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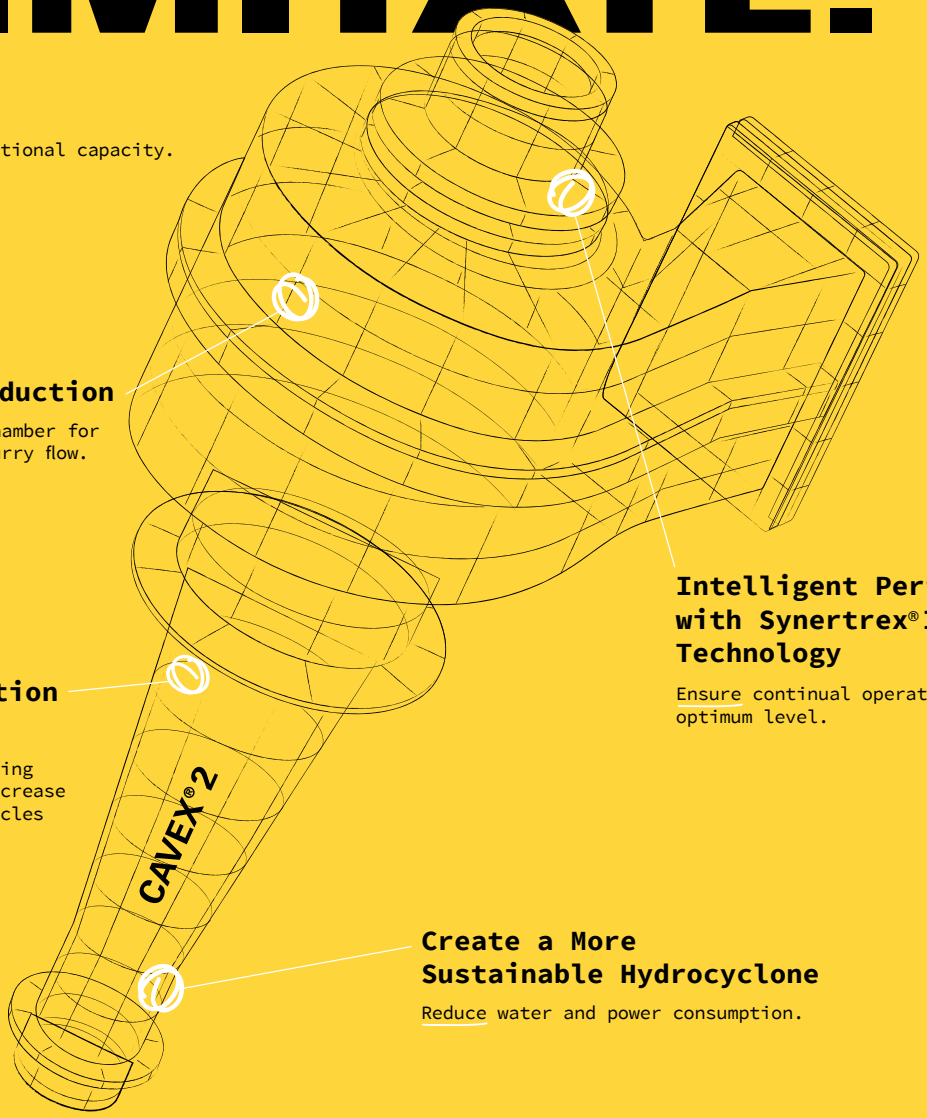


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## Cover

Industrial minerals are the building blocks of the world economy and essential to everyday life, even if they are largely overlooked and often misunderstood. In this issue, SME's Industrial Minerals & Aggregates Division provides summaries of 38 industrial minerals with an introduction provided by Mike O'Driscoll. Cover design by Ted Robertson.

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# The 'lifeblood" civilization;

## Energy is everything, and mining provides that energy

**Marc Herpfer**
**2024 SME President**

Energy is everything, as it is the fuel that powers the conversion of raw materials critical for building a vibrant and growing civilization. What is the foundation of humanity then is our never-ending need for minerals, metals and food that sustains life and inherently nourishes us. Such a construct then drives mankind and inherently fosters its creativity, which in turn drives our insatiable curiosity to explore our world and eventually reach the stars.

If this is so, then the "oxygen" for civilization that is often unseen and unappreciated is ultimately the use of wealth to enable everything … and this is done by financing via human capital (aka work) and perceived intrinsic wealth (aka money).

The SME New York Section held its 9th Current Trends in Mining Finance Conference around "Seeking Certainty in an Uncertain World." It provided diverse and excellent programming topics and speakers around the various aspects of this "oxygen" in the economic circulatory system of civilization called banking and trade … which beyond access to investment finance for mining also deals with the global interplay of people, politics, process and the complex landscape of laws within populations and countries around the world where there is raw-material extraction.

Although modern technological tools and their advancements can help humans tremendously in the quest for raw materials, it ultimately takes people risking their hard-earned wealth on others to bring material into reality through mining and farming.

This action is, and will be, a never-ending, cyclical, yet well-balanced aspect of a thriving community. Life has always been about natural resources and the underlying perceived fungibility, effective distribution and application of "wealth management" to drive action in others and ourselves.

So, it was both intriguing and refreshing to learn more about all the other aspects revolving around the interplay between mining anywhere and the "financial oxygen" leveraged by other industries and disciplines to make our world go around and become a better place to live in. Without this oxygen, mining could never occur on the global scale that underpins the foundations of our civilization.

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**Safety Share** | How important is it to be "present" and "in the now" during conversations, interactions or tasks?

Did you know that 85 percent of employees are dissatisfied with their working environment and cannot maintain attention on their work? Or how about this stat: that 54 percent of employees reported they are not performing as well as they should be as a result of workplace distraction.

Wow! That is more than half of the folks you are working with or around at any given time that do not have their minds on the task at hand. No wonder there are communication frustrations in organizations and incidents that occur all over the world. Here are just a few of the items that can prevent us from being "present" and "in the now" of whatever we are doing:

- Being sick.
- Kid's graduation.
- Elderly parent needing help at home
- Newborn
- Divorce
- Heat
- Cold
- Animals
- Being new at the job
- Headache
- Hunger
- Upcoming vacations.

How many more can you come up with? What has prevented you recently, today even, from being completely engaged in the task you are doing?

How and what can we do to help limit these distractions to prevent injury and illness? On average, people have an attention span of 8 seconds. With this in mind, what can you do differently to be "present"?

**Source:**
**Propulo Consulting**

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# Nuclear energy deployment bill passed by US Senate

**THE U.S. SENATE** passed a bill to accelerate the deployment of nuclear energy capacity, including by speeding permitting and creating new incentives for advanced nuclear reactor technologies.

Expanding nuclear power has broad bipartisan support, with Democrats seeing it as critical to decarbonizing the power sector to fight climate change and Republicans viewing it as a way to ensure reliable electricity supply and create jobs.

A version of the bill had already passed in the House of Representatives and it will now go to President Joe Biden for a signature to become law. It passed the Senate 88-2 votes.

"In a major victory for our climate and American energy security, the U.S. Senate has passed the ADVANCE Act with overwhelming, bipartisan support," said Senator Tom Carper, a Democrat, who is Chairman of the Senate Environment and Public Works Committee.

"Today, we sent the ADVANCE Act to the president's desk because Congress worked together to recognize the importance of nuclear energy to America's future and got the job done," said Republican Shelley Moore Capito, a ranking member of the committee.

Among other things, the bill would cut regulatory costs for companies seeking to license advanced nuclear reactor technologies, would create a prize for the successful deployment of next-generation reactors, and would speed licensing for nuclear facilities at certain sites.

The bill could benefit companies like Bill Gates-backed TerraPower, which is trying to build a $4 billion Natrium reactor in Wyoming on the site of an old coal plant but is struggling to secure a key permit.

Non-proliferation groups including the Union of Concerned Scientists have warned against measures that ease licensing for high-tech nuclear reactors, including those using advanced fuels like high-assay low-enriched uranium (HALEU), arguing that safety should remain the priority.

The U.S. nuclear industry has struggled to expand in recent decades due to soaring costs and complex permitting requirements, and as advanced nuclear technologies prove difficult to fund and develop. ■

# Some major economies eye plans to halt coal funding

**SOME OF THE** world's major economies want to finalize a plan ahead of this year's U.N. climate summit to halt new private-sector funding for coal projects, five sources with direct knowledge of the matter told *Reuters*.

If approved, the draft proposal by the Organisation for Economic Co-operation and Development (OECD), would be the first move by a multilateral institution to curb financing for coal, one of the biggest causes of climate change, which produces more carbon dioxide emissions than oil or natural gas when it is burned for energy.

The draft plan, which aims to set a "gold standard" policy for how financial institutions approach coal, instructs investors, banks and insurers to halt new financing to existing or planned coal projects, and end funding to companies building coal infrastructure, the sources said.

Under the plan, financial institutions would fund the early retirement of coal plants, rather than divest from these assets. And early closures of coal-fired facilities should be matched with financing for clean energy to replace the lost coal capacity.

Commercial banks' lending and underwriting to the coal industry totaled $470 billion between January 2021 and December 2023, the nongovernmental organization Urgewald said in a report last month.

OECD countries — whose 38 members include most of the world's biggest market-focused democracies — are preparing feedback on the proposal, which is set to be put out for public consultation before a formal adoption ahead of the U.N. COP29 climate summit in Azerbaijan in November. The OECD policy would be nonbinding, but would aim to set an international standard used by companies' boards and shareholders.

Previous OECD guidelines — for example, on child labor — have been adopted by some multinational companies, setting a standard for dealing with countries where no formal child labor laws exist.

France, the United States, Britain, Canada and the European Union are among the backers of the proposal, part of a "Coal Transition Accelerator" initiative conceived by France at last year's COP28 climate summit, the sources said.

That project, which also focused on reducing the cost of capital for clean energy investments, was backed by coal-reliant emerging economies including Indonesia and Vietnam, both of which have entered multibillion-dollar deals with donor countries to reduce their coal reliance.

The biggest pushback on the OECD proposal has come from Japan, three of the sources said. Japan is the world's third-biggest coal importer and gets more than a quarter of its energy from coal. OECD members approve new guidelines by consensus.

G7 country leaders — among them, France, the United States and Japan — were expected to debate their efforts to phase out coal at a summit in Italy. Two sources said the outcome of the G7 summit could influence the aims of any OECD deal.

Governments, including the G7, have banned or limited public funding for coal power as they strive to meet climate goals, so most coal funding now comes from the private sector.

Only a quarter of financial institutions currently have policies that restrict their coal financing, according to S&P Global. Global coal power capacity stands at more than 2,000 gigawatts — with another 500 gigawatts of new capacity in development, most of it in China.

Coal project owners can face complex economics to close plants early. ■

# Mineral Processing for the Energy Transition

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# BHP walks away from $49 billion pursuit of Anglo American; **Under UK rules BHP cannot return for at least six months**

**MINING GROUP BHP** Group walked away from its $49 billion plan to take over rival Anglo American, which rejected a last-ditch request for more time, ending for now its six-week pursuit.

BHP's aim was to secure Anglo's prized copper assets in Latin America and increase access to a metal central to the global shift toward clean energy and electric vehicles. But the structure of BHP's deal, which required Anglo to unbundle its South African platinum and iron ore businesses, was a major reason for its collapse.

Anglo had granted BHP a one-week extension to its original May 22 deadline to submit a binding offer, after rejecting a third takeover proposal. Under U.K. rules, BHP cannot return for at least six months, unless there is another offer for the London-listed miner.

"While we believed that our proposal for Anglo American was a compelling opportunity to effectively grow the pie of value for both sets of shareholders, we were unable to reach agreement with Anglo American on our specific views in respect of South African regulatory risk and cost," BHP said.

"We remain of the view that our proposal was the most effective structure to deliver value for Anglo American shareholders, and we are confident that, working together with Anglo American, we could have obtained all required regulatory approvals, including in South Africa," it added.

Anglo has outlined a plan to divest less profitable assets and focus on expanding copper output.

London-listed Anglo had agreed to talk with BHP to try to iron out concerns over the deal's structure.

In an earlier statement, BHP said it needed more time to engage with Anglo, while outlining commitments to minimize regulatory risk in South Africa and saying it would offer a break fee if the deal failed to gain regulatory approvals.

Those commitments included job security for employees in South Africa. BHP also said it would shoulder the costs of increased South African employee ownership that is expected to be required in any demerger.

But Anglo said those commitments were not enough.

"BHP continues to restate its belief that the risks of its complex structure are not material, yet has repeatedly and consistently stated both publicly and during the engagements that it is unwilling to amend its proposed structure to assume these risks," Anglo said in its statement.

Anglo was founded in Johannesburg in 1917 and employs more than 40,000 South Africans, so any withdrawal would be a further economic blow to the country whose miners have been cutting jobs and investment as platinum especially falls out of favor.

Anglo is attractive to its competitors for its prized copper assets in Chile and Peru. Copper is a metal used in sectors ranging from electric vehicles and power grids to construction, whose demand is expected to rise as the world moves to cleaner energy and wider use of artificial intelligence. ■

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# Caterpillar ships first Early Learner 793 **battery-electric truck to BHP's Jimblebar Mine**

**THE FIRST** Caterpillar Early Learner 793 battery-electric haul truck (BEHT) has been shipped to BHP's Jimblebar Mine in Western Australia. It is expected to be in production by October 2024.

"It's incredibly exciting to be here in Tucson seeing this battery-electric truck in action. Not only do these trials represent an important step on BHP's operational decarbonization journey, but the technical outcomes could help to inform how we approach these challenges moving forward," said BHP vice president, operational decarbonization, Dan Heal. "As we progress toward potential deployments, we need to consider how we plan our mines, manage power demand, charge equipment, the skills we will need, and most importantly, safety."

"Taking action requires us to challenge the market to approach technology development differently. It requires the industry to innovate and adopt new collaborative methods, to identify solutions through studies and proof-of-concept trials, and it requires us to learn together as we go," BHP vice president, global mining and services, Sebastian Greco said. "Securing the first CAT Early Learner battery-electric haul truck is a reflection of the ongoing collaboration between BHP and Caterpillar and we are thrilled to be working together on this trial."

In preparation, BHP's Jimblebar Mine is completing upgrades to site electrical transmission and distribution to enable high power charging. ■

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# Chinese Premier visits lithium processing plant in Australia; **China's ability to invest in Australia critical minerals on the agenda**

**CHINESE PREMIER** Li Qiang visited a lithium processing plant in resource-rich Western Australia state, highlighting China's push to secure critical minerals as Washington tries to break Beijing's supply dominance.

Western Australia supplies more than half of the world's seaborne iron ore, with China its top customer, and half of its lithium used in electric vehicles, smartphones and other electronic devices.

Li's visit to Australia is the first by a Chinese premier in seven years and marks a stabilization in ties between the U.S. ally and the world's second-biggest economy.

While China has largely lifted suspensions imposed on $20 billion worth of Australian exports in 2020, after Canberra sought an investigation into the origins of COVID-19, it continues to express concerns about obstacles to Chinese investment in Australia's vast resources industry.

The issue of how Australia screens Chinese investment in its critical minerals sector was expected to be discussed at a business roundtable in Perth attended by Li and Australian Prime Minister Anthony Albanese.

In May, Australia blocked several Chinese investors from increasing stakes in a rare earths miner on national interest grounds, and last year blocked the acquisition of a lithium mine by Chinese interests.

The United States this year extended its support for the first time to back two Australian-listed rare earths projects to help build out the supply chain.

Li said that China hoped Australia would provide "a fair, just and non-discriminatory business environment for Chinese enterprises," and told the business roundtable the two countries benefit from each other's development.

Cooperation was important for stabilizing industrial supply chains and boosting economic growth, Li said, according to Chinese state news agency *Xinhua*.

Albanese told the Australian and Chinese executives that three-quarters of Australia's exports to China come from Western Australia.

He also said his government wants to create jobs in critical minerals processing, refining and manufacturing, and sell to a broader range of markets. "Our commitment to investing in local manufacturing doesn't mean cutting trade ties or pulling up the economic drawbridge. Far from it," he said.

"International partnerships and

*(continued on page 14)*

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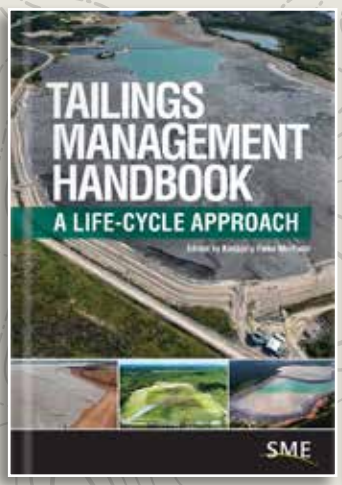


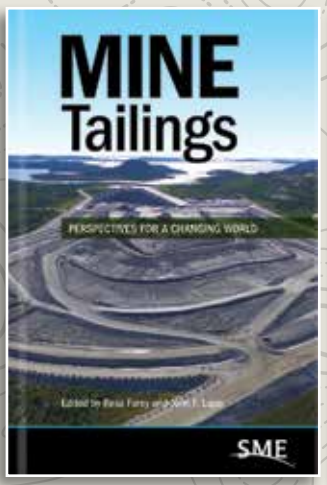


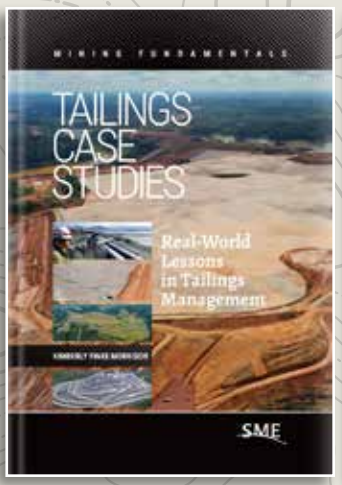


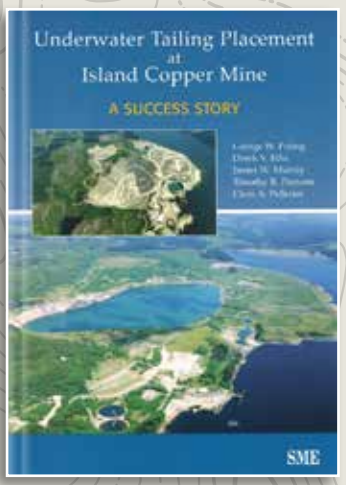


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# Serbia expected to greenlight Jadar project; **Rio Tinto's mine would be the largest lithium mine in Europe**

**RIO TINTO WAS** expected to get approval to move forward with its Jadar lithium project from Serbian President Aleksandar Vucic. The project is the largest lithium project in Europe. Approval of the mine would come two years after Belgrade called off the project, the *Financial Times* (FT) reported.

Vucic told the newspaper that "new guarantees" from the global mining giant and the European Union looked set to address Serbia's concerns over whether necessary environmental standards would be met at the Jadar site in the west of the country.

Rio Tinto previously announced that environment reports found the project to be safe.

Rio Tinto's Serbian unit made public several environmental studies conducted over the past six and a half years. "Results of scientific research show that the Jadar project can be realised safely by respecting highest domestic and international environmental standards," the company said in a statement.

Rio Tinto said in a statement emailed to *Reuters*: "We believe the Jadar project has the potential to be a world-class asset that could act as a catalyst for developing an EV (electric vehicle) value chain in Serbia."

Regarded as a critical material by the European Union and the United States, lithium is used in batteries for EVs and mobile devices.

"If we deliver on everything, (the mine) might be open in 2028," Vucic told the FT, adding that the mine was projected to produce 52.6 kt (58,000 stpy) of lithium, which would be "enough for 17 percent of EV production in Europe — approximately 1.1 million cars."

In 2022, Belgrade revoked licences for Rio's $2.4 billion Jadar project after massive environmental protests. If completed, the project could supply 90 percent of Europe's current lithium needs and help to make the company a leading lithium producer.

In 2021 and 2022, Serbian environmentalists collected 30,000 signatures in a petition demanding that parliament enact legislation to halt lithium exploration in the country. ■

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*Presenter: Ron Miller, Energy & Decarbonization Solutions Expert Consultant, ReliantEnergySolutionsLLC*
August 6, 2024 | 2:00 pm MT

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# Brazil looks to build its rare earths sector; **Advantages include low labor costs, clean energy and regulations**

**MINING GIANT** Brazil has big ambitions to build a rare earths industry as Western economies push to secure the metals needed for magnets used in green energy and defense and break China's dominance of the supply chain.

Working to its advantage are low labor costs, clean energy, established regulations and proximity to end markets, including Latin America's first magnet plant which would provide a ready buyer for the metals.

But low rare earths prices, technical challenges and nervous lenders pose challenges to the Latin American nation's hopes to propel itself into the world's top five rare earths producers.

The pace at which Brazil's rare earths projects come together will be a test for how successful the West may be at building a new advanced industry almost from scratch to break China's grip.

Brazil holds the world's third-largest rare earth reserves. The country's first rare earths mine, Serra Verde, started commercial production this year.

Output is set to grow, analysts, mining chief executive officers and investors say, supported by Western government incentives that are also accelerating a global rare earths refining and processing industry.

"Brazil as a source of potential rare earths is a very exciting proposition because there have been some very meaningful discoveries made in the past couple of years," said Daniel Morgan of Barrenjoey, an investment bank in Sydney. "I do think outside of China, Brazil's projects are the most economic greenfield projects available."

The United States and its allies, almost entirely dependent on China for rare earths metals and magnets, set out to build a separate supply chain by 2027 after deliveries were disrupted during the COVID-19 pandemic early this decade.

China produced 240 Mt (264,000 st) of rare earths last year, more than five times the next biggest producer, the United States, according to U.S. Geological Survey data. It processes around 90 percent of the global supply of rare earths into permanent magnets.

For countries like Australia, Vietnam and Brazil looking to catch up, progress is slow. Serra Verde has taken 15 years to get into production. It is expected to produce 4.5 kt (5,000 st) this year and could double output by 2030, its chief executive officer said.

"Serra Verde and Brazil have significant competitive advantages

*(continued on page 15)*

# Letter to the editor:

**Dear SME Editor:**

Please note my website, www.China-Resources.net. I have had this website for decades and know quite a lot about China's resources industries.

I was also a member of the NCSU chapter of the AIME (no longer extant) predecessor to SME in the early 1970s.

In the June 2024 issue is an article on "Graphite producers turn to US government to impose tariffs" (page 6). This article, which focused on graphite and mentioned in passing, lithium, omitted several critically important minerals that should have been mentioned other than in passing. These, beyond the U.S.'s Section 301 tariffs and others, are also affected by the U.S.'s strictures on trade with North Korea which uses China (PRC) as a way around trade restrictions for several limited commodities, like graphite, lithium, beryllium, the rare earth elements (REEs) and others. These strictures are very strong and directly affect such trade which China enables and which should be restricted, not just to protect U.S. production, but also to close explicitly forbidden loopholes in trade by and with North Korea.

One of North Korea's primary sources of hard income is graphite, all of which deposits occur along the shared border with the PRC, for which it is a significant source of hard currencies for both socialist/communist countries with an abysmal human rights record. While this fact is not well-documented, it is well-known from many sources, both domestic to those countries and to the United States. The PRC openly boasts about its assistance to North Korea to circumvent trade restrictions. So, the U.S. graphite miners should include this as a compelling reason for restricting the PRC's ability to import graphite into the U.S.

Both graphite and lithium are critical components in nuclear reactors. Lithium is the only feedstock for manufacturing tritium, necessary for making H-bombs, far more powerful than conventional nuclear weapons. North Korea has boasted that it has H-bombs and even exploded a device to prove it. Yet, we continue to provide lithium to North Korea through China. The North Koreans allegedly claim they have a lithium recycling industry, ridiculous for such an economically primitive economy with almost no need for lithium batteries. Likewise, North Korea has almost no domestic need or market for graphite, but clearly produces it in large quantities, allegedly for their domestic consumption. This claim is patently ludicrous.

Another major source of income for North Korea is vanadium steel, manufactured by a major electricity-producing lake west of Hungnam. The vanadium (V) is a byproduct of North Korea's processing of uranium (U) at the same site. So, buying vanadium steel from North Korea is directly funding the country's manufacture of nuclear weapons.

The use and marketing of beryllium (Be) for North Korea is anecdotal and by no means certain, but also allegedly involves the PRC as both an importing and marketing arm. At any rate, Be is a significant source of hard currency for the PRC. We import much of our Be from the PRC, even though we have abundant sources of domestic Be. Most of the PRC's Be is mined in Xinjiang-Weiwur Ziziqu (aka Sinkiang-Uyghur Province) and adjacent Gansu Province. The largest processing and refining firm for Be in China is at or in Gansu Province, formerly a part of Xizang Zizhiqu (aka Tibet). Be is also critical for nuclear processing and other uses. I am a former VP for International Beryllium Corp., but am no longer associated with that firm's successor beyond being a very minor stockholder.

Insofar as the REEs are concerned, an Australian firm signed a deal some years back with North Korea for mining the entire country's REEs. What happened with the company or the progress of the mining of REE since then is not known to me. Beyond making supermagnets, REEs have many nationally critical uses. The PRC is marketing much of the world's REEs, for which it has what amounts to a monopoly, not just for its massive Bayan Oboo Mine, but for others throughout the country. The history of the PRC has been to acquire every REE producer and incorporate the REEs into its international supply chain: there is no reason to expect anything else from the association between the PRC and the North Koreans. So, buying REEs from the PRC is also likely underwriting the activities of North Korea.

**Lindsey V. Maness, Jr.**
**Geologist**

# **Australia:** Inflow of foreign investment crucial

*(continued from page 10)*

the inflow of foreign investment will continue to be crucial for Australia as we modernize and diversify our economy, even as we take steps to secure our economic sovereignty and build resilience in sectors that are vital to our national interest," he added.

Ahead of the roundtable, Li toured a lithium hydroxide processing plant owned by Tianqi Lithium Energy Australia, 51 percent owned by Shenzhen- and Hong Kong-listed Tianqi Lithium and 49 percent by Australian miner IGO that is considering whether it will more than double production.

Australia said last month it would consider Chinese ownership when deciding whether companies qualify for tax credits under a new program of incentives and support for the critical minerals sector.

Tianqi Lithium chief executive Frank Ha told the *Australian Financial Review* the company had not sought incentives but now that they were on the table it wanted a "fair go." ■

# Asarco to reopen US copper smelter in Arizona; **Smelter will be third in operation in the United States**

**ASARCO, THE MINING** company controlled by industrial conglomerate Grupo Mexico, is planning to restart its mothballed copper smelter in the United States as prices for the red metal hit record highs, two sources with direct knowledge of the company's plans told *Reuters*.

Asarco, first bought by Grupo Mexico in 1999, is in negotiations with unionized workers to restart the Hayden smelter in Arizona and nearby copper mines, as well as the Amarillo refinery in Texas, the sources said.

Reopening Hayden would boost supply of the key red metal across the country, which uses twice the amount of refined copper it produces because it only has two domestic smelters: Freeport-McMoRan's Miami smelter in Arizona and Rio Tinto's Kennecott smelter in Utah.

The sources said recent copper price rallies motivated Asarco to restart Hayden, given an acute need for copper smelting in the United States.

Mexico City-based Grupo Mexico declined to comment.

Copper demand is expected to grow steadily in coming years, fueled largely by the global clean energy transition and the rising use of artificial intelligence. Recent price jumps, though, appear to be driven in part by speculative activity.

The most-traded front-month copper contract on the Chicago Mercantile Exchange has gained 24 percent since January, hitting a record $5.1985/lb in May.

Asarco's smelter, located about 161 km (100 miles) southwest of Phoenix, AZ has not been fully operational for more than four years after a labor strike by its unionized workforce.

It has widespread environmental damage and is considered a "Superfund" hazardous waste site by the U.S. Environmental Protection Agency.

It was not immediately clear when Asarco plans to officially restart smelting operations, but the company is in negotiations now with a union representing mining and smelting workers, according to one source. Asarco is focused on finalizing a contract with miners first and then staff for the smelter, the source added.

The company last June filed for an extension of the smelter's air quality permit — which had been set to expire in December — with state and federal officials, a request that is under review.

Asarco recently hosted a delegation from Peru, the world's second-largest copper producing nation, at the facility, one source said.

Concentrates from Asarco's nearby Ray and Mission mines are now sold mainly to Chinese smelters.

When last operational, Hayden had an annual capacity of 136,078 t (300 million lb) and processed copper extracted from the Ray Mine.

By resuming full operations at the Hayden smelter, Asarco would be able to process that concentrate into a product known as copper cathode that can be used by its refinery in Amarillo, TX to make wire rod and other products.

Asarco's RAY- and ATR-branded copper cathodes could be delivered onto the Chicago Mercantile Exchange for contract settlement.

The plans also underscore tight global supply of copper concentrates, a form of crushed, flotated ore used by smelters to make copper.

Treatment charge, an indicator of copper concentrates availability, flipped to negative for the first time ever in April.

The United States produced 800 kt (880,880 st) of refined copper last year, according to the International Copper Study Group, although it imported 700 kt (770,900 t) and consumed over 1.4 Mt (1.6 million st) of refined copper. ■

# **Brazil:** Could have two or three more mines by 2030

*(continued from page 13)*

that could underpin the development of a globally significant rare earths industry over the long term," Serra Verde chief executive officer Thras Moraitis told *Reuters*.

Those include attractive geology, access to hydropower, established regulations and a skilled workforce, he said.

"It is still a nascent sector which will require continued support to establish itself in a highly competitive market. Key processing technologies are controlled by a small number of players," he said.

Brazil could have two or three more rare earths mines by 2030, potentially exceeding Australia's current annual output, said Reg Spencer, an analyst at broker Canaccord.

One major obstacle is a 70 percent slump in rare earths prices over the past two years that has made it difficult for companies to raise funds for mines and processing.

"Getting money at the moment is tough," Nick Holthouse, chief executive of Australian-listed developer Meteoric Resources, told *Reuters*.

Meteoric is targeting an investment decision in late 2025 for its Caldeira project in Brazil's Minas Gerais state which will produce light and heavy rare earths.

In March, the U.S. Export-Import Bank (EXIM) expressed interest in providing Meteoric up to $250 million for the project. The company also has a preliminary deal to supply rare earth oxides to a separation plant in Estonia run by Toronto-listed Neo Performance Materials.

Brazilian Rare Earths, too, is in the early stages of developing a large rare earths deposit in the country's northeast, backed by Australia's richest person, Gina Rinehart. ■

# Use of reclaim water turret intake in a cold climate at Porcupine Mine, Canada

by Shaun Banks

Newmont Porcupine is a gold mining and milling operation located in Porcupine, Ontario, Canada (Fig. 1). The climate in Porcupine averages 3 m (10 ft) of snow yearly with daily average freezing temperatures from November to March, and extreme temperatures as low as minus 45 °C. The active tailings management area, 6TMA, is approximately 590 ha in area and 12.5 km (7.7 miles) in circumference. Tailings deposition at the facility is done by the end spill and spigot method at densities ranging from 32 to 40 percent solids.

**Figure 1**

**Location of Newmont Porcupine, Canada.**

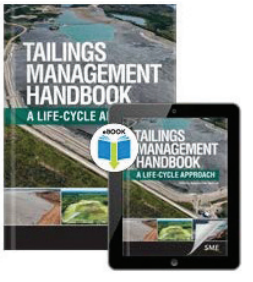
Figure courtesy of MapSherpa and MapTrove

Process water for milling operations is nearly 100 percent reclaimed from the reclaim water pond at 6TMA.

The original reclaim water system, shown in Fig. 2, included four vertical turbine pumps drawing water from a well at the reclaim water pond, fed from an inverted intake pipe at the bottom of the reclaim water pond. The intake has an underwater decant structure with stop logs to prevent tailings sediment from entering the reclaim water intake. The well, reclaim pumps, and effluent treatment plant feed pump were housed inside a concrete block building with concrete floor.

As the embankment raises progress, the reclaim pumphouse is required to be raised periodically and has been raised five times. These raises are quite involved and costly. In addition, the tailings management plan involves transitioning the reclaim water pond to the central area of 6TMA, involving depositing tailings in the reclaim pond and creating beaches along the embankment. This deposition in the pond will impact the reclaim water intake so transition to a top-draw intake system, with the

**This feature article by Shaun Banks of Newmont Porcupine is one of 43 real-world case studies in Tailings Case Studies: Real-World Lessons in Tailings Management, the companion book to Tailings Management Handbook: A Life-Cycle Approach, both edited by Kimberly Finke Morrison and published by SME. For more information, go to https://store.smenet.org/217tqnm/ and https://store.smenet.org/1vmff1t/**



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## Figure 2

**Original reclaim bottom-draw inverted intake and well.**

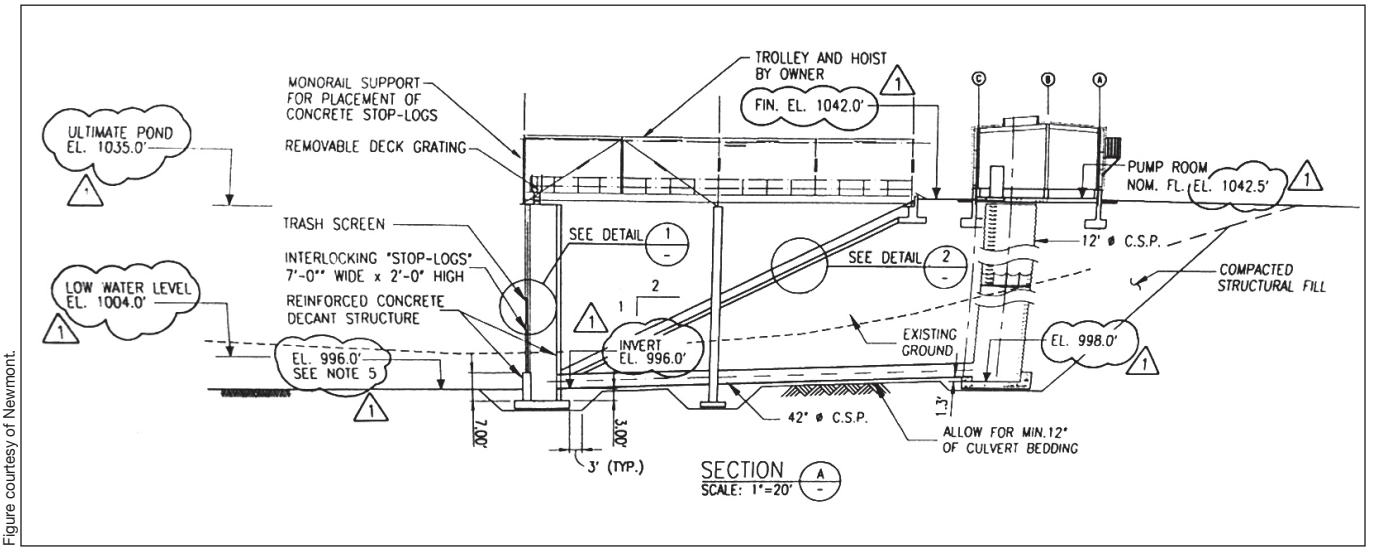


Figure courtesy of Newmont.

## Figure 3

**Turret intake installation at Newmont Boddington, Australia.**

Photo courtesy of Turret Engineering Pty. Ltd.

## Figure 4

**Turret intake with cone and de-icing piping.**

Photo by S. Banks.

ability to be repositioned was required. Mining operations in cold climates in the area generally use barges with short vertical turbine pumps, anchored to shore, with de-icing using agitation or aeration.

A study was undertaken to develop options for installation of a barge. Various examples of barge installations were reviewed. Barges in warmer climates can be open to the elements, and more economical. For northern climates dealing with freezing conditions, considerations are required to prevent freezing around the barge, freezing of standby equipment, maintenance of the system in the winter, and access to the barge. The resulting concept involved a heated enclosure with lifting beams, access gallery and de-icing, leading to a robust barge and costly option, with some practicality issues remaining.

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### Turret intake as an option

It was suggested to Newmont Porcupine to explore the option of using a turret intake with a pump on shore, as

used in Australia. The advantages of the turret intake include requiring only 1 m (3.2 ft) depth of water as well as flexibility to be relocated easily. Figure 3 shows a turret intake installation in Australia.

## Design and engineering

Contact was made with the company that designs and supplies turret intakes for Newmont Boddington, Australia. There was a high level of confidence that the turret intake system would work in our application, and the challenge was to ensure that it would not be impacted by freezing conditions. Criteria in the design included de-icing, maintenance of the pumps in the winter, and an easily movable system. The turret supplier began designing a de-icing system while Newmont Porcupine worked with a multidisciplinary consultant for engineering of the piping, electrical and enclosure. A de-icing pipe with nozzles was designed on each side of the suction pipe and around the turret intake. The first idea was to recirculate a small amount of water from the discharge. To maximize the water supplied from the pumps, an alternative was considered to use a blower to supply air to the de-icing ring; however, the volume of air required a large blower as well as heating for the intake air. This significantly increased the complexity, the power required, and cost. The final de-icing design reverted to the original idea of using recirculated water from the discharge. A cone was added to the 3-m diameter turret intake to prevent snow and ice buildup. A self-priming centrifugal pump is used with the turret intake. A 6-m (20-ft) sea container was modified with a reinforced floor, doors, electrical, ventilation and heating to house the pump. Figures 4 through 6 show the components of the turret system.

## Trial in 2022-2023

A trial was conducted during the winter of 2022-2023 by installing one turret system. The turret pump discharge was connected to the existing header for the vertical turbine pump system. The one centrifugal pump was trialed during the winter in conjunction with the existing vertical turbine pumps to confirm the ability of the suction intake and pump to supply sufficient flow and the effectiveness of the de-icing system. The trial was successful and confirmed the ability of the turret pump to supply the mill, with supplement from an additional pump when required. The de-icing system worked better than expected. Figure 7 shows the effectiveness of the de-icing system, and Fig. 8 shows the turret intake and de-icing system.

Following the success of the initial winter trial, work began to expand the turret system from one turret to three turrets. Refinements

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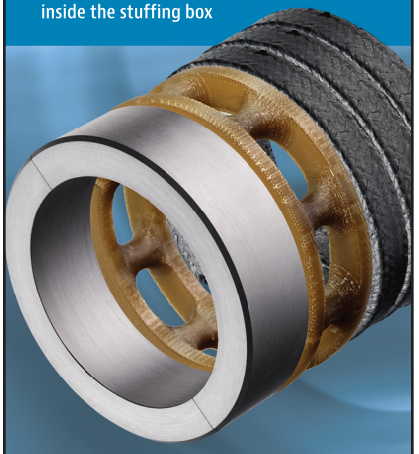

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## Figure 5

**Modified sea container pumphouse.**

Photo by S. Banks.

## Figure 6

**Self-priming centrifugal pump.**

Photo by S. Banks.

were made to the design, and a header was incorporated to tie the three pumps together into the reclaim piping system. The reclaim water system and effluent treatment plant feed has been fully transitioned to supply from the three turret pumps. Figure 9 shows the arrangement of the three-turret system.

The following functionality is incorporated into the system design:

- All three turret pumps are powered by variable frequency drives for variable flow demands.
- All three pumps can supply the mill reclaim water demand, providing redundancy.
- Two of the three pumps are piped to supply the effluent treatment plant, providing redundancy.
- One pump is able to supply normal reclaim water demands with ability to be supplemented by a second pump for increased flow requirements.
- One pump is able to supply effluent treatment plant demand.
- De-icing rings can be back-fed from the operating pump or pumps to ensure that all three intakes remain de-iced.
- Access is available to the side of each sea container to remove a pump if needed to take to the shop for repairs.
- There is flexibility to take one turret pump offline to raise or relocate while the others are operating.

## Benefits of system

This turret system provides the following benefits over the existing fixed bottom-draw reclaim system:

- Ability to easily relocate with pond transition.
- Can co-locate turrets or can locate them in different areas of the pond (once power feed is routed where required).
- Ability to deposit tailings and beach in the area of the existing fixed reclaim water intake that is now redundant.
- Can reduce the amount of water contained in the reclaim pond due to dead zone created by the existing stop log intake.
- Ability to pump in shallow water, as little as 0.4 m depth.
- Capacity to extend intake further into pond.
- Easier maintenance of the centrifugal pumps compared to vertical turbine pumps with extended shafts.

The innovative design of a turret intake developed in Australia has been further adapted for suitability in cold climates, such as Porcupine, to withstand the winter conditions, providing operational flexibility and benefits. This is an example of a "Down Under" design adapted for the "Great White North." ■

## Figure 7

**Effectiveness of turret de-icing.**

Photo by S. Banks.

## Figure 8

**Turret intake and de-icing.**

Photo by S. Banks.

## Figure 9

**Three-turret system.**

Photo by S. Banks.

# Industrial Minerals review 2023

by Mike O'Driscoll*

## Is the "Criticality" of industrial minerals finally being understood?

The importance of industrial minerals to the world economy and everyday lives always used to be a hard sell to the uninitiated. Just having to explain what they are and how they are characterized in the context of the world mining industry was often a steep learning curve for some (especially startup newcomers and those from the metallic minerals sector wishing to diversify for a quick buck).

Often misunderstood, their value frequently underestimated, and even disparaged as "the third world" of the mining industry, industrial minerals have not always had an easy ride.

But that was then, and this is now. 2023 might be considered the year that (finally) marked the decade of industrial mineral criticality recognition.

We know that industrial minerals are the building blocks of our economy and essential to our everyday life, but owing to several factors (such as supply-chain vulnerability exposed by the COVID-19 pandemic, shipping crises, the Russia-Ukraine war, overreliance on China, new technologies), the last few years have seen a growing awareness of industrial minerals' importance in the mainstream — that is, not just by the wider industry, but crucially, by state and national governments and the public sector.

Even the Industrial Minerals Association-North America (IMA-NA), after having represented the industrial mineral mining industry since 2002, decided to rebrand in 2023 and change its name to the Essential Minerals Association (EMA). It was decided that IMA-NA simply did not "fit the mission and nature of the industry."

## Industrial minerals to the rescue — national defense role

Nothing sharpens a government's mind more than issues surrounding a state's defense capabilities.

In a recent article for IMFORMED, Nicholaus Rohleder, cofounder of Climate Commodities, eloquently made the case that the nexus between industrial minerals and national security is a topic of paramount importance, often overlooked in broader discussions about defense readiness and strategic autonomy.

Refractories, materials that are resistant to heat and wear and composed of specific industrial minerals, are indispensable in industries that require high-temperature processes, such as steelmaking, a vital component in military hardware production.

Key minerals, such as bauxite, alumina, andalusite, magnesite and graphite, are not just commodities; they are strategic assets that empower nations with the capability to produce armor, weaponry and other critical military infrastructures. Similarly, the abrasives market, which includes materials used for cutting, grinding and polishing, depends on minerals like fused alumina, silicon carbide, garnet and diamond. Precision manufacturing and maintenance processes for military equipment require the highest-quality abrasives to ensure performance and reliability under the most extreme conditions.

These minerals' strategic importance is also reflected in the geopolitical dynamics of supply and demand, with nations now increasingly aware of the need to secure reliable sources.

## Revolutionary drivers from the energy sector

In this author's career of some 35 years in the industry there have been several notable industry milestones. But in recent times perhaps the two most significant standout gamechangers — and that remain ongoing — which have helped spotlight industrial minerals have been unconventional oil/gas resource development by hydraulic fracturing (fracking), and the new battery "revolution" as part of our fledgling energy transition.

Interestingly, and maybe unsurprising to some, their common denominator is our demand for energy sources (although, often easily forgotten in the hot air of debate, oil is also a raw-material feedstock for the massive petrochemical industry).

Fracking had been around since 1949, was further developed in the 1980s, and then, in the early to mid-2000s came the phenomenal boom in fracking, the "shale gale." This was facilitated by developments in horizontal drilling techniques, using massive volumes of improved mineral-based proppants (mainly silica sand, but also kaolin and bauxite for ceramic proppants) to exploit much-needed cheap shale gas and oil from otherwise earlier unexploitable resources (mainly in North America, but also elsewhere).

Wisconsin was turned into a frac sand mine, since superseded by west Texas. In the United States at least, the humble silica sand has never looked back.

From the early 2000s it was obvious that a

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new era for battery development was occurring with the research and development, then commercial manufacturing of lithium-ion (Li-ion) batteries for all kinds of high-tech consumer and industrial devices, plus municipal storage.

This has opened up a huge, and ongoing market for a range of minerals (including lithium, graphite, nickel, cobalt and manganese) and, most recently, massively raised awareness of their vulnerabilities in availability, sourcing and supply chains.

The battery market continues to evolve with new battery chemistries and applications for more minerals used in niche components of the Li-ion battery (such as fluorspar and high-purity aluminas), and demand for more commercially developed sources of those industrial minerals.

All this has led to the advent of "critical raw materials" (CRM) and their mainstream recognition by media and state governments. Although, frankly speaking, CRM have always been around and recognized in other industries over the last three decades: rare earth minerals, for example.

But it's not all about just lithium and graphite, other industrial minerals are emerging onto the CRM stage, such as salt and fluorspar, which are worth looking at as examples.

## Salt — a critical mineral in the wings?

Since around the mid-2000s, various organizations and states have used criteria to define their respective CRM lists, commonly entailing compilation of a criticality matrix with supply risk and economic importance as key parameters.

Last year, speaking at IMFORMED's Salt Forum 2023 in Namibia, Jack Bedder, founder and director of Project Blue, highlighted the energy transition as requiring both the "usual" and "unusual suspects" as essential, and postulated that salt may play a part if sodium-ion (Na-ion) batteries take off.

Salt is certainly of economic importance, although not a supply risk, though some countries do rely on imports for their salt requirements (the United States has a 25 percent net import dependency on salt; sources are Canada, Chile, Mexico and Egypt).

Things are heating up for Na-ion batteries, especially in China. In 2022, HiNa Battery commissioned the first GWh-scale Na-ion battery production line in Anhui. There are another 35 plants being built. Meanwhile, Chery,


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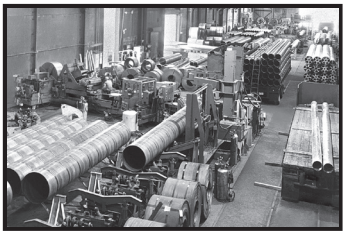

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a Chinese carmaker, is using CATL's Na-ion battery, alongside some Li-ion batteries, in its new "icar" brand, launched in April 2023.

In Project Blue's high case scenario, the salt required to process and produce Na-ion batteries in 2050 would approach 3 Mt (3.3 million st), which is roughly 1 percent of the current total production of processed salt in 2023.

This scale of potential Na-ion demand could elevate sodium, and the salt required to produce it, into critical material status for delivering energy transition.

## Fluorspar — finally achieving recognition

Fluorspar had already made the CRM lists of the EU and the United States (only added in 2018), and in December 2023 it was added to Australia's CRM list.

Fluorspar is essential as the primary feedstock for hydrofluoric acid (HF) manufacture (the precursor to a wide range of fluorochemicals), and is vital in steel and aluminum production. However, its "criticality" has been "raised" owing to its projected demand for use in the manufacturing of Li-ion batteries, solar panels and semiconductors.

In Li-ion batteries, fluorspar is the feedstock source for lithium hexafluorophosphate ($LiPF_6$), used as an electrolyte, and for polyvinylidene fluoride (PVDF), used as separators, coatings and binders. PVDF is also used in backing sheets for solar panels.

In semiconductor manufacturing, HF with greater than 99.99 percent purity is required in the etching process for semiconductors and for removing impurities from the final silicon chip.

World sources of fluorspar are limited. The United States has no established domestic source of fluorspar and is 100 percent net import reliant, supplied by Mexico, Vietnam, China and South Africa. While Canada Fluorspar Inc. is yet to restart operations in Newfoundland, a new U.S. fluorspar mine is in development by Ares Strategic Mining Inc. near Delta, UT (mine and plant construction underway), which will provide an interesting, and for U.S. consumers much-needed, alternative source. New sources are also being evaluated in Europe and Australia.

## U.S. and Europe response

The United States relies on significant imports of industrial minerals: in 2023, according the U.S. Geological Survey (USGS), 32 industrial minerals had 20 percent or greater net import dependency, of which 24 industrial minerals were at 50 percent or greater import dependency (including nine at 100 percent). Eighteen, or more than 50 percent, of the minerals were sourced from China (six at 100 percent, eight at greater than 50 percent, and four at 20 to 28 percent). Graphite, fluorspar and refractory bauxite are in the 100 percent category, and fused alumina at greater than 95 percent.

A series of actions by the U.S. government between 2018 and 2023 have addressed domestic supply-chain vulnerabilities for CRM, with the Inflation Reduction Act of 2022 foremost among these. Several investments were announced in 2023 to address the domestic availability and supply of CRM, including lithium and graphite projects. Most recently, in May this year, the U.S. government announced increased import tariffs on Chinese goods such as electric vehicles, Li-ion batteries, graphite and other "critical minerals," including "aluminum ores and concentrates."

At the same time, the European Council formally adopted the Critical Raw Materials Act (CRMA) to establish a framework to ensure the secure and sustainable supply of CRM by identifying 34 critical and 17 strategic materials crucial for green and digital transitions, and the defense and space industries.

How these actions will unfold and assist desired rapid Western development of CRM remains to be seen — there are many doubters out there. The USGS Critical Minerals List is due for revision in 2025, it will be interesting to see if any further industrial minerals make the so-called CRM grade. ■

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**Editor's notes:** (1) The articles provided by the U.S. Geological Survey (USGS) in this section, edited by Jim Norman, are based on data included in the USGS Mineral Commodity Summaries 2024 (https://www.usgs.gov/centers/national-minerals-information-center/mineral-commodity-summaries). The USGS Mineral Commodity Summaries are published on an annual basis; this report is the earliest government publication to furnish estimates covering nonfuel mineral industry data. Data sheets contain information on the domestic industry structure, government programs, tariffs and five-year salient statistics for more than 90 individual minerals and materials. **Disclaimer:** Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.
(2) Throughout this review, measurements are expressed as metric units unless the author provided conversions.

# ANTIMONY

by Kateryna Klochko, National Minerals Information Center, U.S. Geological Survey

Antimony is a lustrous silvery-white material. Although it is usually described as a metal, it possesses mixed metallic and nonmetallic characteristics and is more properly classified as a semimetal or metalloid. Among the elements found in the Earth's crust, antimony ranks 53rd in abundance. At an average crustal concentration of 0.20 g/t, it is less abundant than tin, arsenic or the rare earth elements but more abundant than bismuth, mercury or silver. Antimony tends to concentrate in sulfide ores with copper, lead and silver. It occurs sparingly as a native metal, usually in association with arsenic, bismuth or silver.

## Production

In 2023, no marketable antimony was mined in the United States. A mine in Nevada that had extracted about 800 t of antimony ore from 2013 through 2014 was placed on care-and-maintenance status in 2015 and had no reported production in 2023. Primary antimony metal and oxide were produced by one company in Montana using imported feedstock. Secondary antimony production was derived mostly from antimonial lead recovered from spent lead-acid batteries. The estimated value of secondary antimony produced domestically in 2023 was about $49 million. China continued to be the leading global antimony producer in 2023 and accounted for 48 percent of global mine production. World production of antimony has not recovered to pre-2020 levels as the leading mine in Russia is focusing its production on gold, and producers in China have decreased production since 2021 as mandated by the government citing environmental concerns.

## Consumption and end uses

Apparent consumption of antimony in the United States in 2023 was estimated to be 22 kt, 12 percent less than in 2022. Recycling supplied about 18 percent of estimated domestic consumption, and the remainder came mostly from imports. In the United States, the leading uses of antimony were metal products, including antimonial lead and ammunition, 43 percent; flame retardants, 35 percent; and nonmetal products, including ceramics and glass and rubber products, 22 percent.

## Imports and exports

The United States is highly reliant on imports of unwrought antimony metal and antimony trioxide. According to the U.S. Census Bureau, imports in 2023 of unwrought antimony for consumption were 7.7 kt, 7 percent less than in 2022. Imports of antimony trioxide were 14 kt, 17 percent less than in 2022. The imported unwrought antimony was principally sourced from the United Kingdom, 22 percent; India, 18 percent; Thailand, 17 percent; Oman, 12 percent; and China, 10 percent. The imported antimony trioxide was principally sourced from China, 74 percent; Belgium, 10 percent; and Bolivia, 7 percent. The United States exported 1.9 kt of unwrought antimony metal in 2023, 7 percent more than in 2022, and 1.7 kt of antimony trioxide, 28 percent less than in 2022. The unwrought antimony was principally exported to Mexico, 45 percent, and Canada, 39 percent. The antimony trioxide was principally exported to Japan, 30 percent; Canada, 14 percent; and the Netherlands, 11 percent.

## Prices

In 2023, the average antimony price was $5.49/lb, 11 percent lower than $6.18/lb in 2022. The monthly antimony price ranged from $5.12/lb in December 2023 to $5.97/lb in June 2023.

## World resources

U.S. resources of antimony are mainly in Alaska, Idaho, Montana and Nevada. Additional antimony resources may occur in lead deposits in the eastern United States. Principal identified world resources are in Australia, Bolivia, Burma, China, Kyrgyzstan, Mexico, Russia, South Africa, Tajikistan and Turkey.

## Trends and outlook

According to Roskill, the shares of antimony consumption within the two main groups of end products, lead-acid batteries and flame retardants, have been decreasing. This trend is expected to continue as manufacturers, driven by increased prices and legislative changes to flame-retardant formulas, turn to substitutes. In batteries, lead-calcium alloys have increasingly been used instead of antimonial lead in battery grids. Antimony ore supply is expected to remain strained due to reduction in antimony output by mines in China and Russia.

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# BENTONITE

by Kristi J. Simmons, National Minerals Information Center, U.S. Geological Survey

Bentonite primarily consists of smectite minerals (usually montmorillonite) with minor amounts of feldspar, biotite and quartz. Formed from the weathering and alteration of volcanic ash deposits,

bentonite has unique properties that include the ability to swell when hydrated. The physical and chemical properties of bentonite make it a highly absorbent and reactive material, useful in a wide range of industries including agriculture, construction, cosmetic, drilling, pet care and environmental remediation. Bentonites used for industrial purposes predominantly consist of sodium montmorillonite or calcium montmorillonite. Sodium montmorillonite, also referred to as swelling bentonite, is predominantly produced in the Western States and has a higher swelling capacity than calcium montmorillonite, also referred to as nonswelling bentonite. Nonswelling bentonite is mostly produced in the Southern States. Bentonite, which is found in shallow deposits over large land areas, is mostly mined using openpit mining techniques. Bentonite is found in a variety of colors including tan, gray-blue, olive, brown and white.

## Production

In 2023, domestic bentonite production (the quantity sold or used by producers) was estimated to have increased by 3 percent to 4.7 Mt compared with 4.58 Mt in 2022. During the past 25 years, U.S. bentonite production fluctuated between a low of 3.65 Mt in 2009 to an all-time high of 4.99 Mt in 2011. In 2023, nonswelling and/or swelling bentonite were produced in the following states, in alphabetical order: Alabama, Arizona, California, Mississippi, Montana, Nevada, Oregon, Texas, Utah and Wyoming. Swelling bentonite comprised an estimated 97 percent of all domestically produced bentonite. An estimated 96 percent of swelling bentonite was produced in Wyoming; Alabama and Mississippi, as in past years, led in the production of domestic nonswelling bentonite. Swelling bentonite production was reported or estimated by 17 companies and nonswelling bentonite was produced by five companies. In November 2023, Wyo-Ben Inc., headquartered in Montana, acquired the Wyoming bentonite operation of M-I Swaco, a Schlumberger company.

Bentonite is widely available in many countries around the world. The United States continues to be the global leader in the production of bentonite, followed, in descending order, by India (3.7 Mt), Turkey (2.4 Mt) and China (2.1 Mt). World production of bentonite was estimated to be 20 Mt in 2023, compared with 20.4 Mt in 2022.

## Consumption

Pet-waste absorbents (48 percent of sales) and drilling mud (23 percent) were estimated to be the leading domestic markets in 2023. Bentonite also was sold for the manufacturing of adhesives, animal food, filler and extender applications, foundry sand, miscellaneous civil-engineering applications, pelletizing (iron ore) and waterproofing. Exported bentonite had similar uses as domestic bentonite.

## Prices

The average unit value of bentonite in 2023 was estimated to be $99/t, compared with $101/t in 2022. The average unit value for exported bentonite was $237/t in 2023, unchanged from 2022, and the average unit value for imported bentonite decreased to $442/t in 2023 compared with $635/t in 2022. Average unit values for exports and imports fluctuate more than the average unit value of domestic production owing to the influence of small, high-value shipments.

## Foreign trade

According to the U.S. Census Bureau, bentonite exports decreased to 784 kt valued at $186 million in 2023, compared with 830 kt valued at $197 million in 2022. The leading destinations for exports of bentonite in 2023 were Canada (56 percent), Japan (12 percent), and Mexico (8 percent). Lesser amounts were shipped to 76 other countries. Bentonite imports increased to 22 kt valued at $9.56 million in 2023 compared with 18 kt valued at $11.2 million in 2022. Mexico (49 percent), Canada (22 percent) and Turkey (11 percent) were the leading sources of bentonite imports while 23 other countries provided lesser amounts in 2023.

## Outlook

Bentonite has various diverse uses, which enable it to remain a mature and stable industry. Pet-waste absorbents and drilling muds are likely to remain the leading uses of bentonite and are likely to continue to influence the demand for bentonite. The pet industry continues to grow, which may result in increased consumption of bentonite for pet-waste absorbents. Bentonite production will also be determined by the natural-gas and petroleum well-drilling industries, which have a greater level of uncertainty compared to the pet-care industry. During the first two months of 2024, the Baker Hughes U.S. rig count had been steady but was lower than the same period of 2023.

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# BORON AND BORATES

**by Amanda S. Brioche, National Minerals Information Center, U.S. Geological Survey**

Four minerals account for 90 percent of natural borates used throughout the world: sodium borates, tincal and kernite; calcium borate, colemanite; and sodium-calcium borate, ulexite. Deposits of borates

are associated with paleo-volcanic activity coupled with modern arid climates. The largest economically viable deposits are located in the Mojave Desert near the towns of Boron and Trona, CA; the Alpide belt in southern Asia; and the Andean belt of South America. Borax, a white crystalline substance chemically known as sodium tetraborate decahydrate, is found as the mineral tincal. Boric acid (hydrogen borate) is a colorless crystalline solid sold in technical, national formulary and special-quality grades as granules or powder and marketed most often as anhydrous boric acid. Ore quality is typically measured as a function of its diboron trioxide ($B_2O_3$) equivalent content. Major end-use industries for boron include glass, ceramics, detergents and fertilizers.

## Production

U.S. production of boron minerals and compounds increased in 2023 from 2022; production data were withheld to avoid disclosing proprietary company data. Two companies in southern California produced boron minerals, primarily sodium borates. U.S. Borax Inc., a wholly owned subsidiary of U.K.-based Rio Tinto Minerals plc, extracted kernite and tincal by openpit methods at its operation in Boron, CA. The minerals were processed into boric acid and sodium borate products in a refinery adjacent to the mine and shipped by railcar or truck to North American customers or distributed internationally through the Port of Los Angeles. Specialty borates, such as agricultural, flame-retardant and wood-preservative products, are made at U.S. Borax's Wilmington, CA, plant. Searles Valley Minerals Inc. (SVM), headquartered in Overland Park, KS, produced borax and boric acid from potassium and sodium borate brines at its Searles Lake operation near Trona, CA. The brines were refined into anhydrous, decahydrate and pentahydrous borax in SVM's Trona and Westend plants.

## Consumption

The glass and ceramics industries remained the leading domestic users of boron products in 2023, accounting for an estimated 65 percent of total borate consumption.

Boron also was used as a component in abrasives, cleaning products, fertilizers, insecticides, various military applications and in the production of semiconductors. Boron was the most widely used micronutrient in agriculture, applied primarily to promote seed production. Boron fertilizers were mostly sourced from borax and colemanite owing to their high solubility in water, allowing boron fertilizers to be delivered through sprays or irrigation water. Boron carbide was used for manufacturing in many industries, including the aerospace and defense industries. Ferroboron was used in the production of permanent magnets and as an alloying agent in steelmaking.

## Foreign trade

According to the U.S. Census Bureau, U.S. exports of refined borax were 604 kt in 2023, a 7 percent decrease from 651 kt in 2022. China, India, Canada, Indonesia, the Netherlands, Mexico, Malaysia and Japan imported the largest quantities of refined borates from the United States (in descending order), comprising 90 percent of total refined borate exports. The average unit value for refined borate exports was $674/t in 2023, a 19 percent increase from $564/t reported in 2022.

Boric acid exports were 253 kt with a value of $856/t in 2023, a 6 percent increase in tonnage from 239 kt and a 3 percent increase in value from $835/t in 2022. Imports of boric acid in 2023 were 38 kt, about 21 percent less than in 2022. Approximately 76 percent of imported boric acid came from Turkey in 2023. The average unit value for boric acid imports was $906/t in 2023, an 8 percent increase from $838/t reported in 2022. The average unit value for refined borate imports was $544/t in 2023, a 37 percent increase from $397/t reported in 2022.

## International

Chile, China, Turkey and the United States (in alphabetical order) led the world in the production of borates in 2023. Chile was the leading borate producer in South America. China mined more than 100 borate deposits in 14 provinces. Boron resources in China, however, are of low quality, averaging around 8.4 percent $B_2O_3$. By comparison, reserves in Turkey and the United States have grades ranging from 26 to 31 percent and 25 to 32 percent $B_2O_3$, respectively. China has become more import reliant on borate products from South America, Turkey and the United States. Turkey opened its first boron carbide facility in March and began construction of a ferroboron facility in September 2022. Boron carbide is produced in only five countries in the world. Turkey's new boron carbide facility has a capacity of 1,000 t/a. The first boron carbide sales were expected to occur in June 2023 to two Turkish defense industry companies.

## Outlook

Consumption of borates is expected to increase as a result of strong demand in the agriculture, ceramic and glass markets in Asia and South America. Demand for fertilizers containing boron is expected to rise as a result of an increase in demand for food and biofuel crops. Higher crop prices may also enable farmers to invest more capital in advanced farming techniques, which includes boron-containing, higher-grade fertilizers.

The expectation of increased boron demand prompted a few companies to continue investment efforts in new borate refineries in the United States. Two Australian-based mine developers previously confirmed that production of high-quality boron

products would be possible from their projects in California and Nevada, respectively. These companies continued to make progress on their respective projects by acquiring some of the permits and funding necessary to begin and continue construction. The project in California continued construction as it neared the completion of its first phase. This project was expected to have a focus on specialty boron products for industries related to global decarbonization and food security once production starts.

These companies have the potential to become substantial boron producers when their projects are fully developed. The project in Nevada was offered a conditional commitment loan of up to $700 million with a 10-year term from the U.S. Department of Energy to fund the project. If work begins at the Nevada project, it was anticipated to create 600 construction jobs and up to 300 operation positions.

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# CEMENT

**by A.K. Hatfield, National Minerals Information Center, U.S. Geological Survey**

Portland, blended and masonry cements are construction materials that, when mixed with water, serve as the binder in concrete and most mortars. Cement contributes all of concrete's compressional strength, despite only comprising about 13 percent of its content by weight. Cements are made from a material called clinker, which is finely ground into a powder and mixed with a small amount of gypsum and potentially supplementary cementitious materials (SCMs). Clinker is produced from a precise combination of calcareous, aluminous, ferrous and siliceous materials, which are transformed through pyroprocessing of the requisite materials in a rotary kiln.

## Production and consumption

In 2023, production of cement in the United States, excluding Puerto Rico, was estimated to be 91 Mt, a slight decrease from 93 Mt in 2022. Production in 2023 was 8 percent lower than the record of 99.3 Mt set in 2005 (Fig. 1). Total world cement production in 2023 was estimated to be 4.1 Gt, unchanged from 2022. China (2,100 Mt), India (410 Mt), Vietnam (110 Mt), the United States (91 Mt) and Turkey (79 Mt) continued to be the leading producers in 2023. The United States manufactured about 2 percent of cement produced worldwide.

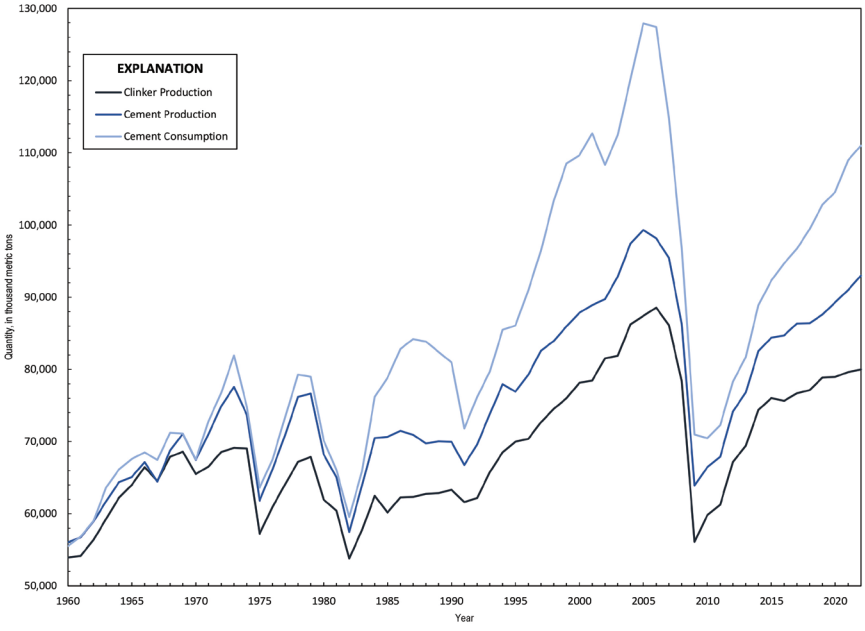
Domestic cement consumption in 2023, as measured by sales to final customers, was estimated to have decreased slightly to 109 Mt from 111 Mt in 2022 but was 15 percent lower than the 2005 record consumption of 127.9 Mt. The difference between consumption and domestic production in 2023 was met, in part, by imports, although total imports of hydraulic cement and clinker in 2023 were unchanged from 2022. Over the past 10 years, imports increased from 7.2 Mt in 2013 to 26.5 Mt in 2023, but imports in 2023 were still well below the record of 35.9 Mt set in 2006. The leading cement-consuming states continued to be Texas, California and Florida, in descending order by tonnage. The major end uses for cement in the United States are, in descending order by estimated market share, ready-mixed concrete, concrete product manufacturers, contractors and other customer types (such as building-material dealers, government, mining, oil-well drilling, waste stabilization and unspecified uses).

## Foreign trade

According to the U.S. Census Bureau, imports of cement and clinker by the United States, including Puerto Rico, in 2023 were 26.5 Mt, compared with 26.6 Mt in 2022. In 2023, Turkey (30 percent), Canada (19 percent), Vietnam (15 percent), Greece (8 percent) and Mexico (8 percent) supplied the majority of U.S. cement imports, with the remainder coming from several other countries. Exports of cement were 918 kt, essentially unchanged compared with 926 kt in 2022. Canada (84 percent), Mexico (6 percent)

## Figure 1

**U.S. clinker production, cement production and cement consumption, 1960–2023.**




and the Bahamas (4 percent) received the majority of U.S. cement exports, with the remainder going to several other countries and localities.

### Prices

The average mill net value ("price") of cement depends on application, quality, quantity purchased, source and type, and therefore encompasses a wide range of prices and was estimated to be $150/t in 2023. In recent years, increased prices have been partially attributed to increased costs of production, having increased from $127/t in 2021. During 2023, the overall estimated value of sales increased to a record-high $16.4 billion.

### Environmental issues

Large quantities of raw materials (mainly carbonate rocks, especially limestone) and fuels are burned at high temperatures to make clinker, resulting in emissions of large quantities of carbon dioxide ($CO_2$) and potentially significant emissions of nitrogen oxides, sulfur oxides, mercury and some other metals, volatile organic compounds and particulates. Increasingly, these emissions are being stringently regulated. The cement industry is one of the leading industrial emitters of $CO_2$, an important greenhouse gas.

### Outlook

The slight decrease in reported consumption of cement in 2023 likely resulted from decreased construction starts of new housing units, monetary policy actions focused on reducing inflation, as well as increased costs for energy, material and service inputs; labor and production shortages; and supply-chain disruptions.

Regulators continued to implement new measures designed to aid industry decarbonization efforts, such as green procurement strategies and research investments. Additionally, funding from the November 2021 passage of the Bipartisan Infrastructure Law continued to be allocated.

In 2022, several cement plants transitioned to portland-limestone blended cement (PLC) following its widespread acceptance by various authorities. In 2023, total blended shipments increased significantly, and 97 percent of the blended shipments were estimated to be PLC (Type IL). Additional company announcements that focused on sustainability and decarbonization efforts included the increased use of alternative fuels and alternative materials, carbon capture utilization and storage projects, increased energy efficiency and digitalization, and shifting to renewable energy sources. Development of other low-carbon and/or new blended cement product lines utilizing various SCMs, and innovative techniques, also progressed.

Imports are likely to continue to augment domestic cement supply to counteract reduced domestic production capacity resulting from kilns being idled owing to environmental concerns. In 2023, an upgrade and capacity expansion of a cement plant in Indiana was completed in June and work progressed on plans to increase the capacity of a cement plant in Texas. However, in 2022 and 2023, cement plant closures were announced at cement plants in California, Maine and New York.

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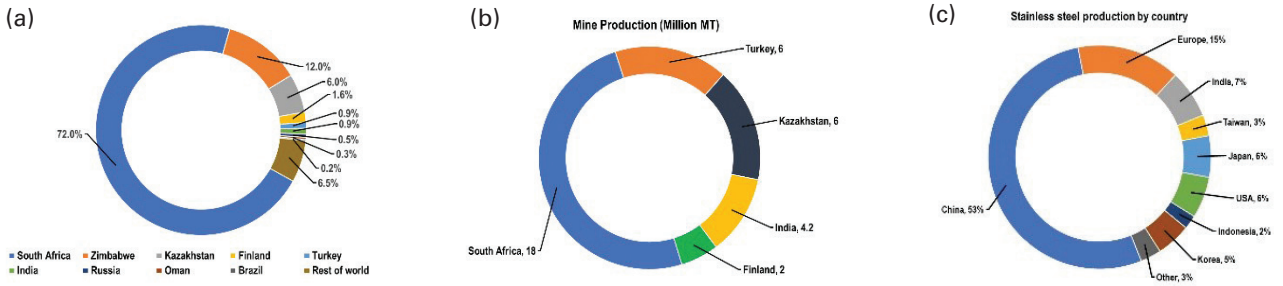
# CHROMIUM

**by Y. Rama Murthy, Research and Development Division, Tata Steel Ltd., Jamshedpur, India**

Chromium is a transition metal in Group VI of the periodic table. It is a very hard, crystalline steel-gray metal with an atomic number of 24 and a molecular weight of 528 g/cm$^3$. Commercial chromite deposits are

## Figure 1

**(a) Chromite reserves by country (Source: ICDA, 2021). (b) Top five chromium producing countries (updated 2024) (Source: Investingnews.com). (c) Stainless-steel production by country.**




found mainly in two forms: stratiform and podiform. Zimbabwe is the only country with notable chromite reserves in stratiform and podiform deposits.

### Production, consumption, import/export

The production of chrome ore has seen an increasing trend. The world's total chromium reserves amounted to 560 Mt as of 2023. The leading chromium producing country in 2023 was South Africa, which has the largest reserves globally. Globally, chromium mine production was 41 Mt, a significant increase from the 2010 production volume of 23.7 Mt. Turkey, Kazakhstan and India were among the other leading producers worldwide. The value of chromium consumption was estimated to be $830 million in 2023 (as measured by the value of net imports, excluding stainless steel), a 44 percent decrease from $1.5 billion in 2022. U.S. consumption was estimated to be about 4 percent of the world chromite ore production with a net import reliance of 74 percent. The major importers or consumers were China, Indonesia and Sweden. China is the leading producer of ferrochromium, followed by South Africa, Kazakhstan and India. Other producing countries include Albania, Brazil, Finland, Germany, Indonesia, Japan, Oman Sultanate, Russia, Sweden, Turkey and Zimbabwe.

### Reserves of chromite deposits

South Africa is home to the world's largest chromite resources, situated in the Bushveld Complex, the largest layered intrusion in the world. Geologists estimate the complex represents more than 80 percent of global chromite reserves, covering an area of more than 65,000 km$^2$ with thickness of 7 to 9 km. It contains dunites, pyroxenites, anorthosites and oxides (chromite and magnetite), and displays a well-marked horizontal layering, with layers a few millimeters to 100 m thick and exceptional lateral continuity. South Africa also supplies chrome ore as UG2 (Upper Group 2 reef) during the production of platinum group metals (PGMs). The supply of UG2, in addition to traditionally mined chrome ore, has changed the structure of the ferrochrome industry. The United States has about 630 kt of chromium reserves (less than 1 percent of the world reserves), primarily found in the Stillwater complex in Montana.

### Marketing, price, economics and transportation

Global chromite ore mine production was estimated to have decreased slightly in 2023 compared with 2022. Production in South Africa, the world's leading producer of chromite, decreased by an estimated 6 percent compared with 2022, owing to disruptions to the supply of electricity and problems with the transportation of ore via rail. In the last year, the average chromite ore price was $290/t, the highest in the past few years. China was the leading ferrochromium and stainless-steel producing country and the leading chromium consuming country.

### Industry news and issues

Depletion of high-grade reserves will create a serious problem for the future of the chromite industry. Ferrochrome production is an energy-intensive process. There is a need to investigate alternate renewable energy sources, such as hydro and wind, for sustainability. Further, a consistent supply of chrome ore at the right price, a steady power supply, reductants such as ultralow-phosphorus and low-phosphorus metallurgical coke, and favorable market conditions are needed. Novel agglomeration processes such as composite briquettes (stiff vacuum extruded briquettes) for utilization of ore fines, coke fines, and so on, need to be implemented. Further innovations are needed in process technology, process control, and plant simulations and equipment design, such as the development of novel ways for the effective utilization of wastes such as slag or sludge generated from ferrochrome plants. Compliance with stringent pollution control norms will be an increasing issue in the industry.

### Uses and new applications

The use of chromium in the metallurgical (about 50 percent), chemical (about 15 percent) and refractory (about 35 percent) industries is well known. It is an essential element in the production of a wide variety of stainless steels, alloy steels, nickel-chromium heating elements and plating metals. Chromium has critical applications in the aerospace, military, agricultural and engineering industries. Alloy 625 is used in seawater heat exchangers in oil refineries and

offshore topside applications. Chrome-nickel alloys (namely, Alloy 28, Alloy 825 and G3) are also used in oil country tubular goods (OCTG) seamless tubes. Alloy 28, which accounts for more than two-thirds of these tubes, contains between 26 and 28 percent chromium. Alloy 825's chromium content makes it resistant to a variety of oxidizing substances, such as nitric acid, nitrates and oxidizing salt.

Another major application for chrome-nickel alloys is in scrubbers used in the marine industry to reduce sulfur oxide ($SO_x$) emissions. Chemical-grade chrome ore represents 3 to 5 percent of the global chrome ore output used by the chrome chemical industry. Globally, around 80 percent of all leather is chrome-tanned. The chromite mineral is widely used in furnace linings as refractory.

## Trends and outlook

The continued demand for stainless steel in construction, automotive and other industries is expected to be a key driver for future chrome consumption. Chrome ore production has seen an increasing trend globally due to high prices and higher demand from China, whereas Europe and the Middle East region experienced improved demand for local smelters, which also led to an increase in the ore demand. Despite power/energy supply issues in South African countries and slower market demands, ferrochrome production is picking up.

## Environment, regulatory and reclamation issues

Chromium has three common oxidation states: Cr (II) and Cr (III), which are basic, and Cr(VI), which is acidic. Chromium in nature comes directly from mining and indirectly from tannery, chrome plating industries, chemical industries, and others.

At the trace level, the trivalent form is considered an essential nutrient; however, the hexavalent form of chromium is toxic, carcinogenic and mutagenic in nature. Considering its toxicity and carcinogenic nature, the maximum levels permitted in the United States for trivalent chromium in wastewater is 5 mg/L and for hexavalent chromium is 0.05 mg/L.

