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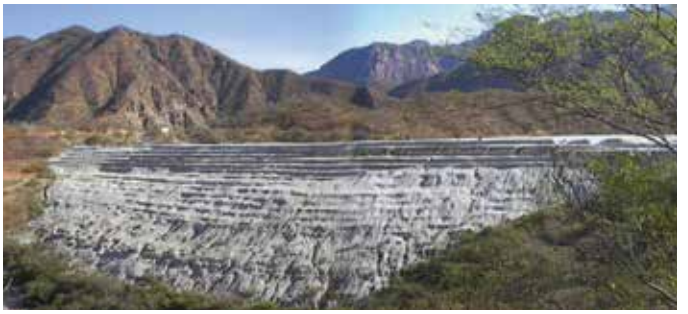
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Industrial minerals again accounted for the majority share of total mine production in the United States by value at $72.1 billion, or 54 percent. In this issue the SME Industrial Minerals & Aggregates Division supplied summaries of 40 industrial minerals. Cover photo credit: Shutterstock. Cover design by Ted Robertson.



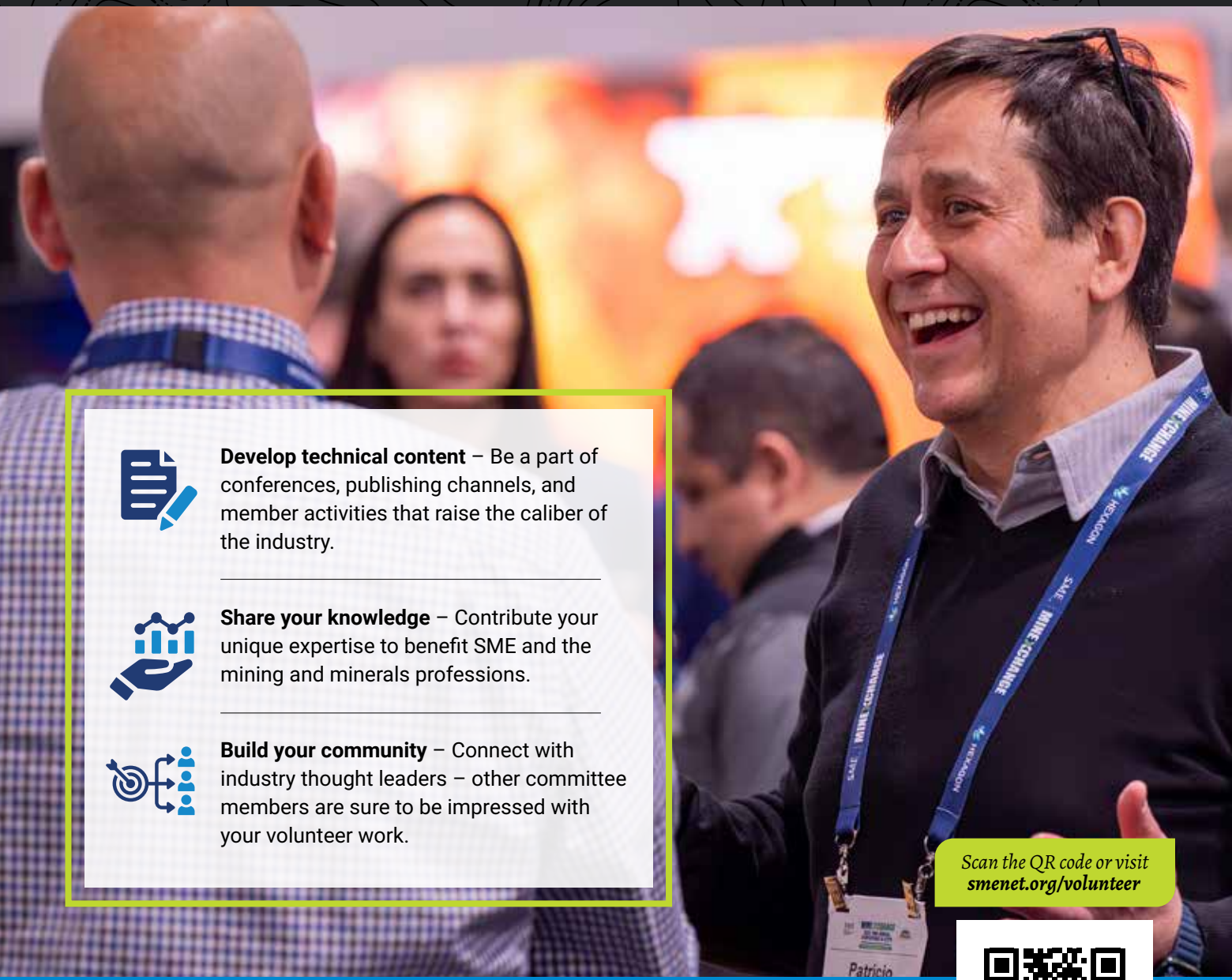
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Workforce challenges remain at the forefront;
SME will continue to support mining education



Bill A. Hancock
2025 SME President

Workforce issues, specifically having enough professionals available to fill positions in the mining and underground-construction industries, is a substantial challenge. Although SME has been redoubling its efforts and investments in professional workforce development programs, the issue will be significantly compounded with the projected dramatic production increases required and the projected reduction in graduation rates over the next decade.

Complicating things for the mining industry are low public visibility of what we do and a general problem of poor perception of the industry. Somewhat encouragingly, surveys of younger people reveal the following insights: (1) there is limited awareness regarding the availability and breadth of professional career opportunities in our industry and (2) their perception of the industry appears much less negative than we feared.

Positively, at a recent inaugural U.S. Mining Summit of mining department heads in Tucson, AZ it was reported that student enrollments are beginning to increase at most of the 14 mining programs. Individuals from the University of Texas, El Paso (UTEP) attended the summit. They are focused on a 2027 start for the launch of a new mining degree program at UTEP. Tennessee State University in Nashville also announced that it will offer a minor in mining this fall with the intention to offer a B.S in mining engineering in two to three years. The June issue of *Mining Engineering* included a feature article about the efforts of Bluefield State University to restart its mining engineering program.

Many students have come to realize that a career in mining is vibrant, technically challenging, exciting and of value. The world's focus on critical minerals production elevates mining's importance in public consciousness, which will further help in recruiting professionals to our industry.

During the past three decades, SME has invested much time and effort to increase mining's visibility and to improve the perception of mining, primarily through the SME Foundation (SMEF). The SMEF's Minerals Education Coalition's (MEC) emphasis has been on K-12 students through a variety of programs, including in-class presentations, teacher class materials, Scout merit badges, the popular SME booths at the National Science Teaching Association regional conferences and, more recently, exhibiting at the annual American School Counselor Association conferences.

More than two decades ago, SME became acutely aware that some universities were closing their small programs that unfortunately resulted in several mining degree programs being shut down, including my alma mater the University of Minnesota. Over the intervening years SME also realized mining faculty was aging as many professors were nearing or were retirement eligible.

Recognizing universities are less likely to close departments that have tenured professors, beginning in 2015 the SME Foundation began

(continued on page 14)

Safety Share | Yard work is a common and often satisfying task, but it comes with a variety of hazards that can lead to serious injuries if not approached with caution.

Physical injuries are among the most common hazards. Lawn mowers, trimmers and chainsaws can cause cuts, amputations or eye injuries if used improperly or without protective gear. Always wear safety glasses, gloves and sturdy footwear, and ensure equipment is well maintained and turned off before servicing.

Heat-related illnesses such as heat exhaustion or heat stroke are also a concern, especially during summer months. Stay hydrated, take frequent breaks in the shade and avoid working during peak heat hours.

Chemical exposure from fertilizers, pesticides and herbicides can lead to skin irritation, respiratory issues or poisoning. Always read labels, wear appropriate personal protective equipment (PPE) and store chemicals safely out of reach of children and pets.

Ergonomic hazards like repetitive motion, awkward postures and heavy lifting can cause strains and sprains. Use proper lifting techniques, switch tasks frequently and use tools designed to reduce strain.

Lastly, be aware of environmental hazards such as uneven terrain, insects and hidden debris. Inspect your work area before starting and keep a first-aid kit nearby.

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Critical minerals tax credit removed from spending bill

U.S. PRESIDENT Donald Trump's tax and spending bill would make it harder for American critical minerals companies to compete with China because it eliminates a tax credit for boosting domestic production of nickel, rare earths and other materials used in advanced electronics and weaponry.

Reuters reported that the U.S. House of Representatives passed a version of his "One Big Beautiful Bill Act" in May that eliminates the so-called 45X credit.

Former President Joe Biden's 2022 climate change law, the Inflation Reduction Act, created the 10 percent production credit — a reduction in corporate taxes for critical minerals extraction and processing. The tax break also covers solar, battery and wind projects.

The version of the bill that passed the House treats government incentives for wind turbines the same as those for mining projects that many view as crucial for national security. Critical minerals companies now say their projects are collateral damage to the political feud over renewable energy.

The tax credit is already law and part of the current federal budget. The nonpartisan Congressional Budget Office, which scores the cost of legislative proposals when asked by Congress, has not studied how much would be saved by removing the credit.

The Republican majority in Congress is seeking savings to fund other priorities such as tax cuts, defense and balancing the budget.

Miners, though, say they need the credit to compete with China. Beijing has halted exports of some critical minerals, used its control of rare earths to strike a trade agreement with Washington and flooded global markets with cheap supply of nickel, cobalt and lithium.

"If we do not have that tax credit, critical minerals producers in the U.S. are at risk of succumbing to closures," said KaLeigh Long, founder and chief executive officer of Westwin Elements, which is building the country's only commercial nickel refinery.

Westwin might not be able to service its debt without the tax credit, Long said, noting the company's loans were modeled using the expectation it would be permanent. In May, Long wrote a letter asking the Senate to keep the credit. It was co-signed by 30 industry executives.

Any changes the Senate makes to the bill must be reconciled with the House version before being sent to Trump.

House Democrats unanimously voted against the bill but their criticism has focused on tax cuts they say will widen the deficit while requiring cuts in health care, food assistance, education, scientific research and other programs.

"There're so many issues right now under consideration in Congress and this one isn't breaking through, but it will certainly break through when we have a shortage of minerals in five years," said Jeff Green, a critical minerals industry consultant.

Trump, who has issued several executive orders aimed at boosting U.S. minerals production, has not commented publicly on the 45x debate. The White House did not respond to requests for comment.

"The tax credit just adds a phenomenal bump to a project's economics and gives us advantages that China already gives its own companies," said Alex Grant, chief executive officer of magnesium processing startup Magrathea, who signed the letter. China controls most of global production of the metal, used in alloys for steel and aluminum. ■

Resolution Copper welcomes republication of FEIS

THE U.S. FOREST Service (USFS) has republished the final environmental impact statement (FEIS) of the Resolution Copper project. The republication allows the USFS to advance the congressionally mandated land exchange, enabling future underground mine development and placing thousands of acres of land into permanent conservation.

Resolution Copper welcomed the republication of the FEIS as a positive step forward for the project.

"Through this process, we have deepened our relationships with local communities and Native American Tribes, including our senior leaders spending time with Tribal leaders to listen and build mutual understanding," said Vicky Peacey, general manager of Resolution Copper. "We welcome the opportunity to continue these conversations as we move into the next phase of permitting. Working together, mining can coexist with cultural heritage, recreation and nature while delivering new economic opportunities in rural Arizona."

