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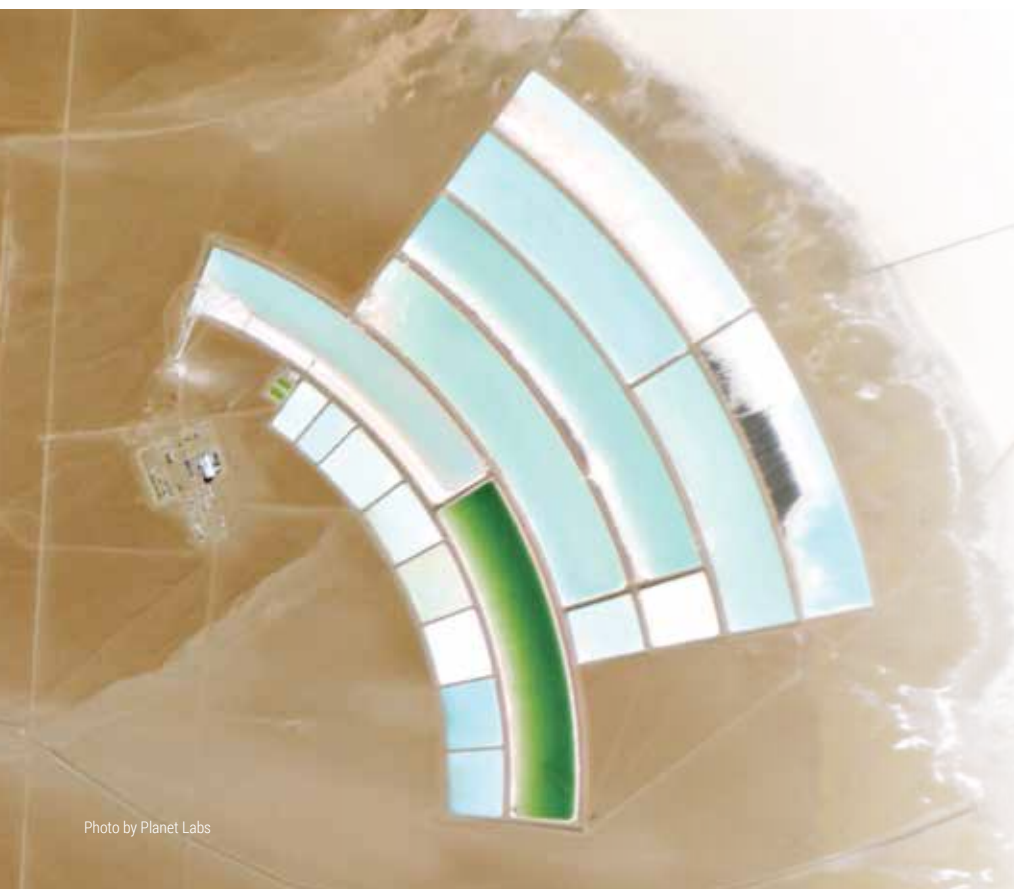


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MINING ENGINEERING (ISSN 0026-5187) is published monthly by the Society for Mining, Metallurgy, and Exploration, Inc., at 12999 E. Adam Aircraft Circle, Englewood, CO, 80112 USA. Phone 1-800-763-3132 or 1-303-948-4200. Fax: 1-303-973-3845 or email: sme@smenet.org. Website: www.smenet.org. Periodicals postage paid at Englewood, CO USA and additional mailing offices. Canadian post: publications mail agreement number 0689688.

POSTMASTER: Send changes of address to MINING ENGINEERING, 12999 E. Adam Aircraft Circle, Englewood, CO, 80112 USA. Printed by Publication Printers.

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- ESG
- **PLUS! Tunneling & Underground Construction Magazine**

OCTOBER

- Responsible mining
- Mineral Processing
- Business Profiles

NOVEMBER

- Heavy equipment
- Permitting issues
- Pump technology
- Media Review
- Products & Services Directory



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Mining engineering®

OFFICIAL PUBLICATION OF SME
www.miningengineeringmagazine.com

AUGUST 2022
VOL. 74 NO. 8



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The mining industry must educate and train additional tailings professionals to provide the labor needed to sustainably manage mine waste now and in the future. On page 16, D. Louise Spencer and co-authors present findings from a study that aims to raise awareness of the growing demand for tailings labor resources and the need for collaboration within academia and industry to recruit, train and retain future tailings professionals. Cover design by Ted Robertson.

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Ronald Parratt
2022 SME President

Before you became a member of SME, you undoubtedly asked yourself some questions such as, “Why should I join SME?” or “What value will I get from being a member of SME?” You obviously found answers to your questions, at least sufficiently enough to move forward and join. I hope that since that time, you’ve answered those questions more fully and are more satisfied with your decision. I know that I am. And I hope that you have found value in expanding the network of mining professionals you have met while also benefitting from the numerous opportunities for professional

growth. I like to think that your membership has helped you to become a more connected, knowledgeable professional.

You can add more to your membership by volunteering in SME activities at your local section or in the parent society. SME currently has 306 committees containing 3,281 positions that are currently filled by 1,577 SME members. These various committees include all facets of our society and offer an opportunity for participation for members of all disciplines.

SME has 48 local sections in the United States as well as local sections in several countries throughout the world. Many of the sections are active in developing annual conferences that showcase activities in their area such as the Arizona Conference in Tucson, the Minnesota Section Conference in Virginia, MN, the Pittsburgh Annual Section Conference, the St. Louis Section President’s Dinner, the Mining Finance Conference in New York, the Nevada MPD Sub-section conference in Reno and more. Participation in these programs is enjoyable and always professionally beneficial. There are other opportunities for involvement in your local section as well. Each section has leadership positions including a chair, vice-chair, secretary, treasurer and program chair. Many have monthly dinner meetings with invited speakers, summer picnics and other events. Volunteering with your local section is a great way to meet other professionals in your area and to learn more about local exploration or mining activities. Check with your local section to see what activities are planned. I encourage you to give it a try. I’m sure you’ll have a rewarding experience.

If you have been involved at your local section for some time and you are looking for

Safety Share: The most pertinent thing to do for your own safety as well as others is to place yourself in the information stream. I love the built-in safety/information share of simply being in the lineout meeting with the crews. This is the place to find out if any changes have been made to the mine road or if a shovel or haul truck is down. Heading off surprises helps mitigate frustrations and ultimately helps in overall safety. The lineout meeting is the place to inform miners of any tweaks in the schedule that may affect resources — the face pump is down, and it will take the first hour of the shift to pump out the heading and gear back in, therefore the pump crew can tackle that task first while the bolter gears into another heading. And be sure to check on miner’s fatigue — shift work is hard. Ask if they got enough sleep? How was the drive? Maybe they have a good safety share for the group. Shut down those computer screens for a bit and join the lineout meeting.

Aaron Larry
Underground shift coordinator
Rio Tinto

something new or if your section is not as active as you would like, consider getting involved with SME. Each of SME’s eight divisions have a leadership group similar to the sections as well as a number of committees. Most importantly, the divisions are involved in developing the programming for the MINEXCHANGE SME annual conference and exhibit. This involves establishing a program chair, session chairs and selecting speakers. All of these are great opportunities to volunteer. The divisions also have scholarship committees who review applicants and select recipients for the numerous scholarships available through the individual divisions. Similarly, there are award committees that review candidates nominated by SME membership and select recipients for the various division awards. There are several committees in each division. Committees are listed on the SME website. I encourage you to take a look.

In addition to the divisions, SME is always looking for volunteers for the numerous standing committees such as Resources and Reserves. Just as our society is diverse, so are the number of committees. This means that there

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USGS to help in battle against illegal mining

THE U.S. Geological Survey (USGS) has collaborated with several international organizations working to track and monitor illegal mining and armed groups funded by natural resources around the world.

The concept of conflict diamonds or “blood diamonds” emerged in the late 1990s when it became evident that several violent civil wars in Africa were connected to mining and trading of rough diamonds. In 2006, the USGS was asked by the U.S. Department of State to help address illegal diamond mining in Africa.

Since then, the USGS has collaborated with several international organizations working to track and monitor illegal mining and armed groups. USGS scientists help detect where illegal mining is likely taking place and develop realistic production numbers to determine a country’s true capacity for mining and exporting various resources. This knowledge helps identify differences between what can be produced versus what is being exported, and whether miners are crossing borders to illegally mine and sell resources.

Many armed conflicts are financed

and sustained by illegally selling or trading natural resources, including gold, tin, tantalum, tungsten, gemstones such as diamonds, rubies and jade and construction materials such as sand and gravel.

Minerals are frequently mined by artisanal and small-scale miners, who commonly operate in the informal sector. They often transport and sell resources outside of the legal flow chain in violation of local or national law.

The informality and large geographic extent of artisanal and small-scale mining can lead to commodities being mined, sold and purchased through unofficial channels, and potentially financing criminal or terrorist organizations. This can increase the risk of conflict, violence and terrorism within a country and with other nations, including the United States.

“USGS science helps determine the extent and value of mineral production in conflict-prone regions,” said Peter Chirico, associate director of the USGS Florence Bascom Geoscience Center and special advisor to the U.S. Department of State’s Office of

Threat Finance Countermeasures. The USGS conducts field investigations, uses satellite imagery, creates geologic maps and publishes reports to pinpoint resource deposits, estimate mineral quantities and determine production capacity.”

“The ability to use satellite imagery to acquire detailed information on artisanal mining activities is invaluable for researchers and policy makers, as it allows us to evaluate challenging and often difficult-to-access regions that also have associated conflict and safety concerns,” continued Chirico.

USGS scientists also do on-the-ground fieldwork to study the deposits and small-scale mining pits to investigate artisanal and small-scale mining processes and determine the extent and quality of the resources. The researchers also work to understand the viewpoint of the miners themselves and their methods, tools, habits and organization. Scientists conduct interviews with artisanal miners to understand how much is or can be mined over a certain period of time, how they are organized and how frequently they move from site to site. ■

Voters in Chile to decide on new constitution

THE FINAL VERSION of the draft constitution that will be put to a referendum in Chile was presented by President Gabriel Boric at a closing ceremony on July 4 in Santiago. The draft was to be put to a referendum as a growing number of voters question the broad changes it would enact from social rights to political rules.

Bloomberg reported that on Sept. 4, Chileans will decide whether to approve the new magna carta or stick with the current document implemented during the 1973–1990 military dictatorship.

The ceremony caps a year of debate and votes on a process sparked by Chile’s biggest social upheaval in a generation. If approved, the document would mark a shift away from market-friendly rules by strengthening workers’ rights, boosting environmental protection,

overhauling water ownership and giving indigenous groups a bigger say in investment projects. Polls suggest the changes may have gone too far, with more voters inclined to reject the draft.

“The perfect constitution doesn’t exist, and this isn’t the exception,” said Gaspar Dominguez, the convention’s vice president. “This draft constitution isn’t a magic wand that will solve our problems, but rather it’s a better toolbox that we can use to advance with solutions.”

September’s vote will also be key for Boric’s administration, which would have an easier path to implement its policy proposals if the current constitution is replaced. Boric has expressed his support for the convention, while also saying that both the options of approving or rejecting the draft are legitimate.

The percentage of voters intending to reject the draft surged to 51 from 33 percent in January, according to the latest survey from pollster Cadem. Support for the “approve” option has fallen to 34 from 56 percent in the same period.

Some of the draft’s most controversial proposals include articles that replace the senate with a regional chamber and create a parallel justice system for indigenous groups. The charter also incorporates new considerations into central bank policy making and protects glaciers from mining.

“We have had to write this text in the midst of social tensions and an unprecedented social-environmental crisis during a pandemic and while new wars happen in the world,” said Maria Elisa Quinteros, the convention’s president. ■

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Hecla to acquire Alexco Resources; Merger will allow Hecla to grow as silver producer in Canada

HECLA MINING Co. announced that it has agreed to acquire all the shares of Alexco Resource Corp. that Hecla does not already own for 47 cents per share.

Hecla is the largest and highest-grade silver producer in the United States and Alexco is Canada's largest and highest-grade silver reserve. In a statement posted on July 5, Hecla said it has also entered into an agreement with Wheaton Precious Metals Corp. (WPM) to terminate its silver streaming interest at Alexco's Keno Hill property in exchange for US\$135 million of Hecla common stock conditional upon the completion of Hecla's acquisition of Alexco.

Hecla will acquire a large, high-grade silver property in the Yukon, a top 10 rated jurisdiction by the Fraser Institute. A fully permitted property with infrastructure that includes a 400 t/d mill, on-site camp facility, all-season highway access, and connection to the hydropower grid. The acquisition increases Hecla's silver exposure by increasing proven and probable silver

reserves 19 percent to 237 million oz, measured and indicated resources 24 percent to 257 million oz and inferred resources 7 percent to 523.7 million oz.

The deal has the potential for Hecla to become Canada's largest silver producer.

The acquisition allows for the advancement of Keno Hill's development with immediate and nondilutive interim financing and transition of Alexco's properties from a single asset and its development risk to a diversified production base of long-lived mines, and a portfolio of high-quality exploration projects.

"At Hecla, we have followed the Keno Hill project closely for a number of years, as it is one of the very few deposits that fit seamlessly into Hecla's strategy of owning and operating high-grade properties in tier one jurisdictions," said Phillips S. Baker Jr., president and chief executive officer. "As the United States' largest silver producer, producing more than 40 percent of silver mined in the U.S., it is natural

that Hecla acquires Keno Hill, which could also make Hecla Canada's largest silver producer. Silver is a critical element to decarbonize the economy and the need for domestic supply is growing. Acquiring Keno Hill allows Hecla to further meet this need with a secure high-grade silver development and exploration project that has a small environmental footprint."

"This transaction delivers significant benefits to our stakeholders," said Clynton Nauman, chair and chief executive officer of Alexco. "By partnering with Hecla, an industry leader in high-grade narrow-vein silver mining, we further position Keno Hill to achieve its full potential. There is no doubt that we have fallen well behind the development and production plan at Keno Hill and our original estimate of achieving commercial production in early 2022. There are myriad reasons for those challenges, but fundamentally, they all led to an increasing level of stress

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Critical mineral producers could gain support of the U.S. government

U.S. ENERGY Secretary Jennifer Granholm offered the support of the United States government to developers of battery metal projects as the United States and other nations seek to counter the dominance of China in clean-technology supply chains.

China has dominated the mining and processing of critical materials like lithium, rare earth elements and cobalt, prompting President Joe Biden to invoke the 1950 Defense Production Act to encourage domestic production.

"Our concern is that critical minerals could be vulnerable to manipulation, as we've seen in other areas, or weaponization," Granholm said in a meeting in Sydney with companies including BHP Group, Rio Tinto Group

and Lynas Corp. "We are very serious about establishing strong relationships with Australia, and with you and with your potential customers for offtake."

Bloomberg reported that producers in nations including Australia can also access support through agencies including the Department of Energy's loan programs office, Granholm said at the meeting.

Syrah Resources Ltd., a Melbourne-based graphite producer with facilities in Mozambique and Louisiana, in April won a \$107 million commitment from the loan programs office.

Lynas Rare Earths Ltd. in June signed a contract with the U.S. Department of Defense to establish a plant in Texas. ■



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PolyMet and Teck to form joint venture; NewRange Copper Nickel will advance projects in Minnesota

POLYMET MINING and Teck American will create a joint venture, NewRange Copper Nickel LLC, in an effort to advance their respective copper/nickel projects in northeastern Minnesota.

PolyMet is working to develop the NorthMet Copper Nickel project near Hoyt Lake. The company said the deposit is home to at least 795 million tons of potentially mineable copper, nickel, cobalt and platinum group metals while Teck's Mesabi project contains 1,740 million tons of measured and indicated resources. The NorthMet project is the closest to becoming a reality but is still working through the complex environmental permitting process.

Swiss mining giant Glencore will retain its majority ownership of PolyMet. Teck American is a

subsidiary of Canadian mining firm Teck Resources.

"This extraordinary venture links the expertise, experience and financial resources of PolyMet, Teck and Glencore," Jon Cherry, PolyMet's chief executive officer, said in a statement. "With both projects representing approximately half of the known resources of Minnesota's Duluth Complex under NewRange Copper Nickel, Minnesota emerges as a global leader and major force in developing strategic minerals to feed the North American supply chain for clean energy technologies, electric mobility and modern societal use. The total assets of the NorthMet and Mesabi deposits make this one of the largest clean-energy mineral resources in the U.S. and globally."

"The NewRange Copper Nickel

joint venture brings together two large, well-defined mineral resources in the established Iron Range mining region of Minnesota," Don Lindsay, Teck's chief executive officer, said.

PolyMet and Teck are each putting \$85 million into NewRange. Glencore is providing PolyMet's share and is also sinking an additional \$30 million directly into PolyMet to cover debt obligations.

The joint venture will be run by a six-member management committee, with three appointees from each company. PolyMet's Cherry will be the committee's chair.

PolyMet's operation would include an open-pit mine in wetlands south of Babbitt and a processing site at the former LTV taconite mining operation near Hoyt Lakes, all within the headwaters of the St. Louis River. ■

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Ford signs agreements with Rio Tinto and Ioneer; Automaker will build steady supply chains for lithium

FORD MOTOR Co. has signed agreements with Rio Tinto and Ioneer to establish a more sustainable supply chain for battery and low-carbon materials and to secure a steady supply of lithium. On July 21, the automaker announced that it has signed a nonbinding global memorandum of understanding to jointly develop a more sustainable supply chain with Rio Tinto.

The multimaterials partnership will support the transition toward a net-zero future by supplying Ford, one of the world's largest automakers, with materials including lithium, low-carbon aluminium and copper. It will allow Rio Tinto, a leading global mining and metals company, to progress its commitment to work with customers to decarbonize value chains.

The company also announced a binding agreement with Ioneer in which Ioneer will supply Ford with lithium carbonate from its Rhyolite Ridge lithium-boron project in Nevada.

Under the agreement, Ioneer will deliver 7 kt/a (7,700 stpy) of lithium carbonate to Ford over a five-year term, starting in 2025. Ford intends to utilize Ioneer's lithium carbonate to produce batteries for use in Ford electric vehicles through BlueOval SK, the Ford-SK battery-manufacturing joint venture.

Under the agreement with Rio Tinto, Ford will explore becoming the foundation customer for Rio Tinto's Rincon lithium project in Argentina. Rio Tinto is currently progressing detailed planning to bring Rincon into production and will work with Ford toward a significant lithium off-take agreement to support its production of electric vehicles.

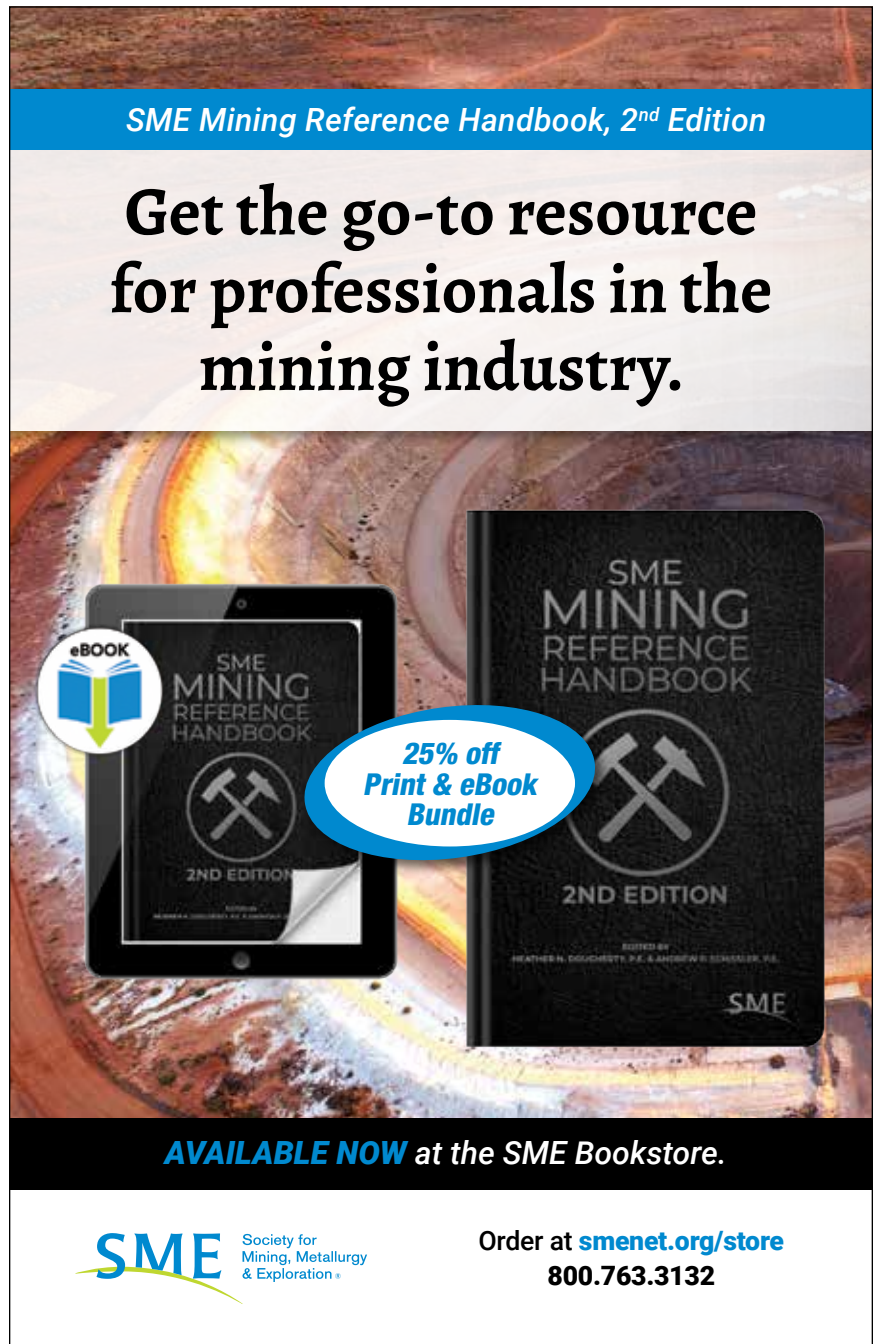
The companies will work together to strengthen the supply of low carbon aluminium for use in Ford vehicles, including metal produced using the zero carbon ELYSIS smelting technology, and from Rio Tinto's hydropowered operations in Canada, helping Ford meet its commitment to the First Mover's Coalition.

Ford and Rio Tinto will also work to develop secure, domestic supply chains for Ford across other essential commodities for the energy transition

from Rio Tinto's operations in North America, including copper produced with a low-carbon footprint.

"We are excited to work with Ford to support the transition to net zero by supplying a range of materials it needs for electric and lower-carbon vehicles, and advance our commitment to work with customers to decarbonize our value chains," Rio Tinto's chief commercial

officer Alf Barrios said in a statement. "Rio Tinto is uniquely positioned to work with companies like Ford to develop more sustainable, traceable and secure supply chains. We are investing to grow in materials needed for the energy transition, and in technology and partnerships to decarbonize our business and value chains. ■



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Komatsu and Codelco agree to conduct trial of tunnel boring machine for use in mining projects

KOMATSU LTD. and Codelco have agreed to collaborate on trialing a new tunnel excavation method using Komatsu's newly developed mining tunnel boring machine (TBM) starting in 2024 at Codelco's Chuquicamata Mine in Chile. Through trial use of the new machine, Komatsu and Codelco aim to speed up the potential introduction of this innovative technology.

Demand for underground mining equipment is expected to increase along with global demand for mineral resources that require increasingly deeper mining operations.

Komatsu developed the first TBM for rock excavation in 1963 for use in civil engineering in Japan. Since that time, the company has introduced a cumulative total of more than 2,300 TBMs (including its microtunneling machine) to the market. Based on Komatsu's experience in excavation, the mining TBM is equipped with new technologies that enable adaptability to small curves, reversing and passing intersections in hard-rock-tunnel

excavation. Previously, the use of TBM has generally been limited to excavating nearly straight tunnels. This new technology improves the flexibility of the equipment and enables excavation of tunnels according to the more unique designs of each mine.

The mining TBM works by continuously performing a series of processes, such as excavating rock with disc cutters and discharging the chipped rock backward with belt conveyors, while fortifying the excavated tunnel wall. Excavation with disc cutters improves tunnel strength and stability by creating a circular tunnel shape with smooth walls with less damage to the excavated tunnel (compared to drilling and blasting methods).

To support customers' needs for increasingly sustainable ways of mining, the new machine runs off electricity, does not require the use of blasting, and performs a series of tunnel excavation processes with a single machine, reducing the number

of vehicles required overall. The result is a new excavation option that reduces the creation of greenhouse gases and particulate matter emissions for an improved underground environment that requires less ventilation than other methods. At the same time, it significantly increases the productivity of personnel associated with tunnel excavation work compared to conventional methods.

In response to climate change and the need for solutions for environmental issues, Komatsu has been focusing on the development of equipment for the future of underground hard-rock mining under the slogan of "No Blasting," "No Batch," "No Diesel." The mining TBM and the new method embody this forward-looking approach and seek to help customers improve safety, environmental friendliness and productivity (shorter tunnel construction period and lower tunnel construction costs) at underground mines, and will also help them achieve a revolution in their mining operations. ■

President's Page: Get more out of SME

(continued from page 6)

there should be a committee for anyone looking to volunteer. Have a look at the SME website and find a committee that fits your area of interest. Beyond the divisions and the standing committees, there are four strategic committees focused on the strategic goals of SME as per the 2020 Strategic Plan. Lastly, there are positions on the SME

Board of Directors and for President. You'll need to find a friend who will nominate you for these if you want to be considered.

Volunteering in SME's leadership, whether at the section or national level, is a rewarding and beneficial experience to you directly but also to the Society overall. SME is a member-managed society with support and guidance from Dave Kanagy and the SME staff. The

volunteer efforts of our members is what make SME the strong, leading professional society today. Make your SME experience the best you can by volunteering and help provide the leadership to allow our society to be a strong leader for the mining industry for years to come. Take an active role by volunteering in SME- the more you put in, the more you'll benefit from your membership. ■

Hecla: Keno Hill project will likely advance

(continued from page 10)

impact on the share price, our finances, our employees, and other stakeholders. As a much larger business, Hecla has the organizational expertise and financial strength to build Keno Hill to the level and

capacity required, while being able to continue to invest in exploration across the district, something that we, as Alexco, independently would likely struggle to achieve. Frankly, the opportunity now afforded to our employees, to the First Nation of Na-

Cho Nyäk Dun and the wider Yukon community as a whole is superior to anything Alexco could offer in the short term. I look forward to working with Phil and his team at Hecla to close this transaction in September 2022." ■

Letter to the editor: Another look at the future demand for lithium

Response to "Huge Lithium investment needed to meet demand," ME, June 2022 page 13.