Numerous treatment technologies are available for chromium remediation, but the suitability/applicability of each method or technique depends on the nature and extent of contamination. Most of these methods suffer from technical and/or economic shortcomings, such as high capital and/or operational costs and/or the problems associated with the disposal of the residual metal-containing sludge. Long-term sustainable methods like bioremediation and phytoremediation are processes that can be adopted instead of disposal in tailing ponds. The tailings (or waste) from chrome ore processing plants (COPP) are disposed of through suitable systems, and the water is recovered back into the system for reuse. Water purification and disposal are expensive operations and are usually influential factors in the location and design of processing plants. All the technologies are well established in other areas of mineral processing; in the mineral industries, particularly in India, effective environmental controls and processing must be established on the plant scale.

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# CONSTRUCTION AGGREGATES

**by Venkata Aneesh Kona, engineering project manager, Vulcan Materials Company**

Construction aggregates include a broad category of coarse- to medium-grained materials used in construction, including sand, gravel, crushed stone, slag, recycled asphalt pavement (RAP) or recycled concrete, and geosynthetic aggregates. They are generally raw materials that are extracted from pits and quarries and are consumed by the concrete and asphalt industry.

Stone is mined and crushed from many rock types. The U.S. Geological Survey (USGS) lists the types of rock sold for construction aggregates as limestone, dolomite, marble, calcareous marl, shell, granite (granite, gneiss, granitic-type rocks), traprock (basalt, diorite, diabase), sandstone/quartzite, slate, volcanic cinder, scoria and miscellaneous materials. Some rock types such as shell, slate, calcareous marl, volcanic cinder and scoria generally cannot meet the specifications required in most states to be used in plain cement concrete (PCC) and asphalt mixtures. Volcanic cinder and scoria may be used as lightweight aggregate sources or in concrete blocks if the material meets the specifications set by that industry, although the percentage of total aggregates supplied by recycled materials remained very small in 2023.

## Production

The aggregates mining industry remains the largest mining sector in the United States in terms of

production by weight, volume and number of active operations. In 2023, the USGS estimates there was aggregates production from 3,500 rock quarries and more than 6,200 sand and gravel pits. The top 10 leading states in crushed stone production were Texas, Florida, Missouri, Pennsylvania, Ohio, Georgia, North Carolina, Kentucky, Tennessee and Illinois. In 2023, the USGS estimated that 1.54 Gt of crushed stone was produced, valued at more than $24 billion, a decrease in production of more than 0.6 percent compared with 2022 but an increase of 9.5 percent in value.

## Specifications and tests

Construction aggregates must meet various state, federal, municipal and sometimes local public-works and public-health department standards for septic sand filtration applications for use in projects for these agencies. Much of the physical testing required is set by ASTM International and the American Association of State Highway and Transportation Officials (AASHTO). Most states agencies base their specifications on those of ASTM and AASHTO. The Federal Aviation Administration and the U.S. Army Corp of Engineers (USACE) have their own specifications for airport runways and taxiways, jetties and armor stone. One test for armor stone used by the USACE is the so-called "drop test." This test requires one 3- to 5-t stone to be dropped about 9 m onto another 3- to 5-t stone. After the drop, the stones are inspected for open fractures, and large losses due to breakage. Generally, it is professional judgement by the engineers or geologists whether the armor stone will be rejected or approved. In addition, railroads have their specifications for ballast stone and traction sand. Traction sand must be dried, so it is supplied by the industrial silica sand industry.

One of the physical tests required by some state, federal and local regulators is the Los Angeles (LA) abrasion test. The LA method covers the procedure for testing coarse aggregates for resistance to degradation. The five-cycle magnesium or sodium sulfate soundness tests determine an aggregate's resistance to disintegration by weathering, particularly freezing and thawing cycles. The LA and soundness tests are initial tests that should be performed on coarse aggregates to determine suitability of the rock to meet specification before other required tests. Additional tests include deleterious material; particle size and shape; mineral contaminants, especially iron sulfide minerals and asbestiform/nonasbestiform minerals; specific gravity and absorption; acid-insoluble residue for skid-resistance (friction) aggregates; hardness and freeze-thaw; alkali silica or carbonate reactivity; and petrographic analysis.

Aggregates for skid-resistant or friction applications generally require all rock that passes physical specifications set by the agency to be noncarbonate. Therefore, limestone or dolomite cannot be used on the top course of most roads. Some states have a specification on the residue left after a certain-size carbonate aggregate is placed in concentrated hydrochloric acid and dissolved. If the residue left is significant enough, the material may be used on the top course of less-traveled roads. In recent years the Micro-Deval test has become popular in some states especially for testing aggregates for the asphalt industry. Officials report that it is a more accurate test for aggregate quality and durability than the LA abrasion test.

States require different tests, or limits on some tests to accommodate the rock or sand and gravel in their area. For example, the Texas Department of Transportation (TXDOT) allows an individual TXDOT regional engineer to decide whether to require a five-cycle sodium sulfate test or a five-cycle magnesium sulfate test on coarse aggregates (magnesium sulfate is harsher on aggregates). In Oregon, a dimethyl sulfoxide (DSMO) test is used to test some aggregates. South Carolina has higher loss limits on the LA abrasion test than most surrounding states, and the New York State Department of Transportation Bureau of Materials requires a 10-cycle magnesium sulfate test on coarse aggregates.

## Markets and transportation

The results of some or all of the physical tests determine the marketability of the product. Aggregates that do not meet certain specifications are sold for low-grade construction products or as nonstate-specification aggregates. Being an approved aggregate source by the state, federal or other approval agencies is an advantage in the marketplace.

Construction aggregates markets can range from low-grade material, such as fill, road base and miscellaneous products, to washed and sized aggregates sold to ready-mix concrete and asphalt producers. The market area is generally within trucking distance of the mine site, as trucks transport about 85 percent of aggregates in the United States. Rail and barge or ship transport together total about 15 percent. As an industry rule of thumb, trucks can generally travel 56 to 64 km (35 to 39 miles) before transportation costs increase significantly. These costs depend on many factors such as road conditions, weather, traffic, tolls, bridges, back hauls and weight laws. For example, relatively straight roads with limited traffic signals can allow trucks to carry material much farther than 64 km at low rates. Conversely, in areas near New York City, Atlanta, Dallas/Forth Worth, Los Angeles and other major cities, trucks are slowed by traffic congestion, traffic signals and tolls. Thus, freight rates are much higher. In these cases, many of the trucks charge an hourly rate. Most aggregates producers do not own their own trucks for delivery and use contract trucking companies. In recent years, the rule of thumb has changed as quarries and sand and gravel pits are

being permitted farther from urban areas, where most of the material is consumed. Truck rates affect many operations on pricing and bidding projects.

Rail rates are lower than trucking rates, but rail limits the areas of service. The producer using rail generally owns or leases a siding on both the production and distribution ends. Once the product is stockpiled in the distribution yard, extra costs can include storage, loading and unloading. Rail companies such as CSX that are in need of railroad ballast would get their material from producers that have railroad access presence on site. Many producers that have rail access generally supply the railroad ballast stone market, as rail companies send their own railcars to be loaded at that quarry.

Barge and ship rates are generally lower than rail, and similarly with rail service, the producer is generally on or near navigable water. A small river barge can carry approximately 1,400 to about 2,900 t of aggregates. Larger barges can carry about 6,350 t. Generally, several river barges are grouped (tied) together and pushed by a tugboat. Producers on or near the Mississippi, Missouri, Ohio, Delaware, Potomac, Hudson and Columbia Rivers use river barges to deliver aggregates to markets in need of crushed stone and sand and gravel. American Bureau of Shipping (ABS) barges or oceangoing barges carry approximately 8,200 t. Some of these barges deliver aggregates through the Intracoastal Waterway and the Great Lakes. Oceangoing ships can carry approximately 32,600 t and the larger Panamex ships can carry approximately 54,400 t of aggregates. The time it takes to unload or load the material (demurrage) and all other handling of material increases final costs at the dock.

## Crushed stone, sand and gravel

Sand and gravel as a category of construction aggregates is used for many of the same purposes as crushed stone. Geology plays a large role in determining the use of crushed stone or sand and gravel in geographic regions. In California, where large alluvial fan deposits are located, sand and gravel is widely used. Glacial deposits are generally mined in the Northeast and North Central states, colluvium and river deposits in Western states, and river deposits in the Mid-South. Where there are large deposits of rock, crushed stone is generally used. Natural sand is generally preferred over manufactured sand (stone crushed to sand size) by most ready-mix concrete and asphalt producers. Crushed stone is preferred over crushed gravel for the same use, if available. In both PCC and asphalt, crushed stone consists generally of one rock type while crushed gravel may contain several lithologies or rock types. In ready-mix concrete and asphalt, different lithologies may absorb varying amounts of water or react differently to the cement or cement additives. In addition, liquid asphalt added to the asphalt mix may not adhere to certain aggregate types, such as quartzite, and large mineral crystals in the rock matrix having a vitreous or glassy luster, and may strip. The producer may have to add antistripping chemicals, thus increasing costs. Sand for use in PCC has been increasingly difficult to find. Sand may seem ubiquitous, but many deposits of natural sand are too fine-grained to meet ASTM C-33 gradation specifications.

In 2023, the USGS estimates that 920 Mt of sand and gravel were produced in the United States, valued at over $11 billion. The 10 leading producing states of sand and gravel were California, Texas, Minnesota, Arizona, Michigan, Utah, Washington, Colorado, Ohio and New York. Most of the sand and gravel production in 2023 was used by PCC aggregates. These leading states have mines in alluvial fans, colluvium, river deposits and glacial deposits. Most specifications required by states for crushed stone are the same for sand and gravel aggregates with a few exceptions; one is that natural gravel must be crushed to meet PCC and asphalt specifications. Natural gravel or gravel that is not crushed is generally used for landscape products, flat commercial roofing material and filtration media. This is generally low-volume, high-price material. Commodities that saw declines in November 2023 from November 2022 included crushed stone and sand and gravel, down approximately 8 percent year over year.

## Recycling and substitutes

RAP and recycled concrete usage are becoming more prevalent in the industry. This material is generally crushed and sized for use as base materials and other low-grade construction aggregates. The material does not meet state specifications for approved PCC or asphalt aggregate. The USGS reports that recycling is a small percentage of aggregates consumption. Substitutes for natural aggregates such as iron or steel slag have quality and environmental issues. Steel slag can cause expansion cracks in concrete, and the stockpiling of slag may release pollutants over time.

Some asphalt producers are recycling asphalt roofing shingles to limit or replace the buying of liquid asphalt for the mix. The oil from the shingles is extracted during the heating process at the plant and added to the mix. Sand is used as a filler in asphalt. The specifications are less rigid than sand used for PCC. One major difference is that asphalt sand is not washed. Many asphalt producers have stockpiles of RAP on their sites and are blending washed concrete-grade sand with RAP for filler material. RAP has an abundance of fine-grained material and therefore the producer uses washed concrete sand to reduce the proportion of finer material. In some areas of the country, concrete sand producers are providing washed sand to both ready-mix concrete and asphalt producers, creating more of a shortage of specification concrete sand.

Crushed glass in asphalt (glassphalt) replacing some aggregates has gained acceptance as a substitute with some producers. Recycled tire rubber and cellulose fiber are also used in asphalt. The main issue with recycled materials in asphalt is implementing a proper and acceptable mix design to the customer.

## Issues

Construction aggregates have many issues facing the industry. As the aggregates industry is the largest mining sector in the United States, the general public is exposed to their operations more than any other mining industry. Although the industry has come a long way in mitigating many of the environmental concerns of local citizens, the fact remains that opposition from NIMBY (not in my backyard) citizens denies or slows the process of permitting or expanding an aggregates mine. In 2023, denials of permits continued in several U.S. states. All the aggregates producing companies have environmental/compliance managers who handle environmental issues and permitting. Many use open houses or environmental days at their mine sites to educate the general public and schoolchildren on the importance of construction aggregates in everyday lives. Because about 85 percent of aggregates production is transported by truck, truck traffic remains a concern to local citizens and is difficult to mitigate. Dust, noise, vibrations, wetlands issues and safety issues have been largely mitigated through the years in most operations.

## Industry news

Caterpillar and Luck Stone announced a collaboration to deploy Caterpillar's autonomous solution to Luck Stone's Bull Run Plant in Virginia. CRH Ventures is to explore autonomous hauling technology with SafeAI, with a pilot program at its most prominent facilities. Women in Aggregates is a new group dedicated to supporting women working in the aggregates industry. Aggregates producers are encouraging employee participation in this group and fostering their mission.

In September 2023, Summit Materials announced a deal to purchase Cementos Argos' operations in the United States, combining Summit and Argos North America Corp. Holcim US continued to strengthen its position in Colorado with its third acquisition (Tezak) in the rapidly growing state. California-based Granite Construction acquired the Brunswik Canyon quarry and asphalt plant in Carson City, NV, and also acquired Memphis-based Memphis Stone & Gravel along with its partner company Lehman-Roberts. SGI Acquired Panamint Valley Limestone, based in California. BMC Enterprises Inc., the largest producer of aggregates in the St. Louis region, acquired Raineri Building Materials, Eureka Materials and Blue Grass Ready Mix. CRH has completed its acquisition of a portfolio of cement and ready-mix concrete assets from Martin Marietta Materials. SRM Concrete announced the strategic acquisition of Vulcan Materials Co.'s ready-mix assets in Texas.

Overall, all the public companies reported at least 5 percent growth in revenues for 2023. Private, nonreporting companies are also ready to participate in merger-and-acquisition opportunities. For example, the new Armada Materials, which was formed with the backing of private equity group Kelso & Co., acquired Tennessee-based Volunteer Materials. Producers remain confident in the industry despite inflation, elevated interest rates and other dynamics that could otherwise limit the growth of their businesses.

## Health and safety

The Mine Safety and Health Administration (MSHA) continues its inspections and enforcement of safety in the industry. Most large aggregates operations have health and safety managers on staff to help comply with MSHA regulations and welcome practical inspections. However, MSHA inspectors often cite violations based on rule with little flexibility. Each aggregates mine is different and a one-size-fits-all approach to safety does not always work.

MSHA drafted a rule on respiratory crystalline silica that would require mine operators to maintain miners' permissible exposure limit at or below 50 µg/$cm^3$ of air for a full-shift exposure, calculated as an eight-hour time-weighted average. This issue is of great concern to producers because most igneous, metamorphic and sedimentary-type rocks mined for aggregates contain some amount of coarsely crystalline or cryptocrystalline varieties of quartz ($SiO_2$), and because quartz is extremely resistant to both mechanical and chemical weathering, it is found in most unconsolidated sand deposits and gravel deposits.

Although 2023 was a good year in terms of construction aggregates production, the industry had its deadliest year in a decade in 2023, as 40 miners died in accidents across the United States. The 40 fatalities were the most in a single year industrywide since 2014. MSHA provided details about the fatalities in reports on its website, attributing the accidents to nine general causes. It characterized 16 of the fatalities as involving machinery, with 10 classified as powered haulage accidents. Combined, machinery and powered haulage accounted for 65 percent of mine fatalities in 2023. The other fatalities were classified in seven different ways: electrical accidents (3); slip or fall of a person (3); drowning (2); fall of roof or back (2); falling, rolling or sliding rock or material of any kind (2); fall of face, rib side or highwall (1); and handling material (1).

## Outlook

Forecasters seem reluctant to speculate on aggregates market growth in 2024 but most report that it is predicted to be a good/decent year. The industry

continued to address health and safety regulations, permitting and zoning issues, and environmental restrictions in 2023.

The 2021 Infrastructure Investment and Jobs Act reauthorizes surface transportation programs for five years and invests in additional funding to repair roads and bridges and support major, transformational projects. Shortages of construction materials in some urban and industrialized areas are expected to continue to increase owing to local zoning regulations and land-development alternatives. These issues are expected to continue and to cause new crushed-stone quarries to be located away from large population centers. Resultant regional shortages of crushed stone and higher fuel costs could result in higher-than-average price increases in industrialized and urban areas.

Large urban areas such as Atlanta, GA; Dallas/Fort Worth, TX; New York City, NY; Los Angeles and San Francisco, CA; Miami, FL and other metro areas always need large amounts of construction aggregates and this will continue to drive the market.

# DIATOMITE

**by R.D. Crangle Jr., , National Minerals Information Center, U.S. Geological Survey**

Diatomite is a chalk-like, soft, friable, very-fine-grained, siliceous sedimentary rock. Typically light in color (white if pure, commonly buff to gray in situ), diatomite is also very finely porous, very low in density, and essentially chemically inert. Diatomaceous earth is a common alternate name, but the term is more appropriate for unconsolidated or less lithified rock of the same origin. Diatomite deposits accumulate in oceans or fresh waters from the cell walls of diatoms, composed of amorphous hydrous silica. Diatoms are microscopic, single-celled organisms, often appearing as colonial aquatic plants (algae). Diatom cells contain an elaborate internal siliceous skeleton. More than 10,000 living diatom species have been identified, in addition to another 10,000 known diatom fossil forms.

## Production, exports and imports

Diatomite deposits are usually mined as openpit operations. If necessary, the mined crude ore is dried and crushed. Dried diatomite is collected in cyclones and fed through air separators to remove coarse material and impurities. Calcination and flux calcination are used to thermally volatilize organic material and oxidize iron. Calcination also is used to increase diatomite hardness, specific gravity and refractive index. The fusing of small diatomite particles into clusters can also be accomplished through calcination, which results in increased pore size and volume. Diatomite products are sold as various grades of calcined powders.

The United States continues to be the world's leading producer and consumer of diatomite. Production of diatomite in the United States during 2023 was estimated to be 830 kt (910,000 st), essentially unchanged from 827 kt (910,000 st) in 2022. Six companies operated 12 mines and nine processing facilities in California, Nevada, Oregon and Washington. According to the U.S. Census Bureau, U.S. diatomite exports were 53.4 kt (58,900 st). Imports were lower at 11.6 kt (12,800 st). Total world production of diatomite was an estimated 2.6 Mt (2.9 million st) in 2023. Following the United States, other significant diatomite producers in 2023 were Denmark (440 kt or 490,000 st), China (270 kt or 300,000 st), Turkey (210 kt or 230,000 st), and Argentina, Mexico and Peru (each with 100 kt or 110,000 st). World resources of crude diatomite appear to be adequate for the foreseeable future. However, increased transportation costs may encourage the development of sources of material closer to markets.

## Prices

The unit value of diatomite varied widely by end use in 2023. The estimated annual average unit value of diatomite in 2023 was $410/t ($370/st), essentially unchanged from 2022. Diatomite used as an absorbent and as a lightweight aggregate in cement was priced at about $10/t ($9/st), but specialty grade diatomite, used in art supplies, biomedical applications or cosmetics, could be priced more than $1,000/t ($900/st).

## Consumption

Domestic apparent consumption in 2023 was estimated to be 780 kt (860,000 st). The internal structure and inert chemical composition of diatomite make it an excellent raw material for filtration, absorbent and filler applications. Filtration, especially the purification of beer, liquors and wine, and the cleansing of greases and oils continued to be the largest end use for diatomite. Other applications included the removal of microbial contaminants, such as bacteria, protozoa and viruses, from public water systems. The use of diatomite as a filler, which serves to displace higher-cost raw materials, and in pharmaceutical applications, including the filtration of human blood plasma, continues to increase, as has its use as an insecticide base and in cement and concrete pozzolan. In 2023, approximately 50 percent of diatomite was utilized in filter aids. The remaining 50 percent was used in abrasives, absorbents, cement, fillers, insulation, lightweight aggregates and other unspecified uses. A small amount, less than 1 percent, was used for specialized biomedical and pharmaceutical purposes.

### Substitutes

Many materials can be substituted for diatomite, especially for lightweight aggregates purposes, such as expanded perlite and silica sand. Synthetic filters, including ceramic, polymeric or carbon membrane, and cellulose fibers offer competition as filter media. Alternate filler materials include clay, ground limestone, mica, perlite, silica sand, talc and vermiculite. For thermal insulation purposes, materials such as specialty brick, various clays, mineral wool, expanded perlite and exfoliated vermiculite may be used. Many alternatives exist for diatomite as a pozzolan, but its use as an ingredient of portland cement has increased in recent years. The encroachment of natural and synthetic substitute materials into diatomite markets has not been significant.

### Outlook

Adequate supplies of diatomite are likely to remain available for the foreseeable future. The economic stability of the diatomite industry was largely owing to its use as a filtration medium, where demand remains strong and is not sensitive to economic cycles.

This is particularly so in the filtration of spirits, as well as human blood plasma and other biotechnical applications.

Likewise, the substitution for diatomite by more advanced filtration products, including carbon membranes, ceramics and polymers, was not a concern in 2023. The high costs associated with these alternatives and a cultural preference toward the use of diatomite in the brewing and wine industries indicate a strong likelihood for the continued widespread use of diatomite in filtration.

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## DIMENSION STONE

**by Jason Williams, National Minerals Information Center, U.S. Geological Survey**

Dimension stone is natural rock material quarried for the purpose of obtaining blocks or slabs that meet specifications as to size (width, length and thickness) and shape. Color, grain texture and pattern, and surface finish of the stone also are normal requirements from customers and the stone industry. Although various igneous, metamorphic and sedimentary rocks are used as dimension stone, the principal rock types are granite, limestone, marble, sandstone and slate.

### Production

Approximately 2.3 Mt of dimension stone, valued at $410 million, was sold or used by U.S. producers in 2023. The amount and value were both approximately 3 percent less than in 2022. Dimension stone was produced by approximately 176 companies conducting mining operations at 224 quarries in 33 states. Leading producing states were Texas, Wisconsin, Indiana, Vermont and Georgia (in descending order by tonnage). These five states accounted for about 70 percent of dimension stone production and contributed about 60 percent of the total value of domestic production. Approximately 51 percent, by tonnage, of dimension stone sold or used was limestone, followed by granite (20 percent), sandstone (14 percent), dolomite and quartzite (4 percent each), and the remaining 7 percent was divided, in descending order of tonnage, among miscellaneous stone, marble, traprock and slate.

### Consumption and pricing

Rough stone represented 58 percent of the tonnage and 51 percent of the value of all the dimension stone sold or used by domestic producers, including exports in 2023. The leading uses and distribution of rough stone, by tonnage, were in building and construction (62 percent) and in irregular-shaped stone (29 percent). The leading uses and distribution of dressed stone, by tonnage, were in ashlars and partially squared pieces (47 percent), curbing (12 percent), slabs and blocks for building and construction (11 percent) and flagging (11 percent).

The average price per ton as reported by domestic producers for dimension stone was $175/t. By value, the leading sales (or uses) were for limestone (49 percent), followed by granite (25 percent), sandstone (9 percent), dolomite and quartzite (4 percent each), slate and marble (3 percent each), and traprock (less than 1 percent). Prices are substantially different not only for the type of stone but also for the appearance of the same type of stone. Color, grain structure, and finish contribute significantly to price and marketability.

### Foreign trade

According to the U.S. Census Bureau, Italy, China, Turkey, Brazil and India were the leading sources of dimension stone imports into the United States in terms of value in 2023. More than 81 percent of the total value of U.S. dimension stone imports came from those five countries in 2023. The value of imports from Canada and Mexico accounted for 8 percent of total dimension stone imports, and the remaining 11 percent was distributed among 88 different countries or localities. Canada received approximately 56 percent

of the total value (and 83 percent of the tonnage) of U.S. dimension stone exports in 2023. Italy, China, the Bahamas and Mexico were also other significant destinations of U.S. dimension stone exports, together accounting for 29 percent of the total value and 12 percent of the tonnage. The remaining 15 percent of the total dimension stone export value was divided among 78 different countries and localities.

## Outlook

The funding of construction projects continued through the 2021 Infrastructure Investment and Jobs Act with more than $370 billion in awards announced. In 2023, U.S. construction spending increased by an estimated 6 percent from spending in 2022. However, there was an estimated 13 percent decrease in new housing starts in 2023 compared with 2022. Lower demand for dimension stone products for residential construction might offset some of the increased consumption for public construction projects if the residential housing market slows in the coming year.

The Dimension Stone Committee of ASTM International proposed a new standard that tests the physical properties of dimension and other natural building stone under freeze-thaw conditions. The testing procedures would produce additional data on the mechanical performance of different building stones that are subjected to especially cold and harsh environments. The dimension stone industry continued to address safety and health regulations and environmental restrictions in 2023, especially those concerning crystalline silica exposure. In 2016, the Occupational Safety and Health Administration finalized new regulations to further restrict exposure to crystalline silica at quarry sites and other industrial operations that use materials containing it. Final implementation of the new regulations took effect in 2021, affecting various industries that use materials containing silica. Most provisions of the new regulations became enforceable on June 23, 2018, for general industry and maritime operations.

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# FRAC SAND

by Jack Sackrider, P.G., Westward Environmental Inc.

In 2023, the hydraulic fracturing sand (commonly known as frac sand) market was valued at around $7.6 billion globally. Although demand for frac sand increased, spot prices declined significantly in 2023. The Permian Basin again accounted for just over half of total U.S. proppant demand, with consumption increasing 10 percent year over year.

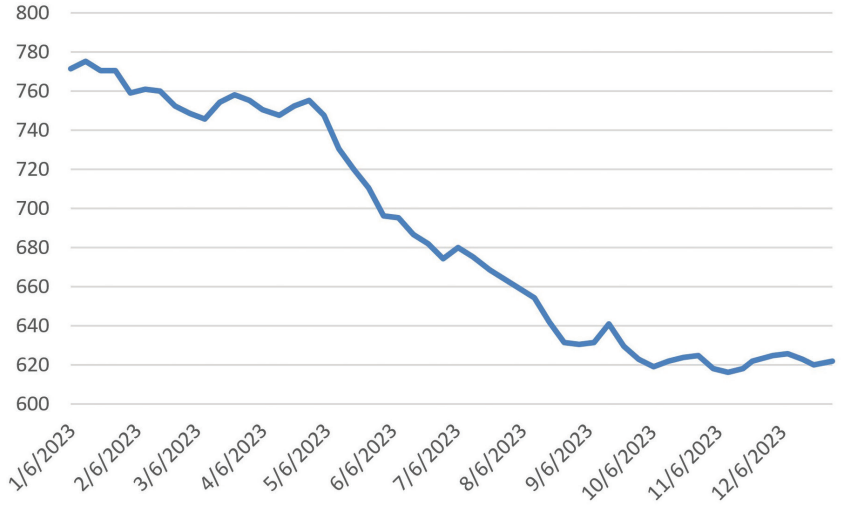
Frac sand is a high-purity silica sand with specific physical and chemical properties. In the fracking process, a mixture of sand, water and other compounds are pumped down a well at high velocities into very small, induced fractures. The frac sand particles become lodged in the fractures, "propping" them open to allow increased flow of oil and natural gas from the well. A range of particle sizes is typically used during the fracking process. These size ranges are often referred to as the mesh and are based on the ASTM International test sieve sizes. Product mesh sizes include 20/40 mesh, 30/50 mesh, 40/70 mesh and 100 mesh, which is sometimes referred to as 70/140 mesh. The name defines the particle size range, and the two numbers separated by a slash indicate sieve size. By convention, the size range includes particles small enough to pass through a sieve indicated by the first number but are retained on a sieve of the second number.

The American Petroleum Institute (API) and the International Organization for Standardization (ISO) have published testing procedures and standards for frac sand, which are defined in API RP 19C/ISO 13503-2, "Recommended Practice for Measurement of Properties of Proppants Used in Hydraulic Fracturing and Gravel-packing Operations." Beyond size, ideal frac sand material will exhibit the following:

- High silica content: Mineralogical purity is indicative of a mature deposit that has endured physical and chemical weathering, reducing impurities that are physically weaker or that may negatively interact chemically with other fracking fluids.
- Homogeneous grain size: Individual well conditions drive completion design, and desired grain sizes and mixtures are designed to optimize recovery. In general, larger grains increase permeability but are less durable, while smaller grains are stronger and result in less permeable conditions.
- High sphericity and roundness: Sometimes referred to as the Krumbein shape factor, sphericity and roundness primarily impact grain strength and completed porosity. More rounded and spherical grains are generally stronger and result in an increased flow of oil and gas during extraction.
- High crush resistance: In order to be effective, individual grains must be able to withstand pressures of 2,000 to 10,000 psi or more. Crush resistance is measured as a percentage of fines generated when a sample is exposed

## Figure 1

**Total U.S. rig count, 2023.**




to increasing pressures. A k-value is assigned, indicating the greatest pressure withstood while generating not more than 10 percent fines by weight. For example, a k-value of 9 indicates a sample generating no more than 10 percent fines by weight when subjected to 9,000 psi, but more than 10 percent fines when subjected to 10,000 psi.

- Low solubility: Solubility tests provide an indication of the amount of undesirable contaminants. Exposing a proppant to a 15 percent solution of hydrochloric-hydrofluoric acid (HCl-HF) may result in the dissolution of part of the proppant, which can reduce fracture permeability.
- Low turbidity: Turbidity is a measure of clays, silts and other fine-grained impurities, which can negatively impact the fracking fluid.

These API standards represent ideal proppant material. However, in recent years, operators have made compromises in proppant quality to drastically reduce well completion costs.

### Uses

While there are few alternate uses for frac sand, geologic deposits yielding frac sand material can produce glass, foundry, recreational and construction sand, as well as high-purity ground silica products used in coatings, epoxies and ceramics.

### Production

Although it was a challenging year for tight shale plays with the total rig count decreasing, U.S. frac sand demand continued to increase, according to estimates from Lium Research, an energy market research firm. With frac efficiency gains and drilled but uncompleted (DUC) well inventory being drawn down, frac sand managed to squeeze out a 7 percent increase in consumption year over year in 2023. A new all-time high demand of 121 Mt was pumped for the year, according to data prepared by Lium Research. The Permian Basin accounted for just over half of total U.S. proppant demand, and consumption there increased 10 percent year over year.

The total North American rig count decreased in 2023. Based on data from Baker Hughes, the total rig count in the United States fell from a maximum of 775 to 622 by the end of 2023. The months of May through September saw the greatest reduction before the count leveled out in the fourth quarter.

### Pricing

West Texas Intermediate (WTI) oil prices in the first half of the year fluctuated between $67 and $83 per barrel. Beginning in July, prices increased steadily to a high of $93 per barrel in late September. Prices then fell in the fourth quarter, ending the year in the low $70s per barrel, according to data from www.macrotrends.net.

Although demand increased year over year in 2023, Lium Research estimates that spot prices for frac sand declined significantly in 2023 as supply additions outstripped demand growth and quarterly consumption peaked early in the year. For example, spot prices in the Permian Basin declined by about 40 percent during 2023, according to Lium Research data. As 2023 ended, both Permian and Eagle Ford local frac sand spot prices, free on board (FOB) from the mine, were hovering near two-year lows. In its Nov. 13, 2023 Benchmark and Analysis report, PanXchange cites a fourth-quarter average spot price for frac sand of around $33/t.

### Trends and outlook

The market research firm IMARC Group projects a frac sand market compound annual growth rate of 7.4 percent during 2024 to 2032, bringing the market to an estimated $14.7 billion by 2032. Increased demand for petroleum products globally is cited as a major market driver for more oil and gas drilling, and thus demand for frac sand.

Sustainable mining practices and logistics are gaining attention as energy efficiency and environmental responsibility occupy stakeholder concerns. North America continues to lead the market; however, markets in China and India represent growing market segments.

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# GEMSTONES

**by Donald W. Olson, National Minerals Information Center, U.S. Geological Survey**

## Production

The value of natural gemstones produced from U.S. deposits during 2023 was estimated by the U.S. Geological Survey (USGS) to be $9.9 million, essentially unchanged from 2022. U.S. natural gemstone production included agate, beryl, coral, diamond, garnet, jade, jasper, opal, pearl, quartz, sapphire, shell, topaz, tourmaline, turquoise and many other gem materials.

More than 60 varieties of gemstones have been produced from U.S. mines, but commercial mining of gemstones has never been extensively undertaken in the United States. Most U.S. gemstone production has been from relatively small mining operations, or production has been as a byproduct of the mining of other mineral commodities. In the United States, much of the current gemstone mining is conducted by collectors, gem clubs and hobbyists, rather than commercial organizations.

The commercial gemstone industry in the United States consists of individuals and companies that mine gemstones or harvest shell and pearl, firms that manufacture synthetic gemstones, and individuals and companies that cut natural and synthetic gemstones. The U.S. gemstone industry is focused on the production of colored gemstones and on the cutting of large diamonds.

During 2023, each of the 50 states produced at least $1,760 worth of gem materials. Ten states accounted for 89 percent of the total value, as voluntarily reported to the USGS by survey respondents. These states (listed in alphabetical order) were Arizona, Arkansas, California, Colorado, Idaho, Maine, Montana, Nevada, Oregon and Utah.

Some states are known for the production of a single gem material, such as Tennessee for freshwater pearls. Other states, including Arizona, California, Colorado, Idaho, Montana, Nevada and North Carolina, are known for producing a variety of gemstones. California and North Carolina have identified deposits of three of the most popular precious gemstones: emerald, ruby and sapphire. Both states reported production of emerald, ruby and sapphire during 2023, and diamonds have been found in both states in the past.

The USGS estimated the value of U.S. synthetic or manufactured gemstone production was $89 million in 2023. Reported output of synthetic gemstones was from eight companies in Arizona, California, Maryland, New York, North Carolina, Oregon, South Carolina and Wisconsin. Production included the manufacture of azurite, malachite, diamond, moissanite and turquoise.

## Consumption and uses

Although the United States accounts for only a small portion of the total global gemstone production, it is one of the world's leading gemstone markets. U.S. gemstone markets were estimated to account for more than 35 percent of world gemstone consumption in 2023. U.S. apparent consumption of unset gemstones decreased by 20 percent over the previous year during 2023 to an estimated $21 billion. The U.S. apparent consumption for unset gem-quality diamond during 2023 was estimated to be about $18 billion. U.S. apparent consumption for unset nondiamond gemstones totaled about $2.2 billion. The major uses for gemstones in the United States were in jewelry, for carvings, and in gem and mineral collections.

## Prices

Gemstone prices are governed by many factors and qualitative characteristics, including beauty, clarity, demand, durability, freedom from defects, perfection of cutting, and rarity. Colored gemstone prices are generally influenced by market supply-and-demand considerations, and diamond prices are supported by producer controls on the quantity and quality of supply. Diamond pricing in particular is complex; values can vary significantly depending on time, place, and the subjective evaluations of buyers and sellers.

## Imports and exports

Trade data in this report are from the U.S. Census

Bureau and were adjusted by the USGS. During 2023, total U.S. gemstone trade with all countries and localities was about $25.8 billion ($22.8 billion in imports plus $2.98 billion in domestic exports). In 2023, U.S. domestic exports of diamond were valued at $2.43 billion. U.S. domestic exports of gemstones other than diamond were valued at $547 million. U.S. imports of diamond were valued at $20.1 billion, and U.S. imports of gemstones other than diamond were valued at $2.70 billion.

The United States is a significant international diamond transit center as well as one of the world's leading gem diamond markets. The large volume of reexports shipped to other centers is one measure of the significance of the United States in the worldwide diamond supply network.

In a four-year (2019 to 2022) average of U.S. import sources by value, the leading gemstone sources were India, 47 percent; Israel, 27 percent; Belgium, 11 percent; and South Africa, 4 percent. Diamond imports accounted for an average of 89 percent of the total value of gemstone imports during 2019 to 2022.

## Outlook

During 2023, U.S. jewelers continued to expand their online business and sales from their websites. U.S. apparent consumption of gemstones has increased to and is continuing at prepandemic levels. The major U.S. gemstone trade shows are being held again.

During 2023, world diamond production decreased slightly from 2022 levels. By 2025, several large mines will reach the end of their mine lives, while only a few new projects are currently being developed. Online auctions gained a higher share of rough diamond sales. Global gemstone sales are expected to increase at a steady rate over the next five years.

Internet sales of diamonds, other gemstones and jewelry are expected to continue at a high level and to increase in acceptance, along with other forms of e-commerce that have emerged to serve the diamond and gemstone industries, partially replacing "brick-and-mortar" store sales.

More synthetic gemstones, simulants and treated gemstones are likely to enter the marketplace and necessitate more transparency in the industry trade standards to maintain customer confidence.

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# GRAPHITE

**by Andrew Stewart, National Minerals Information Center, U.S. Geological Survey**

Natural graphite is classified into three types: amorphous, crystalline flake, and vein. Amorphous graphite is the lowest quality and most abundant. Amorphous refers to its very small crystal size and not to a lack of crystal structure. Crystalline flake graphite is less common and higher quality than amorphous graphite. Flake graphite occurs as separate flakes that crystallized in metamorphic rock, and high-quality flake graphite can be four times the price of amorphous graphite. Vein graphite is the rarest, most valuable and highest-quality type of natural graphite. It occurs in veins along intrusive contacts, and it is only commercially mined in Sri Lanka. An additional type of graphite, synthetic, can be produced by heating petroleum coke to about 3,000 °C to convert the carbon to graphite.

Graphite has metallic and nonmetallic properties, which make it suitable for many applications. The metallic properties include electrical and thermal conductivity. The nonmetallic properties include high thermal resistance, inertness and lubricity. The combination of conductivity and high thermal stability allows graphite to be used in many applications, such as batteries, electrodes, fuel cells and refractories. Graphite's lubricity and thermal conductivity make it an excellent material for high-temperature applications because it provides effective lubrication at a friction interface while furnishing a thermally conductive matrix to remove heat from the same interface.

High-purity natural and synthetic graphites have played important roles in the emerging nonhydrocarbon energy sector and are used in several new energy applications. In energy production applications, graphite is used as pebbles for modular nuclear reactors and in high-strength composites for wind, tide and wave turbines. In energy storage applications, graphite is used in bipolar plates for fuel cells and flow batteries, anodes for lithium-ion batteries, electrodes for supercapacitors, high-strength composites for fly wheels, phase change heat storage, and solar boilers. In energy management applications, graphite is used in high-performance polystyrene thermal insulation and for silicon chip heat dissipation. These new energy applications use value-added graphite products such as spherical graphite, expanded graphite and graphene.

## Production

No natural graphite is mined in the United States, but five natural-graphite projects were under development in 2023. In Alabama, South Star Battery Metals Corp. and Westwater Resources Inc. continued development on the BamaStar and Coosa projects, respectively. Both companies were progressing preliminary economic assessments in 2023. In 2023,

Graphite One Inc. continued to progress a feasibility study for its Graphite Creek project in Alaska. In Montana, Reflex Advanced Materials Corp. continued development of the Ruby Graphite project, having completed a drill program in late 2023. In New York, Titan Mining Corp. began early exploration of the Kilbourne graphite target. The deposit is located on permitted property where Titan currently operates the Empire State zinc mine.

World production of natural graphite in 2023 was an estimated 1.60 Mt compared with 1.68 Mt in 2022. The leading producers of natural graphite in 2023 were China, with 1.23 Mt; Madagascar, 100 kt; Mozambique, 96 kt; and Brazil, 73 kt. These four countries contributed approximately 94 percent of the global natural graphite production.

## Consumption

U.S. consumption of natural graphite decreased by an estimated 5 percent to 76 kt in 2023 from 79.7 kt in 2022. Despite decreased consumption in 2023, U.S. consumption of natural graphite has increased 72 percent since 2019. The major uses of natural graphite in 2023 were batteries, brake linings, lubricants, powdered metals, refractory applications and steelmaking. The major uses of synthetic graphite in 2023 were batteries, electric-motor brushes, electrodes and graphite shapes.

A recent and growing area of graphite consumption is that of lithium-ion batteries, owing to increased demand for electric vehicles, portable electronic devices and other uses. Graphite is an essential component of many types of batteries, making up most of the material contained in the anode. Spherical purified graphite (SPG) is the specialized form of graphite used as battery anode material (BAM). SPG is produced from natural flake graphite concentrate, which has been rounded, micronized, purified to 99.95 percent and coated. Most SPG is produced in China. Anode material can be made with natural or synthetic graphite. Some companies combine natural and synthetic to utilize the strengths of each, especially in the electric-vehicle market.

## Prices

Prices for natural graphite largely depend on flake size, size distribution and carbon content. Prices for individual flake mesh sizes were unavailable. Estimated unit values of imports in 2023 were $565/t for amorphous, $1,200/t for flake and $2,500/t for vein graphite from Sri Lanka. According to China customs data, prices for uncoated spherical graphite exported to the United States were about $4,390/t in 2023, and prices for synthetic anode material were about $5,250/t.

## Foreign trade

U.S. trade data from the U.S. Census Bureau were analyzed by the U.S. Geological Survey (USGS). Total U.S. natural-graphite imports decreased by 18 percent in tonnage to 73.5 kt in 2023 from 89.2 kt in 2022, and the value decreased by 16 percent to $157 million in 2023 from $187 million in 2022. The decrease in natural-graphite imports resulted from decreases in quantity and in value of imports from China, Mexico and Madagascar, partially offset by a 136 percent increase in quantity and 127 percent increase in value of imports from Mozambique. Principal import sources of natural graphite, by tonnage, were China (40 percent), Mozambique (26 percent), Canada (10 percent), Mexico (10 percent) and Madagascar (8 percent).

Total U.S. synthetic-graphite imports decreased by 18 percent in tonnage to 124 kt in 2023 from 151 kt in 2022, and the value decreased by 9 percent to $575 million in 2023 from $635 million in 2022. The decrease in synthetic-graphite imports were largely driven by decreased imports from China, Mexico and Spain. Principal import sources of synthetic graphite, by tonnage, were China (60 percent), Mexico (15 percent), and Canada and Spain (5 percent each).

In 2023, U.S. imports of BAM, combined natural and synthetic, were approximately 39 kt, a decrease of 33 percent compared with approximately 58 kt in 2022. Most of this material came from China, with the rest coming from Japan and the Republic of Korea.

## Industry news

In 2023, two natural-graphite BAM facilities were under construction in the United States. Syrah Resources Ltd. was constructing a plant in Vidalia, LA, and Westwater Resources was constructing a plant in Kellyton, AL. Syrah was expected to begin commissioning of its plant in early 2024. An additional five plants were under early development in the United States.

In 2023, two synthetic-graphite BAM facilities were under advanced development. Anovion Technologies began construction at a facility in Bainbridge, GA. The new facility would add an additional 50-kt/a capacity to the current 5-kt/a capacity. In Chattanooga, TN, Novonix Ltd. continued development of a synthetic-graphite anode facility with an initial capacity of 3 kt/a, expanding to 20 kt/a at full capacity. The facility was expected to begin commercial operation in late 2024. The company also advanced plans for a new facility with capacity of 30 kt/a. Both Anovion and Novonix were recipients of U.S. Department of Energy grants through the Bipartisan Infrastructure Law in 2022.

In 2023, two companies were awarded grants toward development of their natural-graphite projects. In July, Graphite One was awarded a grant of $37.5 million through the Defense Production Act for its Alaska project. Additionally, in September the company was awarded a $4.7 million grant by the Defense Logistics Agency for the development of a graphite-based fire suppressant. In November, South Star was awarded a grant of $3.2 million through the

Defense Production Act to assist in development of its project in Alabama.

In October 2023, China announced export controls to take effect on Dec. 1 on certain goods, including flake graphite, BAM (natural and synthetic), expanded graphite and some synthetic-graphite products. Exporters would need to apply for a license, which according to one graphite producer, required export contracts, technical product specifications, and the identity of the end user as well as the specific end use. In November, Chinese exports of flake graphite and BAM increased by 203 percent and 160 percent, respectively, compared to October. In December, after the licensing requirement went into effect, Chinese exports of flake graphite and BAM were 81 percent and 80 percent lower, respectively, than in December 2022. Top recipients of flake graphite in December were Slovenia (29 percent), Russia (18 percent), Germany (11 percent) and Spain (10 percent). Top recipients of BAM (natural and synthetic) in December were the Republic of Korea (51 percent), Poland (16 percent), Hungary (16 percent) and Germany (12 percent). None of the flake graphite or BAM from China was exported directly to the United States in December.

Multiple natural-graphite mining projects continued to progress globally in 2023. In June, NextSource Materials Inc. announced first production at its mine in Madagascar. Production capacity was planned to be 17 kt/a, potentially expanding to 150 kt/a in phase two. In Brazil, South Star continued to construct a graphite mine, with first production expected in early 2024. Planned production during phase one was 5 kt/a, increasing to 50 kt/a in phase three. In Tanzania, Walkabout Resources Ltd. continued to develop the Lindi Jumbo graphite mine, expected to begin production in 2024. Upon completion, the mine was expected to have a capacity of 40 kt/a.

Graphite production in Ukraine continued to face disruptions owing to the ongoing conflict with Russia, which began in 2022. After the winter season shutdown, production restarted in April but continued to face energy supply disruptions related to the conflict. Prior to Russian military action, graphite production in Ukraine was about 10 kt/a.

## Outlook

Worldwide demand for natural and synthetic graphite is expected to continue increasing as more nonhydrocarbon energy applications that use graphite are developed. Steel production and other types of metallurgical activity, which are important consumers of graphite, are expected to increase as well. Global graphite consumption is expected to increase owing to new technologically advanced applications, such as aerospace applications, fuel cells, graphene, lithium-ion batteries, energy storage and pebble-bed nuclear reactors.

The lithium-ion battery industry has created high demand for natural flake graphite. This has led to large increases in exploration and development, with much of it focused on Africa. Projects are also under consideration in Australia, Canada, Finland, Greenland, Kazakhstan, Sweden and elsewhere.

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# GYPSUM

by R.D. Crangle Jr., National Minerals Information Center, U.S. Geological Survey

## Production

The United States was the world's leading producer and consumer of mined crude gypsum in 2023, with 47 companies mining gypsum in 15 states. U.S. production of crude gypsum was estimated to be 22 Mt (24.2 million st) in 2023, essentially unchanged from 2022. The average price of mined crude gypsum was $12.00/t ($10.90/st). Sales in 2023 of synthetic gypsum, most of which was generated as a flue-gas desulfurization product from coal-fired electric power plants, were estimated to be 15 Mt (16.5 million st) and priced at approximately $10.00/t ($9.10/st). Crude gypsum exports from the United States totaled 44.1 kt (48,600 st). Imports were 7.79 Mt (8.59 million st).

World production of gypsum in 2023 was estimated to be 160 Mt (176 million st), 3 percent more than in 2022. The United States was the largest producer of natural gypsum in 2023 with an estimated 22 Mt (24 million st), followed by Iran with an estimated 16 Mt (18 million st), China and Oman, each with 12 Mt (13 million st), Spain with 11 Mt (12 million st), and Thailand and Turkey, each with 10 Mt (11 million st). Crude gypsum production was reported or estimated in 77 countries in 2023.

## Consumption

Apparent consumption of crude gypsum was an estimated 45 Mt (50 million st) in 2023, 3 percent more than reported in 2022. An estimated 2.5 billion $m^2$ (27 billion sq ft) of gypsum-derived wallboard products were produced domestically in 2023. Synthetic gypsum accounted for 33 percent of total domestic gypsum consumption. Demand for gypsum depends principally on the performance of the building construction industry, particularly in the United States, where about 60 percent of consumed gypsum is used for building plasters, the manufacture of portland cement, and wallboard products. Gypsum has no practical substitute in the manufacturing of portland cement.

Approximately 700 kt (770,000 st) of gypsum scrap that was generated by wallboard manufacturing, wallboard installation and building demolition was recycled. That quantity included an estimated 600 kt (660,000 st) of preconsumer wallboard waste recycled by wallboard manufacturers, coupled with an estimated 100 kt (110,000 st) of post-consumer wallboard. Recycled gypsum was used primarily for agricultural purposes and as feedstock for the manufacture of new wallboard. Other markets for recycled gypsum include athletic field marking, cement production, as a stucco additive, grease absorption, sludge drying and water treatment.

## Trade

As a low-value, high-tonnage bulk commodity normally mined in openpit operations from deposits widely distributed throughout the world, gypsum tends to be consumed within the many countries where it is produced rather than exported. Less than 20 percent of the world's crude gypsum production was estimated to enter international trade. Only a few countries, such as Canada, Mexico, Spain and Thailand, were major crude gypsum exporters; of these, Canada and Mexico were significant exporters because of their large deposits in proximity to gypsum-consuming facilities in the United States.

## World resources

World gypsum reserves are large in major producing countries, but data for many countries are not available. Domestic gypsum resources are adequate but unevenly distributed. Synthetic gypsum,

most of which is byproduct from coal-fired power plants, coupled with substantial imports from Canada, augment U.S. domestic crude gypsum supplies for wallboard manufacturing in the United States, particularly in the Eastern and Southern coastal regions. Imports from Mexico supplement domestic supplies for wallboard manufacturing along portions of the U.S. West Coast. Large gypsum deposits occur in the Great Lakes region, the midcontinent region and several Western States. Foreign resources are large and widely distributed.

### Outlook

The use of synthetic gypsum may continue to grow, albeit at a slower pace. As power companies convert coal-fired electrical generation plants to natural gas to take advantage of an abundant and inexpensive supply of shale gas, the production of synthetic gypsum could further decline because fewer coal-fired power plants would be operating.

Nevertheless, the use of synthetic gypsum by U.S. wallboard manufacturers is likely to continue. Similarly, should the economy continue to expand, and if residential and commercial construction increases, gypsum consumption is also expected to increase in the near future.

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## INDUSTRIAL DIAMOND

**by Donald W. Olson, National Minerals Information Center, U.S. Geological Survey**

### Production, recycling and uses

During 2023, world production of natural and synthetic industrial diamond was estimated to be 15.5 billion carats, the vast majority of which was synthetic. Natural diamond resources have been identified in more than 35 countries. Natural industrial diamond was produced in at least 11 countries as a byproduct of mining gem-quality diamond, and an estimated 45 million carats were produced in 2023, essentially unchanged from the previous year. The leading five producing countries of natural industrial diamond, in descending quantity order, were Russia, Congo (Kinshasa), Botswana, South Africa and Zimbabwe, accounting for 97 percent of global production.

At least 15 countries have the technology to produce synthetic diamond, and synthetic industrial diamond was produced in eight countries during 2023. About 99 percent of the combined natural and synthetic global output was produced in China, Ireland, Russia, South Africa and the United States. During 2023, China was the world's leading producer of synthetic industrial diamond followed by the United States and Russia. In 2023, the two U.S. synthetic producers, one in Pennsylvania and another with facilities in Florida and Ohio, produced an estimated 150 million carats, valued at about $48 million. This production was entirely synthetic diamond bort, dust and powder, and grit. Also, in 2023, at least four U.S. firms manufactured polycrystalline diamond (PCD) from synthetic diamond dust and powder and grit. Data are not available for either domestic PCD producers or domestic chemical-vapor-deposition (CVD) diamond producers for quantity or value of annual production. Current trade and consumption quantity data are not available for PCD or for CVD diamond. Consequently, PCD and CVD diamond are not included in the industrial diamond quantitative data reported here.

The U.S. Geological Survey (USGS) estimated a total of 14 million carats of used industrial diamond, valued at about $640,000, was recycled in the United States during 2023. Of this total, an estimated 75,000 carats were recycled diamond stone with a value of $110,000 and the remainder was diamond bort, dust and powder, and grit. Diamond stone recycling operations have reduced in scale and number, owing to the lower price of newly produced synthetic industrial diamonds. Most of this recycled material was recovered from used drill bits, diamond tools and other diamond-containing wastes. Some diamond also was recovered from residues generated in the manufacture of PCD.

During the past 40 years, CVD diamond use has grown and has been increasingly accepted by multiple industries as an enhanced material of choice owing to its properties of exceptional strength, hardness, durability, stiffness, high thermal conductivity, chemical inertness and electrical isolation. Use of the CVD process facilitates depositing a layer of diamond with these properties on the surface of a tool. Initially, the CVD process was mostly used for growing thin- and thick-film PCD for cutting tools and dressing applications because of the mechanical properties of diamond.

More recent applications that take advantage of CVD diamond's mechanical properties include wear parts, such as watch gears and chemical-mechanical polishing pad conditioners. Diamond has tremendous potential for electronics applications because of its high thermal conductivity. It can significantly improve thermal management while remaining highly cost competitive with other materials. CVD diamond is

used in microelectronic components, such as high-speed processors, medical devices, wide-bandgap radio-frequency devices, power conversion devices, and optoelectronic devices (light-emitting diodes, laser diodes) that generate exceptionally high heat densities requiring innovative approaches to thermal management. Diamond coatings are increasingly being used in these applications because the thermal conductivity of diamond is 10 times that of silicon. Boron-doped diamond (BDD) electrodes for water treatment are attracting significant interest because of diamond's potential as an environmentally friendly, high-performance electrode material. BDD electrodes have many characteristics that make them ideal for eliminating organic contaminants from water.

In the past, diamond has been perceived as an expensive material, but advances in CVD diamond manufacturing, such as the development of microwave carbon plasma technology and the development of higher-throughput hot-filament CVD diamond reactors, have significantly reduced diamond costs and allowed for the use of CVD diamond for an increasing number of applications. In addition to the existing opportunities for synthetic diamond use as gemstones, research and development projects by several companies that use single-crystal CVD diamond materials in high-voltage power switches, lasers, quantum communications and computing, and water treatment and purification have been ongoing.

Research also was being done on the use of industrial diamond in medical applications such as bionic eye implants, bioimaging, biomarking, cancer treatments and surgical tools; in dental applications such as cavity treatments; in cosmetic applications such as beauty treatments, facial exfoliation and wrinkle treatments; in glass shaping and window production; in military uses; in sound speakers; in super lasers; and in many other applications.

## Consumption

The United States remained one of the world's leading consumers of industrial diamond in 2023. Estimated U.S. apparent consumption of natural and synthetic industrial diamond bort, dust and powder, grit and stones was 370 million carats, valued at $56 million. Industrial diamond is used for applications such as truing and dressing grinding wheels, production of fine wire, waterjet nozzles for material cutting, direct precision cutting and material processing, material testing, drilling, grinding, polishing and finishing materials. The major consuming sectors of industrial diamond are computer chip production; construction; drilling for minerals, natural gas and oil; machinery manufacturing; stone cutting and polishing; and transportation (infrastructure and vehicles). Highway building, milling, and repair and stone cutting consumed most of the industrial diamond stone. During 2023, more than 97 percent of the industrial diamond market used synthetic industrial diamonds because the diamond quality can be controlled, and properties can be customized to fit specific requirements.

## Prices

Both natural and synthetic industrial diamonds had prices with a range of values depending on their crystallinity, purity, shape, size, and in the case of synthetic, the absence or presence of metal coatings. During 2023, the average unit value for diamond bort, dust and powder, and grit material produced in the United States was $0.32/carat. According to the U.S. Census Bureau, U.S. imports of all types of industrial diamond had an average unit value of $0.18/carat in 2023. These imports were a combination of natural and synthetic diamond stone that had an average unit value of $14.19/carat and natural and synthetic diamond bort, dust and powder, and grit that had an average unit value of $0.16/carat.

## Foreign trade

During 2023, the United States led the world in industrial diamond trade. Trade data in this report are from the U.S. Census Bureau. U.S. imports of industrial-quality diamond stones (natural and synthetic) were 378,000 carats valued at $5.36 million from 12 countries or localities. U.S. imports of industrial-quality diamond dust, grit and powder (natural and synthetic) were 263 million carats valued at $41.9 million from 30 countries or localities. During 2023, U.S. exports of industrial diamond dust, grit and powder (natural and synthetic) were about 74 million carats valued at $43.3 million to 36 countries or localities.

## Outlook

China is expected to remain the world's leading producer of synthetic industrial diamond. The United States is expected to continue to be one of the world's leading consumers of industrial diamond into the next decade and likely will remain a significant producer and exporter of synthetic industrial diamond as well. Demand for synthetic diamond grit and powder is expected to remain greater than for natural diamond material. Constant-dollar prices of synthetic diamond products, including CVD diamond films, are expected to continue to decline as production technology becomes more cost effective; the decline is even more likely if competition from low-cost producers in China and Russia continues to increase.

Several of the world's largest diamond mines have matured, passed their peak production levels and closed in recent years, causing a decline in global output during the last two years, and additional mines are approaching the ends of their mine lives. As these mines are depleted, global production is expected to continue to decline further in quantity, and the global supply of rough natural diamond is forecasted to steadily decrease.

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U.S. Geological Survey, 2024, Mineral Commodity Summaries 2024—Diamond (Industrial): U.S. Geological Survey, p. 66–67, https://pubs.usgs.gov/periodicals/mcs2024/mcs2024-diamond.pdf.


# INDUSTRIAL GARNET

**by Donald W. Olson, National Minerals Information Center, U.S. Geological Survey**

Garnet's angular fractures, high hardness, specific gravity, chemical inertness and nontoxicity make industrial-grade garnet ideal for many applications. In addition, garnet is free of crystalline silica and can be recycled. Garnet is an umbrella name given to a group of complex silicate minerals, all with an isometric crystal structure and similar physical properties and chemical compositions. Higher-quality garnet is used as a loose-grain abrasive because of its hardness, while lower-quality garnet is used as a filtration medium because it is relatively inert and resists chemical degradation. Garnet is also being used as a proppant in oil and natural-gas well drilling. It may be mixed with other proppants when high temperatures are encountered or in very deep formations.

## Production

In 2023, industrial garnet was mined by three firms: one in Montana and two in New York. In 2023, U.S. production of crude garnet concentrate for industrial use (industrial garnet) was estimated by the U.S. Geological Survey (USGS) to be 68 kt valued at about $15 million, an 11 percent decrease in quantity and a 4 percent decrease in value compared with 2022. The decreases were due to the closing of the Emerald Creek Garnet Mine in Fernwood, ID in July 2022. The majority of industrial garnet mined in the United States was almandite (iron aluminum silicate). Some andradite (calcium iron silicate) also was mined domestically for industrial uses. Refined garnet material sold or used was estimated to be 120 kt valued at $52 million, essentially unchanged compared with 2022.

Total world industrial garnet production was estimated to be 970 kt, unchanged from 2022. Australia (390 kt), China (310 kt) and South Africa (180 kt) were the leading producers in 2023. The United States produced about 7 percent of the industrial garnet mined worldwide.

## Consumption

In 2023, apparent consumption of industrial garnet in the United States was estimated to be 210 kt, accounting for 22 percent of global garnet production. U.S. apparent consumption decreased by 35 percent compared with 2022.

Major end uses for industrial garnet in the United States, in descending order by estimated market share, include abrasive blasting, water-filtration media, water-jet-assisted cutting and other end uses, such as in abrasive powders, nonslip coatings and sandpaper. Domestically, the industrial sectors that consume industrial garnet include aircraft and motor-vehicle manufacturers, ceramics and glass producers, electronic component manufacturers, the petroleum industry, shipbuilders, textile stone washing, water-filtration plants and wood-furniture finishing operations.

## Prices

Prices for industrial garnet cover a wide range depending upon application, quality, quantity purchased, source and type. During 2023, estimated domestic values of industrial garnet crude concentrate averaged about $220/t. The unit values of refined garnet sold in the United States during the year averaged $430/t. The average customs unit value of U.S. garnet imports in 2023 was $211/t, an increase of 9 percent compared with 2022.

## Foreign trade

The industrial garnet market is competitive. Lower-priced foreign imports began displacing U.S. production in domestic markets during the 1990s. Since then, despite increasing domestic production in recent years, the United States has become increasingly dependent upon foreign sources of industrial garnet.

According to data from the U.S. Census Bureau that were adjusted by the USGS, U.S. imports in 2023 were estimated to be 150 kt, a decrease of 43 percent from 2022. Most of the decrease was attributed to large decreases in imports of garnet from South Africa and Australia. In 2023, South Africa (58 percent), Australia (23 percent), India (8 percent) and China (6 percent) were the leading suppliers of imports to the United States. U.S. exports were 20 kt, a decrease of 14 percent compared with 2022. U.S. exports of industrial garnet were shipped to Canada (57 percent), Mexico (19 percent) and Peru (3 percent), with the remainder going to several other countries and localities.

## Outlook

Industrial garnet will continue growing as an abrasive blasting medium, replacing silica sand for use in blast cleaning and surface finishing by the aircraft and the shipbuilding industries and by the oil and natural-gas industry. Garnet use will also continue growing as a water-filtration medium with the growing number of water-treatment plants worldwide. Higher production costs and tighter profit margins will continue to affect the industry.

To increase profitability and remain competitive with imported material, production may be restricted to only high-grade industrial garnet ores or those deposits that contain other salable mineral products, such as kyanite, marble, mica minerals, sillimanite, staurolite, wollastonite or metallic ores. Worldwide industrial garnet production is expected to gradually increase, with the highest growth in consumption in abrasive blasting and water-jet-assisted cutting.

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U.S. Geological Survey, 2024, Mineral Commodity Summaries 2024—Garnet (Industrial): U.S. Geological Survey, p. 76–77, https://pubs.usgs.gov/periodicals/mcs2024/mcs2024-garnet.pdf.

U.S. Census Bureau and Trade Mining LLC, data adjusted by the U.S. Geological Survey

## KAOLIN

**by Debashis Das, P.E., staff engineer, RESPEC**

The kaolin subgroup of layer silicate clay minerals includes halloysite, nacrite, dickite, kaolinite and odinite. Except for odinite and halloysite, these industrially essential minerals show the same chemical composition: $Al_2Si_2O_5(OH)_4$. Mainly formed by the weathering of feldspar and muscovite (for example, alteration of granitic rocks), kaolin minerals are prevalent in the sediments and soils of tropical and temperate regions. Kaolinite is used to manufacture a variety of brick, ceramic and cosmetic products and as filler material in plastic, paint, rubber and paper. This and other kaolin minerals have played a prominent role in human cultural history in the United States and abroad. Kaolin mining has a history in the Southeastern United States, notably, central Georgia (1897 to present), which, according to its Washington County residents, hosts the "kaolin capital of the world."

Key producing countries outside the United States include Uzbekistan, Ukraine, China, India, Germany, and the Czech Republic. Global players in the market include BASF SE, Sibelco and Imerys SA.

### Production and consumption

According to the U.S. Geological Survey's (USGS) 2024 Mineral Commodities Summary, domestic clay production in 2023 was estimated at 26 Mt for a total market value of $1.7 billion, with approximately 120 companies operating mines in 38 states. Kaolin minerals account for about 4.4 Mt, or 16.9 percent of all clay materials recovered in the United States. Half the total kaolin (about 52 percent) went into developing coatings, fillers, extenders and binders, while about 25 percent was used in ceramic products.

### Exports and imports

In 2023, the USGS estimated the United States exported 1.8 Mt of kaolin minerals to Mexico, China and Japan.

Compared to 2022, the total clay and shale exports decreased by 10 percent. By comparison, in 2023, only 0.15 Mt of kaolin was imported into the United States. Kaolin exports were valued at $288 million, and imports at $24 million, resulting in a positive U.S. trade balance of $264 million.

### Trends and outlook

According to Grand View Research Inc., the global kaolin market is forecasted to grow at a compound annual growth rate of 4 percent from 2024 to 2030. Investment in the construction market, increasing demand for paints and coatings, ceramic-based products and cement will drive market growth.

Emphasis on green construction will boost the kaolin market. According to a report from the World Bank's International Finance Corp., green construction will generate investment opportunities worth $1.5 trillion in emerging markets.

Increasing demand for plastics from the construction and packaging industries, especially in China and India, is also propelling the demand for kaolin. Plastics are used in façade panels, exterior coatings and carpentry, and the increasing number of nuclear families in India and China is promoting the demand for plastics.

However, market growth can be impeded by stringent regulations against kaolin mining. Many kaolin mines occur near biodiversity hotspots, potentially degrading water and air bodies. Introducing suspended particles into the air can cause respiratory problems, while the water generated from mining operations can alter the pH level and impact the aquatic flora and fauna. *References are available from the author.*

## KYANITE, ANDALUSITE AND SILLIMANITE

**by David W. Hawkins, Geology and Mineral Resources Program, Virginia Department of Energy**

### Economic deposits

Kyanite, andalusite, and sillimanite make up the sillimanite minerals group. These naturally occuring minerals are polymorphic ($Al_2SiO_5$) but have differences in their respective physical, thermodynamic and crystalline structure properties.

They generally occur as accessory minerals in rocks affected by high-grade regional or contact metamorphism. Stratiform replacement deposits also occur through alumina enrichment of silica-rich metasedimentary and metavolcanic rocks by hydrothermal alteration. Sillimanite may occur within mineralized quartz veins and pegmatites. Additionally, these minerals may occur in paleo and modern heavy-mineral beach and stream placers.

Economic and subeconomic concentrations of kyanite, andalusite and sillimanite occur in the Appalachian region of the Southeastern United States. Other known occurrences are in Alaska, California, Florida, Idaho, Nevada and New Mexico. Other economic occurrences outside of the United States include Australia, Brazil, Cameroon, Canada, China, Finland, France, India, Ireland, Kenya, Madagascar, Nigeria, Norway, Peru, Russia, South Africa, Spain, Ukraine and Zimbabwe.

## Industrial properties and uses

The high alumina content, and thermal and volumetric stability of these minerals make them useful for high-heat-intensive refractory applications, metallurgy, investment casting molds, glass manufacturing and ceramics. High-quality specimens have a market for use as gemstones. Synthetic mullite ($3Al_2O_3 \cdot 2SiO_2$) and silica are produced through calcination of these minerals at temperatures ranging from 1,250 to 1,650 °C. Synthetic mullite has a melting point of about 1,840 °C, which contributes to highly resistant ceramic products.

The majority of mined sillimanite group minerals are used in steel and iron manufacturing, so the production of iron and steel is a good proxy of global mineral production. A little less than a third of these minerals are used to produce ceramics, glass, nonferrous metals and cement. Other refractory uses include insulating brick, firebrick, refractory concrete, kiln furniture, mortar and gunning mix. Additional end products and uses include brake shoes and pads, abrasive products, electrical insulators, additives, fillers, and filtration of aluminum slag and impurities.

## Production and consumption

The U.S. Geological Survey (USGS) estimates global production at 467 kt in 2023, lower than the previous 2018-2022 five-year average of 562 kt. The 2023 estimate included 170 kt of andalusite from South Africa, 100 kt of andalusite from China, 82.4 kt of kyanite and calcined kyanite from the United States, 65 kt of andalusite from France, 40 kt of andalusite from Peru, and 10 kt of combined sillimanite and kyanite from India (not including reclassified beach deposits). 2023 production totals are based on preliminary estimates by the USGS and data from the Virginia Department of Energy's Mineral Mining Program.

In Virginia, Kyanite Mining Corp. (KMC) is the largest producer of industrial-grade kyanite and mullite under the trademark names Virginia Kyanite and Virginia Mullite, respectively. KMC has operated surface mines and processing facilities since 1945 in Dillwyn, VA and produces a range of milled kyanite and calcined kyanite (more than 55 percent $Al_2O_3$, less than 0.85 percent $Fe_2O_3$) products that are shipped mainly by truck to domestic customers and to port facilities for delivery to international customers. Ore deposit geology consists of kyanite quartzite associated with a sequence of interlayered felsic and mafic metavolcanic strata of Ordovician age. Ore-grade material contains 10 to 40 percent kyanite, averaging about 25 percent. In 2023, KMC reported production of approximately 82.4 kt of combined kyanite and mullite product. Annual production capacity at the Virginia operation is about 130 kt for commercial-grade kyanite concentrates and up to 39 kt for calcined kyanite per permit specifications and demand.

Resco Products Inc. (Piedmont Minerals Division) has mined andalusite from an andalusite-pyrophyllite ($AlSi_2O_5(OH)$)-sericite deposit since 1958 to produce high-alumina firebrick and other specialty foundry and ceramic products in Hillsborough, NC. The USGS reports that two companies, based in Alabama and Georgia, produce synthetic mullite from a combination of feedstock materials such as kyanite, kaolin and bauxite. Additional details on production volumes were not available for the southeastern operations.

Globally, South Africa, China, France and Peru produce most industrial-grade andalusite. Imerys Group is the leading producer, with operations in France and South Africa. Imerys Group has been mining in the Brittany region of France since 1970. The source of the andalusite near Glomel, France is highly weathered Ordovician-age schists adjacent to granitic rocks of the Armorican Massif. Imerys Group mines andalusite from the Rhino Mine in the Limpopo Province in South Africa. Mineral deposits are hosted in highly weathered pelitic rocks of the Pretoria Group associated with contact metamorphic rocks of the Bushveld Igneous Complex.

Andalusite Resources (Pty) Ltd mined andalusite between 2001 and 2019 in the Thabazimbi area of South Africa. ARM Andalusite Resources (Pty) Ltd took ownership of the mine in 2022 and is currently focused on making improvements to the facility. Andalucita S.A. has been recovering andalusite since 2009 in northern Peru, with an estimated production capacity of 50 kt as of 2018.

Xinjiang Xinrong Yilong Andalusite Co. Ltd, formerly known as Imerys Yilong Andalusite (Xinjiang) Co. Ltd, reported on its website that reserves of andalusite in China are estimated at 361 Gt. The website also stated that the company has an

annual production capacity of 40 kt for andalusite products.

India is the primary source for the global supply of sillimanite, with operations in the states of Maharashtra, Andhra Pradesh, Odisha and Kerala. Upward of 73 percent of the sillimanite resources occur in heavy-mineral-sand placers along India's modern beaches. The Indian Ministry of Mines estimates total resources of more than 72.3 Mt of sillimanite, which includes approximately 8 Mt in proven reserves. The Ministry of Mines estimates total resources upward of 105.7 Mt of kyanite, with 393 kt in proven reserves.

## Foreign trade and prices

The ore grade and purity, quantity, particle (mesh) size, packaging, monetary exchange rates, source and destination influence annual import and export prices for mineral commodities. In 2023, the U.S. Census Bureau reported global exports of approximately 43 kt of kyanite and 26 kt of mullite. Kyanite was valued at $428/t and mullite at $501/t. According to the U.S. Census Bureau, imports of sillimanite minerals to the United States were estimated at 5 kt in 2023.

## Trends and outlook

Refractory uses of these minerals are important for the global steelmaking industry; therefore, trends in steel production are associated with the market demand for the sillimanite minerals group. The World Steel Association estimated global steel production at 1,892 Mt in 2023. China leads in total steel production (1,018 Mt), comprising 54 percent of the global output for 2023. India (second), Japan (third), the United States (fourth) and Russia (fifth) round out the top five producers. Steel production in the EU, with a 2019-2023 five-year average of 142 Mt, was down 15 percent from the 167 Mt of the previous five years (2014-2018).

The United States will likely continue to see an increased demand for steel as a result of increased electric-vehicle manufacturing and available funds from the Infrastructure Investment and Jobs Act to spur new construction and improvement projects. Demand for raw materials associated with steel production is likely to continue to occur globally; however, effects from the COVID-19 pandemic, supply-chain disruptions and the ongoing Russia-Ukraine war may influence the scale of growth, particularly in European markets.

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# LIME

**by L.E. Apodaca, National Minerals Information Center, U.S. Geological Survey**

In 2023, all commercially produced lime (CaO, $Ca(OH)_2$) in the United States was manufactured from limestone or dolomite, but lime also can be produced from a variety of similar carbonate materials, such as aragonite, chalk, coral, marble and seashells, if they are of high chemical purity. The term lime in this article refers to high-calcium and dolomitic quicklime, their hydroxide (hydrated) forms and dead-burned dolomite.

In the United States, most lime (about 80 percent) is produced as quicklime. Hydrated lime (also called slaked lime) is a dry calcium hydroxide powder made from reacting quicklime with a controlled amount of water in a hydrator. Slaked lime is widely used in aqueous systems as a low-cost alkali to neutralize or balance acidity. Dead-burned dolomite is the primary form of lime used in refractories.

## Production and consumption

In 2023, an estimated 17 Mt of quicklime and hydrate was produced (excluding independent commercial hydrators), unchanged from 2022. At yearend, 28 companies were producing lime, including 18 companies with commercial sales and 10 companies that produced lime strictly for internal use (for example, sugar companies). These companies had 73 primary lime plants (plants operating quicklime kilns) in 28 states and Puerto Rico. Five of these 28 companies operated only hydrating plants in nine states. In 2023, the five leading U.S. lime companies produced quicklime or hydrate in 22 states and accounted for about 80 percent of total U.S. lime production. Principal producing states were Alabama, Missouri, Ohio and Texas. The United States was the world's second-ranked lime producer in the world after China.

Apparent consumption was estimated to be 17 Mt, unchanged from 2022. Major markets for lime were, in descending order of consumption, steelmaking, chemical and industrial applications (such as the manufacture of fertilizer, glass, paper and pulp, and precipitated calcium carbonate and in sugar refining), flue-gas treatment, construction, water treatment and nonferrous-metal mining.

## Foreign trade

According to the U.S. Census Bureau, imports of lime decreased by 3 percent to 343 kt in 2023 from 354 kt in 2022. Canada (73 percent) and Mexico (22 percent) were the leading sources of lime imports to the United States. U.S. lime exports increased by 14 percent to 344 kt in 2023 from 303 kt in 2022. Lime exports were primarily shipped to Canada (97 percent).

## Prices

The U.S. Geological Survey calculates unit values of lime products from the quantity and value data reported for lime sold or used by the lime producers on a free-on-board plant basis, including the cost of containers. These calculations provide average values that eliminate variables such as potentially significant differences between list prices and individual supply contracts. Lime prices are not published in trade publications. To avoid disclosing company proprietary data, value data for dead-burned dolomite have not been reported separately but are included within the weighted average of all types of lime. The total weighted average price of all quicklime sold or used was $155/t and of hydrate sold or used was $185/t in 2023, slightly higher and essentially unchanged from 2022, respectively.

## Outlook

Lime sales in markets such as chemical and industrial, construction and steel are expected to follow the trend in gross domestic product in the overall economy. The outlook for flue-gas systems (lime's third-ranked market) serving coal-fired power plants, incinerators and other industries is easier to predict. With the recent boom in natural-gas exploration, large increases in natural-gas reserves and low natural-gas prices, U.S. electric utilities have increasingly shifted their fuel use from coal to natural gas either by conversion of the coal-fired plants or by shutting down coal-fired plants. Natural gas has the advantage of producing less emissions than coal and, as a result, does not usually require sulfur dioxide ($SO_2$) scrubbing, which could lead to decreased use of lime in flue-gas scrubbing systems. In 2023, 17 percent of domestic utility-scale electricity generation was from coal, a 15 percent decrease from 2022, as a result of increased electricity generation from renewable sources.

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# LITHIUM

**by Debashis Das, P.E., staff engineer, RESPEC**

## Production

Domestic lithium production data were withheld in 2023 to avoid disclosing company proprietary data. Albemarle Corp. produced lithium compounds from domestic brine resources near Silver Peak, NV. U.S. Magnesium LLC produced lithium carbonate from a stockpile of cell salt residue accumulated over the course of 50 years from the production of magnesium in Rowley, UT. Estimated world lithium production (excluding production in the United States) was about 180 kt of lithium content recovered from minerals and brines, a 23 percent increase from 2022. Seven mineral operations in Australia, one mineral tailings operation in Brazil, two brine operations each in Argentina and Chile, two mineral operations in Canada, five mineral and four brine operations in China, and one mineral operation in Zimbabwe accounted for most of the world lithium production. Additionally, smaller operations in Argentina, Australia, Brazil, China, Portugal, the United Staes and Zimbabwe also contributed to world lithium production. In 2023, Australia was the largest lithium producer, with an estimated output of 86 kt. Chile and China ranked second and third, producing 44 kt and 33 kt, respectively.

## Consumption

The U.S. Geological Survey (USGS) reported world lithium consumption was about 180 kt of lithium contained in minerals and compounds, a 27 percent increase from the revised consumption figure of 142 kt in 2022, owing to strong demand from the lithium-ion battery market. U.S. consumption data were withheld to avoid disclosing company proprietary data. Estimated global distribution for lithium used in 2023 was batteries, 87 percent; ceramics and glass, 4 percent; lubricating greases, 2 percent; continuous casting mold flux powders, air treatment, and medical, 1 percent each; and other uses, 4 percent. Lithium's important properties include low density, high specific heat, low coefficient of thermal expansion, high electrochemical potential and excellent thermal conductivity.

## Price

According to the USGS, spot lithium carbonate prices in China decreased from approximately $76,000/t in January 2023 to about $23,000/t in November 2023. For fixed contracts, the annual average U.S. lithium carbonate price was $46,000/t in 2023, a decrease of 32 percent from 2022. Spot lithium hydroxide prices in China (cost, insurance, freight China) decreased from approximately $81,500/t in January to about $22,500/t in November. Spodumene (6 percent lithium oxide) prices in Australia (free on board) decreased from approximately $6,000/t in January to about $2,500/t in November. Concerns over short-term lithium oversupply, the expiration of the Chinese government's decade-long program for subsidies for electric-vehicle (EV) purchases, and weaker-than-expected EV sales worldwide caused the considerable decline in lithium price in 2023.