Peacey added, "This project has undergone one of the most comprehensive environmental and social reviews in U.S. history. The republication of the FEIS reflects the thorough work by the USFS, local communities and Native American Tribes and the seriousness with which all stakeholders have approached this process."

For more than 10 years, the USFS, in consultation with Native American Tribes, local Copper Triangle communities, civil society organizations and a dozen federal and state agencies have shaped the Resolution Copper project through a rigorous, independent review under the National Environmental Policy Act.

As part of the land exchange, Resolution Copper has committed to initiatives that support cultural preservation, recreation, education, employment, economic development and nature through long-term partnerships with Native American Tribes and local communities. This includes significant funding in a long-term Native American Trust Fund and Emory Oak restoration. Other commitments focus on conservation and monitoring of seeps and springs; restoration and preservation of creeks, rivers and watersheds; and habitat enhancement for biodiversity. ■

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Global alarms rise, especially among automakers,
as China's export ban on critical minerals takes hold

ALARM OVER China's stranglehold on critical minerals grew as global automakers joined their U.S. counterparts to complain that restrictions by China on exports of rare earth alloys, mixtures and magnets could cause production delays and outages without a quick solution.

German automakers became the latest to warn that China's export restrictions threaten to shut down production and rattle their local economies, following a similar complaint from an Indian electric-vehicle maker.

China's decision in April to suspend exports of a wide range of critical minerals and magnets has upended the supply chains central to automakers, aerospace manufacturers, semiconductor companies and military contractors around the world.

The move underscores China's dominance of the critical mineral industry and is seen as leverage by China in its ongoing trade war with U.S. President Donald Trump.

Trump has sought to redefine the trading relationship with the United States' top economic rival China by imposing steep tariffs on billions of dollars of imported goods in hopes of narrowing a wide trade deficit and bringing back lost manufacturing.

Trump imposed tariffs as high as 145 percent against China only to scale them back after stock, bond and currency markets revolted over the sweeping nature of the levies. China has responded with its own tariffs and is leveraging its dominance in key supply chains to persuade Trump to back down.

Trump and Chinese President Xi Jinping are expected to talk, White House spokeswoman Karoline Leavitt told reporters, and the export ban is expected to be high on the agenda.

"I can assure you that the administration is actively monitoring China's compliance with the Geneva trade agreement," she said. "Our administration officials continue to be engaged in correspondence with their Chinese counterparts."

Trump has previously signaled that China's slow pace of easing the critical mineral export ban represents a violation of the Geneva Agreement.

Shipments of the magnets, essential for assembling everything from cars and drones to robots and missiles, have been halted at many Chinese ports while the Chinese government drafts a new regulatory system.

Once in place, the new system could permanently prevent supplies from reaching certain companies, including American military contractors.

The suspension has triggered anxiety in corporate boardrooms and nations' capitals — from Tokyo to Washington — as officials scrambled to identify limited alternative options amid fears that production of new automobiles and other items could grind to a halt by summer's end.

"If the situation is not changed quickly, production delays and even production outages can no longer be ruled out," Hildegard Mueller, head of Germany's auto lobby, told *Reuters*.

Frank Fannon, a minerals industry consultant and former U.S. Assistant Secretary of State for energy resources during Trump's first term, said the global disruptions are not shocking to those paying attention. ■

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Perpetua Resources receives
additional funding for Stibnite project

MINING COMPANY Perpetua Resources said it has been awarded up to $6.9 million in additional funding from the U.S. Army for its Idaho antimony and gold Stibnite project, *Reuters* reported.

The Pentagon-backed mine, which would be the country's first antimony project, has an estimated reserve of 148 million pounds of the metal used in bullets and tanks, as well as in alloys for electric-vehicle batteries.

China, responsible for nearly 60 percent of globally mined antimony in 2024, banned exports of the metal to the United States in December last year, prompting efforts to increase production within the United States.

This supplemental award will allow Perpetua to expand the research and support the U.S. Army's objective of establishing a fully domestic "ground-to-round" antimony trisulfide supply chain.

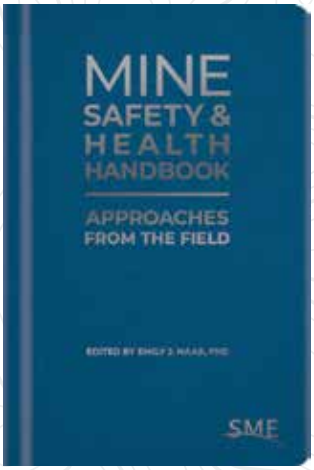
"Advancing America's capabilities to process minerals critical to national defense is essential for our long-term mineral independence and resilience," said chief executive officer Jon Cherry.

The company said that with the receipt of this additional funding, its total awards from the Department of Defense exceed $80 million, including the $15.5 million received under an Ordnance Technology Initiative Agreement in August 2023.

In June, the company received the final federal permit, the Clean Water Act Section 404, from the U.S. Army Corps for the project. ■

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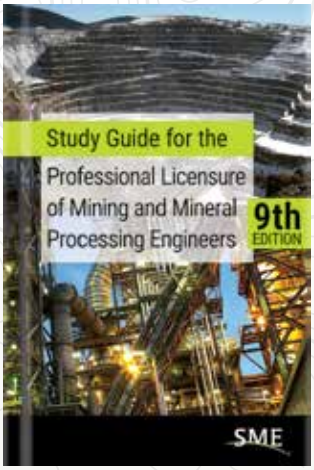
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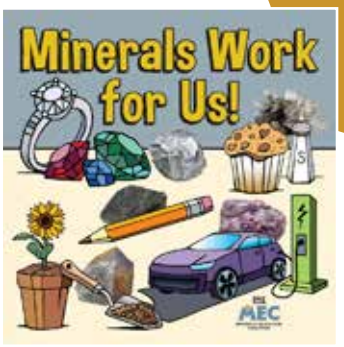


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US Export-Import Bank considers $120 million loan for Greenland rare earths project

CRITICAL METALS CORP has received a letter of interest from the U.S. Export-Import Bank (EXIM) for a loan worth up to $120 million to fund the company's Tanbreez rare earths mine in Greenland, in what would be the Trump administration's first overseas investment in a mining project.

The loan, if approved, would boost U.S. access to minerals increasingly at the center of global economic trade and help offset the country's reliance on market leader China. It also comes after President Donald Trump openly mused earlier this year about acquiring the Danish island territory, an overture that has been repeatedly rejected.

In a letter dated June 12 and reviewed by *Reuters*, New York-based Critical Metals has met initial requirements to apply for the $120 million EXIM loan and, if approved, would have a 15-year repayment term, longer than the company likely would have with private financing.

The project would have to be "well-capitalized with sufficient equity from strategic investors" to receive the loan, the letter said. EXIM, which acts as the U.S. government's export credit agency, said in the letter that Critical Metals qualifies for a loan program designed to support companies that compete with China.

The Tanbreez project is expected to cost $290 million, and the EXIM funds would be used to fund technical work and get the mine to initial production by 2026. Once fully operational, the mine is expected to produce 85 Mt/a (94,000 stpy) of a rare earths concentrate and two minor metals.

"This funding package is expected to unlock significant value for our project and our stakeholders," said Tony Sage, the company's chief executive officer.

Representatives for EXIM were not immediately available to comment.

The move is the latest in a series of supportive actions by Washington toward the Tanbreez deposit and Greenland's mining sector. *Reuters* reported in January that former President Joe Biden's administration had successfully lobbied privately held Tanbreez Mining not to sell to a Chinese developer and instead sell to Critical Metals.

Biden officials were visiting Nuuk as recently as last November trying to woo additional private investment in the island. Trump sent Vice President JD Vance to the island in March.

The island's mining sector has developed slowly in recent years, hindered by limited investor interest, bureaucratic challenges and environmental concerns. Currently, only two small mines are in operation.

Rare earths have strong magnetic properties that make them critical to high-tech industries ranging from electric vehicles to missile systems. Their necessity has given rise to intense competition as Western countries try to lessen their dependence on China's near-total control of their extraction and processing.

Beijing in April put export restrictions on rare earths as part of its trade spat with Trump. The two countries earlier this month reached a truce, although Beijing's control of the sector has exacerbated the West's over-reliance and sparked a global hunt for fresh supplies. ■

Greenland gives European Union-backed critical metals project permit to mine

GREENLAND HANDED a 30-year permit to a European Union (EU)-backed project that aims to mine molybdenum, a critical metal used in aerospace, energy and defense and on which China has imposed export controls, *Reuters* reported.

The resource-rich Arctic island has seen rising activity in its mining sector over the past month, after U.S. President Donald Trump expressed an interest in purchasing it earlier this year. The permit was granted to Toronto-listed Greenland Resources, a company backed by the European Raw Material Alliance, and holds the license to the Malmbjerg project in eastern Greenland, the country's government said in a statement.

The openpit Malmbjerg mine can produce an average 32.8 million pounds of concentrated molybdenum per year, potentially supplying around 25 percent of Europe's molybdenum use, according to the company

Molybdenum is a silvery-white metal used primarily to strengthen steel and improve its resistance to heat and corrosion, making it critical for industrial applications such as defense and clean energy.

China imposed export controls in early February on five metals, including molybdenum-related products, in response to Trump's tariff on Chinese goods. China accounted for about 40 percent of global molybdenum production last year, according to the U.S. Geological Survey. Molybdenum is considered a critical mineral by both the EU and the United States.

Earlier this year, Greenland Resources signed offtake agreements with Finland's Outokumpu and Italy's Cogne Acciai Speciali.

Although rich in natural resources, development of Greenland's mining industry has been slow due to bureaucracy and lack of financing

However, Greenland last month granted an exploitation license to a Danish-French mining group, while the EU this month picked 13 new critical material projects, including a graphite project in Greenland, to increase supply of metals and minerals.

The U.S. government's export credit agency said the company developing a large rare earth mine in Greenland had met initial requirements to apply for a $120 million loan. ■

Provision that would allow mining in Minnesota stripped from "Big, Beautiful" budget bill

MINNESOTA PUBLIC Radio reported that a controversial provision that would open land adjacent to the Boundary Waters in Canoe Area and pave the way for Twin Metals Minnesota to advance its copper and nickel mine was removed from the "Big, Beautiful" budget bill that is being considered by Congress.

The provision called for the return of two federal mineral leases to Twin Metals Minnesota, part of the Chilean mining conglomerate Antofagasta, which is seeking to open an underground copper mine on the shore of Birch Lake outside Ely.

The U.S. House Committee on Natural Resources had included the provisions in the budget reconciliation bill, a budget tool Republicans are using that enables Congress to bypass the 60-vote threshold normally required to pass a bill in the Senate.

But a U.S. House rules committee stripped the language from President Donald Trump's "One Big Beautiful Bill Act." It was one of several provisions taken out for not complying with the budget reconciliation process, because it deals with policy and not strictly budgetary items.

