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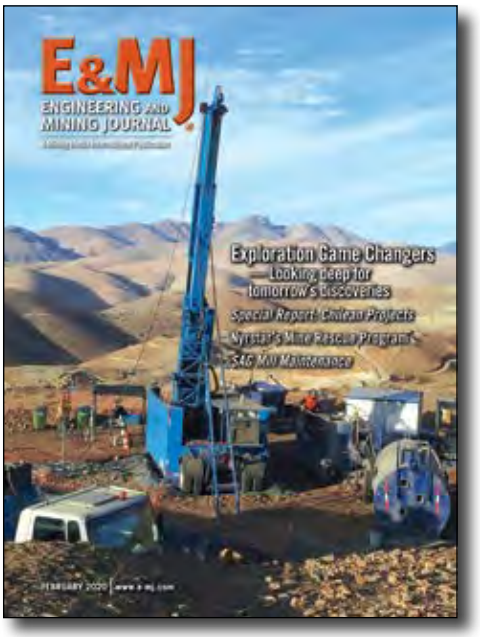

In addition to an extensive report on Chile, this edition of E&MJ *also discusses new trends in mineral exploration. On the cover, one of Griffith Drilling's diamond drill rigs searches for minerals in Chile's Atacama Region. www.griffith-drilling.com*

DEPARTMENTS

Steve Fiscor
Publisher & Editor-in-Chief

US Makes Sweeping Changes to Environmental Policy

The U.S. federal government is making more changes to clarify environmental regulations and the permitting process. The White House Council on Environmental Quality (CEQ) issued a proposed rule to modernize its National Environmental Policy Act (NEPA) regulations (See News, p. 10). The U.S. Environmental Protection Agency (EPA) and U.S. Army Corps of Engineers (Corps) recently released a pre-publication version of their final rule defining the scope of waters federally regulated as "waters of the United States" (WOTUS) under the Clean Water Act (CWA). The hope is that the replacement rule will offer clear delineations between state and federal waterways.

The Federal Permitting Improvement Steering Council (FPISC) voted to add mining to the list of covered sectors eligible for the expedited permitting process available under section 41 of the Fixing America's Surface Transportation Act (FAST-41). Hold it. What? Those are two acronyms that are new to the mining business.

FAST-41 included a statutory bill passed by Congress that created the FPISC, which is based at the White House. Alex Herrgott, executive director for FPISC, spoke at a luncheon during the annual American Exploration & Mining Association meeting during December. Like most *E&MJ* readers, no one in the room had heard of the FPISC. He explained that the council is an independent entity that sits outside and above the other agencies as a coordinating element. "It has no jurisdiction over organic statues," he said. "What we do is bring all the federal elements together to adjudicate disputes."

In a world where a U.S. project is permitted in a reasonable amount of time is the exception and not the rule, Herrgott is working to change that mindset. "We are developing an administrative process that basically promotes quite complicated and crazy ideas, like predictability, transparency, a definite beginning and a definite end point to the process," Herrgott said. "No decision deserts. No one from a federal agency is going on vacation leaving a document unsigned for no particular reason."

Herrgott's council members are the deputy secretaries of all the federal agencies. When two agencies are in a dispute, he has the statutory authority to escalate it to the Office of Management and Budget. "It's the strongest end game that exists, and we haven't had to exercise it yet," Herrgott said.

If a project has a value of $200 million or more, developers submit it to the FPISC. Within 14 days, the council has to decide whether the project qualifies as a covered project. Once a project qualifies, it's added to the PFISC dashboard (www.permits.performance.gov), where its progress can be tracked. "Within 60 days, the council gets all of the stakeholders in one room and they create a coordinated timeline with milestones that cannot be changed arbitrarily," Herrgott said. "Those that aren't involved at the beginning of the process can't file a lawsuit after NEPA issues a Record of Decision. The whole idea is to bring all relevant stakeholders to the front end of the process so we can figure out the rules and respond and identify problems."

Mining companies should not need to hire lawyers and consultants to navigate the maze that is Washington, D.C., and now people on the inside are trying to help.

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E&MJ ENGINEERING AND MINING JOURNAL
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MINING MEDIA INTERNATIONAL

Engineering & Mining Journal, Volume 221, Issue 2, (ISSN 0095-8948) is published monthly by Mining Media International, Inc., 11655 Central Parkway, Suite 306, Jacksonville, FL 32224 (mining-media.com). Periodicals Postage paid at Jacksonville, FL, and additional mailing offices. Canada Post Publications Mail Agreement No. 41450540. Canada return address: PO Box 2600, Mississauga ON L4T 0A8, Email: subscriptions@mining-media.com. Current and back issues and additional resources, including subscription request forms and an editorial calendar, are available at www.e-mj.com.

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POSTMASTER: Send address changes to *E&MJ*, 11655 Central Parkway, Suite 306, Jacksonville, FL 32224-2659.

REPRINTS: Mining Media International, Inc., 11655 Central Parkway, Suite 306, Jacksonville, FL 32224 USA; email: subscriptions@e-mj.com; phone: +1.904.721.2925, fax: +1.904.721.2930; www.mining-media.com.

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Freeport Outlines Growth Plans

The Lone Star copper project in eastern Arizona is being developed to become a major new mine in North America.

Last year, Freeport-McMoRan (FCX) sold 3.3 billion lb of copper, 991,000 ounces (oz) of gold and 90 million lb of molybdenum. According to the company's recently released earnings report, it intends to produce approximately 3.5 billion lb of copper, 800,000 oz of gold and 88 million lb of molybdenum in 2020.

During 2020, it plans to invest $2.8 billion in capital projects, including $1.8 billion for major projects primarily associated with underground development activities at the Grasberg operation in Indonesia and completion of the Lone Star copper leach project in Arizona, USA. This excludes estimates associated with the new smelter in Indonesia, according to the company. FCX said it expects capital expenditures for the development of the new smelter in Indonesia to be $500 million in 2020, of which approximately 49% will be attributable to FCX's equity interest.

"During 2019, we progressed three major initiatives to enhance future cash flows and value for our shareholders," said Richard C. Adkerson, president and CEO, FCX. "We are on schedule to establish large-scale production from our high-grade, low-cost and long-lived underground ore bodies at Grasberg; the Lone Star project in Arizona is nearing completion; and early results from our innovation initiatives to enhance productivity at our operations in the Americas are positive."

Adkerson said plans are designed to increase copper and gold sales by more than 30%, reduce unit net cash costs by approximately 25% and more than double operating cash flows in 2021 from 2019 levels. Sales are expected to increase to 4.3 billion lb of copper and 1.4 million oz of gold in 2021.

A pilot program initiated at the Bagdad mine in northwest Arizona in late 2018 was highly successful in using data science, machine learning, and integrated functional teams to address bottlenecks, provide cost benefits and drive improved overall performance. That innovation initiative is now being implemented across the North America and South America operations. FCX has incorporated higher mining and milling rates in its future plans, resulting in estimated incremental production of approximately 100 million lb of copper in 2021 and approximately 200 million lb in 2022.

In South America, the company reported that debottlenecking projects and additional initiatives to enhance operating rates continue to advance. Cerro Verde's concentrating operations in Peru averaged 396,800 metric tons per day (mt/d) of ore in the fourth quarter, approximately 10% above design capacity. Ongoing productivity and innovation initiatives are targeting the opportunity to increase production to 420,000 mt/d in 2021.

FCX said undercutting, drawbell construction and ore extraction activities in the Grasberg Block Cave continue to track as expected. Ore extraction averaged 11,200 mt/d of ore in the fourth quarter, including a planned three-week outage for the installation of ore-flow infrastructure. Following completion of the maintenance program in mid-December, ore extraction from the Grasberg Block Cave averaged 17,000 mt/d of ore. As production advance, the company is currently projecting 30,000 mt/d of ore in 2020 and more than 60,000 mt/d of ore in 2021 before growing to 130,000 mt/d of ore in 2023 from five production blocks spanning 335,000 m^2.

The Deep Mill Level Zone (DMLZ) underground mine, located east of the Grasberg ore body, continues its ramp up of production. Ore extraction continues to exceed FCX's expectations, averaging 14,900 mt/d of ore in the fourth quarter. Ongoing hydraulic fracturing operations combined with continued undercutting and drawbell openings in the two currently active production blocks are expected to expand the cave, supporting higher production rates that are expected to average 29,000 mt/d of ore in 2020 and approach 60,000 mt/d of ore in 2021.

In connection with the extension of the company's mining rights from 2031 to 2041, it committed to construct a new smelter in Indonesia by December 21, 2023. A site for the new smelter has been selected, and ground preparation is advancing. Engineering and front-end engineering and design for the selected process technology are advancing and expected to be completed in 2020. The preliminary capital cost estimate for the project is estimated at $3 billion, pending completion of final engineering.

Kirkland Lake Shareholders Approve Detour Acquisition

At a special meeting on January 28, Kirkland Lake Gold Ltd. shareholders voted overwhelmingly in favor of the proposed acquisition of Detour Gold Corp. They approved the issuance of up to 77,407,217 common shares of Kirkland Lake Gold.

The resolution was approved by approximately 98.99% of votes cast by shareholders.

Detour Gold shareholders also approved the arrangement at a special meeting.

This transaction will add the Detour Lake mine to Kirkland Lake Gold's portfolio. The open-pit mine in Ontario, Canada, has an estimated production of 590,000 to 605,000 oz of gold.

President and CEO of Kirkland Lake Gold Tony Makuch said, "Once complete, the transaction will create a highly competitive, truly unique company in the gold mining industry. By combining Detour Lake with our Macassa and Fosterville mines, we will have three cornerstone assets in our two core jurisdictions of Canada and Australia, all three of which possess free cash flow generating operations, significant in-mine growth potential, and considerable regional exploration upside." He said the new Kirkland Lake Gold will be a leader in profitability, cash flow generation and cash resources.

Anglo American in Talks With Sirius

Anglo American confirmed it is in advanced discussions with Sirius Minerals in relation to a possible cash offer of approximately £404.9 million ($504 million).

In September 2019, Sirius announced it was undertaking a strategic review to assess the development plan for its polyhalite project in North Yorkshire, England, and an appropriate financing structure to provide relevant funding. Sirius also announced that the strategic review would include a broader process to seek a major strategic partner in the project. In November 2019, Sirius provided an update on the progress of this strategic review, including a revised two-stage development plan.

Anglo American said it identified the project as being of potential interest some time ago, given the quality of the underlying asset in terms of scale, resource life, operating cost profile, and the nature and quality of its product. The company also said it has the potential to fit well with Anglo American's established strategy of focusing on world-class assets, particularly in the context of Anglo American's portfolio trajectory toward later cycle products that support a fast-growing global population and a cleaner, greener, more sustainable world.

Kinross Completes Acquisition of Chulbatkan

Kinross Gold Corp. has completed its previously disclosed acquisition of Chulbatkan, a high-quality, heap-leach development project in Russia, from N-Mining Ltd. for total fixed consideration of $283 million.

The company has now commenced a comprehensive exploration drilling program at Chulbatkan with the view to updating the current resource base at year-end 2020. Kinross expects to spend approximately $10 million on initial exploration drilling at Chulbatkan during the year. The company is also planning to convert estimated mineral resources to estimated mineral reserves, complete prefeasibility and feasibility studies for the project within approximately three years, and is targeting a subsequent two-year construction period.

On October 18, the company received a timely anti-monopoly approval on the acquisition from the Russian regulators. All other conditions precedent regarding the acquisition have been satisfied.

Chulbatkan is a relatively high-grade, open-pit, heap leachable project and is expected to have significant upside potential. The Chulbatkan deposit is near surface with highly continuous mineralization and is open along strike and at depth with potential for additional high-grade structures. Based on substantial due diligence work and internal analysis, Kinross currently estimates approximately 3.9 million gold ounces in indicated mineral resources and 80,000 gold ounces in estimated inferred mineral resources for the project. The footprint of the current Chulbatkan resource represents less than 1% of the total 120-sq-km license area, which hosts multiple, untested high-quality targets.

In accordance with the acquisition agreement, the first installment of $141.5 million, plus $3.1 million of ordinary course working capital adjustments, representing approximately 50% of the $283 million purchase price, were paid. The agreement was amended to permit the first installment to be paid all in cash, which has minimized share dilution and leveraged the company's strong liquidity profile. The amendment also provides that 60%, and at Kinross' sole discretion up to 100%, of the second and final installment of $141.5 million, due on the first anniversary of closing, may be paid in Kinross shares.

Chulbatkan is located in the Khabarovsk region of Far East Russia, approximately the same distance from the company's regional office in Magadan as its existing Kupol and Dvoinoye operations. The acquisition is expected to build on Kinross' extensive operational and development experience and successful 25-year track record in Russia.

Public Database of Tailings Dams is Released

GRID-Arendal has launched the world's first publicly accessible global database of mine tailings storage facilities. The database, the Global Tailings Portal, was built by Norway-based GRID-Arendal as part of the Investor Mining and Tail-

Newmont Goldcorp Rebrands as Newmont

Newmont Goldcorp announced that the company has refreshed its brand, name and logo to Newmont following two historic transactions in 2019. The company's refreshed brand is being unveiled as Newmont enters its centenary year in May 2020 and will begin its next century of superior performance, value creation and sustainability leadership on May 2, 2021.

"We successfully completed two historic transactions in 2019, which have transformed Newmont into a truly international organization with an unmatched portfolio of assets and prospects in top-tier jurisdictions around the world," said Tom Palmer, president and CEO, Newmont. "As this company has done many times in the past, Newmont has demonstrated its ability to adapt to change, which is truly a hallmark of our success over the last 100 years. Updating our brand represents a natural step as we approach the next 100 years in Newmont's long and proud legacy of operating discipline, profitable growth, environmental stewardship, and developing the industry's best talent."

The "Newmont" name is a recognized brand. The updated Newmont logo leverages the gold triangle from the previous logo, which represents the apex of the industry and the pinnacle of leadership, to anchor the strength and stability conveyed by the new logo, the company said.

"While our proven strategy and core values remain key to our ongoing success, we've updated and adapted our brand to reflect our position as a transformed business and the world's leading gold company," Palmer added.

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ings Safety Initiative, which is led by the Church of England Pensions Board and the Swedish National Pension Funds' Council on Ethics, with support from the UN Environment Program.

The Investor Mining and Tailings Safety Initiative is backed by funds with more than $13 trillion under management.

Until now, there has been no central database detailing the location and quantity of the mining industry's liquid and solid waste. "This portal could save lives," said Elaine Baker, senior expert at GRID-Arendal and geosciences professor with the University of Sydney in Australia. "Dams are getting bigger and bigger. Mining companies have found most of the highest-grade ores and are now mining lower-grade ones, which create more waste."

The database allows users to view detailed information on more than 1,700 tailings dams around the world, categorized by location, company, dam type, height, volume and risk, among other factors.

The release of the Global Tailings Portal coincides with the one-year anniversary of the tailings dam collapse in Brumadinho, Brazil, that killed 270 people. After that disaster, a group of institutional investors led by the Church of England Pensions Board asked 726 of the world's largest mining companies to disclose details about their tailings dams. Many of the companies complied, and the information they released has been incorporated into the database.

The portal can be viewed at http://tailing.grida.no/.

Prosecutors Charge Ex-Vale CEO With Homicide

Brazilian prosecutors marked the one year anniversary of the Brumadinho collapse by charging Vale CEO Fabio Schvartsman and 15 others with homicide for their involvement in the disaster. Prosecutors alleged that these individuals knew about the safety issues with the tailings dam and hid them.

In addition to homicide charges, Vale and TUV SUD, the German company responsible for inspecting the dam, were charged with environmental crimes, as reported by *Reuters*. Including Schvartsman, 11 people charged worked for Vale and five worked for TUV SUD.

"Vale, with the support of TUV SUD, produced a large amount of technical information about … various dams owned and managed by Vale, that were recognized, I repeat, internally recognized, as dams with an unacceptable risk profile," said William Garcia Pinto Coelho, a prosecutor on the case.

According to *Reuters*, more charges at the federal level could be coming. Investigators in Germany are also reported to be looking into the case as well.

In a statement, Vale said the charges of fraud were "perplexing." "It is important to note that other authorities are investigating the case and, at this point, it is premature to claim there was conscious assumption of risk to cause a deliberate breach of the dam," the company said.

Vale said it will continue to fully cooperate with the authorities.

Capstone Plans to Achieve 20% Growth by 2021

Capstone Mining Corp.'s 2019 actual production was above the midpoint range of 145 million to 160 million lb of copper and actual costs were below the bottom end of the guidance range of $1.80/lb-$2/lb payable copper.

In 2020, Capstone expects to produce between 140 million and 155 million lb of copper at C1 cash costs of between $1.85/lb-$2/lb payable copper produced.

"Capstone has redefined itself as we enter this new decade. Our business is supported by an expansion at our high grade and high margin Cozamin mine, while Pinto Valley is positioning to amplify best-in-class leverage to copper," President and CEO Darren Pylot said.

"We have made substantial and sustainable reductions to our cost base, achieving our goal of approximately $30 million per year," Pylot said. Capstone is positioned for 20% production growth with a 10% decrease in costs by 2021 and beyond."

Pylot said there will be a slight decrease at Pinto Valley (approximately 5 million lb lower) to account for the installation of new secondary crushers.

At Cozamin, the one-way ramp project is proceeding on schedule, with an expected increase in annual production rates of 50 million to 55 million lb of copper and 1.5 million oz of silver for 2021 and beyond.

BHP South Flank Builds Ore Handling Plant

Fluor Corp. has erected the first 1,500 tons of modules at BHP's South Flank ore handling plant. The company said the "milestone" was a critical step to first ore and follows the announcement in October of the project meeting 50% completion.

Fluor is providing engineering, procurement and construction management services on South Flank, which is located in the remote Pilbara region of Western Australia.

When operational, South Flank will be one of the largest iron ore processing hubs in the world. The project will include an 80-million-ton-per-year (t/y) crushing and screening plant, an overland conveyor system and rail-loading facilities.

South Flank engineering and procurement work is being performed from BHP's office in Perth, with Fluor working together with BHP as an integrated project team.

"We are extremely proud of what we have been able to accomplish with BHP on this project including our commitment to achieve diversity through the hiring of indigenous and local team members," said Tony Morgan, president of Fluor's Mining and Metals business. "The pioneering integrated team approach on this project is truly a collaborative effort."

Fluor previously performed the feasibility study for the project before it was awarded the follow-on construction and project management scope. Construction began in July 2018, and first production of iron ore is anticipated in 2021.

Once operational, South Flank will be one of the largest iron ore processing hubs in the world. (Photo: Fluor Corp.)

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Lucky Friday Strike Ends

Miners are returning to work at Hecla's Lucky Friday mine near Kellogg, Idaho.

On Monday, January 6, by a vote of 86 to 78, union members of the United Steel Workers (USW) Local Union No. 5114 accepted an agreement between USW and Hecla Mining Co. at its Lucky Friday silver mine in the Coeur d'Alene Mining District in northern Idaho. This agreement will end a strike that began in March 2017 due to Hecla's proposed changes to miners' health care, scheduling and bonus pay that the miners deemed "unfair."

The union had previously rejected a tentative agreement on December 16. Shortly after, Hecla announced it was committed to getting the mine back to full production and would be hiring more contractors.

On December 20, the union came back to the bargaining table with Hecla. "We bargained for more than five hours with much dialog and requests for information," Staff Representative Tim Swallow said on the group's Facebook page.

Some of these issues discussed included picket line terminations and the return to work physical and essential functions test, he added.

In a letter to union members, the negotiating committee said the strike settlement agreement also retained the $1,000 signing bonus for all bargaining unit employees not separated from Hecla, after they complete a physical and drug test. Employees will also retain seniority accrued since March 2017.

Hecla Mining said it anticipates re-staffing of the mine to take place in stages, with a ramp-up to full production levels expected by the end of 2020.

South32, Trilogy Form JV to Develop Alaska Projects

South32 Ltd. has exercised its option to acquire a 50% interest in a joint-venture company with Trilogy Metals to develop the Upper Kobuk Mineral Projects (UKMP) in the Ambler mining district of northwest Alaska. The projects include the high-grade, polymetallic Arctic deposit, the Bornite copper deposit, and a highly prospective regional exploration portfolio.

Arctic is a volcanogenic massive sulphide (VMS) deposit where current activities are focused on advancing development studies and permitting, following release of a prefeasibility study (PFS) by Trilogy in April 2018. The PFS describes the potential technical and economic viability of establishing a conventional open-pit copper-zinc-lead-silver-gold mine-and-mill complex for a 10,000-metric-ton-per-day (mt/d) operation.

Bornite is a carbonate-hosted copper deposit located about 25 kilometers (km) southwest of the Arctic deposit. The 2020 field season will include further exploration drilling at Bornite and regional activity across the highly prospective Ambler VMS and carbonate-hosted copper belts.

Trilogy Metals will contribute all of its assets associated with the UKMP to the newly formed joint-venture company, and South32 will contribute $145 million. Establishment of the joint venture follows an initial exploration partnership between South32 and Trilogy over three field seasons to advance both parties' geological understanding of the UKMP.

South32 CEO Graham Kerr said, "Investing in exploration to create shareholder value is integral to our group's strategy. Forming the UKMP Joint Venture will be another important milestone as we reshape and improve our portfolio, by adding high-quality copper and base metals development options.

Trilogy Metals Interim President and CEO James Gowans said, "The Ambler mining district has great potential that we expect will finally be realized with the formation of the joint venture and when the Ambler Mining District Industrial Access Project, providing key infrastructure access, is approved. We are very excited to advance this partnership."

TMAC Considers Options for Hope Bay

TMAC Resources has initiated a strategic process to explore, review and evaluate a broad range of potential alternatives that include a potential sale or merger, a joint venture of the Hope Bay mine in Nunavut, Canada, introduction of a new significant strategic shareholder or various long-term financing alternatives.

"With the support of Resource Capital Funds and Newmont, which represents 58.5% of our outstanding shares, we have initiated a strategic process to explore potential alternatives to maximize shareholder value," said Jason Neal, president and CEO of TMAC. "A transaction in early 2020 would provide an advantage in planning and procurement for the 2020 sealift, which may include additional purchases to support investment that TMAC may not otherwise make itself at this time."

TMAC has been making operational performance improvements at the Hope Bay mine since construction was completed.

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"We have recently initiated development of the second underground mine at Madrid North, and with respect to the production expansion of Hope Bay, we are advancing our prefeasibility study, which is expected to be completed this quarter," Neal said.

TMAC has engaged CIBC Capital Markets and BMO Capital Markets as financial advisors.

PolyMet Will Appeal Court Decision on Permits

Poly Met Mining Inc. will file a petition for review to the Minnesota Supreme Court seeking to overturn a state Court of Appeals decision handed down January 13 remanding the company's Permit to Mine and dam safety permits to the Department of Natural Resources for a contested case hearing.

"The issues raised by the court of appeals' decision are, of course, important to our project, but equally, they have far reaching impact to the state of Minnesota and to any future project that seeks permits from the state," said Jon Cherry, president and CEO. "The potential negative consequences of the decision to any industry or business in the state, and the many Iron Range communities and workers who stand to benefit economically from responsible copper-nickel mining, warrant the Minnesota Supreme Court's attention."

Cherry cited, as a primary basis for seeking review, the court's decision to require an open-ended contested case hearing process, in spite of the Minnesota Department of Natural Resources' comprehensive, 15-year-long environmental review and permitting process for the NorthMet copper-nickel-precious metals project. The company said the process involved extraordinary amounts of public review, public comment and public meetings.

"No other company in the history of the state has been subjected to anywhere near the time and cost that was associated with this permitting process," Cherry said. "We did everything the state and the law required, and more. And the process confirmed that our project will be protective of human health and the environment.

"The court's decision greatly diminishes the role of expert state agencies and their commissioners in permitting in favor of administrative law judges. It sets a precedent that subjects the project and any future industrial project in the state to an endless loop of review, contested case hearings and appeals," he said.

The Minnesota Center for Environmental Advocacy, WaterLegacy, and the Fond du Lac Band of Lake Superior Chippewa filed several appeals with the court in December 2018 after the DNR denied petitions for a hearing and issued the permits for the project located in the Mesabi Iron Range.

In the court's decision, Chief Judge Edward Cleary said the DNR's decision to deny a hearing "was affected by an error of law in its overly narrow interpretation" of a Minnesota statute and "unsupported by substantial evidence." The court also found that the DNR failed to include a "definite term" when issuing the NorthMet permit to mine. "Any permit issued following remand, the DNR shall determine and impose an appropriate, definite term," the court document stated.

The groups also challenged the DNR's decision to transfer an existing permit to PolyMet. However, the court sided with the DNR regarding that decision. The court said the DNR's decision was "not arbitrary and capricious" and it affirmed that decision.

The company will file its petition for review to the Minnesota Supreme Court.

CEQ Proposes Rule to Modernize NEPA

The White House Council on Environmental Quality (CEQ) issued a proposed rule to modernize its National Environmental Policy Act (NEPA) regulations, which were issued more than four decades ago. If finalized, the proposed rule would comprehensively update the 1978 regulations.

The American Exploration & Mining Association (AEMA) said it applauds the CEQ for this much-needed proposal to modernize and clarify its NEPA regulations. As one of the first environmental laws in this country, AEMA explained that NEPA was landmark legislation, signaling the dawning of environmental awareness and the first step down the path of enacting what has become a comprehensive and effective federal and state statutory framework to protect the environment.

However, since it was enacted, there have been more environmental lawsuits filed under NEPA than under any other environmental statute. Delays in reviews and decision-making have slowed energy and mineral projects in the U.S. and deterred future investment in those projects.

"While a NEPA analysis has become 'standard operating procedure' for our members, it also has become increasingly more cumbersome, time consuming and expensive," said AEMA Executive Director Mark Compton. "NEPA is no longer the planning and decision-making tool it was designed to be. Instead, it has become the tool used by obstructionist groups who oppose responsible and lawful mineral development on federal public lands.

"Reforming the NEPA process and creating a more efficient permitting system are critical to improving the competitiveness of the domestic mining industry, job creation, and decreasing our reliance on foreign sources of energy and minerals."

CEQ's proposed rule would codify important aspects of the President Donald Trump Administration's One Federal Decision policy, including establishing a two-year time limit and improving agency coordination through development by the lead agency of a joint schedule; preparation of a single EIS and joint record of decision; and procedures to elevate and resolve disputes that could lead to delays. Additionally, CEQ has proposed provisions setting presumptive page limits, and for determining the appropriate level of NEPA review, ensuring timely submission of relevant information to inform decision-making, and facilitating the use of existing state, tribal, and local studies, analyses, and environmental documents, among other things.

AEMA said it will submit detailed comments on the proposed rule during the comment period.

Paramount Gold Gets Water Permit for Grassy Mountain

Paramount Gold Nevada Corp. has received the permit to appropriate water from the Oregon Water Resources Department for its proposed Grassy Mountain gold mine and processing facilities in eastern Oregon. This is the first Oregon State Agency permit issued as part of the consolidated permitting process initiated by Paramount in 2019.

This permit describes the appropriation and use of 2 cubic feet per second (57 liters per second) of water within the Permit Area described in the Consolidated Permit Application. This permit provides sufficient water for the proposed mining and processing operations throughout the mine life.

(Continued on p. 26)

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Newmont Corp. is transferring experienced mining leader **Jim Cooper,** general manager of Boddington in Australia, to lead the Peñasquito mine in Mexico. He will assume leadership of Peñasquito in the first quarter of 2020 and report to **Dan Janney,** Newmont's regional senior vice president for North America. **Jen Bennett,** currently serving as vice president of operations for Newmont's South America region, will succeed Cooper to lead Boddington and build on the operation's success through a continued focus on safe, efficient production, and project delivery. Peñasquito current General Manager **Brian Berney** will focus on government and community engagement in Mexico while supporting an effective transition with Cooper.

Suresh Vadnagra will take up the role of chief technical and projects officer for *Newcrest Mining* in June. Vadnagra joins Newcrest from MMG, where he has served on the executive committee since January 2018 in his capacity as the executive general manager operations, Americas. **Lisa Ali** will succeed **Ian Kemish** as chief people and sustainability officer for Newcrest. The company also promoted **Seil Song** into the chief development officer role. Song is currently Newcrest's general manager, business development, and will replace **Michael Nossal** who will also retire from Newcrest at the end of March.


Tim Dobson

Heron Resources appointed **Tim Dobson** as CEO, commencing in March. He is currently senior vice president metals for Sherritt International in Canada and former president of Ambatovy in Madagascar.


Joe Dick

Eldorado Gold announced that executive vice president and COO **Paul Skayman** is retiring after almost 15 years with the company. The company hired **Joe Dick** as the company's new executive vice president and COO. Prior to joining Eldorado, Dick was the senior vice president, Latin America, for Goldcorp.


Steve Holmes

First Majestic Silver Corp. appointed **Steve Holmes** to the role of COO. Prior to joining First Majestic, Holmes held the position of vice president, joint venture portfolio at Barrick Gold.


Richard Lock

Richard Lock has joined *Poly Met Mining Inc.* as senior vice president and project director for the NorthMet Project. Lock most recently was construction director for the KAZ Minerals Peschanka open-pit copper mine located within the Arctic Circle in Russia.

Victoria Vargas de Szarzynski will assume the role of vice president-investor relations for *Minera Alamos*.

Crystal Lake Mining Corp. welcomed **Cole Evans** as the company's CEO and a director. **Maurizio Napoli** who has served as the company's interim CEO since September 2019, will remain the president, vice president of exploration and a director of the company.