## Foreign trade

According to the USGS, U.S. lithium imports for consumption in 2023 were 3.4 kt, an approximately 4 percent increase compared to 2022. Import sources were Argentina (51 percent), Chile (43 percent), China (3 percent), Russia (2 percent) and others (1 percent). The United States exported 2.3 kt of lithium.

## Recent developments

In November 2023, ExxonMobil commenced drilling its first-ever lithium well in Arkansas, which has significant quantities of lithium deposits. Initial production is targeted by 2027 and enough lithium production is planned to cater to battery manufacturing for one million electric vehicles annually by 2030.

In September 2023, Gotion High-tech Co Ltd., a Chinese battery manufacturer, announced that it would build a lithium battery manufacturing plant in Manteno, IL in the United States, entailing an investment of $2 billion. In the same month, the U.S. Office of the Assistant Secretary for Industrial Base Policy signed an agreement with Albemarle for the latter's lithium mining and production expansion plans. The budget for the expansion was around $90 million. Albemarle plans to reopen its Kings Mountain, NC mine between 2025 and 2030, which will help increase the domestic production of lithium.

## Outlook

Lithium prices soared in 2022 but came crashing back down in 2023. In the long term, governments will strive to reduce emissions, and there will be support for EVs, which, in turn, will drive the demand for lithium.

In 2024, some lithium miners have reduced their production guidance and delayed expansion plans in response to the prevailing market conditions. Fastmarkets projects that the global lithium supply will increase by 30 percent in 2024. The firm forecasts a relatively balanced market in 2024 and thus expects the price to stay in its current range.

EVs are the primary driver of demand, making the lithium market strongly dependent on EV sales and sentiment. High interest rates, along with limited driving ranges, and frequent and expensive repairs have mellowed interest in EV purchases. However, interest rates are projected to pull back in 2024 and 2025, which may prompt a flip in EV demand. The U.S. Inflation Reduction Act, which includes funding and incentives geared at helping companies involved in the clean energy transition build a domestic supply chain, has been a major driver for lithium companies in North America. Last September, S&P Global released a study that found the act has accelerated demand for critical metals, and projections for lithium demand in 2035 are 15 percent higher than before its introduction.

# MANGANESE

**by Shashi Rao, Natural Resources Research Institute, University of Minnesota Duluth, Coleraine, MN, USA**

## Production and consumption

Manganese ore production and consumption are significantly influenced by global economic trends, particularly in steel production. Historically, the United States emphasized strategic reserves due to manganese's critical role in steel production and its use in dry-cell batteries. However, with the end of the Cold War and economic challenges in

the steel industry, the emphasis on maintaining strategic reserves has diminished. The United States primarily relies on imports for manganese ore, with domestic production halted since 1970. Consumption is predominantly driven by the steel industry, with additional usage in nonmetallurgical applications such as animal feed, batteries and fertilizers.

### Imports and exports

In January 2024, U.S. imports of manganese ore surged to 52.2 kt, a notable increase compared to previous periods. South Africa emerged as the sole source of manganese ore imports, with significant fluctuations attributed to factors such as economic growth in China, a major consumer of South African manganese ore. Exports from other regions like Gabon and South Africa were impacted by internal and external factors, such as political instability and weather-related transportation issues.

### Marketing, prices, economics and transportation

Average spot prices of manganese ore deliveries to China remained stable in January 2024, with prices for different grades reflecting market demand and supply dynamics. Decreased demand led United Manganese of Kalahari to announce plans to reduce production temporarily. Port stocks in South Africa currently exceed usual levels, affecting transportation and indicating weakened demand. Economic factors, particularly in China, significantly influence global manganese pricing and transportation logistics.

### Industry news and issues

Recent developments in the manganese industry include the suspension of operations by two producers in Ukraine due to rising costs and Russian shelling. Additionally, a company in Australia is developing a manganese mine in Arizona, potentially diversifying global manganese supply chains. These developments highlight the geopolitical and operational risks associated with manganese production.

### Uses, new applications and processing technology

Manganese's primary application remains in steel production, but it is also utilized in various nonmetallurgical sectors, including battery manufacturing, animal feed and fertilizers. Advancements in processing technology aim to enhance extraction efficiency and reduce environmental impact. However, challenges persist in ensuring sustainable extraction practices and mitigating health risks associated with excessive manganese exposure.

### Environmental, regulatory and reclamation issues

Regulatory frameworks regarding manganese mining operations vary globally, with countries like Australia and Brazil emphasizing land reclamation efforts post-mining. Concerns exist regarding potential health and environmental impacts, particularly related to excessive manganese exposure and emissions. Regulatory authorities continue to assess the environmental impact of manganese-related activities, such as the use of methylcyclopentadienyl manganese tricarbonyl (MMT) in gasoline additives.

### Trends and outlook

Trends indicate a shift in global manganese dynamics, with increasing reliance on imports and evolving market conditions influenced by geopolitical and economic factors. The industry faces challenges such as fluctuating demand, regulatory scrutiny, and operational risks. However, technological advancements and diversification efforts offer opportunities for growth and sustainability in the manganese sector.

In conclusion, the manganese industry navigates a complex landscape shaped by global economic trends, regulatory frameworks and technological innovations. Understanding these dynamics is crucial for stakeholders to adapt to changing market conditions and drive sustainable development in the sector.

## MICA

**by S.M. Jasinski, National Minerals Information Center, U.S. Geological Survey**

Mica has several unique physical properties. The crystalline structure of mica forms layers that can be split or delaminated into thin sheets. These sheets are chemically inert, dielectric, elastic, flexible, hydrophilic, insulating, lightweight, platy, reflective, refractive, resilient, and range in opacity from transparent to opaque. Mica is stable when exposed to electricity, light, moisture and extreme temperatures. The mica group represents 37 phyllosilicate minerals that have a layered or platy texture. The commercially important micas are muscovite and phlogopite, which are used in a variety of applications. Muscovite is the principal mica used by the electrical industry to make mica-based capacitors that can operate in environments with temperatures and/or frequencies that are too high for polypropylene capacitors. Phlogopite mica is used in plastic composites for automotive applications because of its dimensional stability, increased stiffness, and improved heat distortion temperature.

### Production

U.S. mine production of scrap and flake mica

was estimated to be 38 kt in 2023, a 10 percent decrease from 2022. Production of ground mica was an estimated 65 kt, compared with 66.3 kt in 2022. Mica was mined in Georgia, North Carolina and South Dakota. Scrap mica was recovered primarily from mica and sericite schist and as a byproduct from feldspar, industrial sand beneficiation, and kaolin. Ground mica was produced from domestic and imported scrap and flake mica. In 2023, world production of scrap and flake mica was estimated to have increased to 330 kt from 318 kt in 2022. China (85 kt), Finland (60 kt), Madagascar (50 kt) and the United States (38 kt) were the leading producers. World production of sheet mica was unavailable in 2023, but India (1 kt) was thought to be the leading producer.

## Consumption

Domestic apparent consumption of all forms of scrap and flake mica was estimated to have been 54 kt in 2023, 11 percent lower than in 2022, owing in part to reduced use in oil and gas drilling and lower imports. Consumption of sheet mica was estimated to have decreased to 3.3 kt in 2023 from 4.6 kt in 2022, owing to a decrease in imports.

The leading domestic use of ground mica was in joint compound for filling and finishing seams and blemishes in gypsum wallboard (drywall). The mica acts as a filler and extender, provides smooth consistency, improves the workability of the compound and provides resistance to cracking.

The second-ranked use of ground mica was as an additive to drilling muds by the natural-gas and oil well drilling industry. Coarsely ground mica flakes help prevent the loss of circulation by sealing porous sections of the drill hole. Mica was used in paint, where ground mica is used as a pigment extender that also facilitates suspension, reduces chalking, prevents shrinking and shearing of the paint film, increases resistance of the paint film to water penetration and weathering, and brightens the tone of colored pigments.

The plastics industry used ground mica as an extender and filler, especially in parts for automobiles as lightweight insulation to suppress sound and vibration. Other significant uses for ground mica are in the rubber industry as an inert filler and mold release compound. As a surface coating in the production of rolled roofing and asphalt shingles, mica prevents the sticking of adjacent surfaces. Mica is used in decorative coatings on wallpaper, concrete, stucco and tile surfaces. Ground phlogopite mica is used in automotive brake linings and clutch plates to reduce noise and vibration (asbestos substitute). Wet-ground mica, which retains the brilliancy of its cleavage faces, is used primarily in pearlescent paints by the automotive industry. In the cosmetics industry, its reflective and refractive properties make mica an important ingredient in blushes, eyeliner, eyeshadow, foundation, hair and body glitter, lip gloss, lipstick, mascara, moisturizing lotions and nail polish. Mica is added to latex balloons to provide a colored shiny surface.

Sheet mica is used principally in the electronics and electrical industries. Its usefulness in these applications is derived from its unique electrical and thermal insulating properties and its mechanical properties, which allow it to be cut, punched, stamped and machined to close tolerances.

## Prices

In 2023, the average unit value of scrap and flake mica produced in the United States, which included high-quality sericite, was estimated to be $100/t. The average unit value of dry-ground mica was estimated to be $300/t, and the average unit value of wet-ground mica was estimated to be $350/t. Sheet mica prices vary with grade and can range from less than $1/kg for low-quality mica to more than $2,000/kg for the highest quality. The estimated average unit value of mica splittings consumed in the United States in 2023 was $1.60/kg.

## Foreign trade

According to the U.S. Census Bureau, U.S. imports and exports of scrap and flake mica were 19.4 kt and 3.73 kt, respectively, in 2023. Imports of scrap and flake mica decreased by 14 percent, and exports decreased by 16 percent, compared with 2022. In 2023, China (40 percent), Canada (37 percent) and India (6 percent) supplied most of U.S. imports of scrap and flake mica, with the remainder from several other countries. Most exports of scrap and flake mica went to Mexico (27 percent), Canada (14 percent), and Brazil (16 percent).

In 2023, U.S. imports and exports of sheet mica were 4.32 kt and 1.01 kt, respectively. Imports of sheet mica decreased by 20 percent, and exports increased by 26 percent, compared with 2022. In 2023, China (80 percent), Brazil (4 percent) and India (4 percent) supplied most of U.S. imports of sheet mica, with the remainder from several other countries. Most U.S. exports of sheet mica went to Mexico (34 percent), China (11 percent) and Austria (8 percent).

## Outlook

The major markets for ground mica — drywall joint compounds and paints — are mature and relatively stable, with growth tied to housing construction and interest rates. Demand is also affected by automobile production because interior and exterior parts typically contain dry-ground mica or engineered mica composites, and exterior surfaces may be painted with wet-ground pearlescent pigments and mica-containing coatings.

Demand for ground mica in smaller specialty markets such as coated micas, cosmetics, nylon and

polyester resins, and polypropylene composites, is expected to have an annual growth rate slightly higher than that of the entire ground mica industry.

Consumption of block and sheet mica is expected to increase slowly as demand increases in a few specialty markets, such as electronics. A shortage of domestic high-quality block mica is expected to continue because of the generally low percentage of high-quality mica in deposits currently being mined, mostly from pegmatites. Future supplies of all forms of mica are expected to come increasingly from imports, primarily from Brazil, Canada, China, Finland and India.

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## NITROGEN — AMMONIA

**by L.E. Apodaca, National Minerals Information Center, U.S. Geological Survey**

### Production and consumption

U.S. ammonia production was estimated to be 14 Mt of nitrogen (N) content in 2023, essentially unchanged from 2022. In 2023, U.S. producers operated at about 90 percent of their rated capacity (excluding plants that were idle for the entire year). Apparent consumption was estimated to be 15 Mt of N content in 2023, essentially unchanged from 14.8 Mt of N content in 2022.

The United States along with India and Russia were the world's second-ranked ammonia producers after China and the world's second-ranked consumer after India. Urea, ammonium nitrate, nitric acid, ammonium phosphates and ammonium sulfate were the major derivatives of ammonia produced in the United States, in descending order of tonnage.

Ammonia was produced domestically by 17 companies at 36 plants in 17 states during 2023. About 60 percent of total U.S. ammonia production capacity was based in Louisiana, Oklahoma and Texas because of those states' large reserves of natural gas, the dominant domestic feedstock for ammonia production.

Approximately 88 percent of domestic ammonia apparent consumption was for fertilizer use, including anhydrous ammonia for direct application, urea, ammonium nitrates, ammonium phosphates and other nitrogen compounds. Ammonia also was used to produce explosives, plastics, synthetic fibers and resins and numerous other chemical compounds.

### Foreign trade

According to the U.S. Census Bureau, imports of ammonia (N content) decreased by 11 percent to 1.72 Mt in 2023 from 1.93 Mt in 2022.

Canada (51 percent) and Trinidad and Tobago (46 percent) were the leading sources of U.S. ammonia imports. U.S. ammonia exports increased by 26 percent to 907 kt of N content in 2023 from 720 kt of N content in 2022. Ammonia exports were primarily shipped to Chile (20 percent), Morocco (19 percent) and Norway (15 percent).

### Prices

U.S. Gulf Coast ammonia prices in 2023 averaged $475/st, 56 percent lower than in 2022. The Gulf Coast ammonia price was $885/st at the beginning of 2023, prices decreased to a low of $259/st in late June and increased to $525/st by yearend. Ammonia prices decreased due to lower natural-gas prices, particularly in Europe and the decreased demand for ammonia.

Natural gas is often used as the feedstock to produce ammonia fertilizers, and the cost of natural gas can account for 70 to 90 percent of the production costs. The Henry Hub spot natural-gas price ranged between $1.70 and $3.80/million Btu for most of the year, with an average of $2.50/million Btu. The 2023 Henry Hub spot natural-gas price was 61 percent lower than the 2002 average price of $6.45/million BTU. The U.S. Department of Energy, Energy Information Administration projected that Henry Hub natural-gas spot prices would average $3.25/million Btu in 2024.

### Outlook

A long period of generally stable natural-gas prices in the United States made it economical for companies to upgrade existing ammonia plants and construct new nitrogen facilities. The additional capacity has reduced ammonia imports (Fig. 1). Expansion in the U.S. ammonia industry over the next five years is expected to increase capacity by about 2 percent, which includes decarbonized ammonia projects. Global ammonia capacity is expected to increase by a total of 6 percent during the next four years, with additions in Central and East Asia, Eastern Europe and North America. Consumption of ammonia in fertilizers is expected to increase by 1 percent per year, depending on availability and cost, with the largest increases in demand expected in Latin America and South Asia.

According to 10-year projections (2023–2033) by the U.S. Department of Agriculture, plantings for the eight major field crops (barley, corn, cotton, oats, rice, sorghum, soybeans and wheat) in the United

States were expected to remain at about 100 Mha. Corn, soybeans and wheat were expected to account for about 90 percent of acreage utilization for the eight major field crops. Corn production accounts for about one-half of U.S. fertilizer use, and planting fewer crops affects the demand for nitrogen fertilizers. Overall corn acreage in the United States was expected to remain about the same through the projected period. Corn yields are expected to remain high, with corn being used more for feed and residual use than for ethanol.

## Reference

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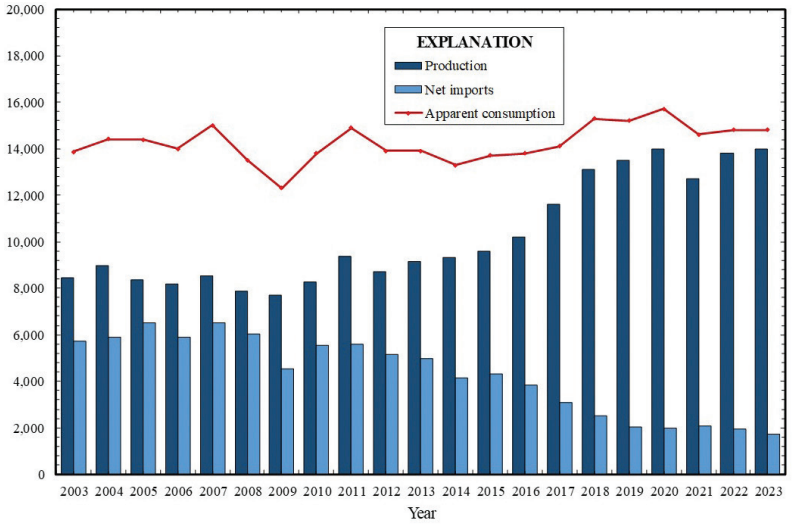
## Figure 1

**U.S. supply and apparent consumption of ammonia, 2003–2023. (Source: U.S. Geological Survey data)**




# PEAT

**by Amanda S. Brioche, National Minerals Information Center, U.S. Geological Survey**

Peat is a natural organic material of botanical origin. Peatlands are situated predominately in shallow wetland areas of the Northern Hemisphere. Commercial deposits are formed from the gradual accumulation of plant matter that is partially decomposed under anaerobic conditions. In 2023, peat was known to be harvested in 10 states, with Florida, Michigan and Minnesota being the leading producing states. Although peat has been produced in Alaska, the current status of operations in Alaska is not known because the Alaska Department of Natural Resources, Division of Geological and Geophysical Surveys discontinued its survey of peat producers in Alaska.

## Production and consumption

In 2023, domestic production of peat, excluding Alaska, was an estimated 360 kt, compared with the revised 350 kt in 2022. U.S. apparent consumption for 2023 decreased by 15 percent to 1,480 kt compared with 1,740 kt in 2022 (Fig. 1). World production was an estimated 23 Mt in 2023. Reed-sedge peat comprised approximately 87 percent of the reported production in the United States, followed by sphagnum moss, with 10 percent.

Deposits of sphagnum moss in the United States occur primarily in the northern states, with active operations in Maine, Michigan, Minnesota, Montana, Pennsylvania and Washington. The permitting procedures for new peat operations have become increasingly time-consuming and expensive, causing some companies to abandon harvesting and reducing the number of new fens and bogs brought into production. In addition, extensive areas of peatlands are in protected wetlands, parks or other natural areas that restrict commercial development.

Demand for peat generally follows that of horticultural applications. Potting soil mixes and general soil improvement were the leading domestic end-use categories, accounting for about 90 percent of domestic peat sales. Sphagnum moss is preferred for custom soil mixes and for sale to retail consumers because of its more fibrous composition. More decomposed types of peat, such as reed-sedge or humus, are used primarily in bulk by commercial landscapers and on golf courses.

In the industrial sector, peat was used as an oil absorbent and as an efficient filtration medium for the removal of waterborne contaminants in mine waste streams, municipal storm drainage and septic systems. Data for the end-use distribution of peat imported from Canada were unavailable, but the imported peat was sold both in bulk for soil blending and packaged for direct horticultural use. Packaged peat, regardless of origin, commanded a higher price than bulk sales.

## Trade

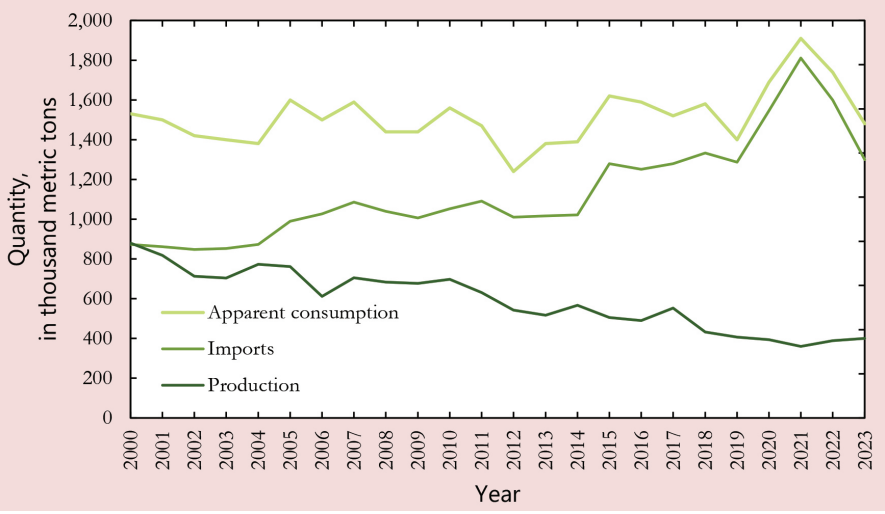
According to the U.S. Census Bureau, imports decreased by 18 percent to 1.17 Mt in 2023 compared with 1.44 Mt in 2022, and exports were essentially unchanged at 42 kt in 2023 from 43 kt in 2022. More than 80 percent of all peat used in the United States was imported from Canada, which has extensive deposits of high-quality sphagnum moss.

## Industry news and issues

In 2023, the National Oceanic and Atmospheric Administration (NOAA) distributed $35 million from the Bipartisan Infrastructure Law and the Inflation

## Figure 1

**U.S. production, imports and apparent consumption of peat, 2000-2023 (Source: A.S. Brioche, Peat: U.S. Geological Survey Mineral Commodity Summaries 2024)**




Reduction Act to fund conservation and restoration projects. NOAA announced the awarded projects in April, one of which was a peatland conservation project in Alaska that planned to purchase 55 acres of peatland and recharge its water levels. Doing so was expected to also alleviate coastal erosion and safeguard the water quality of Kachemak Bay.

Other conservation projects in the United States were done in partnership among conservation institutions and local and federal governments to restore peatlands in Minnesota and North Carolina. In Minnesota, research on how to restore peatlands was done in partnership with a conservation institute, the U.S. Department of Agriculture's U.S. Forest Service, the Minnesota Department of Natural Resources, the Minnesota Board of Water and Soil Resources, two local universities, and a local nonprofit organization. In North Carolina, work was done with various federal and state agencies and institutions to install water management infrastructure, including water control structures, to restore degraded peatlands.

Finland, Germany, Sweden, Canada, Latvia and Belarus were the world's top six leading peat producers, in descending order of production, based on estimated 2023 world production. Climate change concerns have prompted several countries to plan to decrease or eliminate the use of peat, owing to peatland's ability to act as a carbon sink.

Finland continued to work toward its goal of becoming carbon neutral by 2035. To achieve this, peat production was to be phased out in favor of noncarbon forms of energy. In the first half of 2023, only about 2 percent of Finland's energy consumption was supplied by peat. Approximately 42 percent of Finland's energy supply was generated using renewable energy sources, whereas 26 percent was produced by nuclear energy.

Ireland announced the end of its peat harvesting in 2021, as the country transitioned to alternative fuel sources, but peat briquet production was expected to continue until 2024. In 2023, the country released a 30-year climate plan that aims to phase out coal- and peat-fired electricity generation. Instead, renewable energy sources were expected to generate approximately 80 percent of its electricity needs by 2030.

In March 2023, the United Kingdom announced a delay on the ban of peat-based growing media sales to amateur gardeners that had been expected to start by 2024. Owing to concerns from the peat sector, the ban will be delayed until 2026, with some exemptions delayed until 2030 to prepare for the phaseout.

### Outlook

Peatlands also are used for agriculture, forestry, recreation, and wildlife management. Factors such as the growing interest in gardening, golf course development, and landscaping related to residential use indicate that peat usage is likely to remain near current levels for the next several years. However, producers in the United States face increasing competition from imports of peat from Canada and alternative soil amendments, such as composted organic waste, coir (coconut fiber) and wood byproducts (for example, wood fiber and composted bark). The availability of alternative soil amendments as substitutes for peat will determine the future use of peat in different parts of the world. Peat production is expected to decrease across Europe during the coming years as peatland restoration efforts and use of alternative fuel sources increase.

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# PERLITE

by Kristi J. Simmons, National Minerals Information Center, U.S. Geological Survey

Perlite is an amorphous siliceous volcanic glass that contains between 2 and 5 percent water. Light gray to black in color, perlite is found worldwide and is most often mined using openpit methods. When perlite ore is rapidly heated to about 900 °C, the contained water converts to steam and the ore expands up to 20 times its original volume. The resulting material, which is lightweight and bright white, has many properties suited to multiple industrial applications.

## Production

Domestic processed crude perlite sold and used in 2023 was estimated to be 450 kt with a value of $30.5 million, compared with 458 kt with a value of $31.3 million in 2022. The average unit value of processed crude perlite sold and used by U.S. operations in 2023 was $68/t, unchanged from 2022. Crude ore production was from nine mines operated by six companies in six Western states (Arizona, California, Idaho, Nevada, New Mexico and Oregon). New Mexico continued to be the leading producing state. Processed crude perlite was expanded at 51 plants owned by 29 companies in 27 states. World production of perlite in 2023 was estimated to be 4.9 Mt, compared with 4.94 Mt in 2022.

## Consumption

The low-density and porous-structure attributes of expanded perlite, as well as its durability, fire resistance, inertness, low acoustical and thermal conductivity, and water retention capacity make it useful for a wide range of applications. In 2023, construction-related uses, such as concrete aggregate, formed products, and masonry- and cavity-fill insulation remained the leading markets for expanded perlite with 47 percent of total sales and use. Horticultural uses by commercial growers and hobby gardeners accounted for 16 percent of perlite consumption in 2023. Other uses were fillers (15 percent) and filter aids (14 percent). Several other end uses for expanded perlite made up the remainder of consumption. Domestic apparent consumption, defined as processed crude perlite sold or used by producers plus imports minus exports, decreased in 2023 to an estimated 610 kt, from 680 kt in 2022.

## Substitutes

Substitutes for perlite are dependent on the application. In construction uses, diatomite, expanded clay and shale, pumice and slag can be substituted for perlite. For horticultural uses, coco coir, pumice, vermiculite and wood pulp are alternative soil additives and are sometimes used in conjunction with perlite.

## Foreign trade

Trade data for perlite are not collected as a separate category by the U.S. Census Bureau but are included within the "Vermiculite, perlite and chlorites, unexpanded" group. An estimated 140 kt of perlite valued at $19 million was imported into the United States during 2023 compared with 240 kt valued at $35 million in 2022. The estimated average unit value of imported perlite in 2023 was $130/t, compared with $150/t in 2022.

Most imports were estimated to have originated from Greece (95 percent) while smaller quantities also came from Mexico (2 percent). The remainder of imported perlite originated from Australia, China and Turkey. In 2023, exports of perlite were estimated to have decreased to 18 kt valued at $3.4 million compared with 22 kt valued at $3.4 million in 2022. The estimated average unit value of exported perlite was $190/t in 2023 compared with $160/t in 2022. An estimated 92 percent of exports were shipped to Canada.

## International

Global production of perlite was estimated to be 4.9 Mt in 2023, compared with 4.94 Mt in 2022. The world's leading producers were, in descending order of production, China (1.5 Mt), Turkey (1.4 Mt), Greece (1.1 Mt) and the United States (450 kt). Most of China's perlite production was thought to be consumed internally, while Greece and Turkey were the leading exporters of perlite.

## Outlook

The perlite industry is mature and stable. Demand for perlite used for the construction and horticultural markets is expected to remain strong. Construction market fluctuations could impact the perlite consumption in related uses. New and innovative uses continue to be developed due to the numerous characteristics of perlite.

## References

U.S. Geological Survey, 2024, Mineral Commodity Summaries 2024—Perlite: U.S. Geological Survey, p. 132–133, https://doi.org/10.3133/mcs2024

# PHOSPHATE ROCK

by T.M. "Mike" Gurr, P.G., Gurr Professional Services Inc. and Stephanie Gurr, The Vertex Companies LLC

## Production and consumption

For calendar year 2023, phosphate ore was mined by five companies at nine mines in four states for an estimated 19.5 Mt of marketable product (representing 63 percent of the domestic production capacity of 31.1 Mt), making the United States responsible for 9.1 percent of the world production of 220 Mt (Table 1). While the U.S. production quantity in calendar year 2023 was similar to that in 2022, U.S. consumption of phosphate rock increased in 2023 due to increased use related to favorable weather conditions during the planting season.

China has revised its phosphate rock production information to only report production from large mines, which totaled 85 to 93 Mt as compared to earlier reported annual production at 140 Mt. Morocco's production was 35 Mt in calendar year 2023, approximately 16 percent of the world's production (Table 1). Figure 1 shows the U.S. proportion of world phosphate production from 1900 through to the present day.

## Table 1

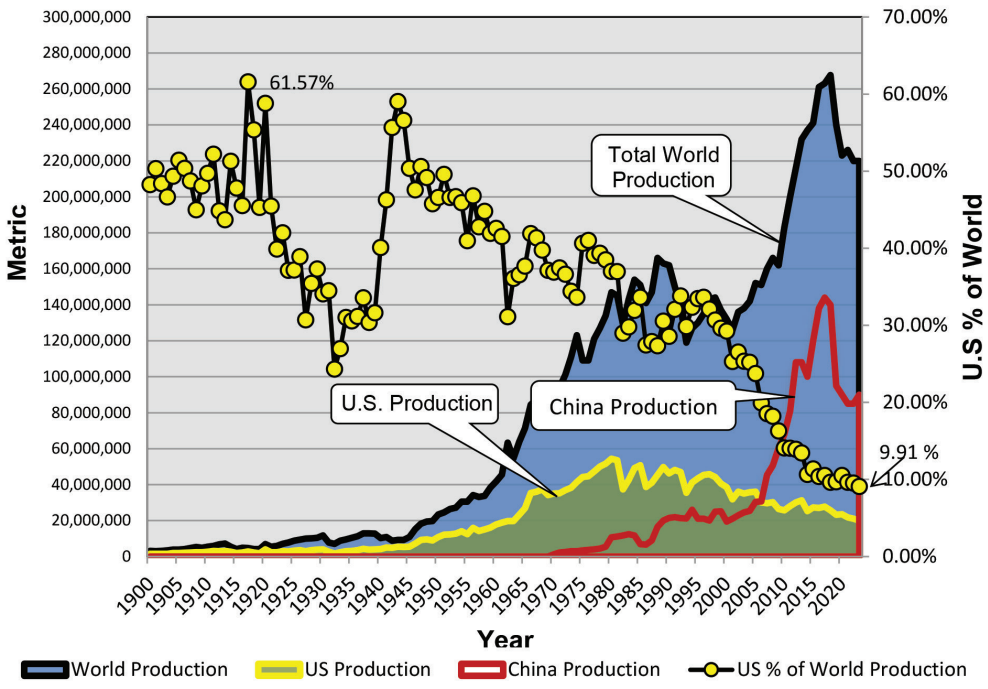
**World phosphate production and U.S. position. (Source: Stephen M. Jasinski, USGS Mineral Commodity Summaries, January 2023, pp. 124–125 Phosphate Rock)**

| Calendar year | Production[1,2] | | | | U.S. (percent) | Morocco[3] (percent) |
|---|---|---|---|---|---|---|
| | World | China | Morocco[3] | U.S. | | |
| 2018 | 267.0 | 140.0 | 33.0 | 25.7 | 9.63 | 12.36 |
| 2019 | 227.0 | 95.0 | 35.5 | 23.3 | 10.26 | 15.64 |
| 2020 | 223.0 | 90.0 | 37.0 | 23.5 | 10.54 | 16.59 |
| 2022[1] | 228.0 | 93.0 | 39.0 | 19.8 | 8.68 | 17.11 |
| 2023[1] | 220.0 | 90.0 | 35.0 | 20.0 | 9.09 | 15.91 |

[1]Estimated for 2022 and 2023 [2]Million metric tons [3]Includes Western Sahara

## Figure 1

**U.S. proportion of world phosphate production. (Modified from data compiled by D.A. Buckingham and S.M. Jasinski, USGS)**




## Imports and exports

There were no reported U.S. exports of phosphate rock in crop year 2023; nor have there been any reported exports of phosphate rock since crop year 2004. U.S. producers continue to prefer to export the higher-value fertilizer products, such as monoammonium phosphate (MAP), diammonium phosphate (DAP) and triple super phosphate (TSP), in preference to phosphate rock. Approximately 25 percent of the MAP, DAP and TSP produced in calendar year 2023 were exported.

Importation of phosphate rock in calendar 2023 is estimated by the U.S. Geological Survey (USGS) at 2.59 Mt as compared to 2022 imports of 2.5 Mt. Imports were from Morocco (2 percent) and Peru (98 percent).

## Uses

The manufacturing of fertilizers and the production of animal feed supplements account for more than 95 percent of phosphate rock consumption. Major fertilizers include DAP, MAP and TSP. The balance is used in a variety of products, such as vitamins, pharmaceuticals, soft drinks, toothpaste, flame retardants, glass, photographic film and

other consumer goods. Continued growth of the world population and the need for dependable food supplies underscore the need for phosphate fertilizers. There is no natural or synthetic substitute for phosphorus, which is essential for life in all growing things: plants and animals alike.

## Prices

**Calendar year.** The 2023 calendar year average price at the mine was reported at $147.32/t, 8.3 percent higher than the calendar year 2022 average price of $136.00/t (Table 2). The price of imported phosphate also increased to $147.32/t in calendar year 2023 from $135.60/t in 2022 (Table 2). Phosphate prices decreased significantly in December 2023.

**Morocco.** Morocco phosphate rock prices at 70 percent BPL increased from $300.00/t in January 2023 to a high of $347.50/t during September through November 2023, closing in December 2023 at $152.50/t.

**Fertilizers.** DAP spot prices, U.S. Gulf granular, free on board, decreased from $631.00/t in January 2023 to a low of $454.00/t in June, closing in December 2023 at $563.75/t. TSP decreased from $569.38/t in January 2023 to a low of $390.00/t in June, closing in December 2023 at $447.50/t.

## Industry news

There are currently only two phosphate rock producers mining in Florida, one in the central district (Mosaic) and one in the north district (Nutrien Ltd). There is only one producer in North Carolina: Nutrien Ltd. In the Western states of Idaho and Utah, there are currently three producers: Bayer, which acquired Monsanto; Itafos, a Brazilian operation, which acquired Nutrien; and J.R. Simplot. The Bureau of Land Management (BLM) is the leading agency for administering and approving phosphate mining and manages more than 245 million acres of public land. The Pocatello field office of the BLM currently has five large, active phosphate mines in southeast Idaho.

China has transitioned from the largest importer of phosphate to the largest exporter of phosphate. At the present time, China has imposed measures including export quotas and lengthy inspection requirements on fertilizer ingredients, which has cooled domestic prices and reduced exports. In 2023, China exports were reported to be less than in prior years.

In Saudi Arabia, Ma'aden's phosphate mine is currently producing up to 5 Mt/a of concentrated phosphate rock from its beneficiation plant. Peru is also producing close to 5 Mt annually.

## Environmental, regulatory and reclamation issues

Mosaic has continued to mine the newly permitted extension reserves of its Wingate East Mine, South Pasture Mine Extension, Ona Mine and the newly permitted South Fort Meade Eastern Extension Mine, all in Florida. Permit applications to further extend the South Fort Meade Eastern reserves, consisting of approximately 6,000 acres further east in Hardee County, were approved in 2023.

The future Desoto Mine was denied mining permits by the local county. Public information workshops are still being held at the county level prior to any future county commission hearings.

Exploration activities on Western phosphate lands have been extensive over the past few years. The permitting activities included extensions of existing phosphate mines, expansions of existing mines, or new phosphate mines.

In June 2023, the Federal District Court of Idaho vacated the BLM's approval of the Caldwell Canyon Mine. Bayer has since provided a new revised mine and reclamation plan, and the BLM restarted the permitting and National Environmental Policy Act (NEPA) process in November 2023. The BLM anticipates a new decision sometime in early 2025.

## Trends and outlook

According to the USGS, domestic production and consumption in 2023 were essentially unchanged from 2022. Favorable weather conditions in the planting seasons helped to increase fertilizer consumption and reduce phosphate fertilizer stocks that had accumulated in 2022.

Global production of phosphate rock was estimated to be lower in 2023 at 220 Mt, compared to 228 Mt in 2022. Global production of phosphorus pentoxide, $P_2O_5$, is expected to increase from 63.6 Mt in 2023 to 69.1 Mt by 2027.

Most of the near-term increases in world production that are expected to be completed by 2026 are ongoing in Brazil, Kazakhstan, Mexico, Morocco and Russia. New mining projects that are planned to be completed after 2027 are under development in Australia, Canada, Congo (Brazzaville), Guinea-Bissau and Senegal.

## Table 2

**Phosphate rock prices. (Source: USGS Mineral Industry Surveys, Stephen M. Jasinski, Mineral Industry Survey Marketable Phosphate Rock in January 2023, Tables 2 and 3, and 2023 Annual Phosphate Rock, pp. 134 and 135)**

| Phosphate use | Calendar year | | | | |
|---|---|---|---|---|---|
| | 2019 | 2020 | 2021 | 2022 | 2023 |
| Domestic production (FOB mine[1]) | $67.90 | $75.50 | $84.80 | $136.00 | $147.32 |
| Exports (FOB port[1]) | N/A | N/A | N/A | N/A | N/A |
| Imports (CIF[1]) | $72.56 | $74.55 | $84.80 | $135.60 | $147.32 |

[1]Price (U.S. dollars per metric ton)

## References

Data compiled predominantly from personal knowledge, contacts in the industry, USGS Mineral Industry Surveys: USCOE and BLM EIS documents; personal communication with Stephen Jasinski, USGS; J.W. (Bill) Stout, US BLM; and Jeffery Cundick, US BLM field office in Idaho; news and financial reports for Mosaic, Ma'aden, Office Che'rifien des Phosphates, Vale, Fosyeiki S.A.C, Itafos, and Simplot; indexmundi; World Bank, National Rural News, CRU; Reuters.com, Nutrien, Ltd, and other various news and trade publications. Personal communication, Hardee County Mining Department, April 2024


# POTASH

**by S.M. Jasinski, National Minerals Information Center, U.S. Geological Survey**

Potash encompasses a variety of mined and manufactured salts, all of which contain the element potassium in water-soluble form. The term potash, however, also can refer specifically to potassic fertilizers, which are potassium chloride (KCl, or the mineral sylvite), potassium sulfate ($K_2SO_4$, or sulfate of potash (SOP), usually a manufactured product), and SOPM ($K_2SO_4 \cdot 2MgSO_4$, or langbeinite or double sulfate of potash magnesia). Muriate of potash (MOP) for fertilizer use is an agriculturally acceptable mix of KCl (95 percent purity or greater) and sodium chloride (halite) that includes minor amounts of other nontoxic minerals from the mined ore and is neither the crude ore sylvinite nor pure sylvite.

Because the potassium content of its common salts varies, the potash industry has established a common standard of measurement for defining a product's potassium content (or purity) related to the approximate potassium oxide ($K_2O$) content.

## Production

In 2023, U.S. potash production was estimated to be 400 kt of $K_2O$, 7 percent lower than in 2022. Domestic sales were estimated to be 470 kt of $K_2O$, 18 percent higher than in 2022. World production was estimated to be 39 Mt of $K_2O$, 5 percent lower than in 2022. Canada (13 Mt), Russia (6.5 Mt), China (6 Mt) and Belarus (3.8 Mt) were the leading producers, accounting for 75 percent of total production. In the United States, MOP was produced by Intrepid Potash Inc. from solar evaporation and solution mines in New Mexico and Utah. Mosaic Co. and Intrepid each produced SOPM from underground mines in New Mexico. Compass Minerals International Inc. produced SOP from solar evaporation of brine from the Great Salt Lake in Utah. SOPM and SOP accounted for the majority of U.S. production in 2023.

## Consumption

U.S. potash consumption was estimated to have increased by 16 percent to 5.9 Mt of $K_2O$ compared with 5.1 Mt of $K_2O$ in 2022. The increase in consumption of potash was attributed mainly to lower potash prices and favorable weather conditions in the planting season compared with 2022.

According to a report from the International Fertilizer Association, world consumption of potash fertilizers in 2023 was estimated to have increased to 37.1 Mt from 35.7 Mt in 2022. Asia and South America were the leading consuming regions.

Because it is a source of soluble potassium, about 90 percent of potash consumed globally is used as fertilizer (plant nutrient). Potassium is one of the three primary nutrients required for plant growth and maturation; the others are fixed nitrogen and soluble phosphorus. The remaining 10 percent of potash consumed is used to produce potassium chemicals, which are used in such applications as aluminum recycling, animal feed supplements, oil-well drilling mud, snow and ice melting, soap manufacturing, steel heat-treating and water softening.

## Trade

According to the U.S. Census Bureau, U.S. imports of potash increased by 15 percent to 5.68 Mt of $K_2O$ in 2023, compared with 4.94 Mt of $K_2O$ in 2022. The United States was 93 percent net import reliant for potash in 2023. Canada (83 percent), Russia (11 percent) and Israel (3 percent) were the leading suppliers. The United States is not a significant exporter of potash. In 2023, exports decreased to 165 kt of $K_2O$ from 267 kt of $K_2O$ in 2022.

## Prices

The price of potash decreased substantially in 2023 compared with 2022, owing to high stocks and stabilization of supply disruptions. The Vancouver, British Columbia, Canada spot price for standard potash began the year averaging $520/t ($473/st) and ended the year at $287/t ($261/st). The U.S. price for SOP began 2023 in the range of $838/st to $955/st and ended the year in the range of $640/st to $680/st. The U.S. price for SOPM, free on board Carlsbad, NM, began the year in the range of $413/st to $568/st and ended the year in the range of $290/st to $330/st.

## Industry developments

In 2023, world production was lower in part due to producers drawing down potash inventories that grew in 2022 when potash sales fell, and prices increased rapidly after supply disruptions from the effects of economic sanctions on Belarus and Russia and the conflict in Ukraine. Production and exports from Belarus both were lower than in 2022. Belarus shifted to exporting potash by rail to China and from ports in Russia, but its export tonnage remained well below

the levels prior to 2022 when it was one of the leading exporters in the world.

Canada is the leading potash producing country in the world, with 38 percent of global capacity. All production in Canada was from Saskatchewan in 2023. Potash was produced by three companies: Nutrien Ltd., which controls 24 percent of world MOP capacity at six mines; Mosaic, which operated three mines; and K+S Aktiengesellschaft, which operated one mine. Total 2023 production in Canada was estimated to have decreased to 13 Mt $K_2O$ from 14.6 Mt $K_2O$ in 2022, owing in part to a dockworkers strike in July 2023 that curtailed shipments of potash from the port of Vancouver, British Columbia. This led to temporary closures of some mines in Canada. Production resumed at those mines after the strike was settled in August.

## Outlook

Potash is an essential fertilizer nutrient for which no substitute exists. Growing world population and its need for food will require continued increases in potash production and consumption. Additionally, increased ethanol production from corn and other crops will require proportional increases in fertilizer use.

World annual potash production capacity was projected to increase to about 67.6 Mt in 2026 from 64.3 Mt in 2023. Most of the increase would be MOP from new mines and expansion projects in Laos and Russia. Other new MOP mines in Belarus, Brazil, Canada, Ethiopia, Morocco, Spain and the United States were planned to begin operation past 2026. The conflict between Russian and Ukraine and sanctions on Belarus may lead to a shift in world potash supply patterns that could last for decades.

## Reference

U.S. Geological Survey, 2024, Mineral Commodity Summaries 2024—Potash: U.S. Geological Survey, p. 138–139, https://doi.org/10.3133/mcs2024

# PUMICE AND PUMICITE

**by R.D. Crangle, Jr., National Minerals Information Center, U.S. Geological Survey**

Pumice is a volcanic rock formed through the cooling of air-pocketed lava, which results in a highly porous, low-density rock. The low density allows some pumice to float on water. Large pumice rafts, consisting in some instances of thousands of individual pieces of pumice clumped together, are a unique geologic phenomenon and have been documented to be as long as 30 km (19 miles) and to have drifted for several years in oceanic waters.

Pumicite is defined as grains, flakes, threads and/or shards of volcanic glass finer than 4 mm (0.20 in.) in diameter. Pumicite and volcanic ash are descriptive terms that are often used interchangeably. The porous, lightweight properties of pumice are well suited for its main use as an aggregate in lightweight building blocks and assorted building products.

## Production and prices

Mine production of pumice in the United States during 2023 was estimated to be 310 kt (342,000 st), 5 percent more than in 2022. The unit value of pumice was estimated to be $68/t ($62/st) in 2023, 5 percent higher than in 2022. Pumice was produced at 10 operations in California, Idaho, Kansas, New Mexico and Oregon. According to the U.S. Census Bureau, U.S. pumice exports totaled 10.6 kt (11,600 st), 25 percent less than in 2022. Imports totaled 54.8 kt (60,400 st), 47 percent less than in 2022.

World resources of pumice are adequate for the foreseeable future. However, transportation costs may encourage the development of deposits closer to markets. Total world production of pumice was estimated to be 18 Mt (20 million st) in 2023, essentially unchanged from 2022. Pumice is used more extensively as a building material outside the United States, which explains the large global production of pumice relative to that of the United States. The top world producers in 2023 were Turkey (8.7 Mt or 9.6 million st), Uganda (1.5 Mt or 1.7 million st), Greece (1 Mt or 1.1 million st), Saudi Arabia (980 kt or 1.1 million st), Algeria (900 kt or 990,000 st) and Ecuador (800 kt or 880,000 st).

## Processing and consumption

Pumice is usually extracted by simple openpit methods using rippers, bulldozers and front-end loaders. Processing typically is limited to drying, crushing and screening, although some abrasive grades may require fine grinding and classification. Lightweight pumice building blocks, the primary use for pumice, may be sawn into a variety of shapes and sizes.

In 2023, other major applications included abrasives and horticulture (including landscaping). Minor applications include the use of pumice as an absorbent, as a concrete aggregate and admixture, as a filter aid, and as a traction enhancer for tires. A small percentage of pumice was used in abrasive-type products, including pencil erasers, polishing agents for circuit boards and television monitors, chinchilla chew stones, exfoliants in cosmetics and the removal of henna tattoos, and a variety of heavy-duty hand cleaners. Imports were primarily used as raw material for building blocks (for example, cinderblock) and other lightweight aggregate applications. Several

substitutes exist for pumice in agriculture, in horticulture, as an aggregate, as a concrete additive, and in other end products.

### Outlook

Although pumice and pumicite are plentiful in the Western United States, legal challenges and public land designations could limit access to known deposits. Pumice and pumicite production are sensitive to mining and transportation costs, especially from deposits in Western States that are far from major markets. An increase in fuel prices would likely lead to increases in production expenditures and sales prices; imports and competing materials could become attractive substitutes for domestic products.

### Reference

U.S. Geological Survey, 2024, Mineral Commodity Summaries 2024—Pumice and Pumicite: U.S. Geological Survey, p. 140–141, https://pubs.usgs.gov/periodicals/mcs2024/mcs2024-pumice.pdf

## RARE EARTH ELEMENTS

**by Himesh Patel, FLSmidth Inc.**

Rare earth elements (REEs) are sourced primarily from minerals like bastnaesite, loparite and monazite. In 2023, the Mountain Pass Mine in California was a major producer, focusing on bastnaesite, a fluorocarbonate mineral from a Precambrian carbonatite deposit. REEs are crucial in various industries and are found in products like cellphones, magnetic resonance imaging (MRI) scanners and wind turbines. They are also vital in hybrid/electric-vehicle batteries, refining crude oil, and in medical devices such as pacemakers. Additionally, they are used in advanced defense technology, including stealth technology and radar systems. The United States saw a 9 percent decline in the estimated value of imported rare earth compounds and metals, dropping from $208 million in 2022 to $190 million in 2023.

**Figure 1**

**World, China and U.S. production of rare earth oxides.**

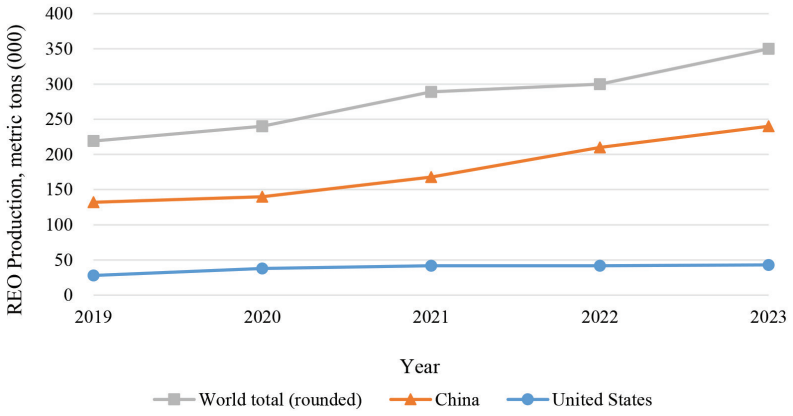
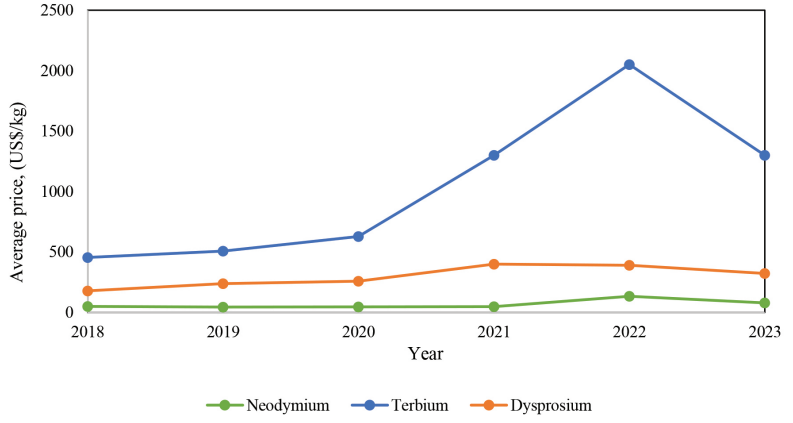



**Figure 2**

**Neodymium, terbium and dysprosium prices, 2018-2023.**




### Production and reserves

In 2023, global production of rare earth oxides (REOs) continued its upward trajectory. As seen in Fig. 1, U.S. production has risen steadily in recent years, reaching 43 kt of REOs in 2023. China maintained its position as the leading producer, with production of 240 kt of REOs, constituting roughly 68 percent of the world's total production.

Table 1 shows the statistics on REO production and minable reserves. Notably, production in Myanmar increased substantially and is now similar to the 2021 level. Countries like China, Vietnam, Russia and Brazil have the world's largest reserves of REOs. These four countries account for approximately 90 percent of world REO reserves.

### Imports, exports and apparent consumption

Domestically, imports, exports and apparent consumption of rare earth compounds and metals decreased from 2022. The United States imported approximately 9.7 kt in the form of either compounds or metals. China was the primary import source at approximately 72 percent. The primary U.S. exports of ores, compounds and metals were approximately 41.1 kt, decreasing by 6.6 kt from 2022. Apparent consumption, defined as production plus imports less exports, decreased by approximately 16 percent. The United States continued to experience greater than 95 percent

net import reliance as a percentage of apparent consumption of compounds and metals.

## Prices and economics

Most REO prices decreased in 2023. As shown in Fig. 2, the prices of neodymium, terbium and dysprosium oxides increased significantly over several years but decreased in 2023. Neodymium prices were stable at around $50/kg for a few years, increased to $134/kg in 2022 but decreased to $80/kg in 2023. Terbium prices continuously increased with the average price reaching $2,051/kg in 2022, but it decreased to $1300/kg in 2023. The average price of dysprosium decreased to $323/kg. The trade balance between the United States and the rest of the world in rare earth oxides, compounds and metals stood at $190 million (net imports) in 2023.

## Trends and outlook

Supply-chain disruptions, geopolitical tensions and environmental concerns are the key issues of the rare earth industry. With growing demand from emerging economies, advances in green technology, and increasing aerospace applications, the REE market is expected to grow at a compound annual growth rate of 4.2 percent from 2023 to 2030. China is projected to remain the top producer, occupying more than half of the market. As a consequence, this makes the global REE market sensitive to the health of its manufacturing sector, economy and geopolitics. Demand for magnets seems to be disproportionally higher than other REE applications and is expected to drive global demand for REEs over the next few years. A vast majority of automakers use neodymium-incorporated permanent magnet motors, with increased use projected for 2024.

**Table 1**

**Global production and mineable reserves of rare earth oxides.**

| Country | Production (t) | | Reserves (t) |
|---|---|---|---|
| | 2022 | 2023 | |
| Australia | 18,000 | 18,000 | 5,700,000 |
| Brazil | 80 | 80 | 21,000,000 |
| China | 210,000 | 240,000 | 44,000,000 |
| India | 2,900 | 2,900 | 6,900,000 |
| Madagascar | 960 | 960 | NA |
| Myanmar | 12,000 | 38,000 | NA |
| Russia | 2,600 | 2,600 | 10,000,000 |
| Thailand | 7,100 | 7,100 | 4,500 |
| United States | 42,000 | 43,000 | 1,800,000 |
| Vietnam | 1,200 | 600 | 22,000,000 |
| Other countries | 80 | | 280,000 |

# SALT

**by Cody Vining and Peter Christensen, RESPEC**

Salt remains the most cost-effective material on the market for maintaining full mobility on roads and highways and preventing accidents during the winter snow season. This mineral is also the most useful component in regenerating the ion exchange resins that are used for water conditioning, is critical in the production of animal feed products, and is the most ubiquitous ingredient used in the food industry. The method used to obtain salt varies depending on the end benefit, with salt being derived from rock salt, salt in brine, vacuum pan salt and solar salt.

## Consumption, production, prices and foreign trade

For 2023, the total U.S. apparent consumption of salt (that is, domestic sold or used minus exports plus imports) was an estimated 55 Mt. This is consistent with the previous three years with apparent consumption in the range of 54 to 57 Mt, but remains significantly lower than 2018 and 2019, both of which had an apparent consumption greater than 61 Mt. The source of the consumed salt for 2023 was rock salt (46 percent), salt in brine (33 percent), vacuum pan salt (11 percent) and solar salt (10 percent).

Domestic annual salt production in the United States differs from year to year and is estimated at 42 Mt in 2023, similar to the estimated 2022 domestic salt production of 41 Mt and in line with the five-year and 10-year averages of approximately 42.7 Mt/a. At the beginning of 2023, 63 salt-producing plants existed in 16 states, which is one fewer reported producer than 2022, with approximately 95 percent of the total production coming from Kansas, Louisiana, Michigan, New York, Ohio, Texas and Utah.

Most of the domestic production (94.5 percent) was consumed within the United States in 2023 with approximately 2.3 Mt of the total domestic production being exported. The estimated 2023 exports are appreciably greater than the 2022 exports of 0.7 Mt, and are also greater than the five-year average for exports, which has been approximately 1 Mt/a. To meet demand in 2023, the United States imported an estimated 16 Mt of salt (29.1 percent of total apparent consumption). Historically, these imports have originated from Canada (29 percent), Chile (28 percent), Mexico (12 percent) and Egypt (11 percent) with the remaining imports (20 percent) coming from several other producing countries.

## Table 1

**World production of salt, estimated.**

| Country | Production (thousand metric tons) | | |
|---|---|---|---|
| | 2021 | 2022 | 2023 |
| China | 64,000 | 54,000 | 53,000 |
| United States | 42,000 | 41,000 | 42,000 |
| India | 45,000 | 30,000 | 30,000 |
| Germany | 15,000 | 15,000 | 15,000 |
| Australia | 12,200 | 13,000 | 14,000 |
| Canada | 11,800 | 12,000 | 12,000 |
| Chile | 8,570 | 9,000 | 9,200 |
| Mexico | 9,000 | 8,700 | 9,000 |
| Turkey | 6,900 | 9,100 | 9,000 |
| Russia | 6,500 | 8,000 | 7,000 |
| Brazil | 7,400 | 6,600 | 6,600 |
| Netherlands | 6,120 | 5,900 | 6,000 |
| France | 5,400 | 5,500 | 5,500 |
| Poland | 4,000 | 4,000 | 4,200 |
| Spain | 4,200 | 3,900 | 4,000 |
| Bulgaria | 0 | 3,300 | 3,300 |
| Pakistan | 3,000 | 3,300 | 3,000 |
| Iran | 2,700 | 2,700 | 2,700 |
| Saudi Arabia | 2,330 | 2,400 | 2,500 |
| United Kingdom | 2,400 | 2,400 | 2,300 |
| Egypt | 0 | 2,300 | 2,300 |
| Belarus | 0 | 2,000 | 2,100 |
| Italy | 1,900 | 1,900 | 2,000 |
| Ukraine | 1,800 | 1,000 | 0 |
| Djibouti | 0 | 0 | 0 |
| Other countries | 31,000 | 32,000 | 27,000 |
| **World total (rounded)** | **293,220** | **279,000** | **273,700** |

The total value of U.S. salt sales in 2023 was estimated to be $2.6 billion, a slight increase compared to $2.5 billion in 2022. The average price of vacuum pan salt in 2023 was $220/t, a modest price increase over the past six years from $200/t in 2017. The average price of solar salt has also modestly increased in the past six years from $100/t in 2017 to $150/t in 2023. The average price for rock salt in 2023 was $61/t, matching the five-year high of $61/t reported in 2018, while the price of salt in brine has also remained fairly consistent with historical trends at about $8.50/t.

Total world production in 2023 is estimated at 273 Mt, approximately 6 Mt less than the revised 2022 production of 279 Mt. China remains the world's largest salt producer at approximately 53 Mt, while the United States and India (the world's second and third largest producers, respectively) produced an estimated 42 Mt and 30 Mt in 2023, respectively. These three countries combined accounted for 46 percent of the total world production, while 19 other countries collectively produced a total of approximately 148 Mt, or 54 percent of the total world production. Although China remains the world's largest producer of salt, China has seen a modest drop in production over the past five-year period while Turkey has seen the greatest increase compared to historic production, followed by Canada, Australia and India.

### Outlook

The U.S. Geological Survey (USGS) expects the demand for salt in brine that is used in the chloralkali industry to continue to increase in 2024 as demand for caustic soda and polyvinyl chloride increases globally, especially in Asia.

### Reference

The production and usage data used in this report relied almost entirely on research conducted by the minerals commodity specialists at the USGS, and the key document referenced was the USGS Mineral Commodity Summaries 2024, https://pubs.er.usgs.gov/publication/mcs2024.

## SODA ASH

**by Debashis Das, P.E., staff engineer, RESPEC**

### Production

According to the U.S. Geological Survey's (USGS) Mineral Commodity Summaries 2024, domestic production of soda ash (sodium carbonate) in 2023 was estimated to be 11 Mt, slightly less than in 2022, for a total market value of $1.9 billion. The U.S. soda ash industry consists of four companies in Wyoming, operating five plants, and one company in California (Searles Valley Minerals Inc.), operating one plant. The combined nameplate capacity of the five operations is 13.9 Mt/a. China was the world's largest producer of soda ash (29 Mt), followed by Turkey and the United States. These three countries produced around 78 percent of the world's soda ash in 2023.

### Consumption

According to the USGS, the reported consumption of soda ash in the United States in 2023 was around 4.5 Mt, slightly less than in 2022. Nearly half of the total soda ash developed in 2023 (approximately 47 percent)

went into glass products, with about 29 percent used in chemicals and the remaining for soaps/detergents, flue-gas desulfurization, distributors and paper.

## Exports and imports

During 2023, the United States exported about 6.6 Mt of soda ash, more than one-half of its total production, according to USGS statistics. The United States only imported around 8 kt of soda ash, most of which came from Turkey.

## Pricing

The free on board plant price of soda ash in the United States increased from $133/t in 2021 to an estimated $180/t in 2023. The upswing was mainly attributed to supply constraints because of trade disruptions through the Panama and Suez Canals. According to ChemAnalyst, the price in the U.S. market is expected to be relatively stable in the short term because of reduced inventory levels and modest downstream demand.

## Trends and outlook

U.S. production, consumption and exports in 2023 were lower than before the COVID-19 pandemic in 2019. Production was slightly lower in 2022, while exports increased slightly.

Future Market Insights and Market Research Future project the global soda ash market to grow at a compound annual growth rate of 4 percent until 2030. The key drivers for the growth include the rising demand for soda ash glass, soaps and detergents, and the increasing adoption of soft water. Growing environmental concerns have also led to the endorsement of soda ash to extract sulfur dioxide from stacked gases, increasing demand for the commodity.

# STRONTIUM

by A.K. Hatfield, National Minerals Information Center, U.S. Geological Survey

Although strontium is the 17th most abundant element in the Earth's crust, only the minerals celestite (strontium sulfate) and strontianite (strontium carbonate) contain strontium in sufficient quantities to make recovery practical. Celestite has been the leading source of strontium since the 1870s because it occurs more frequently in economically attractive sedimentary deposits. The largest celestite deposits are found in China, Iran, Mexico, Spain and Turkey, although no production has been reported for Turkey in recent years. Strontianite has been identified in various countries worldwide.

## Production and consumption

The world's leading producers of celestite in 2023 were Iran, Spain, China and Mexico. Of an estimated 520 kt (570,000 st) of celestite produced worldwide, nearly all of it was produced in those countries. Although celestite deposits occur throughout the United States, none have been mined since 1959; however, in July, an Australia-based company announced its acquisition of an 80 percent interest in a strontium deposit in California that included plans for additional strontium mineralization exploration. In 2023, U.S. apparent consumption of strontium (contained in celestite and manufactured strontium compounds) was estimated to be 5.33 kt (5,880 st), a 69 percent decrease from the revised estimated quantity in 2022. The decrease in 2023 was likely the result of decreased drilling activity and reduced consumption of strontium compounds for various end uses.

## Foreign trade

According to the U.S. Census Bureau, the gross weight of total imports of strontium compounds and minerals in 2023 was 6.02 kt (6,630 st), 41 percent less than in 2022. Mexico was the source of 68 percent of all strontium imports. Imports of celestite, nearly all of which came from Mexico, decreased significantly in 2023, likely the result of decreased use of celestite in natural-gas and oil well drilling fluids. In recent years, celestite imports have been variable, corresponding with the number of operating rotary drill rigs; celestite may be used as an additive in drilling muds or as a substitute for barite in drilling muds, and the substitution is more likely when barite prices increase, and when drilling activity is high. In 2023, drilling activity decreased by about 5 percent from 2022 and remained 27 percent below the level in 2019, before the COVID-19 pandemic. Correspondingly, celestite imports decreased by 82 percent in 2023, and remained nearly 75 percent below the amount in 2019, before the COVID-19 pandemic. Strontium carbonate exports were 89 t gross weight (53 t of strontium content) in 2023, a significant increase compared with 26 t gross weight (15 t of strontium content) in 2022.

## Prices

In 2023, the average U.S. Customs unit value was $1.62/kg ($0.74/lb) for imported strontium carbonate, and $2.64/kg ($1.20/lb) for strontium nitrate. The average value of imported celestite decreased to $82/t ($75/st), down 29 percent from 2022; high-value celestite imports were most likely mineral specimens.

## Legislation and government programs

The U.S. Department of Energy evaluated strontium for the 2023 critical materials assessment,

but strontium did not meet the threshold for criticality and was considered a lower-risk material. The finalized assessment's purpose was to evaluate supply-chain security for clean energy technology. Similarly, the 2022 U.S critical minerals list published by the U.S. Geological Survey in the Federal Register (87 FR 10381) did not include strontium as a critical mineral. The critical minerals list is to be updated every three years and revised as necessary, consistent with available data.

In contrast, in 2022, strontium nitrate, strontium peroxide and strontium oxalate were identified as critical chemicals in a Defense Production Act Title III Expansion of Domestic Production Capability and Capacity Funding Opportunity Announcement.

After comparable evaluations, strontium was variously considered critical or not critical on minerals lists developed by several other countries and regions. In 2023, strontium was identified as a critical raw material by the European Union, and strontium was also included on the critical minerals list released by India.

## Outlook

Celestite is rarely consumed directly, except as an additive to drilling fluids for oil and natural-gas exploration and production, for which celestite is ground but undergoes no chemical processing. In other uses, it is typically converted into strontium carbonate through chemical processing. Strontium carbonate is used directly in some applications and is also converted into downstream chemicals such as strontium chloride, strontium hydroxide or strontium nitrate. Large-scale domestic production of strontium carbonate ceased in 2006, although a few domestic companies continued to manufacture and/or distribute small quantities of downstream strontium chemicals from imported strontium carbonate.

The amount of strontium carbonate used in ceramic ferrite magnets was estimated to be about the same as the use of strontium nitrate in pyrotechnics and signals in 2023. These two end uses are thought to account for most strontium consumption other than in the form of celestite. Other applications for strontium compounds include master alloys for aluminum casting, pigments and fillers in corrosion-resistant paints, electrolytic production of zinc, and glass. With continued developments in advanced applications, consumption of strontium in new end uses may increase.

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# TALC AND PYROPHYLLITE

**by E.F. McCarthy, Performance Minerals LLC**

Talc is a platy, hydrous magnesium silicate mineral. It has the theoretical composition $3MgO.4SiO_2.H_2O$, which equates to 31.7 percent MgO, 63.5 percent $SiO_2$ and 4.8 percent $H_2O$. It occurs in a variety of mineral habitats in association with other minerals like carbonates and chlorite. In addition, atoms like divalent iron can substitute for magnesium in the talc lattice. Depending on the levels of these other minerals or atomic substitutions, the talc ore may not have commercial utility, but many natural talc-chlorite and talc-carbonate ores are milled directly to make saleable products, especially in applications like coatings. Other applications, especially plastics and technical ceramics, require high talc content and minimal levels of specific other elements or minerals.

In its pure powder form, talc is naturally oleophilic, soft, relatively inert and white in color. There is a variety of ways talc can be classified; one is by the natural crystal size of the talc. Microcrystalline talc has a natural crystal size of 5 to 45 µm and macrocrystalline talc 50 to 150 µm. The difference is the macro grades have been repeatedly sheared in geological time, resulting in a larger, more planar structure. The micro grades are particularly good absorbents for paper pitch control, are excellent reinforcing agents for crosslinked rubbers, and have good pressing characteristics for structural ceramics. The macro grades are better in reinforcing thermoplastic polymers and paper coating.

Pyrophyllite is a platy, hydrous aluminum silicate. It has the theoretical composition $Al_2O_3.4SiO_2.H_2O$, which equates to 28.3 percent $Al_2O_3$, 66.7 percent $SiO_2$ and 5 percent $H_2O$. It also occurs with other minerals, most notably quartz, pyrite and mica. Some of these natural mixtures have excellent machining qualities, most notably wonderstone (South Africa) and pagodite (China). In its pure form, it is also oleophilic, soft, relatively inert and white and used competitively with talc in Brazil and parts of Asia in paper and coatings.

## Table 1

**Salient talc statistics, in kilotons. (Source: USGS annual talc and pyrophyllite report and UN Stats)**

| | 2019 | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|---|
| U.S. mine production | 578 | 491 | 577 | 511 | 450 |
| Mill and ore sales | 515 | 461 | 556 | 548 | 460 |
| Imports | 280 | 189 | 278 | 346 | 230* |
| Exports | 229 | 186 | 232 | 196 | 200 |
| Apparent consumption | 566 | 464 | 602 | 698 | 490* |

*There could be an error in this reporting.

## Table 2

**Talc value, in dollars per metric ton. (Source: USGS annual talc and pyrophyllite report and UN Stats)**

| Year | 2019 | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|---|
| U.S. mined ore | 38 | 41 | 45 | 45 | 44 |
| U.S. milled product | 240 | 265 | 321 | 303 | 304 |
| Exported product | 512 | 503 | 503 | 614 | 564 |
| Imported ore | 259 | 293 | 297 | 274 | 338* |
| Imported product | 599 | 635 | 628 | 714 | 695 |

*There could be an error in this reporting.

### Production and consumption

Three companies operated five talc producing mines in the United States in 2023, with production estimated to have declined to 450 kt (Table 1). Magris Talc operated one mine in Montana and one in Vermont, Barretts Minerals operated two mines in Montana, and Daltile operated one mine for its internal use in west Texas. Magris Talc also operates one mine in Ontario, Canada. Barretts Minerals beneficiates talc via color sorting and flotation at its plant in Dillon. Magris beneficiates talc via friction sorting in Montana and froth flotation in Canada. Two companies, RT Vanderbilt and Resco Products, operated pyrophyllite mines in North Carolina, and Trinity Resources recovers the mineral from old tailings in Newfoundland. Pyrophyllite production values were not reported by the U.S. Geological Survey (USGS).

Cimbar Performance Minerals mills imported talc ore at plants in Texas, Indiana and Ohio, and IMI Fabi also processes imported talc ore in plants in West Virginia and New York. Multiple European and Asian companies export finished talc products directly into the United States. Talc imports into the United States were reported at 230 kt in 2023 (there is some question whether the imports of talc were underreported for 2023 as there are inconsistencies in pricing and volumes relative to recent years for Pakistan shipments), a dramatic decrease from the 346 kt reported in 2022. Pakistan, Canada, China, Australia, the Netherlands and India are the major import sources. It is believed that the talc coming from Pakistan is all sourced in tribal-controlled regions of southern Afghanistan.

The United States exported 210 kt of talc in 2023, with Mexico, Canada, South America and Asia being the major destinations.

The average value of U.S. mined talc ore was $44/t and the average for domestic products from the mills was $304/t. The average value of ore imported into the United States was $338*/t and that of finished product $695/t. The average value of exported products (almost all finished) was $564/t.

Outside of the United States, China is the world's largest producer (and consumer) of talc, followed by India, Pakistan/Afghanistan, Brazil, France and Finland. Germany, Japan, South Korea, Thailand, the Netherlands and Mexico are major importers.

### Business developments

In April, Minerals Technologies announced that it was putting its talc subsidiary, Barretts Minerals, into Chapter 11 bankruptcy owing to excess legal costs associated with lawsuits on the safety of talc. The lawsuits against Johnson & Johnson for similar causes continued, with Johnson & Johnson attempting to put its (now discontinued) talc business into bankruptcy.

In October, a New Jersey appeals court reversed a $230 million verdict against Johnson & Johnson that a jury awarded in a 2019 trial. The appeals court ruled that three "scientific experts" used by the plaintiffs should not have been allowed to testify as their scientific theories were unsubstantiated.

### Uses and applications

The major uses for talc mined and sold in the United States were plastics (30 percent), ceramics (27 percent), paint (17 percent), paper (9 percent), roofing (8 percent) and rubber (5 percent). The major use for imported talc is believed to be plastics.

In plastics, talc is used primarily for reinforcing polypropylene compounds for automotive parts like bumpers, interior panels, under-the-hood parts and trim. It is also used in rigid packaging and for reinforcing polyvinyl chloride in construction applications like wood-plastic composites. In ceramics, talc is used in wall and large-form floor tile as well as in honeycomb cordierite for automotive catalyst supports and filters. In paint, talc is used in primers and industrial anticorrosion coatings and in paper for absorbing pitch in pulp mills.

Pyrophyllite is sold for ceramic tile, refractories, paint and as an insecticide carrier. The use of machined imported wonderstone for the manufacture of synthetic diamonds has declined dramatically as the old high-

temperature/high-pressure process is phased out in favor of the new chemical-vapor-deposition process.

### Regulatory

There were no significant new regulations issued for talc in 2023. The Modernization of Cosmetics Regulation Act (MoCRA), which became law in 2022, calls for the issuance of specific testing procedures to ensure that talc sold in cosmetics is free of asbestos fibers, but these are still pending.

## TIN

**by Shivakumar Angadi, CSIR-Institute of Minerals and Materials Technology, Bhubaneswar, India**

Tin possesses many important properties such as malleability, ductility and corrosion resistance. As a result, the metal has found applicability in various areas. In the Bronze Age, tin was alloyed with copper to create bronze, extensively used in making weapons, sculptures, tools and others. Today, tin and its alloys find applications in electronics, plumbing, the chemical industry, polishing compounds and decorative metals.

### Occurrence

Cassiterite is found in both alluvial/placer deposits and primary hard-rock deposits. Tin occurrence in alluvial/placer deposits is due to the weathering of primary hard rocks followed by transportation of eroded material, with significant deposits located in Southeast Asian countries, particularly in Malaysia, Indonesia and Thailand.

The primary hard-rock deposits are late-stage granitic intrusions found in veins and fissures in granite and surrounding country rocks. They are predominant in China, South America and Australia. Estimated tin reserves in the world are about 4.3 Mt, with significant distribution in China, Indonesia, Brazil, Bolivia, Russia, Peru, Malaysia, Australia and Thailand.

### Production

Tin production reached 290 kt in 2023 due to increased demand, with approximately 60 percent coming from China, Indonesia and Burma. Refined tin metal production witnessed fluctuations among different countries over time, yet the general trend indicated an upward trajectory in average production. China, Indonesia, Brazil, Bolivia and Peru emerged as key contributors, driving the cumulative production of tin. However, since the 1990s, reports indicate a noticeable absence of tin smelting activity from U.S. and European producers, signifying a decline in production from these regions. About 15 percent of the global tin output is sourced from secondary materials, with Belgium and China playing significant roles, emphasizing the growing importance of recycling and reprocessing in sustaining the global tin supply.

### Consumption

Tin consumption shows variability across industries over time. During the 1970s, significant quantities of tin were consumed by tin plate industries in the United States and European countries, although consumption rates in these sectors were either stable or in decline by 2000.

Conversely, since 2000, there has been a surge in tin consumption in electronic soldering applications in Asian countries, particularly China and Japan. Solder industries emerged as the largest consumers, accounting for approximately 50 percent of the tin produced in 2022, followed by chemical and tin plate industries.

Reports indicate that global tin consumption maintained a plateau of 300 to 350 kt during the last decade, but post-pandemic, it experienced a slight increase to about 380 kt, reflecting evolving consumption patterns and shifting industrial demands.

### Processing

Cassiterite is the primary mineral from which tin is economically extracted. It is generally associated with lighter gangue minerals and is found in both placer/alluvial and hard-rock deposits.

The beneficiation process for cassiterite involves techniques such as gravity concentration and flotation. Various gravity separators such as jigs, spirals and tables are used for primary concentration, with enhanced gravity concentrators being developed to increase efficiency.

Particle size plays a significant role in gravity concentration, with higher efficiency observed for coarse particles.

Flotation techniques are employed to recover fine cassiterite from gravity tailings, resulting in improved overall plant recovery values. Selective collectors play a crucial role in cassiterite flotation, with various reagents being explored over the years.

Cassiterite beneficiation plants have undergone numerous developments, including modifications in flowsheets, incorporation of new equipment, and adoption of novel chemical reagents. Market-driven factors have largely influenced these developments.

Several case studies highlight the implementation of advanced gravity separators and flotation techniques in treating cassiterite fines, resulting in higher product quality and recovery rates.

# TITANIUM

by Joseph Gambogi, National Minerals Information Center, U.S. Geological Survey

Titanium minerals of economic importance include ilmenite, leucoxene and rutile. As a metal, titanium is well known for corrosion resistance and for its high strength-to-weight ratio. Approximately 90 percent of titanium is consumed in the form of titanium dioxide ($TiO_2$), a white pigment in paints, paper and plastics. $TiO_2$ pigment is characterized by its purity, refractive index, particle size and surface properties.

## Production

Global production of titanium mineral concentrates in 2023 was estimated to be 9.2 Mt of contained $TiO_2$, slightly less than in 2022 (Tables 1 and 2). Less than 10 percent of global production was attributed to natural rutile.

Rounded to one significant digit, U.S. production of titanium concentrates was estimated to be 200 kt of contained $TiO_2$. In the United States, The Chemours Co. produced titanium mineral concentrates at mining operations near Starke, FL and Nahunta, GA. In California, Twin Pines Minerals, LLC reprocessed mine tailings to produce mixed mineral concentrates containing titanium and zirconium.

$TiO_2$ pigment production in the United States in 2023 was estimated to be 920 kt, 20 percent less than in 2022, with domestic consumption estimated to have been 880 kt in 2023, a 15 percent decrease from 1.04 Mt in 2022. U.S. producers of $TiO_2$ pigment, all of which used the chloride process, were Chemours, INEOS Pigments USA Inc., Louisiana Pigment Co. L.P. and Tronox Ltd.

Global titanium metal sponge production in 2023 — excluding the United States, where production data were withheld to avoid disclosing company proprietary data — was estimated to have increased by 22 percent to 330 kt from 270 kt in 2022 (Table 3). In the United States, titanium sponge metal was produced by Honeywell

### Table 1

**World ilmenite production. (Source: U.S. Geological Survey)**

| Country | Production (kt of $TiO_2$ equivalent) | |
|---|---|---|
| | 2022 | 2023[e] |
| Australia | 400 | 400 |
| Canada[1] | 520 | 500 |
| China | 3,140 | 3,100 |
| India | 210 | 210 |
| Kenya | 190 | 140 |
| Madagascar | 320 | 320 |
| Mozambique | 1,400 | 1,600 |
| Norway | 410 | 430 |
| Senegal | 410 | 340 |
| South Africa[1] | 1,100 | 1,000 |
| Ukraine | 190 | 60 |
| United States[2] | 200 | 200 |
| Vietnam | 170 | 140 |
| Other countries | 140 | 160 |
| **Total (rounded)** | **8,800** | **8,600** |

[e]Estimated production
[1]Mine production is primarily used to produce titanium slag.
[2]Rounded to the nearest 100,000 tons to avoid disclosing company proprietary data. U.S. rutile production is included with ilmenite.