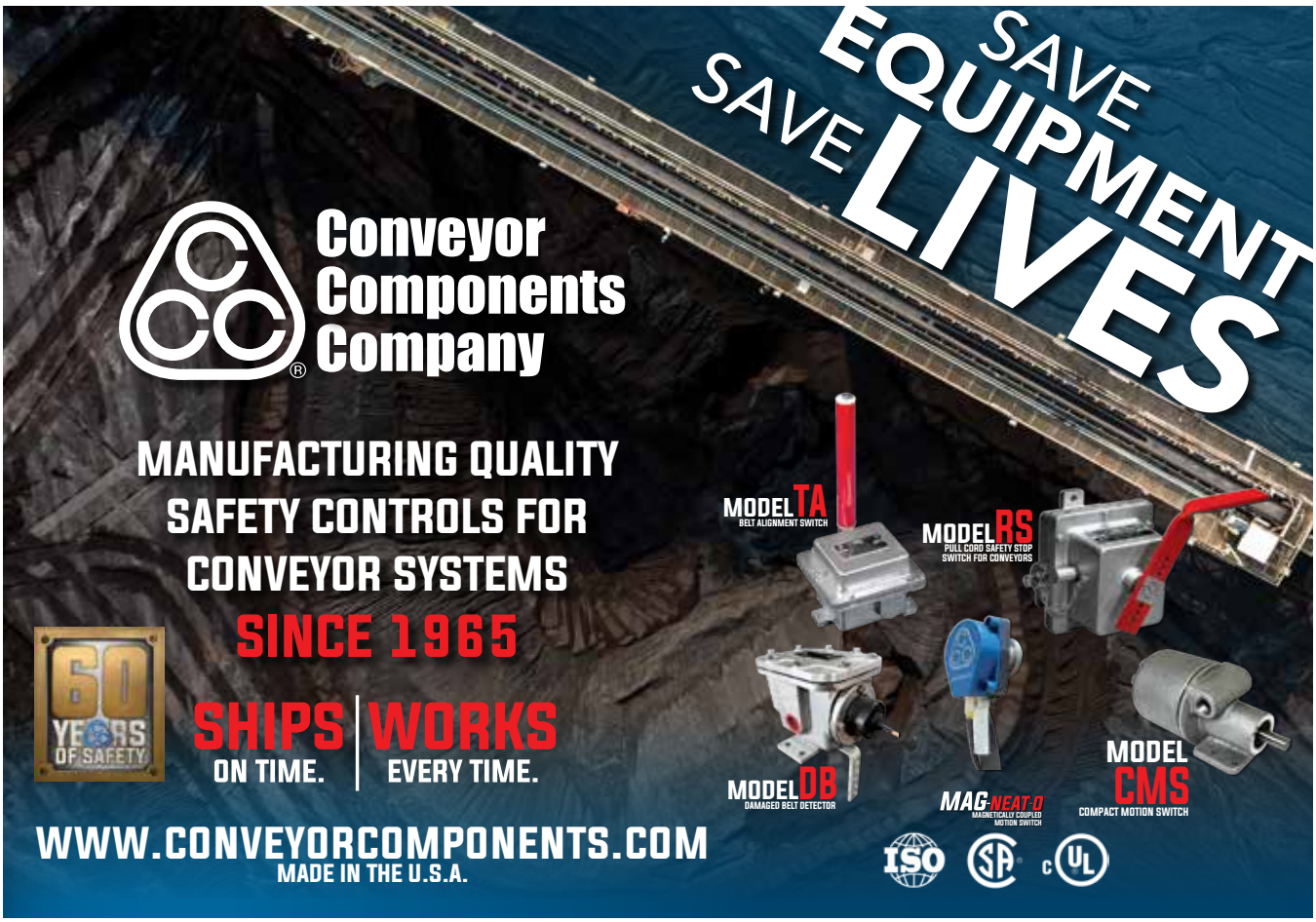
Mining proponents have argued that modern mining methods can protect the Boundary Waters while also providing high-paying jobs in rural Minnesota and the mining minerals needed for the clean energy transition.

Julie Lucas, executive director of the industry group MiningMinnesota, said the language removal delays actions that are needed "to ensure Americans can build and power tomorrow with responsibly mined minerals. Leaders from both sides of the aisle recognize the need to increase our domestic production of minerals, and we welcome conversations about Minnesota's role in meeting those mineral security goals."

U.S. Rep. Pete Stauber, a Republican from the Duluth area who represents northeastern Minnesota in Congress, introduced legislation in February to permanently revoke the mining moratorium and return the leases to Twin Metals.

His bill would also limit the ability of opponents to file lawsuits to block the return of leases to Twin Metals. That language was also included in the stripped portion of the budget bill.

U.S. Sen. Tina Smith has introduced a bill in the Senate to make the 20-year mining ban permanent. Democratic U.S. Rep. Betty McCollum of St. Paul has introduced a similar bill in the House. ■



Teck considers increasing germanium production;
Company talking with governments on funding

CANADA'S TECK Resources is weighing options to expand its production of germanium, a strategic metal key to chipmaking, and is currently talking with governments, including Canada and the United States, on available funding, said Doug Brown, vice president of communications and government affairs.

Reuters reported that Teck's plan comes amid growing efforts to diversify supplies of critical minerals needed for the technology and defence sectors, as geopolitical tensions and trade barriers complicate access to materials mainly produced or refined in China. "We are examining options and market support for increasing production capacity of germanium," he told *Reuters*.

China, which supplies around 60 percent of the world's refined germanium, restricted exports of the metal — along with gallium and antimony, all having broad military applications — to the United States, further escalating trade tensions between the world's two largest economies following Washington's crackdown on Beijing's chip sector.

The export curbs were part of a broader effort launched in 2023, when China began imposing restrictions on critical mineral shipments, citing national security concerns.

By controlling the export of these minerals, China aims to exert influence over the industries that use them, including renewable energy, defense and chip manufacturing.Germanium is also used in semiconductors and infrared technology, fiber-optic cables and solar cells.

Teck is exploring ways to add to the current processing line using existing technology as one of the options, Brown said.

Teck is North America's biggest germanium producer, and the fourth largest globally. Most of its germanium, a byproduct of zinc ore concentrate at its Red Dog operations in Alaska, goes to the United States, via smelting and refining in British Columbia.

Canada's germanium exports to the United States are currently exempt from tariffs as they comply with the USMCA (United States-Mexico-Canada Agreement).

In a speech in Washington last January, Canada's Energy and Natural Resources Minister Jonathan Wilkinson welcomed partnerships with the United States to invest in critical minerals, including germanium.

Canada's Energy Ministry declined to comment on funding for Teck, while saying that the prime minister is leading broader trade negotiations with the United States. ■

Rare earths access is the European Union's priority
at summit with China, sources say

EUROPEAN UNION (EU) leaders will use a summit with China to seek better access to Chinese rare earths and critical minerals, four sources familiar with the plans said, as the two sides tackle an array of tariff-related issues, *Reuters* reported.

For years, China has had a near monopoly on rare earth production. It increased its export controls on the minerals, in demand from automakers, the defense industry and producers of renewable energy, following the tariffs announced by U.S. President Donald Trump on April 2.

China also has grievances with the EU as the bloc has sought to protect its automaking sector from cheaper Chinese imports, while China has imposed measures on France's brandy industry.

European Commission President Ursula von der Leyen and European Council President Antonio Costa will travel to Beijing for the summit on July 24-25. It marks 50 years of EU-Chinese relations and will also take place two weeks after a deadline set by the United States for most trade partners to agree deals to avert higher tariffs.

As automakers have said China's export restrictions on rare earth alloys, mixtures and magnets could cause production delays, European leaders are expected to press their case with President Xi Jinping and Premier Li Qiang in separate meetings, said an EU official, who declined to be identified.

Two EU sources said the EU mission to China is solely focused on rare earths until the summit. China's ministry of commerce in May said a "green channel" expediting rare earth licenses for EU firms had been set up. However, one EU diplomat said that out of several hundred applications, no more than half had shown signs of being processed.

"The situation is improving, although the percentage of cleared licenses does vary. Additionally, even once the license is given, delays can still be seen in customs clearances," Adam Dunnett, secretary general of the European Chamber of Commerce in China, said.

The quest to resolve the supply crunch is among a number of trade conflicts between Europe and China.

Brussels has imposed tariffs on Chinese-made electric vehicles alleging unfair state subsidies, prompting China to impose antidumping measures on EU brandy. Beijing has also initiated trade probes into EU pork and some dairy goods.

The lead-up to the summit has not been smooth. It had been Brussels' turn to be the host but after China indicated Xi would not travel to the Belgian capital, Beijing was chosen as the venue.

Some EU officials said they did not expect the summit to produce major deals, one commenting that China was "playing its cards very well." The official said China had identified rare earths as a major vulnerability and was waiting until the last minute to make any concessions. ■

Weir awarded sustainable tailings solution contracts

for Codelco's tailings dam expansion in Talabre, Chile

WEIR HAS BEEN selected by Codelco, the world's largest copper producer, to supply the tailings transport solution for the Talabre tailings dam expansion project in the Atacama region of Chile.

The brownfield expansion project will combine the thickened tailings streams from three major mines in the area: Ministro Hales, Chuquicamata and Radomiro Tomic. The expansion is expected to have a total productive life of 20 years, and handle a slurry thickened to about 70 percent solid content — creating the opportunity to reuse process water and increasing the safety and stability of the storage facility.

The Weir solution includes a combination of GEHO positive-displacement pumps and WARMAN centrifugal pumps to handle the large volume and high solid content of tailings from the three mines. With the full process enabled with NEXT intelligent digital solutions, the combined equipment will transport more than 10 kt/h using less energy than other available solutions.

The initial £40 million contract awards will be booked in the second quarter of 2025. In total, the contracts represent the single largest order for Weir's GEHO pumps. The company expects revenue to be recognized over the course of the fourth quarter of 2025 and early 2026 in line with project cut-off dates.

After commissioning of the equipment, aftermarket support will be provided locally via Weir's strong service center presence in the region. The receipt of orders associated with the contract award do not result in a change to Weir's full-year 2025 financial guidance as of April 24, 2025.

Commenting on the contract awards, Weir's chief executive officer Jon Stanton said, "We are delighted to have secured these significant contracts for our tailings management solutions, which include both our market-leading GEHO and WARMAN ranges that provide energy-efficient tailings transportation at scale. Our engineers have developed a differentiated solution, particularly addressing Codelco's stringent sustainability goals for operating in the water-scarce climate and geology of the Atacama region. Our proven experience on large-scale tailings operations as well as local presence mean Codelco can come to expect the world-class service Weir is known for." ■



Sandvik Mining earns cybersecurity certification **for secure product development**

SANDVIK MINING has earned an internationally recognized certification for its product development processes, demonstrating its commitment to industry-leading cybersecurity.

Sandvik achieved IEC 62443-4-1 certification at Maturity Level 2 after an independent external audit of its development lifecycle. The IEC 62443-4-1 standard is a leading global benchmark for secure product development in industrial automation and control systems. It helps ensure that products are designed, developed and maintained with cybersecurity in mind, addressing risks including cyberattacks and data breaches throughout their lifespan.

"We're proud to be among the first in our sector to attain IEC 62443 certification," said Riku Pulli, president of Digital Mining Technologies at Sandvik Mining. "This certification reduces cyber risk and operational disruption, enhances safety and regulatory compliance, strengthens supply-chain resilience and provides security assurance for our customers. It emphasizes our commitment to cybersecurity and is a signal of trust and readiness in an increasingly connected and threat-prone industrial environment."