Tim Spencer

Pioneer Resources Ltd. refreshed its senior leadership team, appointing **Tim Spencer** to CEO. He has been with Pioneer since October 2017 in the roles of CFO and secretary. Spencer will replace **David Crook,** who is stepping down after 16 years of service to Pioneer as managing director.

Outokumpu President and CEO **Roeland Baan** has informed the company's Board of Directors that he will resign later this spring to take a CEO position in a company outside Finland.

The *Association for Mineral Exploration* announced its 2019 Celebration of Excellence Award recipients at its awards gala during January in Vancouver. This year's award winners are:
Peter Fischl, P.Geo. of Westhaven Ventures Inc. is the recipient of the 2019 H.H. "Spud" Huestis Award for signicant contributions to enhancing the mineral resources of British Columbia and/or Yukon Territory. He was recognized for his instrumental role in the recent discovery at Westhaven's Shovelnose Project in southern British Columbia.
Steve Todoruk received the 2019 Murray Pezim Award for his perseverance and commitment to financing high-quality early-stage exploration projects that have led to numerous significant metal discoveries.


Dr. Moira Smith

Dr. Moira Smith received the 2019 Colin Spence Award for her development of a new geological model for the Long Canyon prospect in Nevada and the resulting definition of a multimillion-ounce gold resource there.
Chief John French, Chief Donny Van Somer, Dennis Izony and **Chris Rockingham** are the 2019 recipients of the Robert R. Hedley Award for Excellence in Social and Environmental Responsibility. Their collective dedication to further the Kemess Underground mine has set the standard for achieving mutual benfits through understanding, respect and trust. In many practical ways, these nominees are exemplars to others on how to work constructively together and create a pathway to potential shared prosperity associated with responsible mineral exploration and development in British Columbia.
Diamonds in the Rough Emergency Rescue Organization Inc. received the 2019 David Barr Award for providing an invaluable emergency response resource to Canada's mineral exploration industry.
Ed Balon received the 2019 Gold Pan Award for his significant and selfless contributions as a volunteer to AME.
Jim Oliver and **Anne Thompson** received the Frank Woodside Award for distinguished service to AME and/or the mineral exploration industry.
Julia Lane received a 2019 Special Tribute Award posthumously for being an exceptional geologist, widely admired not only for her geological abilities but also for her ability to manage large and logistically difficult exploration projects in remote areas of Canada's Yukon Territory. She passed away tragically at the age of 33 on August 6, 2019, in an aircraft accident during a routine flight from the field. The Julia Lane Foundation was created to continue her passion to encourage young professionals.


Mikko Keto

Effective early July, **Mikko Keto** will join *FLSmidth* as president, mining industry and member of group executive management. He will replace **Manfred Schaffer,** who will retire in 2020. Keto joins FLSmidth from Metso, where he has worked for 10 years of which the last two years as president, minerals services and pumps.


Luke Stephens

RPMGlobal has bolstered its in-house Environmental, Social and Governance (ESG) capabilities after announcing the appointment of **Luke Stephens**, principal social specialist, to the company's Consulting and Advisory division.


Starla Jackson

Starla Jackson has been appointed marketing coordinator for *Eclipse Mining Technologies*.


Chris Pacer

Motion Industries Inc. named **Chris Pacer** to vice president of the company's Central Group.


Anssi Laukkanen

VTT Technical Research Centre of Finland Ltd. announced that **Anssi Laukkanen**, who was involved in the creation of the materials modelling concept VTT ProperTune, has been appointed as VTT's first research professor in computational materials and data sciences.


Dr. Markus Reinhold

Steinert GmbH appointed **Dr. Markus Reinhold** as new Chief Technical Officer (CTO). Reinhold will thereby take over the role of current CTO **Dr. Uwe Habich,** who will move to strategic business development within Steinert.


Jean Savage

Trinity Industries announced that **Jean Savage,** a member of the company's board of directors, has been appointed CEO and president. Previously, Savage was vice president of Caterpillar's Surface Mining and Technology Division.

Steve Nielsen, executive vice president and CFO of *Finning International*, will retire as of March 31. **Greg Palaschuk,** currently senior vice president of commercial and financial performance management for Finning Canada, will step into the position of CFO of Finning International beginning March 1.

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Antofagasta Minerals Exceeds Historic Copper Production

A miner parks his truck for shift change at the Antucoya mine in Chile.

In 2019, Chilean copper producer, Antofagasta Minerals produced 770,000 metric tons (mt) of fine copper, which broke the record it obtained in 2018 when it produced 725,300 mt. This is a 6.2% increase, which includes its Los Pelambres, Antucoya, Centinela and Zaldívar operations, which also contributed to a net cash cost of $1.22/lb.

"In addition to improving production costs, during 2019, we suffered no fatalities at our sites, which is always our first priority," CEO Iván Arriagada said.

In the last quarter of 2019, production reached 185,500 mt.

This comes despite the unrest and protests in Chile that created delays in supplies and travel disruptions for workers during the last quarter of 2019.

"Following the events in Chile, all our mining operations have been operating according to their respective plans, although the Antofagasta Bolivia Railroad (FCAB), which also belongs to Antofagasta plc, has had some interruptions due to occasional blockages in Antofagasta," Arriagada said.

By 2020, the company reported it expects copper production to be between 725,000 and 755,000 mt. This represents a decrease of 2% to 6% compared to 2019, due to a decrease in the amount of ore that Minera Centinela can access in 2020. It is also estimated that the cash cost of the operations in 2020, after credits for byproducts, will reach $1.30/lb.

Codelco Inaugurates 'Recursos Norte'

With ore reserves estimated at 157 million tons and a copper grade of 0.75%, Codelco El Teniente officially began production of Northern Resources, a new operating sector of El Teniente. Once in full production, it will contribute about 20% of the ore produced and processed by Codelco operations daily.

Recursos Norte (Northern Resources), which is part of the El Teniente Development Plan, started operations 15 months in advance of its original plan. This saved the company about $50 million during the construction phase and will allow Codelco to increase the estimated earnings for the initiative by more than $300 million.

Construction Begins on Santana Gold Mine

Minera Alamos Inc. announced that construction of its Santana gold mine in Sonora, Mexico, is under way. This marks a major step in the company's transition from gold project developer to gold producer in 2020. The company said itwill begin to prepare the areas designated for the leach pads and holding ponds as well as initiate road construction within the planned mine area.

"We would like to recognize the collaboration of the local community and the Mexican authorities with our team which has allowed us to reach this significant milestone in a timely fashion," CEO Darren Koningen said. "This year will be an exciting one as we build and commission our first gold mine and complete the transformation of the Minera Alamos into a new gold producer."

Antapaccay's Coroccohuayco Project Gets Approval

The Antapaccay Mining Co., a Glencore subsidiary, has been given the green light for the modification of a detailed environmental impact study (MEIA) regarding the development of the Coroccohuayco project in Espinar, Peru, as a new mining area, as well as the revival of some components in the Tintaya area, and modifications to the Antapaccay mining unit and the Tintaya expansion (Cusco), as reported by the Peruvian news agency *Gestión*.

The MEIA includes changes in the components in Antapaccay, such as the modification of the mining plan of the northern and southern pits and dumping area expansions. The plan includes a 15.5-year mine life. Also, the plan proposed the reactivation of the pits located in the northern zone of Tintaya, where copper oxides and copper sulphides minerals will be extracted through conventional open pits.

The request for the approval of the MEIA was submitted in April 2018. According to the Ministry of Energy and Mines, the investment for Coroccohuayco integration is planned at $590 million. The integrated project contemplates a life cycle of approximately 34 years. It is divided into three stages: the construction of Coroccohuayco and the Antapaccay-Tintaya operation (14 months); a subsequent operation in both areas (22 years); a closing stage (five years); and a conceptual post-closing stage (five years).

Minera Antapaccay's activities cover two areas, the Antapaccay (development area) and Tintaya (enrichment zone, including tailings disposal), which are called Antapaccay-Expansion Tintaya.

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Resolute Sells Ravenswood Gold Mine

The Ravenswood mine in Queensland has produced almost 2 million oz since it opened in 2004.

Resolute Mining Ltd. signed a legally binding agreement to sell the Ravenswood gold mine in Queensland for a total consideration of A$300 million ($207 million) to a consortium that includes EMR Capital and Golden Energy and Resources. The transaction is expected to be completed by the end of March and the proceeds of up to A$300 million consist of A$100 million ($69 million) of upfront value and up to A$200 million ($138 million) in potential payments, which are contingent on future gold prices, future Ravenswood gold production and the EMR Capital's investment outcomes from Ravenswood.

The transaction has been structured to maximize Resolute's exposure to the future success of the Ravenswood Expansion Project while transferring the capital expenditure funding requirements and development risk to a highly credentialed and experienced consortium with a strong relevant track record in successful project development, according to the company.

EMR Capital and GEAR are world-class mine developers and operators with outstanding track records of value generation, John Welborn, CEO and managing director, Resolute Mining, explained.

Ravenswood has been a consistent performer for Resolute for more than 15 years. Since acquisition in 2004, Resolute has mined and processed more than 40 million metric tons (mt) of ore and produced almost 2 million oz of gold. The Ravenswood Expansion Project, as defined by Resolute, calls for the development of two large open pits at Buck Reef West and Sarsfield. The company estimated that the expansion could deliver an addition 1.5 million oz per year (oz/y) for more than 10 years at all-in sustaining costs of A$1,097/oz ($823/oz).

Rio Tinto Awards Construction Contract to Mondium

Rio Tinto has granted Perth-based Mondium a contract valued at approximately A$400 million for the design and construction of the Western Turner Syncline Phase 2 (WTS2) mine in the Pilbara region of Western Australia. Mondium will undertake all engineering and design, procurement and site construction works associated with the WTS2 development, including the process plant, overland conveyor and non-process infrastructure.

The work is expected to create 450 jobs starting in the first quarter of 2020 and is expected to be completed in 2021.

The WTS2 is part of Rio Tinto's Greater Tom Price operations in the Pilbara. In November, a $749 million (A$1 billion) investment in the mine was approved. The investment will facilitate mining of existing and new deposits and includes construction of a new crusher as well as a 13-kilometer conveyor.

Oz Minerals Begins Producing Concentrate at Carrapateena

OZ Minerals has begun producing copper concentrate at its recently developed Carrapateena sublevel caving mine 160 kilometers (km) north of Port Augusta, South Australia. Mine ramp up to a planned rate of 4.25 million metric tons per year (mt/y) will take about 12 months.

Life-of-mine production of metals in concentrate is planned to average 65,000 mt/y of copper and 67,000 ounces per year (oz/y) of gold. Production during 2020 as the ramp up progresses is expected to be in the range of 20,000 mt to 25,000 mt of copper and 35,000 oz to 40,000 oz of gold.

A block cave expansion study is currently in progress, considering the potential for developing a block-caving operation in the lower levels of the Carrapateena mine and expanding average annual production of copper in concentrate to a range of 105,000 mt/y to 125,000 mt/y.

Achieving production of first concentrate at Carrapateena met the fourth-quarter 2019 schedule mapped out when OZ Minerals' board of directors approved the project in August 2017. Preproduction capital costs to production of first concentrate were $970 million.

More than 280,000 mt of development ore was stockpiled on the surface as the mine entered a 12-month ramp-up period.

Rio Tinto Earns 51% Interest in Citadel Project

Rio Tinto has earned a 51% interest in Antipa Minerals' Citadel gold-copper project 400 kilometers (km) east of Port Hedland, Western Australia. The companies have formed a joint-venture company to develop the project, with Rio Tinto as operator.

Rio Tinto earned its 51% interest by funding A$11 million in exploration of the project. The company had until January 30 to elect whether to sole fund an additional A$14 million within three years to increase its interest in the joint venture to 65%.

The Citadel project comprises a 1,330-km^2 tenement package in the Paterson province in northern Western Australia, 5 km east of Rio Tinto's Winu copper-gold-silver deposit. The Citadel project hosts a current global mineral resource of 63.8 million mt grading 0.8 grams/mt gold and 0.2% copper for 1.6 million ounces (oz) of contained gold and 127,000 mt of contained copper. The deposit remains open in most directions.

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Barrick Solidifies JV With Tanzania

The joint venture gives Tanzania a say in operating decisions at the North Mara (pictured above), Bulyanhulu and Buzwagi mines previously owned by Acacia. (Photo: Barrick)

President of the United Republic of Tanzania Dr. John Pombe Magufuli and Barrick Gold Corp. attended a signing ceremony to formalize the establishment of a joint venture between Barrick and the government. The joint venture, according to CEO Mark Bristow, will give the government full visibility of and participation in operating decisions made for and by the North Mara, Bulyanhulu and Buzwagi mines, which were previously operated by Acacia Mining.

This action will take "Barrick's policy of partnership with its host countries to a new level," Bristow said.

The agreement also ratifies the creation of Twiga Minerals Corp., the management company jointly owned by the government and Barrick that will oversee the management of Barrick's local operations, which are now owned 84% by Barrick and 16% by the government. The deal provides for a 50/50 sharing in the economic benefits generated by the mining operations after the recoupment of capital investments.

This agreement marked the end of the long impasse between the government and Acacia over unpaid taxes and fines, which led to the closure of North Mara and the freezing of export concentrate from the two other operations.

Barrick took over the management of the mines after its buyout of the Acacia minorities. Since then, it has negotiated the reopening of North Mara and is engaging with the mines' host communities.

Barrick will partner with the University of Dar es Salaam and commit up to $10 million in funding over a 10-year period for training and skills development in the mining industry, and will also commit up to $40 million to upgrade the road between Bulyanhulu and Mwanza as well as constructing a housing compound and related infrastructure.

"Since taking over the operatorship, we have been engaging with local communities to restore the mines' social license to operate and we are cooperating closely with the authorities to address the environmental issues at North Mara," Bristow said. "In addition, we are working on a local supplier strategy as well as a community development plan to create sustainable economic opportunities for the people around our mines."

Tanzanian nationals are being recruited and trained to replace expatriate employees as has been successfully done at Barrick's other African operations, according to the company.

Sibanye-Stwillwater Achieves 10M Fatality-free Shifts

On January 26, Sibanye-Stillwater's South African gold operations achieved 10 million fatality-free shifts. This is a significant milestone, which has never been achieved in the history of these gold operations, nor in the history of the South African deep-level gold mining industry, according to the company.

The South African gold operations are among the deepest in the world, extending to more than 3 kilometers (km) below the surface. The achievement was accomplished by 30,000 employees and contractors working safely for 8.5 hours a day over a 519-day period since August 25, 2018.

"Milestones like these illustrate what can be achieved when all stakeholders contribute constructively and work together," CEO Neal Froneman said. "Special appreciation goes to our workforce for working safely and living our CARES values (commitment, accountability, respect, enabling, safety).

"Our intense focus on safe production across the group continues, with the implementation of longer-term safety and cultural interventions a strategic priority. We continue to promote meaningful engagement with all our stakeholders."

Ivanhoe Studying Smaller-scale Start at Platreef

Ivanhoe Mines reported in mid-January that its South African subsidiary, Ivanplats, is fast-tracking a feasibility study of a smaller-scale, early-stage development plan using Shaft 1 as a production shaft at its Platreef PGM-copper-gold mining license on the Northern Limb of the Bushveld Complex in South Africa's Limpopo province.

Shaft 1 will be the Platreef mine's ventilation shaft. Development of Shaft 2, which will be the production shaft at full development, is ongoing.

The early production plan would allow Platreef to benefit from current high palladium and rhodium prices, which have soared in recent months.

Development of Shaft 1 had reached a depth of 957 meters (m) below surface at the time of the announcement. The shaft is scheduled to be completed to a final depth of approximately 1,000 m by the end of July. Work on Shaft 1's 950-m-level station, the shaft's third and final station, was scheduled for completion in March.

Platreef has an estimated 26.8 million ounces (oz) of palladium in current indicated mineral resources and an additional 43 million oz in current inferred mineral resources at a cut-off grade of 2 grams/metric ton (mt) three platinum group elements plus gold (3PE+gold).

Platreef also has an estimated 1.8 million oz of rhodium in current indicated mineral resources and an additional 3.1 million oz in current inferred mineral resources at a 2 g/mt 3PE+gold cut-off. The rhodium in the Platreef ore is strongly correlated with both palladium and platinum.

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Kumtor Receives Mining Permits

After six weeks, search operations at the Lysii Waste Rock Dump are unable to locate two missing miners.

Centerra Gold Inc.'s Kumtor mine in the Kyrgyz Republic has received all the necessary approvals and permits to recommence open-pit mining operations and to continue milling activity for the remainder of 2020. The relevant Kyrgyz state agencies have approved the company's 2020 mine development plan for the Central Pit Development, including the revised waste dumping plan and special safety measures to place waste rock material in the Central Valley Waste Rock Dump and the Sarytor Waste Rock Dump.

Open-pit mining operations are currently ramping up and are expected to be in full mining production soon, while the mill continues to process stockpiled ore as planned for 2020, according to the company. In addition, Kumtor is continuing its own internal review and cooperating with Kyrgyz authorities' inquiries in relation to the Lysii Waste Rock Dump.

After six weeks, the search operation at the Lysii Waste Rock Dump returned no sign of the two missing employees. With the consent of the families and the relevant Kyrgyz state agencies, including the Ministry of Emergency Services, the decision was made to stop the search effort. A funeral prayer was held at the site attended by family members, relatives and community supporters.

"Our thoughts, condolences and prayers are with our employees, families and our deepest appreciation is to all those involved in the search efforts," the company said in a statement.

In related news, Centerra announced that the first gold pour from its Öksüt Mine in Turkey occurred on schedule and ahead of budget. Additionally, the project achieved a significant safety milestone this week, achieving 2 million work hours Lost Time Injury Free.

President and CEO Scott Perry said, "This is an important milestone for the project and for the growth of the company as Öksüt is now our third operating mine and our third source of gold production going forward. Reaching the first gold pour is a testament to the dedication and hard work that our Öksüt team has put in to reach this goal safely."

"This milestone would not have been achieved without the initial conviction and perseverance from the Centerra exploration team given that the Öksüt mine, originally started as a greenfield exploration venture in 2009."

Former Mongolian Prime Minister Faces Charges

Former Prime Minister of Mongolia Chimediin Saikhanbileg is currently facing four charges stemming from his role in negotiating a 2015 agreement with mining firm Rio Tinto for the development and foreign investment in the Oyu Tolgoi underground copper mine project located in Khanbogd sum, prospectively the largest mining development in the country's history.

"The charges against Saikhanbileg are thoroughly without merit and lack evidence," said lawyer Robert Amsterdam, founder of Amsterdam & Partners LLP, which was retained by Saikhanbileg.

"What we have in this case is a textbook example of the abuse of the anticorruption process to commit a grave injustice, including direct personal interventions by government officials with judges to rig politically motivated outcomes against their opponents," Amsterdam said. "Former Prime Minister Saikhanbileg is innocent of these farcical charges, and we intend to shine a light on the abuses being committed in this case."

Saikhanbileg is currently in the United States. Numerous other members of the opposition Democratic Party, the independent judiciary, and members of media have come under intense pressure since the 2017 election of President Battulga Khaltmaa, according to Armstrong.

Organizations such as Transparency International and Amnesty International have issued sharp warnings about President Battulga's expansion of presidential powers, including a new law he passed allowing him to dismiss judges and senior members of the nation's legal system via his role as chairman of the National Security Council.

"Former Prime Minister Saikhanbileg negotiated these mining agreements with full transparency and parliamentary authority conforming to the letter of the law," Amsterdam said. "This baseless campaign of persecution represents not only an attack on the country's judicial system, but also damages Mongolia's foreign investment profile by engaging in blatant resource nationalism."

Amsterdam & Partners LLP intends to explore a broad range of response options on behalf of former Prime Minister Saikhanbileg.

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Alamos Expands Resources at Island Gold

Alamos Gold has announced new results from surface and underground exploration drilling at its Island Gold mine in Ontario, further extending high-grade gold mineralization beyond existing mineral resources in all three areas of focus. The 2019 drilling program focused on further expanding the downplunge and lateral extensions of the Island Gold deposit, with the objective of adding near-mine mineral resources across the 2-kilometer (km)-long Island Gold Main Zone.

The program has been successful in extending high-grade gold mineralization across all three areas of focus: Main, Western and Eastern extensions.

Alamos President and CEO John A. McCluskey said, "We had another exceptional year at Island Gold operationally, financially and through the drill bit. The operation produced 150,400 ounces (oz) of gold in 2019, achieving a new record for the fifth consecutive year, and set a new record for free cash flow.

"With the ongoing exploration success, we expect further growth in Island Gold's mineral reserves and resources with our year-end update. This growth will be incorporated into the Phase III expansion study that we plan to complete during the second quarter of 2020. We expect this study will showcase a larger, extremely profitable, long-life operation,"

A total of $21 million has been budgeted in 2020 for surface and underground exploration at Island Gold, an increase from the 2019 budget of $19 million. The focus remains on continuing to define new near-mine mineral resources. The 2020 budget includes 46,000 m of surface directional drilling, 30,000 m of underground exploration drilling, and 900 m of underground exploration development to extend drill platforms on the mine's 340, 620, 790 and 840 levels.

A regional exploration program that includes 10,000 m of drilling is also planned in 2020, focused on evaluating and advancing exploration targets outside the main Island Gold mine area on the 9,750-ha Island Gold property.
(*www.alamosgold.com*)

Exploration Briefs

Rox Resources, in conjunction with its joint-venture partner **Venus Metals**, has reported exceptional gold grades from drilling on the Grace prospect at the previously mined Youanmi property 480 km northeast of Perth, Western Australia. Assays from a round of drilling concluded in late December 2019 included intercepts of 8 meters (m) grading 37.25 grams per metric ton (g/mt) gold from 44 m down hole and 4 m grading 18.06 g/mt from 16 m down hole.

These results are interpreted to be close to true width and define a series of moderate, west-dipping, quartz-hosted gold lodes in granite that remain open at depth and along strike. The drilling has identified new gold-bearing veins that are yet to be tested both above and below the Grace Lode previously identified in recent drilling.

A reverse circulation drilling rig and crew were redeploying to Youanmi in late January to commence a drill-out of the Grace prospect in sufficient detail to facilitate resource definition. Additionally, several diamond holes are planned to characterize the wider gold-bearing veins to allow better correlation between drill sections. Initially, 5,000 m of reverse circulation and 2,000 m of diamond drilling are planned.
(*www.roxresources.com.au*)

Eldorado Gold has discovered a high-grade gold mineralization zone at its Lamaque operations near Val d'Or, Quebec. The discovery, called the Ormaque Zone, is located in a previously undrilled area approximately midway between the historically mined Sigma deposit and the currently mined Triangle deposit, in close proximity to a proposed transportation decline linking the Triangle underground mine and the Sigma mill.

Thirteen holes totaling 10,096 m of drill core have been completed to target depth in the discovery area since July 2019. Assay results have been received for seven drill holes, representing 4,424 m of the total drilling.

A preliminary economic assessment (PEA) for Lamaque has been delayed to allow for incorporation of the Ormaque zone as part of the study, including the pending assays from the 2019 drill program. The PEA will continue to consider three distinct projects: a 2.8-km ore transportation decline, upgrades to the Sigma mill to allow for increased throughput, and construction of a paste plant to provide a long-term tailings solution.

The PEA will also now include the Ormaque zone, which sits in very close proximity to the proposed decline route, enabling convenient access for potential future underground drilling and development, and synergies with the proposed decline infrastructure.
(*www.eldoradogold.com*)

Stavely Minerals has reported significant new assay results from ongoing diamond drilling at the shallow, high-grade copper-gold discovery at the Thursday's Gossan prospect on its 100% owned Stavely copper-gold project in Victoria, Australia.

The results have confirmed further growth in the known extent of the mineralization, which has now been established over a strike extent of approximately 700 m and which remains open in all directions.

Diamond drill hole SMD060 120 m southeast of the discovery hole SMD050 returned several outstanding intercepts within a very broad mineralized envelope from 19.2 m to 135.4 m (excluding 13.9 m of core loss) of 102.3 m at 0.68% copper, including 48.2 m (excluding 13.2 m of core loss) at 1.04% copper, 0.31 g/mt gold, and 14 g/mt silver from 74 m to 135.4 m down hole.

SMD060 also intercepted nickel-cobalt mineralization within the copper-gold mineralized zone similar to that observed in the discovery hole, with an intercept of 2.4 m grading 1.20% nickel and 0.08% cobalt from 116.6 m drill depth.

Stavely Minerals Executive Chairman Chris Cairns commented, "We are working on improving drill recoveries — one of our biggest challenges at the moment — especially as core losses appear to be directly related to the better-mineralized intervals."
(*stavely.com.au*)

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Teck Increases Export Capacity With New Ridley Terminals Agreement

Teck's new agreement with Ridley Terminals increases capacity to 6 million mt/y. (Photo: Ridley Terminals)

Teck Resources Ltd. has expanded its commercial agreement with Ridley Terminals for shipping coal from Teck's British Columbia operations. The agreement runs from January 2021 to December 2027, and increases contracted capacity from 3 million metric tons per year (mt/y) to 6 million mt/y with an option for Teck to extend up to 9 million mt/y. This will enable Teck to increase its shipment volumes through the Ridley terminal to provide greater flexibility and improved performance within its overall coking coal supply chain, according to the company.

"This agreement with Ridley Terminals, in combination with upgrades under way at our Neptune Terminal and our recent agreement with CN, will contribute to improved overall performance throughout our steelmaking coal supply chain," said Don Lindsay, president and CEO of Teck. "We are looking forward to building on our strong working relationship with RTI and new principal owners Riverstone-AMCI to safely and efficiently transport our product to customers."

"Teck is a long time, valued customer of RTI," said Marc Dulude, president and COO of Ridley Terminals Inc. "This agreement further solidifies our strong relationship and demonstrates our commitment to our customers to provide fast, efficient and reliable service. RTI is proud to be a part of Teck's long-term development plan and vision."

The terms of the agreement were not disclosed.

Westmoreland Finalizes New Coal Supply Agreement for Colstrip

Westmoreland Rosebud Mining announced the finalization of a new, six-year agreement to supply coal to Colstrip Generating Station's Units 3 and 4 in December. The new agreement aligns with the needs of the regulated ownership group and will continue to enable Units 3 and 4 to operate reliably. It took effect on January 1 and will continue through to at least the end of 2025.

The Rosebud mine located in Rosebud County, Montana, is a low-cost surface mining operation. Situated in the Northern Powder River Basin, near the town of Colstrip, the mine and power plant sit in close proximity to the Northern Cheyenne Indian Reservation.

Despite the closure of Colstrip's 1 and 2 Units at the end of 2019, the output from the mine will continue to provide sufficient energy to power the energy needs of approximately 1 million typical U.S. homes.

Indonesia's PT Bukit Asam Plans to Increase Production in 2020

Indonesian state-owned coal miner PT Bukit Asam is targeting around 30 million metric tons (mt) of coal production for 2020, according to *Reuters*. That's a 1.5-million-mt increase over the company's 2019 production.

Bukit Asam Director of Commerce Adib Ubaidillah said 60% of the 2020 targeted production will be bought by the Indonesian power utility PLN and 30% will be shipped overseas, mostly to India.

He said, "We will let the rest, the 10% float on the spot market."

The company also said it had scrapped a plan to build a coal gasification project in Riau on Sumatra and focus on plants it is building near its mine in Tanjung Enim in South Sumatra, for efficiency reasons.

PT Bukit Asam Tbk received Indonesia's Most Trusted Companies Award in Good Corporate Governance Awards 2019 organized by *SWA Magazine*. "The GCG implementation was highly supported by the performance of our employees and a good company management system and hence made us win this award," said Arviyan Arifin, president, PT Bukit Asam Tbk.

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(Regional News-U.S. & Canada - from p. 10)

Paramount President and CEO Glen Van Treek said, "This permit, along with the previously received Conditional Use Permit, represents substantial, incremental success in the permitting process. The next milestone is the notice that our application is complete."

The company is currently finalizing the Amended Plan of Operation that it will submit to the U.S. Bureau of Land Management, initiating the federal permitting process.

The feasibility study is well under way and being led by Ausenco Engineering Canada Inc. with expected completion in mid-2020.

Atacama Resources Acquires Kirkland Lake Gold Project

Atacama Resources International Inc. acquired the Tannahill Gold Property located 35 kilometers northeast of the prolific Kirkland Lake Gold Camp in northeastern Ontario. The multiyear deal will provide Atacama with a 100% interest in the property subject to a 2% Net Smelter Return with a buyback option.

Past work at Tannahill has identified two parallel, gold bearing structures: the Upper and Lower Zones.

Of the 28 diamond drill holes drilled into the gold bearing zones, 27 intersected significant gold values. The Lower Zone has returned the higher gold grades to date, including visible gold in four holes, and seems to hold the greatest exploration potential.

Crews are on site to locate the old cut lines and drill hole casings. All of the core from the 1998 drill program is available for evaluation and further analysis.

Future work will include geophysical surveys, prospecting, geological mapping and eventual diamond drilling to expand the existing gold zones.

"Good gold grades and widths, the proximity of the Tannahill project to existing infrastructure, and just 35 kilometers from an existing gold mining area makes this project extremely attractive," President and CEO Colin Keith said. "This is another piece of the puzzle for our company and a key part of our continued development."

Taseko Advances Yellowhead Copper Project in BC

Taseko Mines has reported the results of recently updated technical work on its Yellowhead copper project in southeast British Columbia. Included are a 22% increase in recoverable copper reserves and significantly improved project economics.

Taseko is now considering development of a 90,000-metric-ton-per-day (mt/d), open-pit mine and concentrator producing an average of 180 million pounds per year (lb/y) of copper in concentrate over a mine life of 25 years. Production during the first five years of operations would average 200 million lb/y of copper in concentrate.