Not so fast. Different predictions are being made, mostly, it appears by lithium promoters who follow the presumed production volumes of electric cars. Year-to-year, month-to-month, percentage sales increase makes one dizzy.

In 2020 J.D. Powers, a most reliable car tracking company, predicted that 7.3 percent of the car would be electric by 2020. Yet data shows only 4.6 percent a 37 percent decrease. While STATISTA (www.statista.com) reports that 115 million cars will be on the road by 2030 and CNBC (www.cnbc.com, 2021) improves that number to 140 million, none of these specialists discuss the fate of millions of discarded lithium batteries. Most analysts assume that the lithium required for automotive and storage industries will come from virgin lithium. Multiple companies are eager to tap into the generous critical minerals budget promising to discover lithium deposits and make the United States self sufficient. Unfortunately, those of us in the lithium industry know that another Clayton Valley brine deposit has not, and will not be found. The USGS massive exploration effort in Nevada and California failed to identify a single new brine deposit (USGS Open File Report 80-1234). On the other hand, the recycling industry is already gearing up to produce recycled lithium, which will have a very large impact on the total virgin lithium demand predicted, as show on the graph.

The IEA, analyzing the scenarios presented at the Paris agreement, estimates that, depending on the scenarios, 26 to 45 million electric cars will be on the road (IEA Global EV sales by scenario, 2020–2030). The very latest report from the U.S. Energy Information Agency (EIA),

Annual Energy Outlook 2022, predicts that, because of the stringent emission standards, 78 percent of the vehicles in the United States will continue to run on gasoline until 2040.

Therefore, it is not clear whether \$42 million will be sufficient (or required) to make the United States self sufficient. Lithium recovery from the Great Salt Lake brines and bromine operations in Arkansas have been announced. A tertiary boron-lithium deposit has been identified in the Silver Peak range, Nevada, and many attempts have been made to recover lithium from the

Imperial Valley geothermal brines. Large lithium resources exist in low-grade clay deposits, but commercial lithium recoveries have not been demonstrated.

The existing pegmatites of North Carolina could be put into operation and provide immediate lithium production.

At this point in time, with all these uncertainties, it would seem more valuable to use these funds to produce lithium batteries in the United States from friendly sources.

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Characterizing tailings professional labor demand

by D. Louise Spencer, Christopher A. Bareither, Joseph Scalia IV, Christopher N. Hatton and Kelly J. Ward

Expanding the world's green economy and developing more sustainable energy production relies on critical minerals including rare earth elements, precious metals and base metals. However, mineral extraction generates mine waste. Thoughtful stewardship of mine waste requires skilled tailings professionals.

Management of mine waste has once again been thrust into the forefront because of recent events (for example, Morgenstern et al., 2015, 2016; Robertson et al., 2019), yielding an increased emphasis on improving engineering, management, governance, and transparency. The promulgation of new tailings guidance includes recent contributions from the Canadian Dam Association, Mining Association of Canada, Australian National Committee on Large Dams, International Committee on Large Dams, and the International Council on Mining and Metals (ICMM). The Global Tailings Review convened in March 2019 to create the Global Industry Standard on Tailings Management (GISTM; GTR, 2020) for tailings facility design, construction, management, and closure throughout the lifetime of a tailings facility. The GISTM was finalized in August 2020 with supporting guidance provided by ICMM through the Tailings Management Good Practice Guide (2021) and Conformance Protocols (2021).

The disposition and frequency of tailings dams worldwide is poorly understood and documented. Commonly cited estimates with respect to the number of tailings facilities worldwide vary substantially, with estimates ranging from 3,500 (Davies et al., 2000) to 18,400 (Herza et al., 2019) to 35,000 (World Mine Tailings Failures, 2020). Previous research described in Hatton

et al. (2020) and Spencer et al. (2021) was expanded and refined, updating the estimated number of tailings facilities worldwide. Revised estimates were then used to project the future labor resources required to support tailings operations (including active and inactive operations). Considering the large number of tailings facilities combined with the new guidance to improve the stewardship of tailings, an

important question exists: Is the current tailings professional labor pool sufficient to provide the specialized labor needed to meet new guidance designed to make tailings facilities safer?

The GISTM is supported by ICMM member companies, and these member companies have generally committed the necessary resources to support more rigorous oversight and management of existing tailings facilities, in addition to new guidelines for tailings facility design, construction, and closure. For many mines, following the GISTM guidance increases the number of oversight personnel required to manage existing and future facilities. Thus, the hypothesis in this study was that additional qualified and trained tailings professionals are required now, with even more support projected in the future.

Academic departments and disciplines such as geotechnical, geological, and mining engineering that traditionally fed the pipeline for tailings professions are shrinking at many universities (Sichinava and Goetsch, 2019; Saucier, 2020). The perfunctory disassociation of the general public from the industrial complex and the associated need for raw materials limit the understanding and benefit of mining as a tangible and productive career path (Banta et al., 2021). Further, the generally negative perception of mining combined with the unfairly characterized and challenged credibility of mining to operate in an environmentally friendly manner are also contributing to a declining interest in mining-related career opportunities. The unfortunate consequence is a shrinking educational on-ramp that the industry has relied upon for years to generate qualified professionals. This supply shortage is occurring amid the ongoing and imminent retirements of many of the world's leading experts in tailings management, also contributing to the current labor crisis.

The objective of this study was to assess current and future tailings resource needs. The labor demand for tailings professionals was quantified by estimating a range of expected engineering hours required to support a tailings facility considering the GISTM and other guidance. The labor demand was estimated based on the number of tailings facilities presented in the Global Tailings Portal, whereas future demands were estimated based on expected labor applied to the total estimated quantity of tailings facilities worldwide.

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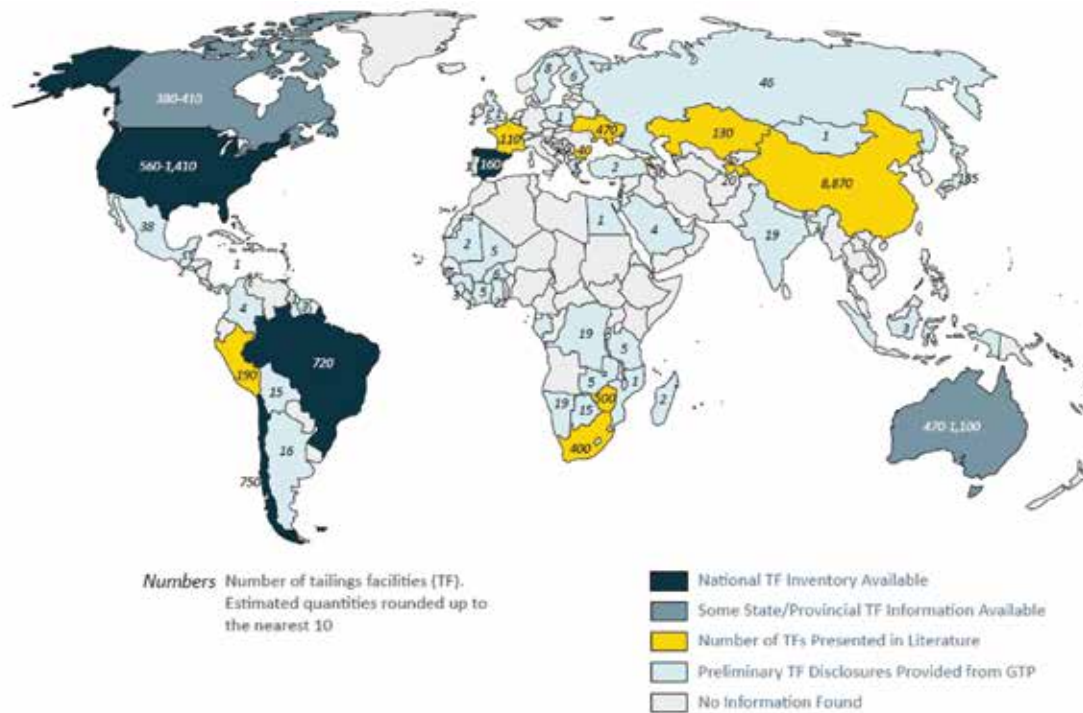
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Tailings Management

Figure 1

Number of tailings facilities around the world.



facilities, state/provincial databases and/or direct disclosures from regulators, referenced literature, and facilities disclosed and categorized in the global tailings database version 4.0 (GTD, 2021) (an earlier version was used by Hatton et al. 2020, and Spencer et al., 2021).

The estimate of

Methods

Tailings labor demand. ICMM members have committed to ensure that the members' tailings facilities with "extreme" or "very high" potential consequences conform to the GISTM by August 2023. All other tailings facilities operated by ICMM members that are not adequately closed are committed to complying with the GISTM guidelines by August 2025. The current and future labor demands were quantified using both the GISTM and Tailings Management Good Practice Guide (ICMM, 2021) to establish the labor demands for a tailings facility adhering to good governance and good engineering practices throughout the facility lifecycle. Calculations included consideration for the feasibility, design, and construction phases to life-of-facility management and closure. Personnel duties (labor hours) required for a tailings facility under the GISTM were quantified and then applied to the global estimate of tailings facilities.

Characterizing tailings facilities worldwide.

The estimated total number of tailings facilities worldwide was characterized. Initial efforts in Hatton et al. (2020) and Spencer et al. (2021) were expanded upon to yield an (conservative) estimate of 17,000 tailings facilities worldwide. A world map is shown in Fig. 1 with estimates of the number of tailings facilities for specific countries and indication of source data. Data sources are described in Hatton et al. (2020) and Spencer et al. (2021) and include national inventories of tailings

17,000 tailings facilities was refined by siloing the available tailings facility inventories by crest height, hazard classification, and status (active or nonactive). Tailings facility characterization was developed to proportionally estimate labor resource needs with an understanding that the effort required to service a smaller, lower-production tailings facility (for example) is less than a larger, high-throughput facility.

A similar proportional distribution of labor resource time was applied in terms of tailings facility hazard classification or status, with high-hazard tailings facilities (for example) requiring more labor to design, effectively manage and close as compared to low-hazard facilities. Hatton et al. (2020) grouped the identified tailings storage facilities into three general classification types (A, B and C) with respect to structure height and hazard potential (United States) or potential associated damage rating (Brazil). The range of percentages for each facility type was then applied to the total number of tailings facilities to aid in labor resource estimates.

The total estimated number of global tailings facilities falling into each of the three general classification types was then partitioned into active and inactive facilities. Although information for some closed tailings facilities is available, an unknown number of historical/legacy facilities are not documented or are completely unknown. Thus, existing data sources collected as part of the Hatton et al. (2020) and Spencer et al. (2021) research were queried to summarize the percent

of total facilities categorized as active. The average percentage of active tailings facilities was then applied to the total number of facilities to approximate the number of active and nonactive (inactive or closed) tailings facilities. The resources required to service a nonactive facility were assumed to be less compared to an active facility (described subsequently).

Tailings labor demand under the GISTM.

Calculations for labor resources required to service global tailings facilities were estimated under consideration of requirements for tailings facility design and management under the GISTM (GTR, 2020). Labor needs include the following personnel roles: senior technical reviewer or independent tailings review board (ITRB), accountable executive, engineer of record (EoR), responsible tailings facility engineer (RTFE), project engineer, and staff engineer.

A summary of experience level, specific GISTM requirements and estimated labor for types A, B and C tailings facilities is presented in Table 1. Experience levels and estimates for labor were developed based on GISTM requirements. The full-time equivalent (FTE) was calculated assuming a 40-hour work week. Initial drafts of Table 1 were circulated to leading tailings industry professionals to provide feedback and guide the estimated values presented herein.

Labor intensity levels by tailings facility classification. The amount of labor required to design and manage a given tailings facility varies based on a combination of factors, such as site geology, topography, climate, hazards, dam height, impoundment volume, and construction method. Labor estimates for each personnel role were divided into three levels of anticipated labor intensity based on the three tailings facility classifications. For example, a type C tailings facility is classified as high hazard (or high dam height) and corresponds to this study's highest estimated level of labor intensity. Labor intensity levels were chosen to represent the range of potential labor resources needed for facilities with varying characteristics and by distinctions in requirements within the GISTM. Under the GISTM, facilities

with potential consequence ratings of high, very high, and extreme have more requirements for independent reviews than facilities with potential consequence ratings of low or significant. The service needs from a given personnel role for a given type of facility are generally consistent based on anticipated needs and represent activities that can be estimated and roughly quantified.

Personnel roles. Assumptions used to quantify personnel duties as described herein were associated with tailings facility design,



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Tailings Management

Table 1

Personnel and labor resource demands under the Global Industry Standard on Tailings Management.

Personnel role	Typical experience range	GISTM applicable requirements	Estimated average labor quantity and frequency for life of project [1]			Resource demand as FTEs (assuming FT = 40 hours per week)		
			Type A TF [2]	Type B TF [2]	Type C TF [2]	Type A TF [2]	Type B TF [2]	Type C TF [2]
Senior technical reviewer or ITRB [3]	25 years +	3.2, 4.2, 4.7, 4.8, 5.7, 10.1, 10.5, 10.6	2 days/year	10 days/year	15 days/year	0.01	0.04	0.06
Accountable executive	10-20 years +	4.3, 4.7, 5.7, 7.1, 8.2, 8.3, 8.4, 8.5, 8.6, 8.7, 9, 12.1	1 hour/month	4 hours/month	15 days/year	0.01	0.03	0.04
RTFE	10 years +	6.3, 6.4, 6.5, 7.2, 7.3, 7.5, 8.5	8 hours/week	16 hours/week	32 hours/week	0.2	0.4	0.8
EoR	10 years +	4.8, 6.3, 6.4, 6.5, 7.4, 7.5, 9, 10.4	4 hours/week	12 hours/week	24 hours/week	0.1	0.3	0.6
Project engineer	5-15 years	None — Assist EoR and RTFE	4 hours/week	12 hours/week	24 hours/week	0.1	0.3	0.6
Staff engineer	0-5 years	None — Assist EoR and RTFE	16 hours/week	24 hours/week	32 hours/week	0.4	0.6	0.8

The information presented in this table does not establish requirements or recommendations for experience or labor quantity for any specific tailings storage facility. This table is solely intended to approximate nonproject-specific averages to estimate global tailings professional resource demands. **Abbreviations:** EoR-Engineer of Record; FT-Full Time; FTE-Full-Time Equivalents; GISTM-Global Industry Standard on Tailings Management; ITRB-Independent Tailings Review Board; RTFE-Responsible Tailings Facility Engineer; TF-Tailings Facility. **Notes:** [1] Estimated labor quantity and frequency are presented as an average over the life of the project for active, regular operations. Estimated labor would be expected to be higher during design and expansion phases and lower in closed/inactive phases. [2] Dam-type classifications are not intended to implicate that specific TFs require the criteria shown in the table. Three dam-type levels were chosen to represent the range of potential labor resources needed for facilities with varying characteristics. For example, the level of effort required to service a smaller, lower production TF would be less compared to a sizeable, world-class facility. [3] Senior Technical Reviewer or ITRB, as required under the GISTM. ITRB assumed to consist of 2-3 people for a total of the days listed.

construction, and management based on the GISTM and Good Practice Guide and include the required interaction with operations and continuous engineering support. The resource demand calculations in Table 1 include support for day-to-day tailings facility operation and intentionally exclude items such as the design of capital expenditure projects (CAPEX), sustaining capital projects, and specific aspects of operational expenditures (OPEX). The calculations do not include associated overhead costs, supporting labor such as word processing, or other administrative support services such as drafting and communications. Finally, and significantly, the estimate does not include associated labor from regulators, manufacturers, vendors, bankers, insurance providers, and educators, among other professions, that are related to serving tailings management and governance of the mining industry.

Senior technical reviewer/independent tailings review board (ITRB). The GISTM stipulates independent (third-party) review of tailings facilities, conducted by either a senior technical reviewer or ITRB, as dictated based on potential consequence rating under the GISTM. Facilities with a potential consequence rating of “low” or “significant” may have their independent review conducted by a senior technical reviewer, whereas facilities with consequence ratings of “high,” “very high” or “extreme” must have a full ITRB conduct the review. Typical minimum experience levels of independent reviewers are generally agreed to be around 25 years.

The independent review duties (Table 1) are assumed to consist of one to three people for approximately two to 15 days per year, per tailings facility. Estimating labor effort ranges for independent reviews is particularly difficult because the level of effort depends on how well

Table 2

Percentages of active tailings facilities (TF) from various sources. Average = 40 percent.

Region	Total TF records	Active TF records	Percent active TF	Data source
Worldwide	1,942	827	42 percent	GTD, 2021
Chile	742	104	14 percent	Servicio Nacional de Geología y Minería (Ser-nageomin), 2019
Chile	449	175	39 percent	Villavicencio et al., 2013
Chile	660	257	39 percent	Ghorbani and Kuan, 2016
Peru	183	90	49 percent	Wallingford, 2019
Western Australia	492	277	56 percent	Personal communication (2020), Mine Safety Directorate of Department of Mines, Industry, Regulation and Safety
United States	1,363	560	41 percent	MSHA, 2019; NID, 2018

stewardship is executed prior to initiating an independent review and/or how long a particular tailings facility has been under independent review. The estimated effort for independent review duties presented is intended to be a wide range to capture a variety of needs.

Accountable executive. The accountable executive is an in-house executive directly

answerable to the chief executive officer and communicates with the board of directors. General experience levels for the accountable executive are assumed to be around 10–20+ years. The accountable executive's duties (Table 1) are assumed to be performed within a range of approximately one to six hours per month, per tailings facility.



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Table 3

Estimates of tailings labor demand for the 1,947 facilities disclosed in the global tailings database (2021).

Percent contribution of tailings facilities (TF)				Full-time equivalents (FTEs) needed to service 1,947 tailings facilities with a 75 percent labor reduction for nonactive facilities						
TF screening criteria	Type A [1]	Type B [1]	Type C [1]	Senior technical reviewer or ITRB	Accountable executive	RTFE	EOR	Project engineer	Staff engineer	Total FTEs
Crest height	43–51 percent	32–40 percent	17 percent	30–31	23–24	387–405	267–276	267–276	554–589	1,528–1,600
Hazard	12–32 percent	17–37 percent	51 percent	43–45	30–32	554–598	408–431	408–431	618–706	2,060–2,242

[1] Classification by dam height: Type A < 30 m, Type B > 30 m and < 100 m, Type C > 100 m. Classification by hazard: Type A = low, Type B = significant or medium, Type C = high.

Responsible tailings facility engineer (RTFE).

The RTFE is intended to be an in-house, onsite engineer who directly oversees day-to-day tailings facility management and monitoring. Typical minimum experience levels of an RTFE start from 10 years. The RTFE duties (Table 1) are assumed to be performed within approximately eight to 32 hours per week, per tailings facility.

Engineer of record (EoR). Under the GISTM, the operator may nominate an external senior engineer to serve as EoR, or appoint an in-house engineer as the EoR. In the latter case, the EoR may delegate design to an external firm that serves as the designer of record (DoR). For this exercise, a senior external engineer was assumed to serve the EoR role or that the EoR and DoR labor load is captured under EoR efforts (that is, EoR and DoR are grouped as one labor effort).

The typical experience level of an EoR is at least 10 years. For high-consequence or complex facilities, experience levels for the EoR will likely be closer to 15 to 20 years. However, 10 years of experience may be sufficient to be an EoR for lower-consequence tailings facilities, which would serve as a typical and often necessary progression in EoR experience. The EoR duties (Table 1) are assumed to be performed within a range of approximately four to 24 hours per week, per tailings facility.

Project engineer and staff engineer. The project and staff engineer roles are not mandated under the GISTM. However, the level of detail in the tasks required for both the EoR and RTFE necessitate an engineering team's assistance, consisting primarily of project-level and staff engineers reporting to the EoR. For example, the EoR and RTFE are responsible for the construction records report but are likely using data compiled by a project engineer and collected/entered by staff engineers and/or

technicians. Like the EoR role, project and staff engineers may be external or in-house employees. Experience levels for staff and project engineers are generally agreed to be around zero to five years and five to 15 years, respectively.

The project engineer duties (Table 1) are assumed to require approximately four to 24 hours per week of support per tailings facility. Staff engineer duties are approximated to be 16 to 32 hours per week, per facility.

Labor quantity discussion. Estimated labor quantity and frequency are presented as an average over the life of the facility for active, regular operations. Estimated labor would be expected to be higher during design and expansion phases and lower in closed/inactive phases. For a conservative estimate of required resources for this study, a labor reduction factor of 75 percent was applied to the labor estimate of inactive/closed facilities to remain in line with the GISTM (that is, it was approximated that, on average, nonactive facilities require 25 percent of the total labor for active facilities). The labor required to service specific tailings facilities varies based on site-specific conditions and may fall outside of the presented labor quantities in Table 1. This project includes assumptions using broad generalizations with the intent to obtain an order-of-magnitude estimate for the number of tailings professionals required to service tailings facilities worldwide. The estimate, in this context, illustrates the significant labor demand for qualified tailings professional resources within the industry.

Total labor demand calculation. The FTE estimations for each type (Table 1) were applied to the estimated number of tailings facilities worldwide to quantify the total labor demand. The estimated FTEs per tailings facility type (Table 1) are multiplied by the estimated number of

active facilities. A 75 percent reduction of FTEs was multiplied by the estimated number of nonactive facilities of each type. The FTE estimations were first applied to the tailings facilities disclosed in the GTD (2021) to reflect the current demand resulting from ICMM member commitments to bring all of their tailings facilities up to the standard within five years. To capture future tailings labor demand, the FTE estimations were then applied to the total global estimate of tailings facilities, with the recognition that to increase the environmental stewardship of mine waste, all global tailings facilities must be brought up to a level of practice with an approximate labor demand like the GISTM requirements. Of note, this future demand does not reflect an anticipated increase in global mining activity in support of future mineral demands.

Results

Characterizing tailings facilities worldwide — characterization by type.

Tailings facilities were grouped into the following three classification types based on crest height (Hatton et al., 2020): (1) type A — small structures with crest height < 12 m (40 ft); (2) type B — intermediate structures with crest height > 12 m (40 ft) but < 30 m (98 ft); and (3) type C — large structures with crest height > 30 m (98 ft). In addition, tailings facilities were categorized into three classification types based on hazard potential (United States) or potential associated damage rating (Brazil): (1) type A — low hazard potential or low potential associated damage; (2) type B — significant hazard potential or medium potential associated damage and (3) type C — high hazard potential or high potential associated damage. The classification types used herein are not meant to represent an established consequence classification and do not align with the consequence classification in GISTM (that is, low, significant, high, very high, extreme), but only to serve as a useful binning technique to support labor demand calculations.

The distribution of tailings facilities in the United States and Brazil that classify into types A, B and C based on height and hazard is shown in Fig. 2. Data available for the United States and Brazil were used to yield estimates of the type A, B and C tailings facilities based on the quality of information available for these two countries on tailings facility quantities and characteristics. Classification by crest height is biased toward smaller dams (type A) for both the United States and Brazil, whereas classification by hazard rating is biased toward high hazard (type C) for both countries. This difference in bias is likely attributed to not accounting for other factors (for example, the volume of tailings impounded, distance from towns/cities) that can influence the hazard rating for a tailings facility with a low dam height. Average distributions of type A, B and C tailings facilities based on height were used to generate a lower-bound estimate for labor demand, and average distributions based on hazard rating were used to generate an upper-bound estimate.

Classification by status (active or nonactive). A summary of relevant literature sources that identify active tailings facilities within a given database is provided in Table 2. The recent global tailings database (2021) catalogued 1,947 tailings facilities, of which 827 (42 percent) are identified as “active.” The mean of all sources in Table 2 is 40 percent, which is comparable to that reported by the global tailings database. Thus, 40 percent active facilities was applied to the estimate of 17,000 tailings facilities worldwide to yield 6,800 estimated active facilities and 10,200 nonactive facilities (inactive or closed).

Labor estimate post-GISTM. Companies that have disclosed tailings facilities to the global tailings database (2021) are already bringing their facilities up to the guidelines outlined in the GISTM. This transition is happening now, and demand for the associated personnel roles in the GISTM is increasing rapidly to meet the guidelines. An initial estimate of labor demand is in Table 3, which includes personnel required to service the 1,947 disclosed tailings facilities in the global

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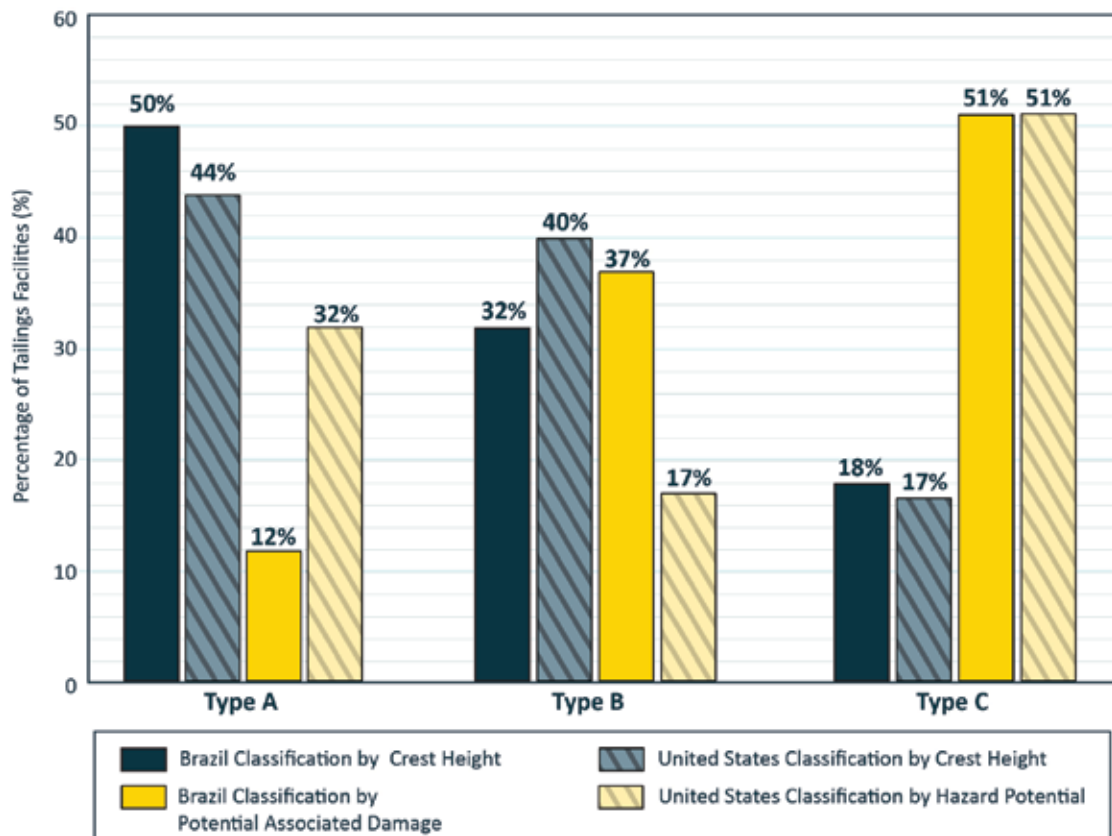
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Figure 2

Percentage of tailings facility inventory for each type based on Brazilian and United States height or hazard classifications.



tailings database (2021). The numbers in Table 3 reflect the 42 percent of active facilities reported in the database; the labor required for nonactive facilities was reduced by 75 percent from the labor required for an active facility.