Maturity Level 2 ensures that cybersecurity is proactively integrated into product design, development, testing and maintenance processes. By embedding robust security measures early in the design of its equipment and digital solutions, Sandvik ensures that cybersecurity is built into its products by default. This "secure-by-design" approach reduces the risk of vulnerabilities from the outset, helping to protect mining operations from cyber threats without compromising productivity.

"Sandvik is at the forefront of mining digitalization and our solutions are integral to our customers' critical production processes," said Jaakko Kuivanen, director of Global Automation Product Development and NPD Projects at Sandvik Mining. ■

President's Page: **New initiative under study**

(continued from page 4)

funding a Ph.D. Fellowship program to support a pipeline of academic career-oriented students to gain their degrees and Career Grants to support professors working to achieve tenure. To date, this expensive, more than $8 million program, substantially funded by companies and donors, has been successful. To date 22 of the students SME has supported have obtained their Ph.D.s and 13 of our supported professors achieved tenure. Further, the average faculty age has decreased by an estimated 15 years. These successes were not all SME but we have helped move the needle.

In a recognition of the mining industry's professional workforce challenges, Congress is working hard to pass a solidly bipartisan bill to provide $10 million/year for five years to our mining programs to help attract students and provide additional department funding.

In a new initiative being studied, SME is considering offering online class sequences on specifically needed subjects. As this will be an expensive endeavor, we are studying the market and options for offering course work where SME can be a platform for online and possibly supplementary in-person courses on focused subject matters through multiple courses leading to a certificate.

These course sequences will provide more depth and greater rigor than short courses but shorter than university course work. Further, the 'SMEU' concept affords the opportunity for mining and underground construction industry engineers to become reskilled in new subject matters. 'SMEU' is potentially an exciting new opportunity that will benefit our members and industry by meaningfully increasing professional capabilities and help our present workforce adapt to an evolving workplace.

SME's intention is to continue adding workforce support programs as our Strategic Committees generate viable value-add opportunities.

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Nippon Steel completes $14.9 billion purchase of U.S. Steel in latest deal

NIPPON STEEL'S $14.9 billion acquisition of U.S. Steel closed on June 18, the companies said, confirming an unusual degree of power for U.S. President Donald Trump after the Japanese company's 18-month struggle to close the purchase, *Reuters* reported.

Under the deal terms, Nippon bought 100 percent of U.S. Steel shares at $55 per share, as it first laid out in its December 2023 offer for the well-known but struggling steelmaker.

The companies also disclosed details of a national security agreement inked with the administration, which gives Trump the authority to name a board member as well as a noneconomic golden share.

White House spokesman Kush Desai called the deal historic and said the golden share would "safeguard America's national and economic security." Eiji Hashimoto, Nippon Steel's chairman and chief executive officer, thanked Trump for his role, adding that "Nippon Steel is excited about opening a new chapter of U.S. Steel's storied history."

The agreement contains an unusual level of control conceded by the companies to the government to save the deal, after a rocky path to approval spurred by high-level political opposition.

The inclusion of the golden share in particular to win approval from the Committee on Foreign Investment in the United States, which scrutinizes foreign investment for national security risks, could drive overseas investors away from U.S. companies, national security lawyers have said.

"The optics of a golden share — they suggest that it's a little bit harder to divorce pure national security analysis from political decision-making," said Josh Gruenspecht, a national security lawyer at Wilson Sonsini. The press release announcing the deal notes the golden share gives the U.S. government rights, including, "The right to appoint one independent director; and Consent rights of the President of the United States, or his designee, on specific matters."

The U.S. government will have veto authority over a raft of corporate decisions, from idling plants to cutting production capacity and moving jobs overseas, as previewed in a weekend social-media post by Commerce Secretary Howard Lutnick. The share also gives the government a veto over a potential relocation of U.S. Steel's headquarters from Pittsburgh, a transfer of jobs overseas, name change, and any potential future acquisition of a rival business, the release shows. ■



(continued on page 17)

Successful conversions of former slurry tailings embankments into filtered tailings storage facilities in Durango, Mexico

by Humberto F. Preciado, Daniel A. Servigna and Pedro V. Porcayo

This case study presents successful conversions of two conventional slurry tailings storage facilities (TSFs) to filtered tailings storage facilities in Durango, Mexico, for two mining operations with production rates ranging from 1,200 to 4,500 t/d (1,320 to 4,960 stpd). In both cases, the decision to make the conversion was driven by:

- Ability to increase the storage capacity via stacking of filtered tailings.
- Reduction of the tailings' impacted footprint.
- Mitigation of long-term geotechnical stability risks.
- Alleviation of environmental risks by reducing tailings water as a source of pollutants, and a net reduction in process make-up water demand.

Figure 1

Original Guanaceví conventional tailings storage facility.



Photo courtesy of Wood

The case studies can be divided in two classes: class 1 facilities, where slurry tailings are loaded almost immediately with filtered tailings because of storage area limitations; and class 2 facilities, where the conversion is immediate but the available area allows gradual or eventual loading of the previously stored slurry tailings.

The condition where slurry tailings must be loaded almost immediately represents the greatest engineering challenge because of the geotechnical risks of instability and liquefaction (under both static and dynamic loads). Regardless of whether these facilities are converted immediately or eventually, they all require monitoring of pore water pressure conditions within the slurry tailings being loaded as the depth of placement of the filtered tailings above the slurry tailings increases. Additionally, where loading rate exceeds the pore pressure dissipation rate, tailings dewatering may be required to increase the rate of consolidation and strength and mitigate the risks of foundation failure.

Guanaceví tailings storage facility conversion

The Guanaceví facility conversion falls within class 1, where land availability limitations required the previously stored slurry tailings to be loaded almost immediately with filtered



This feature article by Humberto F. Preciado and Daniel A. Servigna of WSP and Pedro V. Porcayo of First Majestic Silver Corp. 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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tailings. Because of local regulations in Mexico, and the use of cyanide leaching in the process at the Guanaceví Mine (Endeavour Silver Corp.), the conventional TSF was geomembrane lined and lacked any drainage system. The conventional TSF prior to the conversion is shown in Fig. 1.

The original condition of the conventional TSF allowed a maximum placement of just a few meters of filtered tailings before the geotechnical factor of safety dropped below the minimum required in the design criteria or potentially triggered instability of the facility because of static liquefaction. Further analyses also indicated that piezometric pressure conditions of the slurry tailings had to be consistently lowered as the filtered tailings stack was being raised.

Given the importance of drainage for this conversion, various passive and active dewatering options were considered to reduce the in situ tailings pore water pressure and allow for the loading of the slurry tailings deposits. The passive options included vertical wick drains and horizontal drains. Active options included the removal or dredging of the slurry tailings, and the construction of an extraction pumping well network. Because of the need to load the existing slurry tailings as soon as feasible, and because of the opportunity to recover metal-rich solution from the tailings pore water, the decision favored the installation of a network of extraction wells early in the filtered tailings placement phase as soon as a thin cap of drain material or filtered tailings would facilitate equipment access. Figure 2 shows the converted TSF.

Cupías tailings storage conversion

The Cupías facility belongs to class 2, where the available area allows gradual or eventual loading of the previously stored slurry tailings. This slurry TSF originally consisted of a closed valley embankment built using an upstream raise construction method. Currently, the Cupías TSF is owned and operated by First Majestic Silver Corp. Unlike Guanaceví, the flotation mineral processing allowed for an unlined TSF that could drain through the foundation, as well as through decant towers placed within the tailings impoundment (Fig. 3).

To improve the stability of the tailings embankment and achieve the maximum required storage capacity, stabilization berms (or buttresses) were designed at the downstream toe of the TSF. During design, it was determined that at least three stabilization berms would be required. Given the volumes of material necessary for the construction of these berms/buttresses, consideration was given to changing the tailings processing technology from conventional slurry to filtered tailings.

Once a decision was made to convert the conventional TSF to a filtered TSF, a portion of the planned buttress at the toe of the TSF was constructed with filtered tailings, which resulted in approximately 10 years of storage life before the slurry tailings within the existing impoundment had to be loaded. This period

Figure 2

Converted Guanaceví filtered tailings storage facility.



Photo courtesy of Wood

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Figure 3

Original Cupías conventional tailings storage facility.



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allowed for some drainage and consolidation of the previously deposited slurry tailings to facilitate loading by construction equipment and eventually loading by the filtered tailings stack, reducing risk of liquefaction. Figure 4 shows the current configuration of the Cupías TSF with the buttresses completed and progressively reclaimed and filtered tailings being placed on top of the former slurry tailings impoundment.

Conclusions

Although these case studies apply to production rates below 10 kt/d (11,000 stpd), advancements in filtering technology and co-deposition of various types of waste and dewatered tailings will make conversion of existing conventional TSFs a more common practice. In addition to the technical challenges, the cases presented in this study required the education, understanding and commitment of the mine personnel at various levels, from operations and construction, to be able to implement a filtered tailings stack construction plan that was not prescriptive, but dependent on the evolution of site conditions and the level of dewatering achieved in the underlying slurry tailings impoundments.

This level of interaction is key in the successful conversion of a conventional TSF to a filtered TSF. In both cases, storage capacity has more than doubled because of the successful conversion to filtered tailings management. ■

Figure 4

Condition of the Cupías tailings storage facility through the years after conversion to filtered tailings.



Photos courtesy of First Majestic Silver Corp.

Modifying a conceptual site model through additional data analysis and visualization

by Denise Levitan and Nathan Brandner

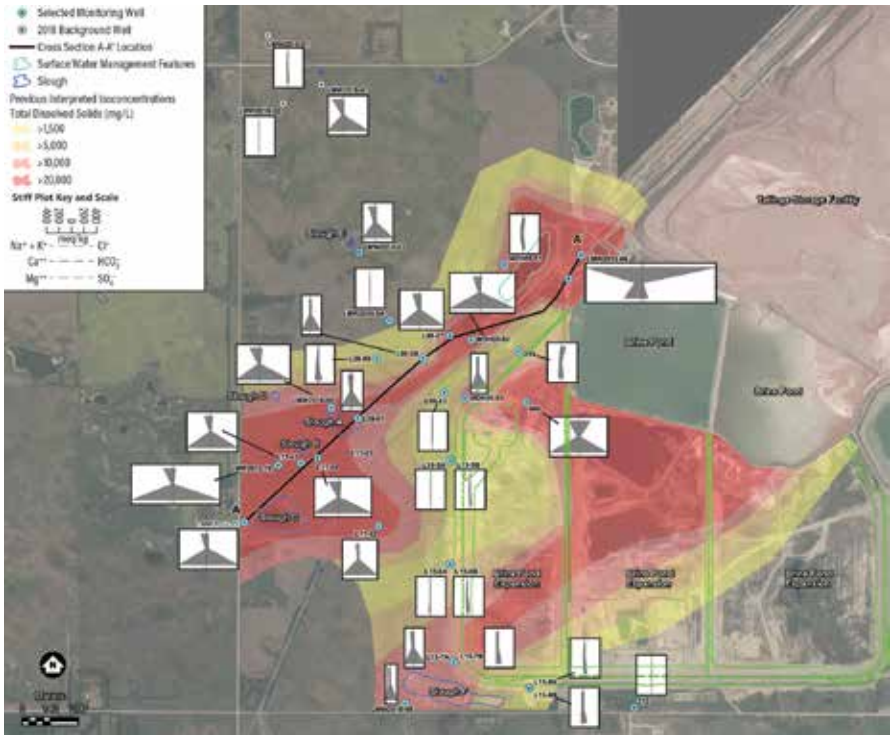
For many decades, a potash operation in Saskatchewan, Canada, has maintained storage impoundments for mine tailings and process-related mine water. The mine water is a concentrated aqueous solution, with most of the total dissolved solids (TDS) consisting of sodium and chloride. Although the facility has a system of slurry walls and collection/diversion ditches, the mines monitor the surface water and groundwater around the tailings storage facilities (TSFs) for releases.