The Yellowhead project has 817 million mt in proven and probable reserves grading 0.29% copper equivalent. Total life-of-mine production is estimated at more than 4.4 billion lb of copper, 440,000 ounces (oz) of gold, and 19 million oz of silver. Total preproduction capital costs are estimated at C$1.3 billion.

Taseko CEO Russell Hallbauer said, "With an average copper equivalent grade of 0.35% combined with a very low on-site operating cost of C$10/mt milled, the mine-site operating margin is a robust C$16/mt, or roughly C$500 million/year for the first five years, at US$3.10/lb copper. The 440,000 oz of gold and 19 million oz of silver, alone, will generate over C$1 billion of byproduct revenues over the mine's life.

"Yellowhead has the potential to be one of the largest open-pit copper mines in North America.

Aquila Receives Amended Permits for Back 40 Mine

Aquila Resources Inc. announced that the Michigan Department of Environment, Great Lakes and Energy (EGLE) approved amendments to Aquila's Nonferrous Metallic Mineral Mining Permit and its Michigan Air Use Permit to Install for its Back Forty Project. The amendments update the permits to align with the project design outlined in the August 2018 open-pit Feasibility Study as well as in its Wetlands Permit that was issued June 4, 2018.

The Back Forty Project, located in Michigan's Upper Peninsula, could produce more than 500 million lb of zinc, 51 million lb of copper and 468,000 oz of gold.

NEWS - CALENDAR OF EVENTS

MARCH 1-3, 2020: **The Prospectors & Developers Association of Canada's annual meeting, Toronto Convention Center, Toronto, Canada.** Contact: Web: www.pdac.ca.

MARCH 30-APRIL 4, 2020: **Alaska Miner's Association's Spring Biennial Conference, Carlson Center, Fairbanks, Alaska.** Contact: Web: alaskaminers.org.

APRIL 20-24, 2020: **Expomin, Santiago, Chile.** Contact: Web: www.expomin.cl.

APRIL 21-23, 2020: **MiningWorld Russia, Moscow, Russia.** Contact: Web: www.www.miningworld-events.com.

MAY 3-6, 2020: **Canadian Institute of Mining (CIM), Vancouver, Canada.** Contact: Web: https://convention.cim.org/2020.

MAY 23-30, 2020: **ALTA 2020 Nickel-Cobalt-Copper, Uranium-REE, Gold-PM, In Situ Recovery, Lithium & Battery Technology Conference & Exhibition, Pan Pacific Hotel, Perth, Australia.** Contact: Web: www.altamet.com.au/conferences/alta-2020/.

JUNE 1-5, 2020: **Elko Mining, Elko, Nevada, USA.** Contact: Web: www.elkocva.com.

JUNE 2-5, 2020: **UGOL & Russia, Novkutznesk, Russia.** Contact: Web: www.ugol-rossii.com.

JUNE 9-11, 2020: **Euro Mine Expo, Skellefteå, Sweden.** Contact: Web: www.euromineexpo.com.

SEPTEMBER 7-11, 2020: **Electra Mining, Johannesburg, South Africa.** Contact: Web: www.electramining.co.za.

SEPTEMBER 28-30, 2020: **MINExpo INTERNATIONAL, Las Vegas, Nevada.** Contact: Web: www.minexpo.com.

MARCH 14-17, 2021: **Haulage & Loading 2021, Hilton El Conquistador Resort, Tucson, Arizona.** Contact: Web: www.haulageandloading.com.

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Nyrstar Rises to Constellation of Champs

In 2019, a mine rescue team from a Tennessee zinc operation went from 'getting killed to killing it' at the biggest competitions in the U.S.

By Jesse Morton, Technical Writer

With their game faces on, from left, Nyrstar's Philip May, Wayne Vineyard and Adam Whittaker work through a problem. The Nyrstar team won the field at three regional competitions in 2019. (Photo: Nyrstar)

The next investment Nyrstar may have to make in its east Tennessee mine rescue team could be a new trophy cabinet. The old one, filling a corner in the small company office building in Strawberry Plains, Tennessee, USA, is at maximum capacity. And it has yet to gather dust.

That's because the trophies and plaques filling the display are almost exclusively from within the last couple of years. The big ones are from 2019.

The mine rescue program, the baby of Bill Hart, manager of Coy mine, continues to gain steam and attention. "We've come out of nowhere and we've been noticed," Hart said.

The success has made the team a center of gravity of sorts, drawing attention from a range of operators and organizations within the mine rescue space. The Mine Safety and Health Administration (MSHA) now regularly extend invites to attend events and compete. Academics reach out for opportunities to meet, discuss the latest and "pay it forward and provide a service," Hart said. "We've seen a bit of that lately, those sorts of things coming our way."

Therefore, it was only fitting for Hart and his A-Team to host *E&MJ* to talk about the parabolic rise of the program. In the interview, sports movie clichés were bandied about flippantly. And duly so, for the tale is, after all, about an underdog. It wasn't so long ago that the program didn't even exist. Instead, their team was barely MSHA compliant.

Origins

Five years ago, joining Nyrstar's East Tennessee Mine Rescue team meant little more than a free lunch and some on-the-clock downtime. The purpose of the team was to maintain compliance with federal standards. Typically, it would compete in the nearest regional competition, but otherwise it was basically invisible.

In early 2015, Hart started with the company as the east Tennessee operation's health and safety manager. Hart had a background in coal. In 2006 and 2007, he worked on the mine rescue program under safety expert and mine rescue hall-of-famer Darren Blankenship at the Pinnacle mine in Pineville, West Virginia. The program there was viable, the team was competitive, and the experience was formative, Hart said.

"I saw how mine rescue was run in the coal industry, which was at a totally different level than what I was exposed to here initially," Hart said. "At Pinnacle, I was exposed to what good looked like."

Hart said he seized the opportunity at Nyrstar to build a program, set higher expectations and raise standards. He stayed in touch with and sought advice from Blankenship. Hart also worked to gain the full support of the operation's general manager, Archie Eksteen, who had a background in mine safety. "I took full advantage of that," Hart said.

Embracing the change, Eksteen launched a safety initiative. With it, the operation would seek to become "the safest, most productive underground zinc mine in the world," Eksteen told *E&MJ*. "To reach this goal, we have to be the best in many areas and that includes mine rescue," he said. "Think about it. Where would you rather work? At an operation where you have to fend for yourself in an emergency, or at a mine where you know someone's got your back, no matter what type of emergency it is?"

Eventually, Eksteen would set the goal "that we would win first place in a mine rescue contest before December 2019," Hart said.

It was an ambitious initiative. Team morale was down. The talent pool drew from three mines and a mill, and team members would have to take on responsibility above and beyond that of their normal jobs. That additional responsibility would include classes, workshops, practice and study that oftentimes would occur on personal time.

"There was a need not only for more in-depth mine rescue training but technical rescue as well," Hart said. "We had no rope rescue, advanced medical training or vehicle extrication capabilities," he said. "We didn't have confined space capability or firefighting experience. We had to start focusing on all that."

In 2016, the mine rescue coordinator resigned. Hart hired Brian Millington, who, though young for the position, had worked his way up in the company and had a range of applicable experiences, to include training as a civilian emergency medical technician. The hire was propitious. Blankenship told *E&MJ* Millington became "the glue that holds the group together."

To improve team morale, Hart began looking at ways to make team membership more appealing to personnel, to retain the talent, and to incentivize growth. Previously, "the mine rescue guys were given a little bit of hourly monetary compensation, an additional $0.33 per hour," Hart said. "I thought they needed to see the benefits of being in a program. We restructured the financial aspects of the program and did two annual payouts, around July 4 and Christmas."

With the Millington at the helm and a bigger kitty came a competitive selection process, which included interviews and testing. "They go through a formal process to actually be accepted on to the team," Hart said.

Membership brought expectations and standards. "There is an expectation that you are the cream of the crop, and you have to act like it at your job and you have to lead the way in safety and do things that people are normally reserved in doing," Hart said. "You have to take the lead."

Hart said the selection process and expectations "weeded out" team members who were only in it for the downtime. "Some people found that it was a little more than they bargained for and they ended up turning over and becoming a former mine rescue team member."

Philip May, trainer, mobile equipment, said the selection process "trimmed the fat." The team captain, Wayne Vineyard, described membership on the old team as a "revolving door. But everybody on it now seems to be dedicated."

Training

Nyrstar provided Hart with funds to buy new gear and to field up to three teams instead of just one. The program had the support of management, who would find cover for personnel who would sometimes be away at training and competitions.

In Q4 2016, a new training regime launched. It started with a week with Blankenship at the National Mine Health and Safety Academy in Beaver, West Virginia. "That was something that the rescue team had never done," Hart said. "We took advantage of the academy to get our guys some higher-level training than what they had been exposed to here previously."

That set the tone, and the team has been back annually for similar training.

In Q1 2017, at the behest of Millington, the team underwent emergency medical responder training, a six-week course with classes often occurring on what would previously be considered personal time. That culminated with state and national tests and certifications.

The training, in its intensity and advanced subject matter, was a radical departure from what the previous team underwent, Anthony Calk, mine engineer, Coy mine, Nyrstar, said. "That was the first paradigm shift."

Once certified, the team was on par with local responders, Michael Robb, exploration geologist, Nyrstar, said. "That way, beyond responding to mine emergencies, we can help out in the greater community as well."

Advanced certifications became possible and a goal for some, Evan Gulling, senior mine geologist, Nyrstar, said. "Some of us are specializing," he said. "Some are naturally becoming more advanced in particular areas."

Next up was rope rescue training, which entailed 40 hours over the course of two weekends. Team members became certified technical rope rescue technicians. "We did low-angle and high-angle training with that," Calk said. "We wanted to have enough rope to get down to the bottom of our deepest shaft."

High angle references rappelling. "We have the ability to do 2,000 ft," May said. "We can tie two ropes together and we can do 4,000 ft."

Hart said the certification is important "because we do shaft mining at all three of our operations where you have potential for a guy to be trapped or suspended from a harness." Previously, "we didn't have a good way to get to somebody in the event of an emergency," Hart said. "Now, I am 100% confident if we had someone get into a bad spot that within 15 minutes we could get there, rappel down and save his life."

Low angle refers to steep slopes and embankments.

The program has gear and personnel for three rope rescue teams. With the certification, the team can help out in non-mine emergencies. In 2018, the team used the rope rescue gear and skills to pull someone out of a sinkhole in a neighboring county. The team also responded to a call about teens trapped in a cave.

Since receiving the certification, team members have taken additional courses and been recertified. The team plans to send three people per year to get advanced certifications.

At the same time, hands-on mine rescue training with Blankenship accelerated and intensified. Gulling said Blankenship was instrumental in shaping thought and discipline. "He brought a lot of experience from coal and changed the way we thought about things and how we go about things," he said. "That is one of the reasons we are more successful compared to other teams."

Blankenship mentored Millington who could then work with the teams. "I thought I knew a lot about mine rescue, but when I first met Darren I found out I didn't know anything," Millington said. "With Darren, I could see really quick I had a long way to go."

Blankenship would come into town quarterly and work with the team, sometimes for a couple days, sometimes for a week.

In Q3 2017, Millington brought in the 16 mine rescue team members and gave a written test based on the written exams he had seen previously in contests. "The seven that scored the highest would be on

Nyrstar's 2019 win streak included three regional competitions. Prior to 2019, the team had not won a regional contest. Consultant Darren Blankenship attributes the success to hard work, team cohesion and leadership. (Photo: Nyrstar)

the first team," Millington said. "The next seven would be on the second team."

From that process, a "brand new team" emerged, which "was predictable," Millington said.

The partition "didn't go over well with some that were put on the second team," Hart said.

Some harbored beliefs that seniority would be of elevated value, Millington said. "I wasn't looking at seniority," he said. "I was looking at who are the best possible people to be successful."

Vineyard said that a few took it personally. They soon got over it, he said. "Everything is good now."

Those who made the first team, dubbed the A-Team, felt "honored, but knew they were going to have to start performing," Vineyard said.

May said on the day he was offered the position, he felt elated but had concerns. "I knew the commitment it was going to take," he said. "I'm not the type of person that is going to do anything halfway. It is all or none."

Making the team, the attention it brought, and the competitions that followed, brought about a personal change of focus, May said. "You've got a lot of eyes on you every single day, not only from management but from coworkers," he said. "Aspects of my life and job that I didn't pay attention to were amplified."

Hart said the A-Team was the best "we had to offer. There was no buddy system, no friends. It is what it is." He also said that, going forward, A-Team members could be cut for work site safety infractions. "I'm not going to have any negativity associated with this program."

Mine manager Bill Hart receives a plaque at the Southeast regionals in Franklin, Tennessee, in 2018. Nyrstar helped fund the contest, where the team 'got smoked,' Hart says. (Photo: Nyrstar)

Millington said nobody aced the test and that the scores revealed that team members would have to study more on personal time. "The training that we do, we do it here," he said. "We don't have time here to study or to read the books. They have to do that on their own time."

And then, Millington said, "In 2017 and 2018, we started venturing out and doing contests."

The Contests

Prior to 2017, Nyrstar East Tennessee had only competed regionally.

Gulling suggested the team attempt the Missouri Mine Rescue Contest, in Rolla, Missouri, in September 2017, where, he said, previously the competition had been intense.

In the contest, the wheels came off, and the team finished in the bottom 25%. "We got smoked," Hart said. "It was a wakeup call."

May described the contest as "outside of our norm." The team was reliant on a communication system, based on radios tethered to a cable, that failed. "It failed quite miserably. I almost had a nervous breakdown," he said. "I took it personal, getting beat down, and lost my cool."

Millington said the event laid bare "all of our weak areas." Identified weaknesses included teamwork, mapping and communications. Subsequently, three members of the team were cut and replaced with people May referred to as "the college kids," aces at problem solving and test taking.

Feeling the heat, Hart told corporate it was "still early" in a "three-to-five-year plan" and pushed for continued support and funds.

More training with Blankenship followed. Blankenship and Millington sought to bring team members out of their comfort zone to inspire different thinking patterns.

Blankenship said the training Nyrstar requested and underwent was diverse. "On several occasions, they would train for competitions, working several competition scenarios, then participate in other mine rescue trainings not related to competitions."

Vineyard said that with 20 years of experience in mine rescue, he was "reluctant to change." May said such resistance was quickly broken down by leadership. "Blankenship forced his will," May said.

Roles changed. Swim lanes were defined for efficiency. Equipment was upgraded.

The next competition was the Mine Rescue Skills Contest, hosted by Blankenship and the West Virginia Mine Rescue Alliance, at the academy in Q2 2018. Described as invitational, it drew a handful of teams, predominantly from coal mines.

The team rolled out the new system, May said, and zeroed the field. "We swept it, all divisions."

Hart said the level of teamwork reached the level he had previously seen at Pinnacle. "That was really cool."

The development was a major milestone and achieved the company goal to win a mine rescue contest. For Eksteen, the goal itself was a "leap of faith," Hart said. Attaining it brought relief, but more importantly validation, he said. "We started believing that we had a good team."

For corporate, expectations then rose. "It changed everything," Hart said. At company meetings with the big bosses from around the globe, "we weren't talking about production tons. We weren't talking about keeping everybody safe. We were talking about winning mine rescue contests," Hart said. "That had not been a major topic of discussion with the corporate leadership team up until that point. It created a whole new level of expectation."

And about that time, the east Tennessee ops won the company's safety award for 2017. "It came together at the same time," Hart said. "We became No. 1 at Nyrstar in every aspect of the business: profitability, cost management, mine rescue performance, health and safety."

It was a peak moment, Hart said. However, even with the result, he would be challenged to maintain uncontested buy-in from corporate and management. "I had to keep pushing to make sure it stayed on the map."

Ultimately, though, the win was a headrush that couldn't be sustained, Millington said. "It overexcited everyone."

At the Southeast Regional Mine Rescue Contest, in Franklin, Tennessee, in May 2018, expectations were high. At Hart's urging, Nyrstar shelled out and co-sponsored the contest. Eksteen took time from the office and drove 3.5 hours to watch. The pressure was real, and Hart wanted a top-three finish.

Fifteen teams competed, including "all your big players," Hart said. "It was

the same level of competition that we saw in Missouri."

The team competed well, but things "ended badly," May said.

Robb said the result was in part self-inflicted. Gulling said the inexperience of some of the newer team members surfaced to sabotage efforts. While the team worked swiftly through the problems, "the speed ended up biting us," May said.

The result grounded team morale and drew renewed commitment to training, Hart said. "Of course, I had to come back and explain to my boss how we got smoked after ponying up a bunch of cash to have a mine rescue contest."

Next, was the National Mine Rescue Competition 2018, in late July in Lexington, Kentucky. "It was the first time that Nyrstar had ever sent a team to nationals," Millington said.

More than 40 teams competed. Vineyard said the new system proved viable in the contest. May compared it to a hot rod. "You've upgraded it, street raced it a couple times and now you're on the track," he said. "We let it rip."

Nyrstar placed ninth on the field and 19th overall. "For me," Hart said, "that was a win, to go from having never competed at the national level to placing in the top 10." It proved "we would be able to continue the efforts of the program into the next year."

May said the team felt they were in over their heads and left thinking they could have won it. The result nixed any self-doubts the team may have harbored and ensured buy-in from the top going forward, Millington said. It also fed the belief that training pays off.

"Seeing those beliefs manifest results was exciting for everybody," Hart said.

Gulling said the team was, at that point, determined to max out. During nationals, the team observed the others to note what worked well and what failed. Other teams, Gulling said, were more efficient at the start. Also, other teams knew and pushed the rule boundaries.

Afterward, what formerly would have canceled training no longer would, May said. "We worked problems in the snow. We worked problems in the rain."

Millington went to the coal nationals to observe, and brought back insights that he put into action. He was recruited for and joined the national mine rescue competition rulemaking committees. "Doors started opening up," Hart said.

Hart and Millington mapped the course for 2019. "We had a very robust training plan and competition schedule, and we had the funds to do it," Hart said. On the calendar were the southern regionals and the southeastern regionals.

In Q4 2018 and Q1 2019, team members all went through the fire academy with the New Market Volunteer Fire Department and became certified firefighters with the state. The training spanned 360 hours. "Not only that," Robb said, "we all went through hazardous materials awareness and hazardous materials operations training."

The team learned about securing a scene, the dangers associated with different chemicals, assessing the risks, how to respond, and the incident command system. "The main part was they got to do live fire scenarios and get certified on live fire," Millington said. "And 90% of mine rescue calls are fires." Going forward, the team would do live burns twice a year, he said.

In February 2019, Hart and Millington were invited by MSHA to compete in the Surface Mining Emergency Response Competition at the Florida Public Safety

Consultant Darren Blankenship says the Nyrstar team requests and undertakes varied training exercises, many of which aren't centered on contest-style problems. (Photo: Nyrstar)

Institute near Tallahassee, Florida. The event was unscheduled and not in the budget. To make it work, the two decided to set the focus for training for the the year on first aid and emergency response "and close that gap," Millington said. Eksteen signed off on it, and "we only took the first aid guys down," he said.

More than a dozen teams competed. Nyrstar placed third and "was heavily featured in their promotional material," Hart said. "It is like a Nyrstar commercial."

Back in Tennessee, training under Blankenship became a monthly event.

In April 2019, the team competed in the Southern Regional Mine Rescue Contest in New Iberia, Louisiana, a 12-hour drive away. Almost 20 teams competed, including a handful of former national championship teams. "I knew going into that one we would get a gauge of how far we had come," Hart said.

To prep, the team spent three days going over problems from previous contests going back as far as three years, Millington said. "We worked problem after problem after problem."

The strategy worked. On day one, Nyrstar zeroed the field with minor discounts. Day two was a repeat performance, but this time onlookers gathered to watch. As the event wound down on day three, fellow competitors and even some of the judges were treating them differently. It was becoming obvious. "We knew we did well, but we didn't know how well, until they called our name." Millington said.

Nyrstar won it, and won big. And Millington won the award for best team trainer.

Hart said he "thought they were lying to me when they called and told me the result." He described the experience as surreal. "I thought they were messing with me," he said. "But that result was proof that when you have a vision and develop a strategy and surround yourself with great people, great things can happen."

Vineyard said it was a day he thought would never come. "It was something to relish for a minute," he said. "But it raised the bar."

Gulling said the result pulled the team from obscurity into the limelight. "We went from going to a competition and getting killed to going to a competition and killing it," he said. "I think everybody at that competition was tired of hearing about Nyrstar."

With the trophy on his desk, Eksteen received congratulations from the company CEO in Zurich, Switzerland. "We had arrived," Hart said. "Typically, you can only go down from here. But we can't peak. We've got to keep this going. This is just the start."

Robb said that the result elevated expectations. "Previously, we expected to go in and do well," he said. "After that, though, we were trying to beat that performance every time."

The next opportunity was the Southeast Regional Mine Rescue Contest in Maysville, Kentucky, in June 2019. Nyrstar had regularly competed in it, and Millington described it as a must-win situation. "This year was different because they turned the lights out," he said. "It was in the dark."

The team prepped by working a mix of problems that included some from coal provided by Blankenship. "He would change them to fit the rules," Millington said.

Once in Maysville, the team was on lockdown, spending any free time studying. "That is a crucial difference for us," Robb said. "Once we are at the location of the competition, from day one, all of our conversations and thoughts are focused on the competition."

Nyrstar won first on the field and third in first aid. "We got knocked out from winning the overall championship due to the tech team's performance," Millington said. "That is when we knew that we had yet to close that gap."

Hart said that even though the team didn't sweep, the fact that it zeroed the field "tells me that in the U.S. we have one of the top groups that would be called in to save lives," which "is why you do this."

The team was called in twice in 2019. The first incident was an underground fire at Nyrstar's Immel mine, up the road from Coy. "We didn't have to save anybody, but we had to clear the mine," Hart said. The team also responded to Nyrstar's Gordonsville, Tennessee, zinc operations for a similar incident.

The team was still within budget and, after gaining the backing of Eksteen, calendared the Colorado Regional Mine Rescue, First Aid and Team Technician Contest, in Loveland. "We didn't want to stop the momentum," Millington said. One of the main goals, he said, was to get a feel for the judges in the western region.

To prep, the team reviewed problems and questions from previous contests.

In the competition, things "didn't start out well," Millington said. The rules would be enforced differently than previously. "I was ready to appeal processes before the team even came out."

May said the judges judged differently than previous judges had. "Their shade of gray was different from the shade of gray that we were used to."

Which is "exactly why we went out there," Millington said, "to see how they judge."

No longer the dark horse, the team was watched by the competition. "There were teams asking us about our methods, how we were doing things," Robb said. "Obviously, you don't want to share all your secrets."

It was a reversal of roles, Gulling said. "It used to be us asking them," he said. "Now it is them asking us."

Nyrstar won it. It placed first overall, ranking first on both field problems.

The run had been epic, but was not without blowback. Due to his ties to Nyrstar, Blankenship was asked to step down from the rule- and problem-making committee for the international mine rescue competition. "He said we cost him a job," Vineyard said.

Hart said the move, which Blankenship shrugged off, spoke to the work ethic and success of the Nyrstar team.

Blankenship said he is still involved with the international competition in other capacities.

Henceforth, preparations targeted nationals.

Nationals and Beyond

In December, the team took a self-contained breathing apparatus class and a get-out-alive class, both of which were tied to firefighting certifications.

Millington said the team would up its use of Blankenship in the runup to nationals.

Blankenship told *E&MJ* the team has likely lost the element of surprise at competitions. Going forward the team can expect to be known by the judges and imitated by the competition. "Other teams will probably implement some of the things that Nyrstar does to give them a competitive edge," he said. But "I really don't think the element of surprise is a real factor in Nyrstar's success."

For example, other programs may be able to get a similar level of funding, support, and equipment, but they will be challenged to get the same level of team cohesion, leadership and passion, Blankenship said. They will also be hard pressed to duplicate Nyrstar's work ethic. "Unless you have been a member of a mine rescue team, it would be difficult to understand how hard the Nyrstar team has worked to achieve the level of success that they have enjoyed in such a short time."

Hart said that in the runup to nationals, the A-Team will be used to help prep and train the B-Team. The goal is to build what he called a feeder system, creating a deep bench, and entrenching and stabilizing the program. "The big thing now is to give back to the program."

Implied in the plan is a new goal: to build a dynasty.

Getting there represents a new level of challenge seemingly far removed from those of yesteryear. "Not that long ago, I was scrambling around trying to find people just to be on a mine rescue team capable of minimal compliance with MSHA standards," Hart said. "Now we've got two or three guys waiting for a chance to step up. That is really cool," he said. "That tells you, you have a program and not a team."

It also suggests Nyrstar may be ascendant for some time to come.

Exploration Game Changers

Machine learning, hydrogeochemistry, SQUIDS, and other techniques are increasing the speed and success of tomorrow's undercover exploration programs

By Carly Leonida, European Editor

The next five to 10 years signal a turning point for the mining industry. Demand for metals such as copper, lithium and cobalt is set to skyrocket as the green economy expands and demand for low-carbon technologies like electric vehicles and wind turbines increases.

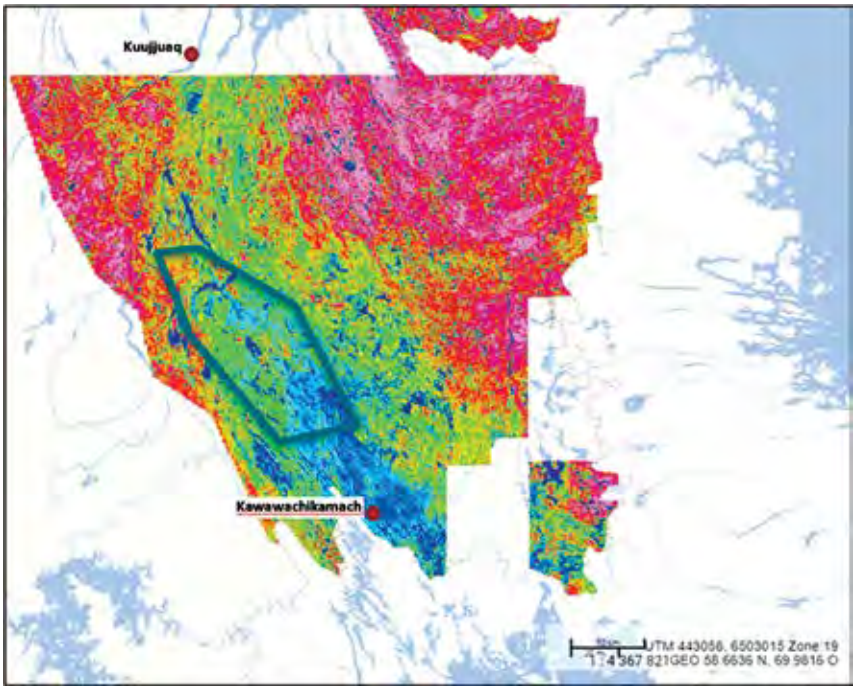
Gold, a safe haven for investors during times of uncertainty, also looks set to remain in high demand as we enter a period of unprecedented global change fueled by climate-related risks and trade tensions.

Demand may be in our favor, but across the industry, average grades are falling and this puts greater pressure on operational mines to extract and process more material, potentially shortening their economic lives if new deposits or extensions to existing ones are not unearthed. In addition, the rate of success in the discovery of greenfield deposits and the speed at which we can develop those we do find, is no longer keeping pace with that of extraction and this, quite rightly, is a significant source of worry for mining companies and economists alike.

To reach our low-carbon energy targets and remain on a (relatively) even keel both politically and economically, the world needs more metals. But, how to find them? Most easy-to-reach, near-surface deposits have been exhausted. The future of mineral exploration lies undercover and for those who know how to find them, treasures still await even in some of the most mature jurisdictions.

The Digital Revolution

While exploration once saw geologists and drill teams in the field with naught but a few outcrops, hand samples and some historical maps to go by. Programs today look very different. We live in a digital age and new data management, modelling and predictive tools are constantly being added to the geoscientist's arsenal.



High resolution map showing thorium concentration in parts per million. Mira Geoscience used automated clustering algorithms to establish the different lithological groups according to the radiometric and magnetic signatures. (Photo: Mira Geoscience)

Always a good indicator of trends in exploration, the AME Roundup exhibition that was held in Vancouver at the end of January, featured a number of technical sessions dedicated to emerging exploration techniques.

One such topic, and one that has received much attention across the industry and its disciplines of late, is machine learning, a subset of artificial intelligence. Jean-Philippe Paiement, director of global consulting at Mira Geoscience, was one of a team of experts who led a short course dedicated to machine learning at the event.

E&MJ caught up with him and John McGaughey, Mira Geoscience's president, afterward to find out more.

"Machine learning or artificial intelligence (AI) is often seen as a black box — hard to interpret and trust because the workflow, decision factors and algorithms can seem obscure," Paiement said. "However, its meaning can be simplified to the application of computational mathematics to big data problems. A model is constructed to automate prediction or decision-making, whether it is a regression problem (predicting values from data) or classification problem (classifying data based on a multitude of variables).