The lower-bound estimate was based on tailings dam crest height and suggests that more than 1,500 FTEs are required to serve the 1,947 tailings facilities, whereas the upper-bound estimate based on hazard rating suggests that more than 2,200 FTEs are required. The total number of FTEs includes all personnel outlined in Table 3.

Appropriate management of all tailings facilities, not just those disclosed in the global tailings database, in accordance with a level of practice equivalent in scope to the requirements of the GISTM, Good Practice Guide, and/or other relevant guidance documents is fundamental for the mining industry to be a leader in its transition to a green economy and sustainable energy future. Additionally, securing investors and insurance policies now and in the future will require mine owners to demonstrate good engineering and governance of tailings facilities. Thus, the interpretation is that the industry will take the steps required to increase uniformity of good engineering practices and

governance of all the estimated 17,000 tailings facilities worldwide.

The labor demand required to service the estimated 17,000 tailings facilities in accordance with the GISTM is in Table 4, which includes an estimated 6,800 active facilities and 10,200 nonactive facilities. This labor demand is considerably higher relative to the 1,947 tailings facilities in the global tailings database (2021) and represents a forward-looking projection to capture the

mining industry's needs. Thus, if the mining industry wants to manage all (current) facilities worldwide, safely and sustainably, it will need approximately 12,900 to 18,900 FTEs. The labor resources required to achieve this will take time to recruit, develop, retain, and replenish. Another major effort will be to find and catalog the extent of all tailings facilities worldwide to define the magnitude of stewardship required to safely manage each for future generations.

Labor quantification in this study was performed to yield a total number of FTEs. However, fulfilling one FTE role likely will require multiple people. For example, most upper-level technical experts who serve as senior technical reviewers or are on ITRBs do so in addition to other professional duties; in other words, most ITRB members do not serve as ITRB members full time. Therefore, the actual number of experts required exceeds the stated FTE requirement to meet 30–45 ITRB FTEs to service the 1,947 tailings facilities disclosed in the global tailings database (Table 3).

Labor demand under the GISTM has increased per tailings facility due to the addition of personnel roles such as accountable executive and RTFE, which were created explicitly in the GISTM. Labor demand for all personnel

Table 4

Estimates of tailings labor demand for the minimum estimated 17,000 tailings facilities worldwide.

Percent contribution of tailings facilities (TF)				Full time equivalents (FTEs) needed to service 17,000 tailings facilities with 75 percent labor reduction for nonactive facilities						
TF screening criteria	Type A [1]	Type B [1]	Type C [1]	Senior technical reviewer or ITRB	Accountable executive	RTFE	EoR	Project engineer	Staff engineer	Total FTEs
Crest height	43–51 percent	32–40 percent	17 percent	255–263	194–201	3,273–3,422	2,253–2,328	2,253–2,328	4,675–4,974	12,903–13,516
Hazard	12–32 percent	17–37 percent	51 percent	361–380	250–268	4,675–5,049	3,450–3,637	3,450–3,637	5,217–5,965	17,403–18,937

[1] Classification by dam height: Type A < 30 m, Type B > 30 m and < 100 m, Type C > 100 m. Classification by hazard: Type A = low, Type B = significant or medium, Type C = high.

roles also increases as the number of facilities managed according to the GISTM increases. Labor demand changes under the GISTM have happened rapidly, with the expectation that once the GISTM was issued, companies expecting funding from the 100 investors with more than \$13 trillion in assets under management supporting the Investor Mining and Safety Initiative will need to bring their facilities up to compliance with the GISTM. The ICMM member commitment pledges to bring all member-owned tailings facilities into compliance with the GISTM between August 2023 and August 2025. This includes retrogressively assessing existing facilities for data gaps to align with the guidelines (although supporting contractor labor for such investigations, such as drillers and geophysicists, is not included in the labor demand estimates), along with modifying existing design and construction projects to comply with the GISTM. Altering the supply chain to incorporate the tailings professionals needed to satisfy the guidelines in the GISTM does not happen instantaneously. New and existing professionals must be drawn into the industry, trained, and spend years gaining practical experience to be qualified to satisfy the personnel roles and the duties listed in the GISTM.

Call to action

The GISTM sets a new standard-of-care associated with the feasibility, design, construction, management and closure of tailings facilities worldwide. The resources required to bring individual tailings facilities from their current management status up to compliance with the GISTM varies widely. For example, some facilities are already operating under the requirements outlined in the GISTM and

are prepared to provide any necessary labor resources to satisfy additional/forthcoming guidelines. Other facilities, however, are operating below the GISTM guidelines and may have limited to no financial and/or personnel resources available to upgrade and adhere to the guidelines. Still, other facilities may have been abandoned without consideration of proper closure and management.

This study aims to raise awareness of the growing demand for tailings labor resources and the need for collaboration within academia and industry to recruit, train, and retain future tailings professionals. With promulgated guidance of the GISTM and the ICMM guidelines for standard of care, the industry must rapidly evolve to bring in more professionals. The mining industry must educate and train additional tailings professionals to provide the labor needed to sustainably manage mine waste now and in the future. As a profession, the industry must promote tailings as an interesting and successful career path to reduce future labor shortages. ■

Author statements and acknowledgments

Financial support for this study was provided by proceeds from the Tailings and Mine Waste Conference. Graphics were produced by Heather Grotbo with financial support from NewFields. The views and opinions in this study are those of the authors, and do not reflect those of Colorado State University, the Tailings and Mine Waste Conference, Golder/WSP, Marsh Mining, Metals & Minerals or NewFields.

References

References are available upon request from the authors.

Openpit codeposition closure backfill; Marlin Mine, San Marcos, Guatemala

by Manuel Aparicio, Newmont Corp.

The Marlin Mine is located approximately 120 km (75 miles) west-northwest of Guatemala City, in a mountainous region of western Guatemala. Mining and milling operations at the mine commenced in late 2005, including openpit and underground mining. Openpit mining was phased out in 2012, while underground mining continued to the end of milling operations in mid-2017. Processing for precious-metal recovery utilized conventional milling with a cyanide leach process and Merrill-Crowe circuit for the recovery of gold and silver. Mill production averaged 4.5 kt/d (5,000 stpd).

The area is characterized by high seismicity, and the regional climate is tropical, reflecting distinct wet and dry seasons with an average annual precipitation and evaporation of approximately 1,200 mm and 1,700 mm, respectively. Average maximum and minimum temperatures are 25° C and 10° C (77° F and 50° F), with an average annual temperature of 18° C (65° F).

Pit backfill closure solution

Mill tailings were initially deposited into a conventional tailings storage facility (TSF) in a valley downstream of the mill, designed and operated to store mill tailings slurry and process water. However, the ultimate TSF capacity did not meet life-of-mine tailings production volumes. The TSF had already been expanded

once, and building a new TSF was not considered a viable option. Marlin's team developed a solution to filter and stack tailings as pit backfill.

A comprehensive mine site closure plan was prepared as part of the initial mine permitting process. The closure plan was updated several times during mine operation as site conditions changed. As such, this scenario presented an opportunity to update the closure plan for the openpit so that filtered tailings could be conveyed and/or trucked to the openpit for partial backfill. The updated closure plan for the openpit was issued and approved by Guatemalan regulators. The filter plant, using pressure filters, was commissioned in 2012, just as the Marlin openpit was finishing operations.

The tailings management plan was also modified as filtered tailings were used for backfill in the openpit in combination with underground mine waste rock, with the TSF as a secondary deposition location for tailings slurry. The tailings deposition plan was evaluated monthly, and a percentage split was established depending on the mine plan tonnages, filter and process plant availability, and remaining TSF capacity.

A total of 1.85 m³ of filtered tailings were placed to backfill the pit, together with 3 Mm³ of waste rock and 0.9 Mm³ of soil cover. This backfill (up to 89 m or 291 ft thick) produced a terrace level and a 60-m (197-ft) high buttress for the pit highwalls, improving the stability of the pit highwall from a fault that exhibited considerable displacement during mining (Fig. 1).

Figure 1

The Marlin pit at the beginning of backfill operations, January 2013. Photo courtesy of Newmont.

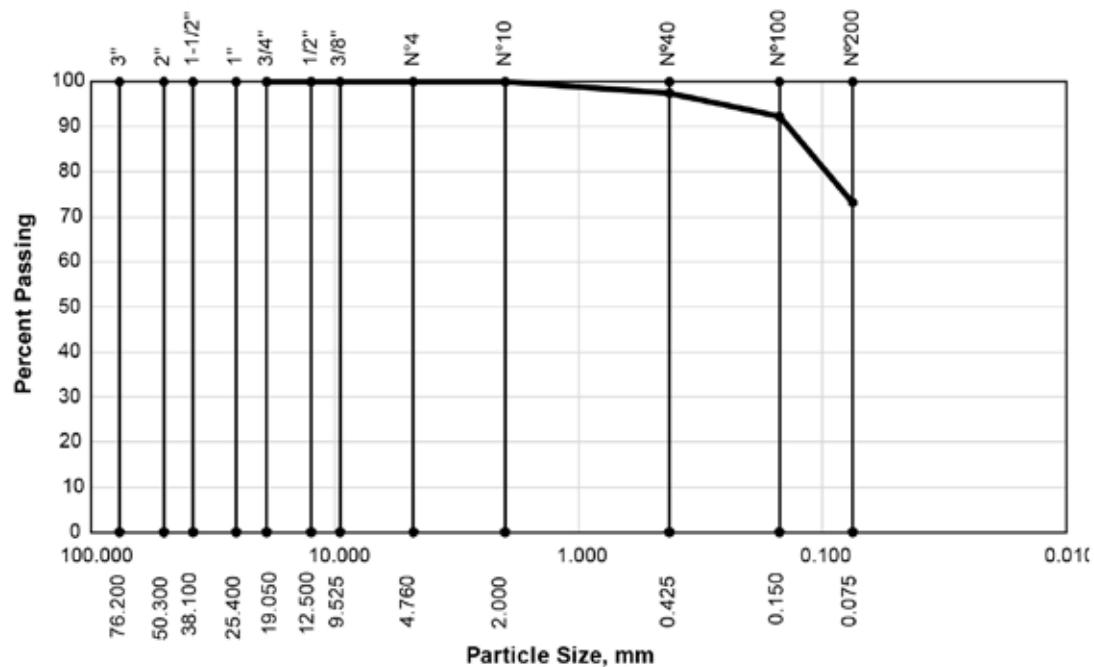


Operational challenges

The general design configuration for the pit backfill comprised a 10-m (33-ft) wide rim of filtered tailings against the pit walls with waste rock placed inside the filtered tailings rim. The materials were placed in lifts with thicknesses of approximately 30 cm (11 in.) for filtered tailings and 90 cm (35 in.) for waste rock. The filtered tailings backfill required sufficient bearing capacity for trafficability conditions during placement, especially during rainy seasons. Because the bearing capacity of the filtered tailings decreased with increasing moisture content, and the clay-rich condition of the tailings caused it to hold more moisture, a solution for wetter than optimum filtered tailings was needed. Approximately 70 percent of the tailings gradation was fine-grained (passing

Figure 2

Typical grain size distribution for filtered tailings. Courtesy of Newmont.



0.075 mm) (Fig. 2), and the average (2012–2017) filtered tailings liquid limits and plastic limits were 33 and 23, respectively, with a plasticity index of 10. A series of laboratory and field tests were developed to find the mixture of filtered tailings amended with cement that would maintain a 19 percent moisture content, compared to an average 14 percent (range from 12 to 16 percent) optimum moisture content obtained from standard Proctor tests, with an undrained shear strength of 100 kPa required for acceptable bearing capacity.

The test results showed that a mixture of 3 percent cement by weight would achieve the desired strength and moisture content. Within the first six months of full-scale operation, field testing demonstrated that the filtered tailings did not require cement addition during the dry season, and that only 1 percent cement by weight was sufficient to achieve the parameters

needed for trafficability during the rainy season. Historical data show that during the high-precipitation months of the rainy season, and when the filter plant presented upset conditions, up to 1.5 percent cement was added. An average of 0.5 percent cement was used during lower precipitation months. Throughout operations, approximately 0.1 percent lime was also added to the filtered tailings. Table 1 summarizes the achieved tailings in-place characteristics as compared to the specifications.

A temporary storage building was included in the design of the filter plant, which allowed the mixture of cement and filtered tailings to cure for at least 12 hours before placement in the pit. The tailings moisture content was checked at the filter plant, within the storage building, and after placement and compaction in the pit. This information aided the operators in adjusting the filtering times during the dry season and the

Table 1

Average achieved tailings in place.

	Tailings in-place properties			
	Percent compaction	In-place density t/m ³	Percent moisture content	Shear strength, kPa
Specification	80.0	1.75 ± 0.05	20	100
Average (2012–2017)	86.1	1.7	19.5	119.1

Tailings Management

Figure 3

Marlin pit final closure conditions, November 2019. Photo courtesy of Newmont.



efficient filtering process because of the high clay content of the tailings.

Benefits of this closure solution

Although there were operational challenges, the codeposition of filtered tailings with waste rock as pit backfill provided a unique solution to address the closure of the openpit at the Marlin Mine. Specifically, the closure approach allowed development of a free-draining cover and partial backfill of the openpit to encapsulate mineralized materials on the pit walls and improve slope stability. As illustrated in Fig. 3, this unique solution facilitated prompt closure of the facility in a tropical climate despite a combination of high clay-content tailings used as pit backfill and the potential for acid generation from exposed pit walls and mine waste rock.

cement content during the rainy season.
Other challenges included:

- Surface water management during fill placement.
- Water sprays installed to control dust at the filter plant.
- Alteration of filter cloth material from the original design to allow a more

Editor's note: This case study was first published in the *Tailings Management Handbook; A lifecycle approach*, edited by Kimberly Finke Morrison, published by Society for Mining, Metallurgy & Exploration, 2022. Available through SME at www.smenet.org/SME-Store/SME-Book-Catalog ■



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Wyoming looks for future of coal as decarbonization trends slow demand

by William Gleason, Editor



As the demand for coal began to slow in 2015 under the global pressure to create a decarbonized energy sector, a team from Energy Capital Economic Development (ECED) began to focus on alternative uses for the coal that is so abundant in Wyoming's Powder River Basin.

For decades, Wyoming's Powder River Basin was the epicenter of the United States' energy sector. The basin produced roughly 40 percent of all of the coal mined in the United States and more than twice the amount produced in West Virginia. But as it became clear that demand for coal as a fuel source was dropping, ECED started work on the development of the Wyoming Innovation Center (WyIC), a state-of-the-art, 9.5-acre facility with two buildings and seven demonstration sites for pilot plants to research alternative uses for coal.

"The idea for the plant originated with the realization that coal is on a downturn and that we needed to do something else to support the coal industry," ECED chief executive officer Phil Christopherson told *Mining Engineering*. "It doesn't promote the energy industry, but it does promote the continued mining and utilization of coal."

Demand for coal rebounded in 2021

following the unprecedented events of 2020, including the COVID-19 pandemic, supply-chain issues and inflationary pressures. In July, the U.S. Energy Information Administration (EIA) reported that it expects coal production to rise by 15.4 Mt (17 million st), or 3 percent, from 2021 to 529 Mt (595 million st) but that coal production is expected to remain flat in 2023.

EIA reported that the expectation of increased production in 2022 primarily reflects demand to replenish depleted coal stocks. Electric-power-sector inventories fell significantly in 2021, and more draws through summer 2022 are expected.

"Much of the decrease in coal mine capacity that has occurred since 2020 appears to be permanent. Coal producers have experienced labor and capital shortages, which we expect will continue to limit coal supply in the forecast," EIA reported.

In its July forecast, U.S. coal consumption is expected to decline 3 percent to 478 Mt (527 million st) in 2022 and to 460 Mt (506 million st) (4 percent) in 2023, compared with 495 Mt (546 million st) in 2021.

EIA expects the retirement of approximately 22 GW of coal-fired power plant capacity

The Wyoming Innovation Center opened in June in Gillette, WY.



The Wyoming Integrated Test Center is in phase III of carbon capture and storage research at the Dry Fork Station in Wyoming.

through 2023, down 10 percent from 2021. As a result, EIA forecast electric power sector demand for coal will decrease by 18 Mt (20 million st), or 4 percent, in 2022.

Coal exports are expected to increase 3 percent to 80 Mt (88 million st) in 2022 from 78 Mt (85 million st) in 2021. EIA reported that it is unclear how much of the U.S. increase in coal exports have been a result of the improved post-pandemic economy and high natural-gas prices or a result of sanctions against Russian coal following Russia's invasion of Ukraine.

With the uncertain long-term outlook for coal, the initial goal of the \$3.3 million WyIC was to keep the coal mines in production, and coal miners working, for as long as possible through alternative uses for coal. The facility opened its doors in June and expects to have its first tenant in place soon.

As it turns out, the facility might also play a large role in helping Wyoming become a significant source of rare earth elements that are crucial to a decarbonized energy future.

"The initial plan was for the facility to be the place for research for coal to products," said Christopherson. "We envisioned that we would be looking at things like coal to activated carbon, coal carbon fiber, or coal to gases and liquids. We never envisioned rare earth elements or critical minerals."

However, WyIC's first tenant, the National Energy Technology Laboratory (NETL), will

focus on those minerals with applied research for the production and use of clean-energy resources.

"There are a lot of critical minerals and rare earth elements that can be co-deposited with coal seams," Scott Quillinan, senior director of research at the Center of Economic Geology Research (CEGR) at the University of Wyoming's School of Energy Resources (UW-SER) told *Mining Engineering*. "We have a program focused on standing up new industries around rare earth element mining where we can hopefully mine the coal at the same time."

"SER is a national leader in energy research, development and innovation and is mission-driven to diversify and protect the energy landscape in Wyoming. For example, SER is leading several research programs in Carbon Valley to help decarbonize fossil-based energy systems, develop new and added-value uses for coal, diversify mining to include rare earth elements and critical minerals, and develop new energy technologies like those that would 'make,' 'transport' and 'use' hydrogen," said Quillinan.

The work at WyIC is modeled after the nearby Wyoming Integrated Test Center that was built adjacent to the Dry Fork Power Plant and aimed at advancing carbon capture and utilization technology. Both allow researchers to set up shop for months, or for years, to test projects ready to advance beyond the laboratory.

The new center is part of a broader effort to



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A demonstration house made of materials from coal was built at the University of Wyoming campus.

spur innovation in the Carbon Valley, utilizing its natural resources and mines to grow and sustain jobs and advance beneficial environmental studies. The WyIC is among several projects that are exploring new options to address the entire lifecycle of carbon, including by the UW-SER.

At the WyIC, private companies and researchers will be able to scale up coal to product and rare earth element research from the laboratory to the precommercialization level. This will help determine the commercial potential and profitability of using coal as a raw material for carbon-neutral, advanced carbon products.

“Most of the coal produced in Wyoming is exported to other states,” said Quillinan. “So we are subject to the rules, policy, economics and regulations of those states. Because of that, we have to think outside of our borders and develop new methodologies. We want to ensure those markets continue to use Wyoming coal going forward. A big push of that is developing new nonthermal uses for coal.”

Quillinan said there are three research areas of focus at UW-SER:

- Coal to products.
- Carbon capture and storage.
- Recovery of other elements from the Powder River Basin.

Coal to products

At WyIC, tenants will be able to research nonthermal uses of coal, such as coal to asphalt, or coal to brick. “A main goal of the innovation center is to promote and advance the diversification of Wyoming’s economy utilizing our wealth of raw materials,” Wyoming Gov. Mark Gordon said in a statement about the opening of the facility. “Backed by state and federal resources, we’re confident that the facility will facilitate the industry’s sizable economic growth and Wyoming’s undeniable leadership in coal processes and production.”

The WyIC’s 371-m² (4,000-sq ft) building will provide office, laboratory and workspace for tenants while a 139-m² (1,500-sq ft) structure will be used to handle raw materials. The campus includes seven demonstration sites ranging from a half-acre to one acre that function as an open-access platform for tenants to upscale their laboratory-proven processes. Researchers can increase their testing capacity by using a few pounds of coal each day to processing up to several hundred pounds of coal or coal-derived materials daily.

At the University of Wyoming, research is also being conducted on building materials from coal. Quillinan said two small homes, one built from traditional building materials and the other from bricks made from coal were constructed side-by-side for testing. Research will also be conducted on coal to asphalt, paint and a host of other materials.

Carbon capture and storage

The Wyoming CarbonSAFE Project, which stands for Carbon Storage Assurance Facility Enterprise, is one of 13 original carbon capture, utilization and storage (CCUS) project sites in the United States that are funded by the DOE with the ultimate goal of ensuring carbon storage complexes will be ready for integrated CCUS system deployment. The Wyoming Project at the Dry Fork Station is currently in phase III, which includes a detailed site characterization. Research at the facility includes testing to determine if it is possible to permanently store 50 Mt (55 million st) of carbon in an economical manner. The site characterization includes additional data collection activities in the field through a front-end engineering design and carbon dioxide (CO₂) capture analysis; baseline data collection



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and surface monitoring; subsurface data analysis and modeling; National Environmental Policy Act approvals; preparation of underground injection control (UIC) Class VI permits to construct; preparation of a risk assessment, mitigation plan and monitoring, verification and accounting (MVA) plan and finalization of a business plan and related commercial aspects.

This phase III three-year effort is sponsored by the DOE under its CarbonSAFE Initiative.

“The goal behind that is to develop methodologies that can be exported to the other facilities that can be deployed commercially and rapidly, we hope,” said Quillinan.

Recovery of rare earth elements

Christopherson said that mining rare earth elements from the Powder River Basin was not thought about when plans for WyIC were first coming together, but significant concentrations of rare earth elements have been discovered above and below the massive coal seams of the Powder River Basin.

Scientists from the NETL will be the first tenants at WyIC and are expected to begin work

this fall or next spring. They will begin working on a method to extract rare earth elements from the ash formed by burning coal.

“What we’re proposing to do is a very small pilot,” Christina Lopano, a research physical scientist at the laboratory, told the *Casper Star Tribune*. The pilot, which has the potential to circumvent the need for new mining, should be concluded by the end of 2023.

“But if we can demonstrate it on the smaller scale, with a couple barrels and some separation technologies, there’s space there,” Lopano added, “if somebody wanted to potentially take it to the next step and commercialize it.”

Creating separation and processing technologies in the United States could help advance a pair of rare earth element projects currently in Wyoming: (1) Rare Element Resources in the northeast corner of the state and (2) Western Rare Earths in the southeast.

Western Rare Earths bought its Halleck Creek project, which was discovered more than a decade ago, last year. It is still in the early stages of the development and permitting process.

Rare Element Resources has been evaluating mining potential at its Bear Lodge rare earth elements project, 63 miles east of Gillette, since 2004.

It has discovered “what we believe is one of the most important rare earth resources in the world,” president and chief executive officer Randy Scott told a Wyoming legislative committee.

The company is trying to bring the rest of the supply chain to Wyoming. Its demonstration-scale processing and separation facility — the stage of development between pilot and commercialization — could be operational in 2024 if permitting goes according to plan.

The roughly \$47 million plant received close to half its funding from a DOE grant last year, and private investors. Permitting is now underway, and 910 t (1,000 st) of ore previously extracted from the Bear Lodge site sits ready to be processed.

Rare Element Resources expects to run the demonstration plant for about a year. If the technique it developed alongside majority shareholder General Atomics, a defense contractor, stands up to larger-scale testing, the company will shift its focus to the commercial plant it hopes to build nearby. ■



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Groundfall risk assessment methodology to minimize fatal accidents in artisanal mining

by Sebastian Cabrera Falcon, Carolina Navia Vasquez, Luis Moscol Sandoval and Rennie Kaunda



Artisanal and small-scale mining (ASM) involves a range of practices, from highly informal and minimally mechanized mining operations with predominantly manual work to formal practices carried out by small but high-tech industrial mining operations [1].

ASM may be a traditional practice, with skills passed from one generation to another. It can be an important driver of local economic development, while simultaneously contributing to a complex array of positive and negative socioeconomic and environmental impacts. There are more than 100 million artisanal and small-scale miners in 80 countries worldwide, and they supply around 20 percent of the worldwide gold production [2].

According to the Peruvian Ministry of Energy and Mining (MINEM), in 2020, 32 percent of fatal accidents in formal (legal) Peruvian mining operations were caused by groundfall events [3]. The lack of resources, knowledge of best practices in health and safety, and insufficient equipment used in ASM make the probability of suffering work accidents very high.