Groundwater on the western side of the facility has been measured as having concentrations of TDS, magnesium, sodium, chloride and sulfate above provincial drinking water quality objectives. In addition, electromagnetic surveys have shown high electrical conductivity in that area. For these reasons, studies were undertaken to investigate the extent of the high TDS concentrations in groundwater and whether the elevated concentrations were related to the TSF.

Chloride and TDS concentrations in groundwater monitoring wells were used to interpret the transport of high-TDS mine water moving along three interpreted zones of elevated TDS west from the facility (Fig. 1). The zones of elevated TDS concentrations corresponded to the areas of high conductivity identified by the geophysical surveys. These results suggested that mine water could be emanating from the TSF and potentially require remediation. However, the interpreted orientation of the high-TDS groundwater and apparent flow paths were perpendicular to the direction of

Figure 1

Plan view of the western side of the facility. The previously interpreted high total dissolved solids (TDS) flow paths are shown as an isoconcentration heat map. Stiff diagrams are shown for selected wells using a common scale. A black line indicates the location of the cross section shown in Fig. 2.



Graphic courtesy of Barr Engineering

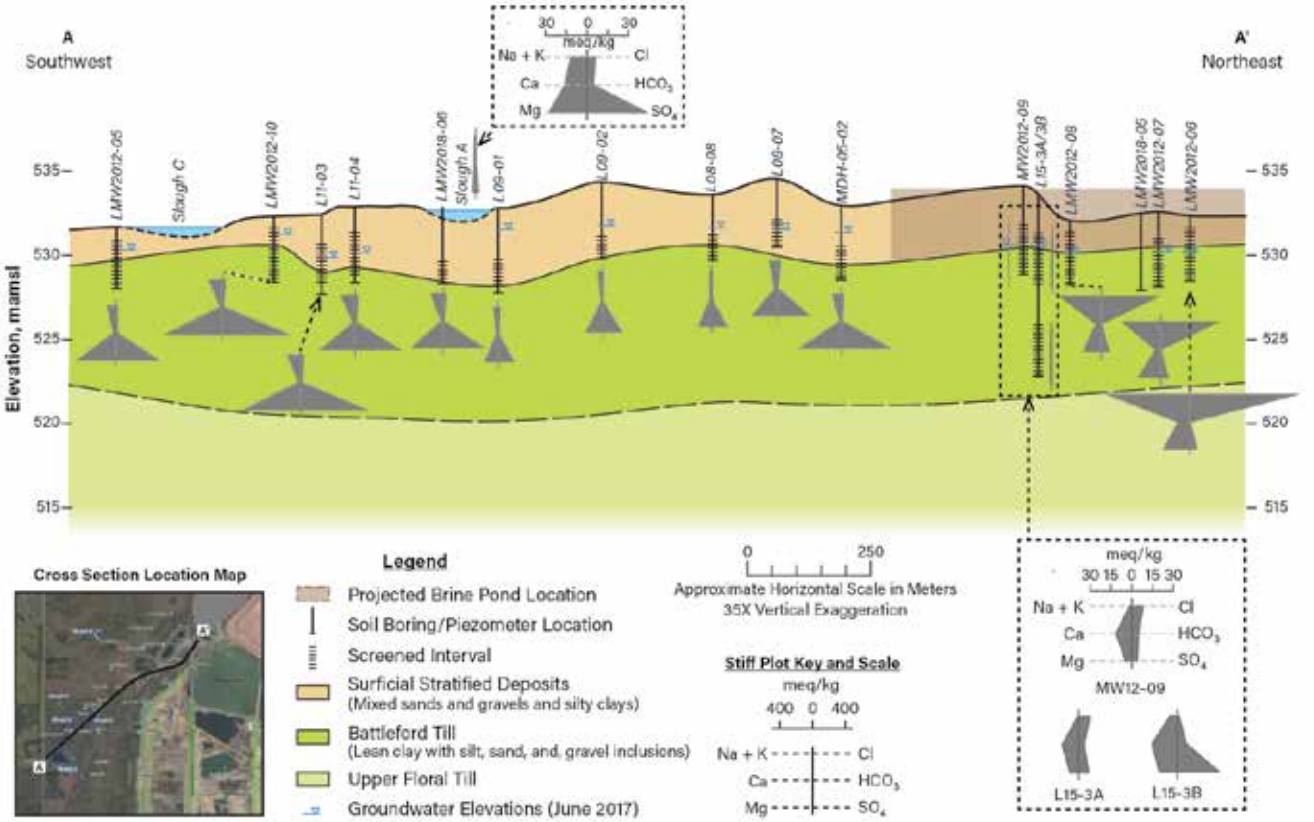


This feature article by Denise Levitan and Nathan Brandner of Barr Engineering Co. is one of 43 real-world case studies in Tailings Case Studies: Real-World Lessons in Tailings Management, the companion book to Tailings Management Handbook: A Life-Cycle Approach, both edited by Kimberly Finke Morrison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



Figure 2

Cross section west of the tailings storage facility (TSF) (TSF on right side). Stiff diagrams show sodium- and chloride-dominated groundwater with high concentrations of total dissolved solids (TDS) near the TSF at right and magnesium- and sulfate-dominated groundwater with high TDS concentrations at left.



Graphic courtesy of Barr Engineering

groundwater flow in the area. The fundamental conflicts in these interpretations led to a re-examination of the conceptual site model for the distribution of potential mine water releases.

Although the data examination and visualization made it clear that TDS concentration alone was not a reliable indicator of mine water release, there was still concern about elevated chloride concentrations. To further evaluate high TDS and chloride concentrations, several background area wells were installed northwest of the facility, beyond where mine water impacts could occur (Fig, 2). The background wells had highly variable chemical compositions. One of the wells had an elevated TDS concentration with magnesium and sulfate as the dominant ions with chloride concentrations above drinking water objectives, similar to the high-TDS wells west of the facility.

The results of the background groundwater investigation (major ion chemistry) were supported by the scientific literature on prairie sloughs throughout the North American Great Plains. These sloughs are small, shallow and sometimes seasonal wetlands found throughout the region. Seasonal cycling in precipitation/runoff and evapotranspiration result in accumulation and mobilization of salts, especially sulfate-bearing phases such as gypsum. The long-term dynamics of these features, which are common on the property west of the facility, likely control the TDS concentrations and compositions in shallow groundwater rather than mine water migration from the site.

The conclusions from this investigation led to a better understanding of the lateral distribution of potential TSF-related impacts versus background groundwater chemistry. Presentation of the data, including the visualizations of different water compositions, to the provincial regulatory agency representative allowed the facility to propose an optimized annual groundwater monitoring plan with reduced sampling frequency and annual sample count. This study underscores the importance of critical evaluation and comparison of various data types, including background levels, from a particular site and the iterative approach to developing and supporting robust conceptual site models for optimizing project outcomes. ■

Tailings deposition in open pits
at Cameco's in-pit facilities in Saskatchewan

by Barry Esford and Scott Donald

Cameco Corp. operates uranium mills and tailings management facilities at its Key Lake and Rabbit Lake operations in Northern Saskatchewan, Canada. Development at both mine sites began in the 1970s, with initial tailings deposition occurring within above-ground impoundments, which was common for these facilities at the time. As open pits became available at each site, and mining continued at other orebodies in the area, tailings management shifted to in-pit facilities to meet stakeholder expectations and improve the long-term security and environmental performance of tailings management at these facilities.

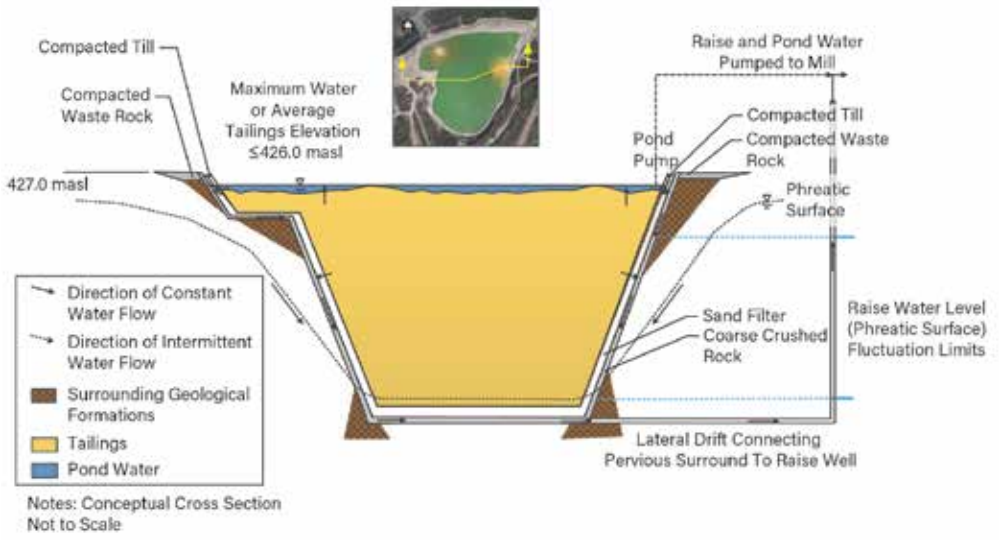
The in-pit facility at Rabbit Lake (receiving tailings since 1984; Fig. 1), was one of the first (if not the first) engineered in-pit tailings facilities in the world and adopted a full pervious surround design concept with subaerial deposition. Under this concept, permeable sand and coarse rock are placed at the base of the pit, around its perimeter, as well as overlying the tailings at closure to promote regional groundwater flow bypassing the lower-permeability tailings. In contrast, at Key Lake, the in-pit facility (receiving tailings since 1996) adopted a partial pervious surround design concept. Under this concept, permeable materials were again placed at the base of the pit, and partway up the side walls; although for the upper portion of the tailings, the material is placed directly against the natural geologic materials.

In the Key Lake case, the natural geologic environment provided the required bypassing of the tailings deposit to achieve the desired environmental performance while the base drain again facilitated pumping during operations to achieve consolidation objectives (Fig. 2).

In both the initial design of the facilities, and through more than several decades of operation, it is clear that although in-pit tailings facilities provide common benefits with respect to long-term geotechnical stability, it is critical that their design approach take into consideration site-specific conditions (geologic,

Figure 1

Cameco's Rabbit Lake operation in-pit tailings storage facility.



Graphic courtesy of Cameco Corp.