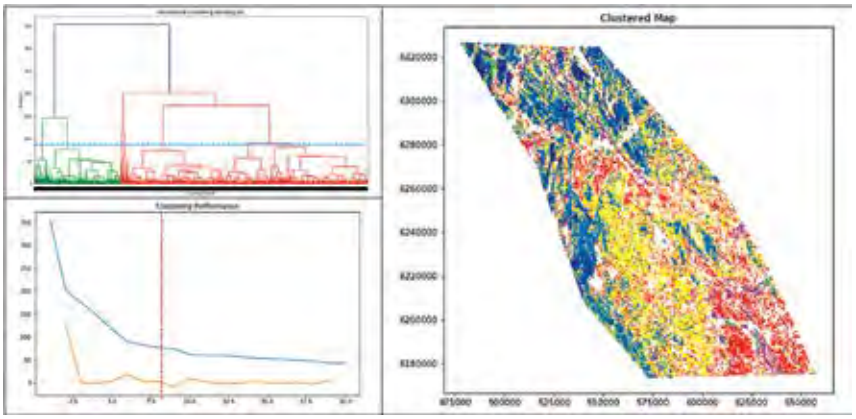
"Not only will the algorithm make a prediction, but it may open the door to new ideas by pointing to previously unrecognized correlations and ranking the importance of individual data sets.

"Thinking outside the box is necessary to make new discoveries as exploration is becoming harder, with greater focus at depth or undercover," Paiement added. "AI applications to interpretative problems can remove cognitive biases from interpretation and provide in-depth insights into multivariate environments."

McGaughey put this into context: "Traditional approaches to data integration applied to geology typically focused on statistical classification models, employing numerous assumptions that are generally not met in practice," he said.

"Recent, successful advances have been made in stochastic, non-Euclidean approaches to the problem of understanding complex data relationships. Predictive models are constructed from the integration of complex data sets without the limiting assumptions of traditional statistical approaches. These new approaches can easily handle continuous, discrete, noisy and missing data with limited impact from interpretative assumptions.

"Over the last five years, machine learning has been a growing subject of conversation in the mining industry, but there has been lots of confusion as to how to apply it correctly and generate useful outcomes for the mining industry. Its practical application in the context of image filtering and recognition, geochemical interpretation, remote sensing and predictive exploration models are already having impact on standard practices in numerous companies."



This map shows clusters that represent probable geological domains within the Labrador Trough located at the Québec-Labrador border. (Photo: Mira Geoscience)

Re-learning Exploration

The potential benefits of AI in mineral exploration are huge, yet its application is far from simple. In the example of mineral deposit targeting, explorers are trying to identify the location of ore deposits at the core of a very complex, natural system, created over millions of years of geological processes including structural reworking and hydrothermal alteration.

Evidence of the deposit footprint must be assembled from interpretation of subtle alteration effects extending kilometers from the target. This is a very different and more complex circumstance than can be found in traditional applications of AI.

The route to solving these challenges includes taking the focus off the methods of AI as a discipline and putting the focus on how the mineral exploration problem is set up for AI predictive models to work coherently. This is where deep domain knowledge and a mining industry-specific, supporting computational framework is required.

It is also important to note that the application of machine learning techniques within earth sciences is still in its infancy and, as a result, no algorithms have been developed specifically for this field yet.

Paiement explained: "Depending on the problem one is trying to solve, different algorithms can be used — there is no single best algorithm out there. It would be difficult and wrong to steer users into a single type of algorithm. A deep knowledge base of machine learning and domain-specific geoscience knowledge is key to choosing the appropriate approach to solving each individual problem.

"From different tests, it seems that in the case of making prospectivity score predictions in geological environments, the Random Forest approach works well. However, when interpreting geochemical pathways and alteration halos, it might be best to use hierarchical clustering approaches. The key does not lie in the application of the algorithm but in the data preparation, labeling, and training versus test set preparation. A lot of issues may arise from incorrect data preparation that even the best algorithm cannot solve."

Every data scientist I've spoken to over the past decade has stressed how important data quality is to the outcomes of a project. If the data quality is good, most mathematical problems can be solved by high performance computers that users can buy off-the-shelf or by renting computing time on cloud platforms in a relatively short space of time. The answer lies in correct data preparation and merging, which represents up to 80% of the work, prior to running the algorithms.

"Quality is not always the focus of data collection campaigns," Paiement said. "We are often faced with generations of legacy data where quality is a particular problem. Setting up the problem correctly and identifying the relevant data to apply machine learning techniques are the key steps in the workflow.

"In the future, companies should focus on data acquisition with the thought that it will provide value for years to come, not just the current exploration campaign. This is true for all types of sampling sources (i.e., drilling or fieldwork) and should include systematic high-resolution pictures (including hyperspectral), physical rock property measurements (magnetic susceptibility, density, conductivity), and geochemical assaying for every sample. It would be very useful for systematic wireline logging to gain more traction in the minerals business."

McGaughey added: "At Mira Geoscience, we have developed a supporting data management and computational framework through intensive, industry-collaborative R&D over the past five years, directly addressing the problem of quantitatively integrating 3D and 4D mineral exploration data sets and interpretation.

"The system is called Geoscience INTEGRATOR. It brings together structured and unstructured data and interpretation, from drill hole data to all types of geological, geophysical and geochemical data. It is fully 4D, tracking both space and time. Documents and files can be stored, managed, and linked to data and interpretation to provide relevant metadata and contextual links. It is the industry's first multidisciplinary, 4D data management framework and, as such, delivers the platform required by computational systems such as AI, that aim to answer questions that only quantitative data integration can answer."

Most importantly, Mira's system provides a "data fusion" capability specifically aimed at mining industry problems.

"This is game-changing technology for mineral exploration," McGaughey said proudly. "It provides a sound, robust solution to the once-intractable problem of integrating highly disparate data across space and time."

Putting Machine Learning Into Practice

The beauty of machine learning is that it is applicable across every commodity and exploration program. Paiement said that more and more mining companies are turning to advanced modelling in the bid to make more informed decisions in their projects.

"These types of approaches have the benefit of being probabilistic and make it easier to quantify the risk associated with the different modelling steps," he explained. "For example, the use of probabilistic geological models would be beneficial to all geologists by building models based on lithological probability and remove some cognitive bias out of the interpretation work.

"There is still a significant amount of work in order to make these new modelling and statistical methods more accepted by the mining industry, but they offer so much more power in terms of decision making, risk assessment, drilling optimization and general exploration successes."

Paiement gave the example of a recent project where Mira Geoscience used radiometric data to generate automated alteration maps based on residual values.

The radiometric spectrometry method is a geophysical tool used to estimate concentrations of potassium, uranium, and thorium by measuring gamma rays emitted by radioactive isotopes of these elements during radioactive decay.

Some alteration profiles, such as potassic alteration, which is often associated with hydrothermal deposits, can be detected using gamma ray spectrometry.

In outcropping or low-coverage environments, it is thus possible to map the different lithologies and potentially estimate changes in potassium and uranium concentrations caused by alteration processes.

"For this project, we used automated clustering algorithms to establish the different lithological groups according to the radiometric and magnetic signatures, coupled with geological calibration," Paiement explained. "Once the dictionary of lithology is created for the study area, it is possible to estimate changes in mass for potassium and uranium, which are characteristic of the various alteration processes.

"The immobile nature of thorium allows us to estimate thorium-potassium and thorium-uranium regression and also actually calculate the residual values for the more mobile elements, potassium and uranium, which can be affected by hydrothermal fluid circulation. This mapping method makes it possible to highlight zones of leaching and deposition of these radiometric elements."

This approach allows rapid generation of more accurate alteration maps than the ternary maps traditionally used for exploration of mineral systems associated with iron oxide copper-gold (IOCG), uranium, porphyry, and other systems that have a large footprint and affect potassium and uranium compositions.

"In order to test the workflow proposed above, we chose the Labrador Trough at the Québec-Labrador border because of its low level of Quaternary cover and potential for IOCG mineral deposits," Paiement said. "These types of deposits come with a substantial alteration footprint that might be mappable using the automated approach proposed here. The data was downloaded from the Quebec public repository and re-gridded at a 500- x 500-m resolution for fast processing."

First, lake and swamp-environment signatures were taken out of the survey using a first round of clustering and domaining. This allowed the Mira team to concentrate on the signatures associated with

Osisko Completes Discovery 1 Deep Drill Hole

Osisko Mining said it has drilled the longest diamond drill hole in Canada at its Discovery 1 project. The final length of Discovery 1 was 3,467 meters (m).

"Discovery 1 is a great success and achievement," said Osisko President and CEO John Burzynski. "We are very proud of our Osisko team and Major Drilling for their tremendous work completing this hole."

The Major Drilling and Osisko teams mark the completion of Canada's longest diamond drilled hole.

Discovery 1 was a planned 3,000- to 3,500-m-deep drill hole, designed to target two down-plunge extensions of known gold zones and investigate the projected source area of the Windfall deposit at depth. The working model for the Windfall deposit interprets an outer shell and center of a possible porphyry intrusion feeding the Windfall-Lynx gold system.

"It is an honor to have been a part of this monumental project," Major Drilling President and CEO Denis Larocque said. "We are proud of the hard work and expertise that our team has contributed along with Osisko Mining to reach this historic milestone in Canadian drilling." Over the years, Major Drilling has positioned itself as one of the largest specialized drilling operators in the world, by leveraging its skilled personnel, specialized equipment and robust safety systems.

Burzynski pointed to other successes working with Major Drilling that include the discovery of the Underdog and Triple 8 extensions, the wide intercepts of anomalous gold values similar to those observed in the Lynx system, and now these new high value gold intercepts at depth. "These results of the Discovery 1 hole show that the Windfall system is extensive with substantial room for potential growth," Burzynski said.

In addition to holding the record as the longest diamond drill hole in Canada, it also achieved a vertical depth of 2,700 m from surface. Analytical results from the final 200 m are at the laboratory, results are pending. The hole was drilled from surface to 3,149 m with NQ rods and finished with BQ rods.

the rock units. Following this first step, the magnetics data was also processed using a high-pass filter to focus on the short-wavelength signature associated with near-surface changes in the magnetics.

The data set consisting of the potassium, thorium, uranium and magnetics was then run through a hierarchical clustering algorithm.

"This algorithm enabled us to group the datapoints (grid cells) into domains of similar signatures in the four input dimensions. The advantage of using this type of algorithm lies in its interpretability and customizability in terms of resulting clusters. Given the model's performance and entropy, it was established that eight clusters existed in the data set, representing probable geological domains.

"Using those eight domains, 3D regressions were estimated for potassium from uranium and thorium, for uranium from potassium and thorium and for thorium from potassium and uranium. A regression for each domain was estimated and the residual values for each element were then calculated.

"Lastly, the three residual maps are combined to generate an alteration map for potassium and uranium mass balances potentially associated with IOCG alteration. When comparing the alteration map to the known deposits, certain trends become visible," Paiement said.

For those who are keen to learn more, the Concepts and Application of Machine Learning to Mining Geosciences short course will be offered at PDAC 2020 in Toronto in March.

"Following this, other more specific course might be proposed," Paiement added. "We also offer customized training for companies looking to focus on key areas of their work."

Explorers Harness Hydrogeochemistry

In case this article has not proven technical enough thus far, lets add some geochemistry into the mix. Hydrogeochemistry to be specific.

The use of hydrogeochemistry in mineral exploration programs is increasing worldwide and particularly in Australia, although many experts still consider it underutilized. The technique offers a relatively low-cost and unobtrusive way to hone potential mineral targets over large areas, which is especially valuable given that the vast majority of undiscovered deposits do not outcrop at the surface.

In the 2011 Field Guide for Mineral Exploration using Hydrogeochemical Analysis guide published by CSIRO, Gray et al. explained that the method exploits the interaction of groundwater and different geological systems to distinguish where mineralization is likely to occur. Groundwater is sampled in areas of interest and concentrations of pathfinder minerals studied to indicate probable areas of mineralization. The inferences gathered via this technique allow the more accurate application of traditional exploration methods such as drilling or trenching to confirm the location and economic viability of deposits.

One organization that is using hydrogeochemical exploration with great success is Nevada Exploration. The company is advancing a portfolio of new district-scale projects along Nevada's Cortez Trend and has been using hydrogeochemistry since the early 2000s to search for new Carlin-type gold deposits.

Nevada is the world's biggest gold producer by area, but more than half of the region's bedrock lies covered beneath its valley basins, which have seen minimal exploration to date because conventional exploration methods offer limited success in covered terranes.

"In addition to being covered with valley basin fill (sand, gravel, etc.), Nevada's vast covered valley basins are also saturated with groundwater," explained Nevada Exploration President James Buskard. "Water is known as the 'universal solvent'. As groundwater flows through the subsurface and interacts with the covered bedrock below, the groundwater acquires a unique hydrogeochemistry signature or 'scent' representative of the bedrock it has encountered, providing valuable geochemical information in covered settings, and representing an important and underutilized sampling medium."

Buskard said when groundwater interacts with a gold deposit where the gold is contained within soluble mineral complexes, such as pyrite and arsenopyrite in Carlin-type gold deposits (CTGDs), these soluble complexes oxidize and release gold (plus related trace elements) into the groundwater, producing a measurable and recognizable hydrogeochemistry footprint.

Because groundwater mixes and flows, a deposit's hydrogeochemistry footprint is often much larger than that seen in other sampling media. This can significantly reduce the sampling density needed to detect a target, and thus decrease the number of samples needed to evaluate large search spaces. Beyond increasing the size of a deposit's geochemical footprint, groundwater movement can also define a gradient or vector pointing back to its source, and because groundwater can recharge from depth, sampling groundwater can provide opportunities to detect deeper mineralization.

Groundwater and Gold

Unlike blind drilling and geophysics, groundwater sampling provides direct and low-cost geochemical information.

"By providing opportunities to increase the size of deposit footprints, reduce the number of samples needed to evaluate an area, vector toward mineralization, and detect deeper mineralization, hydrogeochemistry represents an ideal geochemical exploration tool for opening up covered search spaces to systematic exploration," Buskard added.

"In terms of gold exploration, the best hydrogeochemical pathfinder for gold is gold itself. Despite its relatively low solubility, with proprietary sampling protocols and the latest ultra-trace laboratory analytical methods, Nevada Exploration has established workflows to achieve the robust part-per-trillion (PPT) level analysis needed to detect and respond to gold in groundwater directly."

Even with PPT-level analysis, due to physical and chemical groundwater processes such as mixing and adsorption, a practical implication of gold's low solubility is that the size of a deposit's detectable gold-in-groundwater footprint is generally smaller relative to that of other hydrogeochemistry pathfinders. Based on the results of large groundwater characterization studies around known gold deposits in Australia and Nevada, researchers have shown that the ideal sampling density to respond directly to gold in groundwater during regional-scale exploration is in the order of one sample per square kilometer.

Buskard said most groundwater sampling programs rely on collecting groundwater samples from existing boreholes, so explorers often have no control over sampling locations. Without the ability to collect samples at a density suitable to respond to gold in groundwater directly, explorers have had to rely on more mobile, but less diagnostic, pathfinders such as arsenic and antimony.

"Furthermore, with no control over sampling locations, explorers have been unable to integrate hydrogeochemistry with other geologic tools to provide this important geochemistry data across search spaces identified as prospective based on other lines of evidence, such as projections of favorable geology or geophysics," he added.

To combat this, Nevada Exploration has developed specialized equipment to create purpose-drilled boreholes. This equipment has significantly reduced its costs, and Nevada Exploration stated that it can now evaluate covered terranes in Nevada for approximately $1,000/km^2, which it describes as a "radical cost breakthrough."

SQUIDS Delve for Diamonds

De Beers Exploration's current focus is on priority greenfield areas in Canada, Botswana and South Africa where the company is looking to discover economically viable kimberlites and secondary diamond deposits that could add significant new production.

"Our brownfield work is mainly focused on areas adjacent to our existing mines and around the Chidliak project in Canada," Anre Vorster, senior manager, future exploration and projects, told *E&MJ*.

"Exploring for diamonds is not only technically challenging, consideration is also required of the various legal-commercial elements — many of which are unique to the particular country we're operating in — as well the need to carefully manage multiple and often differing stakeholder interests. In addition, undiscovered diamond sources are likely to be in areas of complex geological terrains and/or under thick overburden, which add to ever-increasing costs of exploration. These aspects all need to be carefully managed whilst ensuring safe discovery in remote and challenging locations."

The Full Tensor Magnetic SQUID (Superconducting Quantum Interference Device) project is a collaborative partnership between the Institute of Photonic Technology (IPHT), Supracon, De Beers, Spectrem Air and Anglo American. It has delivered a pioneering airborne geophysical instrument that provides full tensor magnetic data of superior quality that comes with a wealth of information that was not previously available to mineral explorationists.

SQUIDs are very sensitive magnetometers that can detect changes in magnetic fields billions of times weaker than a typical fridge magnet. At the heart of a SQUID is a device called a Josephson junction: two superconductors made of niobium, separated by a thin insulator through which electrons can pass. An electric current is applied to a SQUID, and minute variations in magnetic fields are detected as changes to the system's electrical resistance. As niobium only acts as a superconductor at temperatures close to -273°C, it is necessary to cool the SQUID by housing it in a cryostat: a container that uses a refrigerant such as liquid helium to maintain it at an ultra-low temperature.

The complete system consists of six magnetic gradiometers and four magneto-

South Australian Government Challenges Data Scientists to Find Next Olympic Dam

This year, the Marshall Liberal Government will become the first government globally to host a $250,000 crowdsourced open data competition to fast-track the discovery of mineral deposits in South Australia.

Hosted with open-innovation platform Unearthed, ExploreSA, the Gawler Challenge will see geologists and data scientists from across the globe try their hand at uncovering new exploration targets in the state's Gawler Craton region using mathematical expertise, machine learning and artificial intelligence.

The South Australian government is the custodian of an extensive amount of geological data across the state, be that data the government has collected to support exploration activities or data they host that has been recorded by private companies. However, historically, it has been a challenge for people to process this data at scale.

Crowdsourcing enables the government to readily share this considerable collection of datasets with people from different disciplines around the globe who can apply their diverse experience and skills to mineral targeting. It also empowers these data scientists, geoscientists and mathematicians to collaborate and work through the data in novel ways. This encourages the development of new workflows, through the application of emerging machine learning and analytical processes to exploration geology.

"This state-of-the-art competition has the potential to unearth the next Olympic Dam or Carrapateena by encouraging global thinkers and innovators to interrogate our open-file data and generate new exploration models and ideas for targeting," said Minister van Holst Pellekaan.

Unearthed's Holly Bridgwater exploring data driven exploration technologies. (Photo: Roy Vandervegt)

"Mining is one of the pillars of the South Australian economy and this competition should add to the pipeline of projects in the resources and minerals processing sector.

"Our existing inventory of discoveries suggest there are major prospects and many other deposit styles and commodities to be identified and this will only serve to bring those internationally significant discoveries forward."

All targets generated, including those from the winners of the A$250,000 prize pool, will be publicly shared to increase innovation and understanding in the resources sector by enabling access to data science approaches and modern geoscience thinking.

Unearthed Industry Lead, Crowdsourcing, Holly Bridgwater said the competition served to leverage data science to its full potential at a time when significant new discoveries are becoming rarer.

"This exciting crowdsourcing competition and world-class open dataset will attract a global community of innovators, some of whom won't have worked in the mining industry before," Bridgwater said.

"We can't wait to see how they will apply their diverse skills, fresh ideas and novel approaches to mineral exploration to accelerate discovery in South Australia."

meters housed in a helium-filled cryostat along with a digital acquisitioning system comprising of a differential GPS, inertial measurement system (IMU) and altimeters.

De Beers' Innovation Focus

Although the airborne SQUID magnetic system does provide De Beers with an industry-unique differentiating capability in the search for new diamond deposits, it remains one of many tools in the company's exploration toolkit.

Other geophysical techniques such as electromagnetic (EM) surveys are also routinely used, and the results are integrated with the SQUID full tensor data to facilitate comprehensive geophysical interpretations of the geology in the search areas.

"New areas may also be covered by sampling programs aimed at recovering heavy minerals to test for the presence of kimberlites, using the resultant mineral chemistry data to determine whether these pipes may have sampled potentially diamond-bearing lithologies/material during their upward journey through the earth's mantle to surface," explained Vorster.

"Innovation is a key focus area in De Beers Exploration and we have been developing some exciting techniques and technologies to assist us in not only reducing the time from discovery to delivery of new diamond sources, but also in opening up new areas for diamond discovery and allowing us to detect potential sources that were previously hidden.

"These techniques and technologies span the exploration pipeline and include novel approaches to exploration targeting, developing new airborne geophysical technologies such as the SpectremPlus airborne EM system, in addition to the SQUID, advancing drilling techniques and also developing new laboratory technologies and techniques that could significantly impact the way we treat samples and interpret results."

De Beers is also harnessing AI techniques to help handle and sort through its mineral exploration data.

"We view AI and machine learning as a key enabler to unlock value from our vast exploration datasets, which span more than 70 years of historic exploration across the globe," Vorster said. "The main goal is to gain new insights and identify patterns and critical relationships in the geoscientific data that could provide early indications of the economic potential of kimberlites and allow us to prioritize those for further work.

"Our team is collaborating with leading research institutes in several pilot studies and the initial results thereof are greatly encouraging, especially in the targeting space where machine learning is used extensively to focus on globally prospective areas much quicker than before and with increased confidence."

One thing is for sure: diamond exploration in the distant future will look fundamentally different from today.

"From a technology perspective, high tech data acquisitioning could be largely driven by unmanned aerial vehicles (drones) delivering real-time streamed geophysical data," Vorster said. "Central data centers and laboratories will use advanced data analytics to process and interpret the data and prioritize high priority anomalies for further follow-up. The use of intelligent equipment, real-time sensors and automated processes will be ubiquitous, such that the footprints and personnel on the ground will be very limited, allowing geoscientists to focus on interpreting the resultant data in new ways."

When Teleremotely Forged Plans Fail

Advanced technologies are changing maintenance planning roles, and revealing the importance of good technicians and the people who manage them

By Jesse Morton, Technical Writer

According to the experts, the latest trends in maintenance planning speak to the state of the technology in the mining space. Like many other roles at the mine, maintenance planning is becoming more data driven, and emergent solutions could someday enable the job to be done remotely. As machine health monitoring data improves, certain maintenance tasks can be automated. Yet, currently some of the efforts in these directions have resulted in fewer wins than previously anticipated.

For example, according to the experts, computer scientists still generally cannot use machine health data alone to arrive at the real reason for a mechanical malfunction. Similarly, teleremote solutions have yet to prove capable of entirely relocating maintenance planning personnel to cubicles at company headquarters downtown. Both fail because they implicitly undervalue the technician who can put hands and eyes on the equipment.

The example of the teleremote LHD offers a telling comparison. The numbers it produces are promising, but by operating unmanned, a set of challenges and constraints emerge. For the moment, there has to be someone on site who knows the machine well to provide critical information on it to keep it up and running. Similarly, teleremote maintenance planning seems advantageous and in some cases could be doable, but in others causes problems that come at a cost.

Therefore, similar to how a future of robots operating alone underground remains pie in the sky for most companies, maintenance planners operating from their home office half a world away is still mostly a pipe dream. Nonetheless, the experts say, that is the way things are trending.

Teleremote Maintenance Planning

Gerard Wood, managing director of Bluefield Asset Management and author of *Simplifying Mining Maintenance*, told *E&MJ* centralized remote planning is trending. "This is also true for other functions, which have been moving to centralized location far from the mine and run remotely," he said. "It is the advances in technology that have been enabling this to occur and it is also the enabling technologies that will eventually enable planning to be done more remotely."

Dr. Peter Knights, professor at the School of Mechanical and Mining Engineering at the University of Queensland, said advances in digital connectivity has allowed at least one major mining company to transition all maintenance planning to city-based offices.

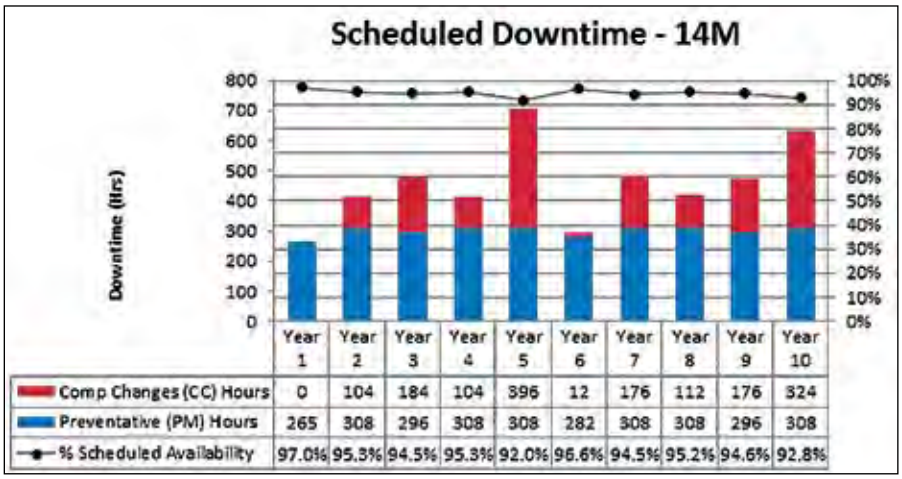
In practice, transitioning maintenance planning to cubicles in skyscrapers is beset by challenges other companies have found to be insurmountable. "At this point in time, the efforts to make maintenance planning a remote function have not been very successful," Wood said. "Some companies have centralized the function but then sent it back to the sites again."

For good reason, he said. The idea of remote planning is based on the idea that maintenance plans can be forged that then work out perfectly. This premise is patently false, he said.

"The worst mistake people can make with planning is to think there is such a thing as a perfect plan," Wood said. "We need to continually work, day in and day out, to improve the planning and make the work execution more efficient." On the ground this looks like plans failing and then being revised, over and over again.

That reality often proves difficult to build neatly into an office schedule. "The short term, month to month, planning requires very close communication with the supervisor," Wood said. "The number of potential problems during scheduled maintenance that can cause delays is very large and only by open communications daily or at least weekly between the planner and supervisor can the site continue to improve the planning and eliminate these problems. It is a process of continual improvement."

Wood said he is optimistic that technological solutions will eventually enable effective remote planning. "These limitations will eventually be overcome through better communication technology and through virtual visual models of the equipment that can be updated when a machine moves past a certain point or is serviced," he said. "Enabling the planner to see the machine and the current condition will assist greatly in the short-term planning environment."



	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Comp Changes (CC) Hours	0	104	184	104	396	12	176	112	176	324
Preventative (PM) Hours	265	308	296	308	308	282	308	308	296	308
% Scheduled Availability	97.0%	95.3%	94.5%	95.3%	92.0%	96.6%	94.5%	95.2%	94.6%	92.8%

Author Gerard Wood tells *E&MJ* that maintenance planners should be involved in developing a scheduled downtime strategy, such as the above, as part of an asset management plan, for remotely operated equipment or for equipment that autonomously completes certain tasks. (Image: Gerard Wood)

Standardized Data and Automation

Knights said transitioning to centralized remote planning requires a significant investment in standardizing data, such as material codes, task lists and failure codes. It would require developing a methodology to manage "standardized data, new digital skills requirements, organizational change management, and management of office and worksite communications."

For many mine sites, the process of standardizing data pertaining to maintenance planning is well under way, and in the future, could allow for the automation of transactional-type tasks, Wood said. "For example, there is still a requirement for people to open work orders in most Computerized Maintenance Management Systems (CMMS), but this is a task that we can use AI to perform."

Bluefield Asset Management deploys a system called Relialytics that, Wood said, "has already removed the requirement to open work orders for oil samples returning to the lab." It automates the process of reviewing sample results, determines what action is required and files a work order in the CMMS.

"No human needs to perform the transactional tasks in the CMMS, and the data analytics is much more effective because the computer can analyze the data in an exponentially more effective manner," Wood said. "By the end of next year, we will have done this for most forms of condition monitoring, which will significantly reduce the workload for site planners and engineers, allowing them to work on much more value-adding tasks."

Data analytics is also being leveraged for the purposes of enhanced shift coverage and the development of proactive, planned maintenance workloads, Kings said. However, as it has been with remote maintenance planning, "the rollout of maintenance data analytics has had mixed success," he said. "Without contextual knowledge of the site and business environment conditions, data scientists can get root causes very wrong."

Successful analytics, Kings said, "requires a team-based approach that brings an appropriate mix of skills to the table related to the statistics and machine learning, operating context, and IT capability."

Thus, for the moment, "with our current technologies, there is still a need to have good, and face-to-face, communications between the planner and the execution team," Wood said.

Scheduled Downtime Strategy Example

Task	Frequency	Duration	Responsible	Timing
Pre-Start Inspection	Each shift	15 mins	Operations	Shift change
Daily Mechanical Inspection	Daily	30 mins	Maintenance	Refueling
In-Pit Machine Washing/Track Cleaning	14 days	4 hrs	Operations/ Maintenance	Pre-service
PM Service, Mechanical Checks, and General Scheduled Repair (using an 8-step fixed time equalised service sheet regime)	14 days	12 hrs	Maintenance	Scheduled Service
Change Bucket GET	1,000 hrs	4 hrs	Maintenance	Scheduled Service
Undercarriage Inspection	3 months	2 hrs	Maintenance	Scheduled Service
Fire-Suppression System Service/Certification	6 months	6 hrs	Maintenance	Scheduled Service
6,500 Hr Shutdown	6,500 hrs	80 hrs	Maintenance	Scheduled Shutdown
Bucket Change	8,000 hrs	12 hrs	Maintenance	Scheduled on Condition
10,000 Hr Shutdown	10,000 hrs	48 hrs	Maintenance	Scheduled Service
13,000 Hr Shutdown	13,000 hrs	240 hrs	Maintenance	Scheduled Service
26,000 Hr Shutdown	24,000 hrs	300 hrs	Maintenance	Scheduled Service

In the scheduled downtime strategy for an autonomous machine, the typical pre-start inspection would be removed. Mechanical inspection could instead occur during refueling. (Image: Gerard Wood)

Single Minute Maintenance

Low-tech solutions to improving maintenance events include what Wood calls the Single Minute Maintenance, which originated in manufacturing. The goal is to "incorporate lean principles into the work procedures, job design and planning" to "reduce equipment downtime and the labor hours required to execute a task," he said.