Furthermore, groundfall is one of the

main causes of accidents and injuries in underground mines around the world [4], and it is also a concerning problem in ASM, where the associated fatality rate is similarly high. Unfortunately, a proper record of accidents in ASM is not kept, so an estimate of the actual number of groundfall accidents cannot be accurately developed [5]. Currently miners rely on empirical and observational tools acquired through previous experience to assess groundfall risks. The risks for artisanal miners can tend to be significantly greater than risks for those from the mining industry. This is due to the lack of regulation of ASM, which tends to operate outside the legal framework and the regulations lack of enforcement in force for occupational health and safety regulations.

The objective of this study is to propose a methodology to assess the risk of groundfall

Artisanal mining supplies approximately 20 percent of global gold production.

Carolina Navia Vasquez and Rennie Kaunda, members SME are, mine engineer, Freeport-McMoRan, and assistant professor, Colorado School of Mines, Golden, CO, respectively. Sebastian Cabrera Falcon, member SME, is mine engineer, Sierra Sun Group and Luis Moscol Sandoval, is mine engineer Dinot, respectively. Email: cnaviasquez@gmail.com.

in underground mines, particularly in artisanal and small-scale mines. The results of this study will be based on observations and historical data, and the study can be used as part of an overall strategy to be deployed by ASM operations to assess the risk of groundfall, and to help miners identify hazards.

Additionally, it was found that the lack of compliance with protocols leads to groundfall-related fatalities within the group of younger miners with less experience working in mines. This research further aims to demonstrate that geomechanical, operational, design and behavioral factors can be combined to assess groundfall risk to minimize fatalities in ASM.

Occupational health and safety in artisanal and small-scale mining

Artisanal and small-scale miners often operate in hazardous working conditions. Although ASM is a source of subsistence for 30,000 to 50,000 miners in Arequipa, Peru working in the ASM sector can mean exposure to irreparable damage to health. In certain instances, such exposure leads to accidents that can be fatal [6].

The most noticeable characteristic of ASM's informal and unregulated nature is that it generally operates outside the legal framework or the enforcement of regulations regarding health and safety issues.

Accidents in ASM have many different causes. It is known from international studies that the five main causes of accidents are the following [7].

1. Groundfall and landslides.
2. Lack of ventilation.
3. Misuse of explosives.
4. Lack of knowledge and/or lack of information/resources.
5. Use of old equipment and poor maintenance.

Additionally, most artisanal and small-scale miners do not use personal protective equipment (PPE) such as hard hats, steel-toe boots, etc. In underground operations, miners are exposed to dust during drilling operations with high chances of experiencing lung diseases (e.g., silicosis) in the future. In ASM there is a high incidence of chronic respiratory illnesses, such as bronchial and pneumoconiosis infections [8]. It is uncommon to find professionally trained miners in ASM. Some former miners laid off from formal mining operations have ventured into ASM and have become the technical resource to advise new miners. Others have acquired

ancestral knowledge orally or practically.

The lack of resources, noncompliance with safety regulations, lack of information, and insufficient equipment for ASM result in high probabilities of work accidents [9]. In Peru, there is not an appropriate formal accident register for ASM. Therefore, it is impossible to provide reliable estimations of the actual number and consequences of accidents [10]. Miners in ASM are reluctant to report illnesses or accidents as they fear official sanctions or interventions that could jeopardize their livelihoods [6].

Behavioral factors influencing work accidents. Despite recent technological developments introduced to remove humans from potentially risky processes, the mining industry still relies on tasks that demand high physical and psychological stress from workers [11]. Thus, in many cases, the risk of suffering an accident is influenced by the actions and behavior of the worker [11]. Even some studies indicate that in 90 percent of the cases, work accidents need human behavioral causes to occur, and without them, accidents are unlikely [12]. Thus, the immediate causes of work accidents are divided into hazardous conditions and unsafe acts. The technical or behavioral factors are the origin of the hazardous work conditions, which may exist due to the way labor is organized or the physical, chemical, or biological work environments. The technical or behavioral factors can include inappropriate working methods, deficiencies in work systems, lack of supervision, inadequate work procedures, deficiencies in workplace and facilities, and environmental defects [13]. Behavioral factors are the origin of unsafe acts, which are human actions or omissions that generate risky situations that result in work accidents. Such unsafe acts are consequences of aptitudes, attitudes, and personal conditions [13]. Unsafe acts derived from attitudes or skills include: professional malpractice, acts due to professional inexperience, and poor understanding or interpretation of orders or instructions received.

The influence of age and time of service on work accidents. Statistics on work experience and age emphasize the relationship between those factors and the accident rates that need to be considered [7]. These data indicate that accidents occur more frequently within the younger inexperienced population [14]. Usually, years of experience increase linearly as a function of age.

According to Angarita and Naranjo (2013) [15], about half of the accidents occur during the

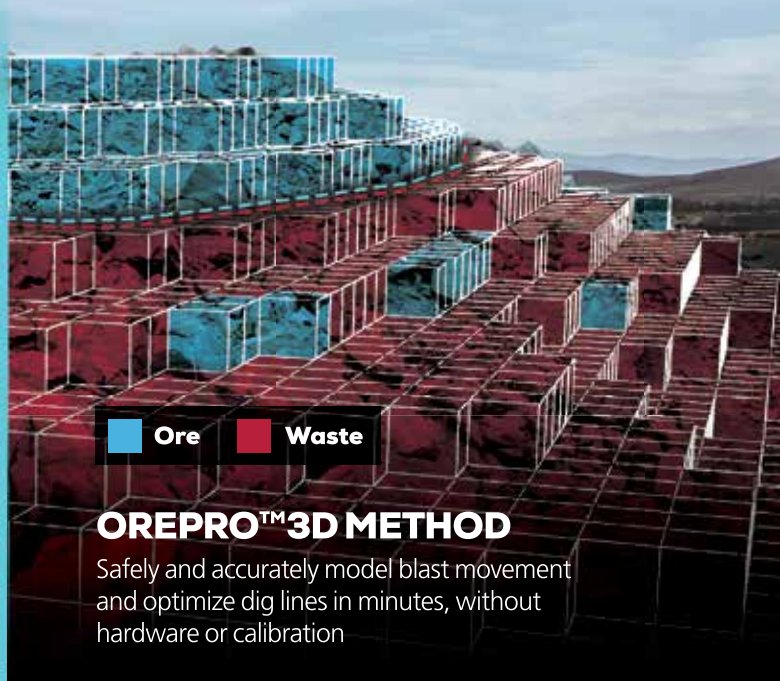
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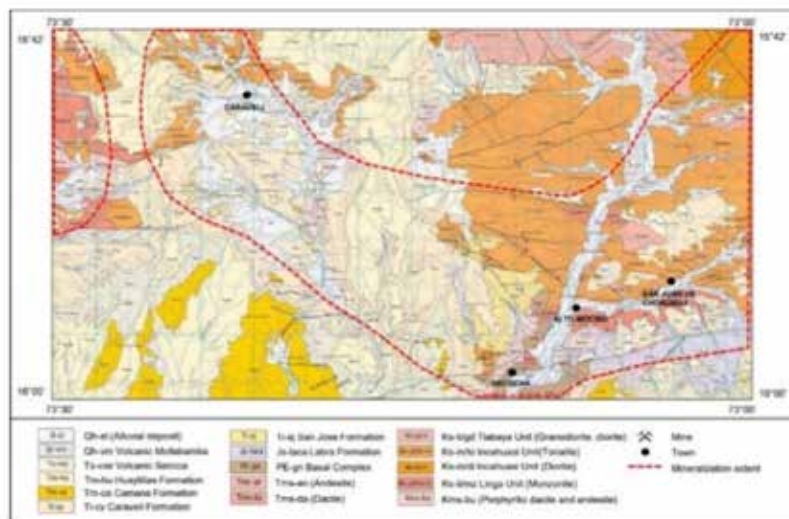
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Figure 1
A geological map of the Nazca-Ocona Gold Belt in the Arequipa region, and some mine sites in the area.



first year of employment, and 75 percent of the accidents occur before the worker reaches two years of employment when employees have little experience. Also, Perez in 2012 [16] found that temporary work conditions (usually, jobs of short duration and precarious conditions) increase the severity and frequency of accidents due to the short time available to learn and the lack of safety measures.

Young miners are also more likely to participate in atypical forms of work in the informal economy, which often lacks safety protocols and responsibilities. Lastly, young miners may be reluctant to report safety and health hazards or incidents [7].

Experience in the workplace can affect workers' self-confidence and how they assess risks in two different ways. Inexperienced workers may become insecure because they are not familiar with the job. Their inexperience prevents a proper evaluation of the risks, as they are unable to identify them. Experienced workers with many years of experience in the same position may think they have "mastered" the process, and end up losing focus on the work details. This overconfidence can lead them to underestimate risks in situations similar to previous ones that were not as hazardous [17].

Definition of groundfall risk

Risk. Risk is the chance of something happening that will have an impact upon the outcomes, as defined by the Australian and New Zealand Standard on Risk Management, AS/NZS 4360:2004 [18]. The source of a risk is usually referred to as hazard, which is the element that alone or in combination has the potential to harm, leading to injuries, damage, delays, or economic losses. Risks are measured

in terms of likelihood and consequences. The likelihood is the probability or frequency of occurrence of an event, while consequence (or severity) is the outcome of an event. Both likelihood and possible consequence can be defined in quantitative or qualitative terms [19].

In 2007, Iannacchione defined the risk of roof fall using the following equation (1) [20]:

$$\text{Risk of roof fall} = \text{Probability of roof fall} \times \text{Miner exposure to roof falls} \times \text{Consequence of roof fall (1)}$$

In this equation, the probability of roof fall (probability based on hazard assessment) and the miner's exposure (which depends on work frequency and schedule) define the probability of roof fall occurrence (likelihood of roof fall happening), while the consequence of roof fall refers to the severity of an event.

Case study description

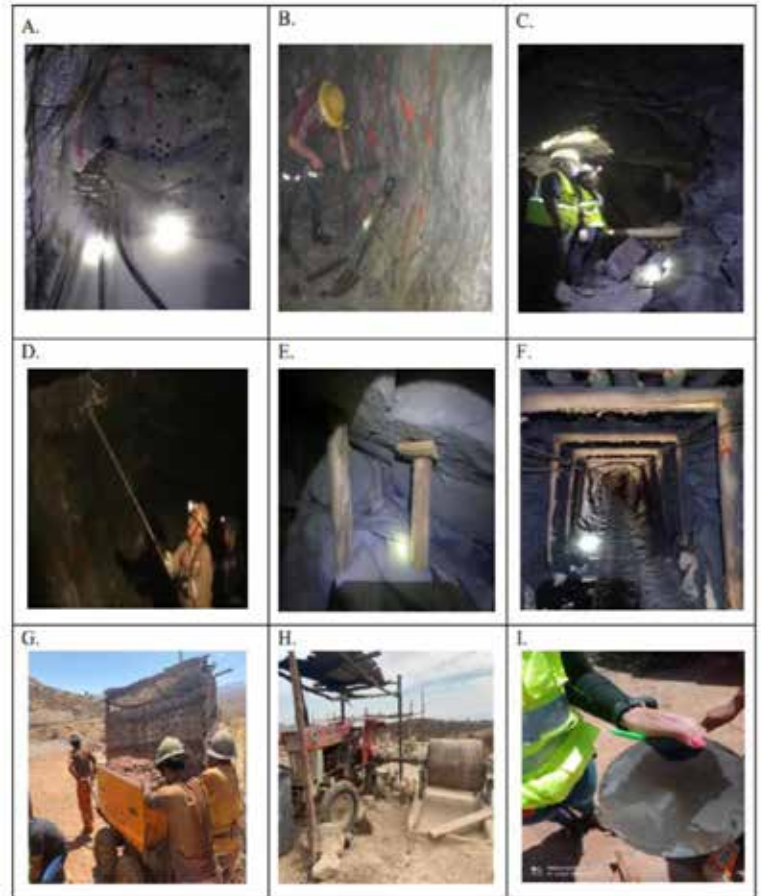
In Peru, mining activities represent approximately 40 to 50 percent of the gross domestic product (GDP). Peru is a main producer of zinc, lead, gold, silver and copper. ASM provides around 28 percent of the gold production, but this number is likely higher, because many ASM activities take place either informally or illegally.

Artisanal and small-scale mines, including mines in the Arequipa region, face different challenges than larger, more mechanized underground mines operated by multinational companies, due to the relative lack of physical, financial, and knowledge-based resources available to local miners, and because of the unique geotechnical conditions that exist in those mine sites [21]. One of the challenges of these mines is the identification of groundfall risk and the control of ground instabilities in their operations to maintain safe conditions and prevent injuries or fatalities. Figure 1 shows the geological map of the Nazca-Ocona Gold Belt.

Generally, in Peruvian ASM, the following methods are applied: “Circado” or reusing, conventional overhand cut and fill, room and pillar and placer hydraulic mining [22]. In narrow-vein mining, the objective is to remove only the mineralized structure with economic gold content and avoid diluting the ore with waste rock. For this study, some narrow-vein mines in Arequipa were visited to become familiar with their mining process. During the visits, it was observed that many artisanal and small-scale mines use the “Circado” method to extract gold. “Circado” is used to segregate the waste

Figure 2

Mine cycle followed by the artisanal miners at the mine site. A: drilling B: blasting C: inspection of overbreak in stopes D: scaling E: support with timber square sets F: support using square G: hauling H: mineral processing I: collection of gold using a pan.



from the ore. This method guarantees adequate selection and recovery of the ore, and it is carried out conventionally [23]. This method consists of making sequential cuts in slices: first, blast the mineralized zone (ore-vein), then clean up the ore, and finally, perform a second blasting on waste rock. Waste is used to backfill the stopes and serves as a platform to receive the blasted ore and continue ascending. However, in many cases, artisanal and small-scale miners extract the mineralized vein with a pick, very carefully and without explosives, placing the mineral on a blanket [24]. Veins generally have widths from 10 cm to 1 m and grades ranging from 1 to 80 oz/Mt of gold. Unfortunately, when miners extract the mineralized zone, they are exposed to risks given increased ground instability.

An accurate record of accidents in ASM is not kept, so an estimate of the real magnitude of this number cannot be given. Nonetheless, the number of fatalities can be at least three times that of deaths associated with formal mining [25].

For safety, these miners often use temporary supports with timber props or timber square sets to prevent groundfall. Figure 2 summarizes the mining cycle used in ASM.

Geomechanical data

In the Arequipa region, where ASM develops, granodiorite and tonalite are the usual host rocks. These are strong to very strong rocks ($UCS > 100$ MPa) fresh or with minimal propilization. These rocks present argillization surrounding the ore-veins, but the strength of the rock is not significantly affected by that [21]. The granodiorite/tonalite rock mass contains three main joint sets as well as some random jointing. The joint sets typically present moderate spacing (0.2 m – 0.6 m) and low persistence (< 3.0 m). The joint surfaces are rough and planar and fresh to slightly altered, with a coating of oxides or infilling (< 1.0 mm) of calcite, chlorite, clay or sulfides (low-strength infilling material is more frequent surrounding the veins). Faults in the area present E-W and NW-SE orientation and typically persist for many meters and contain clayey to sandy gouge (> 5.0 mm).

The RQD of the granodiorite/tonalite is more than 75 percent, and the GSI varies from 50 to 75 [21], [26], [27]. The ore-veins are usually less than 1.0 m wide (0.2 m wide on average). They present silicification or argillization, and their strength can vary because of this. The GSI of the mineralized area can vary from 40 to 65 (Contreras et al., 2020). Figure 3 shows an unstable foot-wall next to an ore-vein, where blocks of rock have detached from the foot wall.

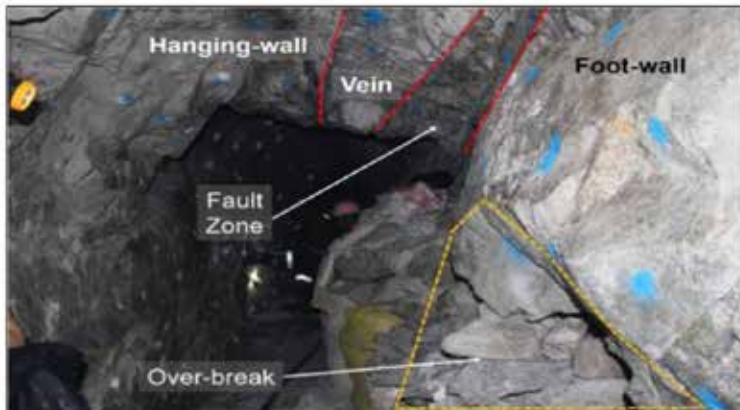
Methodology

There are two sources of information on groundfall: official groundfall accident data and literature on ASM in the Arequipa region. The official data of the Peruvian Government consisted of fatal accident records from 2000 to 2020 available from the Peruvian Ministry of Energy and Mines [3]. They summarized fatal accident reports from 2013 to 2019 of the Supervisory Agency of Investment in Energy and Mines [28]–[30]. These safety statistics and reports include information from formal medium-scale and large-scale mining operations. A trip to the Arequipa region was conducted as a part of this study. Six artisanal mines in the Yanaquihua and the Rio Grande districts were visited during this trip.

The research methodology applied in this study follows seven-step process:

1. Collect historical data, including fatality reports, geological and geomechanical information.

Figure 3
Mine cycle followed by the artisanal miners at the mine site.



2. Inspect underground mines in the Arequipa region.
3. Analyze historical accident data to identify critical geomechanical, operational, and design factors.
4. Analyze historical accident data to determine the role of behavioral factors on groundfall accidents.
5. Develop hazard assessment criteria for groundfall, including geomechanical, operational, and design factors.
6. Define the consequence of groundfall, considering the effect of behavioral factors on the miner's vulnerability.
7. Define a matrix for groundfall risk assessment and associated classification system for risk management.

Results

Analysis of historical groundfall data.

Between 2013 and 2019, there were 44 fatal groundfall accidents in Peru [29], [30]. From Osinergmin accident reports, 11 main causes of fatal groundfall accidents were identified. Figure

4 shows the number of fatalities in groundfall accidents associated with each of the causes. The causes of groundfall indicated in the reports are listed below in order of decreasing frequency. The frequency of each cause is provided in brackets.

- Noncompliance of safety protocols (40 accidents): Failure to comply with safety standards and protocols in the workplace (e.g., failure to scale the rock-mass walls or inspect the excavation before working).
- Presence of highly fractured rock mass (27 accidents): The rock mass is highly fractured and forms small blocks of rock.
- Presence of unstable wedges (25 accidents): The rock mass is structurally controlled and forms well-defined medium to large wedges or rock blocks.
- Presence of faults (22 accidents): Geological faults of different thickness and infill cross the excavation. Usually, faults form large wedges.
- Presence of low-quality rock mass (18 accidents): Rock masses with RMR < 50 or modified-GSI (Vallejo, 2002) < 45 are associated with several groundfall accidents.
- Blasting damage (10 accidents): Blasting damage favors groundfall by creating new fractures in the rock mass or inducing failure of loose wedges. Overbreak, irregular excavation shapes, and new fractured areas are evidence of blasting damage.
- Presence of fake walls (seven accidents): Fake walls are fault zones or highly fractured zones parallel to the ore veins. Typically, "fake walls" form thin tabular rock blocks prone to fail during mining.
- Presence of water (seven accidents): Groundwater flows through the rock mass joints, reducing the effective shear strength of joints favoring groundfall.
- Evidence of support failure (six accidents): Installed rock support elements (e.g., timber square sets, rock bolts) deteriorate (i.e., rotten wood, rusted bolts) and no longer prevent groundfall.
- Irregular excavation shape (five accidents): The excavation shape evidences the damage induced by mining (especially blasting). Regular shapes (e.g., horseshoe shapes) indicate that excavations are stable, irregular shapes (i.e., different to design) indicate that excavations are prone to groundfall.

Figure 4
Number of fatalities by cause of groundfall accident.

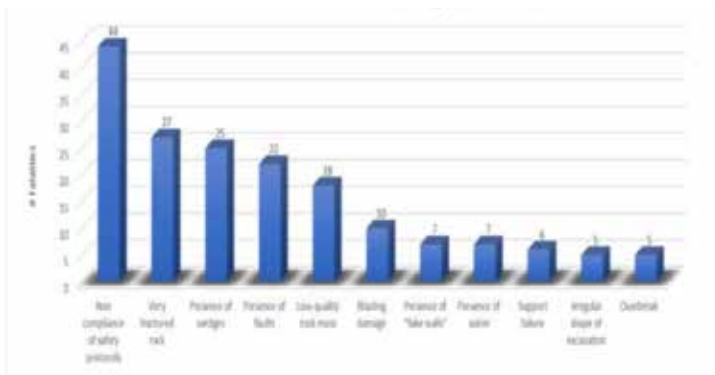


Figure 5

Frequency distribution of fatalities per compliance with safety protocols.

- Overbreak (five accidents): Overbreak in the excavation indicates damage induced by mining (especially blasting). Areas with overbreak are prone to groundfall.

Influence of human behavior. The frequency of reported substandard acts and compliance with safety protocols was analyzed to investigate the influence of human behavior on fatalities. All reports classify the 44 accidents as a result of a combination of substandard acts and substandard conditions. Also, the 44 accident reports state that noncompliance with safety protocols was one of the causes of the accident (Fig. 5). The protocols for pretask risk assessment in the workplace (31 accidents), rock support installation (17 accidents), rock scaling (8 accidents), and other specific mining procedures (7 accidents) were violated in several of the fatal groundfall accidents according to the reports.

Behavioral factors influencing fatalities due to groundfall. The frequency distribution of fatalities by age shows a higher number of fatalities associated with the age groups of 21–25 years, 26–30 years and 31–35 years compared to age groups of 36–40 years, 41–45 and 46–50 years, and 51–65 years. No fatal accidents were reported in the groups 18–20 years and 53+ years. Figures 6 and 7 show frequency distribution of groundfall fatalities by age and time of service.

A combined frequency distribution analysis of the age and time of service from groundfall accidents is presented in Table 1. This analysis shows the highest fatality frequency in the intersection of the 18–35 years old group and the 0–2 years of service group (21 fatalities). This analysis shows that young miners with a few years of service at the mine (< 2 years of service) more frequently suffer fatal accidents due to groundfall, compared to other groups.

Hazard assessment criteria and probability of groundfall. These hazard assessment criteria use the seven measurable critical factors identified from Osinergmin's groundfall accident reports, field observations and literature. The critical factors represent the most significant groundfall hazards found in artisanal and small-scale underground Peruvian gold mines, including those visited for this study. Table 2 summarizes the hazard assessment factors grouped by category with their respective assessment criteria, assessment values and weights.

Miners and professional perceptions

Artisanal and small-scale miners working in Peruvian mines perform operational tasks



facing significant risks on a daily basis. During the field trips to Arequipa, miners expressed that the only technique they know to identify groundfall hazards was conducted using a hammer or a scaling bar.

When miners hit the rock with a hammer

Figure 6

Frequency distribution of groundfall fatalities by age.

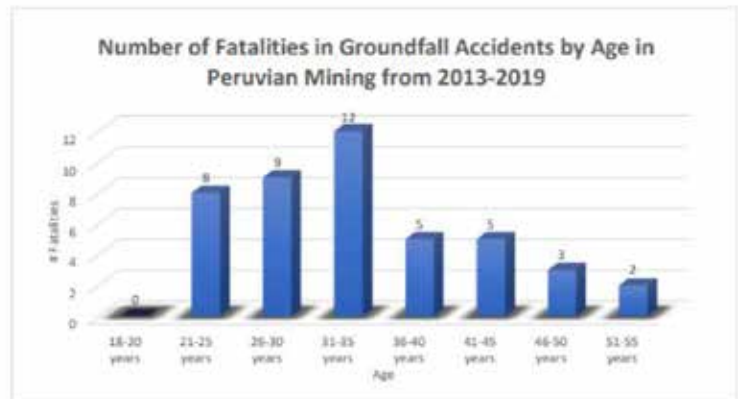


Figure 7

Frequency distribution of groundfall fatalities by service time, expressed in years.

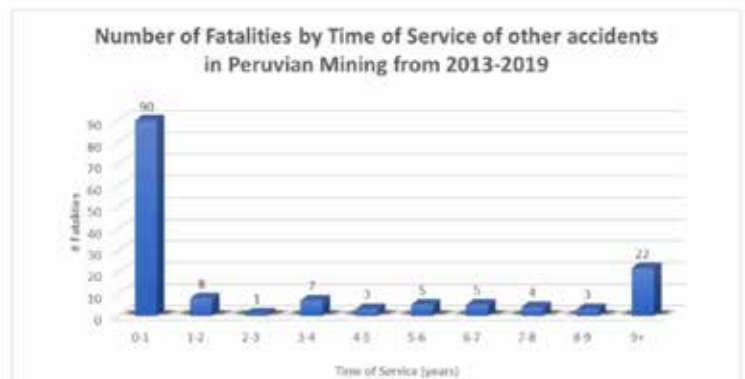


Table 1

Combined frequency distribution by age and time of service.

		Age (years)	
		18-35	35-65
Time of service (years)	0-2	21	7
	>2	8	8

or a scaling bar, they know or can recognize whether the rock is stable by the rock's "sound"; when the rock has a "metallic sound" it is stable, in contrast, when it sounds similar to a drum or has a "hollow sound," it means that a block of rock can fall down at any time.

Miners also stated that prior to entering the mine, a supervisor or someone with the most experience gives a short safety talk, especially to the new or younger miners. These talks may also include information about hazards in the mine and they also may assign the tasks in the mine by selecting the most suitable personnel for the tasks.

Professional miners in Arequipa who work in formal small mines generally have a depth knowledge about safety in the mines to avoid potential accidents leading to fatalities. Formal mines have developed

different safety strategies that comply with government safety requirements. In this regard, the training process for incoming personnel is of the utmost importance to maintain a culture of safety. Such a culture of safety is reinforced for new personnel, but also for the personnel who have been there longer, so that they can be aware of the risks in the mine. The new miners are a constant concern because most of them do not have experience. They do not know the mine and are not aware of safety procedures. Likewise, in this these kind of mines, the mining company has both personnel and equipment that allows them to identifying groundfall hazards. They use rock classification systems like RMR and modified-GSI. In general, professional miners consider that there is a relationship between accidents and the miner's behavior, and agree that new miners are more likely to have an accident and need more supervision.