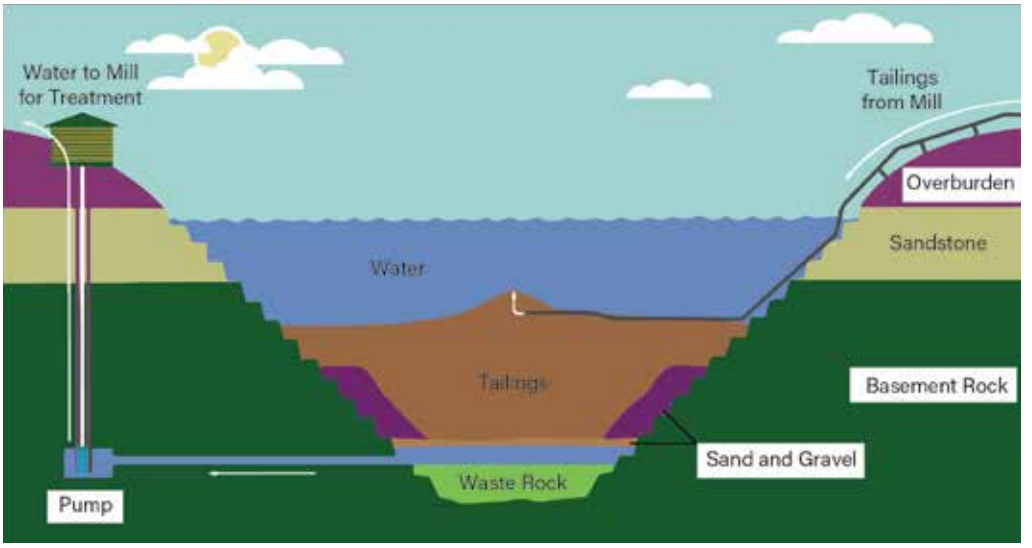


This feature article by Barry Esford of Cameco Corp. and Scott Donald of WSP is one of 43 real-world case studies in Tailings Case Studies: Real-World Lessons in Tailings Management, the companion book to Tailings Management Handbook: A Life-Cycle Approach, both edited by Kimberly Finke Morrison and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



Figure 2

Cameco's Key Lake operation in-pit tailings storage facility.



Graphic courtesy of Cameco Corp.

hydrologic, geochemical, environmental and operational constraints), as well as continue to apply adaptive management principles throughout operation and into closure planning to optimize performance. For example, at Rabbit Lake, deposition evolved from subaerial deposition (the initial deposition approach) to one where the tailings are placed under water cover to prevent further development of ice lenses within the facility (problematic given the cold northern climate). At Key Lake, the additional volumes available in the open pit allowed for co-milling of low-grade ore, while the subaqueous deposition approach allowed for a large reduction in the dewatering volumes requiring treatment and release. As each facility approaches the end of its operational life and enters the closure period, further studies continue to refine the eventual long-term closure plans and evolve optimal approaches to reduce downstream loadings to as low as reasonably achievable. ■



Industrial Minerals review 2024

Editors' note: The editors thank those who make this annual issue possible. A special thank you goes out to **Jim Norman, vice president at Tetra Tech Inc.**, member SME and Industrial Minerals Annual Review Editor; **Jack Sackrider, geology manager at Westward Environmental Inc.**, member SME and Industrial Minerals &Aggregates Division (IM&AD) Technical Committee Chair; the IM&AD Technical Committee vice chairs, and all the authors of the individual commodity profiles. On behalf of *Mining Engineering* readers, the editors thank them.

Additional notes: (1) Among the information sources cited in the articles are the U.S. Geological Survey (USGS) Mineral Commodity Summaries 2025 (https://www.usgs.gov/centers/national-minerals-information-center/mineral-commodity-summaries). The USGS Mineral Commodity Summaries are published on an annual basis and are the earliest government publications to furnish estimates covering nonfuel mineral industry data. The 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. USGS 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.

Foreword by Mike O'Driscoll, IMFORMED

There is no doubt, if any existed, that the commercial minerals world has now moved into a new era of unprecedented challenges in the sourcing, mining, processing, trade and use of industrial minerals.

Industrial (nonmetallic) minerals remain the often unsung workhorse of mineral commodities and specialist raw materials that frankly keep the world's manufacturing industries ticking over, and everyday products we use in sound availability. They are also very much present among the so-called "critical minerals" necessary to advance cutting-edge developments in growing high-tech markets such as in energy transition: for example, lithium, rare earths, graphite and fluorspar.

Indeed, in the United States during 2024, industrial minerals again accounted for the majority share of total mine production by value at $72.1 billion, or 54 percent, followed by metals, 25 percent, and coal, 21 percent, according to the latest data from the U.S. Geological Survey (USGS).

But right now, "industry resilience" seems to be the rallying call, with industrial mineral producers and traders facing straitened times from market slowdowns; environmental regulations; decarbonization and other sustainability issues; pressure to diversify; and near-shore mineral sourcing, and, yes, geopolitics.

The last few years have witnessed a series of geopolitical issues that have impacted and continue to impact international trade in industrial minerals. Above all, it has been the threat and implementation of recent trade tariffs between countries that have been most damaging in creating a potential trade war.

U.S. trade tariff tumult unleashed

The end of 2024 and the first quarter of 2025 saw perhaps the most dramatic episode of trade tariff threats and sanctioning, which have



Tunnel vision? The Las Cuevas Mine near San Luis Potosi, Mexico, operated by Koura Global, is the world's largest fluorspar mine. Fluorspar is a designated critical mineral, of which the United States is 100 percent reliant on imports.

impacted mineral commodities trade between the United States and the rest of the world, especially China.

Rare earths have always been a familiar stamping ground in this arena, but now many other minerals are in the mix.

By the seventh week of the new U.S. administration, the trading world was steeling itself against the latest round of U.S. trade tariffs on March 4, brought to bear on Canada (25 percent), China (doubled to 20 percent) and Mexico (25 percent).

Then on April 2, the industry was sent reeling by President Donald Trump's sweeping "Liberation Day" announcement of so-called "reciprocal" tariff rises for all U.S. imports, which added 34 percent to existing 20 percent duties on all Chinese imports (Canada and Mexico import tariffs unchanged).

The result was that some countries, particularly China, the European Union and Canada vowed to retaliate, thus fanning the flames for an impending trade war.

Since then, there has been backpedaling, pausing and revision of certain U.S. tariffs between certain countries, but it continues to be a very fluid and uncertain situation, yet to be fully resolved. Suffice to say that markets and trade have been negatively impacted.

For mineral producers, traders and consumers, it is an ongoing nightmare. Involved international traders, and crucially, U.S. consumers of these minerals are now busy assessing what the future may hold for the security and cost of maintaining their existing and planned mineral trade flows. Should the trade tariffs hold, then prices will certainly increase and impact U.S. consumers.

Reality check: U.S. has >50 percent import dependency on 24 industrial minerals

Leaving aside the rationale and debate over these tariffs, an analysis of the minerals and markets in the line of tariff fire is instructive in highlighting their importance to the U.S. (and world) economy, and indeed the vulnerability of and reliance on their limited sources.

Acknowledging this point right off the bat was the Essential Minerals Association (EMA; the representative voice for U.S. industrial

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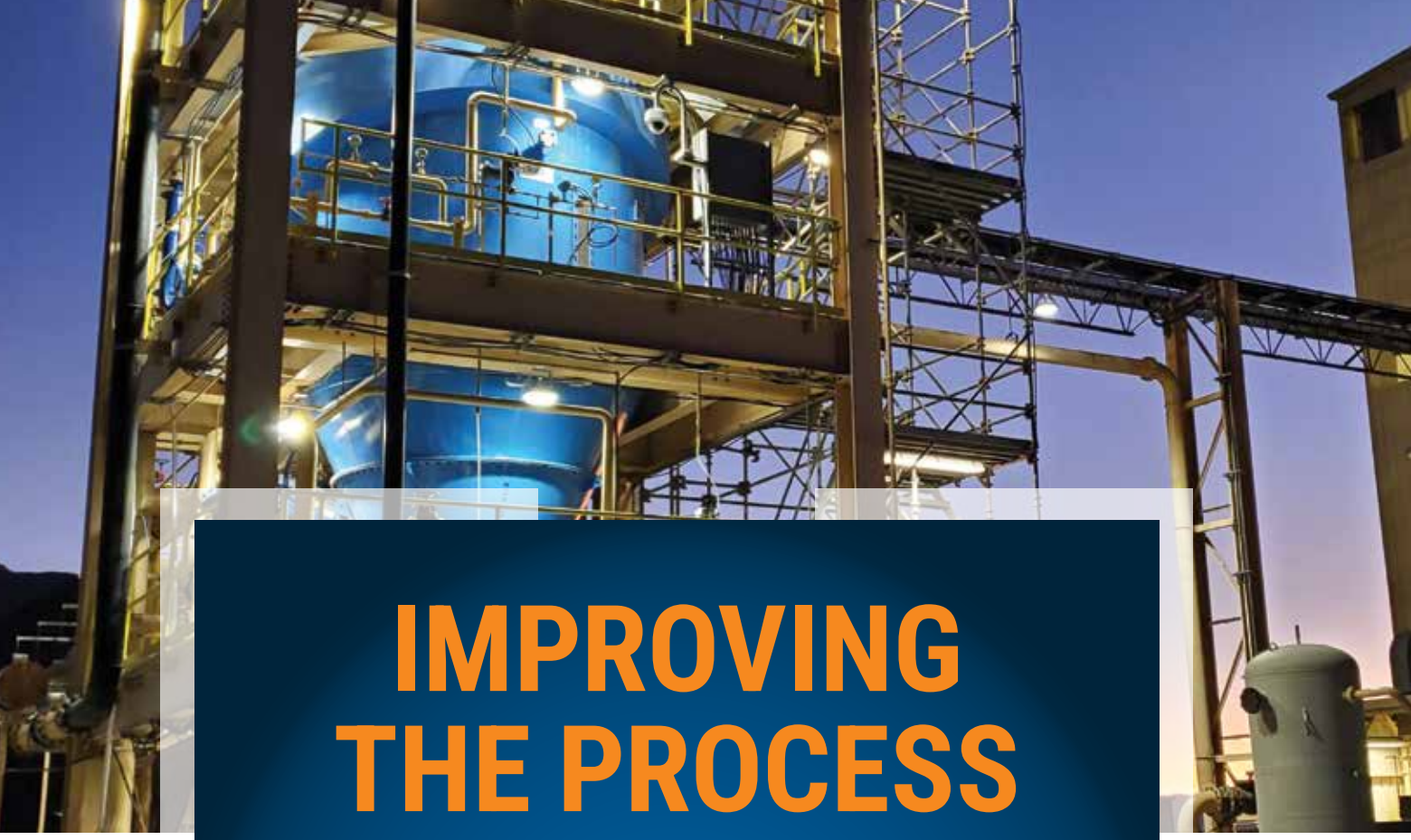
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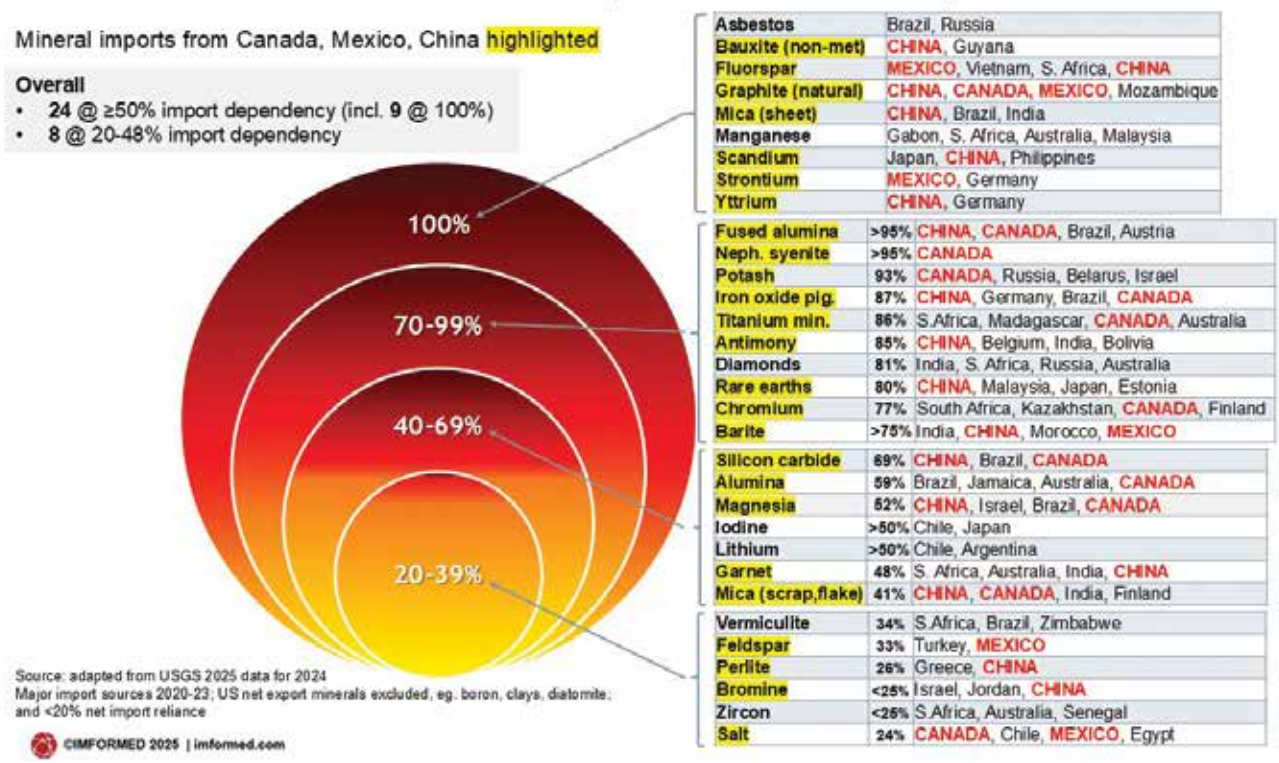