The process involves six steps. First, itemize the tasks of the job to be analyzed. Then document each task duration. Next, identify which tasks are currently performed while the equipment is down. Identify which tasks can be completed while the equipment is still in operation. Next, identify which tasks can be reduced in duration. Finally, document new process tasks and implement required actions.

Trending Mistakes

Currently, the more common maintenance planning mistakes include pushing out the service on machines to increase uptime for the immediate future, Wood said. "The companies that believe they can continually improve their equipment availability by extending service intervals and reducing the scheduled downtime continue to fail."

Better, Wood said, is to develop what he called a scheduled downtime strategy that is part of the asset management plan. "The correct way to reduce scheduled downtime is to utilize tools for making scheduled tasks more efficient," such as the Single Minute Maintenance method, "and not by simply pushing out the time between scheduled service," Wood said. "By defining the needs up front, the site can deliver how much downtime the machine will require over its life and for what type of maintenance."

Another current, common maintenance planning challenge is breaking free from the centralized-to-decentralized planning structure continuum. Wood said that when it comes to planning structure, over time many mine sites will swing like a pendulum from centralized to decentralized planning and then back again.

In a typical centralized structure, the maintenance planners answer to the maintenance superintendents, who answer to the maintenance manager. Oversight is concentrated with the superintendents.

In a decentralized structure, the high-level maintenance planners answer directly to the manager. Those planners share in the oversight with the superintendents and therefore the oversight is more widely dispersed than it is in the centralized structure.

Mine sites, Wood said, transition from one structure to the next and then return depending on performance. The state of almost constant change is due to how "both structures have problems," he said.

Centralized planning, for example, typically has problems with communication between the planning and execution functions. "If the superintendents of those two functions don't work together and communicate well, the manager has to step

in and sort things out," Wood said. "This often creates more work for the manager," he said. "When planning is decentralized, you have only one superintendent to go to in order to get better performance."

But with the decentralized model, planners often get roped into helping fix breakdowns. "They stop planning and become resources for execution," Wood said. "In addition, decentralized planners often do things differently, causing inconsistent planning approaches across the business. When this occurs, managers want to centralize the planning function to get it in control, which introduces communication problems and removes single-point accountability."

The Teleremote LHD Conundrum

The rise of teleremote-controlled equipment has proven to be a mixed bag for maintenance planners, the experts said. "The combination of teleremote bogging and automated tramming gives enhanced production hours as a result of reduced handover time at shift change," Kings said. The back office cheers the increased production rate but "the absence of an operator walk-around at the start of shifts can be detrimental for machine maintenance planning, as small defects can go unnoticed."

Wood said that without these opportunities for inspections on the equipment, it is essential that the equipment onboard data is utilized in a much more effective manner. For equipment with largely automated tasks, the asset management plan should be assessed differently than it would for entirely manually operated equipment.

"For an autonomous machine, the pre-start inspection would be removed, however, there is always a requirement to refuel the equipment, so the site may choose to continue with the daily mechanical inspection during refueling," Wood said. "The critical thing to remember is that the scheduled downtime strategy is the essential starting point for maintaining any machine and being clear on how it will be maintained for maximum reliability and minimum cost."

Reliability — Is It Worth It?

There has always been a point of contention in the mining industry when the budget cuts come and one of the first departments that see cost cutting is the maintenance department. This leads to the discussion around the value of reliability. We often hear of customers who place a low value on reliability because "they have swing units" or "they don't need more tons from the mobile fleet." But in any scenario, there is a value to be placed on availability, more specifically the reliability of the mobile fleet that translates to savings. It is ultimately the combination of the availability of the machines and supported by their reliability that makes a fleet sustainable for the mines production targets. Sometimes the less priority to good practices becomes the culture of the organization, impacting the life of the capital investments.

In 2005, Professor Peter Knights et al. put forward a model to assist maintenance managers in evaluating the benefits of maintenance improvement projects. The model considers four cost-saving dimensions, which are namely the following:

1. Reduction in the cost of unplanned repairs and maintenance;
2. Increased or accelerated production and/or sales;
3. Spares inventory reduction/optimization; and
4. Reduction in over-investment in assets and operating costs.

All of which can be achieved as a result of improving reliability. In this case, reliability is defined by the ratio of unplanned time over the total maintenance time. Mean time to repair (MTTR) and mean time before failure (MTBF) are also common metrics to measure reliability.

In order to understand the cost saving dimensions, the first principle is that there is a time saving to execute a planned task compared to the same task if it was unplanned. It can be assumed that the extra time could take "three times longer." This means that moving any event from unplanned to planned will increase the availability. It also has impact on the cost incurred in the task which is higher than a planned activity.

Reduction in Cost of Maintenance

A cost saving cannot only be attributed because the additional time to complete the unplanned event, but also the unpredictable nature of an unplanned event means that there will either be a backlog of work generated as the planned work is pushed back in favor of the unplanned work, which needs to be cleared by either field service or contractors. In the cases where there are available technicians to fix the breakdown, this would mean the technician would have an efficient utilization and present an opportunity for cost saving.

Increased Production

In the event that the mobile fleet is the bottleneck of production in an operation, then improving the availability will improve the production. It is important to remember that machine availability can only equate to production if it is being utilized.

Spares Inventory Reduction/Optimization

The requirements of the parts are planned for the maintenance activities. They can be ordered effectively and stocked for the minimum time. The high value insurance items can be minimal with reduction in uncertainties in the failures. There is also a relationship between the economic order quantity and the mean time between shutdowns (MTBS).

Reduction in Over Investment

Where the mobile fleet is not the bottleneck, improvements in availability can be attributed to reducing the fleet based around the methodology that less machines can produce more.

A sound strategy does not primarily seek to reduce the maintenance on the equipment. It ensures most of the maintenance tasks are planned rather than unplanned. This can be achieved by leveraging the vast amounts of data from machine maintenance histories, telemetry on the machines and cloud-based lifecycle modeling.

This article was submitted by Sandvik.

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Giving Operators a Helping Hand

E&MJ *looks at the various steps toward autonomy for loaders and dozers, and how operations around the globe are taking advantage of these technologies*

By Carly Leonida, European Editor

There are many benefits to remote and autonomous control of loaders and dozers including safety, precision and consistent performance. (Photo: Volvo)

When it comes to open-pit mines and autonomy, haul trucks are usually the first machines that spring to mind. However, for the purposes of this article lets concentrate on dozers and loaders; the unsung heroes of the mine site. While they may not be the stars of the load and haul fleet, loaders and dozers are vital to keeping a mine running efficiently, from cleaning up around conveyors and crushers, to keeping stockpiles in check, creating pads and maintaining roads and benches. Their work is varied, highly mobile and often requires a high degree of precision.

This is where machine guidance and operator assist features can help. Let's take a look at the different options available.

Line-of-sight

The first step on the journey toward autonomy for loaders and dozers is line-of-sight control. With this feature, operators stand at a safe distance from their machine and control it using an over-the-shoulder unit. The controls are integrated with machine electronics to provide the same control and response as if operating from the cab, allowing the operator to maintain productivity from a distance. They judge the work by eye, as they would in manual operation, so a good vantage point is essential.

Line-of-sight control is useful for occasional duties, which would otherwise be too hazardous for the operator to perform while sitting in the cab. For example, Cat dozers equipped with line-of-sight remote control systems were drafted into Kennecott Utah Copper's Bingham Canyon mine following the 2013 Manefay landslide to help with the cleanup operation.

Australian technology vendor RCT, with the help of local dealer Wheeler Machinery, designed and manufactured three dozer remote interfaces and four remote kits to suit the Caterpillar D8T dozers used at the mine site. These allowed the landslide to be cleared quickly and safely so that operations could return to normal as quickly as possible.

Teleremote Operation

The next step up is teleremote operation where the loader or dozer operator is relocated to a secure, protected location from where they can control the machine remotely with the help of cameras and sensors. This is better for long-term duties, or those that must be performed regularly, as it provides the operator with a comfortable, permanent space to work from — usually a self-contained cabin or mobile trailer with a dedicated chair and controls.

A good example of this also comes from RCT. The company worked with Hexagon Mining to supply teleremote loader technology to Codelco's Andina mine site in Chile a few years back. The mine is located at high altitude and suffers extreme temperature and climatic conditions throughout the year.

Codelco was confronted by the outcome of a risk assessment, which determined that either autonomous or teleremote controlled mining had to be implemented, so RCT and Hexagon Mining collaborated to create a customized solution.

RCT's ATX2200 (teleremote control system) and Muirhead Speed Ltd. were combined with Hexagon Mining's Jmineops Geofencing functionality and SAFEmine CAS and TrackingRadar Object Detection systems. The technologies were integrated and installed on to a Komatsu WD600 wheel dozer and a new communication network was added at the mine.

Now, the dozer can be operated from a safe location — a stationary, insulated cabin within the site — and a line-of-sight, portable remote was also included to provide flexibility for operating the machine in multiple applications across the site if the network goes down.

The project was so successful that Codelco ordered the conversion of a second loader shortly after.

Automation

At the top of the ladder is semi- or full automation. Here, the operator sits at a dedicated control desk or center from where they can supervise multiple machines. The machines work independently, completing their tasks according to preprogrammed plans using sensors and machine guidance technologies. The operator can intervene at any time if necessary and the machines are

programmed to halt work if a potential safety violation occurs.

Arch Coal's Black Thunder mine in Wyoming uses the Cat MineStar Command for dozing system. The mine installed the system on its first dozer in 2011 and it now has four Cat D11T dozers enabled.

Command for dozing includes a semiautonomous solution that enables one operator to operate up to four dozers from an office environment. Caterpillar said this reduces the risk of injury from mounting and dismounting the equipment and from ergonomic challenges presented during ripping applications. In addition to working more efficiently, operators also experience less physical fatigue thanks to their comfortable office environment.

All dozer push functions are automated through the use of satellite positioning via Cat Terrain with Blade Control, Automatic Blade Assist and Auto Carry. When operating autonomously, the dozer cuts to plan using best practices, and it optimizes reverse speed. The remote operator takes control when moving the dozer to a new area.

Black Thunder first used the system for reclamation work and has expanded this capability to production for overburden removal in advance of dragline operations.

Morgan Malkowski, autonomous equipment Supervisor at Black Thunder, spoke about his experience of the system in an interview for Caterpillar's *Viewpoint* magazine. "The biggest value that we see from the Command for dozing is that we have one operator running three machines, so you see increased efficiency from that operator and increased consistency from those machines; we know how these machines are going to perform consistently 24h a day. The material may change, and we may have to make some adjustments to how the machine handles that, but they're going to run consistently."

Jason Cole, one of Black Thunder's autonomous dozer operators, backed this up. "The main thing is that the dozer will find grade on its own when it's in autonomous mode," he explained. "That's a big load off the operator rather than constantly having to chase the grade.

"It also builds a better pad. All the dozers have the same plan and the GPS tells them where the base grade is. All the machines go right to that grade and they won't cut any further. When you're done, your pad is pretty close to being completed."

Wolff Group, a mining contractor in Australia, is also operating seven Cat D11 dozers in semiautonomous mode and has measured a 15% increase in productivity since their introduction. The company has constructed a mobile command center for ease of movement between locations on a mine or between mines, and has identified Command for dozing as a means to diversify operator recruiting.

The Advantage of Assistance

Fleet management expert, Wenco International Mining Systems, offers machine guidance technology as part of its suite of solutions. Senior product manager, Ken Williams, explained some of the benefits of this technology.

"In a modern mine, machine guidance is essential for using dozers and loaders with the precision necessary to execute most mining activities," he said. "High-precision systems enable operators to shape benches, roads and ramps in accordance with engineers' designs — a task that proves difficult and time-consuming without such technology.

"Maintaining flat benches and safe, stable ramps leads to significant cost improvements at a mine by exacting less wear and tear on equipment traveling across those surfaces and by raising the efficiency of hauling. Machine guidance also allows loaders to cut with precision, which lowers contamination of ore with waste material."

Automation, to whatever degree, also helps to relieve the skills pressure on mines in remote areas or in markets where labor is particularly expensive. By using machine guidance technologies, newer operators or those with less experience can still execute tasks to the same standard as veterans. Mines that operate autonomous loaders and dozers can capitalize upon the efficiency and experience of their operators by assigning multiple machines to one supervisor. And, of course, autonomous machines never get tired or need breaks. They perform consistently around the clock.

Another piece of the puzzle is safety. By allowing operators to complete certain tasks at a safe distance from the machines, mine managers have peace of mind that their entire workforce will get home safely that night.

The job also becomes more attractive to new recruits and, open up the doors for better diversity and inclusivity in mine workforces.

For example, during an early phase of implementation for Caterpillar's Command for dozing system at a mine in South America, the operation had on its roster an experienced D10T dozer operator who was working in administrative roles due to a mild injury to his cervical spine.

The operator was still able to work in roles where there was no exposure to vibration. When Command for dozing was installed, he was proud to return to work as a professional operator without interfering with his recovery.

"Mining is one of the most dangerous industries in the world, so if we can remove humans entirely from these sorts of operations then that will have a huge impact on safety," Ulrich Fass, manager for Emerging Technologies Europe, at Volvo Construction Equipment, told *E&MJ*.

"Having one operator in charge of several remote machines will ensure far greater site productivity — and with no humans on site there is no reason why you couldn't provide 24/7 operation with someone controlling the machines from another part of the world?"

Fass said it is repetitive work cycles that benefit most from automated and teleremote operation. "Which is why mining offers the perfect playground to explore this," he enthused. "A particular challenge for the mining industry is that the site conditions vary so widely, so providing an autonomous solution that works under all environments is a tough undertaking."

Volvo Explores New Remote Concepts

Volvo has been researching and developing autonomous solutions for years.

The company's first showcase of its solutions in action was at its groundbreaking Electric Site in Sweden in 2018.

"This was a project we carried out together with our customer Skanska," Fass explained. "Here we proved it was possible to provide for a 98% reduction in carbon emissions, a 70% reduction in energy cost and a 40% reduction in operator cost in a quarry operation — all through

the use of eight HX02 autonomous battery-electric load carriers, the LX01 prototype electric-hybrid wheel loader and the EX01 dual-powered cable-connected excavator prototype.

"These machines may just be concepts, but they have helped us develop solutions that may one day soon be commercialized."

Another ongoing project for Volvo is an industry-first with Telia and Ericsson to test the potential for a faster, more reliable 5G network in an industrial application.

"From our base in Eskilstuna, we have set up a 25-hectare test site to trial a remote-controlled L180 wheel loader powered by a 5G network," Fass said. "The test track itself has a number of physical barriers, uphill and downhill tracks and rough terrain — all designed to mimic the real conditions of a construction site — so we can see what benefits a faster network brings.

"For us here at Volvo CE, our aim with all these initiative is to see if, by minimizing the potential safety risks and downtime associated with sectors such as mining, we can get closer to our goal of zero emissions, zero accidents and zero unplanned stops."

Volvo has a number of systems that support operators with guidance or control primary functions in repetitive mining tasks. For example, Volvo Co-Pilot and its range of intelligent-assist functionalities.

"Before full automation is available, these autonomous functions are going a long way to help operators deliver higher quality outcomes, in less time and with less effort," said Fass. "The challenge we will face over the coming years will be how we bring automation out of the confined and stable production sites and into varying applications. And how we make our machines interact safely with humans around."

Wenco Heads Toward Autonomy

Wenco has recently installed machine guidance systems at Golden Queen's Soledad Mountain project, Mesquite mine in California, and Conuma Coal's sites in British Columbia, Canada, to raise the precision of their earthmoving activities.

Williams said the company has definitely noticed a pique in interest for solutions as mine operators continue their journey toward zero-harm operations.

"We're seeing plenty of interest in safety solutions," he said. "Our machine guidance systems contribute to improved operator situational awareness and include alerts for proximal hazards and other exclusion zones."

Williams said coal mines have historically used machine-guided dozers more extensively than other mine sites. This is likely due to the nature of coal mining — depending on the thickness of the seams, these operations are often more conducive to material movement with dozers than other sites.

Cat Command for loading also enables line-of-sight remote control of Cat 988K wheel loaders. (Photo: Caterpillar)

"Wenco's machine guidance solutions assist operators in creating benches, roads, and other physical features that match their design plans. Using high-precision GNSS, our technology enables operators to position their loader buckets and dozer blades with centimeter-level accuracy," Williams explained.

"Users load their design files into our system and simply follow the onscreen guidelines to create contours at the exact location and elevation required without the painstaking process of surveying and grade staking. Ultimately, this process allows operators to create smooth haul roads, flat benches, and even ramps that produce less wear and tear on equipment, and to do so with much greater efficiency than traditional surveying processes."

Williams said automation is next on the cards for Wenco's R&D efforts. "It is a priority focus for Wenco, and such capabilities are likely to appear on our product roadmap in coming years," he told *E&MJ*.

Hexagon Ensures High Precision

Autonomy is also a growing focus for Hexagon Mining.

"Our machine control technologies mean we can begin to automate blade control on many dozers and graders," explained Andrew Crose, Hexagon Mining's managing director, EMEA. "Teleremote is an area of active development, especially with Hexagon's commitment to safety."

The company's current solution — HxGN MineOperate OP Pro HP — is a high-precision guidance solution for dozers, drills and loading equipment. It enables loading equipment to improve bench elevations, reduce dilution and decrease rework. Dozer operators receive easy-to-visualize design plans, which minimizes costs by eliminating the need for grade staking and survey crews.

The system is OEM-agnostic and can be installed on almost any make and model of loader, shovel, dozer or grader. Crose said Hexagon is seeing increased interest from mining companies.

"Particularly on loading units where there is a more directly visible alignment to production with reduced loading times," he said. "We're also seeing some interest in dozers, too, as mines see the benefits of better grade control to improve mine efficiency."

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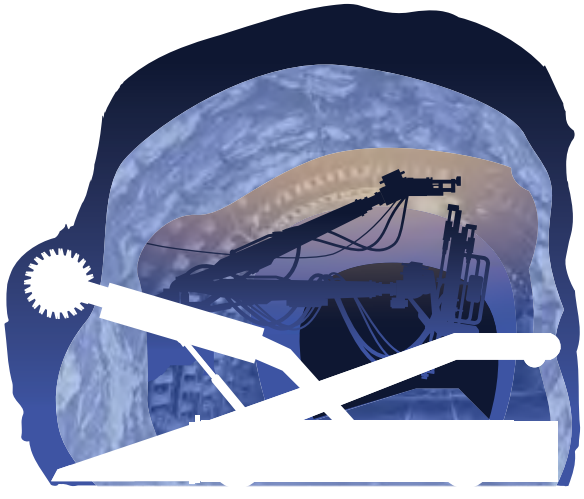


Minding the Grind: Maintenance Options to Keep SAG Mills Turning

When the largest machine in the plant stops working, the silence that follows typically isn't golden – just expensive

By Russell A. Carter, Contributing Editor

Purpose-built structures such as the Skyway system from Russell Mineral Equipment can provide a stable, safe and efficient platform for mill liner bolt removal when compared with the common approach of hanging jackhammers and impact wrenches from a chain hoist.

Modern, large SAG mills are major capital-cost items with price tags reaching well into the eight-figure dollar range. They stand at the entry point to a variety of comminution circuit setups and when they stop for whatever reason, the revenue losses per circuit mount quickly. The hours, days or weeks needed to get a mill back on line are often filled with tense periods of trouble-shooting and scrambling to locate and acquire needed parts, and the characteristics that make SAG mills such robust performers — powerful drives, massive components and capacity to carry a thousand tons or more of ore and grinding balls — also make them difficult and occasionally dangerous for workers to service and repair.

Balancing the vast array of electrical, mechanical and environmental problems that can potentially cause an unplanned shutdown of a mill is an equally substantial assortment of maintenance resources available to mill operators. Typically, large OEMs offer lifecycle management services, site maintenance on demand, spare parts services, remote diagnostics and training programs and more, and any or all of these can be combined into a multiyear maintenance service agreement linked to predictive and preventive maintenance tools to help curb the frequency of reactive maintenance events — in other words, to prevent unplanned downtime.

Improvements in SAG mill components such as bearings, liners and even nuts and bolts also help operators achieve higher availability levels by extending the intervals between stoppages for routine repairs and replacement. The effectiveness of design improvements to mill components can be reinforced by software tools that help keep a mill operating efficiently, such as FLSmidth's SAGwise system, which uses an array of sensors to listen to the sounds of a rotating mill for indications of over- or underloading; or Outotec's MillMapper, which gives operators a quick virtual look inside the mill to assess liner wear without stopping production.

Multiphysics engineering simulation also offers a path toward solving equipment and operational problems, often more quickly and at a lower cost than other approaches, according to Silvia Firmino, marketing manager for the Brazilian company ESSS, which markets Rocky, a discrete element modeling (DEM) program.

DEM can be a valuable tool in ensuring that milling energy goes into producing particles within the desired size range without damaging equipment. By taking into account all the forces acting on each particle in a bulk system, DEM provides insight into how these materials would perform within a given component over a range of process conditions — a vital capability when operators aren't able to directly see what's happening inside the machine. Of particular interest is that Rocky DEM (named for its origins in rock breakage studies) has multi-GPU processing capabilities that can handle large particle counts for quick, accurate prediction of process or equipment performance.

Also, according to Firmino, the program's post-processing tools are designed specifically for engineers, refined over years of close collaboration with mining clients. As a result, users can efficiently extract needed information such as predicted wear profile, power draw or mill grinding performance. Mining organizations that leverage Rocky, said Firmino, have been able to reduce operational expenses by adjusting repair interval timing, cut capital expenses through optimal operational mode selection, detect potential problems before they can hamper production and extend equipment life.

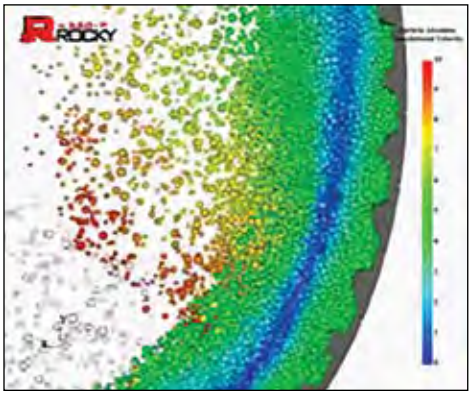
Designing for Durability

The ultimate goal for design improvements to production equipment that typically has to operate at 90% or better availability is to provide a feature that reduces both planned and unplanned down-

time. Outotec, for example, said its new, low-maintenance Polymer HSB mill bearings can do both. The company simultaneously announced the bearing line and introduction of its new MH Series grinding mill product line in December.

The Polymer HSB system will be standard on all its new grinding mills and is designed to maximize grinding mill availability and simplify maintenance. Outotec claims the system significantly improves the reliability and longevity of both radial and axial pads compared to bronze or white-metal pad-bearing systems, eliminating failures associated with surface-to-surface contact caused by journal defects, lock-charge starts or hydraulic system failures. Its self-aligning capability ensures that the pads are always precisely aligned with the mill journal, helping to protect the longevity of the mill by distributing stresses more evenly across the support structure and mill body.

The self-lubricating characteristics of the Polymer HSB arrangement eliminate the need for an emergency accumulator system connected to the mill's hydraulic circuit. Although disconnection of the existing accumulator system is not mandatory, Outotec said doing so can significantly reduce the operational and maintenance costs associated with the servicing of pressure vessels and complex hydraulic systems. According to the company, accumulators are also a substantial source of downtime. Their removal improves grinding mill availability in addition to the improvement achieved due to the robustness of the Polymer HSB.



Rocky DEM, a software tool developed by Brazilian company Engineering Simulation and Scientific Software (ESSS), predicts SAG mill liner wear over time and helps engineers adjust conditions for mill operations by easily assessing change-of-process variables such as speed and fill level.

Component wear, regardless of whether it involves bearings, lifters or other parts of the machine, is a constant concern for SAG mill operators. Industry suppliers have developed a wide variety of liner shapes, composite-material combinations and fastener systems to make liner replacement safer, quicker and more cost-effective in the long run. Given the impact that SAG mill performance has on overall plant performance, operators also have to pay attention to the design and construction of ancillary equipment, such as trommels, to avoid stoppages or loss of throughput from breakage, unexpected wear or loss of processing capacity.

Multotec, a South-Africa based supplier of mineral processing equipment, recently highlighted the capabilities of its SAG mill trommel screen line, describing it as a viable alternative to vibrating screens in SAG mill scalping applications, with features that offer high throughput and extended wear life. The company said it has supplied trommel screens for almost four decades and has the capability to size SAG mill trommel screens with diameters up to 5.5 m. It designs the trommel screens to suit each customer's unique requirements, with capacities ranging up to more than 3,500 tons per hour (t/h) solids. It employs Finite Element Analysis in the design phase to reduce fatigue stresses and ensure structural integrity and covers all frame surfaces exposed to the milled product with wear-resistant materials, usually rubber. Multotec also can supply a range of rubber shell plates and lifter bars to protect SAG mill trunnions against wear.

New Twists on Bolting Tech

When SAG mill liner bolts loosen, break or stretch beyond limits, liner impairment and degraded performance are generally next on the agenda, followed by mill stoppage for repair or replacement. Bolts and nuts — among the smallest mechanical components used in grinding mills — play a big role in ensuring whether a mill can be efficiently serviced at scheduled intervals or on a haphazard basis necessitated by unplanned events. Improvements in bolt-related materials, tools and techniques warrant the attention of maintenance departments concerned about meeting mill performance objectives. Experts in the field of bolted-joint integrity, however, see evidence that not all maintenance organizations are using, or might not even be aware of, all the data that can be accessed and applied to ensure a secure bolted connection.

E&MJ spoke with Trevor Robinson, managing director of Boltstress, an Australian company specializing in ultrasonic bolt-tension measurement, who explained that among some the company's mining clients, "There is generally an acceptance that applying the required torque is adequate — it isn't — and then being at a loss to why liner bolts fail so regularly."

Boltstress provides services and equipment to measure bolt tension, bolt stress, elongation or strain — the information needed to ensure bolted joint integrity, according to Robinson, because it gives insight into true joint performance. Robinson noted that damage or degradation of mill liners is at the root of most problems his team encounters in grinding-mill service calls. On liners, he explained that there can be rough surfaces where cast and forged items interact. This leads to high stress points that in turn can result in high [bolt] tension losses. Additionally, he pointed out that "Lubrication, slurry ingress and hole surface damage are almost impossible to cater for, as they get gradually worse as the mill ages. Direct tension measurement and adjustment is the only solution.

"In most cases, we are called in after repeated failures. However, most sites carry out a re-torque 24 to 48 hours after a reline shutdown has ended. This costs 8 to 12 hours of lost production, but is standard practice as it minimizes failures and unplanned shutdowns. We eliminate this by using much more accurate systems and analyzing real data — not assumed values from torque figures. The payback for the latter is huge, at least $100,000 but often more than $1 million."

Some recent innovations in industrial fasteners and bolting tools can make the job of removing and replacing mill bolts safer and quicker, while others are aimed at ensuring that new bolts are tightened correctly for optimum holding power.

- Valley Forge & Bolt, an Arizona, USA-based supplier of hot-forged industrial fasteners, has developed a bolt design that it claims will improve the reliability of mill liners and liner bolts. The company said it came up with the Sealing Mill Ridgeback bolt out of concern voiced by mill operators about liner breakages triggered by stress concentrations found at the base of the liner pocket where contact is typically made

with the bolt head. Additionally, liner bolt customers also reported problems due to leakage of slurry between liner pocket and bolt head, leading to wear and premature failure.

The Sealing Mill Ridgeback liner bolt was designed and evaluated to prevent problems related to load distribution or slurry leakage. According to the supplier, this bolt produces effective sealing of the bolt to liner pocket throughout the full range of bolt capacity, including very low loading conditions. Its polymer bushing is designed to transfer a predetermined amount of bolt load while remaining load is distributed higher up on the head.

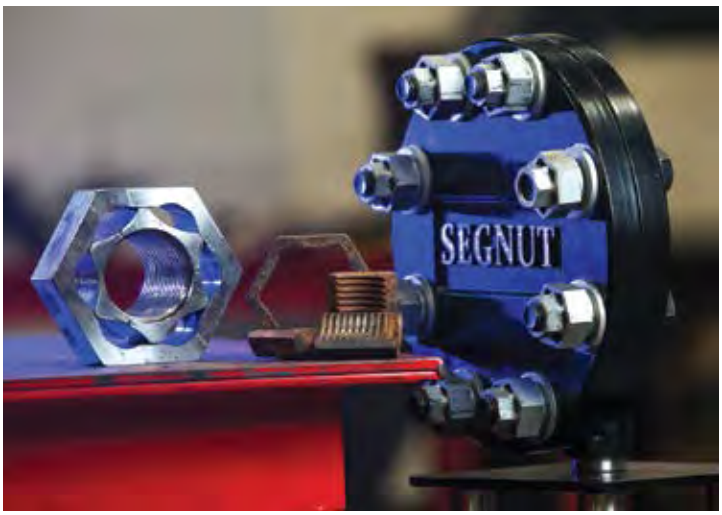
- Another innovative fastener – the SegNut – may offer potential mill-service application benefits as well. The device, as shown in the accompanying photos, comprises an inner segmented, threaded cylindrical section and an outer "shell" that holds the segments in place. In practice, it replaces standard hex nuts and can be installed and torqued using standard bolting equipment. When a SegNut-equipped bolt needs to be replaced, the nut's outer section is turned counterclockwise with a wrench and the threaded segments of the inner section immediately separate from the bolt shank, allowing the Segnut to be removed without need of hammering, splitting, angle grinding or oxy-acetylene torch cutting that is often required to remove frozen, corroded or jammed conventional nuts.