### Table 2

**World rutile production (Source: U.S. Geological Survey)**

| Country | Production (kt of $TiO_2$ equivalent) | |
|---|---|---|
| | 2022 | 2023[e] |
| Australia | 200 | 200 |
| India | 13 | 13 |
| Kenya | 73 | 58 |
| Sierra Leone | 130 | 110 |
| South Africa | 100 | 100 |
| Ukraine | 95 | 50 |
| Other countries | 29 | 29 |
| **Total (rounded)** | **640** | **560** |

[e]Estimated production

### Table 3

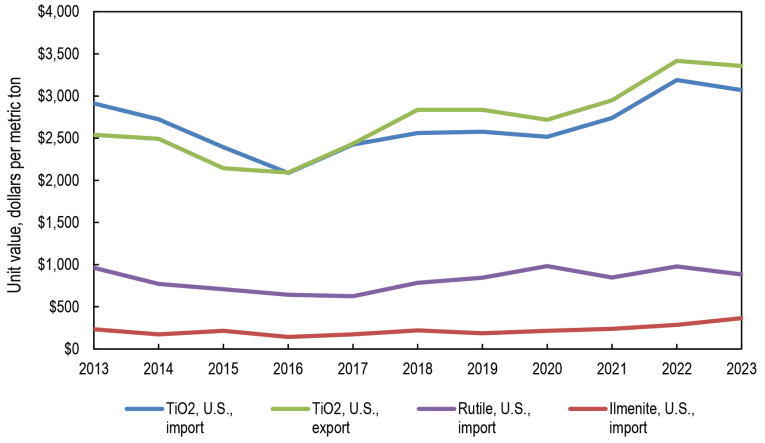
**World titanium sponge metal production, estimated. (Source: U.S. Geological Survey)**

| Country | Production (kt) | |
|---|---|---|
| | 2021 | 2022 |
| China | 180 | 220 |
| India | 0.3 | 0.3 |
| Japan | 47 | 60 |
| Kazakhstan | 15 | 14 |
| Russia | 20 | 20 |
| Saudi Arabia | 9.7 | 12 |
| Ukraine | 1 | 0 |
| United States[1] | — | — |
| **Total (rounded)[2]** | **270** | **330** |

[1]Withheld to avoid disclosing company proprietary data
[2]Excludes U.S. production

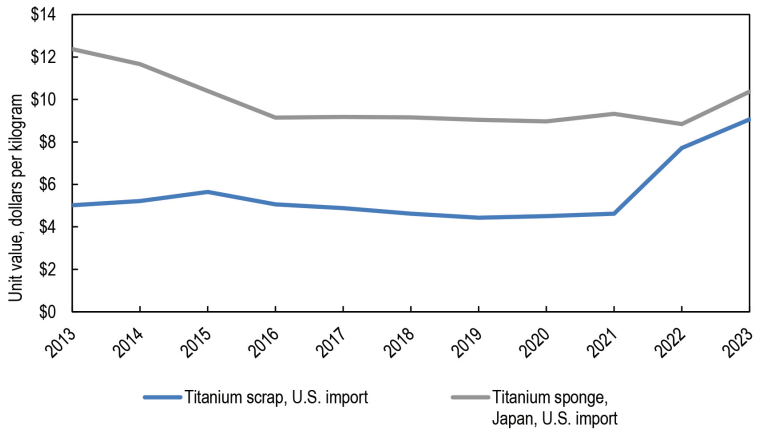
## Figure 1

**Average annual prices (unit values) for ilmenite, rutile and titanium dioxide ($TiO_2$) pigments, 2013-2023. (Source: U.S. Census Bureau)**




## Figure 2

**Average annual prices (unit values) for titanium metal sponge and titanium scrap, 2013-2023. (Source: U.S. Census Bureau)**




Electronic Materials Inc. in Utah. The 500-t/a plant supported the production of high-purity titanium in Fombell, PA.

### Foreign trade

Based on data from the U.S. Census Bureau, in 2023, the United States was import reliant for titanium mineral concentrates (ilmenite, rutile and titanium slag). U.S. imports were 636 kt based on estimated $TiO_2$ equivalent, and the leading import sources were South Africa (26 percent), Canada (20 percent), Mozambique (17 percent), Australia (11 percent) and Madagascar (9 percent). The United States was a net exporter of $TiO_2$ pigments. In 2023, U.S. exports of $TiO_2$ pigments were 271 kt based on $TiO_2$ equivalent, with the majority of these exports going to Mexico (24 percent), Belgium (22 percent) and Canada (17 percent).

The United States was a net importer of titanium sponge metal and imported 40 kt of sponge in 2023, a 31 percent increase from 31 kt in 2022. The leading import sources of titanium sponge in 2023 were Japan (78 percent), Saudi Arabia (14 percent) and Kazakhstan (8 percent).

### Prices

Based on U.S. imports for consumption from the U.S. Census Bureau, the average annual prices (unit values) for ilmenite ($365/t) and rutile ($884/t) increased by 28 percent and decreased by 10 percent, respectively, in 2023 compared with 2022. U.S. import and export prices for $TiO_2$ pigments decreased by 4 percent and 2 percent, respectively (Fig. 1).

The average annual price for titanium sponge metal imported from Japan ($10.37/kg) increased by 17 percent and the average annual titanium scrap import price ($9.06/kg) increased by 18 percent compared with 2022 (Fig. 2).

### Outlook

Consumption of titanium pigments in paints and coatings, paper and plastics links to global economic trends. According to the World Bank, the global economic growth rate was forecast to slow to 2.4 percent in 2024 from 2.6 percent in 2023. Consumption of titanium metal is primarily linked to aerospace demand. According to the International Air Transport Association, the airline industry passenger traffic was expected to recover to their 2019 levels by the end of 2024 and then grow at a rate of around 3 percent. The lingering effects of the global COVID-19 pandemic, increased financial market volatility, and the conflict in Ukraine may affect titanium metal supply and demand.

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# Tungsten

**by Surya Kanta Das, manager, JSW Steel Dolvi Works, Mumbai, India**

Tungsten, also known as wolfram, holds significant importance as one of the critical metals worldwide. It exhibits various vital properties including the highest melting point among all metals (3,422 °C),

excellent hardness, high density (19.25 g/cm³) and low coefficient of thermal expansion, making it essential for numerous applications.

It is primarily used in the form of tungsten carbide, which is essential to the mining, petroleum, ordinance, aerospace, automotive, construction and metalworking industries. Moreover, tungsten-bearing alloys are used in manufacturing various electronics, power engineering tools, medical equipment, heating elements, filaments and others.

## Production

Global reserves of tungsten are estimated to be around 4 Mt, with annual mine production of approximately 78 kt in 2023. Despite the presence of numerous tungsten-bearing minerals worldwide, only scheelite ($CaWO_4$) and wolframite ((Fe,Mn)$WO_4$) are considered primary sources for tungsten extraction. China dominates global tungsten production, accounting for over 80 percent and holding approximately 56 percent of the global reserves. Beyond China's output of 63 kt, other major producers include Vietnam (3.5 kt), Russia (2 kt), Austria (910 t), Rwanda (1.4 kt) and Spain (1.5 kt). Additionally, a substantial portion of tungsten metal is derived from recycling tungsten scraps, such as metal drills, superalloys and tungsten carbide, with about 35 percent being recycled and reintegrated into various end applications.

## Prices

In 2022, global tungsten consumption was valued at $4.75 billion, rising to $5.13 billion in 2023. Projections indicate that by 2031, it is anticipated to reach $9.5 billion, exhibiting an annual growth rate of 8 percent.

Conversely, the average price of tungsten hovered around $260/t of tungsten trioxide ($WO_3$) in 2023, marking a decrease of approximately 5.5 percent compared to 2022.

## Outlook

China is expected to maintain its dominance in the global tungsten supply. Meanwhile, countries such as Austria, Portugal, Russia, Spain and Vietnam have witnessed increases in tungsten production over the past few years. Moreover, there has been a notable rise in the recycling of tungsten scraps for various mainstream applications, a trend expected to persist and grow in the future.

Numerous research studies have focused on recovering residual tungsten values from tailings and advancing technologies for extracting tungsten values from low-grade resources. The primary consumption of tungsten is anticipated to be in the form of cemented carbide across industries such as automotive, aerospace, mining, construction and electronics.

Additionally, the growing electric-vehicle and 3D-printing sectors indicate strong market growth potential for the tungsten industry in the near future.

# VANADIUM

**by Desiree E. Polyak, National Minerals Information Center, U.S. Geological Survey**

Vanadium is extracted from vanadiferous ores, slags and residues, and converted into vanadium pentoxide ($V_2O_5$) or vanadium trioxide ($V_2O_3$). Most $V_2O_5$ and $V_2O_3$ are then converted into ferrovanadium (FeV). In 2023, a majority of the world's supply of vanadium was derived either from vanadiferous titanomagnetite (VTM) mineral concentrates or from steelmaking slags, where the steel is produced from VTM.

## Production

Industry convention for describing vanadium production usually applies the following terms, according to the raw-material source for production: primary production (occurs from mined ore as mineral concentrates from VTM and sandstone-hosted vanadium); joint production (from vanadium slags produced during steelmaking); and secondary production (from residues, industrial waste materials and spent catalysts). The United States did not produce any primary vanadium in 2023. Vanadium production in Utah from the mining of uraniferous sandstones on the Colorado Plateau ceased in early 2020 and has not restarted since. The United States continued to be a major producer of vanadium products from secondary sources such as spent catalysts, ashes and petroleum residues. Secondary vanadium production continued in the United States, where processed waste materials were used to produce FeV, a variety of vanadium-bearing chemicals or specialty alloys, and $V_2O_5$.

In 2023, the vanadium-producing nations (from ore, concentrate and slag) included China (66 percent), Russia (19 percent), South Africa (9 percent) and Brazil (6 percent). Combined, they produced an estimated total of 104 kt of contained vanadium, slightly more than in 2022.

Energy Fuels Inc.'s White Mesa Mill (operated by EFR White Mesa LLC), near Blanding, UT, had the only vanadium coproduct recovery circuit in the United States. However, Energy Fuels has not recovered vanadium from its existing tailings pond solutions since 2020. In the first quarter of 2023, Energy Fuels sold 36 t of $V_2O_5$ (as finished product, FeV) from its existing inventory and as of yearend

2023, Energy Fuels had approximately 410 t of $V_2O_5$ as finished goods inventory and an estimated 450 to 1,400 t of $V_2O_5$ in its tailings solution, which was available for future recovery. No vanadium production was planned for 2024, although the company continually monitors its inventory and the vanadium market to guide future potential production.

## Consumption

Vanadium's primary use is as a hardening agent in steel, in which it is critical for imparting strength, toughness and wear resistance. These properties are especially important in high-strength, low-alloy (HSLA) steels, particularly for products in the construction industry and in tool steel. A smaller but essential use is in titanium aerospace alloys, for both commercial and military aircraft. Nonmetallurgical applications include catalysts, ceramics, electronics, large-scale energy storage and vanadium chemicals. Catalysts are the leading nonmetallurgical use for vanadium.

Large-scale energy storage systems are growing in use owing to the increase in energy production by renewable energy sources. Vanadium redox flow batteries (VRFBs) have almost unlimited energy storage capacity, zero emissions, very long cycle lives, and can remain unused for long periods of time without negative effects. These advantages have made VRFBs a beneficial solution in different energy management strategy scenarios.

## Prices

In 2023, according to Argus Metals International, the average Chinese vanadium pentoxide price (98 percent $V_2O_5$) was $7.497/lb of contained vanadium, a 19 percent decrease compared with $9.285/lb in 2022. The annual average U.S. ferrovanadium price (78 to 82 percent V) decreased by 27 percent to $16.417/lb of contained vanadium in 2023 compared with $22.563/lb in 2022.

## Foreign trade

The United States continued to be a net importer of many vanadium materials in 2023. According to the U.S. Census Bureau, the United States imported (measured in vanadium content) 2.28 kt of FeV, 2.32 kt of $V_2O_5$ and 151 t of other oxides and hydroxides of vanadium. Total imports for consumption of all vanadium-bearing materials increased by 13 percent from 2022. In 2023, the United States exported (measured in vanadium content) 151 t of FeV, 28 t of $V_2O_5$ and 136 t of other oxides and hydroxides of vanadium. Total exports of all vanadium-bearing materials decreased by 31 percent from 2022.

## Outlook

The majority of vanadium is consumed in the production of steel. Therefore, consumption trends are greatly influenced by trends in steel production and the range of steel grades that contain vanadium has continued to increase. The outlook for vanadium consumption in nonferrous alloys is largely dependent on trends in demand for titanium alloys in business, commercial and military aircraft. As worldwide environmental regulations continue to become more stringent on fuels and environmental waste, recovery of elements including vanadium from spent catalysts and fossil-fuel residues is expected to increase.

The global focus on decarbonization continues to influence consumption of vanadium in the global steel industry. The consumption of HSLA steels continues to grow as the construction industry looks to significantly reduce the amount of steel required in its overall infrastructure projects, and therefore carbon emissions, while improving weight and strength. Although the vanadium market is dominated by the consumption of the steel industry, VRFBs have been widely deployed for large-scale energy storage systems. Many countries continue to strive to meet renewable energy targets, and VRFB storage is a potential solution with VRFB commercialization. However, the batteries have several barriers that still need to be overcome: the high cost of the electrolyte used in them, the system complexity of the batteries, and the lack of uniform standards. New battery chemistries are being proposed that use lower-cost and higher-abundance materials; however, many are at earlier stages of research compared with the VRFBs.

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# VERMICULITE

**by Kristi J. Simmons, National Minerals Information Center, U.S. Geological Survey**

Vermiculite is a hydrated magnesium-aluminum-iron silicate and is mined from shallow surface deposits. Raw vermiculite is similar in appearance to mica and contains water molecules within its

internal structure. In a raw state, vermiculite ranges in color from black to various shades of brown to yellow. When vermiculate flakes are heated rapidly to a temperature above 870 °C, the intermolecular water flashes into steam, and the flakes expand into gold- or bronze-colored, accordion-like particles. This expansion process is called exfoliation, and the resulting ultralightweight aggregate is chemically inert, fire resistant and odorless.

Vermiculite was discovered in 1824 by Thomas H. Webb; however, the first successful commercial vermiculite mine did not begin production until the 1920s in Libby, MT.

Today, there are two active vermiculite mining companies in the United States. Vermiculite, which gets its name from the Latin word *vermiculare*, meaning to breed worms, is mostly mined using openpit mining techniques.

## Production

In 2023, an estimated 100 kt of vermiculite was produced in the United States from two mining companies: Specialty Vermiculite Corp. (a subsidiary of Diacalite Management Group Inc.) in Enoree, SC, and Virginia Vermiculite LLC in Louisa, VA.

Data have been rounded to the nearest hundred thousand tons to avoid disclosing company proprietary data.

An estimated 74 kt of vermiculite ore was exfoliated in 2023, a 10 percent increase from 67 kt in 2022. Exfoliation was performed by 13 companies operating 15 plants in nine states: Arizona, Arkansas, Illinois, Massachusetts, Michigan, New Jersey, Ohio, Pennsylvania and South Carolina.

## Consumption

Vermiculite concentrate that has not been exfoliated is used primarily in fire protection products, but most vermiculite is consumed in exfoliated form. Exfoliated vermiculite has a wide range of uses because of its attributes, including fire resistance, high liquid absorption capacity, inertness, low density and low thermal conductivity. Agricultural uses (horticulture, soil conditioning and fertilizer carrier) were estimated to remain the leading uses of exfoliated vermiculite in 2023.

When mixed with peat, bark or compost, vermiculite provides excellent aeration and moisture retention as well as promoting fast growth of plants. Other significant uses include aggregates (concrete, plaster and premixes) and insulation (loose-fill, block, high-temperature and packing insulation, and sealants).

## Substitutes

Several substitutes can be used in lieu of vermiculite. Expanded perlite, as well as less costly alternatives such as expanded clay, shale slag and slate, are substitutes for exfoliated vermiculite in lightweight concrete and plaster.

In agriculture, alternate materials include bark and other plant materials, peat, perlite, sawdust and synthetic soil conditioners. Substitutes for loose-fill fireproofing insulation include fiberglass, perlite and slag wool.

## Foreign trade

Trade data for vermiculite concentrate are not collected as a separate category by the U.S. Census Bureau but are included within the "Vermiculite, perlite and chlorites, unexpanded" group.

An estimated 50 kt of vermiculite valued at $26 million was imported into the United States during 2023. Brazil and South Africa were the leading sources of vermiculite imports.

The United States produces finer-grade vermiculite concentrate and relies on imports for coarser-than-medium-sized concentrate.

Exports were estimated to be 8 kt of vermiculite valued at $2.1 million in 2023 with Canada being the leading destination.

## International

Global production of vermiculite was estimated to be 500 kt in 2023 compared with 516 kt in 2022. South Africa continued to be the leading vermiculite producing country followed, in descending order, by the United States and Brazil. A company in Brazil continued to develop an additional mine and production facility. The project, which is in Catalao, Goias state, is expected to begin production in 2024 with an initial production capacity of 20 kt/a of ore and with production capacity eventually reaching 60 kt/a, equaling that of their other operation. Most of the vermiculite from this new location is expected to be super fine grade.

## Outlook

Vermiculite worldwide production capacity continues to exceed consumption. Production capacity of finer grades of vermiculite continue to far exceed that of coarser grades.

The vermiculite supply issues experienced by the industry in recent years has improved and while some consumers have chosen to use alternative materials during and after that period, global demand for vermiculite is likely to remain strong. Exploration and development of vermiculite deposits containing all grades are likely to continue, while producers are also likely to continue to investigate novel uses of vermiculite, especially with the finer grades in higher-value markets.

## Reference

U.S. Geological Survey, 2024, Mineral Commodity Summaries 2024—Vermiculite: U.S. Geological Survey, p. 194–195, https://doi.org/10.3133/mcs2024.

# ZEOLITES

by Wilfrid Balmer, Alcimex, and Daniel T. Eyde, St. Cloud Mining

This article incorporates information from the summary published by the U.S. Geological Survey (USGS) on natural zeolites based on surveying producers, available at https://pubs.usgs.gov/periodicals/mcs2024/mcs2024-zeolites.pdf. The United States exports high-added-value processed and activated chabazite products for gas purification and ion exchange applications, primarily chabazite from the Bowie deposit in Arizona.

## Prices

Clinoptilolite remains the primary product of U.S. production at more than 90 percent. Chabazite remained at about 5 to 6 percent of production in 2022 and 2023, with the remainder principally made up of mordenite, phillipsite and ferrierite. However, if the products are examined based on the value of finished manufactured products, then the proportion of chabazite sales of specialty ion exchange and sorption products would be much higher than the proportion of its production volume. Prices are generally negotiated; consequently, there are no published price quotes, though Bear River reports its average sale price per ton in the annual report of its parent company, U.S. Antimony, and is a sound benchmark for the industry. In 2023, Bear River's average sale price for clinoptilolite products was reported as $243/t, up about 11 percent from $219/t in 2020.

## Production and distribution

Seven companies in the United States reported zeolite production in 2023 from 10 mines, including a new producer, Zeodorizer, in California. Significant North American producers are St. Cloud Mining Co., UOP LLC, Zeotech, KMI Zeolite, Bear River, Steelhead Resources, Zeo Inc., Zeodorizer, Teague Mineral Products and Kirkland Mining Co. Though listed, Zeo Inc. is actually a major distributor of zeolite products, and Kirkland produces a zeolitized ash used primarily for pozzolan; Steelhead has deposits, but primarily distributes.

## International producers

Outside of the United States, there is a robust industry in natural zeolites with a range of companies from small regional producers to manufacturers exporting worldwide but generally always focused on a single deposit. The value chain includes numerous distributors and increasingly sophisticated processing companies with a range of product offerings. While a significant part of past investments focused on increasing production capacity and productivity, the years 2022 and 2023 were marked by a surge in natural-gas and oil prices with a direct impact on prices. This phenomenon has accelerated the evolution of the main producers toward more economical and, above all, carbon-free technologies. A listing of international zeolite producers is as follows: International Zeolite, Zeocem, Progressive Planet Solutions, Alcimex, Rota Mining, ATZ (G. Apostolico & C. Tanagro, I.Z. (Italiana Zeoliti Srl), Blue Pacific Minerals, Verdi SpA, LITHOS Manufacturing, Josab Water Solutions, SAILE Industries, CM Zeolites (Castle Mountain Ent.), Zeogroup and Zeolite Australia Pty Ltd.

## Uses

**Animal feed.** A substantial portion of clinoptilolite sold worldwide is used in animal feeds, primarily for cattle. Beef prices in the United States continue at record highs, and it finally appears that the herd is beginning to be rebuilt, though that is far from a bankable prediction and will take a while to happen. Feed lots and other large concentrations of animals are point sources of a number of effluents, odors and waste runoffs; there will be increasing regulatory pressure to mitigate the impact of these facilities. Products for swine and poultry are available but have not yet taken off.

**Cement, pozzolans and concrete additives.** Zeolite pozzolan additives improve the physical properties of cement and reduce both the amount of limestone used and carbon dioxide emitted in manufacturing cement. If the U.S Environmental Protection Agency (EPA) designates fly ash from coal-fired power plants as a hazardous waste, it may not be available for use as a pozzolan. In general, the availability of fly ash is decreasing as coal-fired plants go offline. Several companies are considering volcanic ash and zeolite deposits as among the few cost-effective substitutes available. The major uses of natural zeolites outside the United States are in construction materials and pozzolans. There is also a significant interest in treating fly-ash storage areas, which can contain metals and other deleterious contaminants. Kirkland Mining Co. is the newest entrant into this market. Due to the shortage of fly ash in the United States created by the closing of coal-fired power plants, fly ash and natural pozzolan blends, as well as straight mineral blends have entered this market. St. Cloud has completed testing of its ash and zeolite sources and has a fully qualified product for this application with a service area tied to the cement plants in southern California. CR Minerals in southern Colorado has developed a significant market and has developed natural pozzolan

fly-ash blends that actually improve the final product. Zeocem is clearly the leader in the European market with patented solutions, notably for the elimination of chromium in cements or for reducing cement manufacturing costs while improving performance.

**Water treatment.** Zeolites are used in the filtration pretreatment of reverse-osmosis systems for potable water. Zeolite consumption will increase as wastewater recycling and conservation are mandated in the rapidly expanding urban areas of the desert Southwest. Testing on mine waters in West Virginia showed that the clinoptilolite from the Winston, NM operation was effective in remediating acid mine drainage as well as reducing aluminum and manganese contents to acceptable levels both pre- and post-treatment. Several operations are testing zeolite as a final polishing filter in these applications. Encouragingly, testing at one facility showed a drop in chemical oxygen demand (COD) and biochemical oxygen demand (BOD) of more than 30 percent. Manganese and aluminum have both been compliance issues with mine-water discharge at Appalachian coal mining operations in the East, as well as metal mining operations throughout North America. Additionally, ammonia has become a regulatory issue once again in many mining and industrial applications. Large-scale water treatment projects using zeolites to remove uranium from groundwater at treatment rates of as much as 4.5 m3/m (1,200 gpm) began operations in 2015 and continue today. The lead contamination of municipal water in Flint, MI brought national attention to significant issues in the water quality in the United States. Though zeolites were not a solution to water issues at Flint, there are applications for the filtration and treatment of municipal water supplies from both surface and well waters. There is also ongoing filtration testing of total organic carbon (TOC) at a municipal facility in an area prone to blue algae blooms, and the results continue to be encouraging.

The use of natural zeolites in water treatment is increasingly widespread in Europe, particularly for the creation of compact and mobile systems dedicated to export. The broad spectrum of action of zeolites, which act on both particulate pollution and certain dissolved pollutants, makes it possible to reduce the number of treatment steps. This leads to a reduction in capital and operating treatment costs. Iron removal from underground water is an application where natural zeolites stand out clearly. Water treatment units were implemented by Josab Water Solutions in Ethiopia where levels of 2.9 ppm of iron and 0.4 ppm of manganese were respectively reduced to 0.09 ppm and 0.2 ppm. Alcimex designed numerous units of this type in other African countries, such as Gabon and Senegal. In addition to the know-how specific to this type of filter media, it should still be noted that the choice of the type of zeolite is essential because not all are suitable. The European Committee for Standardization has established standard EN 16070, which imposes the characteristics of natural zeolites dedicated to human water consumption.

**Micronized zeolite.** The use of micronized zeolite is growing in Europe. The benefits of clinoptilolite are known, as this zeolite has been authorized by European regulations as an additive in animal feed for more than 20 years. However, the benefits of micronization to smaller than 50 µm, or even smaller than 20 µm, are being discovered for various applications, firstly in animal nutrition, where known properties are increased thanks to micronization. New agricultural applications are being developed: for example, in the fight against parasites and harmful insects, growing regulatory constraints in Europe require the finding of nonchemical alternatives. A micronized chabazite produced by Verdi SpA shows a reduction of more than 90 percent in attacks due to botrytis (Botrytis cinerea) or grape moth (Lobesia botrana). Similar results have been obtained with products marketed by Alcimex, which offers micronized zeolites for both plant cultivation and animal nutrition. Zeocem offers products mixed with carbonates to improve the agronomic impact of their clinoptilolite on tissue resistance, improving yields and photosynthesis.

**Synthetic turf.** A growing market for zeolites is in controlling odor in sports turfs and kennels. In addition, the application of zeolites can help control and disperse the heat buildup in sports turf by absorbing water and then allowing the heat buildup to drive the moisture back off, creating evaporation cooling and acting as a heat sink for the radiant energy as the sun shines on the field.

**Odor and pollution control.** Suburban residential sprawl into areas that were previously agricultural lands is increasing the use of zeolites for concentrated animal feed operation (CAFO) products used to control the odor from feedlots, dairies and other odor-causing agricultural operations. This is a strong area for future growth.

**Nuclear applications.** Chabazite and clinoptilolite-based ion exchange products are used to remove radioactive isotopes in nuclear reactor effluents. Clinoptilolite, because of its lower cost, has been used in the construction of extensive impermeable waste barriers to prevent the incursion of radioactive contamination into ground and surface water. Water Remediation Technology LLC (WRT) uses a modified clinoptilolite that is NSF 61 certified to remove radium, uranium and other contaminants from municipal water treatment systems and is

examining the increasing problem of trace radioactive contaminants in fracking and waste water from the production of natural gas and oil. WRT has more than 100 of these systems installed throughout the United States. Though work at Fukushima in Japan has slowed, worldwide there will be a growing market for the treatment and storage of high- and low-level radioactive wastes as nuclear power plants are decommissioned.

### Health and safety

The natural zeolite erionite has been a major health concern. None of the currently operating zeolite producers has fibrous erionite as a component in their zeolite products. Continued work on zeolite mineralogy has also shown that many deposits previously reported as having erionite actually contained the zeolite mineral offretite or the so-called erionite did not have the chemistry and mineralogy of the current standard for the mineral erionite.

### Trends and outlook

One trend is the development of a series of smaller marketing and distribution companies that do not have their own operations. These include Zeo Inc. in the United States and possibly Steelhead Specialty Minerals (though it does own its own deposits); and Alcimex in Europe and Zeogroup in South America are additional examples. Natural zeolite production should continue to grow at a rate of between 3 and 4 percent per year as the world recovers from the effects of the COVID-19 pandemic.

Only a small portion of the Bipartisan Infrastructure Law has actually been spent. Once it gets going and projects get permitted, additional demand for concrete will be created. As a result, products like natural zeolites that can reduce the carbon footprint of cement production will see significant growth, provided they have been fully qualified for this application. There have also been some developments in the reduction of greenhouse gases particularly methane. While the research is in its early stage, zeolites provide an excellent catalyst substrate in this application. At some point there will be consolidation in the industry and in the United States, Europe and Asia. Market consolidation will allow additional marketing, research and development, and developmental investment to support the zeolite products. Most likely, the treatment of radioactive wastes will be a growing application in the future. There are a number of Department of Energy and private industry projects in the United States, Canada and Europe that are finally coming to fruition.

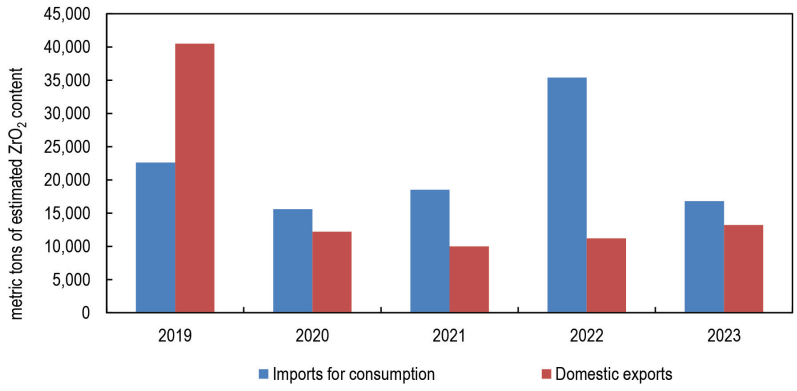
2023 is a pivotal year in which Europe has made "sovereignty" a priority. Industrial sovereignty, including the repatriation of certain activities and reindustrialization, is underway, as are activities linked to zeolites. This development includes taking into account climate change and the reduction of polluting sources. In this context, natural zeolites have a very strong growth potential to the extent that these materials, thanks to their exceptional properties, participate in the reduction of the environmental impact of many industries. We are seeing an increase of more than 15 percent in production on this continent, which is the world leader in natural zeolites. In this context, it is not surprising to see European operators offering their products in the United States and in particular on the East Coast, where sea transport is least expensive. Despite the potential growth, this new competition risks causing a reduction in margins and market profitability in the United States.

## ZIRCONIUM

**by Joseph Gambogi, National Minerals Information Center, U.S. Geological Survey**

### Figure 1

**U.S. salient trade statistics for zirconium ores and concentrates, 2019-2023. (Source: U.S. Census Bureau)**




The principal economic source of zirconium is most often in the form of the zirconium silicate mineral, zircon ($ZrSiO_4$). Zircon is predominantly recovered as a coproduct of the mining and processing of placer deposits for heavy mineral sands including the titanium minerals, ilmenite and rutile, or tin minerals. Ceramics, foundry sand, metal, refractories, and zirconia (zirconium dioxide, $ZrO_2$) and other zirconium chemicals were the leading end uses for zircon with the dominant end use being ceramics, which accounted for about one-half of the total zircon market. Milled zircon is used in ceramics as an opacifier in ceramic bodies and glazes.

Zirconia and other zirconium

chemicals are used in a variety of other uses. Yttria-stabilized zirconia is used in the manufacture of oxygen sensors that control combustion in automobile engines and furnaces and in the manufacture of diverse products including cubic zirconia, fiber-optic connectors, refractory coatings and structural ceramics. Zirconium metal is used in corrosive environments and various specialty alloys. Because of its low thermal neutron absorption cross section, hafnium-free zirconium metal is used as cladding for nuclear fuel rod tubes.

In refractory and foundry uses, zircon is used for facings on foundry molds, where it increases resistance to metal penetration and gives a uniform finish to specialty metal castings. Milled or ground zircon is used in refractory paints for coating the surfaces of molds, and refractory bricks containing zircon are used in furnaces and hearths for containing molten metals.

## Production

Global production of zircon concentrates in gross weight was estimated to be 1.4 Mt in 2023. The leading producing countries, Australia and South Africa, accounted for over half of global production (Table 1).

In the United States, The Chemours Co. produced zircon concentrates at its heavy-mineral-sands mining and processing operations near Starke, FL, and Nahunta, GA. In California, Twin Pines Minerals LLC reprocessed stockpiled mine tailings to produce heavy-mineral concentrates containing titanium and zircon.

## Trade

Based on data from the U.S. Census Bureau, U.S. zircon concentrate exports totaled 13 kt in $ZrO_2$ equivalent weight with a value of $39 million in 2023 and were 17 percent greater on a quantity basis than in the prior year. In 2023, China (34 percent), India (27 percent) and Mexico (18 percent) were the leading destinations of U.S. exports of zircon concentrates.

In 2023, the United States imported an estimated 16.8 kt in $ZrO_2$ equivalent weight of zircon concentrates with a value of $55.8 million, 53 percent less on a quantity basis than in the prior year (Fig. 1).

The leading import sources, in descending order of quantity, were Australia (68 percent), South Africa (17 percent) and Senegal (8 percent). China, the leading global consumer of zircon concentrates, imported an estimated 1 Mt in $ZrO_2$ equivalent weight of zircon concentrates with a value of $1.3 billion.

## Prices

On a gross weight basis, the average U.S. zircon export unit value in 2023 was $1,910/t, a 5 percent increase from the previous year. The average annual U.S. zircon import unit values increased by 7 percent to $2,070/t of gross weight (Fig. 2).

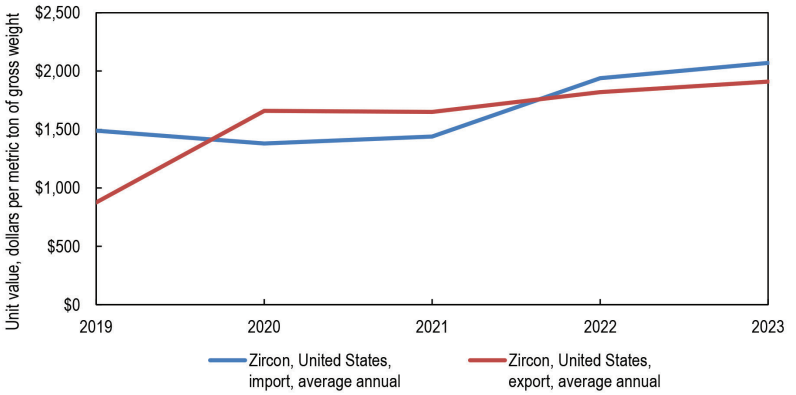
For comparison in global markets, China's average annual zircon unit value of imports was $860/t, a 26 percent decrease compared with $1,160/t in 2022. Some of the change in unit value may be attributed to grade and quality.

## Outlook

Consumption of zircon is tied to global economic growth. According to the International Monetary Fund, the global economic growth rate is projected to be 3.1 percent in 2024 and 3.2 percent in 2025, below the historical 2000-2019 average of 3.8 percent. The ceramics, chemicals, refractories and foundry, and casting applications are expected to continue to lead the consumption of zircon. According to a leading mineral sands producer, declining mining grades was expected to constrain long-term supply.

## Figure 2

**Average annual unit values of imported and exported zircon ores and concentrates, 2019-2023. Import unit values are based on imports from Australia, Senegal and South Africa. Export unit values are based on total domestic exports. (Source: U.S. Census Bureau)**




## Table 1

**World production of zircon ores and concentrates by country, in kilotons, gross weight. (Source: U.S. Geological Survey)**

| | 2022 | 2023[e] |
|---|---|---|
| United States[1] | 100 | 100 |
| Australia | 500 | 500 |
| China | 140 | 140 |
| Indonesia | 97 | 90 |
| Kenya | 27 | 30 |
| Madagascar | 27 | 30 |
| Mozambique | 104 | 90 |
| Senegal | 57 | 50 |
| Sierra Leone | 34 | 30 |
| South Africa | 300 | 400 |
| Other countries | 57 | 140 |
| **Total (rounded)[1]** | **1,440** | **1,600** |

[e]Estimated production.
[1]U.S. production data are rounded to the nearest hundred thousand tons to avoid disclosing company proprietary data.

## References

U.S. Geological Survey, 2024, Mineral Commodity Summaries 2024—Zirconium and hafnium: U.S. Geological Survey, p. 204–205, https://doi.org/10.3133/mcs2024.

Zen Innovations AG, Global Trade Tracker. ■

# The future lies in mining...

## Want to be a force for change? Be a mining engineer.

**by Chee Theng, Managing Technical Editor**

The facts are clear. For a career that is both personally and socially rewarding, becoming an engineer in the mining, geological and metallurgical fields is one of the best options for a student today.

The benefits start on campus with myriad opportunities for internships and scholarships. At a recent career fair at the University of Utah, companies including Freeport-McMoRan, Komatsu and Rio Tinto were recruiting for more than 300 internship openings available in the summer of 2024.

Upon graduation, students choose from a spectrum of career paths, and options to work internationally or across the United States. Graduates can look forward to rapid career advancement, as a retiring workforce makes way for the next generation, along with enviable job prospects, security and compensation. According to the U.S. Bureau of Labor Statistics, the median annual pay for mining and geological engineers in 2022 was $97,490.

In the workplace, mining engineers work with sophisticated technology and cutting-edge concepts. In an age of green transition, they are essential in society to produce the critical minerals and materials needed for clean energy technologies such as solar panels, wind turbines and electric vehicles. On Sept. 6, 2023 the U.S. Department of Energy announced up to $150 million in funding to advance cost-effective and environmentally responsible processes to produce and refine critical minerals and materials in the United States.

Going beyond the rigors of work and career, *Mining Engineering* (**ME**) found an undefinable something that draws students into a lifelong passion as they take the journey into the mining and minerals profession, with references to a close-knit community and camaraderie frequently coming up in the student feedback. ■

*In January,* **ME** *launched Part 1 of the Feature Series on U.S. Mining Engineering Schools, highlighting Q&As with the heads and chairs of ABET-accredited mining programs at universities across the United States and asking students, both past and present, for their candid feedback. In Part 2, we feature The Pennsylvania State University, South Dakota School of Mines & Technology (South Dakota Mines), West Virginia University and The University of Utah.*

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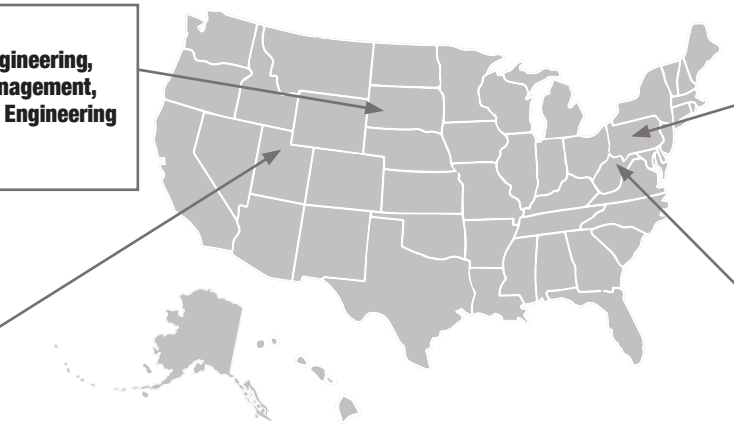

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# The Pennsylvania State University

The Pennsylvania State University is a multicampus, land-grant, public research university that educates students from around the world and supports individuals and communities through integrated programs of teaching, research, and service. Penn State, founded in 1855 as an agricultural college, admitted its first class in 1859. The Pennsylvania legislature designated Penn State as the Commonwealth's sole land-grant institution in 1863, which eventually broadened the University's mission to include teaching, research, and public service in many academic disciplines. Penn State has awarded more than a half-million degrees and has been Pennsylvania's largest source of baccalaureate degrees at least since the 1930s. From top-tier academics, thriving athletics, and engagement opportunities to unparalleled success pathways after graduation, Penn State is more than a university. We are a community that is rooted in imagining, collaborating and inventing our way to a better world. ■

## Q&A with Barbara J. Arnold, Chair and Professor of Practice, Mining Engineering, Penn State, John and Willie Leone Department of Energy and Mineral Engineering

**What are the mining-related degree programs offered by Penn State, and what are some of the subdisciplines?**

Penn State offers a B.S. in mining engineering. M.S. and Ph.D. degrees can be obtained either through a base Energy and Mineral Engineering option or through the Mining Mineral Processing Engineering option. Several mining/mineral processing faculty have also signed up as praxis advisors for the College of Engineering online Doctor of Engineering program. Currently, an associate degree in mining is offered through Fayette, the Eberly Campus in southwestern Pennsylvania. There is also a minor in mining engineering available, though we are in the process of changing those requirements. Either a certificate program or a minor in mineral processing/extractive metallurgy is in the works.

**What are the strengths of Penn State programs?**

The Penn State mining curriculum builds on a strong foundation of science and engineering from across the university. Students come to us with a strong background in mathematics, physics, engineering mechanics and other related fields. We also have a strong geosciences program, with our students taking three courses in that discipline. Students can also choose from a wide variety of general education courses offered at the university. Our core mining faculty provide the students with the basic curriculum that all mining engineers need. But we go beyond that, offering additional mineral processing, automation and control, and sustainability/responsible mining courses.

**Which industries do your graduates find careers in, and what are the career prospects?**

All of our students have found internships and full-time employment in recent years, many with multiple job offers. Most of our students have found their way to the aggregates industry, though a few go into coal and engineering consulting. The prospects for a career are excellent.

**What are the current areas of research?**

Our health and safety research area involves several projects on respirable dust and others on battery fires, automation and other aspects of underground mining. Our faculty are also engaged in projects related to critical mineral resource assessment and recovery from secondary sources, including mining waste and e-waste. Faculty are also engaged in leaching of sulfide ores, recovery of lithium from spodumene, recovery of rare earth elements from red mud and other sources. While we maintain research in coal, a long tradition at Penn State, we also touch metal and nonmetal mining in our research.

**What are the future technology trends?**

We all need to be aware of the move toward artificial intelligence and how that will impact mining and mineral processing

**Barbara J. Arnold**
*"All of our students have found internships and full-time employment in recent years, many with multiple job offers .... The prospects for a career are excellent."*

Logo and photos courtesy of The Pennsylvania State University

## The Pennsylvania State University

*Constructed in 1896, the obelisk, also called the polylith, stands 32.7 ft high and weighs 53.4 t. This "pile of rocks" was created the same year the College of Earth and Mineral Sciences (formerly the School of Mines) came into existence. The obelisk, built by State College stonemason Michael Womer, began as a kind of answer to all the requests the college had been receiving for information on stones. The* Mining Bulletin *recorded, "The numerous enquiries which this Department has been receiving regarding the nature, durability or appearance of certain specified stones, or concerning the identification of a specimen, have impelled the authorities of the College to attempt the erection of an obelisk out of the representative building stones of the Commonwealth, and thus to furnish in a substantial form an attractive compendium of information for quarrymen, architects, students, and visitors." Magnus C. Ihlseng, Penn State's first professor of mining engineering and geology initiated its construction, desiring to create an instructional yet artistic monument that would test the weathering qualities and commercial value of Pennsylvania's building stones. He considered the obelisk to have been the "greatest single expenditure for the year" of the college — $708.09. (Excerpted from https://libraries.psu.edu/about/collections/stones-obelisk)*

from exploration, through mine planning, production, processing, transportation, and so on. Yet, we must not forget to build upon the solid foundation laid by our predecessors in the industry, both mining and processing. Robotics will become more important as we remove workers from harm's way. But understanding how to interface with programmers to truly take advantage of these opportunities will be key.

**What advice would you give to students to get the most out of their time at Penn State?**

Interestingly, I teach one of our first-year seminars. I have the college's student engagement staff speak with them. They have a series of programs on engagement that cover all types of activities — student clubs and organizations, undergraduate research, study abroad. I encourage the students to get involved in something outside of the classroom. We also ensure that the mining students become SME student members so that they can take advantage of the scholarship opportunities. We encourage the students to attend field trips, go to conferences, and interact with faculty as much as possible. ■

**Daniel Buonanno**
**| Junior mining engineer**
**| Hatch Ltd.**

*"I consistently utilize both the technical and soft skills I learned at Penn State. The design, problem-solving, ethical and management skills I developed are crucial in making day-to-day decisions on any project."*

### Daniel Buonanno

*Bachelor's degree in mining engineering with a minor in energy business and finance, 2023*

**Where are you working now; what is your role?**

I am currently working at Hatch Ltd. in Salt Lake City, UT as a junior mining engineer. Projects include South32 Hermosa Taylor Process Plant engineering and Freeport-McMoRan underground basic engineering.

**How has your time at Penn State contributed to your personal growth?**

Penn State gave me the well-rounded education needed to excel as an engineer in the mining industry. The rigorous engineering courses, state-of-the-art laboratories and innovation spaces and hundreds of extracurricular activities all provided many opportunities to grow in different ways. I was involved in the SME student chapter as an officer as well as other clubs and committees, which taught me excellent leadership and interpersonal skills. Throughout the curriculum, I had the ability to develop technical skills from top professors in mining and other adjacent fields, all of whom were extremely passionate and invested in their students' success. The mining engineering department offers a close-knit community that promotes advancement of the industry through research and helps bring internships and full-time jobs to students. This was key to my success in the program and prepared me to enter the industry as a professional. In addition to the education, the atmosphere at Penn State's main campus in State College, otherwise known as Happy Valley, was unmatched. With around 50,000 spirited students, and the largest alumni network in the world, Penn State gave me the opportunity to build some of the most valuable relationships I will have for a lifetime.

**In what way are you using what you learned, and what do you see for the future?**

During my time in the industry thus far, I consistently utilize both the technical and soft skills I learned at Penn State. The design, problem-solving, ethical and management skills I developed are crucial in making day-to-day decisions on any project. Persistence and grit are two additional traits I gained through the mining program at Penn State, which guide me through the many obstacles that present themselves in engineering projects.

Another important concept the Penn State mining engineering program emphasized was

## The Pennsylvania State University

building relationships. Whether it is with other students, coworkers, clients or contractors, establishing good relationships is a key component to being a successful engineer in the mining industry.

Looking ahead, I am excited to see the mining industry expand. The domestic growth of critical mineral production and research, which Penn State is heavily involved in, is an initiative that is increasingly important in our world. Additionally, introducing innovative technologies to operations will be significant in creating a safer, greener and more efficient mining industry.

**What advice would you give to a student considering a career in mining?**

I encourage any students working toward a career in mining to take every opportunity to network with both professionals and students. Building relationships will not only help to obtain a job but will provide insight into the many areas of the mining industry. As a student, one of the goals is to find what excites you, which can sometimes be a confusing process. Taking the advice and wisdom of others will make the journey clearer. Lastly, find internships in mining throughout your education and try different areas of the industry if possible. There are endless opportunities to be on the forefront of this dynamic industry as an engineer to make the world a better place.

Mining, whether it be for metals, aggregates, industrial minerals or coal, provides the resources that form the backbone of modern society. ■

### Chase Gleason

*Senior, degree in mining engineering*

**How has your time at Penn State contributed to your personal growth?**

I think my time at Penn State has allowed me to grow into the person I hope to be for a long time, and I think Penn State has been really great at facilitating that aspect of college lifestyle. Studies are my main focus, but the encouragement to explore creativity, social activity and extracurriculars have allowed me to simultaneously educate myself and develop passions for things like music, community service, and the history of the mining industry.

**In what way are you using what you learned, and what do you see for the future?**

Unsurprisingly, I see myself applying the skills and knowledge learned at Penn State for the rest of my career. Whether it be in specific skills or in a general idea, I believe having familiarity with a variety of topics allows me to understand and choose between lots of options after school where I can remain familiar and comfortable. To give specifics, I see myself going into the aggregates industry, and having taken labs where programs were used to practice modeling an openpit mine are skills I will nearly one-for-one carry over.

**What advice would you give to a student considering a career in mining?**

Biggest advice I can give is to get involved with your college and professors. Classes will teach you, but I've found the most valuable aspect of my education to have come from working with professors directly, seeing the guest lecturers and visiting sites through the student chapter. ■

**Chase Gleason**
**| Senior, mining engineering**

*"Get involved with your college and professors."*

### Ian Penrod

*Senior, going into fifth year, bachelor's degree in mining engineering*

**How has your time at Penn State contributed to your personal growth?**

While studying at Penn State, I have been able to learn a lot about myself. I have learned to have discipline and be able to complete all of my assignments on time. I have also discovered the best practices for myself to complete tasks and set myself up for success.

**In what way are you using what you learned, and what do you see for the future?**

I see myself using what I have learned here at Penn State every day. I will use the curriculum I have been taught to design mines and keep them safe and operating efficiently. I will also use the skills that I have picked up while attending Penn State to make sure my work is completed to the best of my ability.

**What advice would you give to a student considering a career in mining?**

I would encourage new students to ask questions and always try and learn more. Mining has many different topics and each one can go into so much detail, you can learn something new about it every day for years. With all of these options out there mining has a specific field for everybody. ■

**Ian Penrod**
**| Senior, mining engineering**

*"Ask questions and always try and learn more."*

SOUTH DAKOTA MINES
An engineering, science and technology university

# South Dakota Mines

Founded in 1885, South Dakota Mines (SDM) is a STEM university offering bachelor's, master's and doctoral degrees and enrolling roughly 2,500 students. With a placement rate of 97 percent and an average starting salary of $73,547, SDM is consistently ranked among the best engineering schools in the country for return on investment.

SDM is one of only five U.S. universities that offer degrees in all mineral industries disciplines. Today, the core disciplines of geology and geological, metallurgical and mining engineering remain an integral part of South Dakota's economy. Mining alone has a $2.5 billion annual impact on the state. ■

## Q&A with Robert Hall, Professor and Department Head, Mining Engineering and Management, Geology and Geological Engineering

**Robert Hall**
*"Our key strengths are our students, faculty expertise, and infrastructure .... Seventy-three percent of last year's graduates had relevant work experience through paid internships, co-ops or research."*

**What are the mining-related degree programs offered by SDM, and what are some of the subdisciplines?**

SDM has three departments that offer degrees related to the minerals industry: (1) geology and geological engineering (GGE), (2) mining engineering and management (MEM) and (3) materials and metallurgical engineering (MET).

The GGE department offers B.S. and M.S. degrees in geology and in geological engineering. The MEM department offers B.S. and M.S. degrees in mining engineering. GGE and MEM share a Ph.D. in geology, geological engineering, and mining engineering. All MEM graduate courses are offered in person and online.

The MET Department offers a B.S. degree in metallurgical engineering that includes required coursework in mineral processing and extractive metallurgy. MET administers interdepartmental M.S. and Ph.D. degree programs in materials engineering and science.

All three departments offer minor degree options. Of note is a joint effort between the three departments in creation of two minors in critical minerals, one focused on exploration and development and another on processing and extraction.

**What are the strengths of the SDM programs?**

Our key strengths are our students, faculty expertise, and infrastructure. Our programs start with high-quality students. Our incoming students come from a variety of backgrounds but with shared characteristics: a strong work ethic, creativity and ingenuity. They also bring strong scholastic achievement: incoming undergraduate students have an average ACT score of 26 and GPA of 3.6.

The collaboration among faculty in these programs allows us to provide unique solutions to emerging research opportunities — such as artificial intelligence (AI), automation, and energy management — to support the sustainable development of mineral resources.

As for infrastructure, in the fall of 2024, the mineral industries programs will move into the new 63,800-ft$^2$ Nucor Mineral Industries Building. This $41.8 million facility will allow state-of-the-art instruction and research for the next generation of mineral industry leaders. The building was enabled through significant support from the state of South Dakota and the private sector, including Nucor Steel, Freeport-McMoRan and Nevada Gold Mines. The facility represents the first new, dedicated mineral industry training center built in the United States in the last more than 20 years.

Our location in the Black Hills is an asset for faculty and students. The area has a long history of mining, and still has active mining and quarry operations near to the school. Additionally, the school has access to the Sanford Underground Research Facility. The unique geology of the Black Hills provides tremendous learning opportunities for our students.

**Which industries do your graduates find careers in, and what are the career prospects?**

Our students go to work in all facets

## South Dakota Mines

of the mineral industries, traditional mining companies, aggregates and quarry operations, equipment manufacturers, construction companies, and environmental services. Seventy-three percent of last year's graduates had relevant work experience through paid internships, co-ops or research.

**What are the current areas of research?**

Underground production schedule optimization with health and safety requirements; laser-induced rock breakage; integration of production scheduling with geotechnical constraints; mine ventilation and the mining environment; equipment maintenance and reliability, automation, and technology implementation; critical minerals track-and-trace technology; critical minerals concentration and extraction; resource characterization and identification; GIS analysis of conflict zone mining.

**What are the future technology trends?**

As the industry and the world moves toward electrification, increased automation, and integration of AI, we will see significant changes in how we design, operate, locate, recover, process and extract resources. SDM students will be heavily involved in these changes, and our programs are designed to ensure that our students have both the technical expertise and forward-looking skills to support the industry as it embraces

currently emerging technologies and those yet to be developed.

**What advice would you give to students to get the most out of their time at SDM?**

Students should become engaged with the many professional organizations, clubs, and other co-curricular activities available, which will help them become well-rounded mineral industry professionals.

**Any other topics you wish to highlight?**

South Dakota Mines offers a wide variety of mineral industry-focused professional education opportunities for individuals and companies through the Office for Professional Education. Programs include the Mining Industry Primer, Surface Mine Supervisor Training, and Underground Hardrock Mining, among others. Participants can receive professional development hours

SOUTH DAKOTA MINES
An engineering, science and technology university

Logo and photos courtesy of South Dakota Mines

## South Dakota Mines

(PDHs), with some programs counting toward graduate-level certificates and/or degrees at SDM.

Additionally, Rapid City received a U.S. Economic Development Administration strategy development grant to create the Black Hills Deep Underground Frontier, a tech hub that connects SDM to the historic downtown area.

The hub will focus on developing new mining technologies and recruiting the workforce needed to secure a safe and efficient supply of critical minerals for the nation. The key technology focus areas are autonomous equipment and robotics, anthropogenic disaster prevention and mitigation, and advanced energy and industrial efficiency. SDM will be a significant contributor to these efforts through research and economic development activities, including the NSF ENGINES, I-Corps, and Partnerships for Innovation programs along with industry-sponsored research. ■

**Dominic Derting**
**| Junior, mining engineering**

*"There is a projected shortage of professionals in the mining industry in the near future, making it an opportune time to join."*

**Dominic Derting**
*Junior, degree in mining engineering*

**How has your time at SDM contributed to your personal growth?**

My journey at SDM has been instrumental in shaping me into a proficient mineral professional. The institution's unwavering commitment to exposing us to industry norms and practices has been a game-changer.

SDM has opened doors to numerous unique opportunities, such as mine tours and participation in student and professional clubs like SME and Mining and Mucking. The faculty's strong support, be it in upholding industry standards or addressing any queries, has been invaluable.

**In what way do you see your using in the future what you have learned?**

I see myself using everything I have learned to create a safe and efficient mine with a good work environment. I am learning leadership on campus by being involved in multiple clubs. I am also learning economics, surveying, and a wide variety of modern exploration techniques through classes. The best learning environments are internships offered by various mineral companies SDM attracts at career fairs.

**What advice would you give to a student considering a career in mining?**

If you're considering a career in mining, my advice is to dive right in. It's one of the most diverse and fascinating industries, offering opportunities to travel the world and immerse yourself in different cultures. The school environment at SDM is vibrant, with a plethora of clubs and opportunities to bond with fellow students.

Moreover, there is a projected shortage of professionals in the mining industry in the near future, making it an opportune time to join. ■

**Kathleen Tew**
*B.Sc., Mining Engineering & Management and B.Sc., Geological Engineering, both May 2016*

**Where are you working now; what is your role?**

I am working as a project engineer at Cementation USA.

**How has your time at SDM contributed to your personal growth?**

SDM offered me the chance to grow from a shy high-school student to a professional that is not afraid to step up and volunteer to help, but who also has the leadership skills to deliver results and critically solve problems. The classes challenged me both in the classroom and with practice field labs. The school offered me the chance to join professional societies, participate in intercollegiate groups and help start a Mine Rescue Team. The MEM department even supported me from planning to execution when I had the idea to host a one-day conference at the school. The school provided an environment where I could fail, but I had a support network to succeed on the next attempt.

With these opportunities I learned what my leadership style was (and what style was not effective), I learned how to fundraise, how to work with my peers, and how to network. The departments did an amazing job creating opportunities to meet industry professionals, many of whom are still mentors to this day. These factors

## South Dakota Mines

have heavily contributed to who I am today as a professional.

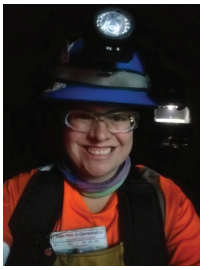
**In what way are you using what you learned, and what do you see for the future?**

SDM developed my critical-thinking skills, which are used on a near-daily basis. The management aspect of the MEM degree covers courses like micro and macroeconomics, human resource management and industrial psychology. These courses set me up to understand mineral finance and see my mine planning tasks differently from when I first graduated from college. In the core classes I learned about the basis of calculations and how to analyze that data to understand how each component affects the outcomes of designs and plans. I use that knowledge to make more informed decisions. Currently, the finance, psychology and management knowledge guide me in asking better questions for the projects I work on, both when reporting to clients and internally. In the future, I see myself continuing to grow my knowledge off the foundations that the school provided. I see myself on a path of continuous learning and finding new ways to be efficient and use the data around me to make best-for-project decisions.

**What advice would you give to a student considering a career in mining?**

Have curiosity in developing yourself: try a leadership position in a school club/society, don't just take the easy elective, take the operational internship, go to the professional society meetings if you have the chance, and try to learn as much as you can about different subjects. Mining has many pathways in terms of jobs: surface, underground, metals, nonmetals, finance, consulting, contracting, equipment manufacturers, suppliers, and software developers. The industry is relatively small but the opportunities are endless.

In general, school can also be overwhelming and stressful, so early on find a person that can act as a mentor or a ventor; the professors in your major generally want to see you succeed and if you ask they may fill the mentor role. Also, take every opportunity you have to grow your network. Even if you only meet one new person at each event, that is someone you didn't know beforehand that could lead to new opportunities. ■



**Kathleen Tew**
**| Project engineer**
**| Cementation USA**

*"SDM developed my critical-thinking skills, which are used on a near-daily basis."*

**Judith Buaba**
*Ph.D., Mining Engineering, May 2023*

**Where are you working now; what is your role?**

I am a mining engineer with Freeport-McMoRan at the Morenci operation in Arizona. In my current role as a slope monitoring analyst, I am responsible for monitoring real-time radar data for any signs of slope deformation and alerting stakeholders in case of a potential slope instability.

**How has your time at SDM contributed to your personal growth?**

Attending SDM has significantly contributed to my personal growth by providing a challenging academic environment, opportunities for hands-on learning through internships, and a supportive community, both in and out of school, that encouraged me to push my boundaries. I have had the opportunity to attend several conferences, including the MINEXCHANGE SME Annual Conference & Expo, to present my research and network with other professionals in mining. My time there has made me more resilient, persistent, and adaptable to different working environments.

**In what way are you using what you learned, and what do you see for the future?**

I am using my analytical, critical-thinking, communication, research and technical-writing skills honed at South Dakota Mines to address real-world challenges. As a slope monitoring analyst, I interpret slope monitoring data, assess slope instability risks in active mine areas, and communicate findings to stakeholders and operators. I play a crucial role in ensuring safe evacuation procedures in case of potential slope failures and produce detailed technical reports following such events. Looking ahead, I see myself continuing to build upon this foundation, embracing opportunities for growth, and making meaningful contributions in my field and beyond.

**What advice would you give to a student considering a career in mining?**

Go for it! Mining plays a crucial role in powering economies and advancing technology, so your work can have a significant impact on shaping the future. Pursue a strong education in mining engineering or related fields, seek out internships or co-op experiences to gain practical knowledge, and stay curious and open to learning about advancements in technology and sustainable practices within the industry. The skills acquired from mining are mostly transferable to other industries as well.

Networking and building relationships with professionals in the industry through SME can also open doors to exciting opportunities. Most importantly, approach your career with a commitment to safety, and environmental stewardship. ■

**Judith Buaba**
**| Mining engineer**
**| Freeport-McMoRan**

*"I am using my analytical, critical-thinking, communication, research and technical-writing skills honed at SDM to address real-world challenges."*

# West Virginia University

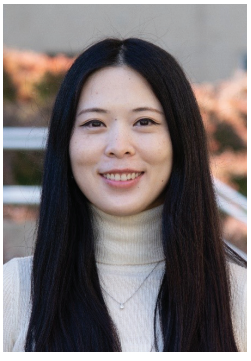
West Virginia University (WVU) is a public land-grant research university with its main campus in Morgantown, WV. It is the state's flagship and an R1 Institution with the highest research activity as described by the Carnegie Classification of Institutions of Higher Education. As a land-grant institution, the faculty, staff and students at WVU commit to creating a diverse and inclusive culture that advances education, healthcare and prosperity for all by providing access and opportunity; by advancing high-impact research; and by leading transformation in West Virginia and the world through local, state and global engagement.

Mining engineering at WVU is a renowned program with more than 150 years of educating students about the advancements in science, safety and innovative technology of mineral extraction and processing. The program at WVU, which is one of the only 14 ABET-accredited mining engineering programs in the United States, dates back to 1868 when the first mine surveying course was offered. The program at WVU is designed to provide graduates with a broad background in mining engineering practice, provide experiential opportunities to gain real-world experience and prepare them to become professional engineers.

Each year, more than 50 departmental and external scholarships are distributed to mining students to help them pursue their degree. WVU mining graduates are employed by the mining industry, explosives and blasting companies, equipment manufacturers and governmental agencies with starting salaries typically ranging from $70,000 to $95,000.

The mining engineering curriculum is designed to provide graduates with a broad background and to prepare them for a successful career in the industry. At nearly a 100 percent job placement rate, graduates are highly sought after by companies such as Caterpillar, Laurel Aggregates, Peabody Energy, Arch Resources, Vulcan, Nevada Gold Mines and many others. Students are prepared for positions in operations, mine development, mine design, construction, sales, management of mines, and professional and continuing studies. ■

## Q&A with Qingqing Huang, Ph.D., P.E., Associate Professor and Robert E. Murray Chair of Mining Engineering



**Qingqing Huang**
*"Our program features nearly 100 percent job placement, field trips, professional conferences, internship experiences and small class sizes."*

**What are the mining-related degree programs offered by WVU, and what are some of the subdisciplines?**

WVU Mining Engineering offers a bachelor's degree in mining engineering, dual degrees in mining and civil engineering, mining engineering and geology, as well as master of science and doctor of philosophy degrees in mining engineering and mineral processing. Our program's subdisciplines include surface and underground mining, rock mechanics and ground control, mine ventilation, mineral processing and extractive metallurgy and mine subsidence.

**What are the strengths of the WVU programs?**

WVU Mining Engineering is a program with a longstanding history in mining education and research. Our faculty specialize in a broad range of areas, including surface mining, rock mechanics and ground control, mine ventilation, mine subsidence, mineral processing and extractive metallurgy, mine planning, mine design and operations management. Our curriculum offers various topics that prepare our students well for dynamic job markets and the ever-evolving mining industry. With the strong support of our industrial partners and professional organizations, WVU Mining Engineering provides more than 50 departmental and external scholarships to our students. In addition, our program features nearly 100 percent job placement, field trips, professional conferences, internship experiences and small class sizes. Our faculty, staff and alumni are committed to creating a welcoming, supportive and inclusive environment to ensure our students succeed academically and professionally.

**Which industries do your graduates find careers in, and what are the career prospects?**

Our graduates are employed in coal, aggregates, and metal and nonmetal surface and underground mines. They are also employed by explosives and blasting companies, equipment manufacturers,

## West Virginia University

consulting companies and governmental agencies. Some choose to further advance their studies by attending law and graduate school. Employment opportunities also exist in large mining companies worldwide. According to Data USA: Mining & Mineral Engineering (2024), only 314 degrees in mining engineering were awarded in the United States in 2021, far less than what the industry needed. There will continue to be a high demand for mining engineers in the short and long terms, especially with the looming labor deficiency associated with retirement over the next two decades and the crucial role mining engineers play in the metal and energy sector.

**What are the current areas of research?**

Our research areas lie in various aspects of mining and mineral processing, including rare earth and critical mineral extraction from primary and secondary sources, mineral carbonization for comminution energy reduction and carbon-negative process development, robotics and drones, ground control, and mine health and safety-related research. Our faculty are also actively researching innovative pedagogical methods and curriculum advancement by implementing virtual reality in a classroom setting and enhancing students' experiential learning experience.

**What are the future technology trends?**

Mining engineering is an ever-evolving industry with constant technological advancement and modernization. With this context, future technology trends will be centered around evolving mining into a safer, more efficient and sustainable industry. Technologies like automation will find wide application in mine production and safety-related operations. In addition, given the ever-increasing demand for critical minerals in the United States, the industry will be driven toward low-cost and clean technologies across the full spectrum of production, ranging from prospecting and exploration to middle-stream extraction, concentration, refining and metal production.

**What advice would you give to students to get the most out of their time at WVU?**

Attend info sessions and talk to mining companies. These info sessions will provide excellent opportunities for students to network with industrial professionals and find internships and jobs. Do well in your academic study and seek opportunities

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to work as a summer or winter intern for hands-on experience. Apply for external and internal mining engineering scholarships; you can almost go to college for free if you apply for the eligible scholarships and have paid internships each year. Connect with people you meet during field trips and professional conferences. These people you network with can be valuable assets and important mentors as you advance in your career and professional development. Be well prepared and seize every single opportunity.

**Any other topics you wish to highlight?**

WVU Mining Engineering has several active student chapters of professional organizations, including SME, Women in Mining Engineering, and the WVU Mine Rescue Team. The student chapters give our students excellent opportunities to be involved in a professional organization and help the mining engineering program with outreach and engagement activities. For example, the WVU Mine Rescue team trains students for mine emergency scenarios and equips them with real-world skills. The team has won eight consecutive SME-Eastern Collegiate Mine Rescue Competitions and is the 2023 and 2024 International Collegiate Mine Rescue Champions. All of these student chapters of professional organizations are open to our mining engineering students to join.

Our students are driven to excel in their academic and professional studies by competing in regional and national contests. WVU Mining Engineering students have won senior design competitions by the Pittsburgh Coal Mining Institute of America and the SME Pittsburgh Section 13 times and placed first in the national Carlson Software Competition four times. They also earned second place in the recent 2024 SME/National Stone, Sand and Gravel Association Student Design Competition for their mine design and reinvestment plan. All those are just examples of the testaments of our student's success.

At WVU Mining Engineering, we foster a collaborative and supportive environment where all our students, faculty and staff work together as a close-knit community. We are fully committed to further growing the program by developing active outreach activities and innovative recruiting strategies. For instance, we implement virtual-reality systems in recruitment, offer summer online blasting camps for middle- and high-school students, and participate in Engineering Boot Camps for K-12 teachers and Scout Merit Badge to expose mining concepts to various audiences. This collective effort paves the pathway for our program to grow further and instills a sense of belonging and camaraderie among our community members. ■

**Trent Cavanaugh | Senior, B.Sc., Mining Engineering**

*"WVU has equipped me with the skills and experiences necessary to succeed."*

**Trent Cavanaugh**
*Senior, B.Sc., Mining Engineering*

**How has your time at WVU contributed to your personal growth?**

I feel that my time at WVU has significantly contributed to my personal and professional growth.

WVU has challenged me to improve my critical thinking, which has been crucial for my development as a student and future professional. The university offers a variety of clubs and organizations, such as the WVU Mine Rescue Team and the WVU SME Student Chapter, both of which I have been actively involved in. Participation in these organizations has provided me with great experiences, including educational trips, hands-on experience through internships, and networking opportunities with industry professionals. Overall, WVU has equipped me with the skills and experiences necessary to succeed in my career while fostering my personal development through diverse opportunities.

**In what way do you see your using in the future what you have learned?**

I see myself using the skills that I gained from my coursework and hands-on experiences to provide the safest, most efficient working environment I can once in the industry. Additionally, I plan to use the knowledge I have gained through my collegiate career to obtain my professional engineering license.

**What advice would you give to a student considering a career in mining?**

The best advice I can offer is to be confident and to get involved. The mining industry provides so many opportunities and crucial elements to our society that it will never become obsolete. ■

## West Virginia University

**Gabriela Kosakowski**
*B.Sc., Mining Engineering and B.Sc., Civil and Environmental Engineering, May 2023*

**Where are you working now; what is your role?**

Following graduation, I joined Colas Inc. in their business rotation program. I am able to utilize both my degrees as a project engineer working in aggregates mining, project management and estimating. Through this program, I have traveled the United States, and I am currently based out of Juneau, AK.

**How has your time at WVU contributed to your personal growth?**

My time at WVU contributed significantly to my growth as both an engineer and a person. The Department of Mining Engineering goes above and beyond to provide students with opportunities to experience the industry firsthand. This includes bringing more than 20 companies on site for info sessions and interviews, site visits, student competitions and sending students to the MINEXCHANGE SME Annual Conference & Expo at no cost to them. This support from the department motivated me to take on leadership positions as SME Student Chapter President and Statler College Ambassador to share the opportunities available through the mining industry.

**In what way are you using what you learned, and what do you see for the future?**

While at WVU, I was not only able to learn about the mining and construction industries but also how to problem-solve, network and communicate my ideas to others. I use these skills daily and as an engineer, the learning never stops. I am excited to build on this knowledge with on-the-job experience, and I am fortunate to work at a company that is dedicated to the development of their personnel so I can continue to grow as an engineer.

**What advice would you give to a student considering a career in mining?**

My advice would be to take advantage of every opportunity you have to network. Although mining is worldwide, many would be surprised by how tight-knit it becomes.

Getting involved with your local SME chapter is a great first step but even your most casual interactions with folks in the industry may create an opportunity for your next internship, job offer or promotion. Don't be afraid to make connections early in your career as they may be crucial down the line. ■

**Gabriela Kosakowski**
**| Project engineer**
**| Colas Inc.**

*"I was not only able to learn about the mining and construction industries but also how to problem-solve, network and communicate my ideas to others."*

**Thommy Bafunye**
*Degree in mining engineering, May 2024*
*Starting at Heidelberg Materials as an aggregate management trainee*

**Where are you working now; what is your role?**

I have accepted a full-time position with Heidelberg Materials as an aggregate management trainee. My position will be based in Bridgeport, TX, and I will be starting in July. As an entry-level position, I will be relegated to different departments to become familiar with different aspects of the operation. I will be using my knowledge to collaborate on various team projects. Other responsibilities include tracking key performance indicators and learning supervisory skills by working side by side with experienced supervisors.

**How has your time at WVU contributed to your personal growth?**

WVU has helped me grow not just as a student, but as a person in general. The school emphasized the importance of social gatherings, which has made me more comfortable with social events and making new connections. I was presented with opportunities to meet and engage with industry professionals from whom I gained a lot of knowledge through our discussions. Participating in student organizations and extracurricular activities has taught me the value of serving others. My courses at WVU have taught me how to overcome challenges and work effectively with teammates.

**In what way are you using what you learned, and what do you see for the future?**

Upon starting my full-time position, I plan on applying my academic knowledge gained at WVU to tackle complex projects. The problem-solving techniques and teamwork skills I developed will be essential in my daily work. I aim to continue leveraging my academic foundation to lead successful initiatives and contribute positively to my community and the mining industry.

**What advice would you give to a student considering a career in mining?**

My advice is to get involved and seek internships. Participating in student organizations helps with putting your name out there and expanding your network.

I would encourage a prospective mining student to keep an open mind because opportunities in the industry are endless. ■

**Thommy Bafunye**
**| Aggregate management trainee**
**| Heidelberg Materials**

*"WVU has helped me grow not just as a student, but as a person ... The school emphasized the importance of social gatherings, which has made me more comfortable with social events and making new connections."*

# The University of Utah

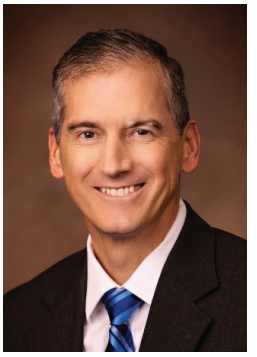
The College of Mines and Earth Sciences was established as the State School of Mines at the University of Utah by the Utah legislature and approved by the governor in March 1901 under the enabling act admitting Utah into the Union. The school is a beneficiary of all land grants, and appropriations made, or to be made, by the United States to the State of Utah for the establishment and the maintenance of a School of Mines. The school established courses of instruction relating to mining, metallurgical, electrical and such other branches of engineering pertaining to all branches of the mining industry of Utah.

In 1948 the name changed to the College of Mines and Minerals Industries and the College of Engineering. The name of the College of Mines and Mineral Industries was changed in 1988 to the College of Mines and Earth Sciences to more accurately describe the academic makeup and programs in Earth-related science and engineering. The College has played and continues to play a vital and historic role in the development and utilization of mineral and energy resources, employment, and economic development in the state of Utah.

The college became part of the College of Science in 2024 and consists of four academic departments that offer six majors and four baccalaureate and graduate degrees. ■

## Q&A with Michael Free, Professor and Chair, Department of Materials Science and Engineering, including the Metallurgical Engineering program, and Charles Kocsis, Professor and Chair, Department of Mining Engineering, and Western Mining Presidential Endowed Chair in Mine Safety

**Michael Free**
*"Because metallurgical engineers are needed all over the world, graduates of our program experience a higher job placement percentage and larger starting salary than they would in nearly any other undergraduate program."*



**Charles Kocsis**
*"Our graduates, design, operate, manage and reclaim mines and mining facilities in a profitable, safe and environmentally responsible manner, while contributing to addressing the future resource demands of our world."*

**What are the mining-related degree programs offered by The University of Utah, and what are some of the subdisciplines?**

We offer degrees in metallurgical engineering and mining engineering. Subdiscipline areas in mining engineering include mine safety, analytics, surface mining, underground mining, senior mine design, rock mechanics, mine ventilation and underground environment control. Mining-related subdisciplines in metallurgical engineering include mineral processing, particle separation technologies, hydrometallurgy and pyrometallurgy as well as additive manufacturing, and nuclear and clean energy.

**What are the strengths of The University of Utah programs?**

We have strengths in mining safety, computational methods for analysis, rock mechanics, mine ventilation, mine design, and spectral analysis.

We also have strengths in mineral separation technologies, hydrometallurgy and pyrometallurgy.

# The University of Utah

**Which industries do your graduates find careers in, and what are the career prospects?**

Our mining-focused graduates find careers in the mining industry, government agencies, industrial minerals, engineering design companies, and related vendor companies.

**What are the current areas of research?**

Our related areas of research include mining safety, computational methods for analysis, mine ventilation, dust monitoring and control, rock mechanics, spectral analysis, and development of novel mine safety training programs using virtual reality (VR) and augmented reality (AR) technologies. We also have research in mineral separation technologies, mineral liberation analysis, comminution, rare earth extraction, separation, and purification, as well as broad ranges of research in hydrometallurgy, biometallurgy, electrometallurgy and pyrometallurgy.

**What are the future technology trends?**

Some of the future technology trends include greater utilization of artificial intelligence in mining and separation technologies, vehicle and equipment automation, vehicle electrification, data analytics, development of new training and education using VR and AR technologies, improvements in separation technologies.

**What advice would you give to students to get the most out of their time at The University of Utah?**

Our mining engineering program prepares students to meet the unique 21st century needs of the mining industry and the world. Our graduates, design, operate, manage and reclaim mines and mining facilities in a profitable, safe and environmentally responsible manner, while contributing to addressing the future resource demands of our world.

We offer a great education that allows students to understand the necessary fundamentals and apply them in solving problems, and by working in labs associated with classes as well as in labs associated with research. In addition, our students usually do internships with companies during the summer months where they continue to broaden the educational and application experiences. We also have engaging student groups that provide opportunities to connect and network as well as take tours of mining and metallurgical facilities. Students should take advantage of these great opportunities to learn, become involved, and gain valuable work-related experience as they study at The University of Utah. We also have industry professionals delivering mining-focused presentations during seminars and who support students and faculty to establish mine visits.

**Any other topics you wish to highlight?**

The University of Utah is located in an amazing area with terrific local outdoor recreational opportunities and a great campus life, while also being in close proximity to local mining and metallurgical processing facilities. These outstanding resources allow for great recreational and learning opportunities.

Metals provide the foundation for our way of life, and it is metallurgical engineers that work to supply those metals through environmentally responsible design processes. They are constantly thinking of new ways to minimize waste, maximize energy efficiency, increase performance and facilitate recycling.