Table 2

Summary of hazard assessment criteria.

Categories	Factor	Assessment criteria	Assesment value	Weight
Geomechanical	Joint spacing	Widely spaced (>0.4 m)	1	9
		Moderately spaced (0.1 – 0.4 m)	2	
		Closely spaced (<0.1 m)	3	
		Unknown	2	
	Faults	None	2	7
		One or more faults (hard infilling, e.g. quartz)	3	
		One or more faults (soft infilling, e.g. gauge)	2	
		Unknown	2	
	Rock strength	Strong rock	1	6
		Moderate rock	2	
		Weak rock	3	
	Water	None	1	2
		Damp	1	
		Drippers	2	
		Steady flow	3	
Operational	Joint separation	None (close fractures)	1	1
		Noticeable or measureable (open fractures)	3	
		Unknown	2	
	Rock debris of floor	None or a few fragments	1	1
		Some fragments	2	
		Many fragments	3	
Design	Excavation shape	Regular	1	1
		Moderate irregular	2	
		Irregular	3	

Conclusions

Although mining accidents have decreased in recent years, the mortality rate remains high, especially in ASM. In fact, the number of fatal accidents in ASM can be three times greater compared to formal mining. The 44 official groundfall accident reports analyzed for this

study indicate that behavioral factors greatly influence groundfall accidents.

According to the reports, the leading causes of the casualties were as follows: noncompliance with safety protocols and the presence of very fractured zones, wedges, faults and “fake walls” within the rock mass. Based on this information, measurable critical factors were identified to be used for groundfall risk assessment. Among the technical elements, the geomechanical factors have more influence on groundfall compared to the operational and design factors. Particularly, the joint spacing and the presence of faults have higher importance. The influence of behavioral factors can be measured through the age and time of service of the miners. The frequency distribution analyses indicate that the age group from 20 to 35 years old is more prone to suffer fatal accidents, with a frequency of 66 percent.

Conversely, miners 36-years-old or older are less likely to suffer a fatal accident with a frequency of 34 percent. Also, a similar analysis for miner’s time of service indicates that miners with less than two years of experience are more prone to suffer a fatal accident (63 percent), as opposed to miners with more than two years of experience (37 percent). The analyses also showed the correlation of the miner’s age and time of service with the frequency of fatalities. Young miners with less time of service suffer fatal accidents more frequently than other groups. From this, it is inferred that miners with less experience are more likely to suffer fatal accidents related to groundfall. ■

References

- [1] H. Clara and K. Ronald, “Addressing Forced Labor in Artisanal and Small Scale Mining (ASM): A Practitioner’s Toolkit,” vol. 1, 2014.
- [2] S. Siegel and M. M. Veiga, “Artisanal and small-scale mining as an extralegal economy: De Soto and the redefinition of ‘formalization,’” *Resour. Policy*, vol. 34, no. 1–2, pp. 51–56, 2009.
- [3] MINEM, “Estadística de accidentes mortales en el sector minero,” 2021. [Online]. Available: http://www.minem.gob.pe/_estadistica.php?idSector=1&idEstadistica=12464.
- [4] A. T. Iannacchione, L. J. Prosser, G. S. Esterhuizen, and T. Bajpayee, “Assessing roof fall hazards for underground stone mines: a proposed methodology,” 2006 SME Annu. Meet. Exhib., pp. 1–9, 2006.
- [5] World Bank, “State of the Artisanal and Small-Scale Mining Sector,” 2019.
- [6] L. Starke, “Breaking New Ground .Mining , Minerals and Sustainable Development,” *Sustain. Dev.*, pp. 314–335, 2002.
- [7] ILO, “Guía sobre seguridad y salud en el uso de productos agroquímicos,” 2019. .
- [8] V. W. L. Tsang, K. Lockhart, S. J. Spiegel, and A. Yassi, “Occupational Health Programs for Artisanal and Small-Scale Gold Mining: A Systematic Review for the WHO Global Plan of Action for Workers’ Health,” *Ann. Glob. Heal.*, vol. 85, no. 1, p. 128, 2019.
- [9] N. M. Smith, S. Ali, C. Bofinger, and N. Collins, “Human health and safety in artisanal and small-scale mining: An integrated approach to risk mitigation,” *J. Clean. Prod.*, vol. 129, no. March 2020, pp. 43–52, 2016.
- [10] J. Kuramoto, “La Minería Artesanal e Informal en el Perú,” *Mining, Miner. Sustain. Dev.*, no. 82, p. 53, 2001.
- [11] Y. Rodríguez Ruiz, E. Pérez Mergarejo, and W. A. Barrantes Pastor, “Evaluación de la exposición a factores de riesgo de desórdenes musculoesqueléticos de tareas de minería subterránea,” *Univ. Tecnológica Pereira*, vol. 24, no. Scientia Et Technica, pp. 256–263, 2019.
- [12] J. L. Meliá et al., “Perspectivas de Intervención en Riesgos Psicosociales,” p. 290, 2006.
- [13] J. Barceló Fernández, *Incidencia del comportamiento humano en los accidentes de trabajo*. 2018.
- [14] A. González, J. Bonilla, M. Quintero, C. Reyes, and A. Chavarro, “Analysis of the causes and consequences of accidents occurring in two constructions projects,” *Rev. Ing. Constr.*, vol. 31, no. 1, pp. 5–16, 2016.
- [15] C. Angarita and C. Naranjo, “Empresa Del Sector De Hidrocarburos , Colombia Julio 2010- Junio 2013,” 2013.
- [16] G. Pérez, M. Sánchez, G. Díaz, E. Oliva, and I. Peon, “Medicina y seguridad del trabajo,” vol. 58, no. 226, pp. 13–26, 2012.
- [17] joel jonatan Condor-Meneses, “Influencia Del Estudio Técnico Economico En La Selección Del Método De Minado De Un Pórfido De Cobre,” 2016.
- [18] N. J. Bahr, “Risk Assessment & Management,” *routledge*, vol. 8, pp. 1–9, 2018.
- [19] E. T. Brown, “Risk assessment and management in underground rock engineering—an overview,” *J. Rock Mech. Geotech. Eng.*, vol. 4, no. 3, pp. 193–204, 2012.
- [20] Iannacchione, L. Prosser, G. Esterhuizen, and T. Bajpayee, “Methods for determining roof fall risk in underground mines,” *Mining Engineering*, vol. 59, no. 11, pp. 47–53, 2007.
- [21] C. E. Contreras, R. Quispe Aquino, R. Canahua Loza, L. Taco Prado, and G. Walton, “Geomechanical assessment of groundfall hazards in a small-scale underground mine in the arequipa region, Peru,” 54th U.S. Rock Mech. Symp., 2020.
- [22] W. Ramírez Salas, “Impacto ambiental de la pequeña minería y minería artesanal en la sub cuenca del río Inambari Madre de Dios,” *Universidad Nacional del Centro del Perú*, 2017.
- [23] E. Mena, “Planeamiento de minado subterráneo para vetas angostas: caso práctico; mina ‘Esperanza de Caravelí’ de Compañía Minera Titán S.R.L.,” 2012.
- [24] K. Crippen, “Evaluación Ambiental Territorial Grupo De Cuencas De La Costa Sur: Palpa - Nasca-Marcona Acari-Ocoña Y Cerro Verde - Yarabamba-Puquina, Elaborada por .,” 1998.
- [25] MINEM, “En los últimos 13 meses murieron 26 mineros informales en Arequipa,” 2020. .
- [26] R. P. Ayma Condori, “Implementacion Del Sistema De Gestion De Costos Para La Valorizacion De Labores De Desarrollo Y Preparacion En Mina Yanahuahua S.A.C.,” *Universidad Nacional De San Agustin de Arequipa*, 2018.
- [27] R. L. Barrantes Huamán, “Geología Económica Y Estructural Del Deposito Aurífero Alpacay Yanahuahua Condesuros - Arequipa,” *Univerisidad Nacional de San Agustín de Arequipa*, 2016.
- [28] Osinergmin, “Guía de criterios geomecánicos para diseño, construcción, supervisión y cierre de labores subterráneas,” 2017.
- [29] OSINERGMIN, “Boletín Estadístico de la Gerencia de Supervisión Minera - Accidentes Mortales,” *Osinergmin*, vol. 2018, p. 12, 2018.
- [30] Osinergmin, “Boletín Informativo de la Gerencia de Supervisión Minera-accidentes mortales 2020,” *Osinerning*, vol. 2020, p. 20, 2020.



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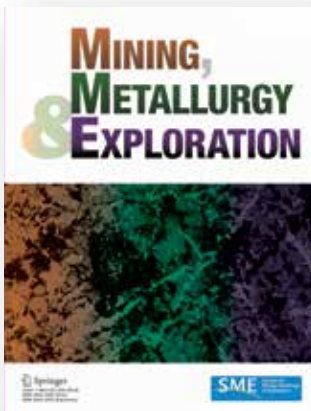
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Stochastic modeling of iron in coal seams using two-point and multiple-point geostatistics: A case study

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Full-text paper:

Mining, Metallurgy & Exploration (2022) 39:1313–1331, <https://doi.org/10.1007/s42461-022-00586-0>

Keywords: Multiple-point statistics, Direct sampling, Training image, Coal deposit, Resource modeling, Sequential Gaussian simulation

Special Extended Abstract

The geological and geostatistical modeling of mineral deposits requires densely sampled drillholes that provide accurate and reliable hard data. Furthermore, quantifying ore-body uncertainty through geostatistical simulation can allow mining engineers to assess long-term risk in mine planning. Nevertheless, ore deposits can sometimes lack dense drillhole information, reliable hard data with proper quality assurance/quality control (QA/QC), or sometimes both. This study is based on a coal mine located in the Republic of Kazakhstan, where an iron dataset is based on data from three newly drilled drillholes, and geological information comes from a massive collection of legacy drillhole data with no evidence of proper QA/QC. For this reason, a workflow was introduced to construct a representative training image from legacy data and stochastically model geological domains within these three

drillholes using a multiple-point geostatistics technique. Once the geological model was obtained, a two-point geostatistics algorithm was applied to model the iron inside each geological domain. The direct sampling algorithm was chosen for modeling geological domains, and sequential Gaussian simulation for iron grade calculation. Both methods were extensively evaluated using different statistical tools and analyses.

Introduction

Geostatistical estimation and simulation provide tools to model the iron grade in a coal deposit that can be used for downstream activities of coal mining projects, such as mine planning, coal preparation and other analyses. These methods aim to use limited exploration information obtained from drillholes and other sources, such as geophysical in-

vestigations or even hand specimens, to produce unbiased and spatially reliable 2D or 3D models [1]. In this case, a typical practice is to model the seam layers as estimation domains and then separately model the mineral grades inside each domain. To model seam layers, multiple-point statistics (MPS) is a promising alternative to variogram-based geostatistical methods and particularly applicable for modeling curvilinear patterns [2]. The premise of MPS-based approaches is to obtain spatial variability information from a conceptual training image (TI) to model multiple-point curvilinear patterns, such as seam layers. Several MPS methods can be applied here [3-5], but this study is focused on DeeSse direct sampling. Unlike other MPS algorithms, DeeSse uses a distance function to directly scan the TI, which significantly increases the simulation speed and lowers the load on memory [6]. In addition, continuous variables, such as iron grade, can be modeled using multi-Gaussian simulation algorithms, such as the sequential Gaussian simulation (SGS) and the turning bands simulation.

Methods

The rationale of DeeSse follows the basic simulation principles of MPS: obtaining the conditional data around the simulated node, then sampling the TI and moving on to the next node. In summary, DeeSse scans conditional data directly from the TI and computes the distance function to find a match between the TI and hard data. Details are available in the full-text paper and the original paper on DeeSse [6].

Results

Records of past geological exploration activities in this case study are primarily handwritten and do not present sufficient evidence of proper QA/QC. However, even though the validity of this dataset is questionable, a geological model produced from legacy data can represent the deposit's geology. In this regard, MPS aims not to replicate TI but rather to reproduce higher-order statistics from it. Therefore, this study used an interpretive geological model of the seam layers

ers obtained by wireframing as a TI (Fig. 1).

Reliable exploration data in this deposit were obtained through three recently drilled drillholes. Additional samples from stopes consisting of both seam layers (only 1b and 2b without shale) and iron grade information were used to address the data scarcity.

The stochastic modeling of seam layers was performed by the DeeSse algorithm using Ar2GEMS software. Simulation parameters were carefully tuned to increase the quality of produced realizations. As a result, DeeSse could reproduce the layered structure pattern of coal seams across 100 realizations. In addition, statistical validation showed that results are acceptable based on the reproduction of categorical proportions, indicator variograms and connectivity functions.

Iron grades were separately simulated inside each geological domain (seams 1b and 2b) using SGS. Cross-validation results suggested that simulated grades are comparable with original grades and demonstrate similar accuracy with kriging. Produced simulations were then juxtaposed into the corresponding coal seams simulated by DeeSse. Figure 2 shows a most probable e-type map representing the average information of both categorical and continuous values. Final statistical parameters show a resemblance with original statistics (Table 1).

Conclusion

Results of this case study showed that MPS can produce geologically realistic seam layers with acceptable reproduction of all orders of statistics, even with limited hard data. First-order statistics were assessed by checking the reproduction of seam layer proportions, and second-order statistics were assessed by variogram validation. The connectivity functions were used to assess the higher-order statistics by checking the reproduction of curvilinear patterns. Moreover, in the proposed combination with the SGS algorithm in the cascade modeling framework, multiple reliable and unbiased realizations can be obtained for use in further mining processes. ■

Table 1 – Statistical parameters of geostatistical realizations.

Parameter	Realizations	Original dataset
Mean	10.05	10.17
Variance	34.14	35.64
Coefficient of variation	0.59	0.58

Selected references

1. Rossi ME, Deutsch CV (2014) Mineral resource estimation. Springer, Berlin
2. Mariethoz G, Caers J (2014) Multiple-point geostatistics: Stochastic modeling with training images. Wiley, New York
3. Strebelle S (2002) Conditional simulation of complex geological structures using multiple-point statistics. Math Geol 34:1–21
4. Zhang T, Switzer P, Journel A (2006) Filter-based classification of training image patterns for spatial simulation. Math Geol 38:63–80
5. Arpat GB, Caers J (2007) Conditional simulation with patterns. Math Geol 39:177–203
6. Mariethoz G, Renard P, Straubhaar J (2010) The Direct Sampling method to perform multiple-point geostatistical simulations. Water Resour Res 46(11)

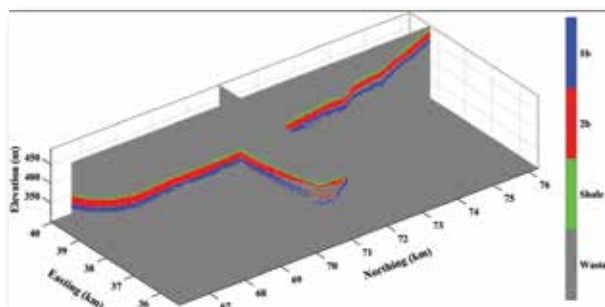


Fig. 1 Training image illustrating the stratigraphic model of the seam layers.

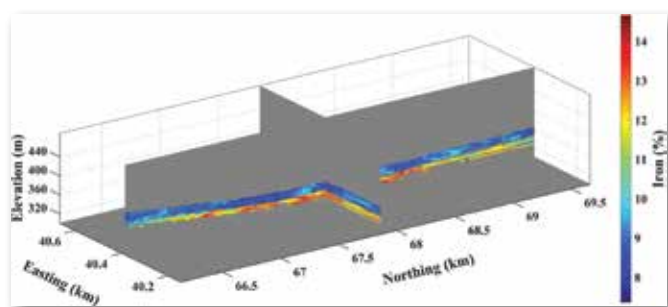


Fig. 2 Most probable e-type model over 100 realizations of DeeSse and SGS.

Experimental study of improving a mine ventilation network model using continuously monitored airflow

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Full-text paper:

Mining, Metallurgy & Exploration (2022) 39:887–895, <https://doi.org/10.1007/s42461-022-00574-4>

Keywords: Mine ventilation, Airflow monitoring, Ventilation network, Atmospheric monitoring system, Barometric pressure

Special Extended Abstract

Mine ventilation simulation software has become an essential tool for the mining industry to design and manage mine ventilation operations. Building a well-calibrated mine ventilation network is time consuming, however, and requires great effort. In the last several decades, the mining industry has seen a steady increase in the use of air velocity sensors to monitor airflow and detect unexpected abnormal airflow in some key locations in underground mines. The present research work was carried out to explore the possibility and methodology of calibrating a ventilation network model using atmospheric monitoring system (AMS) data on a routine and ongoing basis.

Data collection

In order to study how to use continuously monitored AMS data to calibrate and tune a ventilation network, a mine-wide AMS with eight measuring stations was installed in the Safety Research Coal Mine (SRCM) to measure air velocity, temperature and other atmospheric conditions. The airflow velocity and other parameters were continuously recorded every 10 minutes for a month without any unnecessary interruption from mine activities. To obtain the sensor location correction factor for each AMS velocity sensor at the SRCM, the average velocity at each sensor plane was measured using the moving traverse method with a hand-held anemometer once per day for eight days. At the same time, the velocity sensor reading at the time of the traverse measuring was recorded as well.

Results and discussions

It was observed that the fluctuation of the air velocity readings from airflow sensors was largely attributed to the air temperature variation. Figure 1 provides an example of how well the temperature and air velocity are correlated at one of the AMS stations (S1). Due to the fluctuation in the air velocity readings, it is important to use the time-averaged air velocity value for the ventilation network calibration to avoid the error of using instantaneous reading from all velocity sensors.

To obtain the average velocity for the calculation of airflow rate in an entry, the corresponding point sensor reading needs to be converted to the average air velocity using the sensor location correction factor. The correction factor at each sensor location was calculated using the measured

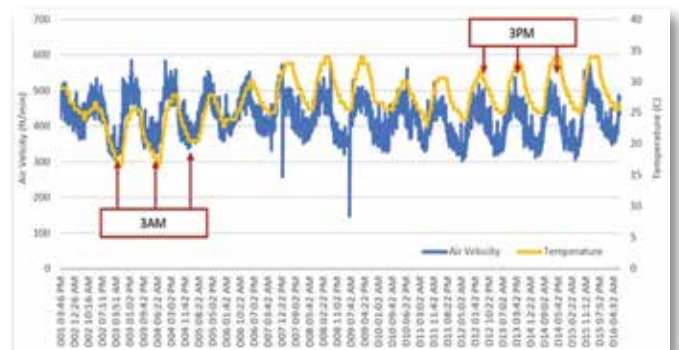


Fig. 1 Monitored air velocity and temperature at AMS station S1.

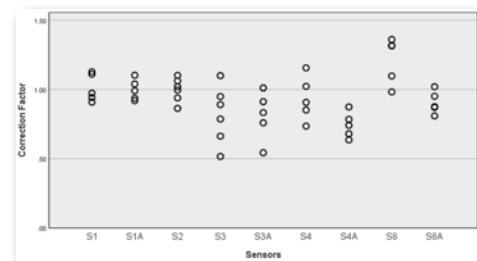


Fig. 2 Correction factors for selected sensor locations.

average air velocities with a hand-held anemometer and monitored air velocities in a time span of eight days, and the variation of the correction factors for different sensor locations is shown in Fig. 2. The correction factors for each sensor fall into a relatively large range; therefore, it is necessary to obtain the average correction factor at each sensor location. The average correction factor at each sensor location is applied to convert the sensor velocity reading to the average air velocity in this paper.

The purpose of ventilation network calibration is to adjust the airway resistances to allow the simulated airflow to match the measured airflow. Before a mine ventilation network can be calibrated or updated, the airways where the resistance changes occur need to be determined. Then the 24-hour average air velocity of AMS velocity sensor readings for that airway was obtained and modified using the ap-

appropriate correction factor to get a more accurate airflow rate for the calibration. One of the advantages of using AMS sensor data to obtain airflow rates over the manual spot check is that the AMS method can produce a time-averaged airflow rate, while the spot check only produces the airflow at the moment of measurement.

Conclusions

A new method was developed to calibrate a mine ventilation network model using the continuously monitored AMS air velocity. The method was demonstrated using the mine ventilation network model of the SRCM and monitored AMS data. Results from the study indicate that the instantaneous air velocity data cannot be used directly for the ventilation network calibration because of fluctuations. It is found that temperature and air velocity readings are well correlated. The sensor location correction factors were

obtained to be used to convert the measured point readings to the average velocity over the cross section of the airway. Results from this study demonstrate that the continuously monitored AMS air velocity data can help mine ventilation engineers better calibrate their ventilation network models to achieve more accurate ventilation simulation results. ■

Disclaimer

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention. Mention of any company or product does not constitute endorsement by NIOSH.

References

A list of all references is available in the full paper.

Stress redistribution in a longwall yield pillar – A comparison between active seismic tomography and theory

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Full-text paper:

Mining, Metallurgy & Exploration (2022) 39:1017–1026, <https://doi.org/10.1007/s42461-022-00579-z>

Keywords: Longwall mining, Seismic tomography, Coal, Ground control

Special Extended Abstract

Safe, efficient underground mining is dependent upon proper pillar sizing. Pillar sizing is typically based on a combination of observation of prior behavior, point measurements, theory and numerical modeling. The actual stress redistribution within a pillar, while assumed for many years, has rarely been imaged. Such imaging can help confirm whether or not theoretical and numerical modeling methods agree with actual conditions within a pillar.

This research presents a case study from a longwall mine

in the western United States. A two-entry, gate-road yield pillar in the headgate of the mine was instrumented with seismometers and convergence monitoring stations, and was monitored over a period of about six months as the longwall face approached the pillar. In this paper, the stress distribution imaged using seismic tomography is compared to the stress distribution expected from theoretical models, geotechnical measurements and numerical models. The tomography results generally agree with those proposed by theory, convergence measurements and numerical modeling results. The agreement of the methods provides validation for the theorized stress redistribution, and this study provides further evidence that tomography can indicate the redistribution of induced stress within a mined rockmass and is another tool available to ensure that mining is conducted safely and efficiently.

Background

Review of coal pillar design indicated potential shapes for the stress distribution within pillars by showing that the stress distribution assumed in the Mark-Bieniawski pillar design formula is a pyramid for square pillars and a rectangular, elongated pyramid (with a linear apex) for rectangular pillars [1]. The load is a maximum in the center of a pillar (at a point for a square pillar and along a line for a rectangular pillar) and a minimum at pillar ribs. The ultimate strength

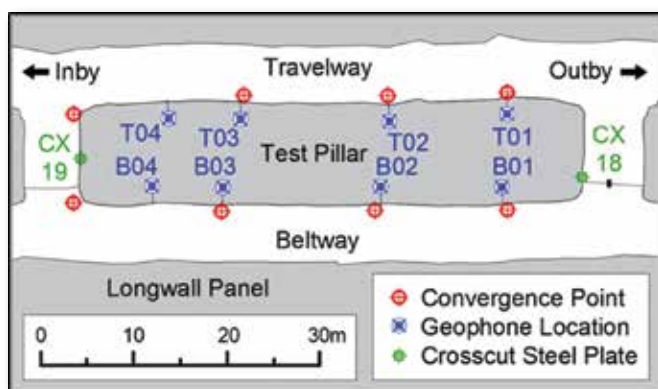


Fig. 1 Locations of geophones and convergence stations.

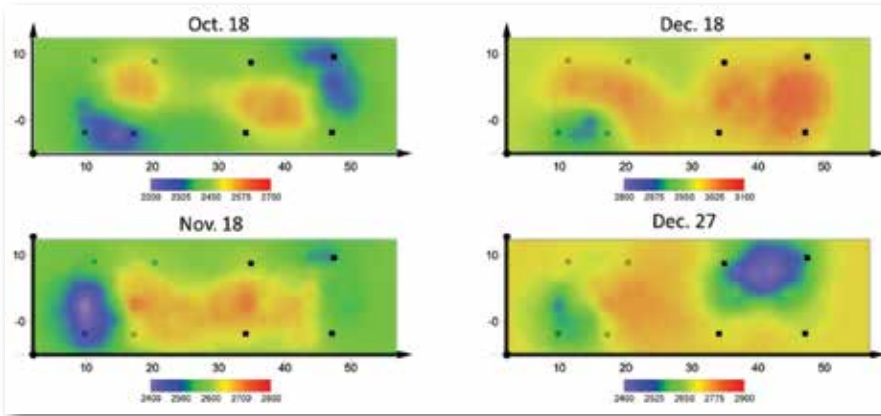


Fig. 2 P-wave velocity tomograms for four time periods, geophones shown as black markers. Axis units are meters; velocity units are meter per second (m/s).

of the pillar is governed by the strength of the core. Prior to this demonstration, Wagner [2,3] presented a model of stress redistribution within a pillar that has been broadly accepted: failure occurs starting at the perimeter of a pillar and gradually progresses inwards toward a confined core which will fail if the stress exceeds the ultimate strength of the pillar.

Methods

Figure 1 shows geophone locations and the locations where convergence was monitored. Six uniaxial and two tri-axial geophones were installed in the study pillar. Drillhole collar locations were selected to provide unobstructed access to the rib and to maintain approximately equal spacing between the sensors on the travelway and beltway sides of the pillar.

Active seismic sources were generated by striking the pillar with a battering ram. During the study, the longwall face advanced approximately 940 m toward the pillar. Active source data from four dates — Oct. 18, Nov. 18, Dec. 18 and Dec. 27, 2017 — were selected for seismic analysis as part of this study. For each active source event, travel times through the pillar were calculated by differencing the arrival times at each geophone from the arrival times at the geophone nearest the source events.

The velocity distribution within the pillar was calculated for each of the four dates using seismic tomography to evaluate how the stress redistribution within the pillar estimated by tomography compared to theoretical and numerical results.

The mean velocity of all P-waves traversing the pillar on a specific date is an indicator of the overall, general stress within the pillar at that time. Laboratory studies have shown that there is a somewhat monotonic relationship between stress and P-wave velocity [4,5]. In many of the studies the P-wave velocity increases with increasing stress, until the stress within the sample nears its ultimate strength, at which time microfractures develop within the sample resulting in a reduced P-wave velocity.