E&MJ spoke with Tom Baskovich, product development director for Perth, Australia-based SegNut, who explained that although the company is focusing its main efforts on other resource-industry sectors such as oil and gas, it collaborated with a provider of mineral processing equipment that validated that the SegNut design can be used in bolt sizes up to M48 (2 in.).

- Kaltech has developed two versions of an "intelligent" bolt — the iBolt and the eBolt — both of which provide progressive indications of liner wear. The iBolt directly monitors liner wear inside a running mill, and when wear reaches predetermined stages, an LED light on the end of the bolt shank flashes in various colors to indicate degree of wear level. With the eBolt, an email alert is sent when the predetermined wear stages are detected. The company said it assumes that the primary use of iBolts is to confirm the liner wear prediction that the maintenance team currently has in place, and because the iBolt is intended for placement in high-wear spots, this can be accomplished with the installation of only a few strategically placed bolts in a mill.
- Columbus McKinnon Corp. manufactures made-to-order high-strength Lister liner bolts for mining applications. After electric induction heating, bolt heads are forged from a selection of more than 200 forging dies. Forged flashings are removed and bolts are heat treated in a controlled-atmosphere furnace to meet precise through-hardening specifications. Bolts are then tested for consistent quality before packing and shipping.
- California-based Poly-Tek makes replacement rubber seals for Lister and other types of liner bolts, offering different seal configurations for specific mill conditions and problems. For enlarged or elongated bolt holes, the company markets cone repair seals in diameters up to 2 in. A repair seal includes a cone that extends through the grinding mill shell, whereas a regular seal does not have a cone. The cone can vary in length. For example, the repair seal cones come in lengths of 2, 2-¼ and 3 in. The length and diameter of the cone will depend upon the size of the bolt and the surrounding metal cup washer. The seals are available in a variety durometers and base polymers, for example, natural rubber durometer, EPDM rubber, or silicon for use in corrosive or high temperature applications.

There are also plenty of equipment choices available for removing stubborn mill liner bolts. McLellan Industries, for example, offers the Bolt Buster, a two-part tool comprising a barrel assembly and a remote-control pendant. It can deliver a 3,200-lb-ft blow — 28 times more powerful than a sledgehammer swing — every two seconds. An overhead crane or optional gantry system is required, while a pitch attitude adjustment on the unit enables it to be positioned with the head of the Bolt Buster impactor against the target.

Russell Mineral Equipment has developed the Thunderbolt 1500 Special Performance Recoilless Hammer, designed to replace heavy manual sledgehammers, hydraulic rock breakers, jack hammers



SegNuts comprise an inner set of threaded segments held in place by an outer sleeve. They replace standard hex nuts and are designed to release instantly when loosened with a wrench.

and heavy battering rams by delivering a 1,100-ft-lb blow strike every second. This tool, according to RME, is suitable for larger mills. Each unit requires a Thunderbolt Power Pack to supply the electrical and hydraulic needs of the hammer and powered suspension options. The hammer can operate with any standard three-phase supply (380, 415, 480, 525, 575 or 600 volts at 50 or 60 Hz). Each unit weighs 449 kg (988 lb).

RME also introduced a hammer guidance and suspension system called Skyway, which it describes as advanced technology aimed at drastically reducing risk by relocating mill relining activity from inside the mill to the safer area outside the mill. Skyway is a purpose-built structure external to the grinding mill that supports and positions Thunderbolt recoilless hammers and operator work platforms. The Skyway system, according to RME, offers precise hydraulic control of Thunderbolt hammers, allowing for faster movement between bolts and faster alignment, along with increased hammer preloading compared with conventional methods. First Quantum Minerals installed the first commercial Skyway package at its Cobre Panama mine to expedite relining of the three SAG mills on site.

The Skyway system joins the ranks of other multi-axis liner manipulator systems and handlers from mill builders Metso and Outotec, third-party suppliers like Kaltech and McLellan Industries, and specialized systems such as the robotic bolt/nut removal/replacement machine developed by the Chilean company MIRS.

Inspect to Detect

Even in the unlikely possibility that someone eventually invents a service-free SAG mill, "maintenance-free" will never mean "inspection-free." As Metso's Moris Fresko pointed out in a blog post, often-invisible defects represent a notorious group of usual suspects linked to unexpected mill shutdowns. Fresko, who is director of Global Engineering–Grinding Services at Metso, lists three of these problems, all of which are usually detectable by nondestructive testing methods:

- Cracks in gears and pinions. "Small cracks can appear in the gears and pinions. If not detected early enough, cracks can progressively become worse until tooth breakage occurs."
- Slurry wash under the liner. "In wet grinding mill applications, slurry can seep underneath trunnion or shell liners and start washing the mill components, particularly when the liner rubber backing is missing or damaged. Often, this goes undetected for long periods of time causing excessive wear to the mill rotating components.
- Structural failure of mill components. "A grinding mill goes through considerable rotations in one year and fatigue cracks can develop over time. If undetected, these cracks will grow until the components fail (crack through). Evaluating the causes of these cracks are as important as detecting them."

Both cracked gears/pinions and structural failures are typically detected using Magnetic Particle Inspection, a non-destructive procedure for discovering surface and shallow discontinuities in ferromagnetic materials. Finding and fixing issues early will avoid undesired wear, broken teeth or even complete failure of the gear and pinion.

MPI is typically used to find cracks, while Ultrasonic Testing is used to find and locate wear or wash in rotating components. UT can indicate the thickness of a mill structural component such as a head, trunnion or the shell, enabling operators to determine the location and extent of the thinning areas. UT testing has the benefit of detecting wash inside the mill without removing the liners, which minimizes downtime required for the inspection as it is performed from outside the mill.

If inspection indicates a structural failure, further evaluation can be done using Finite Element Analysis, an engineering tool used to calculate stresses and deflections within a structure where a complex geometry is broken into smaller simple elements and results are then combined to give a complete picture. In most cases, and especially on newer mills, said Fresko, causes of structural failures are not due to a weak design, but rather mill abuse, mill overload or wash. An FEA evaluation determines if a worn component is too thin and should be repaired before further damage occurs. Similarly, mill loading may be excessive and should be reduced. FEA can also help to determine what options could work as a temporary fix while waiting for a replacement part.

Maintenance-related events such as insurance and warranty inspections, alignment checks, lubrication system troubleshooting and many service and repair tasks require a clean gear set. When a large, conventionally geared SAG mill is involved, cleaning can require several hours of messy, mostly manual labor during a crucial period of mill downtime. Services such as the Traxol EP3 solution from Canada's Guardian Chemicals, for example, offer products for gear cleaning and degreasing that can be purchased directly and applied by a customer or as part of a cleaning job performed by an on-site team from Guardian.

Kaltech's iBolt is designed to flash an externally visible LED warning light when predetermined liner wear levels are reached in a SAG mill.

Greg Pecharsky, vice-president sales, Canada for Guardian, told *E&MJ* that Guardian's innovative combination of specialized extreme pressure lubricants with thixotropic organic chemical technology is featured in its Traxol EP3 low-downtime, rapid "clean on the fly" process. The products, according to Pecharsky, come ready to apply without preheating. He estimates that since their introduction to the marketplace, Guardian's Traxol EP, EP3 and Detrax have been used to clean more than 5,000 grinding mills, rotary kilns and other types of large geared equipment in 15 countries.

He noted that one of the company's Canadian gold mine customers recently cleaned the gears of two very large ball and SAG mills — including setup, rinsing and takedown — in just three hours per mill. In the North American market, Guardian/Traxol provides both product and technical support, as well as application and cleaning teams that perform mine gear cleaning on site within Canada. In the U.S., distributors in Minnesota and Arizona offer both product sales and onsite gear cleaning services. The company's newest innovation, which will be launched at MINExpo 2020, is an organic, hybrid gear degreaser with an unlimited flashpoint and unique application characteristics.

Saudis Pursue Ambitious Mining Projects

Saudi Arabia, the land of black gold, is now in pursuit of the real stuff; the Gulf kingdom hopes to create a domestic mining industry, a sector neglected up until now

By Gavin du Venage, South African Editor

Saudi Arabia has long held the position as one of the world's largest oil producers. However, reliance on a single commodity has shown the vulnerability of the country to external price shocks. In June 2008, crude hit an historic high of more than $150 a barrel. Just months later it could barely fetch $30 a barrel.

Such shocks play havoc with the country's national budget, dependent as it is on crude sales. Now, the kingdom is looking to broaden its economy. The number of business licenses granted to foreign investors in 2019 was the highest in almost 10 years, according to Invest Saudi, the government organization that facilitates and monitors foreign investment.

It is mining, however, that will receive much of the focus for broadening its economy.

"As part of its diversification plan, the kingdom wants to focus on localizing manufacturing and supplying employment opportunities for its citizens," Albara'a Alwazir, economist for the Saudi-U.S. Business Chamber, told *E&MJ* in an interview.

Alwazir is also the author of a comprehensive report the chamber recently published on the country's potential for mineral development. "Saudi Arabia is endowed with a significant mineral base, which it plans to use for domestic production and to become an export leader across a number of minerals, including gold, copper, phosphates and aluminum," Alwazir said.

Albara'a Alwazir, economist for the Saudi-US Business Chamber, says the oil rich state wants to now develop mining. (Photo: Saudi Arabia-US Chamber of Business)

Altogether, Saudi Arabia may have as much as $1.33 trillion worth of mineral endowments, especially in precious and base metals, according to various estimates. Yet, currently, mining takes up only 0.2% of the kingdom's investment, a sum of around $2 billion per year. Even then, most of this went into quarrying rather than actual resource extraction.

To speed up investment, mining has now been given its own ministry, following a royal decree that separated it from energy production. As part of the oil ministry previously, mining was a neglected stepsister, but with its own political and administrative department, it now has a chance to shine. It will now fall to the newly formed Ministry of Industry and Mineral Resources to increase mining's contribution to GDP from around $17 billion currently to $64 billion by 2030, a target set by the government.

Saudi Arabia wants mining to help finance the modernization of its economy. (Photo: Commons)

Digging In

Saudi Arabia is endowed with significant mineral deposits that are widespread across many types, ranging from gold to lightweight aggregate. According to the Saudi Geological Survey (SGS), the bulk of metallic mineral resources are contained in the Precambrian geology of the Arabian Shield, in the western part of the kingdom. The SGS also noted that non-metallic resources reside in both Precambrian and Phanerozoic geology that overlie the Arabian Shield in the central and northern parts of the kingdom.

According to the SGS, a total of 5,574 metallic and non-metallic mineral sites have been discovered by the end of 2018. The breakdown indicates 2,919 discovered sites for non-metallic minerals and 2,533 discovered sites for metallic minerals.

The Saudi Arabia government is thinking beyond simply extracting minerals, however. Much as it did with Aramco, the state-owned petrochemical company that recently celebrated the world's largest initial public offering, the kingdom hopes to develop a broad range of downstream projects.

For instance, the state-owned Ma'aden mining company has had a partnership with U.S. based Alcoa since 2009,

which Alwazir noted is a good example of a "mine to metals" project. The country has large bauxite deposits in Al Ba'itha to the northeast, near the border with Iraq.

The mine on site produces around 4 million metric tons per year (mt/y) of bauxite, and this is transported via the new North-South railway line to Ras Al Khair along the Persian Gulf coast. Here it is refined into aluminum and exported worldwide. "Mining bauxite will service an aluminim rolling mill plant capable of producing 460,000 mt of flat rolled products," said Alwazir. Other metal production is also gaining pace.

"With regards to iron, Saudi Arabia currently produces rebar locally. It also produces significant amounts of wire and cable from its large reserves of copper."

Ma'aden itself, meanwhile, is also going to be a critical vehicle for developing Saudi Arabia's mineral industry, much as Aramco has done for its petro-chemical sector. Ma'aden was formed by royal decree in 1997. Wholly owned by the Saudi Government until 2008, when 50% of the company's shares were floated on the Saudi stock exchange, or Tadawul as it is generally called. The Saudi Government, through the Public Investment Fund (PIF), still retains 65% ownership.

Today, Ma'aden is ranked among the top 10 global mining companies based on market capitalization. The main area of focus for Ma'aden has been gold, phosphate, aluminum, industrial minerals and copper. "Ma'aden is an instrumental player in the mining sector," said Alwazir. "Ma'aden is the mining and metals leader in Saudi Arabia and the largest multi-commodity mining and metals company in the Middle East."

Saudi Arabia has vast mineral resources but remains largely under explored. (Photo: Commons)

Going Large

One of the more ambitious plans in the works, is the $22.7 billion Wa'ad Al Shamal project in the north of the country. This will eventually become a 275-square-mile precinct for mining industries in the region. The area holds around 500 million mt of phosphate ore, which represents around 7% of global proven reserves.

It is estimated that Wa'ad Al Shamal will generate $6.4 billion from non-oil sectors and contribute 3% to the kingdom's GDP. Furthermore, an estimated 30,000 jobs are expected to be created for Saudi nationals. According to Alwazir's report, the project will also benefit secondary industries that depend on mining for inputs, such as glass manufacturing, glass fibers, plastics and solar panels. The net result, said Alwazir, is that the country is set to become a serious mining play.

"Saudi Arabia is looking to develop its mining sector with strong support from foreign enterprises," he noted. "The introduction of the new mining code provides clarity on the regulatory structure of the sector and spells out the numerous advantages available to new entities by way of reduced taxes, financial incentives, ownership rights and ease of obtaining permits."

Kefi Searches for Saudi Gold

Australia-listed Kefi Minerals is one of the few mining companies actively exploring in Saudi Arabia. Kefi has exploration licenses and applications that cover around 1,000 km^2 in the center, west and southwest of the country. Mostly, gold is being targeted.

"They want mining to be their 'third pillar' of the economy," said Kefi Executive Chairman Harry Anagnostaras-Adams. "We've met the new minister and he's deadly serious about it."

Already, the company is confident of at least 730,000 ounces (oz) from its license at Jibal Qutman, in the southwest. Initial production is predicted to be approximately 30,000 oz/y.

"We're one of the few people now on the ground doing things." However, Anagnostaras-Adams thinks this could change as word spreads of the country's new direction toward greater mining. Plus, he said the country's mining code is relatively simple and industry-friendly.

"They are attracting the likes of Newmont and Barrick, two of the world's largest copper-gold companies," he said.

Barrick for instance runs the Jabal Sayid copper operation 350 kilometers northeast of Jeddah. This is a 50:50 joint venture operation with Ma'aden. The first shipment of copper concentrate occurred in December 2015, and the mine commenced commercial production in July 2016.

Kefi, meanwhile, is making progress with its exploration activities. "We appear to be nailing the structure — we know there is gold and there is copper. We haven't gotten grades back yet, but if we get results back, follow up will be required," Anagnostaras-Adams said.

The permitting process has been smooth so far and Anagnostaras-Adams said he is confident that further licenses that the company has sought, will soon be issued. "We believe we will be issued large areas for exploration in the new year," he said.

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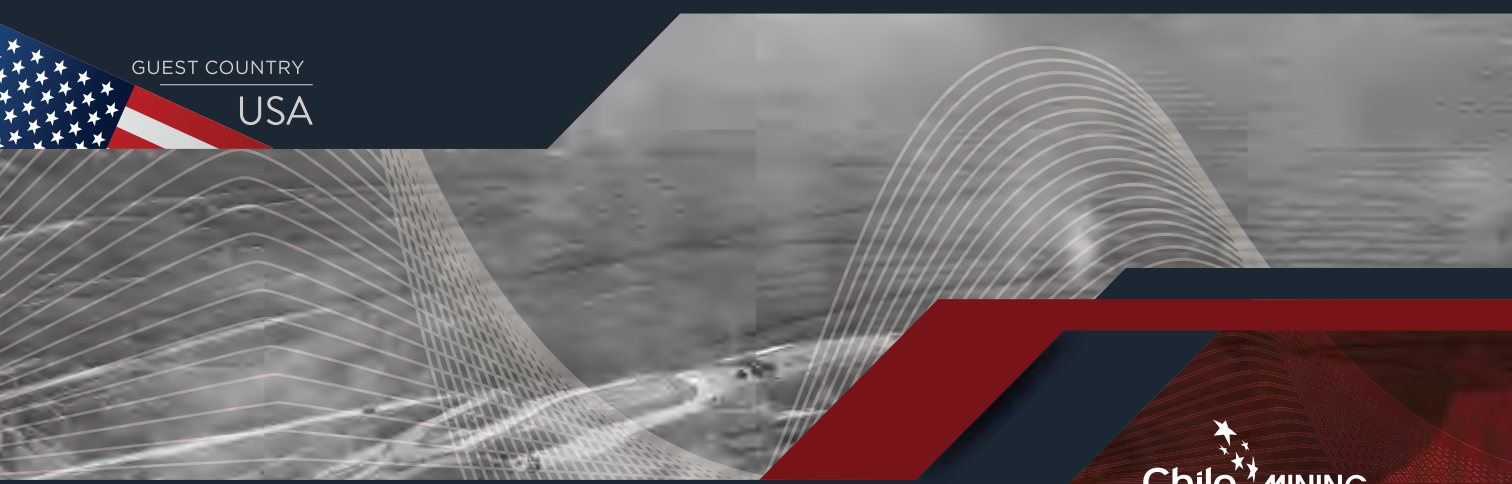

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Mining in Chile

Chilean miners display resilience despite socio-political uncertainty

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A REPORT BY GBR FOR E&MJ

FEBRUARY 2020

Introduction

Social turmoil forces reconsideration of Pinochet era development model

The top copper producing country in the world continues to present enormous opportunities for copper and gold exploration and development. Photo of Cortadera, courtesy of Hot Chili.

Prior to October 2019, the pervasive view held amongst Chileans and outside analysts was that Chile was immune to political destabilization and social unrest. Although populism was spreading across Latin America and several other parts of the world, Chile was viewed as a consistently strong economic performer with relatively moderate politics. At the sustainable mining conference in Santiago in September, the most profound challenges facing the Chilean mining industry were outlined: weakness in the price of copper and lithium, water scarcity, declining ore grades, social license, high energy and labor costs, to name a few. One concern absent from that list was internal stability. For the past three decades, investors have viewed Chile as a bastion of calm in an otherwise politically precarious region. Chile achieved its status as a leading mining jurisdiction not only because of its high quality and easy to exploit resource base, but also because its policies toward mining were regarded as best in class from an ease of doing business perspective.

In light of October's protests that have shocked the country, questions have been raised regarding Chile's ability to maintain its status as Latin America's most stable and successful country. The civil unrest was seemingly triggered by increased metro ticket prices, but at its core the disorder is fuelled by a gathering sense of economic inequality. Since 1990, the country's restored democracy has maintained the broad outline of free-market policies installed by Pinochet's dictatorship, which have enabled consistent economic success. The poverty rate has fallen from over 40% in 1990 to under 10% today, according to World Bank figures. The middle classes now form a majority, income inequality is below the Latin American average and Chile received the region's highest score on the United Nations Human Development Index, which is predicated on a blend of life expectancy, education and national income per capita.

In the context of the region, this performance is strong. However, compared to its OECD peers, Chile ranks highest in economic inequality. UN reporting found that the richest 1% of the population earns 33% of the nation's wealth. This fact is one of the principal reasons why there is such widespread anger. Poor and middle class people, who rely on public transport, feel that the burden of state funding is being unfairly placed on them at a time when middle class wages are stagnating and low skilled jobs are being replaced with technology.

Much of Chile's economic success has come on the back of a robust mining sector that has been and will continue to be the lifeblood of the economy. Chile is the world's top producer of copper, and exports of the metal account for approximately 10% of the nation's GDP. It also possesses the world's largest lithium reserves, based off of a U.S. Geologic Study (USGS) report.

It is unclear what, if any, backlash there will be long term on heavy industries such as mining. The protests have caused disruption to the typically efficient operational environment throughout the country, but strikes within the mines were limited to a few union groups and interruptions were minimal.

According to Joaquín Villarino, President of Consejo Minero: "October and November have been very hard months for Chile. We believe that the social unrest is transitory. However, it will mean profound changes in certain public policies in the country in order to improve the quality of life of those Chileans who are suffering. We are optimistic that regulation of the mining industry will not change dramatically."

In Chile, mining is taxed at a rate of 40-43%, one of the highest percentages globally. Villarino continued, "There is not much room to raise taxes, but it is something we are anticipating."

It is not just those who have taken to the streets armed with clanking pots and pans that are disappointed in the pace of economic growth in 2019; mining companies also had high expectations going into the year. However, predictions of demand outpacing supply for copper and lithium have not materialized thus far. The demand shortfall for these commodities can be blamed on a variety of global economic factors, but the most salient are the China-U.S. trade war and economic stagnation in Europe. Adding to the pain was the fact that Chilean copper production fell 2.5% in the first half of 2019 on the back of declining copper grades, according to a study by the International Copper Study Group (ICSG).

Given these dynamics in the market, and protests that have crippled the nation's retail economy in October and November, it is a testament to the dynamism of the Chilean economy and sound management practices in its mining industry that the economy is still projected to grow at an annual rate of 1.4% for 2019. Although growth has been well below expectations, it is still far better than that of its regional peers: Argentina, which is in recession, and Brazil, whose economy has stagnated.

Chile's history of churning out successfully run local businesses devoted to the mining industry is undoubtedly a positive driver of wealth creation. In describing the advantage Chilean companies have over large global enterprises, Ivan Rayo, general manager of Chilean engineering consulting firm JRI, said: "Being a Chilean company means that our clients benefit from increased flexibility. For example, many operations are struggling to stay profitable with a depreciated copper price. Local businesses excel in responding quickly to adjust costs and implement solutions."

Another locally run business, Perfo-Chile, has 35 years of experience as a provider of drilling services. General manager Osvaldo Carmona outlined his approach to weathering turbulent times: "We have focused on building our cash reserves over time in order to invest through good and bad economic and political climates."

Although mining is not experiencing its best year, companies continue to invest. Almost US$66 billion has been earmarked for Chilean mining projects for the period between 2018 to 2027, and 43 mining projects will be built or will begin production by the end of 2023, according to the Ministry of the Economy. The biggest project is Teck Resources' Quebrada Blanca phase II, which involves US$4.2 billion in investment over the next five years to extend the life of the copper mine in the Tarapacá region. Antofagasta Minerals, meanwhile, will invest US$3.7 billion to expand its Centinela copper mine, with construction starting in 2021. The third biggest project is Nueva Unión, a joint venture between Teck and U.S.-based Newmont, which needs US$3 billion over five years for construction of a copper-gold mine.

These new investments are needed to offset a potential decline in production from some of Chile's largest and most reliable sources of copper. After 104 years of production, Codelco's Chuquicamata, the largest open pit mine in the world, closed its surface operation and commenced its underground phase, and there is uncertainty surrounding the mine's ability to maintain current production levels, particularly in the near term. Codelco is expected to invest US$5.58 billion according to Consejo Minero in order to achieve a production level of 140,000 mmetric tons per day (mt/d) of ore, with a mine life of 45 years.

At the end of the day, it is important to keep in context the sheer size of opportunity that the Chilean market represents. It holds 22% of the world's copper reserves, 11% of the molybdenum reserves, 5% of the silver reserves, 7% of gold and 48% of the world's lithium reserves, according to Invest Chile. Furthermore, the quality of these reserves is often described as best in class.

In light of the civil unrest, political sensitivities have become a more important part of the discussion regarding mining in Chile, but given the role the mining industry can play in delivering a better future for Chileans, it is important that it prevails in the face of any populist backlash. Jorge Maldonado, general manager of Superex, a leading company in sonic and diamond drilling, summed this sentiment up: "Sometimes Chile forgets how vitally important a strong mining sector is to the health of its broader economy. We must not miss our opportunity to lead in mining."

Chile's Project Development

Increasing necessity for new projects today to meet tomorrow's demand

Take a flight to the north of Chile and, as the plane descends, you may notice one of the many deep holes in the earth. Of the top 20 highest producing copper mines globally, seven are located in Chile: Escondida, Collahuasi, El Teniente, Los Bronces, Los Pelambres, Chuquicamata and Radomiro Tomic are all stars in the global mining constellation. Maintaining high production from these large mines, along with additional new production, is essential as the world transitions to a new energy economy. Simply put, the green economy is far more metal intensive than the fossil fuel economy. So long as demand continues to rise for electric vehicles and solar and wind energy, demand for copper and lithium will rise synchronously.


Baldo Prokuriça, Minister of Mining.

Wind and solar energy requires three to 15 times as much copper per unit of output as fossil fuel generation, according to the *Financial Times*. Estimates are that copper consumption from electric vehicles, which was 0.9% of the global total in 2017, will rise to 8.2% of total copper demand in 2030. Given these dynamics, it is increasingly important that Chile continues to invest and innovate in order to offset production declines.

Although Chile is considered a mature mining jurisdiction, Timothy Beale, CEO of Revelo Resources, a prospect generator, described the quality of the country's mining assets: "World class means long life of mine and scalability of production, and Chile has several truly world class mines."

According to Mining Minister Baldo Prokuriça: "Chile has been mining since before the arrival of the Conquistadors and will be a mining country for much longer."

This perspective is especially welcome in a year when several of Chile's top producers have struggled to boost production and earnings. Chilean state-run Codelco, the world's largest copper producer, saw year-on-year profits plunge over 70% from US$1.235 billion in June of 2018 to US$318 million in June of 2019, according to their earnings statement. This drop in earnings is not expected to continue, but it illustrates the impact weak copper prices coupled with the high cost of investing in future production can have on profitability.

Before the wave of protests and riots began in October, Codelco was already facing the difficult task of having to invest billions just to maintain production levels and keep costs from rising. Now, as the government faces a long list of spending demands to appease protesters, the challenge is more formidable. The government announced US$5.5 billion of additional government spending in December, and Codelco will be expected to help fund a larger welfare system in the country. The company can also anticipate a much more tightfisted response from the state in its allocation of funds to meet Codelco's need for financing.

On the spending side, Codelco is now looking to shrink its project budget through 2028 by US$8 billion, or 20%. According to the company's Q3 2019 reporting, there are no plans to suspend any planned projects. At the same time, the company is looking to generate an additional US$1 billion in gross earnings from 2021. According to CEO Octavio Araneda, Codelco is making a "great effort" to help generate the cash Chile needs to address social demands. To achieve the capex savings, Codelco will simplify project design, and reinforce operations maintenance and supply. "Codelco's future depends on finishing structural projects on time and at lower costs. Without them, our production will fall significantly and we will stop contributing to the country," Araneda said.

Meanwhile, the story at BHP's Escondida, the highest producing copper mine in the world, was more optimistic, yet still below expectations. Copper production at Escondida in FY 2019 decreased by 6% to 1,135 million mt/y as a consequence of a 12% decline in copper grades. Revenue from Escondida also fell by US$1.5 billion to US$6.9 billion overall for the year. According to BHP's end of fiscal year 2019 (Australian) conference call on June 30th, 2019, it is believed that Escondida will continue to be a very good cash returner for the next decade despite the down year. Results amongst the majors operating in Chile vary, however, and 2019 has generally proven to be a difficult year with profit margins being squeezed by low commodity prices and high production costs. Driving the high cost of production in 2019


Octavio Araneda, CEO, Codelco.

were falling ore grades, collective bargaining issues and increased water costs.

Given the current dynamics of the market in Chile, there are relatively few greenfield projects being pushed forward today. In a conversation with Claudio Martínez, commercial director at Worley, he confirmed this trend: "There are a lot of greenfield projects, but they are currently dormant due to grades and prices. The mining industry in Chile is thus mostly seeing brownfield expansion at this time."

Projects like Chuquicamata underground and the second phase of Quebrada Blanca, commonly referred to as QB2, dominate the headlines when it comes to investments in the future of mining in Chile. However, these should not overshadow the progress some of the mid-tier and junior mining companies are making in developing assets that could soon become strong producers.

One such company is Los Andes Copper. Its Vizcachitas project, located in the Rio Rocin Valley of central Chile, is one of the largest advanced copper projects in the Americas not held by a major. The project is currently well positioned to continue its development as it is now in the permitting process for its pre-feasibility study. According to executive chairman Fernando Porcile: "The Vizcachitas project not only has a large resource, but also has some qualities that make it more competitive than many new greenfield projects and even some of the brownfield expansions in Chile."

Other important copper projects being advanced by juniors and mid-tier miners are Mantos Copper's Mantos Blancos, Pucobre's El Espino, Sprott Resource Holdings' Minera Tres Valles, Coro Mining's Marimaca, Hot Chili's Cortadera and Aethon Minerals' Arcas. Each of these companies has had to weather a volatile few years, and, given their ability to survive the downturn up to this point, they would all be positioned for success given any uptick in the copper market.

Financing has not come easily for juniors in recent years. In 2018, juniors accounted for only 4.5% of the total exploration budget in Chile, while majors accounted for 88.8% according to Cochilco. There are a few reasons for this, but foremost among them is the difficulty juniors are experiencing to raise capital. David O'Connor, chief geologist at Aethon Minerals, said: "There is a lack of investment in junior companies resulting in a lack of activities from them. It has become increasingly difficult for juniors to raise financing on the stock markets. There has also been a slowdown in exploration activity from the majors, making it hard to do joint ventures."

Nonetheless, 2019 has seen some positive developments as each of the aforementioned juniors has received the needed financing and is continuing to progress through the permitting and approvals process.

