universities is continuing to drop despite nearly guaranteed employment and starting salaries in the $100,000s. In some academic programs, enrollment is only a small fraction of what it was just four years ago.

To combat the trend, SME's Education Sustainability Committee was created in September 2013 with the mission to develop actionable recommendations that "seek to address the long-term challenges that threaten the sustainability of U.S. mining and mineral processing/extractive metallurgy academic degree granting programs."

From this initiative rose two programs. The SME Ph.D. Fellowship Program has been awarding three new fellowships annually since 2015, with each fellow receiving direct disbursement of $60,000 a year for up to four years. Robert Shoemaker and Stantec/McIntosh have been generously supporting the program since 2017, and the WAAIME did so in 2018.

The SME Academic Career Development Grant Program has been awarding grants to two tenure-track assistant or associate professors annually since 2015, each receiving $100,000 a year for up to three years. Freeport-McMoRan Inc. has been generously funding the program since 2017. ■