Results

For this study, the mean velocity within the pillar increased from 2,532 m/s on Oct. 18 to 2,618 m/s on Nov. 18 and 2,899 m/s on Dec. 18, and then dropped to 2,404 m/s

on Dec. 27. This relative increase in velocity is similar to prior work in laboratory coal specimens [6], and as would be expected, these results are parallel to those shown in Fig. 2. The broad conclusion that can be drawn solely from the overall mean velocity is that the pillar appears to have reached its ultimate load sometime between Nov. 18 and Dec. 27; the peak velocity occurs sometime between those two dates. Of the four study periods, Dec. 18 has the highest recorded mean velocity, but it cannot be stated definitively that the peak velocity occurred precisely on this date.

Overall, the convergence monitoring data appear supportive of the tomographic results. In the tomography

study, the mean velocity increased across the entire pillar for the first three dates, indicating increasing load, and then decreased from the third to fourth date, indicating post-peak behavior. This observation is compatible with the observed convergence measurements; the greatest amount of convergence occurred between the third and fourth dates.

Summary and conclusions

The results obtained in the current study agree to a large extent with the expected distribution and relative magnitude of induced stress, as presented in prior studies. P-wave travel time tomography provides a method to examine the redistribution of stress throughout a specified volume of a rock-mass, complementing other methods such as point-location measurements and numerical modeling. The information provided by the tomograms can be useful to confirm that an optimal pillar design is being used — a design that maintains safety and does not sacrifice productivity.

Active seismic tomography was conducted on a yield pillar in a longwall mine in the western United States. Although computed tomography has been relied upon in the medical field for decades, and has the ability to provide information about conditions throughout a rockmass, it is still not a common method in the mining industry. This study provides an opportunity to compare results from active seismic tomography in a well-defined, unambiguous study to those from current theory, numerical modeling and point measurements.

The tomography results generally agree with those proposed by theory, convergence measurements and numerical models. This observation provides two conclusions: (1) the agreement of the methods provides validation for the theorized stress redistribution, and (2) this study provides further evidence that tomography can indicate the redistribution of induced stress within a mined rockmass and tomography is another tool available to ensure that mining is conducted safely and efficiently. We can also conclude that at the mine in the study, for the loading conditions, the pillar size was within acceptable bounds, the pillar did not fail prematurely; at the same time, it was not over-designed and thus inefficient. ■

Selected references

1. Mark C (2000) State-of-the-art in coal pillar design. *Trans-Soc Min Metal Explor* 308:123–128
2. Wagner H (1974) Determination of complete load deformation characteristics of

coal pillars. In: 3rd Congress International Society Rock Mechanics. US National Academy of Science, Denver, CO, 1076–1081
 3. Wagner H (1980) Pillar design in coal mines. J of South Afr Inst Min Metall 80(1):37–45
 4. Terry NB (1959) Dependence of elastic behavior of coal on microcrack structure. Fuel 3:125–146

5. Seya K, Suzuki I, Fujiwara H (1979) The change in ultrasonic wave velocities in triaxially stressed brittle rock. J Phys Earth 27:409–421
 6. Shea-Albin VR, Hanson DR, Gerlick RE (1991) Elastic wave velocity and attenuation as used to define phases of loading and failure in coal. No 9355. Bureau of Mines, US Department of the Interior, 43 pp

A novel approach for the separation and recovery of titanium, scandium and iron from acidic wastewater, and utilization of red gypsum

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Full-text paper:

Mining, Metallurgy & Exploration (2022) 39:1297–1312, <https://doi.org/10.1007/s42461-022-00600-5>

Keywords: Acidic wastewater, Red gypsum, Phosphoric acid precipitation, Solvent extraction, Ammonium jarosite

Special Extended Abstract

Acidic wastewater is at present directly neutralized with lime or limestone, which wastes resources such as titanium, scandium and iron and generates a great deal of solid waste. This study proposes a novel approach for the separation and recovery of titanium, scandium and iron from acidic wastewater, and utilization of red gypsum. The proposed process not only recovers valuable metals from acidic wastewater but also treats the red gypsum that has previously been dumped.

Background

The sulfuric acid leaching method is an essential process for producing titanium dioxide from ilmenite due to the low requirements for feed grade [1]. In China, more than 90 per-

cent of titanium dioxide is yielded by the sulfuric acid leaching method, and the production of 1 ton of titanium dioxide engenders about 8 tons of acidic wastewater [2,3]. At present, acidic wastewater is usually disposed of by neutralization with lime or limestone [4], which not only produces red gypsum as an industrial byproduct but also wastes resources. In this work, in order to effectively separate and recover titanium, scandium and iron in acidic wastewater and realize the resource utilization of red gypsum, a precipitation-solvent extraction-leaching process is proposed.

Experiment procedure

Figure 1 presents the process flow diagram of a novel approach for the separation and recovery of titanium, scandium and iron from acidic wastewater along with the utilization of red gypsum, which mainly comprises four experimental processes: (1) separation of titanium from acidic wastewater to obtain titanium phosphate, (2) extraction of scandium from the filtrate to obtain scandium trioxide, (3) leaching of red gypsum with raffinate to obtain calcium sulfate and (4) separation of iron from leaching filtrate to obtain ammonium jarosite, and obtaining ammonium sulfate from the filtrate after iron recovery by evaporation.

Results and discussion

Titanium phosphate has caught the attention of many researchers due to its excellent physical and chemical stability, low solubility and strong adsorption, which is generally synthesized in a strong acid medium. Although most phosphates, such as $\text{Fe}_3(\text{PO}_4)_2$, $\text{FePO}_4 \cdot 2\text{H}_2\text{O}$, $\text{Mg}_3(\text{PO}_4)_3$, AlPO_4 and

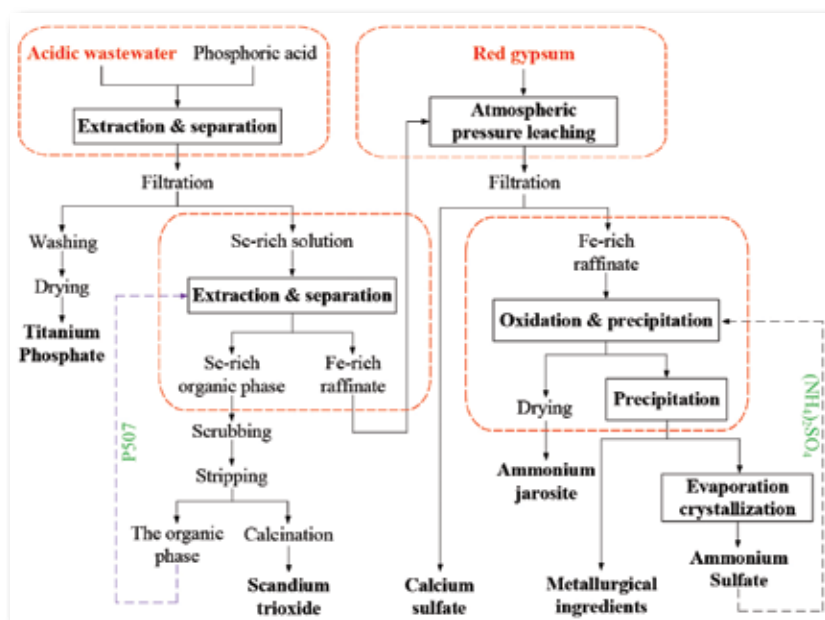


Fig. 1 Process flow diagram for the extraction of titanium, scandium and iron from acidic wastewater, and utilization of red gypsum.

$\text{Mn}_3(\text{PO}_4)_3$, are insoluble in a weak acid medium, when phosphate acid is introduced into acidic wastewater, Fe^{2+} , Fe^{3+} , Mg^{2+} , Al^{3+} , Mn^{2+} and other ions do not produce the corresponding phosphate precipitate due to the strong acidity of the solution. Based on the insolubility of titanium phosphate, adding phosphoric acid to the acidic wastewater will convert the TiO^{2+} into amorphous titanium phosphate precipitates.

As shown in Fig. 2d, under optimal conditions, the coprecipitation efficiencies of iron, magnesium, aluminum and manganese were 0.13, 0.22, 0.17 and 0.30 percent, respectively. The coprecipitation of a small number of impurity ions was caused by mechanical entrainment, and most of the impurity ions introduced by mechanical entrainment could be removed by washing the precipitation

filter cake with dilute sulfuric acid. The concentrations of scandium and titanium in the filtrate after the recovery of titanium were 6.48 and 0.08 g/L, respectively, indicating that the phosphoric acid precipitation method can separate scandium and titanium efficiently in the acidic wastewater.

Many previous studies have shown that increased acidity is beneficial to the extraction of scandium with organic phosphoric acid extractant from the sulfuric acid solution, and the extraction efficiency of scandium in strongly acidic solution is higher. Hence, there is no need to adjust the pH value when extracting scandium with P_5O_7 from the filtrate after recovering titanium, as the stronger acidity is more conducive to the extraction and separation of scandium.

The red gypsum mainly contained iron, magnesium, aluminum and manganese impurities. The red gypsum was a filter residue produced by directly neutralizing acidic wastewater through lime or limestone, so iron, magnesium, aluminum and manganese mainly existed in the forms of $\text{Fe}(\text{OH})_3$, $\text{Fe}(\text{OH})_2$, $\text{Mg}(\text{OH})_2$, $\text{Al}(\text{OH})_3$ and $\text{Mn}(\text{OH})_2$ in the red gypsum, which can be well dissolved by sulfuric acid solution.

Among all the methods for separating and recovering iron, jarosite precipitation is widely used in the metallurgical industry due to its relatively good settling, filtering and washing properties. In addition, this process can be carried out at low pH of 1.5~2 to separate iron from the solution. Among the jarosite species, the ammonium jarosite precipitation method has the advantages of lower costs and faster precipitation rates than sodium jarosite.

Conclusion

Titanium in acidic wastewater can be separated efficiently by the phosphoric acid precipitation method. The recovery

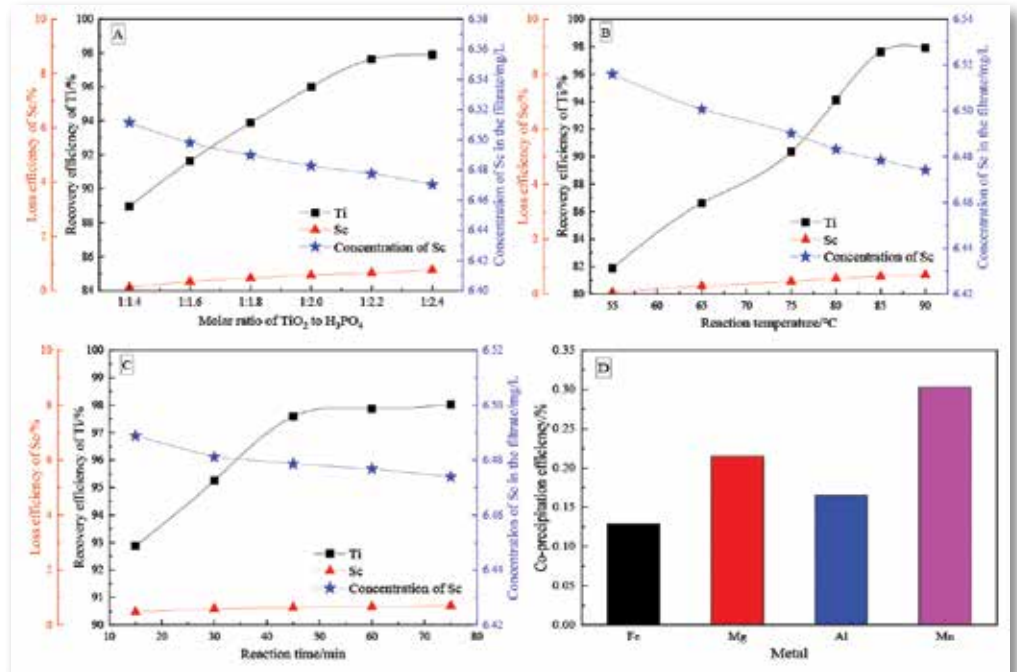


Fig. 2 The influence of (a) phosphoric acid dosage, (b) reaction temperature and (c) reaction time on the recovery efficiency of titanium and loss efficiency of scandium. (d) Coprecipitation efficiencies of iron, magnesium, aluminum and manganese under optimal conditions for recovering titanium.

efficiency of titanium in acidic wastewater was 97.59 percent, while the loss efficiency of scandium only was 0.64 percent. Single-stage extraction efficiency of scandium of 99.79 percent could be reached under the conditions of P_5O_7 concentration of 15 percent, phase ratio (O/A) of 1:13 and extraction time of 6 min. Scandium in the loaded organic phase can be stripped efficiently by 0.5 mol/L oxalic acid solution.

The raffinate after extracting scandium can be used for leaching impurities in the red gypsum, and calcium sulfate product with purity of 98.34 percent and whiteness of 94.27 percent can be obtained under the conditions of leaching temperature of 60 °C, leaching time of 30 min and ratio of raffinate volume to red gypsum mass (L/S) of 3.5:1. The iron in the leaching solution can be recovered by the ammonium jarosite precipitation process. Under the conditions of initial pH of 1.8, multiple of theoretical dosage of ammonium sulfate of 1.3, reaction temperature of 95 °C and reaction time of three hours, a recovery efficiency of iron of 97.64 percent can be reached.

This process not only realizes the harmless treatment of acidic wastewater and red gypsum but also recovers resources such as titanium, scandium and iron. ■

Selected references

- Wu H, Feng Y, Li H, He S, Bian Z (2019) Red gypsum utilization and acidic wastewater treatment based on metal self-enrichment process. *Sci Total Environ* 691:9–15
- Pang H, Lu R, Zhang T, Lü L, Chen Y, Tang S (2020) Chemical dehydration coupling multi-effect evaporation to treat waste sulfuric acid in titanium dioxide production process. *Chin J Chem Eng* 28:1162–1170
- Peng X, Zheng J, Liu Q, Hu Q, Sun X, Li J, Liu W, Lin Z (2021) Efficient removal of iron from red gypsum via synergistic regulation of gypsum phase transformation and iron speciation. *Sci Total Environ* 791:148319.
- de Beer M, Doucet FJ, Maree JP, Liebenberg L (2015) Synthesis of high-purity precipitated calcium carbonate during the process of recovery of elemental sulphur from gypsum waste, *Waste Manage* 46:619–627

Computational fluid dynamics modeling of a methane gas explosion in a full-scale, underground longwall coal mine

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Full-text paper:

Mining, Metallurgy & Exploration (2022) 39:897–916, <https://doi.org/10.1007/s42461-022-00587-z>

Keywords: Longwall, Coal mining, Computational fluid dynamics, Ventilation, Methane explosion

Special Extended Abstract

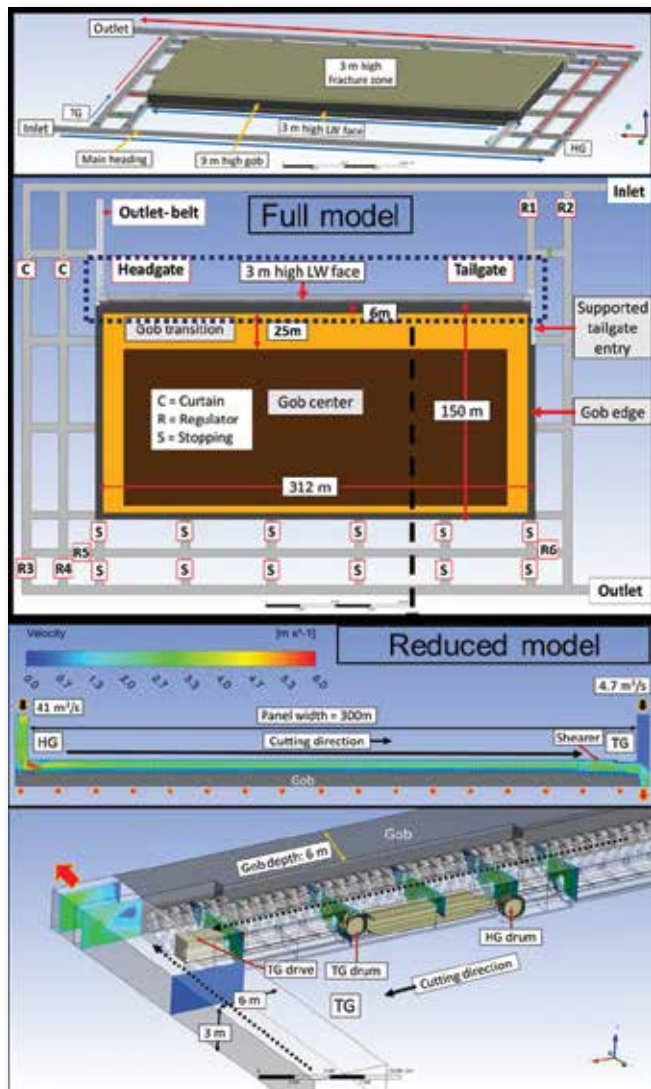


Fig. 1 Longwall bleeder model geometry (top) and flow distribution in the longwall face (bottom).

Methane gas explosions are a major risk in underground coal mining operations. The severity of such explosions can range from local area damage to massive loss of miners' lives along with significant damage to mine infrastructure and ventilation controls that may lead to mine closure and loss of the entire operation. This study demonstrates the viability of integrating a computational fluid dynamics (CFD) combustion model into a longwall mine ventilation model to simulate methane gas explosions in the longwall face area. The resulting 3D methane gas explosion simulation can provide better understanding of the fundamental physics and the potential impact of an explosion in an underground longwall coal mine.

Introduction

CFD modeling can be used to analyze airflow patterns and hazardous gas mixtures formation in the longwall face. Full integration of a CFD combustion model into a full-scale longwall ventilation model is difficult due to computational time and resource requirements. This study demonstrates the viability of modeling a methane gas explosion in a full-scale longwall face model, and the capability of predicting the impact of an explosion, by reducing the model coverage to only include the area of interest and utilizing data interpolation. An improved understanding of methane gas explosions will aid in developing more reliable methane monitoring practices and explosion mitigation strategies to improve safety in longwall coal mining operations.

Modeling methods

ANSYS Fluent version 18.2 was used for the CFD simulations. First, a bleeder ventilation model was modeled, consisting of a single longwall panel and its surrounding bleeder entries. To simulate ignition and methane flame propagation in the longwall face area, the model was then reduced to only contain the longwall face, a portion of the gob behind the shields, and a portion of the headgate and tailgate bleeder entries. To maintain computational accuracy, pressure profiles obtained from the full-scale, steady-state bleeder model were used as boundary conditions. Limiting the model to this smaller section of the mine al-

lows for improved cell allocation by refining the mesh around the simulated ignition location.

The modeled longwall face includes a simplified model of 152 shields support, longwall shearer and other support components such the armored face conveyor (AFC), headgate and tailgate drives, and face curtain. To simulate the airflow interaction between the longwall face and the gob, each shield includes a 0.28-m² opening on the back of the shield. The gob is modeled as a porous medium and divided into three zones with different porosities ranging from 40 percent to 14 percent, and viscous resistances, calculated as the inverse of permeability, ranging from $1.5 \times 10^5 \text{ m}^{-2}$ to $5.0 \times 10^6 \text{ m}^{-2}$, based on findings by Marts et al. [1]. Figure 1 shows the full bleeder ventilation model and the resulting reduced ventilation model, along with the simulation result showing airflow distribution inside the longwall face.

For the chosen bleeder ventilation setup, the tailgate corner provides a back return where the return air is coursed through the first crosscut inby the tailgate. The shearer is located close to the tailgate corner, between shield number 140 and 146, and cutting toward the tailgate. Fresh air enters the longwall face from the headgate side at a rate of 41 m³/s. Some of this face air leaks into the gob, leaving only 16 m³/s of airflow by the time it reaches the tailgate corner. The tailgate entries outby the face is set to supply 4.7 m³/s of fresh air.

In this study, only methane emanating from uncut coal face is simulated. The uncut coal is modeled as a porous medium with thickness of 20 cm. The source term method is used to supply pure methane gas, simulating methane flowing from the cleats in the uncut coal around the shearer drums. Coal face methane inflow was 0.14 m³/s.

After steady-state simulation of the ventilation conditions, the model settings are changed to simulate a transient combustion event. In this scenario, an ignition occurs at the coal face, near the roof, while the tailgate drum is cutting the coal face. Ignition was initiated using ANSYS Fluent Spark Model version 18.2 with spark duration of 1 ms, spark kernel radius of 2 cm, ignition energy of 60 mJ and the laminar flame speed model.

Modeling results and discussion

Figure 2 shows the simulation results. The snapshot at 40 ms shows that the overpressure from the explosion is sufficient to divert face airflow into the gob area where it can mix with additional available methane, creating new or expanding explosive mixtures inside the gob area. Diverting the flow from the shearer drums also reduces the available fresh air to dilute the methane around the drums, potentially creating an environment that can lead to secondary explosions. The snapshot at 60 ms shows that the supplied fresh air is no longer reaching the tailgate corner of the longwall face.

Conclusions and future work

This modeling effort successfully demonstrates the viability of integrating a methane combustion model into a full-scale, 3D longwall bleeder ventilation CFD model. From these results, we conclude that even small ignitions can ini-

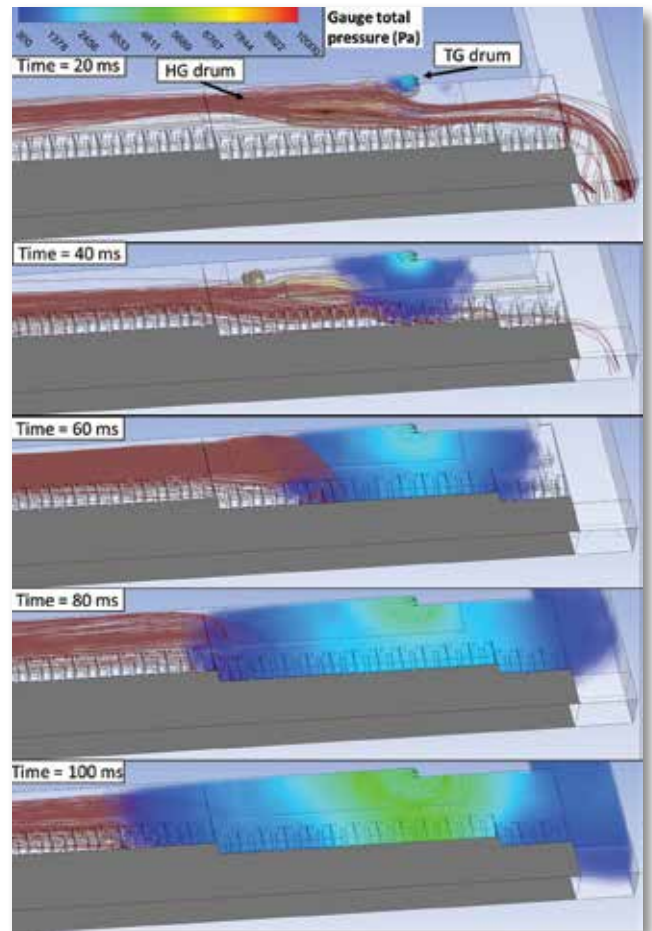


Fig. 2 Volume rendering of gauge total pressure showing explosion overpressure shifting the airflow (brown streamlines) in the longwall face for 0.14 m³/s methane inflow from the coal face.

tiate major explosions underground. The pressure from an explosion can divert airflow away from the face and tailgate, creating more explosive mixtures near the face or potentially transition into coal dust explosions.

Three-dimensional, full-scale CFD modeling can provide a better understanding of the fundamental physics and the potential impact of an explosion in an underground longwall coal mine. Expanding this study has potential for future research, including:

- Expansion and impact of methane explosions for different ventilation scenarios and ignition locations.
- Evaluation of explosion prevention and mitigation strategies, including explosion barriers.
- Improvements in ventilation layout.
- Structural design of ventilation control, such as mine seals. ■

Selected reference

1. Marts JA, Gilmore RC, Brune JF, Bogin Jr GE, Grubb JW, Saki, SA (2014) Dynamic gob response and reservoir properties for active longwall coal mines. Trans Soc Min Metall Explo 2015 Englewood, CO 336:129–136

The effect of trapped fumes on clearance time in underground development blasting

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Full-text paper:

Mining, Metallurgy & Exploration, <https://doi.org/10.1007/s42461-022-00618-9>

Keywords: Auxiliary ventilation, Underground development blasting, Blast fumes, Computational fluid dynamics

Special Extended Abstract

The amount of toxic fumes produced during blasting operation depends on the types of explosives used, product formulation, degree of confinement, conditions of use, and reactivity of the explosives with the host rock. Ammonium nitrate and fuel oil (ANFO) is still the explosive of choice due to its lower price and ease of use/loading. If not properly monitored and controlled, toxic fumes produced from blasting operations can have serious health hazards [1]. This paper presents a novel technique developed to track trapped fumes during a development blasting.

Introduction

Since 1998, there have been 18 documented carbon monoxide (CO) migration incidents from blasting sites in the United States and Canada, and 39 suspected or medically verified cases of CO poisoning. In 2013, at Revenue-Virginus Mine in Colorado in the United States, 20 miners were exposed to CO, including two fatalities [2].

A poor procedure of determining clearance dilution time or re-entry may cause health hazards and increase production delays. Moreover, ventilating the working area to keep the pollutant concentrations below the threshold limit values (TLVs) does not guarantee the elimination of toxic fumes, as 60 to 70 percent of the fumes can remain trapped in the muckpile [3-4].

Previous studies suggest that the porosity of the blasted rocks can range from 30 to 40 percent [5]. The trapped fumes are released slowly, and when disturbed during the digging and transportation of the muckpile high concentrations are released, presenting a possible risk to the miners. The post-blast dilution times must be accurately estimated to minimize problems associated with inadequate or excessive ventilation.

To date, several CFD simulation models have been developed to study the auxiliary ventilation system in a development heading. However, none of the models have considered the effect of the porous medium on the re-entry time. This paper presents a novel technique developed to track trapped fumes during a development blasting. A finite volume method is applied for the numerical solution of the governing differential equations in CFD.