Reaching long-term production goals

Cochilco has stated that the goal for Chile over the next 10 years is to raise copper production from 5.8 million mt/y in 2018 to 7 million mt/y over the next decade. "Some projects are going to increase their production, but development will not be as easy and fast as companies have planned. Mining projects are taking an increasingly long

time to develop due to social, environmental and technical challenges," said Juan Pablo González, president of the Institute of Mining Engineers of Chile (IIMCH).

One of the reasons it takes so long to develop a project in Chile is that the number of permits required to operate is very high. Codelco's Ministro Hales project obtained 645 permits before starting its operation. Another reason the permitting process is so extensive is that communities are now becoming more involved and mining companies are finding it harder to earn and maintain their social license to operate. There have been a number of high-profile court cases that have succeeded in delaying or halting projects, and a lack of wealth and development in mining areas has awakened communities to try to maximize their benefits from mining activity. Chile does not directly reinvest its mineral tax revenue in producing regions, so communities feel the need to apply pressure in order to get their fair share.

When asked about the main issue facing the mining industry in Chile, Cochilco vice president Jorge Cantallopts responded: "Improving the level of engagement between the mining industry and the community is critical. We believe that previous relationships between mining companies and communities have been more transactional rather than developmental. The mining industry should be more involved in the development of local communities, so we are studying how to improve these relations… The entire permitting process can take up to a decade, which is way too long and also too expensive. This scares investors, and it is necessary for Chile to streamline the process to attract more investment. Because the permitting process is timely and expensive, the Chilean mining market is dominated by major mining companies and there are too few juniors operating in Chile."

Lithium

Although Chile is known for its prowess in copper, lithium mining is a new frontier in which the country has great potential. In 2018, USGS figures show the country produced 16,000 mt/y of the mineral, second only to Australia. Given the global trend towards electrification of transportation, lithium production could be poised to become an increasingly important part of Chile's economy. This would be particularly true if demand ends up meeting expectations to triple by 2025.

Currently two major producers, SQM and Albemarle, dominate the Chilean market. Canadian-based companies Lithium Chile and Wealth Minerals are some of the most well known juniors operating in the space, and Wealth Minerals in particular has attracted the attention of potential partners and financiers around the world. In October 2019, Uranium One, a subsidiary of Russia's state nuclear company Rosatam, bought a controlling stake in the firm in the wake of China's Tianqi Lithium acquiring a 24% stake in SQM.

The reason Chile is such an attractive jurisdiction for lithium production is largely because of the Atacama salar, which produces the most lithium of any salar in the world. Wealth Minerals has a 46,200-hectare concession in the Atacama salar, and the company's CEO, Henk Van Alphen, described why it is so compelling: "The Atacama salar is the world's highest grade and largest producing lithium brine deposit and currently produces approximately one third of global lithium output from two production facilities operated by SQM and Albemarle. It possesses a very high grade of both lithium and potassium and has a high rate of evaporation and extremely low annual rainfall."

Gold

In contrast to copper and lithium, precious metals focused companies have not experienced the same level of difficulty in financing their operations. With gold trading at a five year high around US$1,500 per oz and the majority of global central banks devaluing their currencies, there is optimism that gold prices will remain high for a prolonged period. Because of this thinking, the market for new exploration has been reinvigorated and projects are being advanced.

One example is Gold Fields Salares Norte Project. Discovered in 2011 and expected to begin operations in 2022. Salares Norte has completed its feasibility study and hosts a gold mineral resource of 3.9 million oz of gold and 44 million oz of silver while the reserves are 3.5 million oz of gold and 39 million oz of silver. Approximately 90% of the value and volume is in gold and 10% of the value and volume in silver. The initial life of mine is expected to be 11.5 years and the payback period is 2.5 years, given a US$ 1,200/oz gold price. According to Max Combes, Gold Fields Chile country manager: "At today's gold price, the mine would be very profitable."

Located at an altitude of 4,500 m the estimated investment in Salares Norte is around US$850 million in capital investment and a further US$450 million in sustaining capital over the life of mine. "Gold Fields will create a peak of 2,700 jobs during construction of the mine, and an average of 900 workers during the operational phase," Combes said.

The Services Sector

Building resilient businesses for tough times

Efficiency in comminution and material handling remains essential for profitability in Chile's aging mines. Photo courtesy of Metso.

Copper runs through the veins of Chile, and cities such as Antofagasta and Calama have risen out of the desert fuelled by exports of the red metal. Underlying Chile's success as a leading metals producer is a robust ecosystem of service providers. Drilling contractors, engineering firms, mineral processing specialists and consultancies all play an equally important role in contributing to the country's high level of production. Consejo Minero estimates show 6,300 companies in Chile qualify as mining suppliers, with 25% headquartered in mining regions outside of Santiago. That inevitably means regional economic success is highly correlated with the price of copper and the performance of the industry's service businesses. In Antofagasta, mining contributes 54% of GDP, Tarapacá 37% and Atacama 38%, based off Chile's Central Bank data.

Unfortunately, when commodity cycles are in a down phase, service providers are susceptible to tightened margins, falling utilization rates and less ambitious planning for greenfield projects.

Ivan Rayo, general manager, JRI Ingeníeria.

According to Stephanie Ashton, CFO of Griffith Drilling, a diamond drilling company capable of operating at 2,300 meter depths: "There has been little capital for greenfield exploration nor any appetite for it from a timeline and permitting perspective…. The current trend is for companies to do expansions of their existing operations. One of the ways in which the industry is confronting the problem of permitting and not being able to develop new projects is by drilling deeper at their existing operations."

On the engineering side, Ivan Rayo, general manager of JRI Ingeníeria, observed: "Nowadays we have a lower copper price and demand for engineering services has shrunk. There are less opportunities to expand the business, and many engineering companies have been forced to take austerity measures to increase efficiency. It has also meant fiercer competition."

That is not to say that opportunities aren't present for service companies. Both a growing lithium industry and an increasing push into underground mining will continue to keep service providers busy for years to come. Furthermore, the mining industry is becoming much more focused on sustainability, so there will be a host of new opportunities and challenges associated with reducing water usage and lowering carbon emissions.

One of the primary demands on service providers in today's market is to lower costs, and that often means careful planning. Claudio Martinez, commercial director at Worley, highlighted his company's success in this area: "Worley has expertise in the designing and reviewing of capex and opex estimates. We have been able to support customers with

Jorge Maldonado, general manager, Superex.

Stephanie Ashton, CFO, Griffith Drilling.

significant reductions (approximately 20%) in their capex investment in brownfield projects."

There are also opportunities for Chile's service providers to grow their exports. Despite its reputation as an export-oriented country, only 5.6% of local Chilean mining suppliers are currently exporting their products and technologies, according to Prochile.

One of the biggest complaints among service providers is that regulations are too tight, and that cuts into profits. According to Jorge Maldonado, general manager of Superex: "The rules are not clear. We do not have big communities in the north, but a few people are creating big problems for business. In Dominga they have not been able to begin because of environmental regulations and community issues. If government is granting permits, then the rules should be clear."

Ashton of Griffith Drilling also pointed to policy issues complicating operations: "From a cost efficiency perspective, we have to comply with a significant number of standards, which has increased our operational costs over time. The same amount of work that we used to perform with three crews now requires four to meet the current labor regulations."

Opportunities Underground

Given Chuquicamata's US$5.6 billion switch to underground cave mining from open pit and El Teniente's new level proposal requiring an additional US$5.5 billion of investment, underground mining is one of the more promising areas for service companies.

JRI Ingeníeria has a division specifically devoted to providing efficient and innovative designs in underground mining. Throughout the downturn in copper prices, JRI has been able to increase market share and, since 2017, has experienced 20% per annum growth. A large contributor to this growth came from underground mine engineering and design. According to Yamana Gold vice president of finance for Chile and Argentina Andres Guzman: "As underground mines go deeper, costs per ton increase, so managing costs such as energy consumption and ventilation of underground mining operations is a big challenge the industry faces."

Sustainability

With Chile chosen to host COP 25 in December of 2019, the country was set to showcase its efforts to become a leading sustainable mining jurisdiction globally. Ultimately, the event was moved because of protests and instability. However, that does not diminish the progress made in implementation of renewable energy, investment in desalination plants and adoption of more resourceful water resource management tactics.

In October of 2019, BHP announced four new renewable power agreements to meet power demand for its Escondida and Spence operations in Chile. BHP proclaimed its aim to supply Escondida and Spence's energy requirements with 100% renewable energy sources from the mid-2020s onward.

Of course these decisions are not made solely out of good will. There is a strong economic case to be made for the ramp up in renewable energy investments. The cost of energy in Chile is one of the highest in Latin America and higher than the OECD average. In addition, access to water is an ongoing challenge in the arid north, where most of the country's copper mines are located. To resolve the issue of water scarcity, mining companies have been building desalination plants, but the high cost of energy required to transport water up to the mine sites increases the overall mining cost. At the same time, declining ore grades require more water to be used in processing, and ore grades in Chile have fallen significantly from 1.13% in 2002 to 0.65% in 2017, according to Cochilco. Energy consumption is expected to increase by 80% in the coming decade, and the cost of energy represents about 20% of copper production costs according to Consejo Minero.


Max Combes, country manager, Gold Fields.


Jim Spenceley, senior vice president of mining, Black & Veatch.


Juan Castaño CEO, Amphos 21.

For Black & Veatch, a full service provider of energy and water solutions to the mining industry, the transition to more renewable energy and more sustainable water use operations holds great prospects. The company engineered the desalination plant at BHP's Escondida and has several other projects throughout Chile, particularly in the area of studies around ways to capture water that will otherwise be lost to evaporation. "Many of the mines in Chile are at 3,000-4,000 meters of elevation and around 100-200 kilometres from the sea, so transporting water via pipeline requires a lot of energy. These systems must be designed the right way, particularly because they are operating at high pressures, so the design can be very sophisticated. There is significant permitting that comes with this process and mistakes can be very costly," said Jim Spenceley senior vice president of mining at Black & Veatch.

Companies are looking to improve in areas of water reuse and recycling. Yamana Gold, for example, has stated that its focus at El Peñón is on "increasing reuse and recycle rates and minimizing overall raw water consumption." To that end, the company has implemented a dry-stack method of tailings storage at the mine, which allows 80% of the water contained in the tailings to be recovered.

At Gold Field's Salares Norte mine, according to country manager, Max Combes: "A lot of effort and money was invested into creating a sustainable design that ensures water use is kept to a minimum. In terms of tailings, we have an environmentally stable design. We have introduced filtered tailings that will allow us to recover most of the water and produce a dry tailing that will be moved with trucks to be compacted."

Environmental consultancies such as Amphos 21, which provides sustainable reuse and feasibility analysis of water resources, are well positioned to be the beneficiaries of the increased focus on sustainability in Chile. "Companies need help and supervision in the construction of new underground wells, and they need defined conceptual models of how groundwater behaves at a mining site and to develop and implement numerical models that allow them to predict groundwater flow and groundwater chemical behavior. Our purpose is to create a sustainable operation that minimizes its impact on groundwater balance," said Juan Castaño CEO of Amphos 21.

Conclusion

There is no denying that Chile's mining service industry is one of the most dynamic in the world. The sector is full of entrepreneurial local businesses competing with well established global firms for contracts. The service workforce is well educated and qualified and, for these reasons, Chile has been able to reach record production levels, despite the maturity of its market. 2019 has been a year that began with great optimism that new investments would be pushed forward and suppliers would benefit from higher margins. However, uncertainty around the global macroeconomic climate and political chaos at home caused projects to dry up. As a result, the market for services remains extremely competitive, with companies lowering their hourly rates and operating on low margins in order to keep from shedding staff.

In spite of this year's struggles, much optimism remains surrounding opportunities in desalination, water reuse, the paradigm shift to underground mining, the focus on tailings dam safety, and generally any solution that improves operational efficiency. Furthermore, there are still billions of dollars of investments coming online in the next few years that will keep demand for services strong. Regardless of fluctuations in markets and politics, Chile's mining service providers have proven their resilience and are built to weather turbulent market conditions.

Innovation that Offsets

Disruptive technologies are compensating for declining ore grades

Robotics continue to display their potential for Chile's mining future. Photo Courtesy of HighService Corp.

Thanks to George Lucas and his Star Wars franchise, as a society, our most popular image of a robot is R2D2. For a small number of visionary thinkers, however, robots are more than science fiction; they are a critical enabler for a safer and more productive mining future.

Marco Ruiz, general manager of ENAEX Robotics, is one of the thinkers attempting to bring disruptive change to the mining industry. He said: "We recognized that as ore grades decline, there is a need to facilitate access in difficult to reach deposits while protecting the safety of operating personnel."

Within the mining industry, robotics may be considered niche and unready to immediately replace traditional methods, but their development and presence is indicative of a broader trend in which companies are investing heavily in technology. According to a KPMG survey, the highest level of investment in the mining technology space is occurring in data and analytics tools, autonomous vehicles and robotic process automation.

One local Chilean company that is growing its presence as a regional leader in automation for mining is MIRS, a subsidiary of HighService Corp. Its president, Hugo Salamanca, characterized industry enthusiasm for robotics saying: "We believe that the industry is more receptive to technology today than it has been in the past, and that presents a big opportunity. The mining industry is facing many challenges and the importance of robotics in mining is now widely understood. We need technology, in Chile especially, because productivity is low and production costs are high. Robotics can help boost competitiveness, improve productivity and reduce costs."

The company develops robotic applications in the concentrate sampling process and in the plugging of flash furnaces. Its robots are active at Codelco's El Salvador operation and in the smelters at Chuquicamata.

Autonomous Mining and Teleoperation

It is no longer an uncommon sight to see a mine truck cabin empty as it is being operated remotely or fully autonomously. Trucks that drive themselves can spend more time working because software does not need to stop for shift changes or to take a lunch break.

One of the added benefits of investment in autonomous solutions is that it encourages innovation from suppliers. For example, there are several new autonomous trucks being introduced to the market today. Companies such as American Air, which supplies air conditioning, are then incentivized to tailor innovations to complement new fleets. According to Joel Araujo Strul, commercial manager at American Air: "The challenge (of automation) is that there are not enough qualified people in the industry who are prepared for this rapid change. We are developing the most automated AC unit on the market, and it will require minimum work on installation and maintenance."

Additionally, American Air is developing a predictive maintenance system for air conditioning units to be launched in 2020.

Beyond vehicles, there are also autonomous solutions for other segments of the mining process. Technosteel subsidiary Polimet, for example, has developed a technology that can transmit information to a remote operator, which eliminates the need for inefficient manual inspections. Their other subsidiary, Safedrill, developed a 100% hands-free rod handling operation in drilling. Technologies such as these will have big implications for increasing safety in the mines.

Data and Analytics

Coupled with development in autonomous mining, data analytics is also quickly becoming an essential tool for operators. Predictive maintenance solutions that address problems before they occur are one of the biggest benefits that digital technologies can offer the mining industry. Maintenance in mining often occurs on a time-based schedule, rather than as needed, leading to a lot of wasted time and money.

Hugo Salamanca, president, HighService Corp.

Francisco Portilla, general manager, Plasma 4th.

In Chile, there are several companies that specialize in helping customers leverage their use of data through software. Although data and analytics tools are still in their infancy in Chile, they represent a significant opportunity because data has the potential to unlock value in nearly every aspect of the mining process.

EY for example, has been working closely with the large mining companies in Chile on ways in which they can better use the vast amounts of data they collect. In one case, the company provided advice that increased recovery in the flotation plant simply by using data analytics to understand the optimal settings on different pieces of equipment. These subtle changes boosted copper recovery by 3%, which translates into significant cost savings.

According to eBooting Co-founder Juan Vega, a company with expertise diagramming and integrating data flows: "We have access to a significant amount of data today, but it does not mean anything if there is a ton of data and no way of using it to become more productive. We see opportunity in distilling and adding context to the vast swaths of data mining businesses collect. If they use these tools properly it will increase their bottom line."

Beyond Blasting

The market for blasting services is highly competitive in Chile, and this competition is producing some of the most cutting edge technology in the business. Maxam, Plasma 4th, Enaex, Technosteel and Orica all are all developing products that make blasting safer, more efficient and more environmentally friendly. By investing in the appropriate explosives, the way these explosives are positioned and stabilized, the accuracy of the blastholes drilled and the detonation procedure, companies can make a material difference to their bottom line.

While some companies are focused on optimizing the results of blasting, Plasma 4th, a subsidiary of Enaex, is focused on eliminating the need for blasting altogether by using advanced rock fracturing techniques. Fran-

cisco Portilla, general manager of Plasma 4th, noted that the benefits of plasma are far reaching. Blasting is often unpopular with nearby communities and is also considered harmful to the environment. Portilla said: "To develop a project near a community, you need technologies that are minimally invasive. Blasting creates a lot of pollution, a lot of noise and a lot of vibration. Often this can lead to resistance from communities and the risk of a project being blocked."

In order for any new technology to be adopted, however, the product must be cost effective. Portilla noted that 1 kilogram of plasma is more expensive than 1 kilogram of explosives. However, there are other costs to consider. These include community resistance to blasting and the high cost of evacuating the mining site when blasts occur. With Plasma 4th technology, only those within a 150 m radius of the fracture are required to be evacuated. This guarantees operational continuity and limits downtime.

Sanhattan Valley?

With so much focus on technology development in mining, Santiago has become an important regional hub for many of the leading global technology firms. According to Pascual Veiga, president of APRIMIN: "Chile is being used as a laboratory for experiments with new technology because it offers great diversity and variation in style of operations, height of mines and rock types."

Another reason technology companies find Santiago appealing is because the city has some of the most well educated and well trained workers, an entrepreneurial culture and a good climate for investors – characteristics the city shares with other international hubs for the development of disruptive technology such as Silicon Valley.


Tomás Buttazzoni, general manager, Technosteel.

Because Chile is a country where vast geological potential mixes with a well educated workforce, it is able to pilot and test cutting edge technologies in its mines. Companies with experience in Chile can then look to apply their knowledge to other less technologically advanced markets. One such company is Technosteel: "Chile is a mature mining market. Therefore, Chilean companies have an opportunity to contribute in introducing world class technologies into less experienced markets, like Bolivia for example. The technologies we introduce are new for them, but have often been in use for some time in Chile," said Tomás Buttazzoni general manager of Technosteel.

Conclusion

The reality in the Chilean mining industry is that as a result of being the leading copper producer globally for over 30 years, many of its most productive mines are mature. Therefore, in order to spur future growth and maintain production levels, technology must be implemented and used to its full capability. The potential to achieve big breakthroughs is now within the industry's reach and companies have begun to embrace digital and technological innovations that are transforming key aspects of the industry. Technologies that have long been in the works are now available and affordable enough to become operational at scale. This transformation is being experienced at varying degrees depending on the producer, but it is without a doubt happening in Chile. Codelco and Lundin Mining are incorporating autonomous fleets into their operations, Pucobre signed an agreement with Epiroc to digitize their operations in Chile and Antofagasta Minerals is investing US$40 million to strengthen its technological platform in the country. As long as these investments prove that they are saving money for clients and making the industry safer, businesses will increasingly move to adopt technology at an even greater pace in order to replicate results.

The technological applications include building a more comprehensive understanding of the resource base, optimizing material and equipment flow, improving anticipation of failures, increasing mechanization through automation, and monitoring performance in real time. Alone, each of these opportunities has real potential. However together, they represent a fundamental shift in both potential safety outcomes and how value can be captured. 65% of large mining companies in Chile invest in improving what they have, while 21% invest in doing things differently and 14% in radical changes according to Deloitte. These numbers will need to shift if Chile intends to remain the worlds leading producer of copper for another 30 years.

CR Digital Acquires Thunderbird Mining Systems

Thunderbird users will now have access to CR Digital's Orion platform as well as its technical support.

CR Digital announced it will acquire Thunderbird Mining Systems in a transaction that expands CR Digital's product offering, IP, sales/marketing and technical support activities.

Damian Assaillit, head of CR Digital, welcomed the move. "Thunderbird Mining Systems were highly regarded in the mining technology sector, providing world-leading blasthole drill optimization technologies to mining customers for more than 30 years," he said.

Thunderbird founder John Vynne reported his team has pioneered Measurement While Drilling (MWD) technologies since founding the company.

"I am really pleased to see that our technologies will be part of CR Digital's range," Vynne said. "There is immense appetite for digital knowledge of drill planning and blast outcomes, and the Thunderbird technology combined with CR Digital's Load Haul Optimization creates a unique and compelling combination that our mining customers will be able to leverage," he said. "Thunderbird's technology is proven to increase mine productivity, reduce drilling costs and improve blasting effectiveness."

The addition of blasthole drill optimization and rock knowledge systems reflects a strategic move by CR Digital to expand its product range across fragmentation through to load and haul optimization, the company reported.

"Thunderbird Mining Systems products complement our existing CR Digital product range, including our market-leading Titan 3330TM Load Haul Optimization technology," Assaillit said. "Optimized fragmentation is a key variable in the productivity of load haul circuits and being able to offer our customers more real-time knowledge is a great opportunity to further enhance mining productivity using technology."

Thunderbird Mining Systems' customers will benefit from the enhanced capability of the global CR group, CR Digital's proactive technical support, the data analytics capability of its Orion platform, and access to a broader technology portfolio providing enhanced value to their operations.

Russian Ore Processing Site Adopts Zyfra FMS

EVRAZ, a vertically integrated steel, mining and vanadium business with operations in Russia, the United States, Canada, the Czech Republic and Kazakhstan, implemented the ZM KARIER Mine Fleet Management System at the Kachkanarsk ore-dressing combine (GOK) in Russia with the help of Zyfra Co.'s mining division, formerly known as the VIST Group.

Leadership at Zyfra said the system has helped increase truck productivity by more than 8%. Management at Kachkanarsk GOK said in 2020, "We plan to integrate railway transport into the project. The smart equipment will be installed on the traction units."

Zyfra reported its ZM KARIER system has been successfully installed at more than 70 open-pit mines globally.

Zyfra's ZM Karier Mine Fleet Management System was deployed to the Kachkanarsk ore-dressing combine in Russia. (Photo: EVRAZ)

Soosan Buys Junjin Rock Drills in U.S.

Soosan CSM purchased the assets of Junjin CSM, makers of hydraulic drills. With the purchase, the partnership between Larmee Equipment & Supply Co. and Junjin CSM to import, manufacture and market the drills was rebranded Soosan America, LLC, based in Louisville, Kentucky, U.S.A.

The North American market demand for Rock Commander machines prompted the purchase. The rebranding will not affect the current product offerings. The Rock Commander series of drills will remain unchanged. Sales and parts distribution will continue from Soosan America, LLC.

EvoQuip Taps EWPA as Poland Distributor

Terex EvoQuip reported it appointed EWPA as its authorized distributor in Poland. The latter will represent the full EvoQuip portfolio of compact crushing and screening equipment, genuine spare parts and machine maintenance.

In addition to sales, EWPA will provide parts, service and warranty support for EvoQuip equipment by factory-trained technicians. Financing options will be available to qualified customers, EvoQuip reported.

Leadership at EvoQuip said EWPA's history as the distributor for Terex Ecotec and Demag cranes evinced its capabilities. "EWPA has strong relationships with customers while also is able to build a strong network across other sectors," Jamie Mairs, territory manager, EvoQuip, said.

EWPA leadership said it was delighted with the role. "We are a long-established, successful equipment distributor with a strong focus on aftersales support, and we look forward to building a successful relationship with EvoQuip," Szymon Atraszkiewicz, CEO, EWPA, said.

Epiroc Partners with Aramine

Epiroc appointed the French company Aramine as official distributor of Epiroc products for underground mines and tunnels in France and in several strategic countries of the Central and West Africa.

Aramine leadership reported the Epiroc product range completes the portfolio of machines offered by Aramine. "Epiroc trust is a mark of recognition of our long-standing partnership, and this obvious collaboration between our two companies allows us to offer a wide and complete solutions range for mines and tunnels to our customers," Marc Melkonian, president, Aramine, said.

Aramine Burkina, located in Ouagadougou, will manage the regional distribution of Epiroc products in Africa.

Separately, Epiroc reported it will consolidate the manufacturing of dimension stone industry equipment to India and will end manufacturing in Italy.

The production facility in Nashik, India, will get the business. The move is expected to shorten time to market.

The business belongs to Epiroc's Surface and Exploration Drilling and Mining and Excavation Rock Service divisions. The product offering includes hydraulic drill rigs such as the SpeedROC.

The operation at Epiroc Stonetec in Bagnolo, Italy, with about 40 employees, will be closed by mid-2020.

Epiroc leadership described the development as necessary to keep the company strong and agile. "India is a large and growing dimension stone industry market and there we can benefit from an already full infrastructure for production, sourcing and logistics," Helena Hedblom, senior vice president, mining and infrastructure, said.

EvoQuip selected EWPA to be its authorized distributor in Poland. Above, the EWPA team at contract signing. (Photo: EvoQuip)

Messe Düsseldorf to Run USA Pavilion at Expomin

Messe Düsseldorf North America will again organize the USA Pavilion at Expomin 2020, Latin America's Premier Mining Exhibition. In the USA Pavilion, companies can have their own booth design or can purchase the USA Pavilion package, a fully furnished booth, the company reported. Pavilion exhibitors will have access to a lounge with catering, internet access, translation services, and meeting rooms. Expomin will be held from April 20 – 24, 2020 in the Espacio Riesco in Santiago, Chile.

F4M Extinguisher Shines in Joint Project

A joint development project that included ABB and the Norwegian Defense Research Establishment concluded that a FiFi4Marine (F4M) extinguisher has the best mitigating performance for lithium ion battery fires. The project launched in 2017 to evaluate the performance of fire-extinguishing solutions. F4M's extinguishing system, a direct injection foam system, had the best heat-mitigating performance. Leadership at the company said their system achieved the maximum scores on all primary objectives.

JENNMAR Brands, Subsidiary Re-Branded XCAL

JENNMAR USA announced JENNMAR McSweeney's, JENNMAR SANSHELL, Cuda Tools Inc., and JENNMAR Construction Tools will be re-branded XCAL TOOLS. The company also announced TungsteMet will be rebranded XCAL Industries.

All products will retain their product name, the company reported.

The development is not expected to impact timeliness of current business activities, JENNMAR USA reported.

L.S.W. to Distribute Metso Parts

Metso contracted L.S.W. Wear Parts Ltd. to distribute screening media, lining and conveyor accessories. L.S.W. has locations in Fredericton, New Brunswick, and Truro, Nova Scotia. To accommodate future Metso customers, it will open a new Bend & Band facility in 2020.

Metso's Jean Hébert and Rob Paxman welcome L.S.W. Wear Parts Ltd. of eastern Canada to the Metso distributor community (Photo: Metso)

Leadership at Metso said the distributor has a proven record of solid customer service. "We know that partnering with them will provide customers with added value screening solutions," Jean Hébert, vice president, services sales, Canada, Metso, said.

L.S.W. began serving Metso customers effective January 1, 2020.

Minnovare Selects Core Tech to Rep in Peru

Minnovare announced a distributor agreement with Lima-based Core Tech wherein the latter will be the former's official sales and support agent for the Azimuth Aligner product throughout Peru.

Leadership at Minnovare said Core Tech has built a solid reputation in Latin America. "Their cultural fit aligns well with Minnovare's and we look forward to collaborating with them in the years to come," Mick Beilby, commercial director, Minnovare, said.

The Azimuth Aligner is used in mining exploration to automate the drill-rig alignment process and increase accuracy and efficiency while reducing downtime, Minnovare reported.

Established in Lima, Peru, in 1996, Core Tech offer solutions for mining exploration, surface mining, underground mining and construction.

Superior Partners With Manufacturer AMPCO

Superior Industries partnered with manufacturer AMPCO Minerals in an effort to improve the responsiveness, reliability and quality of the former's North American supply chain.

Superior management described the partnership as an investment in a team whose core members have decades of experience developing crushing and screening technology for the international markets. "These are accomplished professionals that people in our industry know and trust," Jarrod Felton, president, Superior Industries, said.

Out of a new facility in Shanghai, AMPCO will collaborate with Superior on manufacturing and will leverage access to a dependable supply chain.

Superior reported its global customers should benefit from access to complete crushing, washing, screening and conveying machinery from Superior manufacturing operations located in the Eastern Hemisphere.

Nevada Copper Engages Redpath for Ramp Up

Nevada Copper Corp. recently announced that it has engaged Redpath USA Corp. to implement the company's ramp-up strategy for the underground mine at Pumpkin Hollow, Nevada. The company commenced production from surface operations during December and it is entering into a new phase of development supporting its ongoing operations. It has high confidence in Redpath's ability as a partner during the ramp-up to full commercial production in 2020.

"Nevada Copper made the transition from developer to producer in Q4 2019 and we now have a clear, straightforward strategy for ramping up our Pumpkin Hollow underground project to full commercial production," said Matt Gili, CEO of Nevada Copper. "Redpath is considered throughout the mining industry as the partner of choice for production ramp up and we are excited to be working with them during this important period of growth."

Redpath replaced another mining contractor and will be the company's principal underground mining contractor going forward. Redpath has a great deal of experience, delivering complex projects internationally and in Nevada — ahead of schedule and under budget.

FLSmidth Wins Order for Russian Gold Plant

FLSmidth will supply a new gold processing plant to JSC Pavlik in the Magadan region in eastern Russia. The order for 7-million-metric-ton-per-year plant was valued at around DKK 290 million ($42.9 million). It will operate alongside another processing plant supplied by FLSmidth in 2013.