Because metallurgical engineers are needed all over the world, graduates of our program experience a higher job placement percentage and larger starting salary than they would in nearly any other undergraduate program. They go on to work for companies that produce pure metals and parts for NASA, Samsung, Apple and GE, while others help create scientific and medical instruments, biomedical implant devices, automotive parts and thousands of other products that utilize metals.

Our degree programs also provide students with:

- Small class sizes, most under 20 students.
- Internationally recognized faculty with close ties with industry leaders.
- Scholarships — our students with higher than 3.0 GPA receive scholarship support.
- More opportunities for internships and part-time employment than

THE UNIVERSITY OF UTAH

Logo and photos courtesy of The University of Utah

## The University of Utah

most programs.
- Unique opportunities to study, work and socialize together.
- Near 100 percent job placement, with many students receiving offers before they graduate.
- Entry-level earnings average higher than $75,000 a year.
- Prestigious research in clean energy/advanced technologies with student lab jobs.
- Accredited engineering program (ABET certified). ■

**Alexander Carhart**
**| Grad Program**
**| Rio Tinto Kennecott**

*"The job market is amazing for mining engineers."*

**Alexander Carhart**
*B.Sc., Mining Engineering, May 2024*
*Starting at Rio Tinto Kennecott as part of the "Grad Program"*

**Where are you working now; what is your role?**

I have accepted a job with Rio Tinto Kennecott in Salt Lake City, UT. I am part of the "Grad Program" at Rio Tinto, which consists of three eight-month rotations. My first rotation will be in mine scheduling/planning and the next two rotations will either be operations leadership, concentrator, or underground operations.

**How has your time at The University of Utah contributed to your personal growth?**

I believe that my time at The University of Utah has contributed my personal growth positively. It gave me great new lifetime friendships and created connections with industry professionals that I would not have otherwise had.

**In what way are you using what you learned, and what do you see for the future?**

I think one of the most important things I learned at The University of Utah was from all of my professors in the Mining Engineering Department. They taught me how to conduct myself in professional settings at conferences and during class time. I believe this has helped me get internships and ultimately a job.

**What advice would you give to a student considering a career in mining?**

My advice is that no matter how difficult classes can — and will — get, just keep going. It is all worth it in the end. The job market is amazing for mining engineers, and the connections made along the way will be lifelong ones. ■

**Jacob Burke**
**| Starting graduate studies**
**| University of Utah**

**Jacob Burke**
*Degree in metallurgical engineering with an emphasis on chemical processing*
*Starting graduate studies in fall 2024*

**Where are you working now; what is your role?**

I am currently performing research under our department chair, Dr. Michael Free, and will be starting graduate studies in the fall.

**How has your time at The University of Utah contributed to your personal growth?**

At the University of Utah, I learned a great many skills that set me apart from other engineering graduates. Included were standard engineering skills such as a deep understanding of mathematics, physics and chemistry, but also skills specific to metallurgy such as the testing of metal properties.

Learning these skills sets me apart from other engineering fields. While very specialized, I feel well set up for success in my future career as a metallurgical engineer.

The Department of Materials Science and Engineering was also excellent at providing us students with research opportunities. Many of the professors personally helped me find work when one of my internships fell through, and for that I am very grateful.

## The University of Utah

**In what way are you using what you learned, and what do you see for the future?**

Since I am performing research under Dr. Free, I use the skills I have learned daily. Certain courses such as "Low Temperature Chemical Processing and Transport Rates and Phenomenon" are more applicable, but I frequently use everything that I have learned. For example, I frequently use Python to smooth out my workload.

In the future, I see myself using these skills in industry to increase the efficiency of metal extraction. I also hope that my skillset will only expand from here on.

**What advice would you give to a student considering a career in mining?**

Metallurgy is a very difficult discipline, just like most engineering disciplines. However, it is extremely rewarding if one enjoys problem solving and a challenge, so I believe that it is well worth it. I recommend going to every career fair your school holds and try to get an internship when you can. ■

*"I frequently use everything that I have learned. For example, I frequently use Python to smooth out my workload."*

### Eliza Watson

*Second-year student, mining engineering*

**How has your time at The University of Utah contributed to your personal growth?**

The time I have spent at The University of Utah thus far has made a significant impact on my personal growth. The challenging, yet enjoyable curriculum has taught me new skills and furthered my appreciation for the mining industry. Additionally, the Mining Engineering Department exhibits unmatched support from advisors, peers and faculty. I feel that I will maintain my connections with mentors and friends from the University of Utah as I enter into my professional career and beyond.

**In what way are you using what you learned, and what do you see for the future?**

I see myself using the skills I gained at The University of Utah to further improve the safety and sustainability of the mining process. I also feel that I will be prepared to work with a team and collaborate with others to get tasks completed as safely and efficiently as possible.

**What advice would you give to a student considering a career in mining?**

When I first discovered mining engineering as a possible career path, I was hesitant due to negative preconceived notions of the industry. However, I have since learned how crucial mining is to our society.

I have also learned how important mining engineers are, as they are tasked with improving the industry in terms of safety and environmental impact. I would advise any student considering a career in mining to keep an open mind and realize the potential for extremely meaningful careers that mining offers. ■

**Eliza Watson | Second-year student, mining engineering**

*"Keep an open mind and realize the potential for extremely meaningful careers that mining offers."*

### Alejandro Camacho

*Senior, Honors degree in mining engineering*

**How has your time at The University of Utah contributed to your personal growth?**

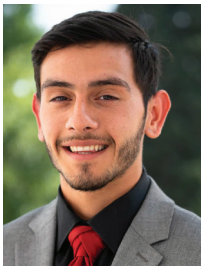
During my time at the University of Utah, I have experienced significant personal growth. Initially, I was quite reserved and participated minimally in extracurricular activities, rarely interacted with peers, and barely connected with professors and advisors. However, through various programs and initiatives, such as the Second Year Experience, I have gradually become more outgoing and engaged. I set a goal to overcome my fear of talking to people and joined an online program to improve my social confidence. These experiences have helped me build a network of connections, take on leadership roles and become more confident in my interactions.

**In what way are you using what you learned, and what do you see for the future?**

The knowledge and skills I have gained at The University of Utah will be invaluable in my future career in mining engineering. The technical expertise, combined with the confidence and networking abilities I have developed, will enable me to excel in my field. I have learned the importance of seeking out opportunities, building relationships and continually pushing myself to grow and improve.

**What advice would you give to a student considering a career in mining?**

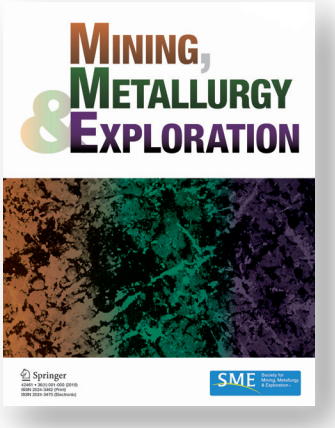
To students considering a career in mining, my advice is to avoid complacency. Don't just follow the syllabus or career plan to earn your degree. Seek out opportunities beyond the classroom. Engage with professors, build friendships with peers, take on leadership roles and embrace risks. As cliché as it sounds, going beyond the minimum requirements will open doors and provide invaluable experiences that will benefit you throughout your career. ■



**Alejandro Camacho | Senior, Honors degree in mining engineering**

*"These experiences have helped me build a network of connections, take on leadership roles and become more confident in my interactions."*

# Extended abstracts from the SME journal Mining, Metallurgy & Exploration

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## Invited Extended Abstracts

## Deep neural network models for improving truck productivity prediction in openpit mines

**Omer Faruk Ugurlu[1], Chengkai Fan[1], Bei Jiang[2,*] and Wei Victor Liu[1,*]**
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Mining, Metallurgy & Exploration (2024) 41:619–636, https://doi.org/10.1007/s42461-024-00924-4

**Keywords:** Artificial neural networks, Bulk material handling, Deep learning, Machine learning, Prediction performance, Regression

*Accurate prediction of truck productivity plays a pivotal role in improving the efficiency and profitability of openpit mining operations. This paper proposes a deep neural network (DNN) model to overcome the challenge of predicting truck productivity in openpit mines. The prediction model was built using eight variables and was optimized by considering different train-test split ratios, numbers of hidden layers and neurons, and activation functions. The proposed model's performance was evaluated using various metrics and compared with other commonly used machine learning algorithms. The results showed that the proposed model outperformed traditional machine learning models by achieving higher prediction accuracy. Moreover, a single-variable sensitivity analysis showed that haul distance is the most influential variable for predicting truck productivity. This study marks a pioneering effort in employing DNN to predict truck productivity in openpit mining, signifying a notable advancement in the field.*

### Background

Accurate prediction of truck productivity, defined as payload per unit of time during each truck haulage cycle, is essential for enhancing efficiency and profitability in openpit mining, influencing decisions on fleet size, dispatch and route design [1]. Researchers have made efforts to develop prediction models for various mining operations using machine learning techniques [2]. Among these techniques, DNNs can achieve high prediction accuracy by addressing high-dimensional data and nonlinear input-output relationships, typical characteristics of truck haulage data [3]. Nevertheless, prior to this study, there were no existing studies

in the literature demonstrating the application of DNNs for predicting truck productivity.

## Method and data

Figure 1 shows the framework employed in the proposed study. Three main steps were included in the study: (1) data processing, including data cleaning and subsampling, (2) model construction, involving data preprocessing, model architecture determination, model training and model evaluation, and (3) model comparison, conducting a single-variable sensitivity analysis to better understand the effect of individual variables on the model's performance [4].

The proposed model was trained on a massive dataset collected by truck sensors from oil sands mine sites. This dataset contained a total of 540,424 truck cycles. Blank rows resulting from recording errors were removed from the dataset, which was then subsampled to a small dataset (2,702 truck cycles).

This dataset was divided into two subsets — a training set and a test set — using a proportional and random split. The splitting ratios used for the training and test sets were 80 percent-20 percent, 75 percent-25 percent and 70 percent-30 percent. The prediction models were then built using multiple linear regression (MLR), support vector regression (SVR), decision tree (DT), random forest (RF), artificial neural network (ANN) and DNN. Hyperparameter tuning was further performed to avoid overfitting on the test set. Then, in the model evaluation step, the performance of the prediction models was evaluated using the test set and four metrics: mean-squared error (MSE), root-mean-square error (RMSE), mean absolute error (MAE) and $R^2$ [2]. Finally, a single-variable sensitivity analysis was used to assess the relative effect of an input variable on truck productivity.

## Results and discussion

**Development of DNN models.** Before hyperparameter tuning, the number of hidden layers ranged from two to five; the neurons were changed starting from 14 and increasing in steps of 14, up to a maximum of 84. Moreover, four activation functions were evaluated in predicting truck productivity, including hyperbolic tangent (tanh), exponential linear unit (ELU), rectified linear unit (ReLU) and scaled exponential linear unit (SELU). After predictive modeling, the best-performing DNN model configuration was found to have four hidden layers with 70 neurons per layer and SELU, resulting in the highest $R^2$ and lower errors compared to other configurations.

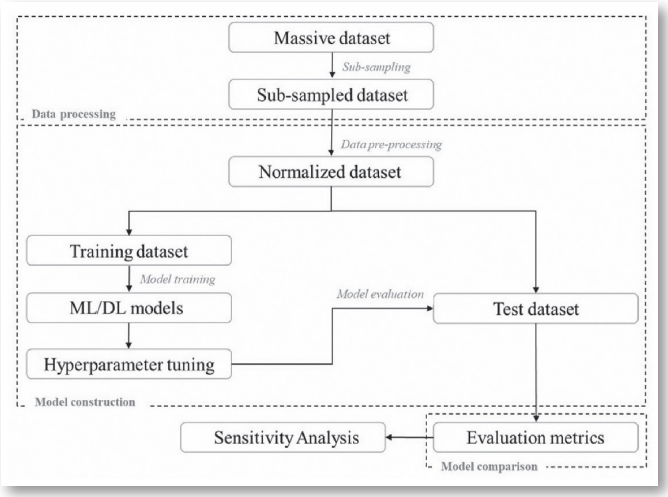


**Fig. 1** Brief outline of the study.

**Model comparison.** In this study, six different machine learning algorithms were applied to predict truck productivity, and their performance was compared using four evaluation metrics: $R^2$, MSE, RMSE and MAE. The algorithms were MLR, SVR, DT, RF, traditional ANN (with a single hidden layer) and DNN (with four hidden layers). Table 1 shows the performance comparison of these six prediction models. From Table 1, DNN, with the highest $R^2$ value of 0.89, outperformed the other models and had a lower MSE of 0.11, a lower RMSE of 0.33 and a lower MAE of 0.22, indicating a strong fit for the data and the highest performance in predicting truck productivity.

**Sensitivity analysis.** In this study, a single-variable sensitivity analysis was conducted using a partial rank correlation coefficient (PRCC) to assess the sensitivity of a dependent variable to an independent variable, as shown in Fig. 2. Haul distance, temperature and destination are found to have the most significant effects on the model output, with PRCC values of minus 0.55, minus 0.33 and 0.26, respectively. In contrast, the impacts of the month, empty speed, haul speed, day and shift are comparatively lower, with PRCC values of 0.19, minus 0.17, 0.08, 0.02 and 0.01, respectively.

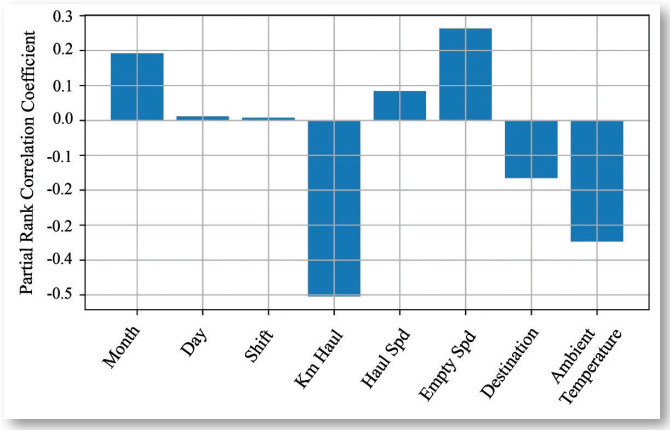


**Fig. 2** Partial rank correlation coefficient for independent variables.

**Table 1** — Performance comparison of the six prediction models by four evaluation metrics.

| Prediction model | $R^2$ | MSE | RMSE | MAE |
|---|---|---|---|---|
| MLR | 0.71 | 0.29 | 0.54 | 0.38 |
| SVR | 0.76 | 0.21 | 0.46 | 0.33 |
| DT | 0.55 | 0.45 | 0.67 | 0.48 |
| RF | 0.78 | 0.22 | 0.47 | 0.33 |
| ANN | 0.62 | 0.38 | 0.62 | 0.44 |
| DNN | 0.89 | 0.11 | 0.33 | 0.22 |

## Conclusions

The main findings can be summarized as follows. Firstly, the DNN model, configured with four hidden layers, 70 neurons per layer, and utilizing the SELU activation function, exhibited superior performance compared with other commonly used machine learning models. Secondly, the results of single-variable sensitivity analysis revealed negative correlations between truck productivity and haul distance, destination and temperature. In contrast, month, day, shift, haul speed and empty speed showed positive correlations. Haul distance emerged as the factor with the strongest negative correlation. This study breaks new ground by being the first to employ DNN for truck productivity prediction within the context of openpit mining, contributing to the advancement of the field. ■

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# Recycling of SmCo magnets by removal of iron via oxidative leaching


**Elif Emil-Kaya[1,2,*], Merve Papakci[2] and Bernd Friedrich[2]**

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[2]IME Process Metallurgy and Metal Recycling, RWTH Aachen University, Aachen, Germany
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**Keywords:** Recycling, Hydrometallurgy, Cobalt, REEs, Oxidative leaching

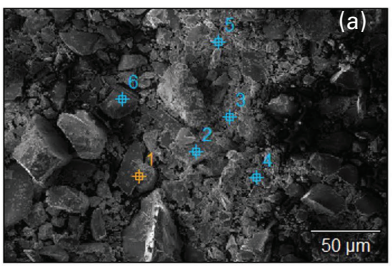


*Samarium (Sm), one of the rare earth elements (REEs), and cobalt (Co) are used in the production of SmCo permanent magnets, which have excellent temperature stability, corrosion resistance and oxidation resistance. Of the two types of SmCo magnets, one contains a high amount of iron, approximately 15.2 percent. This paper focuses on the recycling of iron (Fe)-bearing SmCo. In this study, an oxidative leaching process with nitric acid was developed to eliminate iron through in situ hydrolysis and to dissolve REEs and Co. The influence of experimental conditions on the formation of an amorphous iron compound through the hydrolysis of $Fe^{3+}$ in a nitric acid environment was thoroughly examined based on a Taguchi orthogonal array. The optimal parameters for oxidative leaching were determined to be an acid concentration of 3 mol/L, a solid-to-liquid ratio of 1/10, and a process temperature of 60 °C.*


## Background

In 2023, the EU updated its Critical Raw Materials (CRM) list, identifying key elements for the years ahead [1]. With REEs and Co included in the CRM list, the recovery of these elements from SmCo magnets is becoming increasingly important to meet demand [2-5].

In this study, we propose a novel method for recycling Fe-bearing SmCo magnets. An oxidative leaching process is developed for the first time, in which iron is removed from the leach liquor through in situ hydrolysis in a nitric acid medium, resulting in the elimination of iron during the leaching stage and the dissolution of cobalt and REEs into the solution. We explain the underlying mechanism of oxidative leaching through chemical equations. Furthermore, we




(b)

| | C | O | Al | Fe | Co | Cu | Zr | Sm |
|---|---|---|---|---|---|---|---|---|
| Point 1 | 0.517 | 1.575 | - | 9.852 | 35.714 | 5.355 | 1.624 | 45.362 |
| Point 2 | 0.417 | 2.702 | - | 13.091 | 33.697 | 4.539 | 2.132 | 43.423 |
| Point 3 | 4.737 | 6.953 | 3.480 | 7.607 | 39.687 | - | - | 37.536 |
| Point 4 | 0.552 | 2.604 | - | 12.078 | 31.214 | 4.123 | 1.967 | 47.463 |
| Point 5 | 0.978 | 2.691 | 0.256 | 11.226 | 36.056 | 4.816 | 1.939 | 41.654 |
| Point 6 | 1.574 | 2.534 | - | 17.764 | 29.988 | 4.007 | 2.488 | 40.950 |

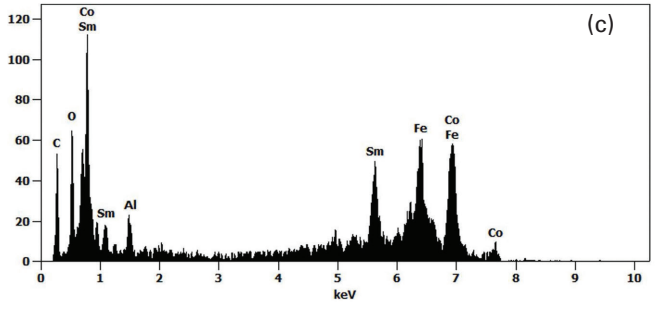



**Fig. 1** (a) SEM micrograph, (b) chemical composition and (c) EDX spectrum of SmCo magnets.

**Table 1** — Oxidative leaching parameters and their levels.

| Parameters | Levels | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| Acid concentration (mol/L) | 1 | 2 | 3 |
| Solid-to-liquid ratio (w/v) | 1/10 | 1/20 | 1/30 |
| Temperature (°C) | 20 | 40 | 60 |

determine the optimal oxidative leaching parameters using statistical analysis combined with Taguchi plots.

## Methods

Taguchi orthogonal array design was used for the oxidative leaching experiments. The philosophy of employing the Taguchi design method in this study lies in minimizing the iron dissolution and maximizing the extractions of Sm and Co during oxidative leaching by identifying the optimal leaching parameters. The oxidative leaching parameters, along with their levels are detailed in Table 1.

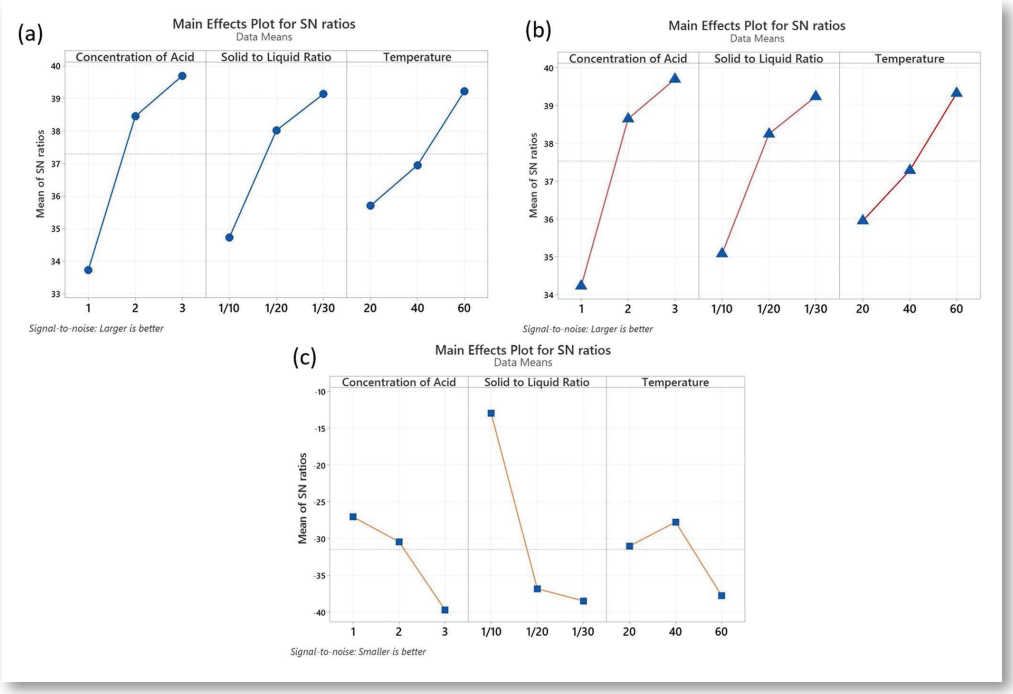
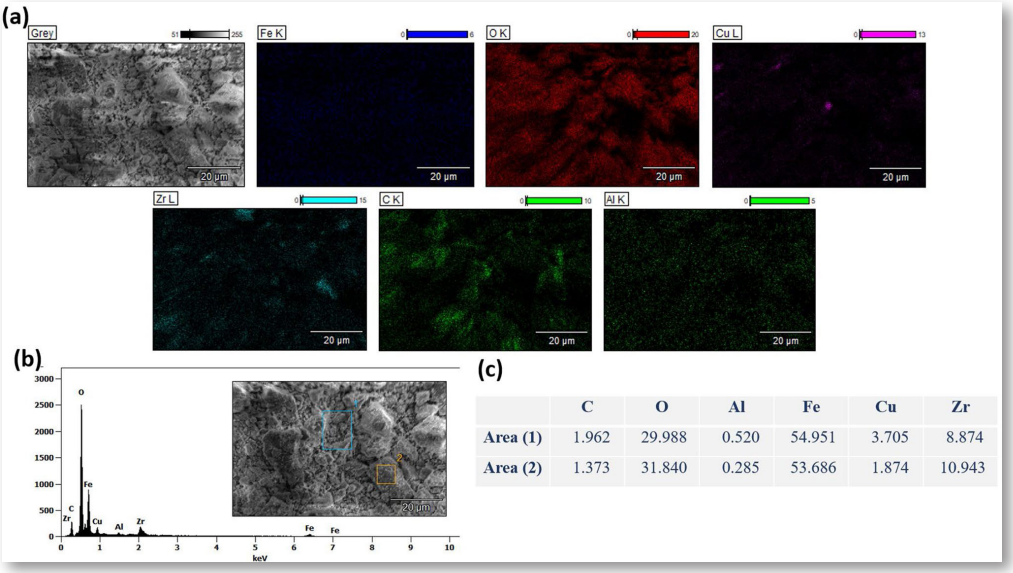



**Fig. 2** Taguchi plots for (a) Sm, (b) Co and (c) Fe.




| | C | O | Al | Fe | Cu | Zr |
|---|---|---|---|---|---|---|
| Area (1) | 1.962 | 29.988 | 0.520 | 54.951 | 3.705 | 8.874 |
| Area (2) | 1.373 | 31.840 | 0.285 | 53.686 | 1.874 | 10.943 |

**Fig. 3** (a) Elemental mapping of the leach residue, (b) EDX spectrum and (c) chemical composition of the selected areas in the SEM micrograph.

## Results and discussion

Figure 1 illustrates the results obtained from the energy-dispersive X-ray spectroscopy (EDX) analysis of the SmCo magnet powders. This figure includes a scanning electron microscopy (SEM) micrograph, a tabulated representation of the chemical composition of the magnet powders, and the EDX spectrum. These data provide valuable insights into the elemental composition and physical structure of the magnet powders, which are crucial for developing an effective recycling process.

The impacts of nitric acid concentration, solid-to-liquid ratio and temperature on leaching efficiency were evaluated. For the creation of the Taguchi plots, the signal-to-noise approach was chosen. For Sm and Co, the "larger is better" approach was selected. Conversely, for Fe, the "smaller is better" approach was chosen as the objective is to minimize the extraction of Fe while achieving high extractions of Sm and Co. This is consistent with the expectation that oxidative leaching should result in high Sm and Co extractions and low Fe extraction. Figure 2 illustrates the Taguchi plots for Sm, Co and Fe.

A new approach is introduced to address the removal of iron from Fe-bearing SmCo magnets during oxidative leaching. This innovative idea involves selectively leaching Co and Sm while

avoiding the leaching of iron. To achieve this, nitric acid is used to create highly oxidative conditions specifically targeted at iron, resulting in the hydrolysis of iron to form an amorphous Fe compound. This method appears to be a promising way to separate and retain valuable elements (Sm and Co) while effectively isolating and converting iron into a more manageable form. It showcases a strategic approach to enhance the efficiency of recycling processes for SmCo magnets.

Elemental mapping of the leach residue was conducted using SEM equipped with EDX analysis. Figure 3 includes (a) the elemental mapping of the leach residue, (b) the EDX spectrum and (c) the chemical composition of selected areas in the SEM micrograph. As illustrated in Fig. 3, the leach residue contains Fe, oxygen (O), zirconium (Zr) and copper (Cu). A small amount of aluminum (Al) was observed, due to the use of an Al stub in the analysis. After the oxidative leaching, Sm and Co were not observed in the leach residue.

## Conclusion

This paper thoroughly investigates the behavior of iron during the oxidative leaching of Fe-bearing SmCo magnets. The research demonstrates that iron ions hydrolyze to form an amorphous iron compound during oxidative leaching, allowing for the successful separation of Sm and Co from Fe in a single step. Within the investigated experimental conditions, the range of nitric acid concentration affects the extraction of Sm and Co, but it does not significantly influence Fe. Statistical results reveal that the solid-to-liquid ratio plays a significant role in Fe hydrolysis. Under the specified conditions of acid concentration of 3 mol/L, temperature of 60 °C, and solid-to-liquid ratio of 1/10, Sm and Co extractions reached approximately 99 percent. Furthermore, Fe was effectively eliminated from the system through Fe hydrolysis during oxidative leaching under these conditions. In summary, this proposed oxidative leaching method for eliminating Fe from Fe-bearing SmCo magnets and achieving high Sm and Co extractions in a single step is promising.

The findings from this research provide valuable insights into the Fe hydrolysis mechanism, laying the foundation for a selective leaching process for Sm and Co. ■

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# Impact of velocity of detonation and charge per bank cubic meter on flyrock throw prediction using support vector machine

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**Keywords:** Flyrock distance, Support vector machine, Velocity of detonation (VOD), Cost per bank cubic meter (CPBCM)

*This study emphasizes the importance of understanding the factors that influence the throwing of flyrock in mining operations, a significant hazard to both workers and nearby structures. Moreover, it highlights how blasting engineers, when estimating flyrock occurrences and their travel distance, typically rely on input parameters such as powder factor (PF), hole length (HL), subdrill (SD), spacing (S), hole diameter (D), burden (B) and stemming length (ST), while overlooking crucial factors like velocity of detonation (VOD) and charge per bank cubic meter (CPBCM). Through analysis using support vector machine (SVM) modeling in MATLAB, the study underscores the impact of including or excluding VOD and CPBCM on flyrock throw distance.*

## Background

The use of explosives in mining operations has associated hazards, including flyrock throw, which poses a substantial risk to workers and neighboring structures. Understanding the elements that influence flyrock throw is critical to assuring blasting safety. Through support vector machine (SVM) modeling, this research investigates the impact of two key parameters on flyrock throw: VOD and CPBCM.

## Methods

The research used data from controlled blasting experiments conducted at Damang, Ghana, a mining site located in West Africa. Both the VOD and CPBCM were systematically included and excluded, and the resultant distances of flyrock throw were measured. The input parameters used for the analysis are outlined in Table 1.

Various SVM algorithms — medium Gaussian support vector machine (MGSVM), coarse Gaussian support vector machine (CGSVM), quadratic Gaussian support vector machine (QGSVM), linear support vector machine (LSVM), and fine Gaussian support vector machine (FGSVM) — were assessed using the modeling shown in the flowchart (Fig. 1).

**Table 1** — Input parameters and their ranges.

| Parameter | Symbol | Maximum | Minimum | Average | Average deviation | Standard deviation |
|---|---|---|---|---|---|---|
| Subdrill (m) | SD | 1.20 | 0.30 | 0.93 | 0.19 | 0.21 |
| Explosive gravity | Sg | 165.00 | 115.00 | 123.24 | 6.99 | 9.84 |
| Hole depth (m) | HD | 18.00 | 3.00 | 6.97 | 1.48 | 1.65 |
| Stemming length (m) | St | 4.13 | 0.00 | 2.99 | 0.26 | 0.36 |
| Hole diameter (mm) | D | 165.00 | 115.00 | 123.24 | 6.99 | 9.84 |
| Powder factor (kg/m$^3$) | PF | 1.90 | 0.28 | 0.71 | 0.45 | 0.31 |
| Spacing (m) | S | 5.00 | 2.50 | 3.87 | 0.25 | 0.34 |
| Burden (m) | B | 5.00 | 2.50 | 3.72 | 0.29 | 0.36 |
| Explosive charge (kg) | Q | 370.76 | 46.26 | 70.11 | 27.53 | 31.28 |
| Velocity of detonation (m/s) | VOD | 4,000.00 | 2,900.00 | 3,443.12 | 279.29 | 322.34 |
| Cost per bank cubic meter ($/BCM) | CPBCM | 2.70 | 0.15 | 1.68 | 0.18 | 0.25 |

## Results and discussions

The research revealed significant correlations between the VOD, CPBCM and flyrock throw distance. Elevated levels of VOD and CPBCM were associated with greater distances of flyrock throw. The SVM model effectively captured these relationships, illustrating the nonlinear nature of the connections between the input parameters and flyrock throw distance.

These findings underscore the criticality of regulating the VOD and CPBCM to mitigate the risk of flyrock throw during blasting operations. By comprehending the influence of these factors, blasting engineers can optimize blast designs to bolster safety measures and reduce the potential for flyrock incidents. Additionally, the utilization of SVM modeling showcases the robust effectiveness of machine learning techniques in forecasting and dissecting intricate phenomena within mining and blasting engineering.

Understanding the correlations among VOD, CPBCM and flyrock throw facilitates more precise risk evaluations. Mining firms can leverage this insight to pinpoint high-risk scenarios and implement tailored mitigation strategies to diminish the occurrence of flyrock incidents.

These findings can be incorporated into training initiatives for blasting engineers and personnel. By educating staff on the factors affecting flyrock behavior and the significance of adept management of blasting parameters, mining enterprises can heighten safety consciousness and practices at the operational level.

Regulatory bodies tasked with overseeing mining activities can leverage the findings of this study to inform regulations and standards pertaining to blasting procedures. By integrating evidence-based best practices into regulatory frameworks, governing bodies can foster safer and more sustainable mining endeavors.

Mining enterprises can use the insights gleaned from the study as part of an ongoing enhancement process. Through real-time monitoring and analysis of blasting performance data, operators can refine blasting parameters and protocols to continually optimize safety and operational efficiency.

## Conclusions

The predictive performances of the LSVM, QGSVM, FGSVM, MGSVM and CGSVM models were assessed. Among these models, the LSVM exhibited the most accurate prediction for flyrock throw distance, achieving a coefficient of determination and root-mean-squared error values of 1.00 and 0.05, respectively. This performance surpassed that of empirical predictions. The study also highlighted the significant improvement gained from incorporating VOD and CPBCM into the models.

The enhancements in coefficient of determination and root-mean-squared error values for each model, attributable to the inclusions of VOD and CPBCM, respectively, are as follows: LSVM, 0.00 percent and 80.00 percent; FGSVM, 39.5.00 percent and 94.00 percent; MGSVM, 14.00 percent

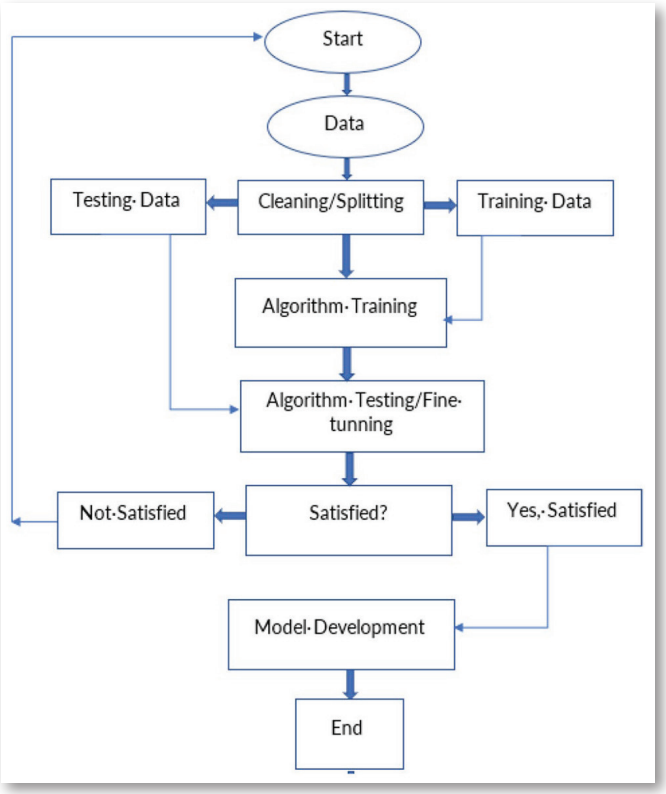


**Fig. 1** Flowchart of SVM modeling.

and 75.00 percent; CGSVM, 3.00 percent and 65.00 percent; and QGSVM, 1.00 percent and 98.00 percent.

While this study was conducted specifically in the context of Ghanaian mining operations, its methodology could be replicated elsewhere provided that relevant data have been adequately trained and evaluated within the utilized model. ■

## References

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

# Application of mining-width-constrained openpit mine production scheduling problem to the medium-term planning of Radomiro Tomic Mine: A case study

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**Keywords:** Openpit, Mine planning, Mining width, Direct block scheduling, OPMPS

*Medium- and short-term mine planning holds immense significance in optimizing production and resource utilization. It serves as a vital link between the long-term strategic plans and the day-to-day operational activities of a mine. In this context, a mathematical formulation is proposed to incorporate mining width constraints into the production scheduling process, aiming to maximize the net present value (NPV) of the schedule while ensuring enough room for the operation of mining equipment.*

## Background

Radomiro Tomic Mine (RT), operated by Codelco Chile, stands as a significant copper mining operation renowned for its rich mineral deposits and strategic importance in the global copper industry.

An algorithm aimed at resolving the linear programming relaxation related to the precedence-constrained production scheduling problem (PCPSP) was introduced by Bienstock and Zuckerberg [1]. Comprehensive studies on the algorithm applied to openpit mine production scheduling (OPMPS) can be found [2,3]. However, traditional OPMPS models often yield nonmineable solutions due to the scarce distribution of blocks mined at the same periods. Thus, the inclusion of minimum mining width conditions in OPMPS models may enhance the mineability of medium-term plans. We present a mathematical model that includes mining width constraints into the OPMPS problem (MW-OPMPS) and solve it in the context of medium-term mine planning.

## Methodology

The mathematical model aims to maximize the NPV of an openpit mine's production schedule while adhering to processing and geometrical constraints. For that, we utilize the Bienstock-Zuckerberg LP (BZ) algorithm to solve subproblems associated with the MW-OPMPS, given that use of the BZ algorithm is particularly relevant at RT, where materials can be processed in different processing plants.

The model considers processing and mining upper limits per period, geotechnical wall slope constraints modeled as a set of block precedence, and multiple destinations for the mined blocks, such as heap leach, mills and waste dumps. To ensure its realism and applicability in medium-term planning, the model accounts for the mining width constraint per period — for simplicity — modeled as a series of rectangular templates [4,5], and a maximum vertical advance (also known as sinking rate) modeled as a set of intertemporal set of precedencies.

## Case study

The key focus is not only on understanding the improvement in mining width satisfiability but also assessing the impact on the NPV and the change in sequence compared to the traditional OPMPS solution. For this reason, we conducted a set of four experiments to investigate the incorporation of mining width constraints in the OPMPS problem and its applications to real medium-term scheduling problems.

Experiment 1 considers the capacities from the baseline case but introduces operational mining widths of a 4 × 4 blocks template, comparing a traditional OPMPS solution with the MW-OPMPS solution and expecting that the traditional OPMPS plan will appear less mineable: that is, scarce spatial distribution of blocks mined at the same periods.

Experiments 2, 3 and 4 encompass different operational scenarios. Experiment 2 evaluates the impact on the mining sequence, production schedule and NPV of adjusting the total mining capacity to match it to real performance. Experiment 3 helps to estimate the impact and the best period for a major truck maintenance. Experiment 4 reevaluates the impact of the major maintenance decision studied in experiment 3 but considering an extra requirement of sulfide ore due to a delay of the Chuquicamata Underground Mine (Chuqui UG).

From experiment 1, the optimality gap was 0.1 percent for the OPMPS and 2.57 percent for the MW-OPMPS. In

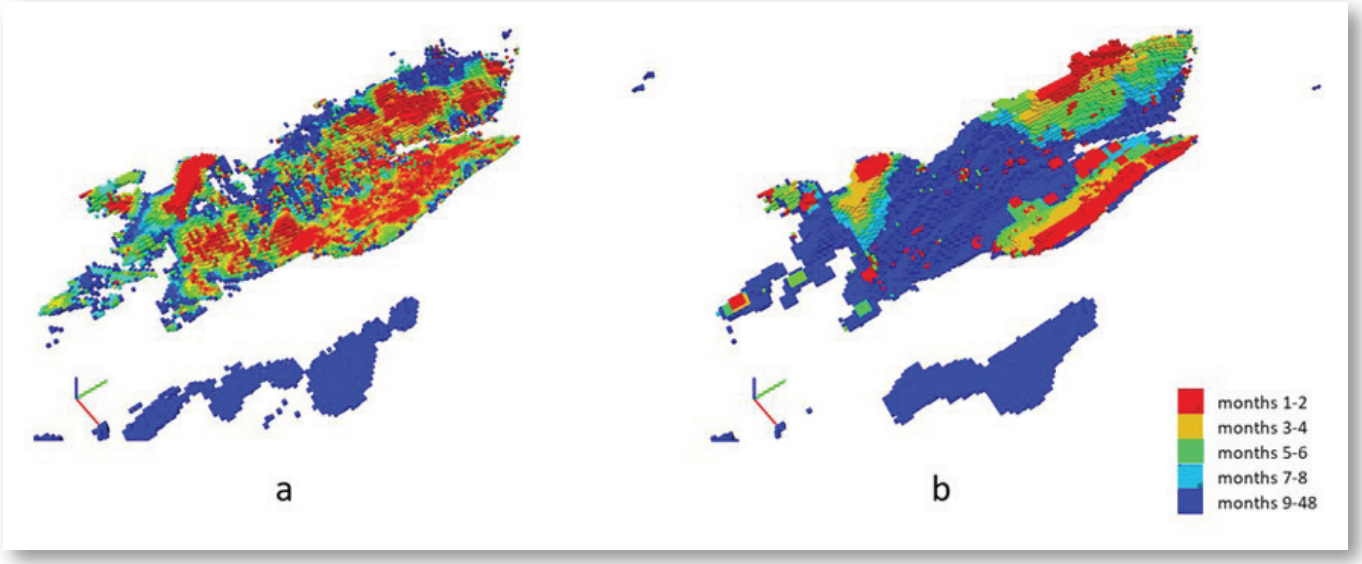


**Fig. 1** Isometric view of experiment 1 results: (a) solution of OPMPS and (b) solution of MW-OPMPS.

terms of mining width satisfiability, the OPMPS achieved a rate of 2.47 percent, while the satisfiability of the MW-OPMPS solution reached a rate of 57 percent.

In general, all the instances of the four experiments obtained an increase in the mining width satisfiability from 2 percent with the OPMPS to 60 percent using MW-OPMPS, and an optimally gap consistently maintained of 4 percent for the MW-OPMPS model.

## Discussion

Particularly, the results of experiment 1 (Figs. 1 and 2) highlight the effectiveness of incorporating mining width constraints in ensuring a greater proportion of blocks satisfies the width requirements, leading to improved operational compliance and making the outputs more useful for engineering designs.

Also, the research offers practical insights into real-world decision-making processes, even though solutions still need to be reworked to make them practical, enable engineers to conduct trade-off studies, such as optimizing the timing of major truck maintenance, and enable informed decisions considering the impact of external factors such as the delay of Chuqui UG.

## Conclusion

By solving multiple instances based on an RT dataset, the study evaluates the performance of the developed algorithms in solving problems of varying complexities. The obtained solutions of the MW-OPMPS exhibit a notable improvement in mining width satisfiability, and the efficacy of the model is further demonstrated by the consistently lower optimal gap for all instances. ■

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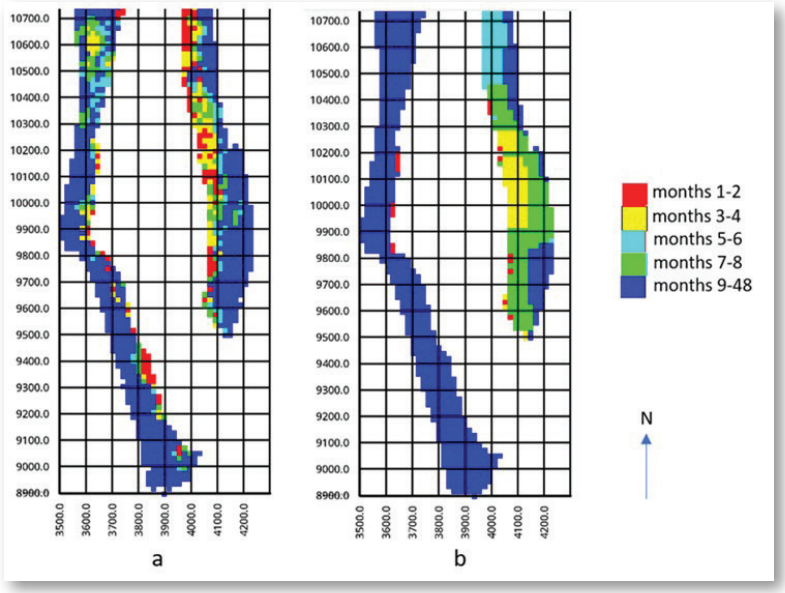


**Fig. 2** Plan view (level 2610) of experiment 1 results: (a) solution of OPMPS and (b) solution of MW-OPMPS.

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# MME Technical-Paper Abstracts

## Selected Abstracts

## Ore types: What they are, how they're made, and their uses and abuses

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**Keywords:** Ore typing, Ore control, Geometallurgy, Orebody modeling

*Prior to mining, all rocks contained in a mineral deposit must be placed in one of several categories known as ore types. Each ore type describes a different way that the rock will behave in processing. The ore type determines which process stream a particular mined unit will be sent to, sets expectations for process engineers and metallurgists, and forms the basis for recovery predictions and production estimates. At first, ore types are assigned mainly by geologists based on visible geological criteria (dominant ore mineralogy, estimated grade, rock type, alteration type). As metallurgical tests are carried out and process data accumulate, the resulting criteria may be factored into the ore typing process, typically as assays and recoverable metal using the relevant process(es). Other variables may also be incorporated into ore typing at operations if they are particularly important, such as grindability, preg-robbing, gangue reagent consumption, and the presence of especially deleterious minerals such as talc or smectite. The mine operation department may also redefine ore types and/or process destinations based on economic criteria. A "best" ore type is designated that (in theory) best describes how the rock will behave in processing. Codes representing this ore type are entered into the drill-hole database, then interpreted on cross sections and level plans, and finally added to the block model. Ore types are iteratively reexamined and adjusted over the life of a project. Major difficulties in effective ore typing are (1) lack of communication between geologists and metallurgists, (2) the imprecision inherent in imposing clean categories on messy natural systems without discrete divisions, (3) the need for ore types to provide useful information for a wide range of processes, (4) difficulties in scaling up laboratory test results to mine production, and (5) conflict among geological, metallurgical, and economic criteria for ore typing.* ■

## Environmental, social and governance considerations in production scheduling optimization for sublevel stoping mining operations: A review of relevant works and future directions

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**Keywords:** Production scheduling optimization, Sublevel stoping, Environmental, social and governance (ESG), Multiobjective optimization

*In operations that use the sublevel stoping mining method, production scheduling takes into account factors — including ore reserve envelopes, ore grade averages, equipment capacity, feed controls to the mill, and geotechnical restrictions — across the scheduling horizon. Mathematical programming is one of the most effective methods for enhancing the decision-making process in regard to the most viable production schedule in light of a given set of limitations. The majority of research on sublevel stope mining focuses primarily on a single objective of optimization, which is to maximize the net present value (NPV). Environmental, social and governance (ESG) considerations are becoming more prevalent in the mining industry. This includes aspects relating to deforestation, land disturbances, gas emissions, community relations and water usage, among many others. Institutional and other kinds of investors are becoming more interested in the work that resource companies do regarding their ESG obligations. This review article identifies the gap in the existing literature and proposes to simultaneously optimize the production schedule around three objectives. Two of these relate directly to ESG aspects.* ■

# The importance of MEC;

## It is up to all of us to educate the public about mining

**by Kurt Doran, Minerals Education Coalition Chair**

How often in your daily lives do you encounter someone who simply isn't aware of how important mining is in everyday life? Or more critically, how important mining is in their life? How often do you personally know a young adult who would be an absolute rock star in the mining industry but isn't aware of the career opportunities in this industry? Chances are, if you are reading *Mining Engineering*, you are an SME member, and if an SME member, you understand fully how unaware the public is about just where humans would be without mining, and where mining will be without the next generation. It still amazes me that those connections are not being made by the public, and that the urgent need to responsibly source the critical minerals, or materials or whatever we want to call them (the elements and processed products we all talk about every single day) isn't recognized by the human population. It is thus incumbent on us, as the professionals that clearly see this every day, to not only give our 100 percent to the industry, but to also be the educated voice in the conversation to better tell the story of where humanity would be without sustained, responsible mineral development and mining.

The SME Foundation's (SMEF) mission is to attract and leverage resources for a sustainable mining industry through education and outreach. The SMEF does this through various programs focused on developing the next generation of mining professionals and increasing public awareness of mining's importance. The Minerals Education Coalition (MEC) is the SMEF's educational program to develop and deliver K-12 material, programs and activities, and to educate the public on mining. The MEC is a unique blend of knowledgeable and passionate SME staff and a committee and subcommittees of SME volunteers, all working together to execute various projects to achieve the aforementioned objectives.

**Kurt Doran**

MEC has several long-standing projects that we continue to implement, including Scouting America's Mining in Society Merit Badge, and programming and attendance at National Science Teacher Association (NSTA) conferences. Both programs are successful because of the quality of what is being presented and the enthusiasm of the SME members presenting. MEC now also has a presence at the American School Counselor Association (ASCA) Conference. Programs newer to MEC include the K-12 Outreach program in Colorado, now being expanded to Utah, and K-12 teacher workshops, first implemented with rural Arizona teachers in conjunction with MINEXCHANGE in Phoenix. This program was repeated with Minnesota teachers in conjunction with SME Minnesota's annual conference in Duluth in April. It is and currently being planned to run in conjunction with MINEXCHANGE in Denver in 2025. The Phoenix and Duluth workshops were good primers to learn from as we plan for the Denver workshop.

A new initiative the MEC is working on is to better align the various MEC programs and make them exportable to local sections to implement at the local level. I ask you to consider what opportunities are out there

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## SME News Contents

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# Summer activities;

## Ideas for all ages, outdoors and indoors

**by Rebecca Smith, MEC Curriculum Coordinator**

Summer is in full swing and the Minerals Education Coalition (MEC) has ideas that are fun and educational to go with the warm weather and summer camps, company picnics and family vacations, or even indoors on rainy days. There are activities for all ages, and for kids and grandkids alike.

Did you know that aggregates mining has contributed quarry areas that now hold fresh water for towns all around the country? This is an important, positive impact that mining has had on local communities. Middle-school-age students can learn more about this in the "Mining Creates Reservoirs and Habitats" activity. Are you heading to a state or national park? In the "Create a Development Plan for a New Reservoir" activity, high-school-age students can try to set up a new recreational area around a reservoir. The goal is to redevelop a site into a multiuse park and recreational area,

*(Continued on page 109)*

## SME Foundation Corporate Roundtable Partnership

# opportunities and benefits

**by Himesh Patel, R&D engineer, FLSmidth**

The SME Foundation (SMEF) Corporate Roundtable Partnership (CRP) was developed in 2013. Since then, numerous companies have been invited to join the partnership and to contribute and support the SMEF programs. The CRP is an investment for businesses across the mining and minerals industry to build a future for world-class mineral education and to encourage young people toward mining careers.

The success of the CRP depends on the support of forward-looking companies who share the SMEF's vision to inspire the next generation to meet the needs of a mineral-dependent future for a better world. Corporations and businesses engaged in the mining and minerals industries are invited to become Corporate Roundtable Partners with an annual commitment of $25,000 or more. Currently, there are 16 companies giving at this level or higher. These corporations have something essential in common; they have invested in the people who make our companies and our industry great. Corporate Roundtable Partners receive many benefits, including:

- Recognition and acknowledgement in SMEF materials and at SMEF events.
- Acknowledgement in SME Drift and *Mining Engineering* magazine.
- Complimentary seating at the SMEF Gala Dinner ($50,000 Corporate Roundtable Partner level and above).
- Access to the SMEF VIP Lounge at the MINEXCHANGE SME Annual Conference & Expo to meet with and interview students and recent graduates for internships and full-time employment.
- Invitation to the Corporate Roundtable Partner Luncheon for SME leadership and corporate partners.

More information on CRP opportunities and a full list of benefits can be found at https://community.smenet.org/smefoundation/crp/home, or contact Megan Martin, SME Foundation Manager at martin@smenet.org. ■

# $4K by 40 Challenge and match;

## Another successful program this year

**by Lorie Laessig**

This year's $4K by 40 Challenge has been a success. A total of 14 donors contributed $5,345 to SME Foundation (SMEF) programs during this spring campaign. Special thanks go to Brooks & Nelson LLC who, once again, generously matched the $4K by 40 donations with a $6,000 contribution, including a $250 match for members who signed up for the monthly recurring donation plan. Brooks & Nelson LLC, a woman-owned, global human resource management and recruiting consulting firm based in Golden, CO is a long-time supporter of SME and the SMEF.

The $4K by 40 Challenge was created in 2018 to encourage and motivate philanthropic giving by young professionals under the age of 40. SME member contributions are tracked, and those who donate $4K or more by the age of 40 will be honored for their contributions and commitment to promote our industry and the outreach goals of the SMEF.

The 2023 $4K by 40 Challenge award recipients are Drew Mason and Matthew Ulizio. They were recognized for their generosity and support at the SMEF Gala Dinner in Phoenix, AZ, and in the March issue of *Mining Engineering* magazine. They also each received a unique mineral sample keepsake with an engraved nameplate. We congratulate Mason and Ulizio for reaching this milestone.

Past $4K by 40 Challenge recipients include:

- 2022 — Joshua A. Patterson.
- 2021 — Matthew D. Furniss.
- 2021 — Thomas C. Rauch.
- 2019 — Peter and Jenessa Haarala.
- 2018 — Ryan M. Murray.

All donors under the age of 40 are encouraged to set up a monthly recurring gift based on how many months are left until they reach the age of 40. We thank the $4K by 40 Challenge recurring donors who donate to the SMEF each month in order to make their goal. They include:

- Jordan Anderson.
- Ruby Barickman.
- Yamile Isabel Casasbuenas Cabezas.
- Kinsley Costner.
- Michael and Jenifer Deal.
- Brianna Drury.
- Matthew Furniss.
- Ryan Sibley.
- Mackenzie Sorensen.
- Kathleen Tew.

Donors have the flexibility to choose the allocation of which SMEF program they wish to support. Donations made will be jointly eligible for this challenge, the $1K Club and the John T. Boyd Challenge. Visit www.smefoundation.org/4Kby40 to donate today. ■

# SME named Association of the Year;

## David Kanagy presented with CSAE Lifetime Achievement Award

At the Colorado Society of Association Executives' (CSAE) 2024 Annual Awards Luncheon on June 6 in Fort Collins, CO, SME was named Association of the Year and David L. Kanagy, SME Executive Director and Chief Executive Officer, received the Lifetime Achievement Award, which honors the individual whose enduring contributions have shaped the association profession and left an indelible mark on the CSAE community.

Kanagy has worked in association management for more than 40 years, the last 20 of which have been with SME as executive director and chief executive officer. He will retire from SME in March 2026, leaving behind an organization that has blossomed into the world's premier mining membership society under his remarkable leadership.

"I am beyond humbled to receive this recognition from my good friends at CSAE," said Kanagy, who served as the 2012-2013 CSAE president. "Serving SME's thousands of members across the globe and supporting the association business at large has been my greatest professional honor."

Kanagy's tenure at SME is marked by a multitude of signature

**David L. Kanagy**

*(Continued on page 111)*

# M&E standing committee overview;

## Many opportunities to get involved with SME and its Divisions

**by Lia Walker, Operational Improvement — Freeport McMoRan Inc.**

SME has a number of standing committees that support the Society's and its Divisions' programming and initiatives. Representatives for each SME Division, including the M&E Division, comprise the members of the standing committees. Continue reading to learn about each standing committee:

- The **Student Member Affairs Committee** provides career guidance, suggestions and coordinates student activities, and exercises general supervision over SME Student Chapters. Members of the committee serve as judges for the annual SME Outstanding Student Chapter Contest and the SME Outstanding Student Paper Contest, undergraduate and graduate divisions.
- The **Government Relations and Public Affairs Committee** helps leverage the expertise of its membership to create a system for providing timely, accurate, fact-based, nonpartisan technical information in response to urgent inquiries from SME stakeholders on topics concerning mining, minerals and extractive industries; and has developed a structured program to create technical briefing papers for informing and educating SME audiences.
- The **SME Professional Engineers Committee** has the duty and responsibility of updating the SME PE Study Guide on a seven-year cycle, and the *Mining Reference Handbook* on an annual basis for the professional engineering examination for Mining/Mineral Processing (MMP) engineering, administered by National Council of Examiners for Engineering and Surveying (NCEES).
- The **Journal Oversight Committee** provides input and feedback on the strategic direction of the *Mining, Metallurgy & Exploration* (**MME**) journal, the quality of the journal and inclusivity of authors and topics, and ensures the journal represents the breadth of SME.
- The ***Mining Engineering*** **Committee** helps identify topics and sources at the request of the *Mining Engineering* staff and, supports the *Mining Engineering* magazine staff. The committee provides the staff with advice and input regarding overall magazine issues including, but not limited to, potential writers and topics for technical and feature articles, industry trends, potential advertisers, and issues referred to the committee by staff.
- The **Sustainable Development Committee** pursues two specific areas: the development, monitoring and assessment of sustainable development criteria for mineral operations, and the development and dissemination of best operating practices for sustainable development.
- The **Board of Directors (BOD) Internship Selection Committee** recommends to the SME Board of Directors an emerging young leader to become a nonvoting member of the BOD.
- The **Inclusion & Diversity Committee** promotes advancement and innovation in the mining community by strengthening inclusion and improving diversity in the SME.
- The **Program Committee & Program Coordination Committee** has the duty of coordinating program plans and providing for such joint programs and social events among the Divisions for the MINEXCHANGE SME Annual Conference & Expo, as deemed desirable.

For additional information on SME committees, including their detailed purpose and structure, visit https://www.smenet.org/committees. For information on how to get involved with a standing committee as an M&E representative, contact Lia Walker at lwalker@fmi.com. ■

***Rock in the Box*** **serves as a forum for the presentation and discussion of facts, ideas and opinions pertaining to the interests and technology of the Mining & Exploration Division. Accordingly, all material published herein is signed and reflects the individual view of the authors. It is not an official position of SME or the division. Comments by readers will be referred to that division for response. The division chair in 2024 is Don Dwyer.**

## MEC

*(Continued from page 105)*

that your local section would participate in if the cost to do so were covered by MEC, and the already-developed programming and materials were provided to you and your section. Taking that one step further, what are you doing for education and outreach that is working? We want to hear about it. Don't hesitate to email MEC@smenet.org with your input and suggestions.

In closing, it takes every one of us to educate students and the public about mining's importance, and to support that, MEC has one of the most pressing responsibilities within the society. As a 501(c)(3), SME does not lobby; however, I submit to you that through the execution of honest, fact-based programs like MEC, we do a far better job of telling the true story about mining, educating people about how important this industry is, and encouraging future leaders to consider rewarding careers in mining. ■

# 2024 Nevada MPD Annual Meeting;

## Conference returning for sixth consecutive year

**by Himesh Patel, R&D engineer, FLSmidth**

The sixth annual meeting of the SME Mineral & Metallurgical Processing (MPD) Division's Nevada MPD will be held Aug. 21-23, 2024 in Reno, NV at the Silver Legacy Resort and Casino. On Aug. 21, we will hold an interactive short course on the "Practical application of mineralogy and geometallurgy," featuring presentations that cover fundamental mineralogy techniques and application of geology and metallurgy in production sites, with a heavy emphasis on case studies. Presenters this year include regional operators like Nevada Gold Mines, Kinross Gold, Argonaut Gold, Ioneer and Nevada Vanadium, to name a few.

The Lifetime Achievement Award recipient this year is John Todd, and the keynote speaker will be Rob Ghiglieri from the Nevada Division of Minerals. Christina Erling of Barrick Gold will deliver a luncheon talk on the "Importance of the role of government engagement in our industry." Finally, this year's technical tour is a visit to Nevada Lithium's research center in Reno. Detailed meeting information can be found at www.nvmpd.com.

### Golden Opportunities

*Golden Opportunities* is a bimonthly publication of short articles that will share ideas, highlight issues and further the knowledge share regionally. If you would like to join and contribute, let us know by sending an email to goldenops.nvmpd@gmail.com.

### Annual scholarship

The Nevada MPD annual scholarship is open for applications. Undergraduates in the metallurgical engineering programs are encouraged to apply. The deadline is Aug. 5, 2024.

Our other initiatives include the annual MPD Handbook Award and Best Student Speaker Award. The Nevada MPD also provides support to the SME Foundation, local SME sections, and metallurgical laboratories in local universities. For queries, questions, sponsorship opportunities and technical presentations, reach out to us at nevada.mpd.7947@gmail.com. ■

***Fine Grind*** **serves as a forum for the presentation and discussion of facts, ideas and opinions pertaining to the interests and technology of the Mineral & Metallurgical Processing Division. Accordingly, all material published herein is signed and reflects the individual view of the authors. It is not an official position of SME or the division. Comments by readers will be referred to that division for response. The division chair in 2024 is Jaeheon Lee.**

## Summer activities

*(Continued from page 105)*

while preserving the pristine water in the lake for public water supply. As you travel around this summer, take note of every quarry and reservoir you pass or have seen in your area. Pick a quarry still in operation and consider how you might design a new recreational area there once the mining is completed.

The most exciting thing you can do is visit an operating mine. Search the internet for mines that conduct public tours and host visitors, either in your state or a state you are visiting. Visiting a modern, operating mine, even viewed from an overlook, is a great way to see how mining is done today with cutting-edge technology and amazing equipment. Some historic mines are also open for visitors.

Be sure to look up information about mining in the area. Rock and mineral shops are great places to learn about local minerals and mining as well.

As always, we have gold-panning resources for fun in "them thar hills" or just a kiddie pool in your own backyard. Kits, pans and gold-bearing sand are all available in the online MEC Store at MineralsEducationCoalition.org/store. The new *Mined Minerals Coloring and Activity Book*, also in the MEC Store, is a perfect indoor activity for young children ages 5-8 who can learn the names and shapes of some minerals you may come across outside.

Find more activities and crafts for summer fun at MineralsEducationCoalition.org/summerfun. ■

## Every decision is a crucial decision;

# How to improve decision-making skills

**by Lara Sims, H&S Division Communications Chair**

How many employees feel that the decisions they make daily could be crucial decisions? I asked this question recently in a small group, and it was apparent they did not feel that any of the decisions they made daily would meet the criteria of a crucial decision. I, on the other hand, believe that every decision a person makes all day, every day is crucial; we just do not recognize them as such. One of the most important tools in everyone's toolbox is the right and the responsibility to stop work if the work is not safe or healthy to continue. How can we encourage more people to make this crucial decision? Hazards are still not being recognized, not being mitigated properly and lives are still being lost in the mining industry. The U.S. Mine Safety and Health Administration (MSHA) reported 40 fatalities occurred in 2023, and in 2024 the U.S. mining industry has recorded eight fatalities as of June. These fatalities are not numbers, they are people. Families are now without a parent, sibling or grandparent. What crucial decision was made or not made that resulted in these fatalities?

Knowing how to make good decisions could be key to helping to reverse this trend. Making the "stop work" decision quickly, and feeling confident about your decision-making skills, could save your life or the life of another miner, not to mention a lot of time and hassle.

We can all become better decision-makers in every area of life by:

### Avoiding overconfidence

- Overconfidence can easily make your judgment go awry.
- Studies consistently show people tend to overestimate their performance and the accuracy of their knowledge.
- Perhaps you are 90 percent sure you know where the office is that you are visiting. Or maybe you are 80 percent certain you can convince your boss to give you a promotion. If you are overconfident about those things, your plans are likely to go awry. It's vital to consider your confidence level in terms of time management. Most people overestimate how much they can accomplish in a certain period of time. Take time every day to estimate the likelihood that you will be successful. Then at the end of the day, review your estimates. Were you as accurate as you thought?

### Understanding the risks

- There's a good chance you make some poor decisions simply because you have grown accustomed to your habits and don't think about the danger or harm you're exposed to or possibly causing.
- For example, you might speed on your way to work every day. Each time you arrive safely without a speeding ticket, you become more comfortable driving fast. But clearly, you are jeopardizing your safety and the safety of those around you, and taking a legal risk.
- Or maybe you eat fast food for lunch every day. Since you don't suffer any immediate signs of ill health, you might not see it as a problem. Over time, however, you may gain weight or experience other health issues.

### Recognizing your biases

- Although it can be a bit uncomfortable to admit, you are biased in some ways. It's impossible to be completely objective.
- Your mind has created mental shortcuts — referred to as heuristics — that help you make decisions faster. And while these mental shortcuts keep you from toiling for hours over every little choice you make, they can also steer you wrong.
- The availability heuristic, for example, involves basing decisions on examples and information that immediately spring to mind. So if you watch frequent news stories that feature house fires, you are likely to overestimate the risk of experiencing a house fire.
- Or if you have recently consumed a lot of news about plane crashes, you may think your chances of dying in a plane crash are higher than in a car crash (even though statistics show otherwise).
- Make it a daily habit to consider the mental shortcuts that lead to bad decisions. Acknowledge the incorrect assumptions you may make about people or events, and you may be able to become a little more objective.

Other tools include:

- Reframing the problem.
- Taking breaks.
- Reflecting on past mistakes.
- Challenging your preconceptions.
- Recognizing emotions that affect choices.
- Treating yourself with kindness. ■

***Safety Share*** **serves as a forum for the presentation and discussion of facts, ideas and opinions pertaining to the interests and technology of the Health & Safety Division. Accordingly, all material published herein is signed and reflects the individual view of the authors. It is not an official position of SME or the division. Comments by readers will be referred to that division for response. The division chair in 2024 is Pedram Roghanchi.**

# SME Environmental Division welcomes new members

**by Annelia Tinklenberg, SME Environmental Division Chair**

The SME Environmental Division welcomes students, industry professionals, and academics to join the Division.

As a member of the Environmental Division of SME, you have access to professional networking and leadership opportunities with peers who share your career objectives. Students are provided a great opportunity to explore careers by networking with potential future employers.

The Environmental Division also provides a forum for the exchange of technical information, publishing technical papers, and organizing technical meetings and programs.

For more information check out the Division's website at https://www.smenet.org/Divisions/Environmental-Division. ■

***Green News*** **serves as a forum for the presentation and discussion of facts, ideas and opinions pertaining to the interests and technology of the Environmental Division. Accordingly, all material published herein is signed and reflects the individual view of the authors. It is not an official position of SME or the division. Comments by readers will be referred to that division for response. The division chair in 2024 is Annelia Tinklenberg.**

## CSAE awards

*(Continued from page 107)*

achievements, including helping to amass more than $39 million in assets through astute strategic planning, financial management, mergers, and new product and service development. This level of growth has allowed SME to better serve its more than 13,000 members by increasing full-time staff from 23 to 55 individuals since his arrival. The staff increases have equipped SME with the ability to cater to the many needs of its growing membership, consisting of professionals in the mining, tunneling and underground construction sectors.

Kanagy also oversaw the development and implementation of OneMine.org, which went live in 2008. OneMine.org is the most extensive online research library for mining. Today, 14 mining societies collaborate to add content to a database consisting of more than 40,000 documents and over 2.5 million searchable pages.

SME's philanthropic initiatives, led by the SME Foundation, have also flourished during Kanagy's tenure. Through the collaborative work of members and staff, Kanagy helped implement vital Ph.D. Fellowship and Academic Career Development Grant programs. These programs have resulted in more than $7 million for 38 individuals to advance toward tenured faculty status, addressing long-term challenges that threaten the sustainability of U.S. mining and mining-adjacent degree programs. In addition, he has helped build key fundraising strategies such as the Corporate Roundtable Partnership to support the many successful SME Foundation programs and K-12 outreach efforts.

To this day, Kanagy attends meetings all over the country and world to meet with and encourage the work of SME's local membership sections. His unique accessibility also extends to long-distance communication, meaning that all SME members can call or email him directly, with everyone getting an answer.

### Association of the Year Award

SME received the CSAE's "Association of the Year Award." Recognizing organizations that excel in driving industry innovation, member engagement and community impact, this accolade highlights the exemplary contributions of associations across diverse sectors. From fostering collaboration to advocating for important causes, recipients demonstrate outstanding commitment to their members and the broader society. ■

# Leonard "Len" Harris, 1927-2024

**Memorial tribute by Marc LeVier and James Komadina**

Leonard Harris, fondly known as Len, passed away peacefully at his home in Fayetteville, AR, April 25, 2024 with members of his family nearby.

Harris was born in the small town of Yeppoon in Queensland, Australia on July 12, 1927, the son of Joseph Harris, a first-generation Irish Australian and Edith Beatrice Littlejohns, a first-generation Cornish Australian. In 1937, the Harris family moved to Mt. Morgan where he completed primary and high school education. Harris attended Mt. Morgan Technical College, where he earned a diploma in metallurgy in 1949.

Harris worked at Mt. Morgan and later at Mt. Isa Ltd. and the Radium Hill uranium project in South Australia. In late 1953, he departed Australia for London. He worked for a short time on the Gold Coast of Africa and in 1955 he traveled to La Oroya, Peru, where he worked for Cerro de Pasco Corp. as a research metallurgist.

In 1956, he met Rosa Haydee Navarro Talavera, a nurse from the company hospital at a company dance. The chemistry between them was magical, and they were married in 1957. Harris rose through the ranks quickly in various capacities of the mill and smelter operations.

In 1971, he returned to Australia as the mine manager of Texada Mines Ltd. at the Lake McLoud operations near Carnavon, West Australia. The operation was producing salt from a dried-up lakebed with 4,400 acres of evaporation ponds and a wash plant. When Harris arrived, the operation was producing 0.3 Mt/a of salt and two years later when he departed, the plant was producing 4 Mt/a of salt. As Harris loved to tell the story, "They shipped me off to the salt mines."

Harris returned to Cerro de Pasco Corp. in 1973 in New York City to serve as vice president of metallurgy for all their projects and operations. However, in 1974, all Peruvian operations were nationalized by the Velasco government, and the corporation collapsed.

Harris joined Newmont Mining Corp. in late November 1974 as a research metallurgist at the Danbury, CT facilities and ultimately worked his way up to vice president of research and development and vice president of metallurgical operations. During the next 16 years, Len and Rosa traveled and worked on five continents, assisting in existing operations and finding opportunities for new projects. He acquired more responsibilities and titles during those years, which continued to add to his reputation and legacy.

In 1989, after the T. Boone Pickens corporate raid of Newmont, Newmont relocated to Denver, CO where the company refocused its organization on gold operations in Nevada's famed Carlin Trend. Harris was an instrumental member of the executive team that formed the strategy and implemented the plan to recreate Newmont, like the phoenix raising from the ashes.

When Newmont made the gold exploration discovery at Yanacocha, Harris was heavily involved in creating the partnership with Buenaventura, owned by his Cerro de Pasco friend Alberto Buenavides. Harris pleaded with Newmont president Peter Phillip to allow him the role of general manager of the Yanacocha Project near Cajamarca, Peru, high in the Andes Mountains. Phillip told Harris that the conditions of high altitude and the political unrest would be too much for him, but Harris successfully pleaded his case to give back to Peru with the first foreign mega investment in years due to civil war. Harris desperately believed in Peru, the people and the country, and after all, Peru gave Len the love of his life, Rosa and their family. He successfully completed the Charachugo Sur project, and Minera Yanacocha became the gem in the Newmont crown of gold operations.

**Leonard "Len" Harris**

Harris desired to improve the world and leave it better than he found it. He had seen many approaches to mining, and these impressions formed values and passions to make mining safer and more responsible. He knew the dangers in Peru and said, "We can do better, and I want it done right." He created a company that improved the communities and lives of the people near Yanacocha. He enlisted his wife Rosa to assist and together they created a successful community plan that subsequently caused other mining companies to seek assistance from them, as well as advice on implementing similar efforts in their mining communities.

Harris retired from Newmont in mid-1995 and went on to become a legendary consultant and mining company director.

Harris was well recognized in his career, receiving the AIME William Lawrence Sanders Gold Medal Award, the ASME Hoover Gold Medal Award for Lifetime Achievement, and the MMSA Gold Medal Award, to cite a few. He was inducted into the National Mining Hall of Fame in 2017 and the National Academy of Engineering, Earth Sciences, in 2022. His achievements are highlighted in AIME Oral Histories, and everyone is encouraged to hear his story, at https://aimehq.org/what-we-do/oral-histories/leonard-len-harris, told as only Len could do.

He was a once-in-a-lifetime acquaintance, a legend, a colleague, a mentor, and a true friend to all who shared his passion for mining, a good story, a beer (or two), and making the world a better place. His stories ("Never build a mill before you have a mine") are too numerous for a

*(Continued on page 113)*

# Raymond L. Lowrie, 1933-2024

Raymond L. Lowrie was born on Feb. 19, 1933, in Alcoa, TN to Carl and Elizabeth Buckner Lowrie. The family moved to Texas when Ray was a young boy and ultimately made El Paso, TX home. He graduated from Austin High School in 1950 and enlisted in the U.S. Navy. He became an aerographer's mate and served his final year of enlistment in Yokosuka, Japan. After leaving the Navy, Lowrie studied at Texas Western (UTEP), where he became a member of Kappa Sigma Fraternity. The summer before his senior year, he worked as a miner at the Climax Molybdenum Mine in Colorado. He received his B.S. in mining engineering and went to work in Oklahoma as a mining engineer in Lone Star Steel coal mines. While there he met his future wife and lifelong partner, Mariann Kroupis. They married in 1962 and moved to Denver, CO where he began a mining career with the Department of Interior's Bureau of Mines (USBM).

In 1964, USBM transferred Lowrie to Washington, DC. After a few years, the family returned to Denver where Lowrie conducted mineral and technical studies for USBM and received his master's degree in mineral economics from the Colorado School of Mines. In 1973, he was seconded to the Ohio Department of Natural Resources as the state's Chief of Reclamation.

Lowrie returned to Denver with USBM in 1975 and served as Chief of the Intermountain Field Operations Center. In 1977, the U.S. Congress passed the Surface Mining Control Reclamation Act and Lowrie was appointed regional director of the Office of Surface Mining Reclamation and Enforcement (OSMRE) in Kansas City, MO. He continued serving OSMRE as administrator of the Eastern Technical Center in Pittsburgh, PA and finally as assistant director of the Western Field Operations in Denver. On his retirement in 1994, he received the Interior Department's Meritorious Service Award.

After retiring from the government, Lowrie became the Professional Engineering Coordinator for SME. In this role, he helped prepare the professional licensing examination for mining engineers. He also edited the award-winning first edition of SME's *Mining Reference Handbook* and wrote extensively. In 2005, he received SME's President's Citation Award for this work and in 2007 was honored as a Distinguished Member of SME. Later, he served as president of Carbon Energy Reserve Inc. in developing a large coal deposit in Montana and wrote an historical novel (*The Elephant's Grip*, Wild Rose Press, 2016) centered around the 1859 Pike's Peak gold rush and social issues of the time.

Raymond L. Lowrie

The Lowries moved to Sun Lakes, AZ in 2016. Lowrie took pride in being a lifelong learner through adult education classes, his book club, and what he called "meaningful conversations" with family and friends. A glass of red wine in his hand during those discussions made them even "more meaningful."

Lowrie died April 1, 2024, and was preceded in death by his parents and three siblings, Mildred Cornelison Meder, Ernest Benson Lowrie and Carlene Lowrie. He is survived by his wife, Mariann, of Sun Lakes, AZ; children, John C. Lowrie, of Denver, CO and Suzanne Lowrie, of Sun Lakes, AZ. Burial was held at the Arizona National Memorial Cemetery. In lieu of flowers, please consider making a donation in Ray's memory to support the SME Professional Engineers' Fund online at https://community.smenet.org/smefoundation/plannedgiving/memorial or by mail at SME Foundation, 12999 E. Adam Aircraft Circle, Englewood, CO 80112. ■

# Harris

*(Continued from page 112)*

single memorial tribute, but he was extraordinary. His love for his family was the most important in his life, and Rosa and his children were everything to him. He was loyal to his Catholic faith and to his colleagues and friends, no matter the issue or the need. He was a man of the highest integrity and as a naturalized citizen of the United States, maintained his love of both Australia and Peru.

Gordon Parker, former chairman and chief executive officer of Newmont, once said of Harris, "Len has the greatest job in the world. He travels around the world attending all the best mining conferences, telling fantastic stories, buying everyone drinks, and offering everyone a job." Although Parker's comments were "tongue in cheek" at that moment, the words were very true. Harris was always present at conferences and the crowd around him was always several deep, trying to say hello, ask a technical question, or just to get a bit closer to hear the story.

Harris' legacy will carry him on for decades to come. However, in the end, he will be remembered for his wit, his charm, his kindness and huge smile. His life is best summed up by this quote from the bible: "And now these three remain faith, hope, and love. But the greatest of these is love." Harris was all about his love of mining, family and friends and that everyone should have fun doing just that.

He is survived by his wife Rosa, their son Leonard Alfredo and daughter Mary Ann. He is also survived by a son and daughter in Australia, David and Lynette, along with 10 grandchildren, 15 great grandchildren, and five great-great-grandchildren.

Well done Len! "You gave it a bash!" ■

# Rebecca Bweupe-Siwale

**Memorial by the WAAIME Executive Committee**

It is with deep sorrow that we extend our heartfelt condolences to the family, friends and colleagues of Rebecca Bweupe-Siwale. She joined WAAIME in 2018, was elected to the executive committee in November 2023 and began her tenure in February 2024. Her tragic passing on June 8 left us all in profound grief.