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Figure 1

U.S. industrial mineral net import reliance, 2024.



mineral producers) releasing a statement on March 3 urging the U.S. administration to "refrain from implementing tariffs on imports from Canada and Mexico" and seek alternative solutions.

The EMA statement warned: "tariffs would cause prices to rise steeply across the economy … many companies would see an increase in costs in the tens of millions of dollars per year, if not worse. The tariffs, instead of strengthening the domestic mineral supply chain, would cause U.S. manufacturers to become more reliant on foreign sources, including from hostile nations."

So, which industrial minerals are key to the U.S. economy? The United States has a 100 percent net import reliance on nine industrial minerals, more than 50 percent on 15 industrial minerals, and 20 to 48 percent import dependency on a further eight minerals — so, 32 industrial minerals in total.

Significantly, of these 32 minerals, 25 are sourced from Canada, China and Mexico, countries which are facing 20 to 25 percent import tariffs. These minerals are highlighted in Fig. 1, along with their respective import source countries and overall net import reliance as a percentage.

Tariff-targeted countries' supply to U.S.: Specific mineral analysis

Figure 2 shows more detail on the specific industrial minerals sourced for U.S. consumption from Canada, China and Mexico:

- Whether they are defined as a "critical mineral."
- Their overall U.S. net import reliance.
- Total import volume for 2024.
- The respective country's import share.
- Their primary market applications in the United States.

This may make sober reading for U.S. economists forecasting the fall-out for domestic manufacturing sectors from this latest round of U.S. trade tariffs.

Of critical minerals, Canada supplies four, China eight, and Mexico two — quite a tally (10 different critical minerals in total).

More examination reveals that these include critical minerals with considerable supply contributions from the tariff-targeted countries:

- Antimony oxide: China, 76 percent (other major sources: Belgium, 11 percent; Bolivia, 6 percent).
- Barite: China, 25 percent; Mexico, 14 percent (others: India, 40 percent; Morocco, 17 percent).
- Fluorspar: Mexico, 62 percent; China, 8 percent (others: Vietnam, 14 percent; South Africa, 9 percent).
- Graphite: China, 43 percent; Canada, 13 percent; Mexico, 13 percent (others:

Figure 2

Industrial minerals from Canada, China and Mexico consumed in the United States that have a greater than 20 percent net import reliance to meet demand.

Country under US import tariff	Industrial mineral	Critical mineral?[1]	US net import reliance[2]	Total import volume 2024[3] (000s tonnes)	Country import share[4]	Primary market applications
CANADA	Alumina	N	59%	1,300	5%	abrasives; cement; ceramics; chemicals; flame retardants; refractories; water treatment
	Chromium	Y	77%	500	6%	chemicals; foundry; metallurgy; pigments; refractories
	Fused alumina	N	>95%	120	11%	abrasives; ceramics; refractories
	Graphite	Y	100%	60	13%	batteries; foundry; friction; metallurgy; refractories
	Iron oxide pigments	N	87%	180	7%	cement; construction; pigments
	Magnesia	N	52%	520	8%	agr markets; cement; ceramics; chemicals; construction; environment; flame retardants; metallurgy; refractories
	Mica (scrap, flake)	N	41%	20	35%	cement; oilfield; paint; pigments; plastics; rubber
	Nepheline syenite	N	>95%	470	99%	ceramics; glass; paint; pigments; plastics
	Potash	N	93%	6,100	79%	agr markets; chemicals
	Salt	N	24%	14,000	29%	agr markets; chemicals; environment; food/pharma
	Silicon carbide	Y	89%	110	3%	abrasives; ceramics; metallurgy; refractories
	Ti-minerals	Y	86%	600	13%	chemicals; paints; pigments; plastics; paper
CHINA	Antimony oxide	Y	85%	20	76%	batteries; ceramics; chemicals; flame retardants; glass
	Barite	Y	>75%	2,000	25%	chemicals; oilfield; paints; pigments
	Bauxite	N	100%	2,800	80%	abrasives; cement; chemicals; environment; metallurgy; oilfield; refractories
	Bromine	N	<25%	61	3%	agr markets; chemicals; environment; flame retardants; oilfield
	Fluorspar	Y	100%	440	8%	batteries; chemicals; electronics; metallurgy
	Fused alumina	N	>95%	120	64%	abrasives; ceramics; refractories
	Garnet	N	48%	100	9%	abrasives; filtration
	Graphite	Y	100%	60	43%	batteries; foundry; friction; metallurgy; refractories
	Iron oxide pigments	N	87%	180	43%	cement; construction; pigments
	Magnesia	N	52%	520	61%	agr markets; cement; ceramics; chemicals; construction; environment; flame retardants; metallurgy; refractories
	Mica (scrap, flake)	N	41%	20	40%	cement; oilfield; paint; pigments; plastics; rubber
	Mica (sheet)	N	100%	4	79%	cement; oilfield; paint; pigments; plastics; rubber
	Perlite	N	26%	180	4%	agr markets; construction; filtration; paints; pigments; plastics
	Rare earths	Y	80%	8	70%	ceramics; chemicals; electronics; glass; metallurgy
	Scandium	Y	100%	n.a.	n.a.	chemicals; glass; metallurgy
	Silicon carbide	Y	69%	110	85%	abrasives; ceramics; metallurgy; refractories
	Yttrium	Y	100%	0.5	93%	batteries; ceramics; chemicals; electronics; glass; magnets; metallurgy
MEXICO	Barite	Y	>75%	2,000	14%	chemicals; oilfield; paints; pigments
	Feldspar	N	35%	220	6%	ceramics; glass; paint; pigments; plastics
	Fluorspar	Y	100%	440	62%	batteries; chemicals; electronics; metallurgy
	Graphite	N	100%	60	13%	batteries; foundry; friction; metallurgy; refractories
	Salt	N	24%	14,000	14%	agr markets; chemicals; environment; food/pharma
	Strontium	N	100%	4	65%	ceramics; chemicals; glass; magnets; metallurgy; pigments

Notes
Source: based on USGS 2025 data for 2024.

[1] based on USGS Critical Minerals List 2022 & USDOE Critical Materials Assessment 2023.

[2] ie. overall US net import reliance for that mineral, specific import source countries can change annually, as can their respective share of US imports of that mineral

[3] ie. total volume of imports for US consumption of all grades (incl for metallurgical uses) from all countries.

[4] ie. average import share during 2020-2023.

n.a. not available

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Mozambique, 13 percent).
- Rare earth compounds and metals: China, 70 percent (others: Malaysia, 13 percent; Japan, 6 percent; Estonia, 5 percent).
- Silicon carbide: China, 85 percent; Canada, 3 percent (others: Brazil, 4 percent).
- Titanium minerals: Canada, 13 percent (others: South Africa, 32 percent; Madagascar, 16 percent; Australia, 11 percent).
- Yttrium: China, 93 percent.

Moreover, just to complete the picture on all possibilities: Trump announced earlier this year that he might also consider imposing 100 percent tariffs on the countries referred to as the BRICS+ countries (Brazil, Russia, India, China, South Africa, Egypt, Ethiopia, Indonesia, Iran and United Arab Emirates). This would also then impact several of the other source countries for these critical and other minerals on which the United States has high import dependency:

- Brazil: silicon carbide, plus fused alumina, magnesia, bauxite.
- South Africa: fluorspar, chromite, plus zircon.
- Vietnam, which recently became a partner of BRICS, is a key source of fluorspar for the United States.

"Noncritical" minerals also have significance

It is also important to be reminded of the other industrial minerals from Canada, China and Mexico not officially designated (yet) as "critical," though many U.S. manufacturing sectors strongly rely on these imports:

- Fused alumina: China, 64 percent, Canada 11 percent (others: Brazil, 7 percent; Austria, 5 percent).
- Bauxite: China, 80 percent estimated refractory grade (others: Guyana, Brazil).
- Magnesia
  - Caustic calcined magnesia: China, 73 percent; Canada, 21 percent.
  - Dead burned and fused magnesia: China, 70 percent (Brazil, 18 percent; Turkey, 3 percent).
  - Magnesium hydroxide: Mexico, 59 percent (others: Netherlands, 14 percent; Israel, 13 percent; Japan, 5 percent).
- Mica
  - Scrap and flake: China, 40 percent; Canada, 35 percent (others: India, 9 percent; Finland, 5 percent).
  - Sheet: China, 79 percent (others: Brazil, 6 percent; India, 4 percent).
- Nepheline syenite: Canada, 99 percent.
- Potash: Canada, 79 percent (others:

Russia, 11 percent; Belarus, 4 percent; Israel, 3 percent).
- Salt: Canada, 29 percent; Mexico, 14 percent (others: Chile, 27 percent; Egypt, 8 percent).
- Strontium: Mexico, 65 percent (others: Germany, 30 percent).