FLSmidth will supply equipment across the complete flowsheet, including materials handling, flotation, gravity concentrators, screens, gold leaching, dewatering, pumps, cyclones, valves, instruments and reagent systems. The order also includes a complete plant electrical and automation package.

The contract follows the successful partnership with JSC Pavlik for Line 1, for which FLSmidth designed and supplied all the main process equipment. "We want to thank FLSmidth's team for the hard, detailed work that was completed throughout the timeline of the order," said Artyom Bolshakov, vice president of JSC Pavlik. "We are familiar with FLSmidth's equipment since the start of Pavlik and we trust their quality and transparency."

FLSmidth was awarded the engineering contract in 2019 and, following this new contract, the equipment supply will begin in Q4 2020. The plant is expected to commence operation in late 2021.

FLSmidth will supply a new gold plant, which will operate alongside JSC Pavlik's Line 1 (above).

Ukraine Iron Ore Mine Turns to ASI for Fleet Automation

Ferrexpo's truck automation program started with a single Cat 793D and will likely expand to the rest of its fleet.

ASI Mining, a subsidiary of Autonomous Solutions Inc. (ASI), has started work on a project in Ukraine to retrofit and automate a fleet of 15 haul trucks at the Ferrexpo Yeristovo mine (FYM).

"This project is one of the first major autonomous haulage deployments in eastern Europe. It represents a major milestone for the accessibility of automation at sites across the world," said Patrick Hald, general manager, ASI Mining. "Autonomous mining is no longer a luxury available only to the largest mines."

FYM and ASI Mining successfully completed an initial test on October 21 by converting and autonomously operating a Caterpillar 793D haul truck. Ferrexpo plans to expand autonomous operations to a total of 15 trucks within the next two project phases, subject to market conditions and cash flows.

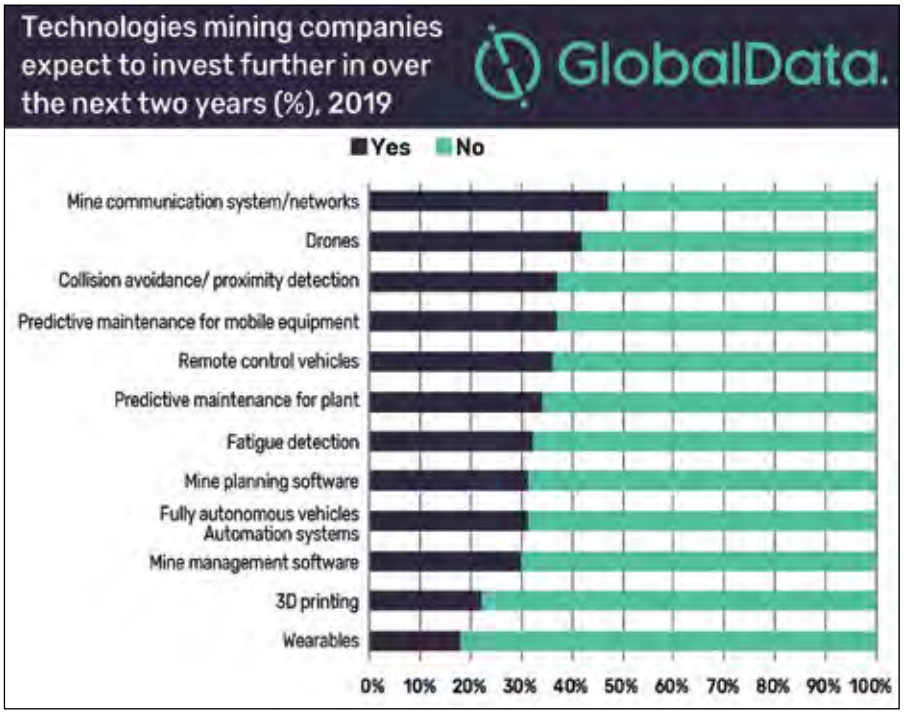
By employing ASI's Mobius software at FYM, Ferrexpo anticipates improvements in utilization, along with increased productivity gains. FYM expects the autonomous mining fleet to deliver significant safety benefits to employees, particularly by eliminating fatigue-induced accidents. The safety benefits will also be complemented by expected improvements in productivity and better control over the quality of the company's ore mix.

ASI's Mobius Haulage A.I. will be a key component in the implementation and operation of the project. According to ASI, Mobius leverages advanced multi-vehicle command and control software to set up and manage a coordinated system of haul trucks. The Mobius Haulage Platform manages autonomous traffic, coordinates manned or unmanned vehicles, and regulates the haul cycle in the most efficient way possible, according to the company.

Ferrexpo is a Swiss-headquartered iron ore company.

Survey Highlights Top Mine Productivity Investments

The drive to improve productivity, efficiency and safety is leading to rising investment by mining companies, large and small, in a wide range of



technologies. Already the extent of mines having invested in mine planning and management software is high, but rising levels of investment are particularly evident in mine communication systems and drones, according to GlobalData, a data and analytics company.

The company's latest report, *Global Mine-Site Technology Adoption Survey 2019*, indicates that 61% of mine sites have invested significantly in fully implemented mine communication systems, such as private LTE networks or 5G (55% in 2018), while 56% of mines have invested to some extent in drones compared with 44% in 2018. Furthermore, 47% of mine sites surveyed intend to invest within the next two years — either for the first time or in addition to existing investments — in mine communication systems, while 41% intend to invest in drones.

David Kurtz, director of analysis–mining and construction at GlobalData, said, "Further investment in communication systems is critical for mines looking to extend levels of automation or deployment of Internet of Things (IoT) devices. This is driving the rising use of private LTE networks and 5G use within the mining sector as it seeks continued improvements in productivity through higher utilization."

While the majors have led the way toward investment in communication systems, small and midtier miners are now joining suit. Similar shares of both groups have made considerable investments or fully implemented communication systems, while 53% of smaller miners are expecting to make investments in this area over the next two years — the highest share of any of the technologies investigated.

Drones were used less widely, but uptake is growing rapidly. Some 21% of mine sites surveyed at the end of 2019 had fully invested in drones, compared with just 9% in 2018, and 45% of majors and 41% of non-majors expect to invest in drones in the next two years.

According to Kurtz, "Investment in drones is not expensive, but the payback in terms of cost savings, faster decision-making and improved productivity means it is not surprising to see such a rapid increase in levels of investing."

Reduce Conveyor Maintenance Time Through Better Access

'Access' can mean observation points, entry doors and workspace for service.

Conveyor systems should be designed with convenient points along the length of the belt to allow technicians to inspect its condition, perform service as needed and help prevent catastrophic failure. Unfortunately, this type of access is often overlooked with engineering conveyor systems until a pressing need arises, which increases the difficulty of ongoing inspection that could have allowed technicians to observe and service critical components before a crisis develops. As a result, costs go up and productivity goes down.

Conveyor manufacturers have responded to the need for increased accessibility to system components by developing components and accessories specially designed to reduce labor time, while improving safety during service. Innovative equipment designs such as slide-out cradle frames, belt cleaner assemblies, idler assemblies — as well as sealed heavy-duty inspection doors — offer better access for safer and more efficient maintenance, resulting in fewer injuries, reduced labor time and a lower total cost of operation.

"This is a cascading issue," said Daniel Marshall, product engineer at Martin Engineering. "Insufficient access leads to poor maintenance practices, resulting in emergency outages and diminishing the operation's productivity and safety. From an ownership and management perspective, downtime and injuries affect profitability through loss of production, capital expenditures for new equipment, and ongoing insurance implications."

In the past, managers often decided against the expense of adding safer and easier access points to a conveyor system beyond what is required by code. However, over the conveyor's lifetime, safety professionals estimate that poor access adds as much as 65% to maintenance and cleaning costs.

When designing proper access into a bulk materials handling system, there are three easily achieved goals:

- Easy to see - If equipment cannot be seen, neither can the problems.
- Easy to reach - Equipment maintenance is likely to be postponed if it is awkward or dangerous to access.
- Easy to replace - Broken equipment is likely to remain that way if it is complicated and time-consuming to service.

Loading Zone Innovations

"Many conveyor transfer points still have an antiquated roller system tasked with absorbing impact and centering the cargo," Marshall continued. "These components often break and seize, causing friction and a potential fire hazard. To replace them, several workers must remove the skirtboard and break the plane of the conveyor to reach across the stringer with heavy tools to assess and repair equipment."

To reduce maintenance time and labor, improve safety and extend equipment life, operators should consider track-mounted impact cradles and belt-support cradles. Located under the skirtboard and mounted with rugged steel assemblies, the cradles feature large impact-absorbing UHMW polymer "box bars" engineered with smooth surfaces that the belt can slide across with little friction or belt wear. These assemblies can be pulled out by a single worker and — working safely from outside the conveyor and using only a single tool — the box bars can be simply removed and flipped in a matter of minutes to double the service life.

Along the cargo path in the settling zone and beyond, retractable idlers support the belt and maintain the trough angle. Exposed to the punishing environment, gritty dust and extreme weather, rollers can seize over time. Often set closely together in the loading zone to avoid belt sag, slide-out/slide-in roller frames permit

Inspection doors and track-mounted components facilitate maintenance for extended equipment life.

workers to perform idler service outside of the belt plane without the need to raise the belt or remove adjacent idlers.

Discharge Zone Maintenance

"Wear parts such as belt cleaner blades need to be monitored, serviced or changed regularly to prevent carryback from causing dust and spillage along the belt path," Marshall said. "However, blade adjustments and changes can require several hours of downtime."

Primary cleaners, located on the underside of the head pulley, are mounted on rotating assemblies designed to retain the proper tension between the blade and the belt. Secondary cleaners are located behind the head pulley and raised slightly above the belt line for tension. Specially designed units can slide in and out by simply pulling a lever and releasing a pin. This allows blade maintenance to be performed outside of the system by a single worker in under an hour.

Inspection Doors

A tight seal is the key to preventing fugitive dust from leaving any chute. Many current setups require workers to crouch or crawl under the system or even enter a confined space to inspect it or perform maintenance, which can result in serious injuries. Inspection of the system needs to be fast, easy and safe. Small inspection doors — either solid or grated — can allow several observation points. Larger doors can offer access points with ample space for service of specific wear parts.

Case Study

A coal plant in eastern China had belt damage, spillage and dust issues at two conveyor transfer points with outdated equipment in the loading zones. Raw coal ore was loaded on to the 40-in. (1000 mm) wide belts traveling 500 fpm (2.56 mps). The first chute had a 16.5-ft (5-m) high drop chute that loaded into a 40-ft (12-m) long loading/stilling zone. The second chute had a similar drop, discharging into an 85-ft (26-m) long loading/stilling zone.

Suffering from an old design, the belts were supported by impact idlers and a troughed roller system, neither of which was equipped to cope with new production demands. Equipment failures happened regularly, and without proper accessibility for routine maintenance, long periods of downtime were common. Belt sag created gaps between the belt and rollers, causing fugitive dust emissions throughout the facility. Inadequate impact control led to spillage becoming entrapped between the belt and tail pulley, damaging them both. Excessive downtime, costs for cleanup and equipment replacement seriously impacted profitability.

Technicians from Martin Engineering China were invited to perform an on-site assessment. After offering a detailed proposal, the team installed modern equipment that addressed the issues on both conveyors. The first chute was equipped with a track-mounted impact cradle to improve loading and protect the belt and tail pulley. In addition, slider cradles for smoother centering were installed, along with a full-length apron seal to prevent dust and spillage from escaping. A comparable solution was installed in the longer chute, with added cradle support down the entire length. Both chutes featured non-powered dust bag systems to collect emissions.

Since installation, spillage around the loading zones is under control. Dust emissions have been drastically reduced. Operators report that a considerable drop in equipment failure rates has resulted in a substantial increase in productivity. Contributing to the success was workers' ability to easily inspect and service components by sliding them out and servicing them outside of the conveyor.

Track-mounted idlers allow easy access for quickly swapping out seized rollers.

This article was provided to E&MJ *on behalf of Martin Engineering.*

New Grader for Haul Roads

Shandong Lingong Construction Machinery Co. Ltd. (SDLG) announced the heavy-duty G9290 motor grader for haul road maintenance. With a 14-ft-wide blade as standard and many of the design features of predecessor models, the unit has an engine supplied by Volvo and a Volvo-designed transmission.

The SD130B Stage II common rail diesel engine offers high torque at low revs from a 211-kW output with variable horsepower technology as standard, the company reported. The HTE840S automatic transmission has eight forward gears and four reverse gears.

The engine is cooled by a thermostat-controlled, hydraulic fan, which can be reversed by flipping a switch.

The moldboard is kept level by the 16° oscillation on the front axle, 18° wheel leaning and +/-15° oscillation on the rear tandem, the company reported. The chain-driven tandem with a no-spin differential lock on the rear axle bearings delivers optimal traction and reliability.

The unique SDLG circle drive system comes with five support shoes and non-greasing slide bushings for better grading, an extended service life and easier maintenance, the company reported.

A ROPS/FOPS-certified cab ensures the safety of the operator. It is fitted on the front frame to reduce vibrations and heat. The cab offers large windows and excellent all-around visibility, the company reported.

Leadership at SDLG described the unit as "reliability in action" that is "built to last" and deliver "best-in-class grading performance."

www.sdlg.com

Microgrid Power Source

Single Phase Power Solutions introduced the 50 horsepower (hp) 1-to-3 Microgrid Power Source featuring a patented BELLE Motor with Written-Pole technology to deliver three-phase power from single-phase utility service. It can be used to operate a 25-hp three-phase motor, and multiple other motors up to the remaining 25 hp of capacity.

Ideal for areas without three-phase service, the solution eliminates the fuel and maintenance costs, and the pollution of conventional gensets, while delivering superior power quality to that of a conventional phase converter, the company reported. It can start a single motor up

to roughly 50% of its rating, and smaller motors up to its output rating. A large flywheel can be added to greatly improve the motor-starting capacity.

The 1-to-3 Microgrid Power Source is available in 75- and 100-hp configurations. ***www.sppowersolutions.com***

Suspended Magnets Remove Tramp Metal

Eriez reported the release of CP-20 and TP-25 Suspended Magnets for removing tramp metal, both of which are available with either a standard electric drive or a hydraulic drive. The magnets are designed for mobile crusher and mobile equipment applications.

The CP-20 Series Magnets use a single-pole permanent magnet circuit to provide a uniform field across the feed belt to optimize separation efficiency, the company reported. The magnets have a maximum suspension height of 10 in. and are available in both manual and self-cleaning configurations.

The TP-25 Series Magnets use a twin-pole permanent magnet circuit for horizontal lift of longer ferrous objects such as rebar or wire, the company reported. The magnets can be suspended from a height of 12 in. and are available in both manual and self-cleaning configurations. ***www.eriez.com***

Fat Truck Goes Anywhere

Premier Truck Rental (PTR), in Fort Wayne, Indiana, reported it will rent the Fat Truck, which is designed to move up to eight people, or 2,200 pounds, across otherwise inaccessible terrain, to include wet or flooded land. The truck is capable of transporting people and gear into hard-to-reach locations regardless of weather and road conditions, the company reported. An optional trailer, also amphibious, is available.

Among other features, the Fat Truck is certified to the highest Rollover Protection Structure standards, is compliant with Environmental Protection Agency guidelines, and offers 360° visibility to the driver, PTR reported. It has an intuitive joystick drive and dash display, automatic transmission, and the ability to be driven on the left or right side of the vehicle. ***rentptr.com***

Tools for Automation, Software Developers

Siemens reported its Industrial Edge, described as a digitalization solution, adds machine-level data processing to automation devices and components. It locally preprocesses data that can be sent to the cloud or to IT infrastructure. This action cuts storage and transmission costs and makes possible a range of descriptive, diagnostic and predictive applications, Siemens reported.

The company described the solution as closing the gap between local data processing and cloud-based data processing.

Separately, Siemens released the Totally Integrated Automation (TIA) Portal V16 for software development and testing. The portal's project server is designed to facilitate project revision, reporting, and archiving and commissioning. Siemens reported the server has no functional restrictions on organizing automation tasks on a device, object or function. ***Siemens.com***

Light Weight Conveyor Drum Pulley

Superior Industries showcased the Prime Mine Duty Pully, a new conveyor drum pul-

ley manufactured in diameters from 4 in. to 30 in. and face widths of 12 in. to 78 in. The pully is designed with a solid steel end disc, which eliminates welding at the hub of the pully, the company reported.

Leadership at Superior reported the pully has many of the same design characteristics of Mine Duty 2.0 and Super Duty drum pulleys, but is lighter, resulting in lower costs.

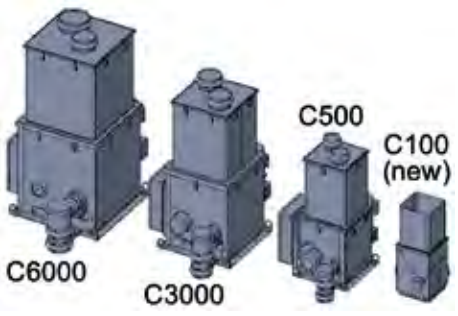
The pulley is one of four available from Superior.

The company also introduced new SpinGuard Idler Seals, designed to offer greater protection in applications known to expose bearings to fugitive material prematurely. The SpinGuard line includes Wet, Dry, Low Drag and Titanium.

www.superior-ind.com

Feeder for Small or Lab Extruders

Schenck Process introduced the ProFlex C100 feeder. The smallest of the company's C series, it is comparatively lightweight and fits on small extruders. Up to five feeders can be grouped around an inlet of a lab- or small-size extruder.



The feeder is equipped with an integrated gearbox for turndown ratios of up to 1:120. It is NEMA drive-ready for compounding and masterbatch.

The ProFlex C feeding system is characterized by asymmetric design, steep hopper walls, encapsulated cabling, ease of management, and ease of maintenance, the company reported.

www.schenckprocess.com

Software Democratizes Systems Engineering

Maplesoft released MapleMBSE, which the company described as software that enables companies to employ a Model-Based Systems Engineering (MBSE) process within their design projects without requiring every stakeholder on the project to be an expert in complex MBSE tools.

MapleMBSE provides a streamlined, Excel-based interface to the systems model with task-specific views for editing the model directly, thereby ensuring consistent information and knowledge sharing across the design group, Maplesoft reported. The familiar Excel interface enables subject-matter experts to obtain and analyze the information they need to make decisions, and to feed the results back into the model.

By eliminating the need to funnel everything through a small number of systems engineering tool experts, MapleMBSE democratizes the engineering process and significantly reduces the overhead, time and errors that typically come with using a standard systems engineering tool.

www.maplesoft.com

Injections Repair Concrete, More

Avanti International released the AV-500 Epoxy line, a range of injection solutions that stabilize soils and rock, restore structural integrity, stop leaks, and control groundwater. The AV-502 Series was developed for structural concrete repair by crack injection, gravity feed or patching. The two-component AV-522 was designed for anchoring/bonding applications. The AV-580 and AV-590 were designed for filling sawcut control joints and contraction joints in concrete.

www.avantigrout.com

'Crud' Removal Tool

Snap-on Industrial introduced the Crud Thug Removal Air Tool, which, the company reported, safely removes rust, paint, gasket material, seam sealers and more, without fumes, heat buildup or damage.

The solution, equipped with a .45-hp thermally balanced air motor, is ideal for industrial fleet vehicles. Features include a planetary gear system for increased torque, an ergonomic cushion grip that insulates against cold and vibration, and a 10-position power and speed regulator for easy RPM adjustment.

www.snapon.com

Pliers Designed to Last

Emerson announced the 9-in. High Leverage Pliers and the Water Pliers, available in 8 in., 10 in., 12 in. and a three-piece set. Both units have a double-dipped grip. The High Leverage Pliers are forged from chrome vanadium steel and are designed with a circular toothed pipe grip. The Water Pump Pliers feature a multi-purpose jaw with opposing offset teeth for use on pipe and hose connections. With more than 24 jaw adjustments, the pliers adapt to a wide range of sizes, the company reported. They feature a push-button design and double-dipped vinyl handle rips.

www.emerson.com

Conveyor Rip Kit

Flexco unveiled the Rip Repair Kit for emergency rip repairs in conveyor belts. The kit contains everything needed to splice up to 50 ft of belt with a power tool. The kits are available in a variety of belt thicknesses, and come in a bucket filled with the appropriate fasteners, a bolt horn, bolt breakers, a power punch, a power-boring bit, two power wrenches, and a quick-change chuck.

www.flexco.com

Boots Offer Better Grip, Comfort

HYTEST Safety Footwear released the FootRests 2.0 Tread Hiker and the Mission Zipper Boot. Both deliver grip protection and comfort, the company reported.

The Tread Hiker features abrasion-resistant TecTuff material; a nano, non-metallic safety toe; a lightweight Xergy anti-fatigue foam midsole; and the new FootHolds enhanced-rubber outsole, described as an oil and slip resistant outsole.

The Mission Zipper Boot is an athletic-inspired duty boot, HYTEST reported. It has lightweight and breathable fabric with minimal seams, Xergy and FootHolds technology, and an easy-on-and-off zipper.

www.hytest.com

Solution Advises on Jetlag Recovery

Rensselaer Polytechnic Institute announced a solution that leverages data from smart wearable technology to generate advice on beating jet lag. The solution uses a series of algorithms to analyze biometric information taken by a smart device, and then recommends the best combination of sleep and light to help the user cope with jetlag. The research into the solution was funded by the Department of Defense.

https://rpi.edu/

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Equal Opportunity Employer/
Protected Veteran/Disability.

Copper, China and the Coronavirus

After it was diagnosed in late 2019 in Wuhan, China, the capital city of Hubei Province, the coronavirus quickly spread to other Chinese cities. The outbreak was declared a public health emergency by the World Health Organization on January 30, and there were more than 28,000 diagnosed cases at that time. In response to the outbreak, China took measures to contain the spread of the virus. All the cities in Hubei Province were quarantined. Trains and flights were canceled with (several) checkpoints set up on the roads. As a result, land freight, especially interprovincial transportation, has been significantly affected.

Unlike copper fabricators, smelters and refineries did not stop operating over the Chinese New Year, a national holiday. However, this does not mean there are no risks to smelter production. The two main concerns center around the raw material freight movement and acid sales.

The Daye smelter and refinery, which is located in Huangshi, Hubei province, produces 500,000 metric tons per year (mt/y) of refined copper. As all the cities in Hubei Province have been quarantined, Daye is the largest smelter of concern among the Chinese operations. Concentrates are typically shipped to Huangshi Port along the Yangtse River and then trucked to the smelter. It is taking longer for concentrates to reach the smelter, but there has been no impact on its production. There has been a general loss of efficiency across the concentrates supply chain from ports to smelters due to restrictions on movement and extension of holidays for couriers, customs brokers, customs, etc. Delay in delivery of concentrates is also being experienced by many other smelters in China.

According to WoodMac's estimates, for every ton of primary copper production, Chinese copper smelters are producing an average of 3.6 tons of sulphuric acid. It is critical for copper smelters to sell and ship the acid before acid storage is full. Hubei is the largest phosphate fertilizer producer in China, an important sulphuric acid consumer. Hubei accounts for roughly 20% of total sulphuric acid consumption in China, which it sources from local smelters as well as those in neighboring provinces. Acid inventories at smelters are rising. WoodMac cited one major primary smelter, saying, "if the acid disposal situation does not improve over next few weeks, we will have to cut the utilization rate by 30%." Other smelters have expressed similar views.

As pressure on acid storage mounts, Guixi, the largest smelter in China, started to reduce the amount of concentrate charged into the furnace in the first week of February. Due to the high inventory of acid and difficulties obtaining some other consumables, Tongling Nonferrous started to reduce utilization rates at its smelters. WoodMac believes utilization rates have been reduced to 70%-90% at these smelters. How long production cutbacks will last or whether there will be further curtailments will depend on when the state of emergency, due to the virus, will be revoked.

Elsewhere in China, one of the major primary smelters in east China has had significant difficulties obtaining imported concentrates trucked to site from the port. Due to a lack of concentrate, the smelter has started its maintenance ahead of schedule. At another inland smelter, purchased concentrate cannot be delivered. Currently, this smelter is relying on the inventories on site, but they seem optimistic that the transportation issues can be solved before production is impacted.

At press time, smelters cutting production had a total primary capacity of 2.7 million mt/y, with another 1.7-million-mt/y primary smelting capacity at risk. According to the current situation, the primary production loss is more than 60,000 mt contained copper in February, assuming smelting capacity at risk all maintain full operation. Going forward, if the epidemic can be brought under control in March, the loss of production could be partially compensated for over the rest of year. But if the state of emergency continues, the smelters will have to further reduce utilization rates and more smelters will have to cut production.

This article was adapted from a report issued by WoodMac's copper team. www.woodmac.com

E&MJ PRICES INDEX

(February 5, 2020)

Precious Metals ($/oz)		Base Metals ($/mt)		Minor Metals ($/mt)		Exchange Rates (U.S.$ Equivalent)	
Gold	$1,552.70	Aluminum	$1,687.00	Molybdenum	$22,880	Euro (€)	1.100
Silver	$17.55	Copper	$5,652.00	Cobalt	$34,750	U.K. (£)	1.300
Platinum	$967.00	Lead	$1,854.50			Canada ($)	0.753
Palladium	$2,428.00	Nickel	$12,800.00	Iron Ore ($/dmt)		Australia ($)	0.675
Rhodium	$10,700.00	Tin	$16,155.00	Fe CFR China	$81.63	South Africa (Rand)	0.068
Ruthenium	$250.00	Zinc	$2,217.50			China (¥)	0.143

Gold and silver prices provided by KITCO Bullion dealers (www.kitco.com). Platinum group metals prices provided by Johnson Matthey (www.platinum.matthey.com). Non-ferrous base and minor metal prices provided by London Metal Exchange (www.lme.co.uk). Iron ore prices provided by Platts Iron Ore Index. Currency exchange rates were provided by www.xe.com.

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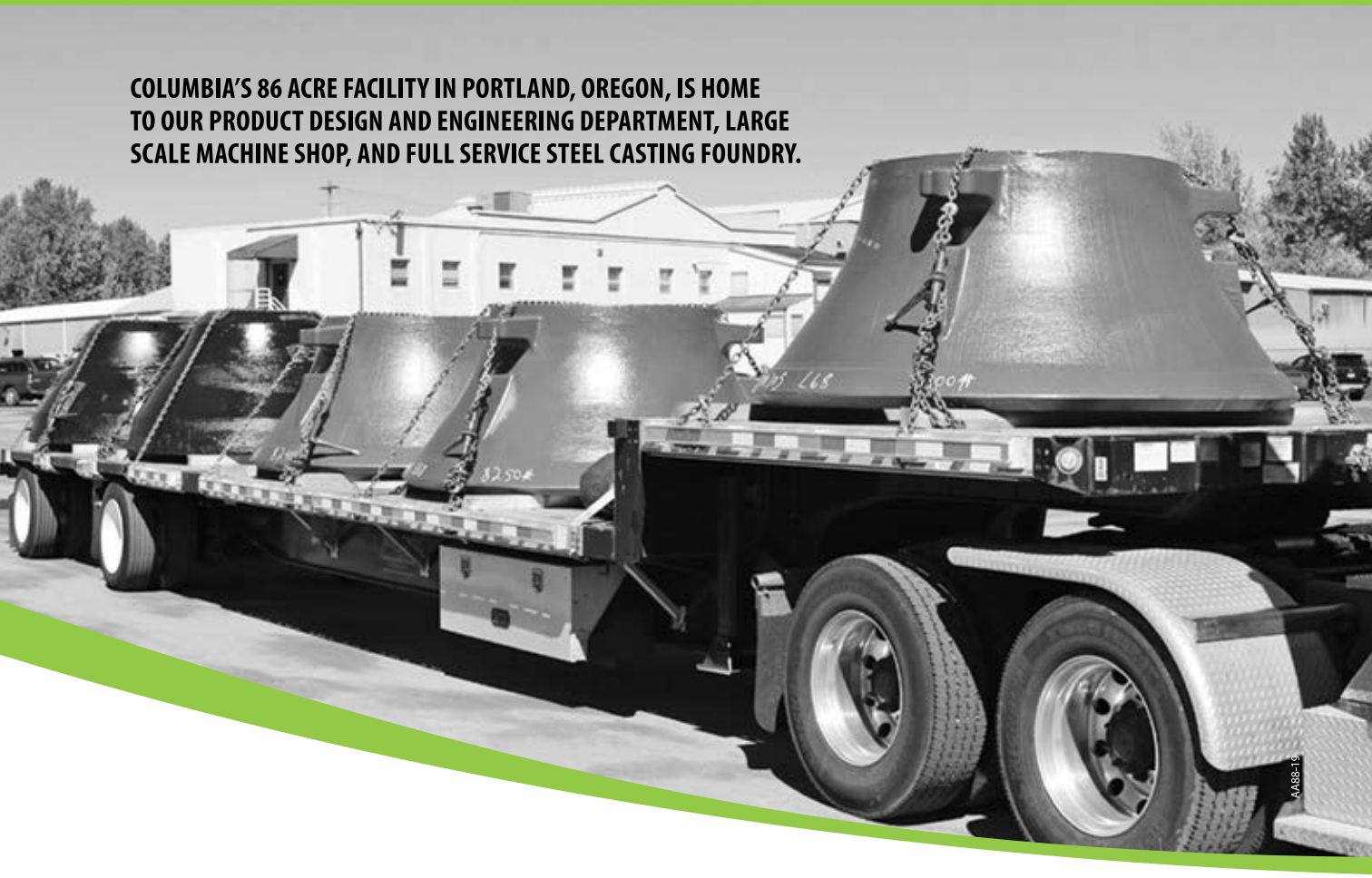

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