Bweupe-Siwale was a remarkable individual whose contributions to the mining industry were significant and far-reaching. As vice president and head of digital services at FLSmidth, she led with passion, driving innovation and inclusivity in her field. Her dedication to promoting women in science, technology, engineering and mathematics (STEM) and her efforts in advancing diversity and inclusion within the industry left an indelible mark. Rebecca's adventurous spirit and her unwavering commitment to her family, faith and professional community were truly inspirational.

Her biography was a testament to her expertise and commitment. She began her career in the mining industry 24 years ago as a plant metallurgist and front-line supervisor. Bweupe-Siwale joined FLSmidth in 2012 as a senior process engineer and held various positions of increasing responsibility. Her extensive experience in leading teams and driving digitally enabled operational improvements was invaluable. She held a bachelor's degree in chemical engineering from Copperbelt University, an MBA from Cleveland State University, and executive education from Henley Business School. She was also a 100 Global Inspirational Women in Mining awardee.

Rebecca Bweupe-Siwale

Bweupe-Siwale actively participated in various technical committees and networking events. She served as the Past Chair of the SME Inclusion & Diversity Committee and co-chaired the Women of SME Breakfast event, which engaged and empowered men and women in the industry.

In accordance with her daughters' wishes, we chose to remember Bweupe-Siwale for the vibrant and impactful life she led. Her legacy will continue to inspire us as we strive to uphold the values she championed. We will honor her memory by fostering a culture of kindness, compassion and inclusivity within our organization and beyond. Our thoughts and prayers are with her family during this difficult time. May her memory be a blessing and her legacy live on through the positive changes she brought to the world. ■

# Robert "Bruce" Kennedy, 1951-2024

Bruce Kennedy was one of those men who lived his life in a way that he always had a story to tell. Kennedy was a source of joy and laughter in the lives of those around him. He used his often adventurous and funny life experiences, peppered with puns and a few eyebrow waggles, to entertain and create deep friendships.

Kennedy was born in Harrisburg, PA, on June 11, 1951, to Roxie (Redmond) and Robert Kennedy. One year later, they moved to Salt Lake City, UT, where Bruce would spend his childhood and gain his two younger siblings, Lauri Beth and John. He would spend summers with his cousins, getting into all sorts of "explosive" trouble, violating safety standards and neighborhood noise ordinances, but everyone survived with their lives and limbs intact, and they moved to Silver City, NM, where Kennedy would meet his best friends and mentor through the Explorer Scouts. He married Karen King of Silver City for 19 years and had Julia Rose (Morgan).

After moving throughout the Southwest, Kennedy returned to Silver City, where he met Linda (Strahan), the woman he would spend the rest of his life with as they traveled the world. Kennedy also gained two stepdaughters, Katelyn and Kelly. He taught them to golf in Alpine, AZ, at the family cabin, to fish and shoot, and to appreciate the natural and cultural wonders around them. He practiced patience and kindness when they brought home yet another cat, dog, bird or other various animals that needed help, and he was generous with his time with anyone in his sphere who needed a helping hand.

Kennedy's interest in stories extended to the land around him, and he used that interest to pursue his mining engineering degree at the New Mexico School of Mines. A rockhound, he could pick up a rock or look at a formation and tell you how it came into being. His keen understanding of geology moved him and his family around the Southwest and South America. It also extended his travels to locations worldwide to share his expertise. He would come home after such trips with larger-than-life tales, a giant album of photos, and a souvenir to commemorate. One time, after a trip to Kazakhstan, he and his group were stopped by the Russian army. Kennedy, ever the diplomat and with his desire to connect, found a common thread with one of the officers. They were invited for dinner with the officers, consisting of a goat's head and copious amounts of vodka. No matter where Kennedy went, he was able to find a connection with people.

Robert "Bruce" Kennedy

The last few years for Kennedy were spent in the mountains and farmlands of Georgia with his wife Linda and his dogs Toby and Tallulah. He passed away after a brief battle with cancer in Atlanta, GA, on May 15, 2024.

Bruce is survived by his wife, Linda (Strahan); daughter Julia and son-in-law Jason Morgan; grandchildren Bailey (Rodriguez), Naomi and Lucas; stepdaughters Kelly Tucker and Katelyn Tucker, and son-in-law David Pilles. ■

# Mary Korpi is the nominee for SME President in 2026

**A CHEMICAL ENGINEERING** graduate of Michigan Technological University in Houghton, MI, Mary Korpi began working for Newmont Mining Corp.'s Magma Copper Co. in San Manuel, AZ in 1976. She held various metallurgical services positions, including shift supervisor, quality control analyst, metallurgist, and senior metallurgist for customer relations.

She transferred to Newmont's Nevada operations in 1987 and served in a variety of capacities, including director of metallurgical services, director of loss control, leach and mill superintendent and director of external relations and communications for North America. In this role she oversaw Newmont's North American regional activities in issue management, local government, media management, community relations and development, external communications and minerals education. Korpi retired from Newmont in 2016 after almost four decades in the mining industry.

Korpi has continued her involvement and support of the industry through volunteer boards and commissions. She served as the SME Foundation's 2019-2021 President, where she led the SMEF in its mission to be the source of funding for education and outreach to SME and the community it serves.

Appointed by Nevada Governors Brian Sandoval in 2017 and Steve Sisolak in 2021, Korpi serves on the State of Nevada's Commission on Mineral Resources. She was elected to the National Mining Hall of Fame and Museum's board of governors in 2021, currently serving a four-year term.

Korpi was recognized in 2016 as a Distinguished Nevadan for her profound and lasting impact on the lives of all Nevadans. She has been inducted into Michigan Technological University's Presidential Council of Alumnae and the Nevada Women's Fund Women of Achievement.

Mary Korpi

Besides SME, she is also a member of the Mining and Metallurgical Society of America, Women's Mining Coalition, Geological Society of Nevada, Mining History Association, and the American Association of University Women.

# Nominees for the 2025 SME Board of Directors

**SA RAVISHANKAR** (Ravi) has been serving in the mineral industry for more than 32 years and SME for more than three decades, providing technology solutions to industry challenges as an outstanding global leader. He has a doctorate from Virginia Tech in material science and engineering and two master's degrees from Indian Institute of Technologies in metallurgical engineering and chemistry. He has developed several patented sustainable technologies on energy efficiency, economic beneficiation, minimal water usage, and enhancement of physical separation to several industrial minerals. His distinguished service in SME over 30 years has been both as boots-on-the-ground, organizing technical sessions, and in leadership roles, including as the Industrial Minerals & Aggregates Division (IMAD) Chair and program chair, and member of the SME Structure & Governance Committee. His technical and managerial leadership in the industry has been interlaced with a keen sense of public service to professional and educational institutions such as SME, UAMA, Columbia and NC State universities as industrial advisory board member. He also represents SME on the Hoover Medal board. He has published more than 30 publications in journals and books, and presented several papers and keynote speeches at SME and other international conferences.

SA Ravishankar

Ravishankar has been recognized with several awards for his outstanding technical innovation/leadership, both from the industries he worked for and from SME/AIME, includingg the prestigious Frank F. Aplan and Robert H. Richards Awards. He was selected as an "SME Fellow — Class of 2022," a clear testimony of his technical and leadership contributions. He continues to work at

**In compliance with the SME Bylaws, upon board approval of the Nominating Committee's proposed nominees for officers and directors, the names and biographies of the nominees will be published in an issue of *Mining Engineering*. Any group constituting at least five percent (5%) of the members of the Society may, by written petition signed by all of such members, submit additional nominations for these positions for the upcoming meeting. Such nominations must be received by SME staff no later than 90 days from the date of this publication.**

Saint-Gobain in a senior leadership role with the Surface Solutions group. He has exemplified the SME mission with well-exhibited confidence, professionalism, honesty, humility, passion, accountability and creative thinking, and has had an impact on younger members through positive mentoring.

**MICK ROUTLEDGE** is currently working as the chief operating officer (COO) of Coeur Mining, starting in June 2020, covering all the operations including Palmarejo Mine in the Chihuahua region of Mexico. Previously, Routledge worked with Alacergold developing its operational excellence program across the Copler Gold operations in Turkey. Additionally, he owns a business driving the development and rollout of fatal risk reduction and business performance improvement processes and tools as chief executive officer of RUT LLC. He has 30 years of experience in mining, metals, contracting and the power generation sectors. Most of his career was spent with Rio Tinto in executive roles including COO and vice president of HSE & Capital Projects at Kennecott Utah Copper covering all operating disciplines, strategic planning and business transformation. His international experience covers the United Kingdom, United States and projects across Australia, Canada and Europe, including a period as chairman of the RTAs Smelting Global Technology Committee. Routledge is a member of SME's Health & Safety Division and served as its Chair in 2021.

Mick Routledge

# Coal & Energy Division officer nominees

## CHAIR

**EDWARD F. ZEGLEN JR.**, P.E., has more than 42 years of experience in the coal mining industry and is currently working as a mining engineering consultant. Zeglen was previously the chief engineer at Alpha Natural Resources, Pennsylvania Services Corp., where he covered approximately 20 mines and held ventilation training classes for those operations. He also worked for GMS in various capacities including project management, mine coordinator and shift foreman, mine examiner and chief mining engineer.

Edward F. Zeglen Jr.

Zeglen has performed ventilation troubleshooting at company-affiliated mines in Pennsylvania, West Virginia, Kentucky, Alabama, Virginia, Utah and Colorado as well as in seven coal mines in New South Wales, Australia. He has a bachelor of science degree in mining engineering from the Pennsylvania State University (Penn State) and is a registered Professional Engineer in Pennsylvania. He holds Mine Foreman certificates in Pennsylvania and Utah, and has been active in mine rescue for 33 years and is coach/mentor of the Penn State student team.

Zeglen currently serves on the board of directors for the Pittsburgh Coal Mining Institute of America (PCMIA). He is a past chair of the Pittsburgh Chapter of SME.

## VICE CHAIR

**SAM BAKER** is a mining engineer at Rosebud Mining Co., a leading underground metallurgical and thermal coal producer in western Pennsylvania. He is responsible for underground directional drilling, multiple-seam mining analysis and ground control, methane mitigation, and special projects. A graduate of the Pennsylvania State University with a B.S. in mining engineering, Baker has been active in SME since his freshman year of college. Since then, he has served as a Coal & Energy (C&E) Division representative on the Young Leaders Committee (YLC), as vice chair of the YLC and as a C&E Division technical session chair, and he is a member of the board of the SME Pittsburgh Section.

Sam Baker

## SECRETARY/TREASURER

**JIM HAUGHEY**, P.E., is the business development director for Komatsu's underground soft rock division with a focus on industrial minerals' applications. He is responsible for customer development strategies, corporate office engagement and application engineering.

A 30-year Komatsu veteran, Haughey has held technical and product management positions on many of the Joy products and has been significantly involved in the application of such equipment in different markets and minerals. A graduate of Grove City College, he holds a bachelor of science degree in mechanical engineering and is a Professional Engineer in Pennsylvania.

Jim Haughey

## PROGRAM COMMITTEE CO-CHAIR

**JON BOBBERA** is the capital project manager for Robindale, based in Latrobe, PA. Within this role, he is responsible for the development and implementation of new construction and major renovation projects within a broad range of industrial sectors, including coal mining and processing, bulk material handling and marine terminals. He holds bachelor's degrees in both mining and civil engineering from West Virginia University and a master's in mine engineering and management from Colorado School of Mines. Bobbera is a registered Professional Engineer in both Colorado and Pennsylvania. He has been an active SME member since 2010 and has served in various student and professional committee roles. Currently, he is the acting chair of the C&E Division Scholarship Committee.

Jon Bobbera

## PROGRAM COMMITTEE VICE CHAIR

**JASON TODD** is a senior mining consultant with Barr Engineering in Salt Lake City, UT. He is responsible for overseeing and managing large, multidisciplinary projects, providing operations and engineering oversight assistance, and supports marketing and business development activities.

He began working in the mining industry nearly 30 years ago in the Powder River Basin and has spent most of his career in the coal industry; both domestic and internationally.

Todd has a bachelor of science degree in mining engineering from Montana Technological University (Montana Tech).

Jason Todd

# Environmental Division officer nominees

## CHAIR

**OMAR SMITH** is an assistant vice president at WSP. He has more than 16 years of experience supporting the mining industry on a variety of projects at numerous properties throughout Arizona, New Mexico, Nevada, Mexico and South America.

Smith has a strong civil engineering technical background with proven professional skills in site civil design, hydrologic and hydraulic engineering design, three-dimensional computer-aided design, construction quality assurance and quantity takeoff/cost estimates. He has served on the SME Tucson Section board for the last 13 years and is currently serving as the vice chair and scholarship chair. He is also currently serving his third term as a member of the SME Structure & Governance Committee.

Omar Smith

## VICE CHAIR

**AMAR R. PATEL** is a senior air quality scientist at Barr Engineering in Salt Lake City, UT. He received a B.S. in chemistry from Tulane University with a minor in finance. Patel started his career with Freeport-McMoRan at the Morenci Mine in Arizona before joining Barr in 2016. At Barr he currently supports the mining, manufacturing and refining industries as a technical advisor and project manager.

During his career, Patel has been involved in numerous projects focused on air quality, water quality, permitting, compliance and wildlife. He has served on the SME Young Leaders Committee since 2019, in subcommittee leadership roles and as an SME division/strategic committee representative.

Amar R. Patel

## SECRETARY/PUBLICATIONS

**HEATHER HALDERMAN** is a senior project manager with Knight Piésold. She has more than 26 years of experience in civil and environmental engineering, including environmental compliance, site investigation, remediation, feasibility studies, mine planning and closure, tailings management system integration, Global Industry Standard on Tailings Management auditing, and hazardous-waste projects.

Halderman has extensive experience in project management

Heather Halderman

and execution, including regulatory analysis and negotiation, permitting, data interpretation, cost estimating and risk analysis. Halderman has served as chair on several Environmental Division committees.

## PROGRAM CHAIR

**GENEVIEVE M. SUTTON**, P.E., is a two-time graduate of Missouri University of Science & Technology (Missouri S&T, formerly University of Missouri-Rolla), with B.S. degrees in metallurgical engineering and in mining engineering. She has worked in aggregates, coal and metal mining over a 20-year career in operations, engineering, environmental compliance and project management.

Genevieve Sutton

Sutton has been with The Doe Run Co. since 2011, filling various key roles in the environmental and remediation departments. She is currently its remediation business manager, overseeing all active remediation projects including the Old Lead Belt, Viburnum Trend, Glover and Herculaneum sites. She regularly participates in community engagement activities to promote the public perception of mining and is involved in a committee to enhance the working partnership between Doe Run and Missouri S&T. In 2015, she was invited to participate on the Missouri S&T Mining Engineering Department's advisory board, and was inducted into the Mines and Metallurgy Academy in 2017.

Sutton has NCEES Professional Engineer licensure in mining and mineral processing. She has been an SME member at the local-chapter and national levels since 1997, and has served as chair of the local section for multiple terms, on the SME Structure & Governance, Products & Services and Association Growth committees, and on an ad hoc committee to improve relations between local sections and national SME. She is currently serving as chair of the reformed SME PE Committee.

## PROGRAM PLANNING CHAIR

**NINA ASTILLERO** currently works for ioneer, Ltd. in Nevada as the ESG director overseeing sustainability activities in addition to environmental, health and safety compliance management.

Nina Astillero

Previously, Astillero has worked at Holcim (US) Inc., Freeport-McMoRan Inc., and Bureau Veritas North America in roles of increasing responsibility. She has more than 13 years of experience in the mining, building products and environmental consulting fields.

Astillero has held several technical roles overseeing environmental permitting, remediation, auditing and sustainability strategy development. She is also actively involved in several professional organizations. She serves as the Women in Mining USA national secretary and has held numerous roles in SME.

Astillero was a Grainger Foundation Frontiers of Engineering Symposium speaker representing the mining industry as well as a contributing author to the National Academy of Engineering's *The Bridge* quarterly publication.

She holds a B.S. in geology and environmental studies from Temple University and M.S. in environmental engineering from the New Jersey Institute of Technology.

# Health & Safety Division officer nominees

## CHAIR

**KIMBERLY WALSTER**, CMSP, is mine safety manager at Prairie State Generating Co. in southern Illinois. In addition to being a Certified Mine Safety Professional (CMSP) and Certified Occupational Safety Specialist (COSS). Walster holds certifications in leadership psychology from Cornell University and in management from the University of Notre Dame.

Kimberly Walster

At Prairie State her focus is on the CORESafety Health and Management System, including continuous improvement of safety processes and risk management. As an on-site emergency medical technician (EMT) and cardiopulmonary resuscitation (CPR) instructor, she is passionate about sharing knowledge on best practices in the mining industry.

Amy J. Richins

## VICE CHAIR

**AMY J. RICHINS** received B.S. and M.S. degrees in mining engineering from the University of Utah. In 2019, she received the Robert S. Shoemaker Ph.D. Fellowship Grant and is now completing that degree at the University of Utah.

Richins was with FLSmidth Minerals for several years holding many different roles, including project manager and flotation products specialist, and is presently property and range manager for Circle R Livestock LLC, a producer of grass-fed beef cattle. She has authored three book chapters, several conference papers and many conference presentations. She is particularly interested in mineral processing, health and safety management, leadership and communication, and innovative teaching and training methods.

## PROGRAM CHAIR

**ADAM GREGOR** serves as the director of health, safety and loss control at Coeur Mining, where he plays a pivotal role in shaping and executing comprehensive safety strategies for the organization. With a career spanning 22 years, he has become a driving force in promoting health, safety and wellness excellence and operational efficiency within the mining industry.

Adam Gregor

Gregor is tasked with overseeing all aspects of health, safety, and loss control initiatives across the company's portfolio of mining operations. Prior to joining Coeur, he held positions of continuous improvement manager at Vulcan Materials and health and safety manager at Roger Group, Inc.

## PROGRAM VICE CHAIR

**LARA SIMS** is an experienced leader with more than 20 years in the mining industry developing and managing health and safety strategies for several large-scale mining operations across the United States. Sims specializes in health and safety standards, staff management, loss prevention and strategic continuous improvements.

Prior to joining Ivanhoe Electric, Sims established Sims 360, a consulting business based in Yerington, NV, focused on building and implementing adaptive health and safety frameworks for more than 20 mines in the United States. Her previous work experience includes time with Rio Tinto, Ouray Silver Mines, Oceana Gold and Nevada Copper.

Lara Sims

Sims holds a technical master's degree in safety sciences from Indiana University of Pennsylvania. She is an International Academy of Mine Safety and Health (IAMSH) Certified Mine Safety Professional (CMSP) through SME and participates in the Energy Resource Governance Initiative (ERGI) Academy through the University of Nevada in Reno.

## COMMUNICATIONS CHAIR

**MATT MAIN**, CSP, is the health and safety manager at Climax Molybdenum Co.'s Climax Mine. He earned a B.S. degree in mining engineering from the Colorado School of Mines. Main has been with Freeport-McMoRan since 2005 and has been in health and safety at four operations across the United States. He has been a Board-Certified Safety Professional since 2006. He has served on the Health & Safety (H&S) Division Executive Committee as a Member-at-Large and has presented at the MINEXCHANGE SME Annual Conference & Expo and served as session chair.

Matt Main

# Industrial Minerals & Aggregates Division officer nominees

## CHAIR

**GAURAV SONI** is a proposal manager (plant solution) with Metso Outotec in Denver, CO. He graduated with an M.S. in mining and mineral engineering from Virginia Tech in 2013 and B.Tech. in mineral engineering from IIT(ISM), Dhanbad in 2009. He is a certified project manager with Project Management Institute (PMI). He is currently pursuing a weekend program for an MBA at Booth School of Business (University of Chicago).

Gaurav Soni

Before joining Metso Outotec, Soni worked at Tata Steel and Imerys. His work experience has been focused on business development, supply-chain management, large Capex cost analysis, project execution and operation.

## VICE CHAIR

**TUSHAR GUPTA** is senior metallurgical engineer, research at MP Materials in Mountain Pass, CA. After graduating with a Ph.D. in mineral processing and extractive metallurgy from the University of Kentucky, his work as

# Division Officer Nominations

Tushar Gupta

a research scientist at Columbia University in New York City focused on innovation in fine particle flotation for base metals.

With a passion for making the most of natural resources through innovative extraction techniques, his current role is in research and development for characterizing and reprocessing rare earth tailings as feedstock for producing saleable rare earth concentrates. In this role, he serves as the technical lead for process innovation and development, working hands on to improve resource utilization. His strong academic background, coupled with his research and industry experience, has equipped him with a comprehensive understanding of the rare earth industry.

Gupta's dedication and contributions to the field earned him the SME Raja V. and Geetha V. Ramani Graduate Scholarship award in 2021 and SME Mineral & Metallurgical Processing Division Scholarship for outstanding graduate in 2020.

## SECRETARY/TREASURER

**HIMESH PATEL** is a research & development (R&D) engineer at FLSmidth, Inc., with a focus on the development of innovative process solutions concerning the natural resource industry. His primary duties include research and technology development for new concepts, process improvements, and optimization of existing products in the mineral processing industry. Patel has more than six years of research and industry experience. Before joining FLSmidth, Patel worked at McClelland Labs, Kinross Round Mountain, Freeport McMoRan and India Power Corp.

Himesh Patel

Patel is an active member of SME and the Industrial Minerals & Aggregated Division (IM&AD). He has served on the IM&AD Program Committee, Technical Committee, Scholarship Committee, and NSSGA Student Design Competition Committee. He is an alumni of the SME Young Leaders Committee (Class of 2019) and current secretary of the Nevada MPD subsection (2021-present). Patel has published several articles in *Mining Engineering* magazine and at various conferences.

Patel received his M.S. in metallurgical engineering from the University of Nevada, Reno and a dual degree in mineral engineering from the Indian Institute of Technology (Indian School of Mines), Dhanbad.

In 2016, he was awarded a student exchange fellowship at the Universidad Politecnica de Madrid (UPM) under the ERASMUS+ program. He is passionate about educating the public about the mineral industry.

## PROGRAM CHAIR

Jack Sackrider

**JACK SACKRIDER**, P.G., is a geologic consultant with a focus on environmental and economic geology as it relates to construction aggregates, industrial minerals and associated industries. As a Professional Geologist licensed in the state of Texas, he has performed an array of tasks, primarily related to geologic exploration, modeling and calculations of economic aggregate reserves; geologic assessments over the Edwards Aquifer and sensitive recharge feature training of mine and quarry staff. Sackrider also volunteers his experience with industry and the community through organizations such as SME and educational events like the Texas Hydro-Geo Workshop.

## TECHNICAL COMMITTEEE CHAIR-ELECT

Rudrajit Mitra

**RUDRAJIT MITRA** is an associate professor and Syd & Felicia Peng Professor in Mining Engineering at the South Dakota Mines. Prior to this, he has worked in Germany, South Africa and Australia.

Mitra obtained his Ph.D. from Virginia Tech and M.S. from Penn State. His area of expertise includes rock mechanics, mining systems engineering focusing on resource efficiency through use of digitalization,virtual-reality applications in mining and innovation in learning and teaching.

He has more than 130 research publications in book chapters, journals, peer-reviewed conferences and reports and has been involved in various projects for the mining industry across different countries. To date, he has graduated 12 Ph.D., 13 M.S. and 77 undergraduate honors students under his supervision. He is an active member of the SME, ARMA, MMSA (QP — Mining), AusIMM, SAIMM and SOMP. He is in the editorial boards of multiple journals and has been responsible for organizing various international conferences.

## SCHOLARSHIP COMMITTEE CHAIR

Raghav Dube

**RAGHAV DUBE** graduated with an M.S. in mining and mineral engineering from the University of

Kentucky in 2012 and with a bachelor's degree in mineral engineering from Indian School of Mines in 2009. He is currently working as technology manager, flotation in Metso Outotec.

Dube has more than 11 years of experience in the mineral processing industry, including laboratory test work, pilot plant operation, modeling and simulating plant flowsheets, and the startup and commissioning of greenfield plant projects.

## MEMBERSHIP COMMITTEE CHAIR

**STEVEN STOKOWSKI**, a registered Professional Geologist, is the owner and materials geologist of Stone Products Consultants. His primary professional interest is industrial minerals, especially aggregates. He has an M.S. in geology from the South Dakota School of Mines and Technology and a B.S. in geology from George Washington University.

Stokowski is the recipient of the 2014 Herbert C. Hoover Award from the Washington D.C. Section of SME, the 2017 Robert W. Piekarz Award from SME and the 2020 Chair award from the Industrial Minerals & Aggregates Division of SME. He is a past chair of the Washington D.C. Section of SME, and the current program chair of the Georgia Section of SME. He has presented 10 papers at MINEXCHANGE SME Annual Conference & Expos, chaired five SME symposiums and sessions, presented five papers at past Forum on the Geology of Industrial Minerals (FGIM) meetings, which are now part of IM&AD, chaired an FGIM meeting and is the co-author of two chapters and edited three other chapters in *Industrial Minerals and Rocks*.

Steven Stokowski

Stokowski joined SME in 1978 and has since participated in numerous committees. He is registered or certified as a geologist in Georgia, Maine, Virginia and other states.

# Mineral & Metallurgical Processing Division officer nominees

## CHAIR

**TARUN BHAMBHANI** is principal scientist at Syensqo Mining Solutions, where he has been for the last 17 years, engaged in the development of novel reagents to solve challenging separations and enable step-change in flotation outcome. His contributions include the development of novel collectors for gold, platinum-group metals and oxide copper, modifiers for problematic gangue and selective separations of sulfides, and novel switchable frothers. His efforts to set up collaborations between vendors, mining companies and academia has translated into much-improved understanding of mechanisms governing mineral separations, and approaches for treating complex ores.

Tarun Bhambhani

Bhambhani has lectured extensively on the role of chemistry in flotation at many mining companies and their processing plants. He has organized several SME Mineral & Metallurgical Processing (MPD) technical sessions and symposia, and has served on research, membership and scholarship committees. He was a co-organizer of the Sulfide Flotation Symposium at the Extraction 2018 conference and is a co-chair for the XXXI International Mineral Processing Congress (IMPC) 2024 conference to be held in Washington, DC. He has authored more than 42 papers, holds six sets of patents, is n associate editor on the editorial board of SME's *Mining, Metallurgy & Exploration* journal, and received MPD's Outstanding Young Engineer Award in 2013. He holds a bachelor's degree in mining and minerals engineering from Virginia Tech and a Ph.D. from Columbia University.

## ASSOCIATE CHAIR

**AARON NOBLE** is a professor and the head of the Department of Mining and Minerals Engineering at Virginia Tech. His instruction and research are in the general areas of mineral processing, process economics and mine environmental management. He has published more than 45 journal papers, delivered more than 120 professional presentations, and has received three U.S. patents for innovative process equipment.

Aaron Noble

Noble has a B.S., an M.S. and a Ph.D. all from Virginia Tech and all in mining and minerals engineering. He is a licensed Professional Engineer in the Commonwealth of Virginia, and he currently serves as an associate editor on the editorial board of SME's *Mining, Metallurgy & Exploration* journal. He is an inaugural recipient of the SME Academic Career Development Grant (2015). Other notable awards and honors include the J.W. Woomer Award (2019), the MPD

# Division Officer Nominations

Outstanding Young Engineer Award (2018), the Rossiter W. Raymond Award (2017), the Stefanko Best Paper Award (2014) and Henry Krumb Lecturer (2016 and 2018).

## FIRST VICE CHAIR

**KIMBERLY MILLS** is a senior process engineer at Samuel Engineering in Greenwood Village, CO. She holds a Ph.D. and B.S. in metallurgical and materials engineering from the Colorado School of Mines (CSM). She is a hydrometallurgical expert spanning rare earths and base, precious and battery metals, and is an MMSA Qualified Professional in Processing.

Kimberly Mills

Mills has served SME through the Council of Education, Student Member Affairs, scholarship and award committees, chaired technical sessions, and currently serves as the chair of the upcoming Extraction 2025 conference. She received the 2014 SME MPD Outstanding Young Engineer Award, is an affiliate faculty member of the Kroll Institute for Extractive Metallurgy and member of the Mining Engineering Department Industry Advisory Council at CSM.

## SECOND VICE CHAIR

**NICK GOW** is a senior study manager for Paterson & Cooke in Golden, CO. He earned B.S. and M.S. degrees in metallurgical engineering and chemistry from Montana Tech. He received his Ph.D. from the University of Montana blending chemistry and mineral processing.

Nick Gow

Gow is a diverse metallurgist with 15 years of experience based in early-stage project metallurgical development and late-stage/brownfield process optimization. His experience comes from numerous years of hands-on metallurgical testing focused on the impacts of geometallurgical considerations and bridging the metallurgical needs of a site to relevant and realistic analytical testing.

Gow currently serves as the SME Board of Directors Intern and co-organizer of the upcoming Copper 2025 and World Gold 2025 conferences. He is an MMSA Qualified Professional, CN code auditor, research associate at the Colorado School of Mines and recent recipient of the Ivan Rahn Education Award.

## SECRETARY-TREASURER

**JIM WICKENS** obtained his B.A.Sc. in mining and mineral process engineering from the University of British Columbia in 1987. He has spent most of his career in operations with Placer Dome and Barrick Gold in Canada and the United States.

Jim Wickens

More recently, Wickens has had the opportunity to diversify his experience working for Weir Minerals and McClelland Laboratories as a private consultant, for Augusta Gold Corp. as vice president, operations, and is currently process engineering manager, Mining and Metals for Wood Group USA. Wickens is active at the SME section level, serving as a past chair of the Nevada Mineral Processors subsection.

In 2022, Wickens was awarded the SME President's Citation for Individual Service for his work pioneering the Nevada Mineral Processors Subsection.

## TECHNICAL PROGRAM ASSOCIATE

**ADAM HOUSE** is the process optimization lead for Paterson & Cooke. He received a B.S. in metallurgical engineering and later an M.S. in project engineering and management from Montana Tech.

Adam House

House began his career working as a metallurgical technician. He then gained invaluable experience working in operations as a metallurgist and supervisor before moving into projects, where he completed both minor and major capital projects. He has also served in consulting roles to global mining operations. He specializes in operational optimization and debottlenecking, but has provided extensive design support, project management, commissioning support, and owner's team support.

House has served in multiple roles within SME, including award committees and unit committees. He is also a member of the Responsible Mining & Underground Construction Strategic Committee, as well as serving as the secretary for the Colorado MPD subsection committee. House is currently serving as the membership associate for the MPD Executive Committee.

## MEMBERSHIP ASSOCIATE

**ZACHERY ZANETELL** is currently the metallurgy manager at Newmont Corp.'s global laboratory in Englewood, CO. He earned his B.S. in chemistry from the University of Northern Colorado

Zachery Zanetell

before pursuing an M.S. degree in metallurgical engineering from the Colorado School of Mines.

Over his 17-year career, he has navigated a diverse array of technical and operational roles. His contributions include pivotal involvement in testing and validating emerging technologies, from initial concept to bench-scale and pilot-plant experimentation.

In 2020, he was awarded the MPD Outstanding Young Engineer Award. Furthermore, he actively engages with the local Colorado MPD subsection committee, showcasing his dedication to fostering collaboration and innovation within the industry.

# Mining & Exploration Division officer nominees

## CHAIR

**JENESSA HAARALA** is a principal mining consultant at Haarala Mining in Montana, where she provides underground mine design and project scheduling services. Since starting her own consulting business in 2021 she has worked on polymetallic underground projects in Montana and Missouri. Prior to consulting, she worked in various engineering and supervisory roles in Nevada, New Zealand and Utah.

Jenessa Haarala

Haarala has nearly 20 years of experience as an underground mining engineer. She holds a B.S. in mining engineering from the University of Nevada, Reno and is a Registered Member of SME. Since joining SME as a student, she has been an officer of the Northeastern Nevada Section, served as a program area manager for the M&E Division, served on the Sustainable Development Committee, and received the M&E Outstanding Young Professional Award in 2018. She a member of Women in Mining and is passionate about promoting inclusion in the mining industry.

## CHAIR-ELECT

**DANIEL ROSENBACH** is a mining engineer with more than 17 years of professional experience in the mining, geotechnical and construction industries, and a graduate of the Colorado School of Mines. He currently serves as president of Petra Drilling Supply, a company he helped establish in 2023, and resides with his family in Lubbock, TX. Rosenbach has specialized in drilling tools and materials for many different applications since he began his professional career with Atlas Copco in 2011.

Daniel Rosenbach

Rosenbach has remained an active member of SME since he first joined the organization during college in 2005. He has presented a paper, chaired three technical sessions, and served as a program area manager for the M&E Division in 2018. He was appointed to the M&E Executive Committee in 2021 and currently serves as the vice chair of program planning for the MINEXCHANGE 2025 Annual Conference & Expo in Denver, CO. One of his goals is to keep the next generations involved in SME, and he makes an effort to mentor students in the industry.

## VICE CHAIR-PROGRAMS

**LIA WALKER** is the manager of innovation for Freeport-McMoRan Inc., where she is the business leader for integrating data-driven innovation and technology transformation into the company. She leads highly engaged business teams to leverage Agile and change-management techniques to deploy technology and data-science solutions that amplify business growth and profitability.

Lia Walker

Walker has an M.S. degree and 27 years of experience in the mining industry, functioning in various roles throughout her career. Some of her key contributions are innovation engineering, quality leader, inventor, digital-solutions innovator, change-management advocate, enterprise product management and accomplished Agile coach. Walker is committed to SME's vision and has served in diverse positions.

## VICE CHAIR-PROGRAM PLANNING

**KATIE ROBERTSON** has more than 15 years of experience in openpit and underground hard-rock mining in the Western United States, primarily in gold and copper. She received her B.S. in mining engineering from Michigan Technological University (MTU) and MBA from the University of

Katie Robertson

Utah. Her involvement in SME started as a student at MTU and since then she has been involved in the Young Leaders Committee, eventually serving as chair; multiple technical sessions, as speaker and chair; and recently as the M&E operations program manager. She is currently the general manager, Technical, at Rio Tinto Kennecott Copper, where she oversees the technical team across the value stream, from mine to refinery

## ASSISTANT VICE CHAIR-PROGRAM PLANNING

**RUSSELL SHEETS** has nearly 20 years of experience supporting the mining industry. His mining career began with a couple of summers in underground coal in western Colorado and continued in the Carlin Trend in northern Nevada for 14 years. For the past five years, Sheet's current role as a senior geotechnical engineer with Barr Engineering Co. has provided the opportunity to support various surface and underground operations across metals, rare earths, coal and aggregates. He received his B.S. in geological engineering from Montana Tech, where he has also served on the GEOE Industry Advisory Board for many years, including chairperson for the past couple of years. Sheets subsequently earned an M.S. in geological engineering from the University of Wisconsin. He has been a member of SME since 2005, and a Registered Member since 2014. He has been both a technical speaker and chair/co-chair for several years. In 2023, he served as the M&E geosciences program area manager. He is also a member of the SME PE Committee.

Russell Sheets

## SECRETARY

**ROSA MARIA** is a bilingual senior mining engineer, consultant, project manager and board member with 17 years of professional experience working for global mining companies such as BHP, Freeport-McMoRan and Barrick in the areas of mine operations, mine planning and design, ore control, control centers, data management and business improvement in various commodities in South and North America; and in research and development of digital transformation in mining.

Rosa Maria

Maria holds a B.Sc. in mining engineering from PUCP, Peru and an M.Sc. in mining engineering from the University of Arizona. She has presented her research work on digital transformation, mining education, and diversity and inclusion in mining at more than 14 international conferences.

She is currently an independent director of Arizona Metals Corp. and project manager at Stantec USA. Maria is a mother of two young boys and lives in Tucson, AZ. She is a volunteer member of the SME, WIM, Tusuy Peru AZ, Boy Scouts of America and Feed my Starving Children organizations. She has been an SME member for 18 years, starting in 2006 as a student member, and is currently a member of the SME Structure & Governance Committee. She was previously the M&E program area manager for innovations and technology, and vice president of the SME Global Young Leaders Executive Committee (YLC).

# UCA Division officer nominations

## CHAIR

**Erika Moonin,** P.E., founder and president of Moonin Associates PLLC, based in Las Vegas, NV, is a licensed professional civil engineer with 30 years of experience in civil and heavy civil/underground construction industry.

Moonin earned her bachelor of science in civil engineering from the University of Nevada, Las Vegas in 1991 and is a licensed Professional Civil Engineer (PE) in California and Nevada. She worked as a consultant in the beginning of her career and then 25 years with the Las Vegas Valley Water District/Southern Nevada Water Authority managing large water infrastructure programs for Southern Nevada and interfacing with many local, state, regional and federal agencies related to the Colorado River Basin. She was the engineer project manager of the Major Projects team and led integrated teams of professionals to successfully plan, design and construct various water supply projects ranging in value from $35 million to $2.2 billion. Her most challenging project was the Lake Mead Intake No. 3, which is a critical water intake tunnel that ensures continued access to the local communities' primary drinking water source, even with drastically lowering lake levels due to drought. Moonin formed her own consulting company in 2019, Moonin Associates, a 100 percent woman-owned and certified WBE firm, to assist other owners and major project

Erika Moonin

teams with major technically challenging underground and tunneling infrastructure projects.

## CHAIR ELECT

**Leon "Lonnie" Jacobs** has almost 40 years of New York metropolitan area heavy civil and underground construction experience. Jacobs joined Frontier-Kemper in 1995. Some of the projects he has constructed with Frontier-Kemper over the past 28 years include the New York City Department of Environmental Protection Water Tunnel Shaft 26B; the 26 Ward Water Pollution Control Plant Pilot Program; the New Croton Aqueduct Rehabilitation Project; the TBTA Queens Midtown Tunnel Rehabilitation Project; the NJ Transit Hudson Bergen Light Rail Weehawken Tunnel/ Bergenline Avenue Station Project; rehabilitation of the New Croton Aqueduct; MTA East Side Access Manhattan North Structures and the Cleaning and Inspection of City Tunnel No. 3, Stage 2, in Queens and Brooklyn.

Lonnie Jacobs

In addition to his work experience, Jacobs has served several industry associations and presented at numerous conferences. Highlights include serving on the UCA George A. Fox Conference Committee since 2007, including serving as chair in 2008, 2009, 2015 and 2016. He was recently nominated as vice chair of the North American Tunneling (NAT) Conference Planning Committee and has participated in organizing the 2012, 2014 and 2016 NAT Conferences. He was vice chair of the 2016 NAT Conference Committee when it was held in conjunction with the World Tunnel Congress.

## PAST CHAIR

**Mike Rispin** is vice president, tunneling for Strata Worldwide's global division, Strata Tunneling. Rispin brings more than 36 years of international tunneling and mining expertise to the position, having spent decades working in upper management for companies such as BASF, Normet and Dyno Nobel.

Rispin is a Professional Engineer with memberships in both the American Society of Civil Engineers (ASCE) and The Moles organization.

Mike Rispin

# WAAIME Division officer nominations

## CHAIR

**MARGARET MARY MELVIN MANSANTI (MARGIE) MANSANTI** is a graduate of Idaho State University and completed her dietary internship at Miami Valley Hospital in Dayton, OH. She has been a registered dietitian and member of the American Dietetic Association since 1981.

Relocating with her husband John to different mining communities, she practiced in hospitals, nursing homes and private clinics. She taught nutrition at community colleges and was a substitute teacher for local schools. An advocate for education and literacy, she was active in local library programs and is a more than 35-year member of P.E.O., a women's philanthropic and educational organization. Mansanti served on the Humboldt County Hospital board and chaired the board through a bond passage and construction of a medical office building, hospital expansion and nursing-home addition.

Margaret Mansanti

After learning of the more than 100-year legacy of WAAIME and its scholarships to support the minerals industry, she became involved with WAAIME, reviewing scholarship applications. She became a member of the WAAIME Executive Committee in 2021, helping WAAIME to restructure the Division through the SME Board of Directors-approved omnibus resolution. She and her husband have returned to Montana, where they have three children and six grandchildren.

## EXECUTIVE COMMITTEE

**BARBARA FILAS** is a licensed professional mining engineer and a veteran member of SME. She was the first female SME President in 2005 and was instrumental in forming its Environmental Division and Student Mentor Program. She is also a past chair of the WAAIME Division of SME. She has served on the boards of trustees of the SME Foundation and the American Institute of Mining, Metallurgical and Petroleum Engineers (AIME) and was vice president of finance for AIME.

Filas has hands-on experience with operating gold and coal mining and processing facilities; executive experience in consulting, public companies and nonprofits; and technical expertise in base and precious metals, coal, uranium and industrial minerals in various engineering and environmental

Barbara Filas

capacities. She currently sits on the boards of directors of two publicly traded companies, volunteers as the nominations chair and chair of the board of governors for the National Mining Hall of Fame and was inducted into the National Academy of Engineering in 2022.

**SUSANA PALOMINO PARODI** is an interior designer who has been involved with WAAIME since 2005 when she became the scholarship director for the Cajamarca Section. She served as president of that section from 2008 to 2014, served on the board of the WAAIME Lima Section as its scholarship director in 2015, was the president of that section in 2016-2017 and served as WAAIME vice president, scholarship director of the Lima Section in 2018.

Among her achievements with WAAIME, Palomino Parodi participated in the modernization of the WAAIME organization with the support of strategic partner EY Peru. She helped with the reorganization of the scholarship program, resulting in the increase of scholarship holders from two to three years in the last seven years and improved the administrative documentation regarding scholarship programs in order to facilitate the scholarship process.

Susana Palomino Parodi

She helped with the launch of a new WAAIME Coaching Program, including custom sessions and workshops with up to 64 scholarship recipients, and with an agreement with the Instituto de Ingenieros de Minas del Perú (Peruvian Mining Institute) to grant facilities to WAAIME in its office building. Palomino Parodi participated in the last four PERUMIN convention events with booth implementation, awarded scholarships in the south region and achieved affiliations of recognized companies in the mining, energy and petroleum businesses in Peru. More than $65,000 during the last seven years has been obtained for WAAIME.

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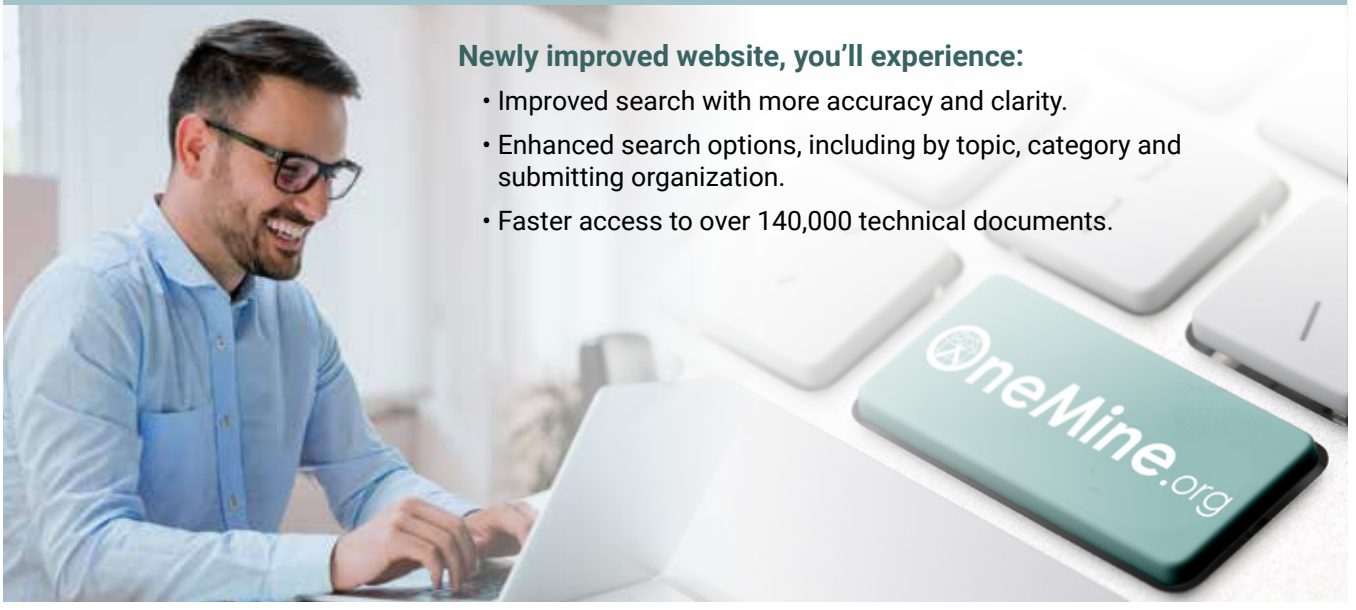

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Contact:
Kelvin Smith, Operations Manager Americas
kelvins@safeai.ai

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### Marietta Silos, LLC
www.mariettasilos.com
Marietta Silos, LLC is an industrial silo construction company that specializes in building, repairing, and inspecting silos all over the United States of America.

2417 Waterford Road
Marietta OH 45750
info@marietasilos.com

### Meridian Manufacturing
www.meridianmfg.com
Since 1965, Meridian Manufacturing has been the frontrunner for on-site storage and offers industry-leading storage solutions for your mining operation. We have the storage you need for your commodities with a line of SmoothWall Nitrate Pearl, Ammonium Nitrate, Fly Ash, and Emulsion Silos that are welded, sealed, assembled and ready to deliver with sizes up to 18' diameter and capacities up to 8,700 ft3. For massive capacity, our Bolt-Together Silos are assembled on-site and are available up to 38' diameter and capacities up to 68,000ft3. Our silos are made from high quality steel, powder coated for superior wear, and are custom designed and built to your exact needs, including optional overhead drive-through structures to maximize efficient loading and unloading. Ask about our other available products such as insulated silos, fuel tanks, secondary containment and more! Visit us online at meridianmfg.com to learn more and request a quote today

### USA Silo Service, Inc.
www.usasilos.com
USA Silo Service, Inc. is an industrial silo cleaning company that specializes in cleaning industrial silos and placing and repairing rubber roof coatings.

2517 Waterford Road
Marietta OH 45750
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## BLASTING ACCESSORIES, EQUIPMENT AND AGENTS

### Dyno Nobel
www.dynonobel.com
Dyno Nobel provides customer solutions through our people, our products, and our services. Our blasters are among the most highly trained in the industry. We offer a full range of reliable explosives products from manufacturing plants throughout the US and blasting services from a distribution network unmatched in the industry. Our R&D focuses on practical ways to use new technologies to benefit our customers. Renowned for our excellent safety performance and innovative explosive products and services, Dyno Nobel continuously delivers trusted technology, unmatched expertise, and explosive results.

6440 S Millrock Drive, Suite 150
Salt Lake City, UT 84121 USA
Telephone: (800) 732-7534
Fax: (801) 328-6452
dna.marketing@am.dynonobel.com

## BOLTING SOLUTIONS

### Nord-Lock Superbolt

Bolting applications in the mining industry can be especially challenging. You need a bolting solution that can be installed and removed safely and quickly. One that will keep your bolted joints tight through demanding operations and improve your bottom line. That's where Superbolt tensioners come in.

Superbolt tensioners are designed as direct replacements for standard bolting. They can be threaded onto a new or exiting bolt, stud, threaded rod or shaft. With Superbolt tensioners, bolting is safe, fast, easy and accurate – only hand tools are required.

Superbolt tensioners have been successfully implemented on leading OEM mining equipment such as rope shovels, draglines, haul trucks and much more.

Superbolt, Inc.
1200 Clifford Ball Drive
Clinton, PA 15026
T: +1 412 279 1149
E: bolting@nord-lock.com

### Valley Forge & Bolt Mfg Co.

www.vfbolts.com/mining-industry/

Valley Forge has proudly manufactured both standard and custom fasteners in the mining industry for over 40 years. Our innovative solutions are manufactured in the USA including well-known technologies like the Maxbolt®- our visual load indicator in each fastener, which has long set the standard for bolted joint load-indicating solutions around the world.

Our innovative ideas are directed by continuous improvement, the simplification and accuracy of the installation of fasteners, and the resulting improvement in productivity and safety for our customers.

We are constantly developing new technologies to help our customers find solutions that optimize the integrity of the bolted joint. We are proud to continue our extension into the technology arena with cutting-edge upgrades to our core offerings. The RTM™ Meter Collection features wireless probes added to our SPC4® bolts that can continuously monitor fastener load in any application with industry-leading, unique features. This vigorous commitment to innovation continues to steer additions to these products with recent rollouts of a companion Android application available now on the google play store and on our site.

To learn more about specific developments to our products for the mining industry or access recent case studies visit: www.vfbolts.com/mining-industry/

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Phoenix, AZ 85043
sales@vfbolts.com
Toll Free: (800) 832-6587
Local: (602) 269-5748

## BORING EQUIPMENT

### Expander

Expander is an award-winning solution with over one million systems installed since 1985. The design is adaptable for any obstacle or application, and has been used on a variety of the world's largest Original Equipment Manufacturer machines.

Each Expander System comes with a full Lifetime Warranty. We guarantee your solution will perform as expected from the moment it is installed until the end of its intended lifecycle. Finally, a long-term permanent solution to pivot lug wear.

Contact:
Rod Whipple
MRO Manager – Expander – North America
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Email: rod.whipple@nord-lock.com
Expander: 223 Industrial Street, De Witt, IA 52742

### Northrop Grumman LITEF GmbH

Based on more than sixty years' history in the development and production of inertial sensors such as micro-electromechanical accelerometers and fiber-optic gyroscopes and an excellent reputation in the aviation and military industries, LITEF provides the innovative, handheld alignment tool LiPAD®-100.
The LiPAD®-100 is a battery driven hand-held gyrocompass that outputs the three spatial angles, North direction, pitch and roll angle simply and precisely. This handheld gyrocompass is designed for the mining, foundation, and special construction industries to perform quick and reliable alignment of equipment such as drill rigs or tunnel boring machines in above ground and underground applications.

The LiPAD®-100 offers Bluetooth® connectivity to communicate with a handheld device. An Android-based software app enables the operator to control the device and display the measurement data in real-time. All data can be recorded and exported for quality control or further processing.

LiPAD®-100 provides real cost savings versus standard surveying and alignment methods.

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industrial@litef.de
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## BRAKES - DYNAMIC, FRICTION, DISK - BLOCK, MAGNETIC

### Dellner Bubenzer USA, Inc.

www.dellnerbubenzer.com

Dellner Bubenzer is focused on the design, production, and service of high-quality braking systems for both static and dynamic applications which involve the precise control of small to very large amounts of kinetic energy. Dellner Bubenzer manufacturers brakes designed for use on various pieces of mining equipment such as overland conveyor systems, bucket-wheel excavators, rail car dumpers etc. Dellner Bubenzer also provide an extensive line of pneumatic drum clutches & brakes for draglines and mining shovels. The Dellner Bubenzer extensive portfolio of brake products will provide you with a solution for all of your braking needs.

DELLNER BUBENZER USA, INC.
20026 Hickory Twig Way
Spring, TX 77388
Telephone – 908-482-4830
Fax – 281-288-2114
Email – info.us@dellnerbubenzer.com

### FORCE CONTROL INDUSTRIES, INC.

www.forcecontrol.com

Force Control's Oil Shear Technology significantly reduces wear of the clutch and brake friction material, and due to the lubricating properties of the transmission fluid, extends life of the bearings, splines, and drive pins. Removing the heat greatly reduces degradation of the friction material causing glazing, and fade.

Our Oil Shear clutches and brakes do not require adjustment because there is minimal wear of the friction materials. The torque maintains nearly full torque through the life of the brake. This means no torque fade when that extra heavy load is on the crane, or missed position on an indexing machine.

Because our units contain transmission fluid, they must have a totally enclosed, sealed housing. This not only keeps dust, dirt, moisture and chemicals out of the clutch or brake which cause corrosion, rust, sticking parts, friction material wear, but also contains any friction material dust from escaping the unit.

3660 Dixie Highway
Fairfield, OH 45014
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Fax: 513-868-2105
E-Mail: tstoner@forcecontrol.com

## Kobelt Manufacturing Co. Ltd.

www.kobelt.com

Kobelt designs and manufactures rugged, reliable braking systems for a broad range of applications in mining, material handling, oil & gas, transportation, material processing and the marine sector. Our strength is our ability to deliver bespoke braking solutions with very little lead time. Utilizing our experienced engineering team, an in-house foundry and extensive machining capability, we eliminate any lag time between design and manufacturing. Kobelt brake systems are used on overland conveyors, heavy equipment, marine shaft brakes, offshore turret winches, drawworks, cranes, steel uncoilers, paper converting lines and a variety of other applications. Kobelt is known for rugged and reliable products, trustworthy customer service and industry leading delivery times.

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sales@kobelt.com

# CABLE MANAGEMENT

## CAB Products

www.cabproducts.com

Cab Products continues to be a leading manufacturer and supplier of Hooks, Hangers, and Mine Safety Products. Throughout the mining industry, CAB Products are widely recognized for their high quality and excellent design. CAB Hangers greatly improve safety and help cut operating costs by supporting and organizing pipe, tubing and all types of cables. CAB also manufactures a wide range of high visibility reflective products that greatly improve safety in mines and tunnels such as tubes, streamers, and safety apparel. Other innovative products include CAB Lifeline. Partnering with a mine in 1985, CAB was the first company to produce a Lifeline for emergency escape from underground mines. CAB Products is dedicated to providing job opportunities and services to persons with disabilities. All CAB Products are manufactured by CAB employees with great pride and integrity. More information on our products can be found at www.cabproducts.com

175 Industrial Park Road
Ebensburg, PA 15931
Telephone: (814) 472-5077
Fax: (814) 472-7179

# CENTRIFUGES

## Flottweg Separation Technology, Inc.

www.flottweg.com

With over 40 years of experience in the US and Canadian markets, Flottweg provides Fluid/Solid separation equipment for precious and industrial mining processes. Our centrifuges dewater CRUD, TAILINGS, LEACHING RESIDUE, and many other emulsions resulting in high throughput and cake dryness.

10700 Toebben Drive
Independence, KY 41051 USA
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Fax: (859) 448-2333
sales@flottweg.net

## Sentinel Solutions LLC

https://sentinel-solutions.com/

Sentinel has been bringing Science and experience to the drilling and solids control industry since 2016.

With Sentinel's continued growth, we are now able to bring a full line of rental equipment to serve the drilling community and hold a national distributorship of drilling fluids. But most of all, bringing the science and experience with it.

Chuck Skillman takes a personal interest in each project and takes mud engineering and his experience to determine what combination of fluids and equipment that meet your goals and make projects profitable.

Sentinel can provide professional site operations.

Each project is unique and presents its own challenges. The most important issue on any project is understanding the problem before you provide a solution.

Sentinel can help define the cause of your problems or better yet, point out potential issues before you spend unnecessary money.

As a national distributor, Sentinel can bring the products, equipment, and provide solutions for drilling, De-watering and solids control. We can oversee your job from start to finish, including the engineering behind it.

866-GOT-MUCK
555 Furrows Rd. Holtsville, NY 11742
Sentinel@Sentinel-Solutions.com

# COMMUNICATIONS EQUIPMENT

## EVERYWHERE Communications

everywherecomms.com

The EVERYWHERE Always Connected™ Platform combines the EVERYWHERE Mobile App, the inReach® by Garmin®, and the EVERYWHERE Hub to deliver global SOS, dynamic location monitoring, and secure messaging via the Iridium® satellite network. These vital communication links improve team connectivity and situational awareness while supporting worldwide worker safety and duty of care. EVERYWHERE Communications has enterprise and government customers deployed in over 150 countries around the world. Connect and protect your most valuable assets, your people.

30 West St.
Annapolis, MD 21401 USA
Telephone: (207) 370-0499
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## MST Global

mstglobal.com

MST Global specialize in harsh industrial technology that empowers customers to unearth safety and productivity improvements. We believe that, without the right technology solution for a mine's unique situation, there is only partial components delivering partial results. Our disruptive digital vision for hardware and software embraces next-generation technologies and challenges paradigms to provide customers with value now and into the future.

With over 30 years at the face of underground operations around the world, MST Global is a trusted partner to Tier 1 and Tier 2 customers.

A customer-centered, flexible approach offers solutions designed with an open-standards protocol ensuring interoperability in a multi-vendor environment.

MST's suite of solutions are focused on improving and enhancing:

- connectivity (secure digital network, network capability extenders),
- safety (proximity detection, situational awareness, through-the-earth communication),
- tracking (visualization software, personal and asset tracking, collision avoidance),
- productivity (software providing

communications, insights, monitoring and control).

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Golden, CO 80403 USA
Telephone: +1 303 951 0570
americasales@mstglobal.com

## NORTHWEST TOWERS

Northwest Towers designs and constructs complete mine-wide wireless networks. Projects are delivered from Northwest Towers in true turnkey fashion. System design, procurement, construction, installation, training, and 24/7 maintenance, all managed, hands-on by Northwest Towers. With years of experience in LTE, MESH, millimeter wave, microwave, WIFI, and 2-way radio, Northwest Towers applies the best suitable technology.

Networks by Northwest Towers support the most critical of applications and conquer the most challenging environments on the surface or underground. Systems are designed to provide fail-safe operation for the most critical of applications including full autonomy and safety. Northwest Towers is also available for routine maintenance and system upgrades.

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Website: www.nwtowers.com
E-Mail: sales@nwtowers.com

## Tunnel Radio of America

www.tunnelradio.com

Tunnel Radio of America is an ISO-9001 certified manufacturer and Women-Owned Small Business, headquartered in Corvallis, Oregon. For 35 years, Tunnel Radio has distinguished itself as the trusted designer, manufacturer and installer of specialized radiating-cable antenna systems ("leaky-feeder") for underground or unreachable areas.

Tunnel Radio's Ultracomm® Leaky Feeder System provides rugged and reliable communication and RFID tracking solutions for today's mining environment. A custom-designed Ultracomm network eliminates dead zones, improves safety, efficiency and security underground and on the surface.

Tunnel Radio's 24/7 technical support is service-led and staffed by the people who built your system. Ultracomm® provides lower installation and maintenance costs than other systems. Robust components ensure consistent communications, improved safety and productivity, and shortened response times.

For more information, visit www.tunnelradio.com

# COMPUTER - HARDWARE AND SERVICES

## Juniper Systems

www.junipersys.com

Juniper Systems provides ultra rugged mobile computing solutions that help workers thrive. Our products are designed for challenging environments where a consumer tablet would fail or where workflow needs to jump from ancient pen and paper to digital data entry. The mining industry presents extreme work environments; the workdays are long and require the ability to perform office work outside. Juniper Systems' products are built to help you accomplish it all. Our mission is to eliminate the disruptions to the workday by improving connectivity and delivering a workhorse tablet or handheld that users can trust to complete their tasks each day. With features like hot-swapping batteries, various touch profiles for wet, stylus and gloved use, and a Juniper Rugged design, our tablets may be one of the toughest tools you put to work in your mine. Whether you are running Windows or Android operating systems, our solutions allow you to perform the same functions you would in the office, anywhere, in any environment.

1132 W 1700 N
Logan, Utah, USA 94341
Tel: 435-153-1881
sales@junipersys.com

## Propeller

https://www.propelleraero.com

Propeller is an easy-to-use platform that combines the best GIS and survey technologies. We empower users to map, measure and manage their worksites like never before, powering over 52,000 users across 20,000 worksites in over 120 countries.

Propeller's realistic 3D map is the place where collaboration happens. One map means one team. It's a one-stop hub for communication and transparency between teams and businesses. And, with just a few clicks, project teams access critical insights that make their jobs simpler, faster, and smarter. Revolutionizing the way they work, from the ground up.

hello@propelleraero.com

## Trimble Geospatial

https://geospatial.trimble.com

Trimble Geospatial provides solutions that facilitate high-quality, productive workflows and information exchange, driving value for a global and diverse customer base of surveyors, engineering, and GIS service companies serving mining owners, operators, and consultants. Trimble's innovative technologies include integrated positioning sensors, field applications, real-time communications, and office software for processing, modeling, and data analytics for slope stability, volumetrics, and construction as-built. Using Trimble solutions, organizations can capture the most accurate spatial data and transform it into intelligence to deliver increased productivity and improved decision-making. Whether enabling more efficient use of natural resources or enhancing the performance and lifecycle of mine infrastructure, timely and reliable geospatial information is at the core of Trimble's solutions to transform the way work is done.

Trimble
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Westminster, CO, USA 80021

# COMPUTER - SOFTWARE AND SERVICES

## Airth.io

www.airth.io

Airth.io is a customer focused global mining technology company that provides solutions for miners by miners. The vendor-agnostic ecosystem of data-driven products connects planning, operations, mineral processing and finance on an integrated easy-to-use platform.

Execute a profitable mine plan, reconcile against operational KPIs, leverage predictive intelligence with machine learning for improved forecasting, minimize operational variance through short interval control, and understand the financial impacts before it is too late.

Airth.io solutions improves the business value chain by closing the gap between planned and actual.

airth.io
PO Box 35242
Tucson, AZ 85740
www.airth.io
contact@airth.io

## Actenum

actenum.com

Actenum DSO/Mine, AI-powered scheduling and optimization software, with powerful decision optimization support technology and advanced analytics, improves mine planning and operational efficiency, and helps mining companies achieve their business goals.

With DSO/Mine, you can rapidly and effectively build and manage schedules for multiple aspects of your operations including core drilling, drill & blast, mucking, load haul dump, ISR, dewatering, and other critical activities.

DSO/Mine also enables you to:

1. Overcome your labor shortage challenges by quickly and easily identifying the number of workers needed and what level of productivity can be achieved with fewer workers.

2. Make key operational decisions with confidence by creating multiple "What if?" scheduling scenarios so you always know what to do in any situation.

3. Reduce NPT and improve your performance by analyzing your resource assignments and then automatically optimizing your schedules so your expensive equipment is working and not sitting idle.

2015 Main Street, Vancouver, BC V5T 3C2
604-245-8266
info@actenum.com

## Eclipse Mining Technologies

www.eclipsemining.com

SourceOne® Enterprise Knowledge Performance System (EKPS) is a vanguard data transformation system that handles the vast amount of complex data generated by mines by using an ontology framework and knowledge graphs. SourceOne alleviates the need for manual data management by automating the organization and classification of your data for quicker and easier retrieval. It gives data meaning with context, relationships, and implications, transforming the most valuable asset you own into actionable knowledge.

Data becomes information. Information becomes knowledge.

3602 E Fort Lowell Road
Tucson, AZ 85716
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info@eclipsemining.com

## Hexagon Mining division

www.hexagon.com
https://lifeofmine.hexagon.com/

Hexagon is a global leader in digital reality solutions, combining sensor, software, and autonomous technologies. Our technologies are shaping production and people-related ecosystems to become increasingly connected and autonomous—ensuring a scalable, sustainable future.

For the mining industry, this means a holistic, data-driven approach to integrating, automating, and optimizing critical workflows. From exploration and planning to drill and blast, material movement and survey and monitoring, these workflows are digitally transformed by the Power of One, a life-of-mine smart solution that connects sensors and software, infield apps and cloudware both in open pit and underground environments.

Hexagon (Nasdaq Stockholm: HEXA B) has approximately 24,000 employees in 50 countries and net sales of approximately 5.2bn EUR.

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## KPI Mining Solutions

www.kpimining.com

KPI Mining Solutions provides significant value to the mining industry by developing and commercializing cutting-edge software and services. Our flagship product, KPI-COSMO Stochastic Mining Optimizer, is the first stochastic and simultaneous optimization software for mineral value chains. This solution optimizes production schedules, increases recovered reserves, and boosts the life-of-asset net present value (NPV) by up to 40%. Take mine planning to the next level! Maximize NPV, manage technical risk, and capitalize on operational synergies with KPI-COSMO's stochastic planning capabilities. We strive to bring innovative stochastic mine planning and orebody modeling solutions to the mining industry, transforming their entire operation.

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## Metsim International, LLC

www.metsim.com

The basis for analysis of all chemical and metallurgical processes is the mass and energy balance. Plant design, capital costs, and technical evaluations are all dependent on such calculations. METSIM® is a general-purpose process simulation system designed to assist the engineer in performing mass and energy balances of complex processes.

METSIM® uses an assortment of computational methods to affect an optimum combination of complexity, user time, and computer resources usage.

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## Micromine

www.micromine.com

Micromine is a leading provider of innovative software solutions for the mining industry, offering a comprehensive range of products that cover the entire mining cycle. From geological exploration and data management to resource estimation, mine planning, and design, our solutions deliver cutting-edge capabilities. Our portfolio includes Micromine Pitram, a real-time fleet management and mine production system, and Micromine Alastri, an integrated open pit mine planning software.

With a global presence across 22 offices, we have established ourselves as an integral part of the mining sector. Operating in over 90 countries, we serve 50 active mine sites and have completed 3,000 diverse projects. Our advanced solutions provide mining operations with precise control, enhanced visibility, and optimized efficiency, driving productivity and success in the industry.

Discover the transformative power of Micromine at www.micromine.com

## talpasolutions GmbH

talpasolutions.com

TALPA is an industry-leading provider of advanced industrial AI and IoT solutions. Our robust platform utilizes powerful AI and machine learning algorithms, combined with pre-trained data science models and industry-specific content, to transform vast amounts of data into actionable insights. By automating complex aspects of the industrial data science process, we enable businesses to quickly develop models that drive operational and financial outcomes.

With TALPA, organizations can easily aggregate data from diverse sources, including machine signals, enterprise systems, market information, and operational benchmarks. Our user-friendly framework empowers users of all technical backgrounds to leverage the platform's algorithms or configure their own, facilitating streamlined data analysis and decision-making.

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# CONCRETE MIXING AND TRANSPORTATION EQUIPMENT

## GALLOVICH CONSULTING LLC

www.gallovichconsultingllc.com
www.fiorigroup.com

GALLOVICH CONSULTING LLC, with more than 20 years experience in America, is a certified rental operation offering all solutions made by FIORI GROUP SPA, a company with headquarter in Finale Emilia (MO) Italy which designs, develops and manufactures off-road Concrete Batching Vehicles, Powder Dispensers, Silos and Dumpers for the construction industry, with wide range of solutions for tunneling construction.

The company's product portfolio is rounded off by the Group capabilities in finding the most effective solution for any customer in making and transporting concrete on-site with a great flexibility, minimizing energy costs and reducing environmental impact.

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DORAL FL 33166
P:+1(240)8936580
www.gallovichconsultingllc.com
www.fiorigroup.com

## CONCRETE REINFORCEMENT

### Bekaert
www.bekaert.com/underground

Bekaert is a global leader in advanced steel wire transformation and coatings. With a rich history spanning over a century, Bekaert has evolved into a diversified company serving various industries, including mining. Bekaert's mining products offer innovative solutions for the extraction and processing of valuable minerals.

Through its cutting-edge wire technology and advanced coating applications, Bekaert provides mining companies with a range of high-performance products. These include steel wire ropes, steel and synthetic fibers and other reinforcement solutions that enhance safety, durability, and efficiency in mining operations.

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www.bekaert.com/underground

### VROD USA, Inc.
www.fiberglassrebar.com

VROD has been a world premier manufacturer of Fiberglass Rebar since 1997. We manufacture many different grades of material for any application. We have the ability to custom tailor our products for your needs including custom lengths, grades and bend shapes. We also offer professional Engineering Support for all projects.

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Kernersville, NC 27284
+1-336-993-2461
Email: chris@fiberglassrebar.com

## CONSTRUCTION – CONTRACTING SERVICES

### BARNARD CONSTRUCTION COMPANY, INC.
www.barnard-inc.com

Whether we're tunneling through the mountains of northern British Columbia or below the streets of downtown San Francisco, our people arrive at projects determined to do the best for their communities and be the best in the industry. We self-perform heavy civil and underground construction including TBM tunneling, drill and blast, and sequential excavation methods. We have built our reputation on skill, innovation, reliability, and safety.

Many of our projects have been conducted under a wide range of contracts, including the first Progressive Design-Build TBM tunnel project in the US, the SVCW Gravity Pipeline Project in Redwood City, California. Our teams stick with projects from start to finish, serving on a bid team and then heading into design or directly to the field to construct the project they've bid. We live where we work and know our projects personally. We build for People.

For more information, please contact Dawn Dobson-Markman.
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### Great Basin Industrial
www.MYGBI.com

Great Basin Industrial was founded in the early 2000s by plate steel industry leaders. Since that time Great Basin Industrial (GBI) has grown into an exceptionally competent and diverse General Contractor. We attribute our growth to a peerless work ethic and a determination to help the company and people of the Great Basin Nation to reach our fullest potential. GBI continues to deliver Turnkey Industrial Construction, Commissioning, Maintenance and Shutdown Services. Our customers include many of the world's leading companies in the Power, Petro-Chemical, Mining, Water & Other industries throughout the U.S. and Canada. GBI works closely with our partners in the industry whether they be engineering firms or end users to provide General Industrial Construction projects including Tanks & Plate Steel, Instrumentation & Electrical (I&E), Structural/Mechanical/Pipe (SMP), Civil/Concrete, Coatings and Railroad solutions of the highest Quality and Safety.

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Phone: (801) 543-2100
https://www.linkedin.com/company/great-basin-industrial

### KIEWIT MINING GROUP INC.
https://indd.adobe.com/view/6b5c2232-f37e-42dd-a2bd-c3b4483fd6ad

Kiewit is one of North America's largest and most respected construction and engineering organizations with roots dating back to 1884. Our employee-owned organization operates through a network of subsidiaries in the United States, Canada and Mexico. We had 2022 revenues of $13.7 billion and employs 25,700 staff and craft employees.

We execute mining and mineral processing projects safely, on time and on budget. Since entering the market in the 1980s, our experienced project teams have constructed a wide variety of mining and mineral processing projects, including expansion or upgrade projects at operating plants and in some of North America's most remote locations. From greenfield startup to mining operations through final reclamation, Kiewit has the comprehensive experience, equipment and people for your mining and mineral processing project needs.

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Lone Tree, CO 80124
Ph: (303) 649-6800
Meg.Anrezjewki@kiewit.com

### MATRIX SERVICE COMPANY
www.matrixservicecompany.com

MATRIX SERVICE COMPANY, through its subsidiary – Matrix Service Inc. – is a leader in the design, construction, maintenance and repair of industrial infrastructure across North America. With specialized expertise in mining and minerals, we are proud of our reputation for delivering projects safely, with the highest quality possible, on-time and on-budget. We count a number of North America's most recognized mining companies among our clients. Matrix also provides industrial cleaning services.

With a focus on sustainability and living our core values, Matrix is ranked among the Top Contractors by Engineering-News Record, has been recognized for its Board diversification, is an active signatory to CEO Action for Diversity and Inclusion, and is recognized as a Great Place to Work®. To learn more about Matrix Service Company, visit www.matrixservicecompany.com and read our inaugural Sustainability Report.

### MILLER CONTRACTING
www.Millercontracting.us

MILLER sinks shafts conventionally or using our raisebore machines. We have the capability to sink shafts and bunkers from 6' to 30' in diameter and from 50' to 2,400' deep. We offer steel liner or cast in place concrete liner, whichever best meets your scheduling and cost needs. Our team of professionals use the non-standard processes that MILLER has developed to minimize hazards, speed up the project, and save costs . MILLER acquired O J Industries and integrated that experience and reputation into our company and support it with our new fabricating and machining shop. This has greatly increased our offerings of in-house manufactured headframes, skips, cages, loading pockets, and related handling components. This compliments our earlier offerings of turn key man and materials hoist from 40 ton capacity to down to skid mounted emergency escape hoists. We are your one-stop shop for all in-shaft personnel, equipment, and material handling.

9580 State Route 13W
Carrier Mills, IL 62917
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## CONSULTING - DESIGN AND PLANNING

### BabEng, LLC
www.babeng.com

BabEng is a global engineering and consultancy company specializing in underground works. Detailed knowledge about TBMs and tunnelling makes us a highly qualified project partner, able to complete critical tasks and solve problems decisively, swiftly and competently. Having worked on 200 tunnelling projects worldwide, we support you from pipe jacking for water supplies to major projects, from feasibility study to design, and from construction to contract closure.

With our core product TPC, our Tunnelsoft software became a family of four! TPC (the data powerhouse), TPC Mobile (the ultimate app), TPC Cyclic (for conventional tunnels) and the TPC Group Server (the whole story – all your projects). All together tailored to the needs of any underground construction site. We continue enhancing our software to ensure you have access to all the information you need to make smart decisions.

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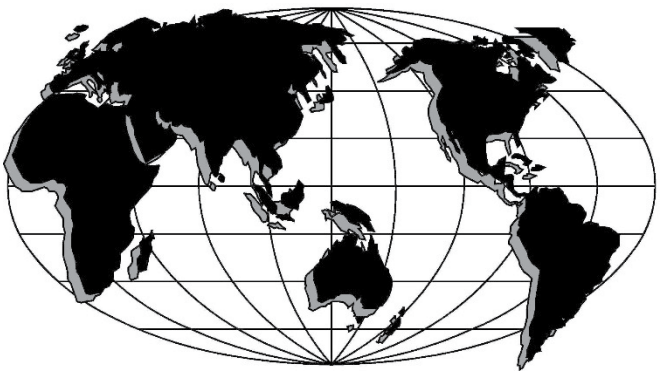

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Doctor Mole, Incorporated (DMI) is a sole-proprietor consulting practice that was started in January, 2013 when Dr. Brierley stepped down as President of Brierley Associates Corporation. DMI specializes in providing advice to project owners, contractors, and designers about all aspects of the design and construction of underground openings. Dr. Brierley has been involved with the implementation of scores of subsurface investigations and with the preparation of the Geotechnical Data and Baseline Reports associated with those investigations. DMI is also retained on a regular basis to provide forensic evaluations relating primarily to claims for Differing Site Conditions. When things go wrong during tunnel construction it is necessary to evaluate what is happening in order to minimize potentially detrimental impacts both to the construction process itself and to existing third party structures and utilities.

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mbarish@somersetint.com
724-473-3515

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Manager Business Development
cnewport@somersetint.com
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### Malcolm Drilling Company Inc.
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Malcolm Drilling Company Inc. has for over 6 decades been an innovator and leader in the deep foundation industry. Our list of core services includes drilled shafts, auger cast, displacement and micro piles, excavation support systems, diaphragm, soil-mix and secant pile walls, slope stabilization, underpinning, various ground improvement and dewatering techniques. Our experience facilitates a Design/Build approach to projects and allows for timely collaboration with owners and contractors. We provide these services nationwide through our regional offices. Our large equipment fleet and highly skilled personnel affords Malcolm the unique ability to comply with the most rigorous schedule compression, while delivering a high-quality product or service. Whether the project is large or small, public, or private, hard bid or design/build, with or without schedule compression, our list of projects will demonstrate Malcolm's experience and expertise to help guide your project to a successful completion.

More information at www.malcolmdrilling.com

### Premier Drilling Co.
www.premierdrilling.com

Premier Drilling Co. has been a champion for its Western U.S. Clients since 2014. Premier Drilling Co. is an experienced rotary and core drilling and sampling company built and run by drillers. Premier Drilling Co.'s field supervisors, veteran drillers, and driller assistants utilize state-of-the-art tooling, sampling systems, rotary drilling packages, and new rig advantage core packages to meet our mission of providing our clients with Safe, Clean Production while sampling and drilling water and mineral exploration boreholes, piezometers, water supply, dewatering, injection, and monitoring wells. Premier Drilling Co. specializes in utilizing the following methods: Flooded Reverse Circulation, Reverse Circulation (RC), Direct Air Rotary, Direct Mud Rotary, and Diamond Core Drilling to obtain your Geotech, Mineral Exploration, and Water Exploration samples.

Premier Drilling Co.
www.premierdrilling.com
775-340-8668 Office
775-397-0963 Darrell Tweidt
480-200-8300 James Stephens
2021 Meadow Ridge Drive
Elko, Nevada 89801

## DRILLING SERVICES AND EQUIPMENT

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Crux is a leader in geotechnical construction and exploration, combining innovative equipment and techniques with experienced team members to provide engineering and drilling services on some of the most logistically challenging projects in North America. With significant experience on a wide range of tunnel projects, we offer a broad understanding of challenging data acquisition and ground improvement techniques for tunnel upgrades and new tunnel construction. Expertise extends to high core recovery, borehole surveying and instrumentation, as well as pre-excavation stabilization including dewatering, permeation and compaction grouting, tube arch canopies, and cased horizontal boreholes.