Methods

Three different scenarios are considered for the CFD study to understand the effect of trapped fumes in the muckpile. Scenario 1 is a case with no muckpile, used as a reference/test case to compare the effect of muckpile volume on gas emissions in the drift. Scenario 2 is a case with a nonporous muckpile, the objective of which is to see how

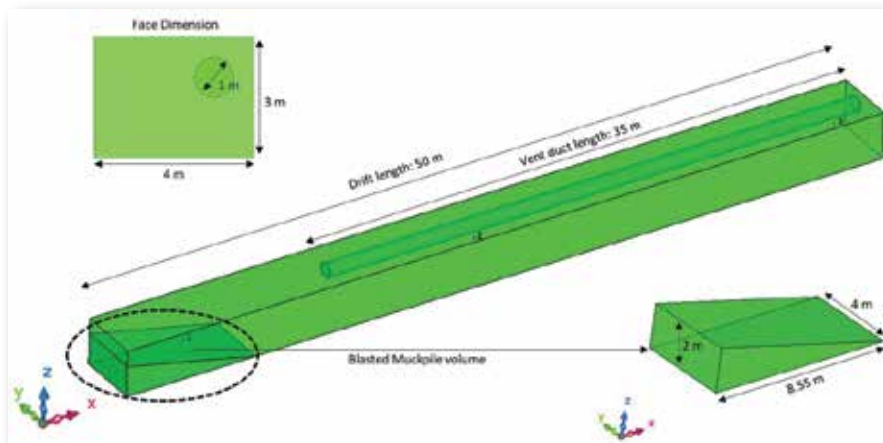


Fig. 1 Drift and muckpile design.

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the physical presence of the muckpile volume affects the dilution times. Scenario 3 is a case with a porous muckpile, representing a condition where a significant part of the blast fumes is trapped in the muckpile after a development blast.

The geometry model with drift dimensions of 4 m wide and 3 m high is considered. The total length of the drift is 50 m. The vent duct is 1 m in diameter and 35 m long, while the muckpile is 2 m high, 8.55 m long and 4 m wide with a volume of 34.2 m³, as shown in Fig. 1.

Results and discussion

Three points were selected to analyze gas concentrations and flow parameters in the computational domain.

Point 1 is located near the face (at a distance of 5 m in the *x*-direction, 2 m in the *y*-direction and 1.5 m in *z*-direction from the origin (0, 0, 0)), point 2 is located halfway through the drift (at a distance of 25 m in the *x*-direction, 2 m in the *y*-direction and 1.5 m in the *z*-direction from the origin), and point 3 is located near the end of the drift (at a distance of 49 m in the *x*-direction, 2 m in the *y*-direction and 1.5 m in the *z*-direction from the origin), as shown in Fig. 1.

Figure 2 shows a sudden increase in the concentration of CO and nitrogen dioxide (NO₂) to the maximum level in scenario 3 at point 1, due to the sudden generation of the gases during the blasting operation. It quickly reaches the highest concentration and then starts to diminish due to mixing with the fresh air blown into the working face through the vent duct. Gas concentrations at points 2 and 3 follow similar trends. The time lag between the highest concentrations at points 1, 2 and 3 is due to the time taken by the fumes to travel through the drift.

Scenario 1, the case without muckpile volume and the method used by previous researchers, attained TLVs at 265 seconds, while scenario 2, the case with nonporous muckpile volume, attained TLVs at 229 seconds and scenario 3, the case with porous muckpile volume that represents a real-world environment, attained TLVs at 583 seconds (Table 1).

Conclusion

Previous studies on blast fume clearance and workplace re-entry time did not consider the toxic gases trapped in the muckpile. Fumes can be released at higher concentrations during the digging and transportation of a muckpile, posing a possible health risk to the miners. To minimize problems associated with inadequate or excessive ventilation, it is essential that the post-blast dilution times be accurately estimated. The times required to reach the TLVs for CO and

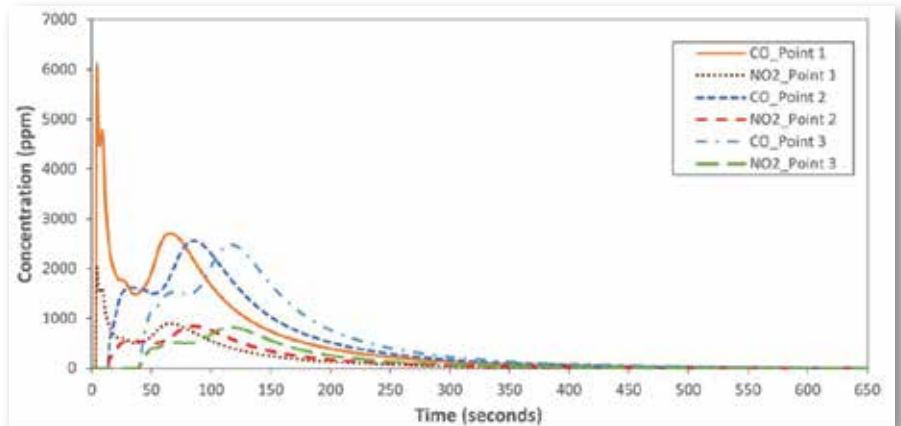


Fig. 2 Concentration versus time.

Table 1 — Time required to attain TLVs for scenario 1 (S1), scenario 2 (S2) and scenario 3 (S3).

Point (scenario)	Time (s) to attain TLV (50 ppm) for CO	Time (s) to attain TLV (5 ppm) for NO ₂
1 (S1, S2, S3)	179, 148, 394	214, 176, 530
2 (S1, S2, S3)	197, 167, 418	231, 194, 555
3 (S1, S2, S3)	230, 202, 447	265, 229, 583

NO₂ are compared for three different scenarios. The difference between scenarios 1 and 3 shows that the trapped fumes can significantly affect the dilution time. Therefore, the trapped fumes should not be overlooked when estimating blast fume dispersion and clearance in the underground mine.

This study builds on the experimental work conducted by previous researchers and investigates the blast fume dilution using a numerical simulation approach (computational fluid dynamics, CFD). Given the uncertainties associated with the simulation studies, particularly in representing the exact field conditions, we recommend using a factor of safety in the re-entry times presented in this paper. ■

Selected references

- Bakke B, Ulvestad B, Stewart P et al. (2001) Effects of blasting fumes on exposure and short-term lung function changes in tunnel construction workers. *Scand J Work Environ Health* 27:250–257
- MSHA (2013) Final Report - Fatality #16 & #17- November 17, 2013
- De Souza EM, Katsabanis P (1990) On the prediction of blasting toxic fumes and dilution ventilation. *Min Sci Technol*
- Taylor KR (2015) Small scale study of the role of the muckpile in the blasting fumes of commercial explosives
- Johansson D (2008) Fragmentation and waste rock compaction in small-scale confined blasting. Luleå University of Technology

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Scholarship season at the SME Foundation begins September 1

by Lorie Lassieg, SME Foundation Coordinator

Each year the SME Foundation offers multiple scholarships to SME student members who demonstrate a desire for a career in the minerals industry. The SME Foundation prides itself on helping SME students reach their educational and career goals. During the MINEXCHANGE 2022 SME Annual Conference & Expo in Salt Lake City, UT, the SME Foundation awarded 17 scholarships totaling \$68,500. All available SMEF scholarships are listed below:

- **MMSA/SMEF Presidential Scholarship:** The Mining and Metallurgical Society of America and the SME Foundation offer one or more significant scholarships on an annual basis to outstanding students whose study program encompasses any aspect of the extractive minerals industry. Up to \$4,000 in scholarships may be awarded.
- **Syd S. and Felicia F. Peng Ground Control in Mining Scholarship:** An undergraduate and/or graduate scholarship(s) is awarded annually to encourage the development of ground-control engineers and to promote the science of ground control. Up to five \$5,000 scholarships may be given.
- **The Raja V. and Geetha V. Ramani Graduate Students Award:** Provides support for one or more outstanding graduate students pursuing an M.S. or a Ph.D. degree in their thesis writing (Ramani Thesis Writing Award) or travel to the SME annual conference to present papers based on their thesis (Ramani Travel Award). Nominees must be enrolled in a graduate study program in mining, mineral processing, geological engineering or other similar engineering fields at the time of nomination and be a student member of SME. The Thesis Writing Award recipient will receive \$4,500 (including up to \$3,000 in travel expenses). The Travel Award recipient

will receive \$3,000.

- **Stantec/McIntosh Engineering Scholarship:** Awarded annually to promising undergraduate students entering their junior year of an accredited undergraduate degree program in mining engineering with a focus on underground mining. This is a renewable scholarship with total potential funding of \$12,000 per student: \$5,000 for junior year and, subject to renewal approval, an additional \$7,000 for senior year.
- **J.H. Fletcher & Co. Underground Mining Scholarship:** Awarded annually to one or more students pursuing an undergraduate degree in mining or minerals engineering, with a desire to use their skills to apply technology to improve safety and productivity in underground mining. Up to two \$2,500 scholarships may be given to deserving students. J.H. Fletcher & Co. Underground Mining scholarship recipients are eligible for a second year of funding; please refer to the scholarship guidelines and procedures for further information.
- **Ernest K. Lehmann Memorial Scholarship:** Established in 2014 by the Ernest and Sarah Lehmann Family Fund of the Saint Paul & Minnesota Foundations in memory of Ernest K. Lehmann. Up to two Lehmann scholarships may be awarded annually at a minimum of \$1,500 each to one or more students pursuing an undergraduate degree in geology or geological sciences. Lehmann Scholarship recipients are also eligible for a second year of funding as noted in the scholarship guidelines and procedures.
- **George V. Weisdack Memorial Scholarship:** Awarded to promising college students to continue their education in mining engineering, mineral engineering and mineral, ore and coal processing. Although preference will be given

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 Edinson Esteban Alcantara Aguilar, San Pablo, Peru
 Juan Alvarado, Lima, Peru
 Helen Kassandra Alvarez Farfan, Cusco, Peru
 Luis Vela Arellano, Lima, Peru
 Byram Stalin Berru Quizhpe, Loja, Ecuador
 Gunjan Bhattarai, Frisco, TX
 Stephane Bilodeau, Rosemere, QC Canada
 Conrad Boley, Muenchen, Germany
 Nichole Boulton, Markham, ON Canada
 Spencer Cameron, Colorado Springs, CO
 Anthony Jerson Canari Tovar, Huancayo, Peru
 Francesco Candia, Rural Hall, NC
 Norka Antonela Carazas Serrano, Cusco, Peru
 Kevin Cargill, Sterling, VA
 Justin Carl, Alexandria, VA
 Nat Carll, Aliquippa, PA
 Jhon Wilfredo Choque Puma, Arequipa, Peru

Alexandre Cochenne, Virginia Beach, VA
 Valerio Colonna, Hillside, NJ
 Jairo Manuel Condori Escalante, Cuzco, Peru
 Charles Conlon, Cary, IL
 Leonardo David Correa Vinas, Loja, Ecuador
 Abner DaSilva, Omaha, NE
 Emanuele Davitti, Charlestown, MA
 Jose Carlos Tong Ladron DeGuevara, Arequipa, Peru
 Brian Delfino, Mt Pleasant, SC
 Jeffery Dingle, Norcross, GA
 Thomas Egan, San Francisco, CA
 Sean Enright, Farmington, UT
 Fabrizio Fara, Seattle, WA
 William Fischer, Brewster, MA
 Tracy Foran, Buford, GA
 Tom Fuerst, Westlake, OH
 James Hurley Gammon, Glendale, CA
 Chase M Gleason, Royersford, PA

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Calling all students; Get ready for the 2022-2023 Metallic Design Competition

by Nick Gow, MPD Executive Committee, and Deniz Talan, West Virginia University

Thank you to the 23 teams who participated in the second annual SME Metallic Design Competition, sponsored by Rio Tinto, and congratulations to the six teams (listed below in no specific order) who made their way to the second phase held March 2, 2022, at the MINEXCHANGE 2022 SME Annual Conference & Expo in Salt Lake City, UT, and competed in the “live” presentations portion:

- Universidad Nacional De Ingeniera — MM UNI Mining Consultants.
- University of Arizona — Los Gatos Consulting.
- University of Arizona — Stonecrushers Consulting.
- Universidad Nacional Mayor De San Marcos — Global Mining.
- National University of San Agustin of Arequipa — QHUYA TEAM UNSA.
- University of Kentucky — Team Kentucky.

The University of Kentucky team of Zachary Wedding, Chris Dewalt, Kyle Ressler, Cassidy Crouch, Anthonie Meador and Elliot Morgan, led by Prof. John Silva, have thrown down the gauntlet and challenged everyone as the 2021-2022 winners.

The SME Metallic Design Competition evolves each year, bringing different deposit types to the table. When the competition was first held in 2020, it involved a copper-gold deposit; later, in 2021, it was a lithium-boron deposit. The 2022-2023 competition will continue bringing a new challenge and twists. For those of you who are interested or have the influence to pull together a team, the competition is geared toward evaluating a hard-rock mineral deposit and developing an economically viable process flowsheet. This competition is designed as a cross-disciplinary adventure for teams to simulate project work revolving around mine planning, metallurgical processing, cost estimation, and environmental, social and governance considerations.

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Teams may consist of up to six undergraduate students with valid SME memberships from any program on campus, including but not limited to mining, chemical, metallurgical, geological, geotechnical engineering and any related sciences. Each participating team will have access to competition software and training, which have in the past included Cost Mine, Metsim and HxGN MinePlan. In the first phase of the competition, each team member is allowed up to 25 hours over a 21-day period to provide a full design report with the data provided. The submitted report is reviewed by multiple well-respected industry experts who will provide comments and feedback.

The top six teams will then be asked to participate in an in-person, two-day event at the MINEXCHANGE 2023 SME Annual Conference & Expo in Denver, CO. In the second phase, each team is provided with additional information to elaborate on their initial design and then asked to present to a live panel of judges where they will be judged based on their presentation skills, their ability to answer questions and, of course, their technical response to the challenge posed.

Team registrations will begin in early October, so watch out for the emails and announcements.

You can send emails about your intent to register early to either Mona Vandervoort at vandervoort@smenet.org or Nick Gow at ngow@forteanalytical.com. For more information, please visit the competition website at <https://www.smenet.org/Professional-Development/Awards-Competitions/METALLIC-Student-Design-Competition>. We look forward to all teams joining and seeing who can come out on top of this year's challenge. ■

Upcoming SME Events

2022 SME THRIVE Conference
Sept. 22, 2022
Reno, NV

SME Arizona Conference
Dec. 4-5, 2022
Tucson, AZ

MINEXCHANGE 2023 SME Annual Conference & Expo
Feb. 26-Mar. 1, 2023
Denver, CO

For additional information, contact: Meetings Dept., SME
Phone 800-763-3132 • 303-948-4200 • Fax 303-979-3461 • email sme@smenet.org • www.smenet.org

I graduated from college ... now what?

by Kathleen Tew and Emily Rose

Have you recently graduated and found it challenging to gain better connection, value and involvement with SME? Society involvement during college or directly after graduation is crucial for networking and mentorship opportunities. Society engagement allows you to connect with professional chapters locally, regionally and globally.

Student chapter involvement provides access to networking opportunities, industry mentors, job opportunities, scholarships, student competitions and the opportunity at leadership during your college years. Integrating into SME after graduation can be challenging, especially if you attended a university that did not have an on-campus student chapter. After graduating, feeling lost, or that you no longer need a society membership are normal thoughts to have. We're here to give insight into what Society life is like after you graduate.

Like the first year of a student membership, your first year of professional membership is free. This allows a smooth transition from your student life into your professional career, giving you the same benefits but with more career advancement and development opportunities. Post-graduate memberships get you access to the Professional Engineer exam study courses, the Certified Mine Safety Professional courses, short courses and learning about cutting-edge technology that may be relevant to your job. Involvement on the international, national and/or local levels provides key industry connections benefiting you and the Society.

As younger and actively engaged members of SME, Emily Rose and Kathleen Tew recommend the following for how to stay involved post-graduation:

- Find ways to attend the MINEXCHANGE SME annual conference through your current employer by submitting an abstract for a project you are currently working on. In our experience, companies tend to support a technical paper presentation more than simply the desire to attend. Continued involvement in the technical programming at the annual conference is a great way to get noticed and to become more involved in the Society. As you become more involved it becomes easier to justify your attendance at the conference.
- Save all the business cards and connections you collect. Write the date and a detail about the

conversation on the back of the cards and store them in a binder. You have a higher chance of remembering the interaction the next time you connect with that person. This is a great tool — especially when you only see someone once or twice a year.

- Take some time to learn about the structure of SME. It is organized into eight divisions (Mining & Exploration, Coal & Energy, Industrial Minerals & Aggregates, Health & Safety, Environmental, Mineral & Metallurgical Processing, Underground Construction, and WAAIME). You select your division when signing up for membership and your division should reflect your career objectives. Within your division, you will find opportunities for involvement and make valuable connections. Divisions are responsible for the technical programming and luncheons at the annual conference. Several of the divisions also now host virtual coffee-break meetings, and these can be a great way to learn more about the organization.
- Attend the business meeting and luncheon for your division during the annual conference. Sign up to be added to the division email distribution list. Adding your name to this list means you will receive information on what the division and committees are involved in and opportunities to get involved. Participating in this meeting, the luncheon and the technical program are some of the best ways to show your eagerness to be involved in your division.
- Apply to be a part of the Young Leaders Committee (YLC). The YLC is active within every division and committee in SME. It is open to all SME members who have a bachelor's degree and are under the age of 40 at the time of applying. Tew served as a previous chair of the YLC and now serves on the board of the SME Foundation — the youngest member of the Foundation Board. Dedication to the YLC and SME as an organization helper helped her successfully be nominated to the board.
- Try to become active at some level: locally, nationally or globally. This will allow you to connect with members in your area, across the nation or across the globe, and find individuals to build your own support network.

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The MINEXCHANGE SME Annual Conference & Expo can appear glamorous or overwhelming (depending on your introverted or extroverted personality), but the benefits of attendance and lifelong connections last well beyond your first industry position. If your university

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SME Environmental Division

Outstanding poster contest award

by Julie Neilson, University of Arizona

The SME Environmental Division would like to congratulate the poster award winners from the Environmental Division poster session at the MINEXCHANGE 2022 SME Annual Conference & Expo in Salt Lake City, UT. Ten graduate and undergraduate students participated in the poster session. All of the posters were interesting and well presented. We encourage more students to participate in the Environmental Division poster session at the MINEXCHANGE 2023 SME Annual Conference & Expo.

The first-place award for \$1,000 was presented to Younes Shekarian from Penn State for the poster: Precipitation of Co-Mn from Low Concentration Solutions using Various Ligands and A Chemical-Free Process.

Second place was awarded to Elham Rahimi, who is also from Penn State, for the poster: Bio-conversion of Coal to Produce Energy and Carbon Sequestration as a Potential

Solution for Climate Change. The second-place award was \$500.

Third place was awarded to Saeede Kadivar from the University of Nevada, Reno for the poster: Assessing the Environmental Footprints of Critical Metals Recovery from Spent Li-ion Batteries using Biohydrometallurgical Processes. Third place was awarded \$250.

Congratulations to the three Environmental Division poster award winners. ■

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SMEF scholarships

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to a University of Pittsburgh student, candidates from any university will be considered. One scholarship will be awarded at a minimum of \$2,000. All eligible George V. Weisdack Memorial Scholarship recipients may apply for a second year of funding as detailed in the scholarship guidelines and procedures.

The SME Foundation scholarships will open for applications Sept. 1, 2022, with a deadline of Oct. 15, 2022. Applications that do not meet minimum qualifications or requirements will not be considered. All applications are to be submitted online. For full details and specific scholarship requirements, visit <https://www.smenet.org/scholarships>. ■

New Members

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Tania Gomez, Santiago, Chile
Juan Andrés Guapi Cabeza, Guayaquil, Ecuador
Roger Hafenschere, Wien, Austria
Brian Hamilton, Philadelphia, PA
Troy Helming, Richmond, CA
Marcelo Henriquez, Las Condes, Chile
Elizabeth A. Holm, Pittsburgh, PA
Rony Wilmer Huilca Montoya, Cusco, Peru
Hannah Iezzoni, Philadelphia, PA
Adrian Infantes Mamani, Arequipa, Peru
John Jacobs, Birmingham, AL
Alistair James, Calgary, AB Canada
Vijay Jeyakrishnan, New York, NY
Luis Alberto Kankeri Morales, Arequipa, Peru
Bradley Krumel, Gretna, NE
Carlos Lang, Fairview Park, OH
Jhoan Armando Layme Crispin, Cusco, Peru
Brandon Lucia, Helendale, CA
Jose J Machaca Condori, Arequipa, Peru
Jim Mahoney, Houston, TX
Jose Maldonado, Guayaquil, Ecuador
Yash Mandhana, Buffalo, NY
Bryan Martucci, Vanderbilt, PA
Frederic Masse, Canonsburg, PA
Connor Maxon, Milwaukee, WI
Shawn McWilliams, Pittsburgh, PA

Kenneth Mebane, Norfolk, VA
Franz Giovani Memdoza Guerra, San Jeronimo De Tunan, Peru
Domenica Salome Mendieta Cueva, Loja, Ecuador
Bhaumik Merchant, New York, NY
Keith Merl, Houston, TX
Joshua Miranda, El Paso, TX
Janaide Fita Mounouna, Sudbury, ON Canada
Andrew Nichols, Huntington, WV
Tim O'Connor, Woodbury, MN
Javier Olivares, Flushing, NY
Laura Ouvrier, Lattes, France
Emmanuel Yaw Owusu-Fordjour, Salt Lake City, UT
Alvaro Padilla, Hermosillo, Son Mexico
Jonathan Alejandro Palacios Paccha, Loja, Ecuador
Jhordan Ivan Panez Meza, Huancayo, Peru
Brice Philippe, Oakville, ON Canada
Steve Pinault, Baltimore, MD
Danny Jayo Quellcca Carrasco, Cusco, Peru
Roy Washington Quispe Huarcha, Cusco, Peru
Ali Rader, Omaha, NE
Andy Leonardo Robles Riofrio, Quito, Ecuador
Carlos Rojas Cahuaya, Arequipa, Peru
Nadia Cecibel Romero Medina, Yantzaza, Ecuador

Gerald Rosario, Naperville, IL
McKinley Ross, Norfolk, VA
Victor Silverio Salazar Julca, Cajamarca, Peru
Darlene Schuster, New York, NY
Daniel Slane, Duluth, MN
Zachary Spera, Westford, MA
Christian Stoddard, Superior, AZ
Daniel Trask, Houston, TX
Yamile Aidee Urquidí Cerros, El Paso, TX
Edson Miguel Villanueva Carpio, Cusco, Peru
Stefania Vittuari, Singapore, Singapore
Christian Vivas, Kalgoorlie, WA Australia
Ryan Whaley, Auburn, AL
Molina Gaspar Xina Mafer, Huancayo, Peru
Frank Eduardo Ysla Quiroz, San Pedro De Lloc, Peru
Carlos Fernando Zhumi Pandiguana, Loja, Ecuador

Necrology

date elected name and city

2008 Dr. Corneille S. Ek **
Liege, Belgium

**** Legion of Honor**

Progressive five-year plan of China's industrial mineral industry

by Leslie M. Watson, chair, and Stuart Sanderson, GPAC consultant

2015–2020 was the period of the 13th National Five-Year Plan in China. The industrial mineral industry in China enjoyed great progress. Its ability in technology innovation, green processes, and low-carbon sustainable development had been significantly enhanced. China became one of the few countries in the world with abundant and all types of industrial mineral resources.

Resources, production and sales. Over the five years, China's proven reserves of 20 major industrial minerals continuously grew, among which crystalline graphite increased 62 percent compared with 2016, while fluorite increased 8.56 percent, and most other minerals also increased. Accordingly, the productions of various key minerals such as crystalline graphite, calcium carbonate, wollastonite, barite, magnesite, kaolin, bentonite and fluorite increased significantly. China became one of the major countries in terms of production, consumption and trade of industrial minerals, with all types of industrial mineral resources.

Although impacted by the COVID-19 pandemic and an increasingly strict environmental protection policy, total revenue of the industry increased from \$96.4 billion in 2016 to \$134 billion in 2020, while total profit increased from \$6.17 billion in 2016 to \$7.45 billion in 2020. Production and sales of deep-processed products and functional mineral materials largely increased.

Locations of mining and processing. China has gradually formed a profile of industrial distribution originated and centered on the mining sites. The major graphite production is in Jixi and Luobei (Heilongjiang) and Pingdu (Shandong); fluorite is concentrated in Lishui (Zhejiang), Shangrao (Jiangxi), and Nanping (Fujian); quartz in Fengyang (Anhui) and Heyuan (Guangdong); barite in Tongren and Tianzhu (Guizhou) and Yongfu (Guangxi); diatomite mainly in Baishan (Jilin) and Shengzhou (Zhejiang); wollastonite in Xinyu (Jiangxi), Lishu (Jilin) and Faku (Liaoning); calcium carbonate in Hezhou (Guangxi), Nanyang (Henan) and Ya'an (Sichuan); kaolin in Maoming (Guangdong), Beihai (Guangxi) and Suzhou (Jiangsu); and bentonite in Jianping (Liaoning) and Ningcheng (Inner Mongolia).

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Table 1

Production and growth rates of major industrial mineral products in China, 2016–2020 (thousand metric tons).

Product	2016	2020	CAGR (%)
Crystalline graphite	600	920	11.3
Fluorite	4,200	5,000	4.5
Calcium carbonate	30,000	67,000	22.2
Feldspar	2,000	3,000	10.7
Magnesite	13,800	17,000	5.4
Kaolin	4,800	8,000	13.6
Talc	1,900	1,800	–1.3
Bentonite	5,800	8,000	8.4
Wollastonite	530	800	10.8
Natural gypsum	28,000	25,000	–2.8
Barite	1,500	3,500	23.6
Asbestos	190	200	1.3
Diatomite	350	380	2.1

Optimization of industrial structure. During the period, the output and value of mining and processing showed a downward trend, though those of deep-processed mineral products increased rapidly. The degree of industrial concentration was improved, while the industrial structure was continuously optimized.

Driven by market demands of agriculture, biomedicine, environmental remediation, new energy, electronic information and green building materials, those industrial minerals with deep-processed and functional utilizations were continuously developed and applied, such as in functional fillers, soil conditioners, mineral fertilizers and battery materials. Statistics showed the revenue of deep-processing products of major industrial minerals had been close to 60 percent.