4308 N. Barker Road
Spokane Valley, WA 99027
Telephone: 509-892-9409
Fax: 509-892-9408
E-Mail: marketing@cruxsub.com

### Equipment Corporation of America
ecanet.com

Equipment Corporation of America is the deep foundation industry's premier provider of the world's most advanced, innovative and reliable drilling, pile driving, hoisting and rigging, slurry cutting, soil mixing and soil stabilization equipment. Over the past 100 years, we have demonstrated our unrivaled product knowledge, and ultra-responsive service and support, by meeting and exceeding our customers' expectations every day.

We are the exclusive distributor for BAUER Drilling Rigs, KLEMM Anchor and Micropile Drilling Rigs, RTG Piling Rigs, and BAUER MAT Slurry Handling Systems. We also distribute HPSI Vibratory Pile Hammers, WORD International Drill Attachments, Pileco Diesel Hammers, Dawson Construction Products, ALLU Ground Improvement Equipment, Pile Master Air Hammers, DIGGA Dangle Drills, and Olin Concrete Pumps. ECA offers sales, rentals, service, and parts from 10 facilities throughout

the Eastern U.S. and all Canadian Provinces. Visit ecanet.com for the latest information on our ever-improving specialty foundation equipment solutions.

Jeff Harmston
VP Sales and Marketing
336-736-2124
Jharmston@ecanet.com

## Mitsubishi Materials USA

www.mmus.com

Mitsubishi Materials USA's Rock Tools Group supplies a full line of top hammer blast hole and underground mining rock drilling tools that are considered some of the best in the world. Our products are engineered and manufactured under strict quality control standards. Our parent company specializes in the manufacturing of tungsten carbide buttons which are used in all our drill bits. In addition, we make casing advancement systems for the water well drilling, construction drilling, foundation drilling, and geothermal drilling industries and these products have a reputation for supreme quality. We have also recently added a full line of Down-the-Hole hammers and bits that are manufactured in the USA.

Mitsubishi Materials USA
105 Corporate Center Dr. Suite A
Mooresville, NC 28117
P: 980-312-3150
F: 704-746-9595

## REI Drilling, Inc.

www.reidrilling.com

REI Drilling, Inc. (REI) operates a fleet of directional/core drills for various mining and civil applications. Whether on the surface or from underground, working in coal or hard rock, REI works directly with mine operators to provide directional drilling solutions for geologic exploration, water drainage/depressurization or transfer, mine gas control, abandoned mine verification, solution mining, monitoring and instrumentation, utilities installation, and gravity drainage of hydrocarbons. Working alongside Drilling Products, Inc. (DPI), REI develops specially engineered drilling solutions and equipment to get the job done. With more than 40 years of experience, we take on drilling challenges that others are not able to.

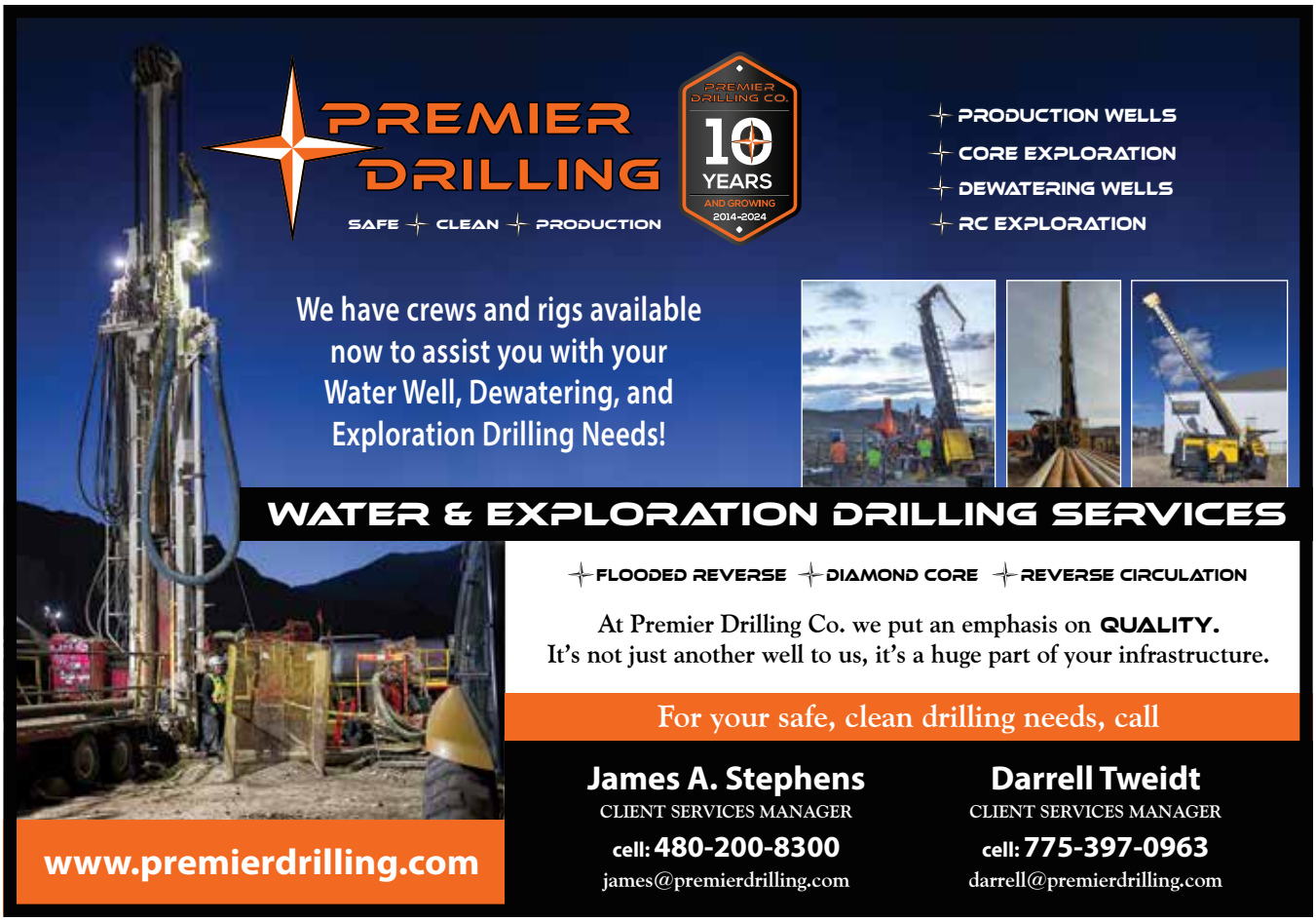
DPI was formed in 2008 to manufacture and distribute our field proven downhole technology world-wide to the mining and exploration industry. DPI supplies its reliable EDGE series high torque downhole motors, the Accu-Dril line of downhole motors, advanced LWD and MWD technology, Zero-Trip wedges, plugs and packers (Van Ruth), and high pressure wellhead control technology.

250 West Berger Lane, Salt Lake City, UT, 84107
REI Drilling: (801) 201-6937
dan@reidrilling.com
DPI: (801) 270-2148
dhammond@drillingproductsinc.com

## TERRA SONIC INTERNATIONAL, LLC

www.terrasonicinternational.com

Terra Sonic International SONIC drilling technology improves the speed, accuracy, efficiency, and safety of drilling projects worldwide. Terra Sonic Drill Rigs include the truck-mounted 150T, the compact truck-mounted 150CT, the crawler-mounted 150C, the compact crawler-mounted 150CC, and the articulating 150AC8. The TSi 150 SONIC Oscillator, with an oscillator frequency of 0 to 150 Hz, 50,000 pounds (222.5kN) of force output and a maximum torque of 4,677-foot pounds (6,341 Nm), proffers the world's most productive and efficient use of SONIC power. Available acceleration is maximized through the use of specially designed SONIC tooling to propagate the energy and facilitate drilling and sampling to the

deepest depths of any SONIC drill system available today. TSi SONIC tooling is precision crafted from only the highest quality steel, heat-treated and machined to be the industry's most durable and longest lasting. The result is unmatched efficiency, reliability and productivity. Learn more at www.terrasonicinternational.com.

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614-305-4999

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Nelson Irrigation Corporation (NIC) plans, designs, manufactures and sells proprietary products for the irrigation equipment market. NIC has a solid reputation in the industry due to a rigorous quality assurance program and the company's enduring commitment to workmanship and customer service. State-of-the art technologies, such as CNC machinery, plastic injection molding and automated assembly, provide consistency in process and product quality. NIC employs a team of dedicated engineers for new product development, manufacturing and application development. Innovation results from listening to customers always with an eye on the future. Industrial-grade Nelson products have been used in the mining industry for dust and debris control for decades. Products include the Original Big Gun® Sprinkler, 800 Series & 1000 Series Control Valves, TWIG® Wireless Controls, the R75 Debris Sweeper and PC-R3030 Rotator®. BUY AMERICAN – CHOOSE NELSON.

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Tel: 509.525.7660
info@nelsonirrigation.com
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# EDUCATION

## Center for Underground at Colorado School of Mines

www.underground.mines.edu

We develop new ideas and technologies to advance underground civil infrastructure, including space and structures for working, living and playing, and tunnels for transit, roads, loop/hyperloop, water, utilities, and energy. We develop techniques to better characterize soil, rock and groundwater conditions, next gen digital underground that weaves the built environment with geotech/geology and construction operations with spatial stats and AI, and ultra-rapid tunnel construction methods. Explore the Center, attend a short course, come work with us, and reach out if for specialized testing or help in any way.

1500 Illinois Street
Golden, CO 80401
Telephone: (303) 384-2434
underground@mines.edu

## Great Basin College

www.gbcnv.edu

Great Basin Colleges offers a range of training programs for the mines and other industries including Career Technical Education (CTE) in the following fields:

- Diesel (Elko and Ely campuses)
- Welding (Elko)
- Industrial maintenance (Elko)
- Manufacturing machinist (Pahrump)
- Electrical (Elko, Winnemucca and Ely)
- Instrumentation (Elko and Winnemucca)
- Land surveying & Geomatics (online)

In addition, various certificates are offered through the new Mining Center in Elko, and others are planned to encourage more people to enter the mining industry and study particularly geology, mining and metallurgy. Currently two high school dual credit certificates are being offered that will seamlessly transfer to Great Basin College or the University of Nevada Reno particularly for degrees in geology, mining and metallurgical engineering.

Main Campus:
1500 College Parkway,
Elko, NV 89801
Main telephone: 775-3275002
www.gbcnv.edu
Contact:
A.J.S. (Sam) Spearing
Executive Director
sam.spearing@gbcnv.edu
Jessica Johnson
CTE recruiter and advisor
Jessica.johnson@gbcnv.edu

## Northwest Laborers-Employers Training Trust Fund

Safety and Hazard Awareness for Tunnels (SHAFT) program

www.nwlett.edu

The Safety and Hazard Awareness for Tunnels (SHAFT) program, developed by the Northwest Laborers-Employers Training Trust with input from a team of industry experts and stakeholders, is comprised of a blend of classroom discussion and interactive use of materials and mockups.

The curriculum offers comprehensive safety training for both new and experienced tunnel professionals; classes focus on tunnel safety, rail, and utilities.

The training facility, located in Elma, Washington, features a TBM mockup, rail, and access to 1,400' of 12' diameter tunnel – providing students with a unique educational experience.

Northwest Laborers-Employers Training Trust
27055 Ohio Avenue NE
Kingston, WA 98346
+1 (800) 240-9112
www.nwlett.edu
nwlabor@nwlett.edu

## Penn State Mining Engineering

Penn State John and Willie Leone Family Department of Energy and Mineral Engineering

www.eme.psu.edu

The Penn State Mining Engineering program, ranked #2 in the US per the QS 2022 global ranking, prepares students for a career in the industrial minerals, metals, and energy industries that sustain the domestic and global economies. Importantly, the program provides an emphasis on sustainable mining through integration of environmental health and safety, and societal responsibility principles in the design and operation of mineral enterprises. Graduates of the program will be prepared to work domestically or internationally to develop and operate mines or to work in supporting activities including engineering consulting, banking, equipment development and supply, regulatory enforcement, and research.

Contact:
Dr. Sekhar Bhattacharyya, Chair of Mining Engineering Program
Dr. Sanjay Srinivasan, Department Head,
John and Willie Leone Family Department of Energy and Mineral Engineering
The Pennsylvania State University
118 Hosler Building
University Park, PA 16802
Telephone: (814) 865-3437
Email: eme@ems.psu.edu

## University of Arizona

mge.engineering.arizona.edu

The Department of Mining and Geological Engineering at the University of Arizona is one of the top-ranked mining engineering programs in the nation. Longstanding industry ties, a focus on sustainability, generous scholarships, a mine of its own, global connections and a tight-knit, entrepreneurial community make this the destination of choice for students the world over.
Mining is one of the oldest forms of engineering, but these days autonomous trucks are doing the heavy lifting to supply materials for green technology and construction, high-performance computing systems, improved urban infrastructure, smart manufacturing and space exploration.

Our students have diverse backgrounds that demonstrate cultural competency; they are adept at creative problem solving, leadership, communication, with strong fundamentals in engineering and science. Our innovative research emphasizes leading technologies that solve tomorrow's problems. Graduate programs are offered both on-campus and online. Come learn from and work with the best!

Department of Mining and Geological Engineering
The University of Arizona
1235 E. James E. Rogers Way
Tucson, AZ 85721-0012
520.621.6063
mining-engr@arizona.edu

## University of Utah Mining Engineering Department

www.mining.utah.edu

The Mining Engineering Department has been serving the Mining Industry for over 100 years, providing high quality education of mining engineers, impactful research and industry collaboration. In addition financial support is available to qualified students through the Browning Scholarship during their undergraduate degree https://mining.utah.edu/scholarships/the-browning-scholarship.php. Graduate student education provides mentoring and financial support through research projects designed to improve technologies and approaches for more effective and sustainable mining. Our goal is to prepare graduates to work in any area of the mining industry, disseminate newly acquired knowledge via publication of original research, provide professional service to the mining industry and public to assist in the environmentally responsible and safe extraction of mineral resources, and inform the public at large about the importance of mining to society.

135 South 1460 East Rm 313
Salt Lake City, UT 84112
Telephone: (801) 585-5176
Mining-info@lists.utah.edu

COLLEGE OF ENGINEERING
MINING AND MINERALS ENGINEERING
VIRGINIA TECH

## Virginia Tech Department of Mining and Minerals Engineering

www.mining.vt.edu

Virginia Tech's Department of Mining and Minerals Engineering is one of the largest and most prominent mining-related programs in North America and enjoys a reputation as a global leader in the field, with a stated mission to serve society through education and innovation that supports the safe, efficient, and environmentally responsible production of energy and mineral resources. The department houses world-class facilities in a newly renovated Holden Hall, with over 100,000 sq. ft. of cutting-edge research, teaching and advising space. The Department is home to two renowned and highly productive research centers: the Virginia Center for Coal and Energy Research, and the Center for Advanced Separation Technologies. Its tenured and tenure-track faculty are globally recognized experts in mineral processing, geoenergy, and mine health and safety. A diverse research portfolio includes federal, state and privately funded projects, with annual expenditures averaging about $6,000,000 in the past eight years and a notable focus on capacity building and graduate student education.

Department of Mining and Minerals Engineering
378 Holden Hall, Virginia Tech
445 Old Turner St.
Blacksburg, VA 24061
Phone: (540) 231-6671
mineinfo@vt.edu

## West Virginia University Department of Mining Engineering

https://mine.statler.wvu.edu/

The Department of Mining Engineering at West Virginia University provides educational programs at the bachelor's, master's and doctoral levels. Degree options at the undergraduate level include mining engineering, and dual degree programs in mining engineering and civil and environmental engineering, mining engineering and civil engineering and mining engineering and geology. At the graduate level, degrees are offered in mining engineering and mineral processing. Our mission is to produce graduates who are thoroughly prepared to meet the operational and engineering challenges of the mining industry, and to continue their studies in graduate programs. For more information about our Department, please visit https://mine.statler.wvu.edu/

Department of Mining Engineering
1374 Evansdale Drive, PO Box 6070
Morgantown, WV 26506
Email: Vlad.Kecojevic@mail.wvu.edu
Telephone: (304) 293-7680

# ELECTRIC MOTORS AND GENERATORS

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Arup's approach to tunnel design embraces innovation and applies practical real-world experience and state-of-the-art digital tools to multidisciplinary projects. From geological characterization, ground support and lining design to life safety, materials technology and lifecycle cost analysis, Arup's contribution to tunnel projects extends from concept to operation and beyond. Using a holistic approach, our global team of experienced tunnel designers draw on the capabilities of a wide array of disciplines to deliver optimized solutions to some of the world's most complex underground projects. These challenges are welcome and provide Arup the opportunity to implement integrated projects of real value to clients.

Arup
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+1 212 896 3000

## HNTB Corporation

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HNTB Corporation is an employee-owned infrastructure solutions firm, one of the top U.S. mid-size firms, serving public and private owners and contractors. Professionals nationwide deliver a full range of innovative solutions on a wide range of tunnels, including cut-and-cover, bored tunnels, SEM tunnels, immersed tube tunnels, and shaft construction and micro-tunneling. Our history in planning, program management, design, construction management and technical services for tunnel and complex underground structures, includes award-winning solutions on some of the country's most challenging transportation programs. For more information, visit hntb.com, or follow HNTB on LinkedIn, Twitter, Facebook or Instagram.

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350 Fifth Avenue, 57th Floor
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(212) 294-7567

## Schnabel Engineering, LLC

In continuous operation since 1956, Schnabel Engineering, LLC is a leading national provider of tunnel, geotechnical, and dam engineering services. Specialized services include geotechnical and geostructural engineering as well as dam and tunnel engineering, environmental, geophysical and geosciences services, construction monitoring, and resident engineering.

Schnabel specializes in design and construction management services for tunneling and other heavy civil construction projects in the areas of transportation, water and wastewater infrastructure, and hydroelectric power. We combine our expertise in the design and construction of underground structures with a keen understand-

ing of nuances and interrelationships of geology, hydrogeology, and geotechnics on underground projects. We provide tunnel design services including feasibility studies and preliminary design, construction documents/design reports, initial and final design support, mine engineering, cavern design, tunnel inspection and rehabilitation, and microtunneling/trenchless design services.

Schnabel Engineering, LLC
12720 Hillcrest Road, Suite 585
Dallas, TX 75230
972-250-3322
tunnels@schnabel-eng.com
https://www.schnabel-eng.com/

## ENGINEERING - ENVIRONMENTAL

### Geo-Logic Associates

Geo-Logic Associates (GLA) is an employee-owned, multidisciplinary consulting firm that specializes in civil, geo-environmental and water resources services. With more than 260 professionals in 28 US office locations and an office in Peru, GLA and its subsidiaries, Daniel B. Stephens & Associates (DBS&A), Clear Creek Associates, the MINES Group, and Geo-Logic Peru provide specialized mining services from initial permitting and design through closure to mining clients worldwide. Please see our website at www.geo-logic.com for more information.

Tom Mackowiak
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Geo-Logic Associates
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Sparks, NV 89431
Office: (775) 284-5500 | Mobile: (775) 813-3303
tmackowiak@geo-logic.com

## ENVIRONMENTAL CONTROL EQUIPMENT AND SUPPLIES

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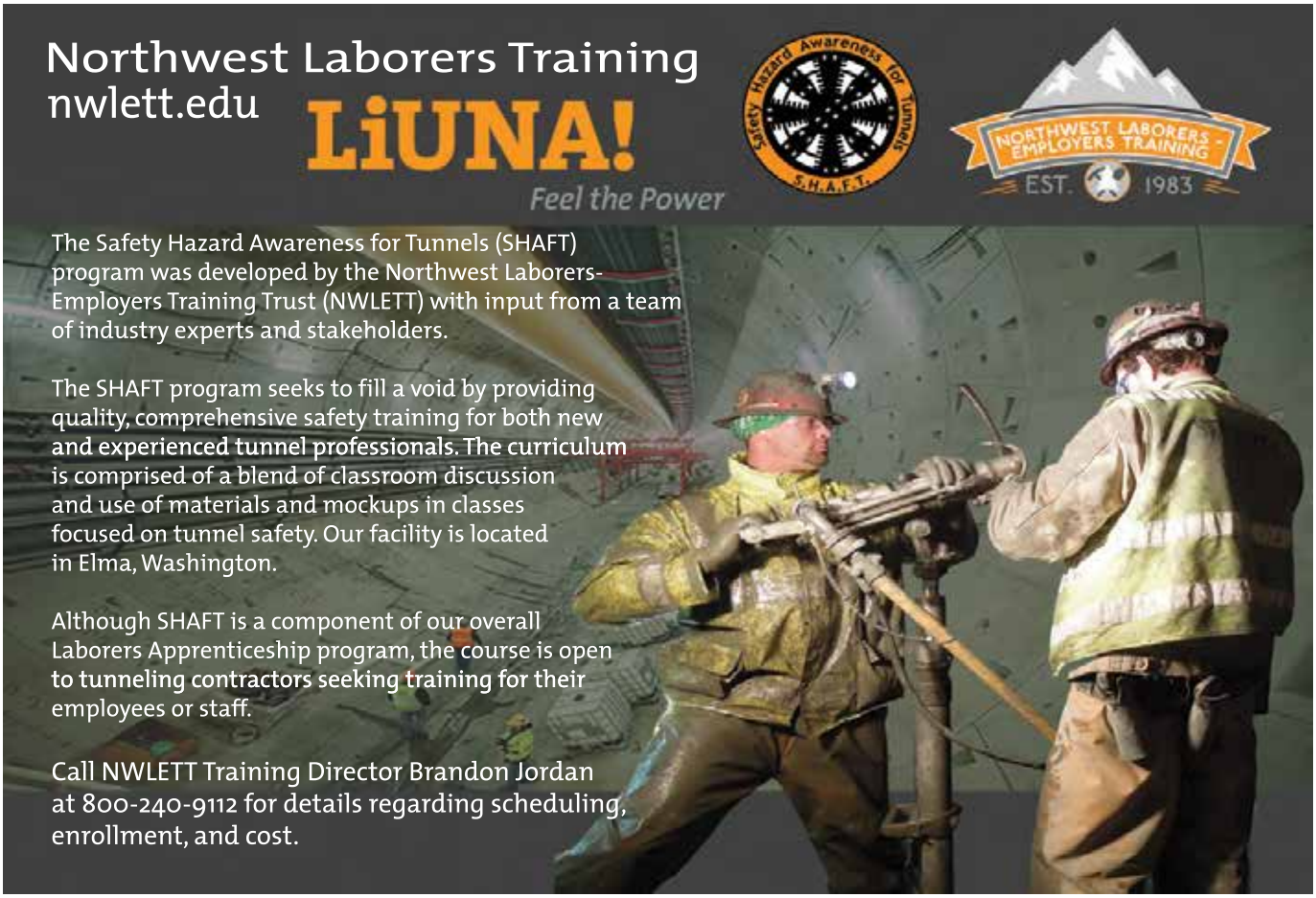

## EQUIPMENT REPAIR

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Terrahertz™ provides exploration and analysis services. Our patent pending services and instruments utilize resonant earth signal frequencies and analysis to provide information regarding minerals, water, natural resources, and other materials. We utilize surface-level instruments to locate and triangulate the desired materials in the proximity of the search area. Measurements are taken for two to four weeks depending on the target materials. As a result, we are efficient, environmentally and property friendly, cost-effective, and cutting-edge. We provide detailed visual reports of the strongest signal locations for identified materials including the location and depth. Our customers are using our services to find precious metals, water, and other resources. Our motto is Measure Twice Drill Once. Testimonials are available from a number of very satisfied customers.

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Manufacturing & BoltSenseTM Product Team
+1-602-352-4815
www.copperstate.com
lmf@copperstate.com
3622 North 34th Avenue
Phoenix, AZ 85017

Distribution & Branch Support Team
+1-520-882-0611
www.copperstate.com
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HEICO's driving focus is based on two principles: to effectively and efficiently serve our customer and to ship quality products that contribute to bolted joint integrity in the most demanding of applications.

Our family of HEICO-LOCK® wedge locking washers and HEICO-TEC® tensioning products ensure the safety, accuracy and lifespan of critical bolted connections.

HEICO is a 122-year-old, 4th generation family-owned cold forming fastener manufacturer that emphasizes both high-level engineering and production quality (IATF 16949, ISO 9001).

Since 1997, HEICO Group's North American facility has ably served customers from our location in Hickory, NC. Our sales engineers are located throughout North America.

2377 8th Ave NW
Hickory, NC 28601
888.822.5661
sales@heico-lock.us

## FILTERS, FILTER CLOTH AND ACCESSORIES

### BabEng, LLC

www.babeng.com

BabEng is a global engineering and consultancy company specializing in underground works. Detailed knowledge about TBMs and tunnelling makes us a highly qualified project partner, able to complete critical tasks and solve problems decisively, swiftly and competently. Having worked on 200 tunnelling projects worldwide, we support you from pipe jacking for water supplies to major projects, from feasibility study to design, and from construction to contract closure.

With our core product TPC, our Tunnelsoft software became a family of four! TPC (the data powerhouse), TPC Mobile (the ultimate app), TPC Cyclic (for conventional tunnels) and the TPC Group Server (the whole story – all your projects). All together tailored to the needs of any underground construction site. We continue enhancing our software to ensure you have access to all the information you need to make smart decisions.

Get in touch with us, we look forward to showing you more!
28205 203rd Ave SE
Kent, WA 98042
Phone +1-253-630-2221
Fax +1-253-323-2339
Contact: Kris Babendererde

### DIEMME FILTRATION SRL

www.diemmefiltration.com

Diemme Filtration, headquartered in Lugo (Italy), is one of the most advanced specialists in solid-liquid separation technologies for a wide range of Industries.

The product portfolio includes different models of filter presses available indifferent sizes, design and technical characteristics. The equipment is tailor made and designed according to the needs of every specific process. Mining & Metals, Chemical & Pharmaceutical, Oil & Gas, Power Industry, Quarry and Construction are, among the others, the most relevant fields of application delivered by this company which is part of a German Multinational called Aqseptence Group. Diemme Filtration also began to design and supply its own range of high-rate thickeners, thus broadening the company's scope of supply and increasing the support to the customers within their flowsheet. One important differentiating factor is provided by a special team of R&D engineers who are continuously involved in satisfying the changing market's demand, improving the available systems as well as finding new solutions.

DIEMME FILTRATION SRL
Via Gessi 16 – 48022 Lugo – Italy
Phone: +39 0545 20611
Email: info@diemmefiltration.com

### Landry Filtration Products Inc

http://www.landryfiltration.com/

Landry Filtration Products is a leading Canadian manufacturer and global supplier of custom engineered filtration products. Since 1988, we've been providing the mining industry with rotary disc sectors, disc sector covers, drum filter covers, filter belts, press cloths, hydraulic pressure filter belts and pollution control baghouse filter tubes. With access to over 4,000 different types of industrial textiles, we provide a broad array of high performance filtration solutions.

Our technical team has decades of experience engineering custom solutions that optimize filtration performance and maximize equipment service life. At our in-house testing facility, we conduct ongoing quality control and quality assurance analysis on the tensile strength, elasticity and permissible flow rates of our filter media.

11 Cidermill Ave., Unit 2
Concord, ON L4K 4B6, Canada
Telephone: +1 905-660-1900
Fax +1 905-660-1701
Email: office@landryfiltration.com

## FIRE PROTECTION

### Dafo Vehicle Fire Protection

www.dafo-vehicle.com

With a total fire protection solution Dafo Vehicle Fire Protection mitigates the overall risk of a heavy vehicle fire.

Dafo Vehicle works with mining environments to reduce risk, mitigating any potential damage, downtime and threat to life within your high-risk operation. With low-maintenance, cost-effective systems that offer complete protection, Dafo Vehicle provides integrated solutions that reflect your needs.

As the mining industry moves towards a sustainable future, an increasing number of mining sites are transitioning to electric vehicles (EVs). EVs have a whole new set of fire risks due to the lithium-ion (Li-ion) batteries that power them, which Dafo Vehicle's SafEV™ unique solution aims to address.

With an extensive heritage of over 100 years, Dafo Vehicle has been at the forefront of fire safety development worldwide and was one of the first companies to develop integrated firefighting solutions for vehicles.

440 Raleigh Street Unit C
Wilmington, NC 28412 USA
Phone: +1 (910) 769-6299
info@dafo-vehicle.com

### Reliable Automatic Sprinkler Co., Inc.

www.reliablesprinkler.com

Founded in 1920, Reliable Automatic Sprinkler Co., Inc. is a manufacturer and distributor of fire protection equipment. Reliable manufactures the highest quality and most innovative nozzles, sprinklers, and deluge systems on the market. At the heart of ever Reliable deluge system sits the Model DDV Diaphragm Deluge Valve. Manufactured in the USA with globally sourced parts and FM Approved for up to 400 psi (27.6 bar), its compact footprint allows for installation in the tightest of spaces and can be installed horizontally or vertically. In addition, Reliable's range of closed and open nozzles are suitable for many types of underground applications. All Reliable products are backed with by Technical Service experts with 300+ years of industry experience. Reliable's corporate headquarters is located in Elmsford, NY with manufacturing headquarters in Liberty, SC. Regional sales and distribution centers are located throughout the US and around the world.

103 Fairview Park Drive
Elmsford, NY 10523
Telephone: 864-843-1700
info@reliablesprinkler.com

## GEOTECHNICAL CONSTRUCTION

### Forgen, LLC

www.forgen.com

At Forgen, we deliver even the most complex mine reclamation and remediation projects. We've successfully delivered large, multi-disciplinary projects for public and private sector clients across the U.S. for more than a decade, safely tackling complex challenges across the mining industry.

As one of the largest self-performing environmental contractors in the United States, our integrated environmental remediation and geotechnical construction services restore and strengthen our natural surroundings to protect people, communities, and the environment for generations to come.

Headquarters
6025 S. Quebec Street, Suite 300
Centennial, CO 80111
Telephone: 720.266.6030
info@forgen.com

## Keller
www.keller-na.com

Keller's full range of geotechnical construction techniques has been applied to hundreds of mining projects. Our solutions for mining include tailings management, tailings dam stabilization, deep shaft and excavation support, mine abandonment solutions, groundwater migration control, instrumentation and monitoring, and increasing mineral recovery with our patented leachate recovery process.

By connecting global resources and expertise with local knowledge and focus, Keller develops innovative, practical, and cost-effective solutions to geotechnical challenges. Keller builds projects designed by others and offers full design-build services for any geotechnical construction application.

Keller was founded in 1860 and is the largest geotechnical specialty contractor in the world with ongoing operations in over 40 countries across 5 continents. With a North American presence of over 100 years, Keller operates as the market leader with over 60 offices throughout the US and Canada and is the sole source for a complete geotechnical construction solution optimally designed to meet clients' needs.

Legacy North America Keller companies include Bencor, Case Atlantic, Case Foundation, Hayward Baker, HJ Foundation, Keller Canada, McKinney Drilling, and Moretrench.

7550 Teague Rd, Suite 300
Hanover, MD 21076
Telephone: +410-551-8200
info@keller-na.com

# GEOLOGICAL, GEOTECHNICAL SERVICES AND EQUIPMENT

## Ackcio
www.ackcio.com

Ackcio develops and builds reliable wireless data acquisition systems specifically designed for mining applications. The company's focus is on automating monitoring processes and delivering remote, intelligent data to enhance safety and facilitate efficient risk management in the mining industry. Ackcio's flagship solution, Ackcio Beam, is a cutting-edge industrial data acquisition platform that employs a patented long-range wireless mesh network. This innovative technology enables accurate and dependable monitoring of sensors in various mining environments, both above ground and underground. By leveraging Ackcio's solutions, mining companies can enhance operational efficiency, improve safety measures, and effectively manage risks associated with mining activities.

75 Ayer Rajah Crescent, #03-01/02, Singapore 139953
+61 437 453 948
sales@ackcio.com

## Bird Seismic Services
www.birdseismic.com

Bird Seismic Services offers high-resolution techniques in aid to mine safety in locating and resolving historic mine workings and voids, offer surveys to assess tailings and tailings dam stability, equipment to monitor geologic hazards, and stability assessment of municipal solid-waste landfills, seismic exploration in search for base metals, gold, copper, silver, and massive sulfides, lithium brines and resources, as well as gas exploration including helium. Seismic techniques applied to mining can especially help for depths far greater than 400 m, we offer seismic techniques to reveal with good accuracy, geologic properties including geometry of faults, fractures, bedding, and overburden depth. In addition to exploration, seismic is useful for engineering applications, APP (Aquifer) permits, geotech surveys for rock properties, rippability, pre -tailings and dam construction siting, depth to bedrock, coal seam fractures, and many more.

Kenneth Bernstein
Bird Seismic Services
661 S. Broad Street
Globe, Arizona 85501
928 719-1848
www.birdseismic.com

## Call & Nicholas, Inc. and Call & Nicholas Instruments, Inc.
www.cnitucson.com
www.slideminder.com

Since 1979, Call & Nicholas, Inc. has been providing Geologic and Geotechnical engineering consulting services to the worldwide mining community. Call & Nicholas, Inc. are recognized experts on open pit design, slope optimization and cost benefit analysis, underground rock mechanics and support, mining method selection, and geological, geotechnical, and hydrogeologic modeling.

In 2003, Call & Nicholas Instruments, Inc. provides geotechnical instrumentation services including piezometer and TDR cable installation. They also designed and manufactured the trusted SlideMinder remote wire-line extensometer, which provides fully automated continuous monitoring of ground movement. With SlideMinder's real-time monitoring, people and equipment can be repositioned when there are unsafe conditions identified. SlideMinder's affordable durable construction provides unparalleled up-time and needs minimal routine maintenance from field technicians, saving time, money, and, most importantly, lives. Now with cellular communications, it gives the end user maximum flexibility for communications and critical alerts. SlideMinder is optimal for monitoring waste and leach dumps, road cuts, etc., during and after operations.

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Tucson, AZ 85745 USA
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Fax: (520) 670-9251
cni@cnitucson.com slideminder@cnitucson.com

## GEOKON
www.geokon.com

GEOKON offers a full complement of products for remote, long-term monitoring of Open Pit, Tailings Dams, and Underground Mines. Recognized as a world leader in geotechnical and structural instrumentation production, GEOKON has been manufacturing products of the highest quality for over 40 years.

GEOKON utilizes state-of-the-art manufacturing processes and equipment to produce the best-performing products on the market. Collaboration of the mechanical, electrical, and software engineering teams at GEOKON creates highly innovative, accurate, and reliable instrumentation. All GEOKON products are supported by an experienced team of factory-trained associates who can assist with instrument design, selection, and installation.

GEOKON has been awarded ISO 9001:2015 registration from both ANSI•ANAB, USA, and UKAS of Great Britain. The factory calibration program complies with the ANSI/NCSL Z540-1 Calibration Laboratory and Measuring and Test Equipment General Requirements, and all products have achieved Russian GOST certification for safety.

Telephone: +1-603-448-1562
info@geokon.com

## TRE Altamira
www.tre-altamira.com

TRE Altamira is the world leader in displacement monitoring services using satellite radar data. With over 20 years' of experience, we are experts in providing InSAR (Interferometric Synthetic Aperture Radar) services for a broad range of applications, including slope stability, surface mining, tailings, heap leach, underground operations and tunneling. We draw on the expertise of our highly trained and diverse staff that includes geologists, geophysicists, environmental engineers and radar

KELLER

# BUILDING THE FOUNDATIONS FOR A SUSTAINABLE FUTURE

## The leading geotechnical specialty contractor

Keller provides solutions to a wide range of geotechnical challenges across the entire construction spectrum. With offices throughout the US and Canada, we are the sole source for your complete geotechnical construction solution.

Learn more about our geotechnical solutions

go.keller-na.com/solutions

- Deep foundations
- Environmental remediation
- Ground improvement
- Groundwater control
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- Liquefaction mitigation
- Releveling structures
- Slope stabilization
- Support of excavation
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## GEOLOGICAL-PHYSICAL-TECHNICAL SERVICES AND EQUIPMENT

### Telemark Energy Services LLC

www.telenrg.com

With over 50 years of combined experience, Telemark Energy Services (TES) is a geophysical technology company providing geophysical solutions across mining and numerous other industries. TES provides geophysical data acquisition, processing, interpretation, and consulting services with project designs tailored to individual project requirements. TES specializes in active and passive seismic data project design and acquisition with an extensive network of partners to provide a full suite of geophysical field operations and data services across core hole logging, borehole seismic, potential fields and electromagnetic surveys.

Contact Information:
+1 (720) 295-9875
info@telenrg.com

## GOVERNMENT AGENCY - ENTITY

### U.S. Geological Survey (USGS) Mineral Resources Program (MRP)

https://www.usgs.gov/programs/mineral-resources-program

The USGS Mineral Resources Program (MRP) delivers unbiased science and information to increase understanding of ore formation, undiscovered mineral resource potential, production, consumption, and how minerals interact with the environment. MRP supports data collection and research on a wide variety of non-fuel mineral resources that are important to the Nation's economic and national security.

Contact: Jim Mosley, MS., MBA., Program Analyst Energy & Mineral Resources Mission Area (EMMA), & MRP Outreach Coordinator
Email: jmosley@usgs.gov
Phone: 703-648-6312
Website: https://www.usgs.gov/programs/mineral-resources-program

## GRAVITY SEPARATORS

### Action Mining Services Inc

www.actionmining.com

AMS Wave Tables for concentration and separation are ideal for testing or production, with amazing fine particle recovery! Established in 1979, emerging from a mining background, Action Mining Services Inc. began providing supplies and equipment to the independent mining community. Since the 1980's the Wave Table, a product of years of research and refinement, has proven itself over and over to be one of the best separation and production recovery units for fine gold and other metals that have resisted gravity separation, both in the mining and recycling industries.

315 E. Railroad Ave.
Plains, MT 59859 USA
Telephone: (406) 826-9330
sales@actionmining.com

### FGX SEPTECH GLOBAL LLC

www.fgxseptechllc.com

FGX SepTech Global LLC is the world leader in supplying the dry coal (pneumatic) separators. The FGX dry cleaning technology offers an advanced, dry coal preparation method - An effective and efficient way to deshale coal without using water. The FGX technology not only provides a low cost to removing unwanted ash but also removes unwanted heavy metals such as pyrite, mercury etc. There are more than 2400 FGX pneumatic coal processing units operating throughout the world. FGX have machines capable of processing from 10tph to 500trph of the run-of-mine coal. The pilot scale test unit is available to use at the client site for feasibility.

289 Blue Sky Pkwy
Lexington, KY 40509 USA
Telephone: (859) 263-8300
Cell: (859) 327-7133
Fax: (859) 226-5207
Email: fgx@fgxseptechllc.com

## GRINDING MEDIA AND LINERS

### Silver Lake Analytical Service

www.silverlakeanalytical.com

Silver Lake Analytical Service, LLC, provides expert metallurgical grinding media analysis with new supplier evaluation, regular quality checks and breakage analysis. We deliver information you need to negotiate with suppliers of one of your largest cost items. Our lab only works with grinding media, both forged steel and high chromium cast balls. Silver Lake helps to ensure mining companies get quality grinding media and is the only lab of its type in the world. An independent party, Silver Lake can help you shorten evaluation time and expense, and better control consumption.

Our process includes: • Hardness testing • Estimating prior austenitic grain size • Full chemical composition analysis • Calculation of multiple chemical composition characteristics. From this information we can provide an accurate estimate of how the media will perform.

Clients include many mines from each of these companies and others, Rio Tinto, Nevada Gold Mines, ASARCO, KGHM, Newmont, Freeport McMoRan and Capstone Copper.

Telephone: (303) 522-0412
awilson@silverlakeanalytical.com

## GRINDING MILLS

### CEMTEC Cement and Mining Technology GmbH

www.cemtec.at

CEMTEC: Leading the Way in Cement, Mining, and Minerals Technology

CEMTEC stands as a global leader in providing solutions for the cement, mining, and minerals industries. With our headquarters located in Enns, Austria, and an office in the US, our expertise lies in the areas of grinding, drying, and pelletizing, enabling us to offer comprehensive solutions tailored to meet our customers' specific needs.

At CEMTEC, we pride ourselves on our flexible approach, to provide the best-suited solutions for their requirements. As a technology provider, we go beyond merely delivering equipment, complete plants, process optimization, and services. Our goal is to deliver solutions that add tangible value to our customers' operations.

With over 30 years of industry experience, we have amassed a wealth of knowledge and an extensive list of references. Leveraging our engineering capabilities, state-of-the-art workshops, and a world-class process laboratory, we are fully equipped to deliver solutions that exceed expectations and address complex challenges faced by our clients worldwide.

Ennshafenstr. 40, 4470 Enns, Upper Austria, Austria
+43 7223 83620
info@cemtec.at

## EIRICH Machines

www.eirichusa.com

EIRICH Machines, part of worldwide EIRICH Group, is an international manufacturer and supplier of innovative material processing technologies. Our EIRICH product line includes grinders and mixers with peripheral equipment for complete systems.

Our grinding mills are for dry and wet grinding of industrial minerals, ores, raw materials for ceramics, glass, and fertilizers. They are custom tailored and energy effective. For example, with the TowerMill you can reduce power consumption by 30-35% and have media consumption rates that are 45% of what conventional mills do.

EIRICH's grinding product line includes:

- TowerMill: Continuous wet fine grinding in vertical agitated media mills.
- MaxMill: Continuous dry and wet grinding of coarse-grained materials to fine-ground and ultrafine-ground products.
- FluxxMill: Continuous dry fine grinding of industrial minerals and hard materials for ceramic applications.
- OrbitMill: Continuous dry fine grinding of industrial minerals.
- TurboGrinder: Continuous dry grinding, deagglomeration and drying of soft materials.

EIRICH Machines
4033 Ryan Road
Gurnee, IL, 60031
Telephone #: 847-336-2444
E-Mail Address: grindingsolutions@eirichusa.com

# GROUND FREEZING

## SoilFreeze Inc.

www.soilfreeze.com

SoilFreeze, Inc. is the largest U.S. construction and engineering company specializing exclusively in ground-freezing technologies. We have successfully completed complex and technically challenging excavation support projects throughout the U.S. We provide temporary frozen soil shoring systems to support excavations and provide groundwater cut-off. Our technology can be used for; contaminated site remediation, groundwater cut-off and in situ-isolation barriers, foundation excavation shoring, ground stabilization, and more…

As a specialized construction company, we design, fabricate, install, and maintain customized freeze systems for each client's needs. The installation can be designed to be maintained for a few weeks, as long as several years, or even decades. We serve both the private and public sectors and have a substantial list of successful projects and satisfied clients. SoilFreeze has advanced and refined freeze technology to create freeze systems that are mobile, reusable, and expandable to address the needs of any sized project.

5931 238th St SE, Suite 201
Woodinville, WA 98072
Telephone: 206-420-2759
E-Mail: mmcmillan@soilfreeze.com

# GROUND IMPROVEMENT

## Geoform Systems Corporation

www.geoforming.com

Geoform Systems, the leading Full-Service solutions provider, combines innovative German technology with North American construction experience to tackle water and material leaks, as well as ground instability challenges in infrastructure and tunnelling projects. Geoform as the exclusive distribution partner of TPH Bausysteme, offers a wide range of construction solutions for waterproofing, tunneling, injection technology, joint sealing, and surface protection.

Introducing the fastest, most efficient system in the world to stabilize soil while stopping and preventing water disasters before, during and after construction, above and below ground;

GEOFORMING™ PLUGS LEAKS & KEEPS WATER AWAY

Because we prevent the disruption that impacts groundwater flows and soil stability, we help our clients avoid * unexpected expenses; * loss of construction time; * overhead costs; * potential safety hazards and * the domino effect.

Our customers witness 100% success in their projects with our turn-key Geoforming Full-Service Solutions.

1180 Avenue of the Americas, 8th Floor
New York, New York 10036
T: +1.833.GEOFORM
E: sales@geoforming.com

# GROUTING EQUIPMENT, SERVICES, AND MATERIALS

## AVANTI INTERNATIONAL

www.avantigrout.com

Avanti International is an American owned and operated manufacturer of injection grouts located in Houston, TX. Since 1978, Avanti's injection grouts have been used worldwide in municipal, industrial, and geotechnical applications to stop leaks, stabilize soil, and control groundwater – permanently.

Starting with only one product—AV-100® Chemical Grout (acrylamide) – Avanti's product line has grown to include a comprehensive line of injection grouts and accessories including acrylamide, acrylics, polyurethanes, Ultrafine cements, epoxies, pumps, injection accessories and more.

Avanti's unique injection grouting products are designed to address many of the most common challenges associated with geotechnical construction including improving facilities and operations in mines, mine shafts, bulkheads, tunnels/subways, concrete and earthen dams, excavations, and numerous other applications. For 45 years and counting, our knowledgeable and experienced team regularly assists engineers, contractors, and owners through every aspect of the grouting selection and process.

For more information on Avanti's injection grouts or applications, visit avantigrout.com.
822 Bay Star Blvd.
Webster, TX 77598
Telephone: 281-486-5600
E-Mail: info@avantirgout.com

## Bauer Foundation Corporation

Bauer Foundation Corporation is a leader of ground engineering in the United States. It was established in 2004 as the US subsidiary of Bauer Spezialtiefbau GmbH. With its global network, Bauer Foundation prides itself on being the home of some of the finest minds in the industry and on its use of the most advanced state of the art equipment. Its range of solutions includes, among others, slurry walls, deep foundations, seepage cutoff walls, deep soil mixing, jet grouting, rock grouting, soil improvement. Bauer Foundation has capabilities and experience to tackle projects of all sizes and levels of complexity both as a main contractor and as a subcontractor.

info@bauerfoundations.com
727-531-2577

## ChemGrout Inc

www.chemgrout.com

With almost 60 years of experience, ChemGrout continues to manufacture the world's largest selection of grouting equipment. Their Underground Series offers exceptional productivity for the grouting of water cut-offs, cable stays and rock bolts. ChemGrout's patented pumps are industry standards offering reliability and durability, along with unique features simplifying clean up and maintenance. One of ChemGrout's most popular pieces for water cut-offs and contact grouting in the underground industry is the CG680 High-Pressure Series. This high-capacity, high-pressure colloidal grout plant mixes and pumps slurries of cement, fly ash, bentonite and lime flour. These units feature a 17 cubic foot homogenizing colloidal mixer, a 17 cubic foot agitating storage tank, and a 32 GPM double-acting plunger pump. The colloidal mixer is equipped with a 2X3X12 high sheer centrifugal diffuser-type pump that disperses

the cementitous material down to its finest particle size to achieve complete particle wetness. The agitating storage tank uses a variable speed, high-efficiency paddle mixer that maintains a thoroughly mixed grout while waiting to be pumped.

805 E 31st St
LaGrange Park, IL 60526 USA
Telephone: (708) 354-7112
Fax: (708) 354-3881
cginfo@chemgrout.com

## ConMICO, Inc.

www.conmico.com

ConMICO Inc. of Concord, Ontario, with more than 59 years experience, specializes in custom made high pressure pump systems for tunneling and mining applications. Their products include durable, light weight grouting and cement-injection plants for use in soil consolidation, grout jetting to 10,000 psi, pile formation, tunnel forming and repairs, forming water curtains, back filling, and grouting of cracks in tunnels and mine shafts. For the grout pump systems, conMICO Inc. manufactures high speed colloidal mixers, double mixers, agitators, as well as accessories including packers, valves and high pressure fittings. An extensive product line of shotcrete machines and accessories are also available. ConMICO Inc. also engineers and manufactures high pressure water jet systems up to 50,000 psi and up to 1,200 hp for jet boring, hydro-fracturing of rock, underground hydraulic power units, coating removal, de-scaling and cutting and hydrostatic testing of pipelines

ConMICO Inc.
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Concord, Ontario,
Canada
L4K 1K8
Tel: 905.660.7262
Email: conmico@conmico.com

# HOISTS AND HEADFRAMES

## FKC-Lake Shore

www.fkc-lakeshore.com

FKC-Lake Shore offers design-build-install services for innovative hoisting, elevator, and vertical conveyance systems used to transport personnel and material. Our Field Services Division provides 24/7 emergency repair of electrical and mechanical systems. Products & Services: vertical belts, skips, hoists, sheaves, elevators, cages, headframes, brakeman cars, controls, field services, and wire rope NDT.

1695 Allen Rd
Evansville, IN 47710 USA
Telephone: 1 (877) 554-8600
information@frontierkemper.com

# HYDRAULIC HAMMERS AND DRILLS

## Yamamoto Rock Splitter Inc.

www.yamamotorocksplitter.com

Yamamoto Hydraulic Rock Splitters offers non-explosive excavation of hard rock without noise, vibrations or flyrock. The excavator-mounted rock splitters are based on the wedge principle and are the largest of its kind on the market. Applications include open pit excavation, highway widening, building foundations, shaft-sinking, and tunnelling. The first unit of Yamamoto Rock Splitter was supplied in 1981 and is known worldwide for high durability and reliability. The Drill & Split method is now standard for excavation in sensitive areas. We offer two models, HRB-1000 for 4" holes and HRB-1700 for 5" holes. Yamamoto is the ideal choice if you don't want to blast!

3 Germay Drive
Unit 4 #2882
Wilmington, DE 19804
Tel: 1-646-543-8940
Email: info@yamamotorocksplitter.com

# HYDRAULIC SYSTEM COMPONENTS

## Open Loop Energy, Inc.

"A Mining Partner"
www.openloop.net
www.SMRparts.com

Founded in 1992 Open Loop Energy has offices in Safford, Arizona, Winnemucca, Nevada, Cedar Fort, Utah and Farmington, New Mexico. Open Loop Energy is ISO 9001 certified at all locations to insure the focus on enhancing customer satisfaction. Each location has Six Sigma professionals on staff that enable projects and daily tasks to function in an efficient manner. Sixteen staff members hold certifications within the International Fluid Power Society, with this knowledge comes application expertise. Our innovative focus begins with Hydraulic Repairs. New manufacturing includes HydroStruts for Cat and Komatsu haul trucks, Bladder Accumulators, and HydroSNUBB Snubbers for Electric Shovels. One Key innovation is the "Patent" Digital Controlled Water Distribution System known as DCWD-G2. This is the only system that can track and report water usage of water trucks based on the ground speed of the water truck.

1722 North 8th Ave.
Safford, Arizona 85546
Telephone: (928) 348-9200
emotes@openloop.net

# INFLATABLE & MECHANICAL PACKERS

## INFLATABLE PACKERS INTERNATIONAL LLC.

www.ipipackers.com

IPI Packers manufacture a wide range of inflatable packer products for high-pressure PEG grouting – permeability/aquifer testing – well repair – rock-burst mitigation – rock stress testing – plug-and-abandonment – custom solutions to meet customer requirements.

The patent-pending Grout-free Expandable Standpipes for drill-and-blast, and our Drill-through Inflatable Standpipes for TBM applications, both provide effective and time-saving methods for advancing probe holes and Pre-excavation Grouting (PEG) in tunneling and mining.

DuraFRAC® high-pressure packers are the global standard for rock burst mitigation, block cave preconditioning, rock stress testing, and hydro-fracturing in water, mining, and geotechnical applications.

SWiPS and STX are field-proven permeability test systems that don't require inflation lines to surface, making testing at greater depths and low angles from horizontal possible.

Custom solutions include diverters for drill-hole control, highly-instrumented packer systems for research and development projects, long-term monitoring and more.

www.ipipackers.com
mwgmt@ipipackers.com
PO Box 2446
Red Lodge, MT 59068
Telephone: 406-446-9940
E-Mail: jadams@ipipackers.com

## QSP Packers LLC

www.qsppackers.com

QSP Packers, LLC is a Manufacturer / Supplier of Inflatable Packers, 1.9" O.D. to 19" O.D. Inflated Sizes, used for Wireline/Core Drilling Permeability Testing. Pressure Grouting, Foundations, Tunnels, Dam Stabalization and Repairs. Single & Straddle Systems, set up for Pumps, Pressure Transducers, etc. Environmental, Low Pressure, Fixed End Style, used for Groundwater Monitoring, Gas Leaks, in Cased Wells Only. Mechanical Packers for Freeze Plugs, Low Flow Monitoring. Let us help you with your needs.

13701 24th St. E. Unit A-9
Sumner, WA 98390 USA
Phone: 253-770-0315
Fax: 253-770-0327
Email: info@QSPPackers.com

# INFORMATION TECHNOLOGY PRODUCTS

## Esri

https://www.esri.com/en-us/industries/mining/overview

Esri delivers groundbreaking geospatial solutions tailored for the mining industry. Our ArcGIS platform facilitates comprehensive spatial analysis, predictive modeling, mine planning, and asset management. Our customers also leverage the power of location intelligence to track real-time operations, optimize logistics, and assess environmental impact. These core technologies can be configured "out of the box" to address specific mining workflows. For example, our environmental tailings management solution provides storage facility stakeholders with increased operational visibility, workflow efficiency, and a single source of truth by integrating crucial monitoring information, geotechnical sensor data, and field inspection reporting on any smart device. In addition, ArcGIS offers cutting-edge cartography tools to simplify mine modeling and subsurface investigations. Esri's imagery solutions transforms UAV-captured data into turnkey professional-quality 2D and 3D information products. Harness the full potential of geospatial technology with Esri's mining-focused suite. Explore, innovate, and sustain with Esri.

Contact:
Peter J Will
Esri
Principal Mining Account Manager
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# INSTRUMENTATION EQUIPMENT AND SERVICES

## EMERSON AUTOMATION SOLUTIONS

www.emerson.com/en-us

Emerson is a global solutions provider focused on Miners exceeding their key performance indicators, such as Safety, Reliability, Production, Cybersecurity, Environmental Stewardship, and Sustainability. Emerson's solutions portfolio in concert with Aspentech software provides Miners enterprise optimization through data analytics and machine learning, in concert with industry proven valve, instrument and controls products by Rosemount, Micro Motion, Clarkson, and Delta V. Underground, open pit, or in-situ, your mining operations and assets are safer and more predictable, more reliable, more profitable, and more sustainable with Emerson on your team.

8200 Market Boulevard
Chanhassen, MN 55317
Telephone: 952-949-7126
E-Mail: lisa.holmberg@emerson.com

## Geocomp, Inc.

www.geocomp.com

At Geocomp, we provide mine owners with unparalleled value through our advanced expertise in subsurface conditions, geotechnical laboratory testing, and cutting-edge monitoring technologies. Our global experience ensures safe and efficient operations at every stage.

We help our clients reduce exploration, production, and transportation costs, minimize environmental impacts, and make informed mining decisions by minimizing the need for destructive explorations and unnecessary excavations.

Our unique combination of products and service solutions are customized to address client-specific challenges, ensuring the success and safety of mining operations.

Areas of Expertise:

- Site characterization using InSAR presenting surface evolution and digital typography via satellite mapping
- Geophysical investigations using S-scan in 2D and 3D
- Customized field and laboratory testing programs to determine mechanical and physical properties of soils and rocks
- Performance monitoring in real-time using iSiteCentral® data management system
- Evaluation and interpretation of data about site conditions for safety and risk assessments

125 Nagog Park
Acton, MA 01720 USA
978-263-0012
info@geocomp.com

## Senceive

Senceive.com

Senceive wireless remote condition monitoring technology is used in 40 countries, primarily in mining, construction and infrastructure applications. Our precise, reliable and robust products are built to empower clients who are responsible for high value and safety-critical assets.

Senceive users installed more than 30,000 sensors in the last year – helping them manage ground and structural movement, landslide risk, geotechnical behavior, railroad track geometry, and much more. A wide range of parameters can be measured including:

- Sudden and incremental ground movement
- Environmental conditions including wind speed/direction, rainfall, temperature
- Engineering parameters including strain, crack movement, deformation
- Geotechnical conditions including automated logging of in-place inclinometers and piezometers in both horizontal and vertical borehole orientations.

All of this is achieved using wireless sensors that can be installed in minutes and last more than a decade with minimal maintenance.

812 W 13th Street
Deer Park, TX 77536-3166 USA
(346) 200-6477
info@senceive.com

## Sonitus Systems

sonitussystems.com

Sonitus Systems

Creating better environments for people to live and work.

Sonitus Systems provides noise, vibration and dust monitoring solutions that make environmental compliance easier. Automate your environmental compliance checks with rugged, automated monitoring equipment for a range of applications such as construction, demolition or manufacturing. Our Sonitus Cloud tools can help turn your measurement data into useful insights about your site. Talk to us about how we can help you with automated monitoring.

Unit C7, Citylink Business Park,
Bluebell, Dublin D12 VK10
Ireland
Tel: +353-1-6778443
sales@sonitussystems.com

## Terra Insights

www.terrainsights.com

Powered by the trusted and experienced brands RST Instruments, Measurand, 3vGeomatics, Syscom Instruments, and NavStar, Terra Insights is a comprehensive platform of geotechnical, structural, and geospatial monitoring technology, along with purpose-built data delivery solutions.

Terra Insights' monitoring technology can measure areas of interest at scale, from high-production mine sites to entire networks, such as railways, highways, and pipelines with a combination of geospatial, ground-based, and structural-based instrumentation. Our platform is also used to measure movement in airports, bridges, water dams, tailings dams, mines, and tunnels.

Terra Insights provides expert advice and service at every stage—from planning to implementation to ongoing post-work monitoring, all backed by after-market technical support.

We offer our clients an unprecedented level of data-backed insight that cannot be found anywhere else.

Address: 11545 Kingston Street, Maple Ridge BC, V2X 0Z5 Canada
Telephone: 1-800-665-5599
Email: info@terrainsights.com

## INSURANCE

### AssuredPartners
www.assuredpartners.com

Assured Partners is the SME endorsed broker for professional liability insurance. With over 20 years of experience, AssuredPartners provides complete risk management solutions for all lines of insurance including: general liability, workers comp, professional liability, directors' and officers' liability, inland marine, commercial auto, and employee benefit packages.

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Denver, CO 80237 USA
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### McGriff
www.Mcgriff.com

For more than a century, McGriff has provided highly customized insurance, risk management, and employee benefit solutions for organizations of all sizes. Our experienced insurance, risk management and employee benefit professionals work with you to develop highly tailored services and deliver them based on a proprietary and proactive approach we call Client Focused Risk Solutions.

Based in Denver, McGriff Mining is a team of mining risk specialists who will work alongside you throughout our relationship. Our mining industry experts take the time to listen and understand your specific risks. Then we work with you on a proven plan to address them. We have expertise in all insurance lines including Property and Casualty, Executive Risk (D&O), Surety and Political Risk among others.

Our focus is on identifying and mitigating risk, not selling insurance. One of the reasons why we have a 95% client retention rate.

When you choose McGriff, you'll be joining thousands of other businesses around the world who made the decision to select an agency which focuses on long-term relationships.

Paul W Prouty, CPCU, ARM
Executive Vice President
PProuty@mcgriff.com
(720) 639-1461

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Our mining industry experts take the time to listen and understand your specific risks. As a subsidiary of the 5th largest insurance broker in the world*, our focus is on identifying and mitigating risk, not selling insurance.

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- Surety
- Political Risk

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McGriff.com

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### Skyward Specialty Insurance Group
www.skywardinsurance.com

Skyward Energy, a division of Skyward Specialty Insurance Group, specializes in providing insurance protection to the Mining industry…either above or below ground and in quarries as well. We underwrite all types of mining operations and the various servicing contractors to include Machine Shops as well. We have four P & C carriers that are all A Rated with two being admitted that offer all lines of coverage. These include Workers' Comp, General Liability, Excess Liability, Business Auto, Property and Inland Marine. Mining insurance is our specialty and the only thing we do…so it is what we do best!

Jimmy Godfrey, Chairman-Energy
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## ION EXCHANGE EQUIPMENT AND RESINS

### Purolite, An Ecolab Company
www.purolite.com

Purolite is a leading developer, manufacturer and supplier of ion exchange, adsorbent and specialty resins. Headquartered in Pennsylvania, USA, we have ISO 9001 certified manufacturing facilities in the USA, China, and Romania and operate five global R&D centers. Established in industries such as hydrometallurgy, mining, metals plating, ultra-pure water among others, Purolite brings more new products to the market than any other resin company. We are the only company focused exclusively on resin technology. With the largest, most knowledgeable technical sales force and over 40 sales offices in more than 30 countries, Purolite can help solve your metallurgical process challenges.

2201 Renaissance Blvd
King of Prussia, PA 19406 USA
T +1 610 549 1548
Gabe.Austin@purolite.com

## LABORATORY AND SCIENTIFIC SERVICES

### ACZ Laboratories

Founded in 1980, ACZ Laboratories is an accredited environmental testing laboratory with inorganic, organic, geochemical, and radiochemical capabilities. We specialize in the analysis of trace-level contaminants in water, soil, sediment, sludge, waste, and biota.

ACZ has built a reputation as one of the highest-quality environmental laboratories in the mining industry. ACZ provides analytical support services to gold, silver, copper, coal, rare earth, lithium, trona, soda ash, base metal, and uranium mining operations. We currently support mining operations throughout the United States, Central & South America, Africa, as well as Asia.

ACZ understands the analytical requirements and data quality needs of the modern mining industry. We deal with the unique water matrices that are associated with mineralized zones around mining operations on a daily basis. We also perform specialized static and kinetic mining-related testing in-house including MWMP columns, humidity cell testing, acid-base accounting, and LEAF methods.

Phone: (970) 879-6590
Email: sales@acz.com
Web: acz.com

### Geopyörä Breakage Test
www.geopyora.com

Geopyörä offers state-of-the-art rock breakage characterization testing. Our innovative solution facilitates cost-effective testing for mining companies, accommodating various samples for applications such as geometallurgical, comminution design, and control.

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Oulu, 90510, Finland
+358 (0)50 5011458
info@geopyora.com

## Skyline Assayers & Laboratories

https://skylinelabs.com

Skyline is the oldest laboratory continuously serving the mining industry in North America. We were founded to serve the Copper Queen Mine in Bisbee, AZ in the 1880's, and have been in continuous operation ever since. We offer a full suite of Sample prep services including Core-cutting, Crushing & Pulverization. Six different Trace Element assay packages by Aqua Regia or Multi-Acid Digestion, with up to 50 elements able to be reported / Cu-Mo Total and Partial Extraction Techniques / Single and Multi-element Methods / Whole Rock Analysis / In-House Fire Assay Au/Ag with Single-use Crucibles for All Clients. ICP-MS / ICP-OES / Atomic Absorption (AAS) / Automated Titration / Automated Sulfur Analysis. Regional sample pickup service. Assistance with freight for bulk 'core' and pulp samples throughout North & South America is also available. We're ISO 17025 & ISO 9001 accredited. Our consistent accuracy is renowned in the industry.

Skyline Assayers & Laboratories
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Tucson, AZ 85756
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520.622.4836

# LEAK REPAIR

## InduMar Products Inc.

www.indumar.com

InduMar Products, Inc. has made use of advanced materials, composites, and technologies to provide innovative repair and protection solutions to a range of industrial sectors since 1986. Our products are designed to address pipe and tank leaks, corrosion control, and mechanical pipe rehabilitation with an emphasis on ease of installation, high performance, and long life. Our products include the Stop It® Pipe Repair System, Gas Riser RescueTM, the BoreShieldTM line of abrasion resistant outerwraps (AROs), the XCorr suite of epoxy repair products, and the StopCorrTM line of polyolefinic wraps, pastes, and sealants. Contact us at info@indumar.com or +713-977-4100 in Houston, TX to discuss potential solutions to your repair and remediation needs. Learn more at: www.InduMar.com.

2230 W. Governors Circle
Houston, TX 77092-8732
Telephone: 713-977-4100
E-Mail: Info@InduMar.com

# LIGHTING SYSTEMS AND LAMPS

## IoT Automation

www.iotautomation.com.au

IoT Automation proudly owns the FireFly Smart Lighting System. IoT Automation enables Real-Time Situational Awareness in underground mines and tunnels through connecting current safety and productivity solutions to the FireFly Smart Lighting network. The FireFly System reinforces safety procedures in the event of emergencies such as seismic events, gas leaks, fires, ground movement, and other mine/tunnel-wide emergencies through its customisable modes and colours that can provide red, green, amber, blue, or white tunnel illumination.

Purposely built for underground mining and tunnelling, FireFly utilises industry-standard cabling and connectors and IP66-rated modules. The FireFly System is IoT-enhanced through onboard Wi-Fi and Bluetooth radios for wireless device integration such as asset tracking and proximity alerts. Through smart illumination and user-friendly controls, the FireFly System is a robust solution that any underground operation would be remiss to do without.

1624 Market Street, Suite 202
Denver, CO 80202, United States
Ph: +1 720 446 6603
Email: sales@iotautomation.com.au

## x-Glo North America Inc.

www.x-glo.ca

x-Glo North America, distributor of industrial grade LED lighting solutions and is committed to developing and supplying high quality x-Glo LED lighting products and systems that are purpose built for mining, tunneling and oil & gas.

All x-Glo lighting products and systems are purpose designed and built to work safely and effectively in harsh conditions that often operate 24/365, and at the same time minimize maintenance costs.

x-Glo is marketed, supplied and backed up by a global network of authorized distributors who are passionate about delivering great products.

x-Glo North America supports its Distributor network with a lighting design and selection service to assist end customers obtain the right solution that is fit for purpose, cost effective and most importantly safe.

Contact us for support with a lighting design and selection that is fit for purpose, cost effective and most importantly safe.

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Markstay, ON P0M 2G0, Canada
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# LINERS - MILL LINERS

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www.clindustrialsolutions.com

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Applications are engineered for steel, concrete, composite substrates and direct to earth (hard rock, salt and dirt).

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719-966-9376
mark@customlinings.com

## FC Mill Liners, Inc.

www.fcmillliners.com

At FC Mill Liners, Inc. we apply 50+ years of industry expertise to provide you an excellent supplier experience. Highly knowledgeable account representatives and engineers will collaborate with you to define, design, and manufacture high quality liners that deliver the performance you need, specific to the size and application of your grinding mills. As a reliable supply chain partner, we deliver consistent lead times you can count on. And we can help maximize your up-time by engaging expedited response capabilities to quickly resolve unplanned liner issues so you can keep your operation running. Visit fcmillliners.com to learn how our expertise and capabilities can benefit you.

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Tucson, AZ 85718, USA
Telephone: (480) 622-1263
Kris.kidney@fcmillliners.com

# LININGS AND CLADDINGS

## AGRU America, Inc.

agruamerica.com

Since 1988, Georgetown, SC–based AGRU America, Inc. has been on a mission to build a better future through the development of innovative plastics solutions and fostering strong relationships built upon the highest standards of quality, service, and dependability. AGRU America is a subsidiary of AGRU GmbH, an Austrian family-owned business since 1948 with production facilities in Austria, the United States, Germany, and China. AGRU solutions, which include state-of-the-art products such as AGRU geosynthetics, concrete protective liners, pipes and fittings, and semi-finished products, are

distributed in over 80 countries worldwide. Learn more about AGRU America at https://www.agruamerica.com and AGRU at https://www.agru.at.

AGRU America, Inc.
www.agruamerica.com
500 Garrison Rd., Georgetown, SC 29440
800-373-2478
salesmkg@agruamerica.com

## American Biltrite

www.american-biltrite.com

Offering engineered products for the mining industry including rubber linings with and without bonding layer, uncured & custom mixing capabilities.

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bmeadows@american-biltrite.com

## Fisher Company

https://fisherutah.com/

Over the past fifty-two years our addresses have changed, and our company has grown from two to thirty employees, but the values on which it was founded have not. Specializing in fluoropolymer coatings and linings. We offer reliability, innovation, dependability, and our wealth of experience to all our customers. In the course of our coatings and lining work we have developed and improved upon traditional methods including the first ever fluoropolymer coatings above 1.5 mm in thickness. This was more than 25 years ago. That boundary has been surpassed again as we can apply Kynar® PVDF coatings in excess of 8mm in thickness. We are constantly improving; ongoing research remains a significant part of what we do. We look forward to working with you on your future coating and lining needs.

Phone: 801-298-2570
Fax: 801-298-2590
CONTACT@FISHERUTAH.COM
955 North Main Street
North Salt Lake, Utah, 84054
CONTACT@FISHERUTAH.COM

## KALENBORN ABRESIST CORPORATION

www.kalenborn.us

Kalenborn Abresist is a leader in the design and supply of wear solutions for a wide range of industries utilizing various mineral and metallic solutions. These linings and coatings also serve a variety of processing equipment including hydraulic and pneumatic components and pipes handling large quantities of bulk materials. The lining materials include cast basalt, alumina, zirconium corundum, silicon carbide, chrome carbide, hard alloys, trowelable epoxy, flexible wear resistant piping, anti-corrosion coatings and combinations of the above. Kalenborn Abresist is a decades-long supplier of engineered wear solutions to the aggregates and mining industries. Located in Urbana, IN, the company's wear and abrasion resistant linings and coatings reduce downtime and maintenance and are marketed throughout the United States, Canada and Mexico.

Kalenborn Abresist Corporation is part of Kalenborn International GmbH & Co. KG., a parent company with subsidiaries and facilities in Asia, Europe, North America and South America.

P.O. Box 38
5541 North State Road 13
Urbana, IN 46990
Telephone: (800) 348-0717
Fax: (888) 348-0717
Email: craig.frendewey@abresist.com

# LONGWALL MINING EQUIPMENT

## R.M. Wilson Co.

www.rmwilson.com

**Mine Productivity Systems & Equipment**

R.M. Wilson Co., serving the Mining industry since 1966, is a product specialist and partners with many of the leading machinery and equipment manufacturers around the world to offer engineered optimum solutions to the special requirements of the customer. Headquartered in Wheeling, West Virginia and with locations throughout the United States, we not only supply our customers with the equipment they need when they need it, but also provide unparalleled service and product knowledge that sets us apart from other machinery distributors. We partner with to sell and service the mine productivity systems and equipment of Betek, Eichoff, Flexco, Kennametal, Krummenauer, MultiGear, Setco, Thiele, and Voith among others. Please feel free to contact us at info@rmwilson.com for questions and inquiries.

3434 Market Street
Wheeling, WV 26003 USA
Telephone: (304) 232-5860
Fax: (304) 232-3642

# LUBRICANTS AND EQUIPMENT

## FUCHS Lubricants Co.

www.fuchs.com/us

FUCHS has been a trusted partner in the mining industry for more than 90 years. Our comprehensive range of lubricants provide solutions for every mining application. Continuous product development and optimization underline our mission to achieve technical perfection.

FUCHS' quality and dedication to service and support is our foundation for developing long-term partnerships with major mining customers. We are a true global partner with a focus on local manufacturing and distribution, coupled with a global support network.

FUCHS Lubricants Co.
17050 Lathrop Avenue
Harvey, IL 60426
708-333-8900
inquiry@fuchs.com

# MAINTENANCE EQUIPMENT AND SUPPLIES

## Certech USA Inc.

www.certeusainc.com

Certech is one of the world's leading in developing, manufacturing, and installing its patented rubber linings for grinding process, mining, and ceramic industry. Throughout the years has expanded its offering including. • Automation • Material management • Industrial vibratory sieves, iron removers and filters • Engineering and fabrication solutions.

Proudly representatives of the engineering Made in Italy, the Holding has invested its resources to create a full in-house manufacturing process.

Headquartered in Italy, the company currently operates in Spain, Mexico, USA, and Canada.

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Lebanon, TN 37090 - USA
Telephone: (615) 784 4501
info@certechusainc.com

## FISCHERCHEM MINING CHEMICALS

Fischerchem.com.au

Fischerchem Mining Chemical has been a trusted supplier of specialty flotation reagents since 2014, serving the Asia Pacific and North American regions from our base in Singapore. Our tailored solutions, sourced from top-tier providers across the globe, are meticulously crafted to address

the unique needs of mining operations. Backed by seasoned metallurgists, our products ensure optimal performance while offering cost efficiencies, thanks to our agile small business structure. Discover how Fischerchem can elevate your flotation processes. Visit our website or reach out to our team today.

Alan Fischer
afischer@fischerchem.com.au

## Guardian Chemicals

www.guardianchem.com

Guardian Chemicals provides advanced chemical solutions tailored to the specific needs of the mining, metallurgy, and exploration sectors. With a strong focus on innovation and environmental safety, Guardian Chemicals high-performance products are designed to enhance operational efficiency and reduce environmental impact. Our specialized solutions include heavy equipment cleaning and degreasing chemicals: chemical water treatment for boilers, chillers, and closed loops; and ball-mill gear cleaners.

Our proactive partnership approach ensures solutions are not just delivered but continuously supported with expert advice, regular service, and emergency support, ensuring optimal performance and extended equipment lifespan. Guardian Chemicals is committed to developing chemical solutions that are safe for users and the environment, adhering to strict industry standards and certifications, including ISO 9001, ISO 14001, and ISO 45001. Contact us today for all your chemical needs.

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Sturgeon County, AB T8L 5C1
Canada
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## HYTORC

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HYTORC makes industrial bolting safer and simpler. With over fifty years of experience, we are singularly focused on developing the highest quality industrial bolting systems. HYTORC is the most trusted name in the industry. From steel mills and mining equipment to refineries, power plants, and wind turbines; we have developed solutions for every bolting application imaginable. For custom projects, our highly experienced engineering team is at your service to design the most efficient solution for your job with simple operation and economical pricing in mind.

We are consistently improving upon existing products, and developing new tools, based on feedback from the people that use our tools every day. Our latest product line features patented industry-firsts like hands-free operation to keep tool operators at a safe distance from the application, onboard documentation systems to provide job accountability and assurance, and industry-leading bolt load accuracy to reduce nut loosening and joint failure.

info@hytorc.com

# MAINTENANCE SERVICES

## Technogenia Lasercarb Oklahoma Inc

www.technogeniaUSA.com

Technogenia is a leading provider of hardfacing solutions - Laser Cladding Process and Welding Consumables.

Our laser cladding technology Lasercarb® was developed for strategic application of Technolase® powders to the OD and ID of critical components to extend wear life. Technogenia's Torch and MIG Applied Welding products are also the leading products against abrasion, erosion, impact and corrosion.

Benefits of cast spherical Tungsten Carbide Spherotene® products:

- High hardness: 3000 HV ‡ 500
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- Spherotene® is not affected by LaserCarb®
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- Large range of thickness deposit

APPLICATIONS:

Tunneling, Mining, Geodrilling, Mixing Equipment, Industrial, Oil & Gas, Agriculture, Construction.

(405)470 33 50
sales-usa@technogenia.com

# MEASUREMENT AND MONITORING SYSTEMS

## Canary Systems Inc.

www.canarysystems.com

For over 25 years, Canary Systems has continued to successfully provide integrated geomonitoring solutions for a broad range of general mining applications. Encompassing tailings monitoring, surface mining, heap leach, underground, as well as operations, closure, and civil/structural monitoring, Canary Systems provides a single integrated turnkey risk management solution with innovative data acquisition systems and the browser-based MLWeb3 data visualization platform.

With Canary Systems, clients can better manage risk, monitor performance, and improve the overall safety of their operations through data-integration solutions including instrumentation, installation services, system architecture, hardware and software development, database development, TARP and ERP implementation, and remote support. Reach out about a pilot project today!

998 S. Cherry Ave
Tucson, AZ 85719 USA
Phone: 603-526-9800
info@canarysystems.com

## CiDRA Minerals Processing

CiDRA Minerals Processing provides customers with the ability to convert data into actionable information through the development, manufacturing and marketing of step-change technologies that provide accurate, real time measurements and information used to optimize industrial processes, enhance production, recovery and efficiency. CiDRA's SONARtrac flow and entrained air measurement systems together with the revolutionary CYCLONEtrac Particle Size Tracking System (PST) technology provide customers with control and insight into their processes that they have never before seen, thus allowing them to improve their company's performance and the sustainable development of resources.

For over 21 years CiDRA has worked closely with industry leaders to develop unique and effective solutions that meet their strategic initiatives.

50 Barnes Park North
Wallingford, CT 06492 USA
Telephone: (203) 265-0035
Fax: (203) 294-4211
sales@cidra.com

## Dibit Measuring Technique USA Inc.

www.dibit.at

Dibit Measuring Technique USA, Inc. is a worldwide operating engineering office specialized in tunnel-surveying. Through decades of experience, hardware and software technologies have evolved steadily, enabling Dibit to provide high-skilled surveying services and sophisticated scanning solutions.

Each scanning system and solution is specialized for different tasks, such as excavation scanning, as-built documentation or inspections. Independently of the various scanning systems, the result is always a true color, high resolution 3D-model. This 3D-model builds the basis for any further analysis like volume and thickness calculations, geometry and clearance checks as well as mapping geological and geotechnical information.

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office@dibit-scanner.com
www.dibit.at

## GEO-Instruments

https://www.geo-instruments.com

GEO-Instruments provides geotechnical monitoring services. We supply, install, commission, and monitor automated systems that help owners and operators mitigate risk, optimize designs, and document regulatory compliance. We work from 10 offices across the US and implement monitoring programs for projects of all sizes. Leveraging expertise gained from hundreds of other projects, we evaluate your requirements propose various monitoring solutions, including innovative alternatives for the project at hand. We have developed special expertise in blast monitoring, tunneling, tailings dams, bridges, and rail tracks. The GEO office closest to your site manages the installation, drawing additional personnel from other offices, as needed. We work safely and follow best installation practices. Our automated systems feature wireless data acquisition, web-based data management, and easy website access to graphs, and reports. Project managers remain hands-on throughout the project, verifying that the systems are operational and that data values look correct.

Website: https://www.geo-instruments.com
Email: sales@geo-instruments.com
Address: 24 Celestial Drive, Narraganset RI 02882 + 9 others.
Phone: 800-477-2506

## Geosense

www.geosense.com

Geosense is a leading manufacturer and global supplier of Geotechnical sensors and data acquisition systems used worldwide for safety monitoring of elements such as tunnels and metros, deep foundations, infrastructure, mines, dams and geohazards.

Geosense specializes in Vibrating Wire and MEMS technology as well as offering other types of instruments for all applications.

With a comprehensive in-house design and manufacturing capability, Geosense provides products not only to tight deadlines but also to suit custom-engineered solutions for specific project requirements.

Utilizing our expertise, clients have installed our sensors across more than 80 countries on some of the world's largest and most prestigious projects.

Geosense's manufacturing facility is in the UK and the company has a North America office in New York.

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15 West 38th Street
Suite 632
New York, NY 10018
T +1 518-920-3483
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## GeoSonics/Vibra-Tech

www.geosonicsvibratech.com

GeoSonics/Vibra-Tech is your blasting and vibration consultant with over 60 years' experience. We are also your one stop resource for noise, dust, geotechnical and environmental monitoring. Our technology converts your site data into valuable engineering information. Re:mote Monitoring Technology provides web-based data access to continuously collect and post data to a customized website. Let us show you how the GeoSonics/Vibra-Tech Re:mote Monitoring System allows you to get data to project personnel without requiring them to spend hours in the field, saving you operational time and resources. Please visit www.geosonicsvibratech.com to learn more.

109 East First Street, Hazleton, PA 18201
1-866-806-9676

## SENCEIVE CORPORATION

www.senceive.com

Senceive wireless remote condition monitoring technology is used in 35 countries in mining, civil engineering and transportation.

Applications include the use of wireless tilt meters to monitor the stability and safety of slopes. Tailings dam integrity can be monitored using a range of surface and borehole instruments to measure movement and ground conditions such as water pressure to provide early warning of instability.

Innovative solutions such as InfraGuard™ send alerts of small-scale slope movement indicating early signs of failure, with graded alerts of further movement, backed-up by photographic images.

Below ground, a combination of wireless monitoring sensors including optical displacement sensors and tilt meters can provide insight on tunnel convergence and divergence

- Proactive risk management: near real-time updates and automated alerts
- Low power, long life: safer, more affordable monitoring
- Fast and flexible: quick to install and easy to adapt and expand.

812 W 13th Street
Deer Park, TX 77536
Telephone: 346-200-6477
E-Mail: DMiller@senceive.com

## Waites Sensor Technologies

www.waites.net

Waites eliminates downtime by blending advanced machine learning with hands-on human insight for industry-leading equipment management. By utilizing wireless sensors and big data analytics, Waites makes maintenance more efficient and reliable.

Beyond its technological capabilities, Waites' dedicated team of analysts is available 24/7. They provide timely, expert responses to maintenance queries, minimizing downtime and extending equipment life. The Waites approach typically delivers a proven ROI in just three to six months.

Distinctive for its compact sensor size, comprehensive API, and adaptable solutions, Waites provides a practical and efficient maintenance solution, delivering significant cost savings to its clients.

20 W 11th Street, #200
Covington, KY 41011
sales@waites.net

## Weir Motion Metrics®

www.motionmetrics.com

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TBM Supply – Division of BPS Supply Group
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Matt Wolford, Director of Communications and Electronic Tools
mwolford@dodgeindustrial.com

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Jason Epstein
Director of Membership
jepstein@nssga.org
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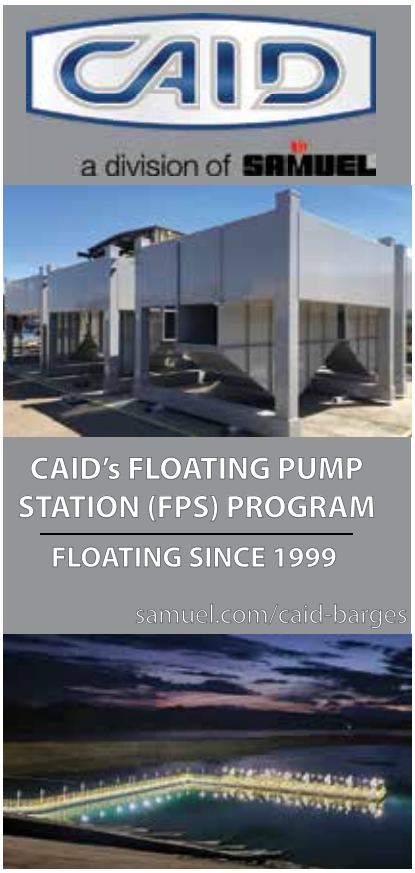


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## VERTIFLO PUMP COMPANY

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### Antraquip Mining and Construction Products

www.antraquip.net

North American based Antraquip Corp., continues to be a leading manufacturer and supplier of mining and construction equipment worldwide. With a 40+ year history of supplying roadheaders, hydraulic rock cutters (ie. drum cutters) and saw attachments, as well as mine/tunnel support systems, their products have become synonymous for quality, reliability and durability for the most challenging underground mining conditions. Whether it is the AQ roadheader line, which is used predominantly for mine development and tunneling operations, or the versatile AQ cutting attachments (scaling, mine development, production in soft rock, etc.), Antraquip products are designed to increase efficiency and safety for their mining clients.

AQ is also your reliable partner for various ground support products for tunneling and underground mining including lattice girders, steel sets and arch roof canopy systems. If you want to increase your bottom line contact Antraquip for more information about their full range of equipment and products at:

+1 301-665-1165 or info@antraquip.net. More product information can be found at www.antraquip.net.

**Hiring and HR Experts in Mining & Green Energy**

Executive, technical and professional role recruiting
Interim contract employee solutions
Human Resources consulting

P&C RECRUITING | HR
People and Project Solutions

pandcrecruiting.com

## ROCK DRILLS

### Epiroc
www.epiroc.us

Epiroc is a leading global productivity partner dedicated to providing innovative equipment solutions for mining, exploration, geotechnical, quarrying, well drilling, oil and gas, civil engineering, urban development, and deconstruction and recycling applications. Our product lineup includes drill rigs and drill strings, rock excavation products and construction equipment. Together with our strong partner network, we also provide world-class service and consumables. At Epiroc, our focus is on listening to and collaborating closely with customers to deliver cutting-edge technologies for greater safety, efficiency, productivity and sustainability in their operations.

8001 Arista Place, Suite 400
Broomfield, CO 80021 USA
Telephone: (844) 437-4762
inquiries@epirocmarketing.com

## ROCK SPLITTING

### Daigh Company, Inc.
www.Da-mite.com

Established in 1999, the Daigh Company provides Da-mite® rock splitting mortar for the demolition and fracturing of rock and concrete. Da-mite® is an alternative to explosives and breakers in sensitive areas where "no-blast" conditions and complications from vibration, noise and flyrock is a concern or prohibited. When you need to break, fracture, split rock or perform concrete demolition, Da-mite® Rock Splitting Mortar is the Ideal Solution. Da-mite® is silent, creates no vibration and requires no licensing or permits to use. Da-mite® is versatile enough to be used in drilled diameter holes from less than 1" up to 3". This flexibility allows Da-mite® to be tailored to any size project by small contractors up to large construction contractors.

111 Industrial Park Drive
Cumming, GA 30040 USA
Telephone: (770) 886-4711
Fax: (770) 887-3783
sales@daighcompany.com

## ROOF - GROUND SUPPORT

### Jennmar
www.jennmar.com

JENNMAR is a global, family-owned company that leads the way in ground control technology for the mining, tunneling, and civil construction industries. Since 1972, our mission has been focused on developing and manufacturing high-quality ground control products. We design and manufacture a wide range of reliable ground control products, including bolts, beams, channels, trusses, resin, rebar, and so much more. We take pride in creating products that enhance safety and efficiency in the mining, tunneling, civil, and construction industries.

Understanding the ever-changing and demanding conditions above and below ground, we have built the richest portfolio of diverse and complementary brands. JENNMAR sets the standard in every industry we serve, and as we continue to grow, our unwavering focus remains on the customer. Our commitment to our customer is guided by three words: SAFETY, SERVICE, and INNOVATION. It's these words that form the foundation of our business. It's who we are. For a comprehensive list of our brand portfolio, please visit our website at www.jennmar.com.

258 Kappa Dr
Pittsburgh, PA 15238 USA
Telephone: (412) 963-9071
Fax: (412) 963-9767
info@jennmar.com

### MINOVA
MINOVA AMERICAS
www.minovaglobal.com

Minova's purpose is to preserve and enhance the value of assets both production and structural. We provide safety critical products and solutions that deliver safe ground support and drive productivity for our customers. Our portfolio comprises steel and polymer based bolting systems, capsule and bulk cementitious and resin grouts for anchorage, seals, void control and backfilling, injection resins for water stopping, flotation reagents for ore processing and sprayed coatings for structural and water control. We have >140 years global experience and manufacturing on five continents, with research and development in North America, Australia and Europe. Minova's core industries are underground mining, tunneling and surface ground engineering.

150 Summer Court
Georgetown, KY 40324
Telephone: 502-863-6800
Fax: 502-863-6805
E-Mail: laura.smith@minovaglobal.com

### Williams Form Engineering Corp.
www.williamsform.com

Williams Form Engineering Corporation has been providing threaded steel bars and accessories for rock, soil and concrete anchors, post-tensioning systems, and concrete forming hardware systems in the construction industry for over 105 years.

Our rock and soil anchor product line includes our Spin-Lock mechanical rock anchors, polyester resin anchors, multiple corrosion protection anchors, soil nails, strand anchors, Manta Ray soil anchors, Geo-Drill Hollow-Bar anchors, and micropiles. For concrete anchoring we offer Spin-Lock anchors, undercut anchors, reusable anchors and cast-in-place anchors. We also have a full line of All-Thread Rebar for tiebacks, micropiles and post-tensioning.

Williams Form Engineering Corp.
8165 Graphic Dr NE
Belmont, MI 49306
616-866-0815
williams@williamsform.com

## ROTARY DRUM CUTTERS

### Alpine Equipment Group
www.alpinecutters.com

For over 50 years Alpine has been a trusted supplier of equipment for the construction, underground, and environmental sectors. We are specialists in hydraulic drum cutter attachments with our premier ROCKWHEEL product line, allowing for rapid and precise removal of rock and concrete, and filling the niche between bucket excavation and heavy hammers. We also offer the most comprehensive line of excavator mounted SOIL MIXING attachments for soil remediation, stabilization, and solidification activities. New to our product line are the Hartl ROCKCRUSHER and ROCKSCREENER Buckets for on-site material processing. If an off-the-shelf tool won't do the trick, job-specific customization is always an option. Alpine's experienced team will always strive to identify the optimum solution for your project, and is always available for technical support, service, and parts. All Alpine products are available on a rental basis with purchase option.

## SAFETY EQUIPMENT AND PRODUCTS

### Belt Conveyor Guarding
www.conveyorguarding.com

Belt Conveyor Guarding is a leader among the industrial machine guarding companies. We provide customers with premium guarding for existing bulk handling equipment and other rotating equipment. For more than 30 years, BCG has helped companies all over North America keep workers safe by providing compliant, ergonomic, and user-friendly machine safety guards.

3478 Penetanguishene Road
Barrie, ON, Canada L4N 4W1
1-866-300-6668
safety@conveyorguarding.com

## Carroll Technologies Group

https://www.carrolltechnologiesgroup.com/

Carroll Technologies Group is a leading provider of Communications, Electronics, and Safety Equipment for the tunneling and mining sectors. We distribute products for over 80 manufacturers, repair/calibrate over 75% of those products, and have a service team on hand to help facilitate those needs. Our company is dedicated to give you a service model 24/7 and we focus on the individual needs of our customers by providing a robust stock of the products they need at all times. Our number one goal is taking care of our customers and building a strong relationship. Customers trust us to supply all their needs with products supplied through companies such as MSA, PBE, Harrington, Industrial Scientific, NLT, Samson, Eaton, and so many more.

Josh Johnson
Sales Account Manager
Metal/Non-Metal Mining & Industrial
jj@carrollengineeringco.com
865-771-4074

## Dräger

www.draeger.com

For more than 125 years, underground workers have depended on safety equipment and quality products from Dräger to protect their lives. Our technical solutions are all components of an integrated safety concept that is dedicated to the improvement of underground safety – this begins with respiratory protection and gas detectors for everyday workplace safety and extends to self-contained self-rescuers and refuge shelters for emergency situations.

Dräger
7256 South Sam Houston Pkwy. W. Suite 100
Houston, TX 77085
Telephone: 1-800-437-2437
E-Mail: us-safety@draeger.com

## Driver Industrial Safety™

www.DriverIndustrialSafety.com

Driver Industrial Safety™ is a quality manufacturer of market-driven Safety Products for industrial and commercial industries. SAFETY IS ALL WE DO™. We are headquartered in Phoenix, Arizona (USA) with manufacturing and warehouse facilities in the US & Canada and sell through our global distribution channels. Driver Industrial Safety™ was originally founded in 2004 under our former recognized name SafetyWhips®.

Driver was founded on the basis that there is a critical need for well-engineered and dependable products for work site safety. Clients depend on Driver to keep their worksite safe. Our combined 100+ years in LED and electronics manufacturing provides the best engineered products available for worksite safety. Driver Industrial Safety™ products are still unmatched in performance and durability.

Our 5 branded product lines lead the industry in robust quality and engineering: NVIZN Identification Displays®, SafetyWhips® Warning Whips, Helios Warning Lights®, Toro® Heavy Duty Wheel Chocks, and Industrial Decals Co™.

## MineARC Systems America, LLC

https://minearc.com/

MineARC Systems stands at the forefront as a premier global supplier of emergency refuge chambers and safety gear tailored specifically for the mining sector. Since its inception in 1999, MineARC has earned acclaim for its delivery of top-tier, cutting-edge solutions that prioritize the safety and welfare of subterranean miners. Their comprehensive product lineup encompasses emergency refuge chambers, meticulously crafted to provide a secure, breathable sanctuary amidst life-threatening scenarios like fires, explosions, and gas leaks. MineARC Systems' offerings extend beyond refuge chambers, featuring safe havens and disaster shelters engineered to safeguard and sustain life during critical emergencies. Additionally, their product portfolio includes EnviroLAV toilets, Stench Gas Systems, Cap Lamps, Gas Monitors, Tracking Devices, Light Alert Systems, Mine Rescue Vehicles, Ambulances, and other mining-related technologies.

2135 Industrial St.
Lancaster, TX 75134
daniel.urbina@minearcusa.com
joshua.hill@minearcusa.com

## PROVIX

PROVIX.net

PROVIX Inc. provides Proximity Detection and Collision Awareness & Avoidance Systems with mine management, position and tracking software. These systems meet EMESRT Level 9 regulations to autonomously stop or slow mobile and rotating equipment.

PROVIX also manufactures, assembles and installs custom camera systems for all mining applications, providing a safer, more productive operation. Wireless inspection camera systems integrate recording capability, remote monitoring, and enhanced lighting such as for stope, brow, pass, bin and drift inspection.

Digital or analog camera systems wirelessly transmit remote operations for loading pocket, chute, breaker, bin and conveyor systems, or mucking, drilling and bolting activities. Video systems are used on scoops, loaders, LHDs and drill rigs to haul-truck drivers and control-tower monitors.

PROVIX also supplies broadband back-up alarms, the finest LED and HID equipment lighting, cabled communication, thermal cameras, and gas detection systems for mining, tunneling, and mine rescue. For more information visit Provix.net.

3 Greengage Rd., New Lowell, ON L0M 1N0
Canada
Telephone: 1 (888) 434-0253
Fax: 1 (705) 435-6419
Email: sales@PROVIX.net

## Strata Worldwide

https://miningdirectory.org/listing/strata-worldwide.html

Strata Worldwide, an international company established in 1992 and headquartered in the USA, supports the global mining industry with a selection of innovative, intelligent safety technologies and underground networking systems. The company's mission is to ensure the day-to-day safety and effectiveness of underground operations. Strata's strengths lay in its broad product offerings, extensive underground experience, global presence, and attentive customer support.

A selection of the company's most prominent products includes proximity detection and collision avoidance systems for any and all types of equipment, including artificial intelligence technologies; underground communications and IoT networking, emergency refuge chambers, and a collection of specialized polymers and resins for mining construction, repairs, problem-solving and waterproofing.

Strata Worldwide maintains a successful track record by working closely with customers and fully understanding individual project needs. On-site and remote service capabilities provide ongoing support and ensure long-term system success.

8800 Roswell Rd. Ste 145
Sandy Springs, Georgia 30350
United States
(800) 691-6601

## SAMPLE DEVICES

## Geotech Environmental Equipment, Inc.

Geotech Environmental Equipment, Inc. offers a range of products designed to meet the specific needs of the mining industry. These include fluid level monitoring instruments, metals detection with XRF technology, filtration for trace metals analysis, and air quality instrumentation. These tools provide accurate and reliable data to ensure safe and efficient mining operations while minimizing the environmental impact. Geotech's comprehensive suite of products helps mining professionals effectively monitor and manage critical aspects of their projects, resulting in improved productivity, compliance with regulations, and protection of the environment.

Geotech Environmental Equipment, Inc.
800-833-7958
www.geotechenv.com

## SCREENS

### Derrick Corporation
www.Derrick.com

Since its inception, Derrick® Corporation has expanded its product portfolio to serve a variety of challenging markets within the Mining & Industrial, Oil & Gas Drilling, and Civil Construction industries. Derrick remains committed to providing the latest technological enhancements that evolve alongside industry best practices and market developments – allowing end users to maximize resource efficiency for a greener world. For more than 70 years, Derrick has been leading the Mining & Industrial market in the design and manufacture of high-frequency vibratory screening machines and patented screen surfaces. With a pioneering spirit driving innovative solutions, the organization is continuously in the forefront advancing the field of fine particle and solid-liquid separation technology. Known worldwide for their high-capacity and superior separation efficiency, Derrick products are used successfully around the world. Its advanced technology allows processors to screen a wide variety of wet or dry fine materials in the range of 6.2 mm to 45 µm. Derrick's global family – comprised of employees, sales representatives, and distributors – are strategically positioned worldwide to provide superior customer service and technical support to customers around the globe. Our success is fully dependent on people. Priority one is to serve our global families; our tenured employees, multi-national partners, and surrounding communities.

590 Duke Road
Buffalo, NY 14225 USA
Telephone: (716) 683-9010
Fax: (716) 683-4991
info@derrick.com

### Federal Screen Products, Inc.
federalscreen.com

Federal Screen is a custom manufacturer and fabricator of wedge wire screens, delivering high-quality products and unmatched customer service. We provide filtration solutions that help lower maintenance costs and maximize systems efficiency for mineral processors.

We manufacture the most comprehensive range of screens for refining applications and specific machines, including large diameter, one-piece construction screens, providing an alternative solution to wire mesh and perforated metal filters. Wedge wire screens offer increased strength, higher flow rates, and reduced pressure loss while maintaining clog-free filtration greater than conventional metal filters. With the best delivery times in the business, you can count on us to help keep your project moving forward.

7524 Bath Road, Mississauga, ON L4T 1L2
Phone +1-905-677-4171
Fax +1-905-677-8959
info@federalscreen.com

### Fluid Systems, Inc
www.fluidsystems.com

Fluid Systems is a developer and manufacturer of process technology to the mining, industrial, environmental and oil/gas industries for the past 40 years. We also design and manufacture stainless steel and urethane screen panels for FSI equipment along with other OEM replacement screen panels.

Fluid Systems technical expertise lies in our ability to design and develop equipment, systems, plants, 3d modeling, finite element analysis (FEA), package integration, installation, and commissioning. We have a line of equipment for all wet or dry applications. If you need more capacity, higher efficiencies or finer cut points from the same machine inquire about our HI-E technology. The HI-E Kit Option generates more energy on the screening area only and comes on all new FSI equipment as well as refurbishments.

18703 Intercontinental Crossing Drive
Houston, Texas
Contact Us (832) 467-9898
sales@fluidsystems.com

### GENERAL KINEMATICS
www.generalkinematics.com

General Kinematics is one of the world's largest suppliers of vibratory processing equipment. GK is a significant contributor to the technical advancement of equipment design and application in the mining industry. GK serves a worldwide customer base through engineering-oriented sales representatives who cover industrial markets throughout the United States. International markets are serviced from subsidiary operations and through a combination of representatives, manufacturers, and strategic alliances with industry-specific organizations in other strategic locations. Today, over 50,000 General Kinematics units have been installed.

5050 Rickert Road
Crystal Lake, IL 60014-7333
Telephone: 815-455-3222
Fax: 815-479-9428
E-Mail: info@generalkinematics.com

## Haver & Boecker Niagara
www.haverniagara.com

Haver & Boecker Niagara is a leading provider in screening, pelletizing and mineral processing plants and systems. The company's mission is to deliver the best of these technologies to customers in the mining, minerals, aggregates, cement, building products, fertilizer and salt and recycling industries. With deep roots and years of experience in these industries, Haver & Boecker Niagara uses its innovative and shared technologies to effectively meet the needs of customers around the world.

225 Ontario St.
St. Catharines, ON L2R 7B6
Canada
Tel: 905-688-2644
info@haverniagara.com

## JOHNSON SCREENS
www.johnsonscreens.com

As the manufacturer of stainless steel and polyurethane screening systems, Johnson Screens offers the most comprehensive, innovative range of screen surface media and mining screening equipment in the industry.

Johnson Screens has developed world-class proprietary Vee-Wire® and polyurethane manufacturing processes. Our comprehensive range of products and services is well positioned through in-house product innovation, fit-for-duty material selection, mineral sizing, cleaning, and dewatering know-how.

Our screening systems:

- Remove moisture in coal preparation, which lowers coal heating value. Also, too much moisture leads to handling/freezing problems and increased transportation costs.
- Improve density media recovery in coal preparation to optimize process costs.
- Satisfy classification and purity specifications dictated by the metals and minerals markets.
- Ensure correct particle reporting will maximize asset efficiency in your downstream processes.
- Eliminate pegging and blinding (near-size material nesting in the screen openings) that improves process production yield and efficiency.

1950 Old Hwy 8 NW
New Brighton, MN 55112
Telephone: 651-636-3900
E-Mail: Info.us@johnsonscreens.com

## Polydeck
www.polydeck.com

Polydeck is the leading provider of modular synthetic screen media for the aggregate, energy & industrial, and mining industries. Our core competencies center around the ability to couple custom designed screen media products with screening application solutions that reduce costs and increase efficiency.

1790 Dewberry Rd
Spartanburg, SC 29307 USA
Telephone: (864) 579-4594
info@polydeck.com

# SEALS

## GCP, a Saint-Gobain company
https://gcpat.com/

The DE NEEF® portfolio from GCP, a Saint-Gobain company, provides waterproofing injection solutions that stop leaks under any circumstances and in any application - foundations, infrastructure and more. The major advantages of DE NEEF® products include the fact that they are easy to use, are not diluted, and can be applied quickly and reliably. The portfolio is mostly based on single-component, closed cell, hydrophobic polyurethanes, which are both durable and lasting. Therefore, leaks that are stopped once will remain stopped. For taking care of leaks that slow down the progress of a job site, endanger the future of a construction, or prevent full use of a building, DE NEEF® has become the world's most trusted brand.

GCP, a Saint-Gobain company
100 Research Dr
Wilmington, MA 01887
+1(866) 333-3726
Customersolutions.na@gcpat.com

# SEDIMENT & EROSION CONTROL

## Desert Mountain Corporation
www.desertmtncorp.com

Desert Mountain Corporation provides dust control, erosion control, road and soil stabilization for both underground mines and open pit mines. We offer proven, customized solutions for:

- Haul Roads
- Ash Piles
- Tailings Impoundments
- Open Pits
- Vendor Routes
- Over Burdens
- Parking Lots

With the right dust suppression, road stabilization, and soil erosion plan – utilizing our traditional and state of the art blends – most mines can reduce their water usage up to 50% along with other short and long-term costs.

We offer products approved by the environmental departments at some of the largest mines in the United States. They will make the work environment SAFER and save money at the same time. Or we will work with your mining environmental department to create a specialized solution to address your unique needs.

Desert Mountain provides dust control, erosion control, soil and road stabilization for the mining industry in nine Western US states.

Corporate HQ: PO Box 1633, Kirtland, NM 87417
Arizona/Mining Branch: 1930 S. Alma School Road, Suite B-219, Mesa, AZ 85210
Phone: 877-718-3878
email address: info@desertmtncorp.com

## Maccaferri
https://www.maccaferri.com/us/

Maccaferri is a leading global company in civil engineering solutions based in Italy. The company has been providing innovative and sustainable solutions to various engineering challenges for over 140 years. They specialize in the design, manufacture, and supply of geosynthetics, geotechnical, and hydraulic products and solutions for the construction industry, including retaining structures, erosion control, soil reinforcement, and drainage systems.

With a strong focus on research and development, Maccaferri has developed cutting-edge technologies to offer solutions that are not only efficient and cost-effective but also environmentally friendly. They have a global presence with operations in over 100 countries and have completed thousands of projects worldwide. The company is committed to quality, safety, and sustainability, and their solutions are designed to meet the specific needs of their clients, from small-scale projects to large infrastructure developments.

Email: info.us@maccaferri.com
Phone: +1 301 223 6910

## PRESTO GEOSYSTEMS
www.prestogeo.com

Presto Geosystems' GEOWEB® Geocells offer a better solution set to soil stabilization challenges for haul roads and accessing sites over soft ground, controlling and containing stormwater, protecting geomembranes in basins, tailings, and heap leach pads, and reclaiming and protecting cut slopes at the time of closure. The HDPE 3D confinement system strengthens and stabilizes fill, allowing for 50% less cross-section in roads and

the use of lower quality onsite fill—even on-site waste rock. GEOWEB solutions offer increased speed of operation, significantly lower maintenance requirements, safer installation, and a lower total cost of ownership.

Free Project Evaluation Services.

Presto Geosystems
920-738-1328 | 800-548-3424
info@prestogeo.com

## SEGMENT ACCESSORIES

### Technical Tunnelling Components Ltd.

www.ttcltd.org

Technical Tunnelling Components Ltd is at the forefront of quality assured segment accessory supply worldwide.

TTC's expertiseis focussed solely on the segmentally lined tunnel industry and with the enviable in-house design and manufacturing capabilities it has, gives TTC a flexible and competitive edge when it comes to segment accessory supply. This also enables TTC to offer bespoke products for specialist and challenging situations as well as supplying standard parts.

TTC has over 40 years' experience of manufacturing and supplying segment accessories including, connection bolts and sockets, grout/lifting socket assemblies, segment packers, grummets and other ancillary items, along with the award winning Dowelock connection, alignment and shear system, making TTC a true one stop shop for segment accessories.

Unit K Radius Court, Tungsten Park
Coventry Road, Hinckley
Leicestershire, UK
LE10 3BE
Tel +44 (0)1455 234401
info@ttcltd.org

## SENSORS

### Steinert US, Inc.

https://steinertglobal.com/us/company/subsidiaries/steinert-us/

STEINERT magnetic separation and sensor sorting solutions for improved throughput and recovery rates in ore sorting and mineral processing.

STEINERT offers magnetic and sensor sorting solutions to help mining and mineral processing customers improve throughput, recovery rates, and profitability. STEINERT's specialized equipment and tailored services aim to increase yield, reduce costs, enhance product purity, and even limit environmental impact. As a pioneer in mechanical mining separation, STEINERT continuously develops new high-tech solutions to meet the challenges of our customers. STEINERT's sorting and mineral processing technologies enable better process control, allowing economically viable processing of previously unfeasible ores. STEINERT's solutions also selectively improve the quality of mining tailings to make them economically viable. With a focus on delivering value-added services, STEINERT helps customers achieve their goals through its comprehensive portfolio of magnetic and sensor sorting solutions.

285 Shorland Drive
Walton KY 41094
1-800-595-4014
Sales@steinertus.com

## SEPARATORS AND CONCENTRATORS

### Eriez & Eriez Flotation

www.eriez.com

See our ad on page

Eriez and Eriez Flotation offer best-in-class magnetic and flotation separation, material handling and metal detection systems to concentrate ores, recover coarse or ultra fine particles, remove tramp metals, and convey or feed heavy material. Eriez Mining equipment includes: Coarse and fine particle flotation columns, and mechanical cells, Wet Drum Separators that provide continuous recovery of magnetite or ferrosilicon in heavy media operations and/or concentration of ferrous and weakly magnetic ores, Suspended Electromagnets to remove damaging tramp metals from conveyed material, Metal Detectors built to handle harsh environments that can detect tramp and non-magnetic metals as small as ½ inch, Heavy Duty Feeders for low-horsepower, high-capacity mechanical feeding of bulk materials in volumes up to 2250 tph. In addition, customers can count on Eriez' Five-Star Service for a 24/7 service hotline, original OEM parts, on-site field service, equipment remanufacturing and full "as new" warranties.

For more information, visit www.eriez.com; Eriez Flotation: telephone (604) 952-2300, EriezFlotation.com

2200 Asbury Road
Erie, PA 16506 USA
Telephone: (814) 835-6000
eriez@eriez.com

### TOMRA Sorting Mining

https://www.tomra.com/en/sorting/mining

TOMRA Sorting Mining provides proven sensor-based sorting technology for efficient material separation in various mineral and ore applications such as in the processing of gold, diamonds, gemstones, industrial minerals, and metal recovery from slag. World-wide, numerous sorting systems are already contributing to more energy-efficient and cost effective pre-concentrations as well as material recovery. TOMRA's sensor-based solutions help to extend the life of mining operations and increase the value of the deposit.

Harold.cline@tomra.com, +1 (720) 361-9033

## SHOTCRETE EQUIPMENT, SUPPLIES AND SERVICES

### MASTER BUILDERS SOLUTIONS

www.master-builders-solutions.com/en-us

Master Builders Solutions is the world leader for reliable, customer-oriented product solutions to the underground mining sector. For more than 100 years, our innovations have become today's industry benchmark; we supply customized solutions that perform in the ever-changing geological environments and challenging underground conditions. Today we continue to support the underground mining sector with technological advancements that can directly enhance safety and improve productivity for a sustainable mining future.

The MasterRoc® product range is comprised of market-leading innovations and application expertise for the mining and tunneling industries. Our reliable, customer focused solutions include several outstanding technologies for:

- Shotcrete
  - Accelerators and Fibers
- Rock Bolting Resins
- Injection
  - Chemical Grouts
  - Cement Grouts
- Chemical Technologies for Mine Backfill
- Admixtures for Concrete
- Thin Spray-on Liner (TSL)

23700 Chagrin Blvd.
Beachwood, OH 44122
Telephone: 216-839-7500
Fax: 216-839-8830
E-Mail: james.lindsay@masterbuilders.com

## Normet Americas Inc.

Normet is an industry-leading technology company offering continuous improvement to underground mining and tunnelling processes for increased safety, productivity and profitability. We work in close collaboration with our customers and utilise our process expertise amassed over thousands of mine and tunnel projects all over the globe into concrete actions and financial results for our customers.

We have a broad underground offering, including equipment for concrete spraying and transport, explosives charging, scaling, lifting, installation works, and logistics. We supply construction chemicals for sprayed concrete, admixtures, injection systems for ground and water control, waterproofing systems and additives for TBM technology. We have high quality and innovative rock reinforcement products that reduce the risk of accidents in challenging rock conditions. Our services are to ensure safety and productivity for our customers throughout the lifecycle this includes the supply of spare parts, rental equipment, remanufacturing and upgrades, field services, training and more.

Normet Americas, Inc.
1414 S Gladiola St | Salt Lake City, UT 84104 | United States of America
Tel. +1 801 5964700

## Sika Corporation

usa.sika.com/STM

For more than a century, Sika has been pioneering underground construction and continues to be involved with the most challenging tunneling and mining projects ever built. We continue to forge ahead to bring modern-day shotcrete, tunneling, and mining technologies a step above the rest.

Focused on the entire North American continent, our Sika STM - Shotcrete, Tunneling, and Mining portfolio incorporates our technical expertise along with pre-packaged shotcrete materials, shotcrete accelerators, structural shotcrete fibers, tunnel boring machine solutions, injections and grouting solutions, mine backfill, waterproofing systems, and concrete admixtures.

In addition, the recent acquisition of Thiessen Team USA further expands our portfolio by offering complimentary shotcrete and grouting solutions along with a reputation for excellent quality and hands-on technical support.

With a fully integrated, innovative, and high-quality product portfolio, Sika is your ideal business partner to help you face the challenges and requirements of the civil and underground construction industry.

Sika Corporation
201 Polito Avenue
Lyndhurst, NJ 07071
(800) 933-7452
robertson.kevin@us.sika.com

## Shotcrete Technologies, Inc.

www.shotcretetechnologies.com

Shotcrete Technologies, Inc. is a Colorado Company with a global reach that supplies mining, tunneling and infrastructure projects with quality Shotcrete Products and Services. Our service starts long before the spraying begins. With 40+ years of global experience, expect our professionals to be involved from start to finish on your Shotcrete project. Our products and services include:

STI Shotcrete Equipment, including our industry standard; Shot-Tech Robotic Arm, which can be mounted on many types of carriers.

STI Shaftlining, a robotic system for lining/repairing shafts and tunnels. This new process is quick, non-disruptive, efficient and all at a lower cost than conventional techniques.

STI Shotcrete Accelerators and admixtures, including our well-known Shotset 250 accelerator and STI Alkali Free.

Technical Support Training: STI's team of professionals understand, support and add value to every aspect of your shotcrete application.

Auxiliary Equipment: pumps, hoses, everything you need for a complete system.

1431 Miner St. / P.O. Box 3274
Idaho Springs, CO 80452 USA
(303) 567-4871 Office

# SLURRY SERVICES AND MACHINES

## SCHAUENBURG Maschinen- und Anlagen-Bau GmbH

Schauenburg-mab.com

Efficient separation plants form the basis for the successful use of fluid-assisted mining methods for tunneling, microtunneling, horizontal directional drilling (HDD) and diaphragm wall construction. Worldwide, the specifications for construction companies when using bentonite flushes and suspensions are becoming more and more demanding. On the one hand, this concerns ensuring the rheological properties of the rinses used during operation and, on the other hand, the disposal of the used rinses. SCHAUENBURG MAB supplies complete systems for the treatment of these slurries, which have been in use worldwide for many decades. Our systems for slurry treatment are continuously optimized for the various applications based on many years of experience. Thus, we can support our customers with our plants to meet these requirements sustainably and economically.

Weseler Straße 35, 45478 Mülheim an der Ruhr, Germany
+49 0208/9991-0
mail@schauenburg-mab.com or a.limberg@schauenburg-mab.com

# SOLVENTS - EXTRACTION, MIXER AND SETTLERS

## Quinn Process Equipment Company

www.quinnprocess.com or www.qpecsx.com

We at Quinn Process Equipment Company (QPEC) have been designing and manufacturing QPEC Solvent Extraction Mixer-Settlers for over 45 years. In that time we have produced a wide range of QPECSX systems for flows from a few liters per minute up to 7.5 cubic meters per minute flow rates. We have produced numerous systems recovering minerals for the "GREEN" energy EV's and "STRATEGIC" metals that have attracted so much attention the past few years.

Telephone: (303) 295-2872
Mail: PO Box 2589
Littleton, CO 80161-2589

# SPECTROMETERS

## RADOM CORPORATION

www.radomcorp.com

Radom's Microwave Coupled Atmospheric Plasma-Optical Emission Spectrometer 1000 (MICAP-OES 1000) delivers a quality product while increasing efficiency, profitability, and customer satisfaction. This small, lightweight optical emission spectrometer will provide trace metal analyses faster than traditional methods while decreasing the cost per analysis. Learn more about microwave inductively coupled atmospheric plasma – optical emission spectrometers which require minimal infrastructure upgrades but maximum productivity.

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# Eriez Concentration & Separation Equipment for

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Eriez offers wet and dry, low-, medium- and high-intensity magnetic separators to concentrate magnetic ores or remove metallic contaminants and industrial minerals.

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Eriez designs and manufactures specialty flotation equipment, with more than 1,000 flotation column systems installed worldwide for cleaning, roughing and scavenging applications in base metals, gold, industrial minerals, coal and oil sands, phosphate and potash. Eriez also offers hydraulic separators, slurry distributors, spargers and an array of laboratory and pilot-scale equipment.

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- Column Flotation
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## STEEL FABRICATION

### Structural Steel & Plate Fabrication Co.

www.ssandpf.com

With more than 44 years in business, SS&PF has the experience and expertise to budget, estimate, and execute complex fabrication projects from basic materials to exotic alloys. Our product offerings range from pressure vessels, tanks, ducting, bins, chutes, hoppers, pipe racks, bridges, and structural steel buildings. Our office is staffed with highly experienced estimator/project managers and our 90k sqft shop is equipped with high-end automated machinery, 100T lifting capacity, a 15'x50' post-weld-heat-treat oven, and over 75 craftsmen. We adhere to ASME & AISC standards with the certifications, endorsements, and quality program necessary to be a premiere supplier to the biggest companies in the mining, refining, and industrial processing industries. Our extensive list of return customers stands as a testament to our superior quality and positive customer experience.

125 W 500 N
North Salt Lake City, UT 84054
Telephone: (385) 243-9148
sales@ssandpf.com

## STEEL WIRE ROPE/CABLES

### WireCo

www.wireco.com

WireCo is the world's leading manufacturer of mission-critical wire rope, synthetic rope and netting, and electromechanical cable. WireCo creates premium products that serve as the strength behind the world's evolution. WireCo's products span a wide range of industries, including fishing, maritime, mining, energy, and industrial lifting. WireCo markets value-added products under several brands recognized worldwide and used in a wide range of market applications. WireCo is headquartered in Prairie Village, Kansas, with manufacturing plants, distribution facilities, and research and development centers worldwide.

2400 W. 75th Street
Prairie Village, KS 66208
Telephone: 816-270-4700
Fax: 816-270-4707
E-Mail: info@wireco.com

## STRESS RELIEF

### BONAL TECHNOLOGIES

Website: www.Bonal.com

Meta-Lax, the name of a stress relief process and equipment, has been helping countless number of mining and tunneling companies minimize the time and cost of heat treat stress relief, as well as minimize weld cracking and weld distortion. Bonal Technologies developed and patented a SUB-harmonic vibration stress relief process they call Meta-Lax. According to the US Dept. of Energy "Meta-Lax is a proven substitute for 80-90% of the heat treatment stress relief applications." Meta-Lax, as a stress relief process, matches heat treat stress relief for quality and consistency, has limitless size and weight capacity, and is portable. As used during welding, Meta-Lax "Weld Conditioning" prevents most weld cracking and weld distortion, at the time of welding and later in service. Meta-Lax stress relief has been routinely used on components such as booms, augers, screen decks, motors and more. Meta-Lax Weld Conditioning has been used on components such as bucket teeth, grader blades, crusher housings, ripper shanks, pulverizers, and more. Bonal offers a lineup of Meta-Lax equipment through sales and rentals.

Bonal Technologies, Inc.
1300 N. Campbell Rd.
Royal Oak, MI 48067
(800) Meta-Lax or (248) 582-0900
www.Bonal.com

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### PhySep Components and Service

www.physep.com

Minerals Are Our World™

Celebrating over 10 years serving our customers. PhySep Components and Service specializes in the supply of spare parts and service for mineral processing and separating equipment. OEM & OES spare parts and consumables: motors, bearings, brushes, Kevlar® processing belts, anti-static/ionization bars, transformers, electrical components, and more. PhySep Components and Service is a division of NobleMEIR, Inc., an independent supplier and manufacturer.

sales@physep.com
Jacksonville, FL - USA
+1(904)693-1091

## SURVEYING EQUIPMENT, LASERS, AND SUPPLIES

### Amberg Technologies AG

www.ambergtechnologies.com

Amberg Technologies is the world market leader in railway and tunnel surveying. The systems are flexible and modular and adapted to your project's requirements. With our experience and know-how, we develop customized solutions.

Amberg Tunnel & Navigator combines precise measuring instruments with tunnel-specific surveying applications. Reduce your costs by streamlining your excavation processes. Scale your survey based on your project progress. It is ideal for TBM and conventional tunnel excavation. When your tunnel survey must be fast, precise and efficient.

Trockenloostrasse 21
8105 Regensdorf, Switzerland
Philippe Matter, Regional Sales Manager
+41 44 870 92 50
phmatter@amberg.ch

### CARLSON SOFTWARE

www.carlsonsw.com

Carlson Software provides user-led solutions from software to precision laser measurement and mapping technology. Celebrating 40 years of innovation and service, Carlson is focused on offering dynamic function and capability in all its solutions. Users can enjoy connected workflows in aerial mapping and post flight processing, mine design and planning, machine control for quarries, surveying, blast pattern design, and more. Carlson instrumentation and technology offerings include borehole deviation measurement systems, cavity mapping for unreachable areas, lightweight and accurate GNSS receivers, onboard machine guidance systems and long-range surface scanners. Fill in the gaps of what you're missing or utilize a complete Carlson workflow package with support from start to finish. Do more. See more. Know more. All with Carlson.

33 E. 2nd St.
Maysville, KY 41056
606-564-5028
E-mail: info@carlsonsw.com

## EMESENT

www.emesent.com

Emesent is a world-leader in drone autonomy, LiDAR mapping, and data analytics. Founded in 2018, Emesent has since built a reputation for delivering high-quality data capture in the mining, infrastructure, survey, and mapping industries.

Our flagship product, Hovermap, is a smart mobile scanning unit that combines advanced collision avoidance and autonomous flight technologies to map hazardous and GPS-denied environments. Hovermap is uniquely versatile, it can be handheld, drone-or vehicle-mounted to map challenging, inaccessible areas. With a wide range of applications, Hovermap is being used by customers around the world.

9200 E. Mineral Ave. #100
Centennial, CO 80112
https://www.emesent.com/contact/

## Frontier Precision

www.frontierprecision.com

Frontier Precision is a distributor of geospatial survey and mapping products, unmanned aerial and ROV products, as well high precision satellite imagery and software. We are an employee-owned company, with over 35+ years of experience working in mining environments. Since our founding in Bismarck, ND in 1988, we've expanded our footprint to South Dakota, Minnesota, Colorado, Alaska, Montana, Idaho, Hawaii, Oregon, Washington, Florida, and Texas. Additionally, Frontier provides service in the states of Wyoming and Utah, along with our remote Frontier Precision Unmanned specific offices in Ohio, North Carolina, Florida, and Arizona. We pride ourselves on offering unmatched customer service with industry experts who always find a solution to fit your needs.

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Bismarck, ND 58554
(701) 222-2030
(701) 258-5324
Andrew Munson
Technical Sales (Monitoring) Representative
howyoumeasurematters@frontierprecision.com

## SYSTEMS & EQUIPMENT

## REDWAVE

www.redwave.com

REDWAVE is your reliable partner for profitable solutions in the recycling, mining and metal industries. It supplies economic single and whole plant sorting machinery designed specifically for maximum result. REDWAVE ROX's sturdy industrial design achieves a high-performance level and reliable quality recovery of materials. Every REDWAVE machine has individual software and hardware knowledge onboard giving clients the required flexibility to continuously develop their products and react quickly to market and customer needs. REDWAVE has 1000+ machines operating worldwide and is headquartered in Austria. It maintains branch offices in Germany, China, Singapore and the US. Our US based office is located in Atlanta, where we continue to provide swift service, comprehensive training and ongoing maintenance support for both single machines and complete plant solutions.

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Alpharetta, GA 30005
office-us@redwave.com
Office: 470.699.1688

## TAILINGS MANAGEMENT

## Paterson & Cooke

www.patersoncooke.com

Paterson & Cooke is a recognized leader in the design and implementation of slurry systems and associated processes. Since our formation in 1991, we have consistently provided technologically superior slurry systems for projects located throughout the world. Our key areas of expertise include: Laboratory Testing, Dewatering Circuit Design, Tailings System Engineering (conventional, cycloning, high density paste, thickened and filtered), Long Distance Slurry Pipeline Systems, Leak Detection Systems, Mine Backfill Systems, Optimization Services, Process Engineering, Process Control, Pilot Plants and Specialized Training Courses.

Paterson & Cooke USA, Ltd
221 Corporate Cir, Ste D
Golden, CO
80401
United States of America
(303) 800-6280
www.patersoncooke.com

## TESTING

## Pocock Industrial, Inc.

www.pocockindustrial.com

Pocock Industrial specializes in solving solids/liquid separation problems. We believe the integration of laboratory expertise with substantial engineering capability, plant operating knowledge, and practical experience, provides a basis for exceptional service. Since 1983, we have served a broad-spectrum of industry and have provided services to many of the major mining, oil, chemical, pharmaceutical, food, and environmental companies. We have also served as consultants to engineering companies, research organizations, legal firms, and academia. We work on a flexible basis and can provide services from complete project responsibility to limited solids/liquid separation testing and consulting. We will work within tight budget constraints, under secrecy agreement, and will provide our services on a competitive basis.

6188 South 300 West
Salt Lake City, Utah USA
Telephone: (801) 265-9000
Cell: (801) 703-8055
maempey@pocockindustrial.com

## TRAINING SERVICES

## Balmert Consulting

www.balmert.com

Recognized as the leader in safety leadership and risk management training Balmert Consulting is a global management consulting firm headquartered in Seabrook, Texas. We offer training products and consulting services designed to achieve a sustainable improvement in execution in operations.

Over the last two decades we have trained over 100,000 line leaders, from front line supervisors and managers to vice presidents, division presidents, presidents, and CEO's, and provided services on six continents, in seventeen different languages, in a wide range of industries achieving exceedingly successful results. The focus of our consultancy and our expertise is at the intersection of execution, leadership and operations. We believe that execution is the difference that makes the difference in converting goals into results.

Our ideas work: it's that simple. They come from our own experience: what we've seen work, and what we've successfully done ourselves. The techniques and practices are simple: instead of programs or processes that create more work, our tools are simply things that leaders do to lead — better. The tools can be immediately put into practice and will start making a difference immediately.

All of which makes what we teach powerful!

Now you can experience the training for yourself, In-person or virtually. You may qualify to attend as our guest.

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Telephone: (281) 359-7234
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## TRENCH SAFETY

### United Rentals Trench Safety

www.unitedrentals.com/trenchsafety

United Rentals is your go-to partner for customized, cost-effective excavation support solutions. With nearly 100 Trench Safety locations and the largest fleet of shoring and underground excavation equipment in North America, we ensure you get what you need, when you need it, on time and on budget. Recognizing that some projects demand unique approaches, our dedicated engineering department offers tailor-made underground solutions that align with your specific requirements and budget constraints. Our innovative and efficient methods not only meet but often exceed traditional shoring techniques, helping you save both time and money. Trust United Rentals to deliver the expertise and equipment necessary for the successful completion of your excavation projects.

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Kansas City, MO 64129
davisch@ur.com

## TRUCKS AND HAULAGE UNITS

### Philippi-Hagenbuch, Inc.

https://www.philsystems.com

Philippi-Hagenbuch, Inc. is a global leader in off-highway truck customization and has engineered innovative haul truck solutions for the mining industry since 1969.

PHIL HiVol® bodies provide excellent stability and safer operation with their accessible loading height, low center of gravity and efficient weight distribution.

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Rear-loading Lowboy trailers from PHIL are simple to operate and designed to offer safe and fast loading and unloading of equipment within 20 minutes.

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### SmithCo Side Dump Trailers

sidedump.com

**Transporting ore more than 7 kilometers?**
Costs add up when hauling longer distances. Traditional haul trucks are expensive and not suited for distance hauls or satellite sites. But there's a solution: SmithCo double-tub tipper mine trailers.

**Going the Distance in Baffinland**
SmithCo tipper mine trailers have been solving the distance haul dilemma for years.
SmithCo tipper mine trailers are engineered for off-road distance hauling with payloads up to 100 tons, and 200 tons with trained trailers. These rugged compact trailers have been used at Baffinland operations since 2015, moving ore more than 100 kilometers from mine to port.

**Compact, Quicker, Lower Costs**
The smaller footprint of tipper mine trailers allows operation in areas too small for traditional haul trucks. The optimized design means lower costs from purchase to production. Optional hydraulic suspensions reduce maintenance and eliminate freeze-ups.

Call or visit sidedump.com/rugged-compact-mining-trailers

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(800) 799-8099
sales@sidedump.com

## TUNNEL BORING EQUIPMENT

### AKKERMAN INC.

www.akkerman.com

Established in 1973, Akkerman develops, manufactures and supports powerful and versatile guided boring, microtunneling, pipe jacking, sliplining, tunneling and earth pressure balance underground construction solutions that accurately install 4-inch through 14-foot pipe diameters for a broad range of ground conditions and project challenges.
Since 1973, our industry-leading equipment has enabled contractors worldwide to productively and cost-effectively install a variety of infrastructure. We back our equipment systems with a powerhouse of skilled sales, engineering and technical professionals dedicated to superior reliability and responsive service. Akkerman factory certified field technicians represent an extensive portfolio of hands-on equipment experience to train your crew on the project site. Aftermarket parts sales are efficiently dispatched to minimize project delays and ensure that your equipment is prepared for optimal performance on its next challenge.

58256 266th Street
Brownsdale, MN 55918-9737
Telephone: 507-567-2261
Fax: 507-567-2605
E-Mail: jholden@akkerman.com

### CREG TBM Germany GmbH

creg-germany.com

CREG - China Railway Engineering Equipment Group Co., Ltd. - is a leading TBM supplier for mechanized tunnelling construction all around the world. CREG provides a full-range of TBM hard- and soft rock solutions together with its up-to-date technical solutions highly oriented towards project challenges and customer expectations.

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40549 Duesseldorf
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Phone: +49 211 522 889 00
Email: info@creg-germany.com

### E-BERK

e-berk.com

E-BERK, a global leader in Tunneling and Foundation Technologies, is headquartered in Ankara, Turkey, with an 18,000 m² state-of-the-art manufacturing facility. For over 25 years, we have been the trusted partner of the tunneling industry, providing cutting-edge disc cutters and cutting tools for Tunnel Boring Machines. Our comprehensive product portfolio includes single, double, twin, and center disc cutters ranging from 7" to 21" in diameter, as well as scrapers, knives, buckets, rippers, ring cutters, and tail brushes compatible with all TBMs. We also produce our own brand TBMs (EPB, slurry, and single shield) and Multi-Purpose Service Vehicles (MSV). We offer cutterwheel design and manufacturing services. Our innovative fabrication techniques deliver cost-effective, high-performance solutions to clients. With a presence in over 30 countries through our subsidiary E-BERK Corporation in the USA and ÖZSÖZ Group, we deliver unparalleled quality, safety, and results to our clients worldwide. Choose E-BERK for Excellence. Reliability. Success.

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## EarthGrid
earthgrid.io

EarthGrid has invented plasma tunnel boring & trenching robots that are solar-powered, use no water, have zero emissions and can bore tunnels 100x faster at 1/10th the cost of conventional techniques. They are building a network of large, underground utility tunnels that improve infrastructure and rapidly accelerate the transition to 100% clean energy by enabling underground clean energy power lines, high-speed data, water, and wastewater, H2 pipelines, e-commerce parcel transportation via pneumatic tubes, etc. They have a BOOM model (Build, Own, Operate and Manage) to lease space to investment-grade utilities, and a BADASS model (Boring And Digging As a Simple Service) to charge per meter or cubic meter at costs of up to 80% below HDD, TBM, and conventional hard-rock trenching.

Contact info:
info@earthgrid.io
833-327-8441

## Herrenknecht Tunneling Systems USA, Inc.
www.herrenknecht.com

Herrenknecht is a technology and market leader in the area of mechanized tunneling systems. As the only company worldwide, Herrenknecht delivers cutting-edge tunnel boring machines for all ground conditions and in all diameters – ranging from 0.10 to 19 meters. The Herrenknecht product range includes tailor-made machines for transport tunnels (Traffic Tunneling) and supply and disposal tunnels (Utility Tunneling). Under the umbrella of the Herrenknecht Group, a team of innovative specialists has formed to provide integrated solutions around tunnel construction with project-specific equipment and service packages upon request. Herrenknecht develops innovative technical solutions to sink vertical shafts down to great depths as well as to successfully excavate sloping shafts. The company also produces state-of-the-art deep drilling rigs that drill down to depths of 8,000 meters.

1613 132nd Ave East, Suite 200
Sumner, WA 98390
Telephone: 253-447-2300
Email: dube.seffen@herrenknecht.com

## Messinger Bearings
www.messingerbearings.com

With over 100 years of experience, Messinger Bearings is one of an elite few companies capable of producing extra-large (up to 18 feet in diameter), custom-designed bearings for TBMs. In fact, Messinger focuses only on manufacturing new and expert repairing of large custom bearings for special applications. Messinger goes above and beyond supplying just the bearing, offering complete solutions (field inspection, bearing storage tanks, bolt torqueing, vibration analysis, etc.) With Messinger's expanding core of expertise and experience, you can expect a quick response, unparalleled technical support, field service and timely delivery to better support the tunnel market.

Contact: Don Barnhurst
Phone: 215-824-4987
Email: dpb@kingsbury.com

## Palmieri spa
www.palmierigroup.com

With over 40 years of experience in the manufacturing of Tunneling and Drilling parts and consumables, the Palmieri is nowadays one of the most experienced and specialized group of companies worldwide.

Design and production of either rolling and fixed tools for any type of excavation; from horizontal boring (Tunnels for road, railways and water) to vertical boring and drilling.

Engineering development, manufacturing, refurbishment and rental of underground equipment such as TBMs, Raise Boring Machines, Microtunnelling/Pipejacking equipment, Cutterheads, Back-Up systems, Rolling Stock, as well as innovative and non-conventional solutions for all the above-mentioned business sectors.

Via Industria 58
40041 Gaggio Montano
Bologna, Italy
info@palmierigroup.com
Ph. +39053432511

## TERRATEC
www.terratec.co

Incorporated in 1990, TERRATEC is a world renowned designer & manufacturer of Tunnel Boring Machines, encompassing all ground conditions and diameters – ranging from 0.60 to over 16 metres – as well as TBM back-up equipment, Raise Boring Machines and other custom-engineered products for the tunnelling and mining industries. TERRATEC's success is based on the experience and excellence of its global engineering team. TERRATEC is also fully managed by engineers enabling quick and efficient solutions that meet customer expectations.

TERRATEC products are well-known in the industry as Robust, Durable and Safe, basic principles that must prevail in the design of any equipment made to work in the extreme conditions encountered underground. Providing Total Tunnelling Solutions, TERRATEC's scope of work extends to custom engineering, as well as the operation and maintenance of tunnel boring equipment and the supply of ancillary equipment.

As a result, it is becoming more and more common for TERRATEC to supply a Total Tunnelling Solution package consisting of the TBM/s, other main equipment in the tunnel (Trains, Conveyors, Segment Moulds and Ventilation), spares and consumables for the equipment and a team of field personnel who assist in the operation and maintenance of the supplied equipment throughout the project.

TERRATEC offers full range of equipment from pipe jacking machine to open TBM, soft ground to very hard rock machine. TERRATEC's continuing success on global projects is a result of tailor-made robust TBM design, prompt onsite assistance, readily available stock of TBM spares and highly-skilled specialised TBM support throughout tunnelling operations.

171 Davey Street
Hobart, Tasmania, 7000 AUSTRALIA
Telephone: +61 362233282
Fax: +61 362233268
Email: info@terratec.co

# TUNNEL COMMUNICATION SYSTEMS & EQUIPMENT

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iwtwireless.com

Innovative Wireless Technologies, Inc. (IWT) is the leading supplier of wireless communication, tracking and data systems for underground applications. IWT's SENTINEL™ system is easy to install and maintain and provides clear voice communications for maximum productivity and low cost of ownership. Continuous tracking and sensor data is also available – all in one system. IWT offers line-powered infrastructure for long term projects, or battery-powered infrastructure for short term inspections. IWT equipment is 100% recoverable and reusable once the project is completed.

Start the conversation today at iwtwireless.com.

Always Thinking. Always Solving. Always Innovative.

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sales@iwtwireless.com

# TUNNELING AND UNDERGROUND CONSTRUCTION

## RiteChoice Ducting, LLC
www.ritechoiceducting.com

RiteChoice Ducting is a leading US manufacturer of flexible ducting for tunneling and underground

construction. We offer highly customized options that are tailored to your needs. The flexible ducting that we offer is an integral component in tunneling and construction used for vacuuming, heating, cooling, and dehumidifying. They help reduce contamination and cleanup for tight spaces, while also providing venting in outdoor/indoor construction sites.

What makes RiteChoice, your choice? Simply, we offer great customer service and quick turnaround. We have our ducts in the warehouse and ready-to-ship, often the same day. RiteChoice Ducting is one of those companies that will truly make an impact on your business.

7265 S 1st Street
Oak Creek, WI 53154
Telephone: 262-297-8900
E-Mail: kate@kedersolutions.com

## TUNNEL LINING AND SUPPORT MATERIALS

### BarChip Inc.

www.barchip.com

BarChip is the worlds' leading manufacturer of high-performance macro synthetic fiber concrete reinforcement. BarChip is a solutions provider, not just a fiber supplier, and is focused on providing customers with the highest level of technical and application support. For more than two decades BarChip has supplied trusted reinforcement solutions to clients all over the world and has become the fiber of choice for major infrastructure projects.

Research and development are core philosophies of BarChip, who engage in world leading research with academic institution and industry bodies that keep BarChip as the industry benchmark for high performance fiber reinforcement.

We believe the future of concrete reinforcement exists in materials that:

- Eliminate corrosion.
- Are low carbon.
- Are safe and easy to install.
- Reduce construction time and cost.
- Enable 100+ year design life with minimal maintenance

By embracing BarChip technology, we've created a concrete reinforcement system for the 21st century, a system that delivers long lasting value to our customers and to society.

Office: 704-843-8401
400 N. Broome St. | Suite 200
Waxhaw, NC 28173
naadmin@barchip.com

### Channeline

https://channeline.com/

For over four decades, Channeline has been a global leader in the custom design and manufacture of high-quality, fully structural glass reinforced plastic (GRP) lining systems in any shape, and any size, for the trenchless rehabilitation of existing sewers, tunnels, culverts, stormwater, and other buried structures. With a worldwide presence in over 30 countries, we offer turnkey, innovative, and sustainable solutions with a design life of 150 years, for our clients, consultants, and contractors from design to installation.

597-546, Dubai Investment Park 2,
Dubai, United Arab Emirates
Phone: +971 4 8848383
Fax: +971 4 8848384
info@channeline.com

### Dolenco Tunnel Systems

www.dolencodrain.com

Dolenco Tunnel Systems is manufacturer of Dolenco® Drain - a unique drainage solution for tunnels and other underground structures.

Installing Dolenco® Drain on the negative side, permanently prevent water pressure behind shotcrete in tunnels, basement walls and floors, shafts, mining, retaining walls and slopes, both for new and existing structures.

A fast and durable solution, which makes it cost effective both during construction and service life period.

We help to improve underground structures and keep it dry during the lifetime of the structure, and reduce construction time, costs and $CO_2$.

Build safe underground structures, by permanently preventing pressure with Dolenco® Drain.

Mark Riabenko
Business Development Representative
riabenko@dolencodrain.com

## UNDERGROUND - CONSTRUCTION AND STRUCTURES

### Frontier-Kemper Constructors, Inc.

www.frontierkemper.com

Frontier-Kemper's Mine Development Division provides comprehensive, mine development services to our owners and partners. With techniques such as Blind Drilling, Raise Boring, Conventional Shaft Sinking, and Slope Construction, Frontier-Kemper has developed underground mines for coal, salt, copper, gold, and other minerals throughout North America.

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Evansville, IN 47710 USA
Telephone: (877) 554-8600
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### HUESKER Inc.

www.HUESKER.us

HUESKER Inc. - Made in America since 1991.

Minegrid® has become the industry standard for longwall recovery, roof, and rib control due to its high strength-to-weight ratio, flexibility, and safe handling.

HUESKER has supplied over 1,400 Minegrid® longwall recovery systems in the United States, Australia, South Africa, Norway, and the United Kingdom since 1994, making coal mining safer, faster, and more cost-effective.

Minegrid® conforms to Fire Retardant Anti-Static (FRAS) requirements, which complies with Standardized Small Scale Flame Test Procedure for the Acceptance of Roof-Rib Grid Material from MSHA.

Minegrid® is used successfully as rib support, highwall protection and in shotcrete applications due to ease of handling and installation, durability and withstanding extreme conditions, while still offering higher tensile strength compared to wire mesh.

Over the course of four decades, HUESKER's Minegrid® has earned a global reputation for increased safety and productivity.

Tom Bailey
Business Area Manager - Mining
P.O. Box 411529, Charlotte, NC 28241, USA
Telephone: [704] 588-5500
Telephone: [704] 927-7907
Mobile: [704] 737-1462
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### MAPEI UTT

MAPEI's UTT team's experts understand underground construction's challenges & provide customized solutions including chemicals for shotcrete, mechanized tunneling, injection & waterproofing.

Underground Technology Team
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### MICHELS CORPORATION

http://www.michels.us

Michels is a turnkey contractor for the design and construction of trenchless solutions for energy, energy transition, transportation, water and wastewater projects in North America. Through early contractor involvement and alternative delivery models, Michels partners with customers to clearly understand the desired outcome before reviewing options and risks to provide customers with the safety, best-value options for completing complex projects. Michels' self-performed support services include shafts and bracing systems to connect underground work areas to the surface while keeping crews and equipment separated from water, groundwater, rock and soil.

817 Main Street, PO Box 128
Brownsville, WI 53006
Telephone: 920-583-3132
E-Mail: corpinfo@michels.us

## UNDERGROUND EXCAVATION SERVICES AND EQUIPMENT

### ASI Group Ltd.
https://asi-group.com/

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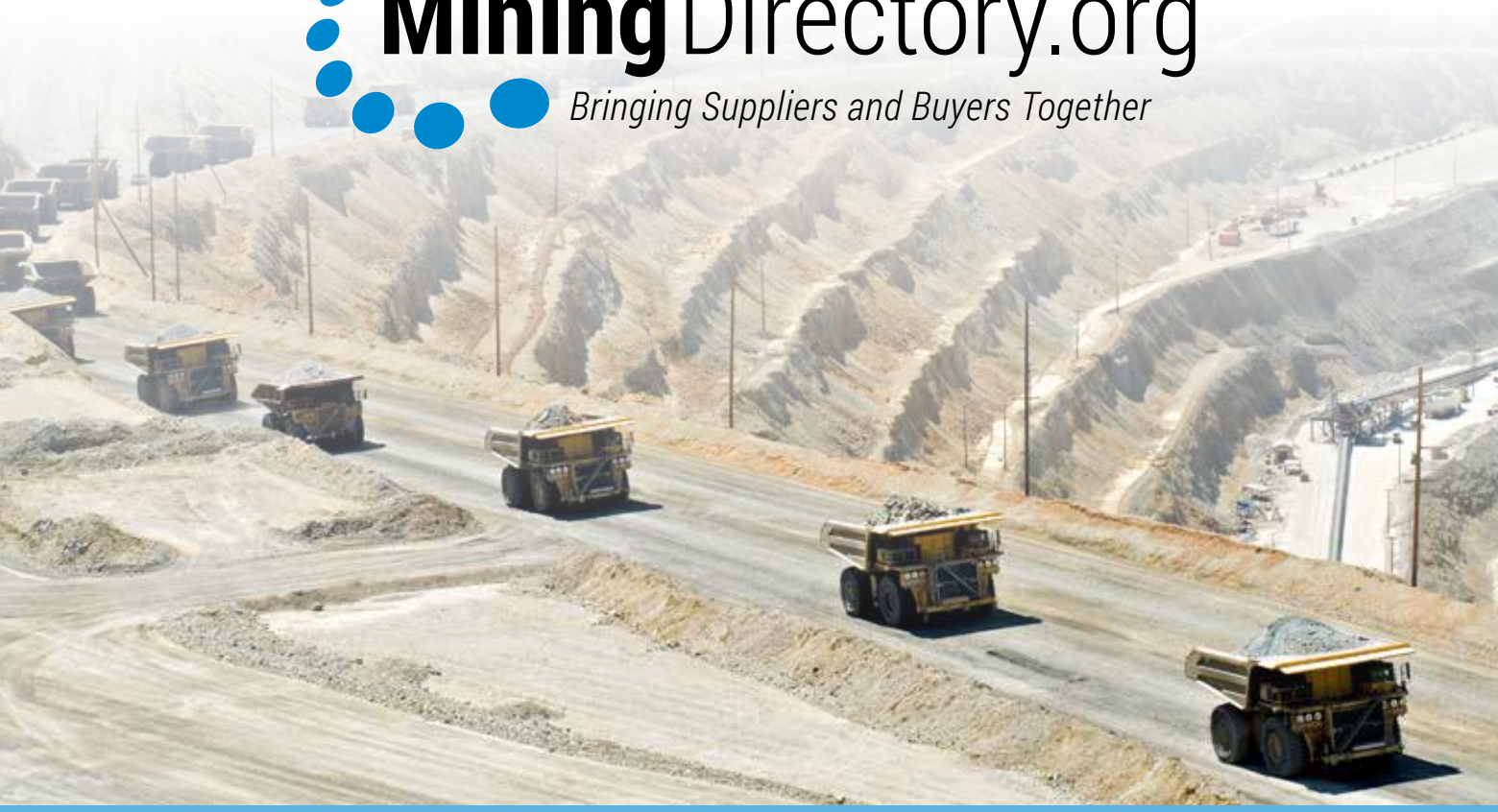

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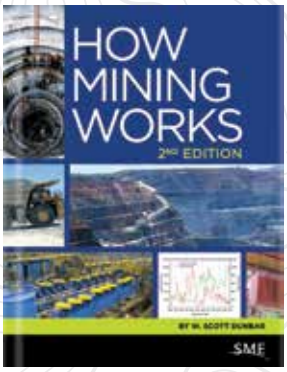


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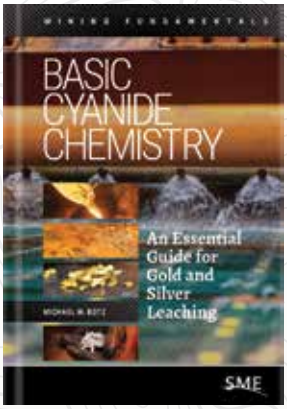


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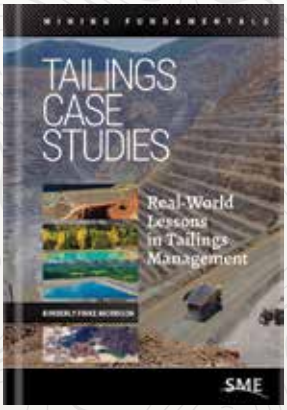


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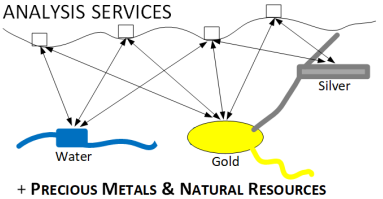


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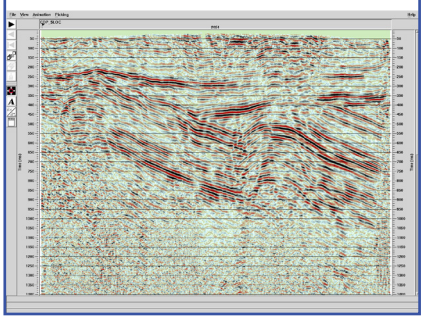

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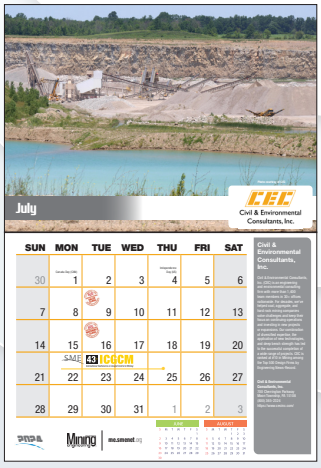


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# Diversity drives mining industry forward

**William Gleason**
**Editor**

While reviewing the content for this month's edition of *Mining Engineering* I noticed a theme of diversity emerge. When we crafted the annual editorial calendar a year or so ago, diversity was not a topic for this issue and there are no articles specially dedicated to this very important issue to the industry, but it emerged nonetheless in the form of people, commodities and areas of interest.

Each year, the July issue features the Industrial Minerals Review. My sincere thanks go out to Jim Norman, Himesh Patel and all of the authors for their herculean effort to pull together the summaries of all the commodities, 38 this year. I'd also like to thank Mike O'Driscoll for his summary of the industrial minerals sectors. O'Driscoll keeps his finger on the pulse of this interesting, yet sometimes overlooked, sector of the mining industry. In his introduction to the section, O'Driscoll writes that while the sector has sometimes been called "the third world" of the industry, now might be the time for industrial minerals to gain the rightful recognition of their importance. He says, "2023 might be considered the year that (finally) marked the decade of industrial mineral criticality recognition. We know that industrial minerals are the building blocks of our economy and essential to our everyday life, but owing to several factors (such as supply-chain vulnerability exposed by the COVID-19 pandemic, shipping crises, the Russia-Ukraine war, overreliance on China, new technologies), the last few years have seen a growing awareness of industrial minerals' importance in the mainstream — that is, not just by the wider industry, but crucially, from state and national governments and the public sector."

Which brings me to the theme of diversity. We are often inundated with news about copper or gold. Whether it's about a company trying to get permits to begin mining or a potential mega merger, much of the news is about the higher-profile minerals. But in this issue we see the importance of a diverse range of commodities, including those needed for national defense.

"Key minerals, such as bauxite, alumina, andalusite, magnesite and graphite, are not just commodities; they are strategic assets that empower nations with the capability to produce armor, weaponry and other critical military infrastructures," O'Driscoll writes on page 22. "Similarly, the abrasives market, which includes materials used for cutting, grinding and polishing, depends on minerals like fused alumina, silicon carbide, garnet and diamond. Precision manufacturing and maintenance processes for military equipment require the highest-quality abrasives to ensure performance and reliability under the most extreme conditions."

O'Driscoll goes on to write about the importance of minerals for batteries, including salt, used to make the sodium for Na-ion batteries.

In addition to the Industrial Minerals Review this issue includes a full circle look at the industry's most important commodity, its people.

Starting on page 80, managing technical editor Chee Theng continues *Mining Engineering's* multipart series highlighting the universities in the United States that offer mining and/or mineral processing degrees. We are all aware of the challenges these universities face in attracting students to the industry, and we hope this series can help support them. Theng provides an insider look at South Dakota Mines, The University of Utah, The Pennsylvania State University and West Virginia University in this installment. A diverse range of voices share their insights into their experiences at these institutions. A common theme throughout is the vast opportunities they have found in an industry that is desperate for qualifed and educated people.

In the SME News section of this issue, you can see the diversity of the people in the industry and get introduced to many people who are moving into leadership roles within SME through SME's Divisions. The work done by these folks is incredibly important to the Society and to the mining industry as well.

And finally, this issue also pays respect to some industry leaders and legends who are no longer with us. On page 112, Marc LeVier and Jim Komadina share a tribute to Len Harris, a true legend in the industry. Along with his wife Rosa, the pair lived a life that seemed to be torn from the pages of an Ernest Hemingway novel. A life that will leave a lasting legacy for generations. Likewise, we share the memoriam of Raymond Lowrie, whose distinguished career included time with the U.S. Bureau of Mines and work editing SME's *Mining Reference Handbook*. And Robert "Bruce" Kennedy, who made connections around the world during his career. And it is with great sadness we share the memoriam of Rebecca Bweupe-Siwale, a remarkable leader whose career included a place among the 100 Global Inspirational Women in Mining, and whose life ended far too soon. ■

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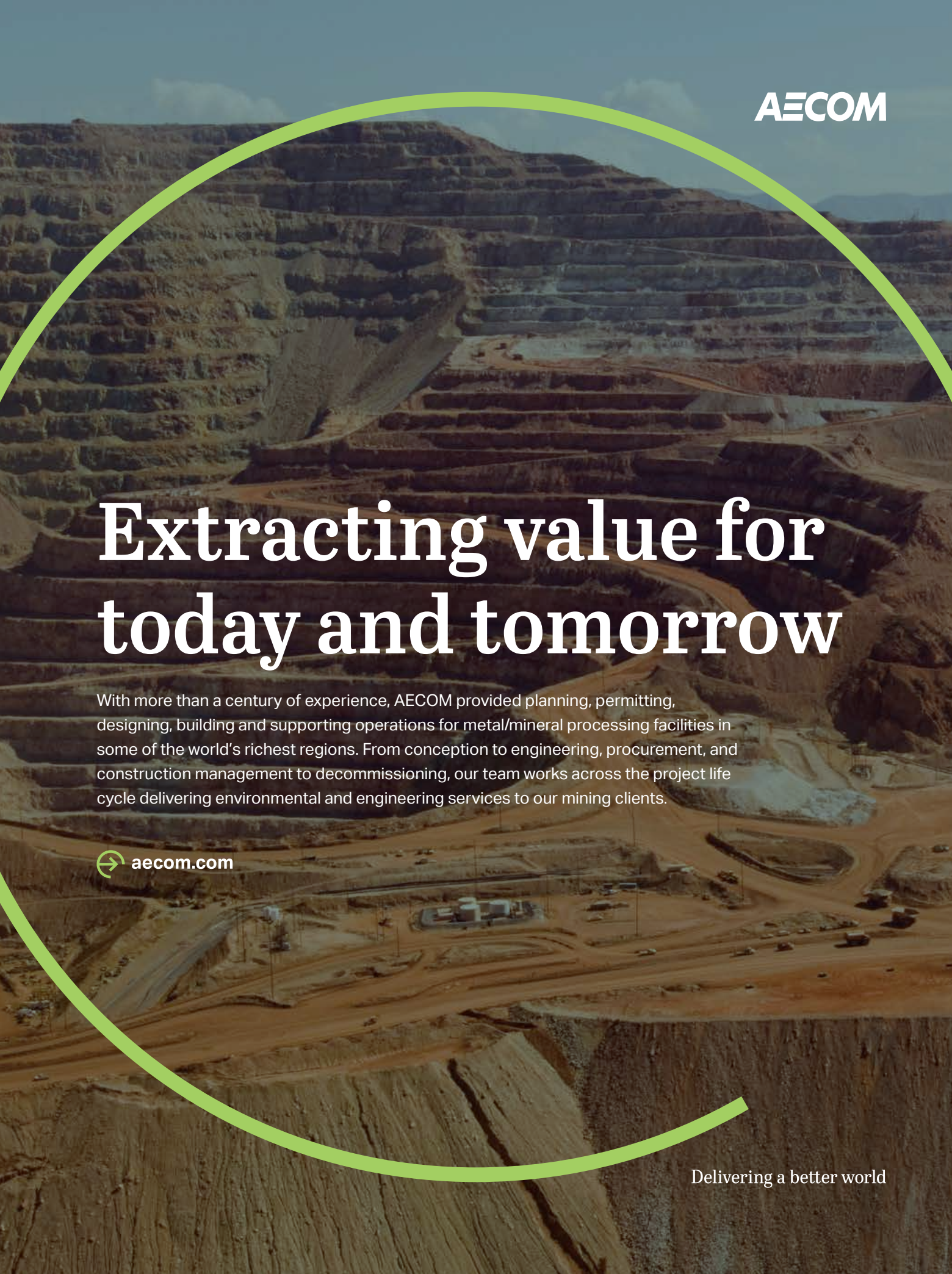
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