Industrial minerals and their functional products were favored by the capital investors. More and more enterprises are actively planning to be listed in the capital market.

Technological innovation. The industry was greatly enhanced by the emerging scientific findings and technological innovations with continuously increased innovation platforms and centers. Technological innovation has become the driving force of the sustainable development of the industry. A number of leader enterprises in industrial minerals established their own research centers, which significantly improved the innovation capacity. A series of new technologies were well developed such as high-performance mineral

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A call to action from the Minerals Education Coalition

by Wendi Cooksey, Minerals Education Coalition Chair

Rocks in Oreos? Minerals in houses? Transition metals in medicine? More copper for green energy? Those of us in the industry shrug, and say “of course,” but the public is often surprised how heavily we rely on mining for the important items in our life.

How do we change public perception about the mining industry? We have an obligation to bridge the disconnect between the everyday things consumers need and the vital role played by the minerals industry. As we all know without mining, there would be no smart phones, there would be no electric vehicles, there would be no electricity grid, and, critically, there would be no green energy future. This is your call to action.

The SME Foundation’s vision is to inspire the next generation to meet the needs of a mineral-dependent future for a better world by focusing on outreach, education and fundraising. The Minerals Education Coalition (MEC) is a committee under the SME Foundation supporting this mission. These first few months as chair of the MEC have been extremely gratifying. Our work continues on the Move Mining improvement, Move Mining NextGen, BSA scouting Jamboree and mining merit badge training, the National Science Teacher conferences, Earth Science Week, and collaborating with other SME education groups.

One of the MEC’s goals this year is to have a stronger presence in primary and secondary classrooms by setting up a speaker’s program. This is where you come in. We encourage our SME members to get into a classroom and share the story of our industry. We are creating a program to supply tools helpful in giving mineral presentations. These presentations will teach and engage the students with hands-on rock samples, while also helping teachers meet science standards set out by their school districts. Our schoolteachers are often overwhelmed by the material that must be covered throughout the year and we can help with their science curriculum by having a mineral professional visit their class. The ready-to-use presentation resources will focus on four age groups; kindergarten to 2nd grade, 3rd to 5th grade, 6th to 8th grade, and high school.

The presentations will also encourage the bright young students to consider a career in our industry. We have a great SME community with vast experiences to share with young students. They can learn about blasting, opportunities to fly drones, apply their Minecraft ability, be on the forefront of environmental science, work on climate challenges, travel the world and much more.

The long-term goals of showing this global outreach program will be a greater public understanding of mineral uses, an improved belief of mining, and getting K-12 students interested in mining and minerals industry careers. The engagement of SME members is essential for outreach activities in the local communities.

The diverse program group members come with different mining and outreach backgrounds. The group meets twice



MEC volunteers Dan O'Connor and Wendi Cooksey.

monthly, in partnership with the Colorado MEC, developing a pilot project to be implemented in two chosen Colorado public schools (Place Bridge Academy K–8, and Denver South High School 9–12). This initial small-scale program with presentations and pre- and post-student/parent/teacher surveys will allow for immediate feedback, leading to a more successful global program.

Over the past 30 years, I have been making minerals presentations with students happily engaged in classrooms with hands-on activities. Later, getting a pile of notes about their favorite rock or activity always puts a smile on my face. Once I received a special note from a student, saying, “Dear Rock Lady, Thank you for coming to my class and telling me about your job. I want to be a magiclergical engineer when I grow up because it sounds fun and easy. I think I can do it now and I’m only 9 years old. Love, Naomi.”

I admire her confidence, and I hope she follows her dream.

I am grateful that my employer, FLSmidth, recognizes the urgency in reaching students and for their support as we work toward this education goal. FLSmidth provides valued support through mineral sample collections and crushing, mineral kits, the time for committee meetings, National Science Teacher Association conferences, presentations at schools, funding and volunteers for the FLS science festivals.

A heartfelt thank you is extended to the generous donors who support the SME Foundation as well as our committee members. Each of you has positively impacted the mission of the MEC through philanthropy, dedication and hard work, and these efforts are truly appreciated. MEC wants to inspire and motivate you to get into a classroom and make a difference. You have wonderful experiences to share, kids want to hear about the minerals needed for nearly every item they have, and the rewarding thank-you notes are a treasure. ■

James F. Kvitkovich

James F. Kvitkovich, 72, of Greensburg, PA, passed away on June 18, 2022 at Oak Hill Health Care, Greensburg. Born Sept. 7, 1949 in Spangler, he was the son of the late Joseph and Mary Ursula (Gueguen) Kvitkovich.

Kvitkovich was a retired mining engineer from John T. Boyd Co., a mining and geological consulting firm.

He is survived by his wife Jacqueline Hite Kvitkovich; brother David Kvitkovich of Northern Cambria and two sisters, Ann Nelson of Alpharetta, GA and Regina Kvitkovich of Fairfax, VA. He is preceded in death by two brothers, John and Stephen Kvitkovich.

An avid reader and learner all his life, Kvitkovich brought curiosity and a keen analytical mind to every task. He enjoyed his travels around the United States and the

world for his work but never lost his taste for the foods he ate while growing up on a small farm in St. Benedict. These qualities and his innate good nature and thoughtfulness made him beloved by his extended family, colleagues and friends.

Kvitkovich was a longtime volunteer for the Pittsburgh Section of SME, spearheading its major annual fundraising project, with much of the funding going for student scholarships.

He and his wife, Jacqueline, were also volunteers for the Salvation Army Greensburg Corps.

In lieu of flowers, the family requests that donations be made to either the scholarship fund of the Pittsburgh Section of SME or to the Hastings Public Library. ■

In The Aggregate

(continued from page 60)

functional fillers, soil modifiers and multifunctional mineral fertilizers. New equipment was developed, such as microwave dissociation devices, large-scale production lines of ultrafine grinding and classification, and large-scale superconducting magnetic separators.

Green mining construction. “Green Mine Construction Specification of Non-metallic Mineral Industry,” drafted by the China Non-metallic Minerals Industry Association (CNMIA), was adapted and issued by the central government to rule the mining activities of industrial minerals across the country. CNMIA also established the “Three Indexes Scheme” (mining recovery rate, process recovery rate, resource utilization rate) for the individual minerals. The completed minerals include gypsum,

wollastonite, bentonite, diatomite, asbestos, talc, magnesite and siliceous materials.

Currently, the main challenges to the industry include:

(1) The production needs to move forward from the low end to the middle-high end of the demand-supply chain. (2) Green mining and manufacturing systems still need to be upgraded. (3) The production capacities of high-performance mineral products are still on a small scale. (4) The innovation capability of the industry-university-research system has yet to fully focus on the bottlenecks and demands of industrial development. (5) International collaborations in technology, production, investment and trade need to be enhanced.

Authors: Tang Jingyan, Guo Jia, Zhang Yang (China Non-Metallic Minerals Industry Association) and Gu Xili (Suzhou Sinoma Design and Research Institute of Non-metallic Minerals Industry Co., Ltd.). ■

Rock in The Box

(continued from page 58)

hosts an event, attending a society alumni night is an easy way to introduce yourself to professionals early in your career. If your university is not hosting one, there are many after-hours events available to attend, such as the “Friends of Minnesota” social. Large gatherings can be intimidating and if you find multiple interactions stressful, SME offers an official mentor program that individuals may join at any time of their career. This program provides an opportunity to be assigned a mentor to connect with one-on-one at the annual conference.

SME has three sections: SME Global, SME Local Sections and SME Student Chapters. Involvement in your local section provides community involvement, help with local scholarships, regional technical programming, and networking opportunities. Local section chapters can

be found on the SME website (<https://www.smenet.org/Membership-Benefits/Sections-and-Chapters>).

SME offers a variety of opportunities for involvement through the divisions, subcommittees, ad-hoc committees, scholarship groups, Mineral Education Coalition (MEC), Foundation and many others. A benefit of the pandemic is that SME now provides many more opportunities to engage with the society virtually. Being involved in SME offers unique leadership opportunities to work with a cross-disciplinary group of people.

Regardless of your interest or your time commitment, SME has a need for volunteers and has a fit for each person. The best thing to do when you don't know how to be involved is to ask an existing SME member and show up to virtual or live events. Events can be found on the SME website (<https://www.smenet.org/Event-Calendar>) or on the SME Community calendar of events (<https://community.smenet.org/events/calendar>). ■

SME and SME Division scholarships awarded during MINEXCHANGE 2022 Annual Conference & Expo

Each year, SME and the SME Foundation offer multiple scholarships to SME student members who demonstrate a desire for and the probability of success in a career in the mining and minerals industry. A list of available scholarships is provided on the SME website, www.smenet.org/students/grants-scholarships. Click on the name of the scholarship to view the full guidelines and application criteria. Questions regarding SME scholarships may be directed to scholarships@smenet.org or by phone to 303-948-4200. All applications are to be submitted online. The application period begins Sept. 1, 2022 and is open until Oct. 15, 2022. For full details and specific scholarship requirements, visit the SME website at www.smenet.org/scholarships.

Robert E. Murray Innovation Scholarship

The Robert E. Murray Scholarship was established in 2017 to encourage undergraduates, graduates and researchers in the academic pursuits in implementing innovation that can change the mining industry through the inclusion or adaptation of cutting-edge technologies and innovative processes.

The winner of the 2022 scholarship is **ISABEL PENALOZA ARAUJO**, University of Nevada Reno.

SME Foundation Scholarships

Ernest K. Lehmann Memorial Scholarship recipients: **MACKENZIE STONE**, West Virginia University.

George V. Weisdack Memorial Scholarship recipient: **CASSIDY CROUCH**, University of Kentucky.

J.H. Fletcher & Co. Underground Mining Scholarship recipients: **REBECCA RAY**, University of Utah; **GABRIELA KOSAKOWSKI**, West Virginia University.

Stantec/MacIntosh Engineering Scholarship recipient: **JAI ANAND**, Indian Institute of Technology (Indian School of Mines), Dhanbad.

MMSA/SMEF Presidential Scholarship recipients: **EMILY STREET**, Michigan Technological University; **VANESSA SALINAS**, New Mexico Institute of Mining and Technology.

Raja V. and Geetha V. Ramani Graduate Students Award recipients: **BEHZAD VAZIRI HASSAS**, Penn State University; **NANA KOBINA AMOAKO AMOAH**, Missouri University of Science and Technology.

Syd S. and Felicia F. Peng Ground Control in Mining Scholarship recipients: **ABDALLAH BASIRU**, University of Alaska Fairbanks; **AKASH CHAURASIA**, Colorado School of Mines; **ANASTASIA XENAKI**, University of Kentucky; **FAUSTIN KUMAH**, New Mexico Institute of Mining and Technology; **PETER KOLAPO**, University of Kentucky; **QINGWEN SHI**, West Virginia University; **ROBIN FLATTERY**, University of Kentucky; **YUN ZHAO**, West Virginia University.

Coal & Energy Division

The Coal & Energy (C&E) Division awarded 14 scholarships in 2022. Some of the scholarship recipients received their scholarship certificates at the division luncheon during the MINEXCHANGE 2022 SME Annual Conference & Expo in Salt Lake City, UT. In addition, the division presented two John Sidney Marshall Memorial Scholarships as well as the Mine Ventilation Scholarship. The Marshall scholarships, formerly presented by AIME, are now administered by the C&E Division.

John Sidney Marshall Memorial Scholarship recipients: **EMILY BALLARD**, University of Utah; **MOHAMMAD ANWAR KARIM**, New Mexico Institute of Mining and Technology.

Mine Ventilation Scholarship recipient: **SIKANDAR AZAM**, Pennsylvania State University.



Coal & Energy Division chair Ryan Murray (l) is pictured with scholarship winner Alison Mertz, C&E Scholarship Committee chair Matthew Gray and scholarship winners Jared Morse, Kelley Anne Severinsen and Emily Ballard.

Coal & Energy Division Scholarship recipients: **ALISON MERTZ**, New Mexico Institute of Mining and Technology; **BAXTER JONES**, Virginia Tech; **JAI ANAND**, Indian Institute Of Technology (Indian School of Mines),

Dhanbad; **JARED MORSE**, West Virginia University; **KELLEY ANNE SEVERINSEN**, University of Utah; **ZUBIN SOOMAR**, University of Arizona.

Environmental Division

Each year, the Environmental Division awards scholarships to promising college students in fields related to mining and the environment. A thoughtful review of all the applications identified four outstanding students to receive scholarship awards.

Veolia Water Technologies Scholarship recipient: **HEATH ORCUTT**, Colorado State University.

Environmental Division Scholarship recipients: **GABRIELA KOSAKOWSKI**, West Virginia University; **ZEYNEP CICEK**, West Virginia University; **JOSEPH BINDNER**, Colorado State University.

Top: Environmental Division Scholarship Chair Heather Halderman (l) is pictured with Gabriela Kosakowski, Zeynep Cicek and Joseph Binder.

Bottom: Heath Orcutt (c) is pictured with Jill Browning and David Oliphant of Veolia.



Industrial Minerals & Aggregates Division

The Industrial Minerals & Aggregates Division (IM&AD) annually awards the Gerald V. Henderson Memorial Scholarships to promising college students who are pursuing degrees in geology, mining engineering or mineral economics with special interest in an industrial minerals and aggregates oriented program. Three students received scholarships at the MINEXCHANGE 2022 SME Annual Conference & Expo.

Gerald V. Henderson Memorial Scholarship

recipients: **EMILY STREET**, Michigan Technological University; **BAXTER JONES**, Virginia Tech.

Stewart Wallace Memorial Scholarship (presented in conjunction with Mining & Exploration Division)

recipient: **MUSTAFA BARIS ATES**, West Virginia University.

Top: Industrial Minerals & Aggregates Division Chair Rusty Winn (r) is pictured with Gerald V. Henderson Memorial Scholarship winner Baxter Jones.

Bottom: Industrial Minerals & Aggregates Division Chair Rusty Winn (r) is pictured with Gerald V. Henderson Memorial Scholarship winner Emily Street.



Mining & Exploration Division

The Mining & Exploration (M&E) Division awards the Eugene P. Pfeleider Memorial Scholarship to students pursuing careers in mining engineering.

In addition, three other scholarships are presented that are administered by the division. The Henry DeWitt Smith Graduate Scholarships (AIME) are awarded to students studying in the mining, metallurgical, materials or petroleum departments of a university in the United States or Canada. The Stewart Wallace Memorial Scholarship (presented with the IM&AD) and the Steven C. Potter Scholarship are awarded to master's degree candidates in exploration geology or geological science.

Steven C. Potter Scholarship

recipient: **CELINE BEAUCAMP**, Montana Technological University.

Eugene P. Pfeleider Memorial Scholarship recipient: **GABRIELA KOSAKOWSKI**, West Virginia University.

Henry DeWitt Smith Graduate Scholarship recipients: **ISABEL PENALOZA ARAUJO**, University of Nevada Reno; **YAMILE ISABEL CASASBUENAS**, Colorado School of Mines.



L to R: Mining & Exploration Division past chair Shaun Graber, scholarship winners Yesh Kumar, Mackenzie Stone, Gabriela Kosakowski, Alison Mertz, Rebecca Ray, Hunter Fowles and Celine Beaucamp, and M&E Division chair Matt Blattman.

Mining & Exploration Division Scholarship recipients: **SHIVENDRA KUMAR ACHARYA**, Indian Institute of Technology (Indian School of Mines), Dhanbad; **YESH KUMAR**, Birsa Institute of Technology; **ALISON MERTZ**, New Mexico Institute of Mining and Technology; **HUNTER FOWLES**, University of Utah; **CASSIDY CROUCH**, University of Kentucky; **REBECCA RAY**, University of Utah; **MACKENZIE STONE**, West Virginia University.

Mineral & Metallurgical Processing Division

The Mineral & Metallurgical Processing Division (MPD) awarded 10 scholarships — the Richard Klimpel

Memorial Scholarship and eight division scholarships — as well as the Rong Yu Wan Ph.D. Dissertation Scholarship in Metallurgical Engineering.

Richard Klimpel Memorial Scholarship recipient: **BAXTER JONES**, Virginia Tech.



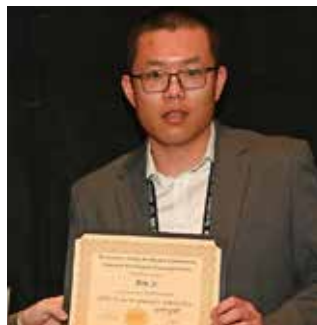
MPD Scholarship Committee Chair York Smith (l) with Richard Klimpel Memorial Scholarship winner Baxter Jones.



MPD Scholarship Committee Chair York Smith (l) with Rong Yu Wan Ph.D. Dissertation Scholarship winner Deniz Talan.



Zeynep Cicek



Bin Ji



Isabel Penaloza Araujo



Mohammad Anwar Karim

Rong Yu Wan Ph.D. Dissertation Scholarship recipient: **DENIZ TALAN**, West Virginia University.

Mineral & Metallurgical Processing Division Scholarship recipients: **COLE KAGEOS**, Virginia Tech; **ZEYNEP CICEK**, West Virginia University; **BIN JI**, Virginia Tech; **ISABEL PENALOZA ARAUJO**, University of Nevada Reno; **YOEL JESUS HUAMANI QUILLUYA**, Universidad Nacional de San Agustín de Arequipa; **JORDAN GILLIS**, Virginia Tech; **SUDESHNA KUNDU**, Indian Institute of Technology (Indian School of Mines), Dhanbad; **MOHAMMAD ANWAR KARIM**, New Mexico Institute of Mining and Technology. ■



Jordan Gillis

MiningMinnesota names Julie Lucas as new executive director

The MiningMinnesota board of directors announced that Julie Lucas will be its new executive director. Lucas will begin her new role on Aug. 1, 2022, replacing outgoing executive director Frank Ongaro, who served MiningMinnesota for 15 years.

“Julie is well positioned to help MiningMinnesota expand the organization’s reach,” said LaTisha Gietzen of PolyMet Mining and president of MiningMinnesota. “She understands the mining industry, the board’s vision for MiningMinnesota’s future, and she is energized to share the story of mining’s importance to a greener and more sustainable future.”

Lucas brings vast industry and community background, knowledge and involvement to MiningMinnesota. She has served as environmental manager and water resources director for several mining and mineral development companies. Lucas also serves as a board member on various regional and community organizations. She is currently on the board of directors for the United Way of Northeast Minnesota, RAMS and the Minnesota Discovery Center. In addition, Lucas was recently elected as a township supervisor in French Township. She earned a master of science degree in water resource science from the University of Minnesota, Duluth.

“Minnesota has an opportunity to lead our nation in providing the critical minerals needed for the transition to clean energy and to address climate change. Minnesota can have both mining and a clean environment, and we can be a model for the rest of the world,” said Lucas. “I

look forward to this tremendous opportunity of leading the organization, its members and the industry into the future.

“Minnesota’s world-class mineral deposits contain 95 percent of the United States’ resource of nickel, and 88 percent of our domestic resource of cobalt.

In addition, for the World Bank Group projects we will need to mine as much copper in the next 25 years as had been mined in the last 5,000 years. Proposed projects have the potential to provide thousands of high-paying jobs and billions of dollars for funding students in Minnesota schools.”

“Julie coming on as the new executive director is exciting for the future of the industry and the association,” Ongaro said. “Her talent, knowledge and experience make Julie the perfect person to lead the trade association in its next chapter of developing this essential industry.” ■



Julie Lucas



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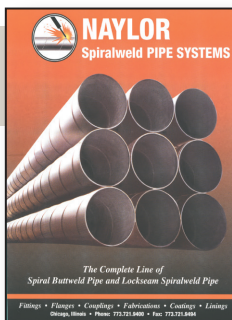
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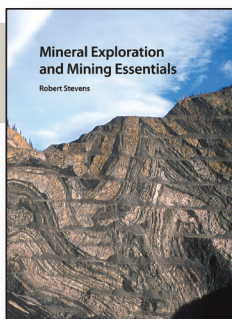
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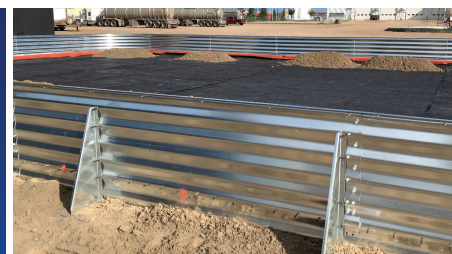
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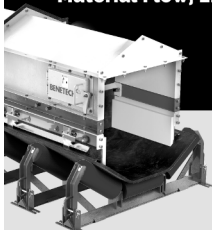
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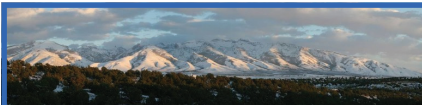


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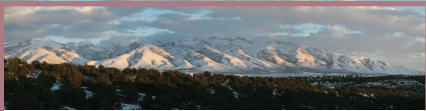
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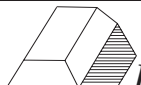
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Innovation could provide a better future for coal



William Gleason
Editor

Just a few yards away from the semi-famous welcome arch that reads “Home of Rock Springs Coal” is a marker that commemorates the site where coal was first mined in Rock Springs, WY in 1868. Between that marker and the train depot that now houses a trendy coffee shop and across the street from a brewpub is another plaque that details how coal mining was the driving economic force in the area until the 1950s, when many of the underground mines were closed. The discovery of trona to the west of Rock Springs followed by the opening of the Black Butte surface

coal mine in the 1970s have kept the town alive.

In the northeastern corner of the state, another coal discovery in the 1970s would have an even larger impact on Wyoming when coal mining began in the Powder River Basin (PRB). With the opening of the North Antelope Rochelle Mine in 1977, the PRB became the largest coal mining region in the world. In 2019, 77.4 Mt (85.3 million st) of coal was sold from the North Antelope Rochelle Mine and the mine produced \$2.3 billion direct and indirect benefits according to Peabody, the owner of the mine.

Coal is clearly crucial to communities like Rock Springs and Gillette, WY. But as we all know, the future of coal does not look as good as its past. In the global efforts to meet climate change goals and reduce carbon emissions on a grand scale, coal has been vilified as a dirty fuel source. Global efforts to move away from fossil fuels to renewable energy have presented challenges for the industry and for the communities that have thrived because of coal.

Recent global events including an uptick in demand after the COVID-19 pandemic and Russia’s invasion of Ukraine have paused some of the rapid transition away from coal. In Germany, for example, coal-fired plants that were scheduled to be retired have once again been put into production. However, this is only temporary, according to German Chancellor Olaf Scholz, who said Germany’s move to bring fossil fuel power plants back onto the grid was only to make up for an expected shortfall because of cuts in natural gas supplies from Russia amid the war in Ukraine.

In the United States, the Energy Information Administration reported that coal production is expected to rise in 2022, but that coal consumption will decline in 2023.

Throughout Wyoming, lawmakers have looked for ways to keep the state’s coal mines in production, including introducing legislation that could slow the shuttering of coal-fired plants. Among these is a plan that would require public utilities to first analyze the cost of retrofitting the coal-fired plants targeted for retirement with carbon capture, use and sequestration (CCUS) technologies. Other measures would require utilities to seek a third-party buyer willing to take on the risks and responsibilities of keeping the facility running.

According to preliminary filings by PacifiCorp and Black Hills Power, the cost of retrofitting a single coal unit with CCUS ranges between \$400 million to \$1 billion, and the cost to the average rate payer in the state could be an additional \$100 month according to a report for *WyoFile*.

With those kinds of challenges and expenses there will need to be some innovative thinking to keep the lights on at the mines.

Last month, I had the pleasure of speaking with Phil Christopherson, the chief executive officer of Energy Capital Economic Development, the group that built the Wyoming Innovation Center (WyIC) in Gillette as well as Scott Quillinan, senior director of research at the University of Wyoming’s Center of Economic Geology Research. Much of these conversations formed the article about the WyIC on page 26. In short, the WyIC was built to support the coal industry in Gillette by providing a research center for those who seek to find alternative uses for coal.

“The idea originated several years ago with the realization that coal is on a down turn and that we need to do something else to support the coal industry,” Christopherson said. While the original intent of the WyIC was to find alternative uses for coal, like bricks or asphalt made from coal, Christopherson told me that in a strange twist of fate, the WyIC might also help the state become a significant contributor of rare earth elements that are vital to the new energy transition.

Working closely with University of Wyoming School of Energy Resources and modeled after the Wyoming Integrated Test Center that is attached to Basin Electric Cooperative’s Dry Fork Station, the newest coal-fired power plant in the nation, the work taking place in Wyoming is the kind of innovative thinking that could potentially create solutions for an industry that helped build and power the nation. ■

THANK YOU!

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Each year, a team of volunteers from SME's **Industrial Minerals & Aggregates Division** pulls together summaries of dozens of industrial minerals commodities for the July issue of *Mining Engineering*. This year the result is an impressive overview of 40 commodities that power the world.

The Editors of *Mining Engineering* would like to thank the committee for its hard work to make this issue possible each year. If you would like to contribute to next year's Industrial Minerals Review or if you would like to join the technical committee, please contact Jim Norman (Jim.Norman@tetratech.com) to inquire about becoming a vice chair or shadow for this effort.

A special thank you goes out to the Industrial Minerals Annual Review editors, James Norman and John Macfadyen, Technical Committee chair, Gaurav Soni, and the many vice chairs and authors of the individual commodity profiles.

Special thanks to:

- Jim Norman, member SME, of Tetra Tech Geo, is the industrial minerals annual review editor.
- John Macfadyen, member SME, retired
- Gauravi Soni, member SME, proposal manager, Metso Outotec, chair of the Industrial Minerals & Aggregates Division's Technical Committee.
- Mike O'Driscoll – wrote Introduction to the IMAD Annual Review Director, INFORMED Industrial Mineral Forums & Research Ltd.
- Himesh Patel, metallurgist/project manager, McClelland Laboratories Inc.
- Riddhika Jain, product manager, Metso Outotec.
- Tushar Gupta, research metallurgist, MP Materials.
- Xihui Yin, senior research scientist, Kemira Chemicals.
- Steven Fortier and his staff at the USGS National Minerals Information Center who supplied many of the reviews for this issue.

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