These are all stand-out minerals much needed for U.S. consumer sectors.

Fused alumina and bauxite are in high demand for refractory and abrasive manufacturing, with 75 percent fused alumina imported from China and Canada, and most refractory bauxite from China.

Likewise, all U.S. demand for dead burned and fused magnesia essential for refractories must be imported, and mostly from China.

Caustic calcined magnesia and potash (both from Canada) are essential to U.S. agrimarkets, with caustic calcined magnesia serving the dairy cattle market, and potash mainly for U.S. fertilizer production.

Magnesium hydroxide from Mexico is used in a range of markets including chemicals, water treatment and flame retardants.

Mica and salt use in the United States is also highly dependent on China and Canada (mica), and Canada and Mexico (salt). Salt markets are wide-ranging, but the northeast U.S. deicing market relies strongly on imports.

Strontium supply from Mexico is used in ceramics, chemicals, glass, magnets, metallurgy and pigments.

It should be said that it seems that certain minerals will not be subject to the reciprocal tariff — that is, those already subject to Section 232 tariffs — although some observers remain unclear on this. The official "Annex II" enumerates the following industrial minerals exempt "as ores, oxides and salts": antimony, asbestos, barite, bauxite, chromite, fluorspar, fused alumina, graphite, iron oxides, lithium, magnesia, manganese, phosphate, potassium, rare earths, silicon carbide, strontium, titanium and yttrium.

However, industrial minerals imported by the United States that appear not to be exempt include nepheline syenite (greater than 95 percent, Canada), garnet (48 percent, South Africa, Australia, India and China) and those minerals with U.S. import dependency of less than 40 percent: bromine, feldspar, perlite, salt, vermiculite and zircon.

Impact on U.S. consuming markets

The last column of the table highlights the main market applications for these minerals and will be seen to include some very important sectors essential to the U.S. economy.

Many of these markets are intermediate manufacturing sectors that are imperative for ultimate end markets.

Refractories, ceramics and abrasives, for example, are vital to help manufacture components used in defence and military uses, as well as the primary use of refractories in all plants making steel, metals, glass, cement, ceramics and petrochemicals.

Regarding the rapidly evolving lithium-ion battery market, especially for electric-vehicle and municipal applications, fluorspar and graphite stand out as the critical minerals on which the United States relies 100 percent on imports from Canada, China and Mexico.

There are ongoing projects in the United States in trying to develop domestic sources for graphite and fluorspar, but how soon they will come to fruition is unclear, and certainly not in time to ease these immediate import tariffs.

If anything, perhaps this latest round of trade tariffs may provide a boost for such U.S. mineral development projects. For example, on March 20, Trump signed an executive order to drive U.S. mineral production, streamline permitting and enhance national security. "Minerals" covered by the order include critical minerals, uranium, copper, potash, gold, and any other element, compound or material as determined by the chair of the National Energy Dominance Council.

An accompanying White House statement commented: "The United States currently imports a significant portion of its minerals from foreign countries, creating economic and security risks, despite possessing a vast supply of critical minerals. A strong domestic mineral production industry would ensure U.S. companies can compete globally without overly relying on foreign supply chains." So, some, if belated, recognition of minerals' importance.

How the U.S. manufacturing sectors will absorb or pass on these cost increases for their required minerals is top of the agenda, as is the consideration of future exports to the United States by producing companies in Canada, China and Mexico. Perhaps, as has happened in the recent past, certain industries may be able to successfully lobby the U.S. government to exempt their minerals from the tariff list.

Regarding potash, the significance of any tariff impact on this mineral and its market was at least recognized very swiftly. Just two days after the March 4 decree, a reduction of tariffs was announced on potash not already covered under the United States-Mexico-Canada Agreement (USMCA; signed in Trump's

first term) from 25 percent to 10 percent. U.S. Secretary of Agriculture Brooke Rollins described it as "… a critical step in helping farmers manage and secure key input costs at the height of planting season while reinforcing long-term agricultural trade relations." Could this sentiment be applied across other mineral consuming markets?

Meanwhile, this whole trade issue may also prompt U.S. (and other) industrial mineral consumers to start seeking alternative sources of mineral supply from nontariff-targeted countries, particularly near-shore, and even to consider switching to using alternative/recycled minerals from domestic sources. Challenges yes, but also opportunities. Let's see. ■

**Mike O'Driscoll is director and cofounder of IMFORMED Industrial Mineral Forums & Research Ltd, UK; organizing Fluorine Forum 2025, Baveno, Lake Maggiore, Oct. 22-24 and Salt Forum 2025, Abu Dhabi, Nov. 17-19; mike@imformed.com or visit www.imformed.com.*

BALL CLAY

by Dibyajyoti Behera, Ashapura Group of Industries

Ball clay is a type of clay whose name is derived from its early extraction methods in 18th-century England, when it was dug by spade as cubes, which then became rounded during subsequent transport. It is strong yet flexible, can withstand high temperatures during firing and helps create smooth, even surfaces in ceramics. As demand for ceramic items rise due to the ceramics boom, so does the demand for ball clay. It is commercially extracted through openpit mining, followed by multiple processing steps, including refining, blending, forming and firing.

Ball clay offers enhanced plasticity, excellent durability, high binding strength, low iron content, easy moldability and good drying properties. It is also a cost-effective, versatile, readily available and chemically stable product that improves the color and texture of finished goods. As a result, ball clay finds extensive applications across the construction, ceramics, foundry, paints and coatings, refractory and agriculture industries.

Market size and growth

The ball clay market size is estimated at $455.30 million in 2025 and is expected to reach $583.03 million by 2030, at a compound annual growth rate of 5.07 percent during the forecast period (2025 to 2030). The global ball clay market has been experiencing steady growth, driven by its extensive use in the ceramics industry, including applications in tiles, sanitary ware and tableware.

Export and imports

More than 91 countries contribute to the global import of ball clay. India is the largest importer with 5,119 import shipments, for a market share of 38 percent. Following India, Bangladesh is the next key player with 3,251 shipments and a 24 percent market share. Vietnam's 1,504 shipments translates into an 11 percent market share.

A total of 52 countries export ball clay globally. The leading suppliers are India, the United Kingdom and the United States. India tops the list with 3,394 shipments, which equates to a 22 percent market share. It is closely followed by the United Kingdom with 2,890 shipments, representing a 21 percent market share, and the United States with 2,832 shipments, for a 21 percent market share.

Outlook

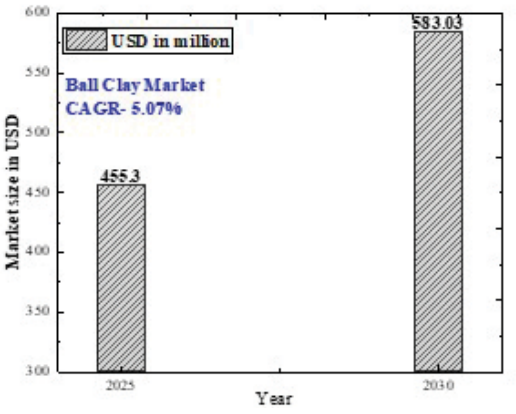
The Asia Pacific and North American ball clay markets are experiencing growth driven by demand in the ceramics and construction sectors. The growing demand for lightweight and durable materials in the automotive and aerospace industries further supports market expansion. Advancements in mining technologies are improving extraction efficiency, enhancing product quality and reducing environmental impact. Additionally, the widespread adoption of ball clay in sanitary-ware manufacturing and the growing popularity of aesthetically appealing ceramic tiles are key trends shaping the region's market dynamics.

Key players

Leading ball clay market companies include Ashapura Group of Industries, Ashok Alco-Chem Ltd, Finore Minerals LLP, G&W Mineral Resources (Zimco Group (PTY) Ltd), Garg Minerals and Chemicals, Golcha Associated Exports LLP, Gujarat Mineral Development Corporation Ltd, Imerys S.A., JLD Minerals Private Ltd, Old Hickory Clay Co., Plainsman Clays Ltd and Sibelco.

Figure 1

Ball clay market size, 2025-2030. (Source: Mordor Intelligence)



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BARITE

by John Newcastle, The Barytes Association

Barite (or baryte) is the naturally occurring mineral form of barium sulfate ($BaSO_4$). Its main properties are its high specific gravity (4.50 g/mL) and very low solubility; it is nontoxic, and chemically and physically unreactive. It is extracted by both surface and underground mining, followed by simple physical processing methods to produce correctly sized product free of extraneous materials and beneficiated to meet end-user specifications.

Barite is the preferred weighting agent in fluids used during oil and natural-gas exploration and production (E&P) drilling, accounting for more than 70 percent of worldwide consumption. Other uses are in added-value applications including car components, electronics, television screens, rubber, glass, ceramics and paint, radiation shielding and medical applications (barium cocktails). Barite is supplied in a variety of forms and costs depending on the scarcity of certain grades as well as the amount of processing required. Filler applications command higher prices due to intense physical processing by grinding and micronizing, and there are further premiums for whiteness, brightness and yellowness. Being a relatively low-cost mineral as mined, logistics costs add significantly to the final landed costs in many markets: for example, the major trade lanes of China and India to the U.S. Gulf for processing of lumps and on to drilling rigs. Trucking, barging, loading, unloading, railing and shipping via dry bulk ocean vessels typically add more than 100 percent of the cost of mined and beneficiated lumps to arrive at the delivered powder cost.

There are globally accepted minimum drilling grade specifications that are largely determined by the American Petroleum Institute (API) in committees. The committees are made up of technical experts from E&P and service companies. Customers may expand or modify API specifications based on unique needs. Typically, these extra requirements include low heavy metals for environmental disposal reasons, low iron (Fe) to prevent magnetic tool interference, and low carbonate content to avoid unwanted chemical interactions with some fluid formulations.

The economics of barite are like those of many industrial minerals. Its final form is a precisely sized powder achieved by pulverizing and classifying naturally occurring lumps. The optimal landed cost is usually achieved by pulverizing (grinding) as close to the ultimate consumption point as possible, minimizing wasted packaging and avoiding double handling.

Chemical- and filler-grade barite specifications are less standardized than drilling grade, but often require higher degrees of whiteness, high percentages of $BaSO_4$ or very low levels of certain contaminants like strontium (Sr).

Production and consumption

The industrial (chemical and filler) grades of barite have enjoyed relatively steady gradual growth over recent decades. However, the more significant demand swings in barite are driven by variations in global drilling activity.

Drilling demand is, unsurprisingly, traditionally a factor of oil and gas activity. Historically, rig count translated to barite demand, and although the variations still track that way, U.S. drilling has seen a shift in the ratios of tons of barite per rig. This is due to massive productivity gains and a greater percentage of horizontal drilling in shale plays — the so-called fracking boom. A better indicator of barite consumption than rig count is feet drilled.

The United States is the largest consumer of barite in the world by far, followed by Saudi Arabia. There is no domestic sourcing of barite in Saudi Arabia, and the United States is an approximate 80 to 85 percent importer with only three companies mining and three companies processing native ore, all in Nevada.

Resources of barite in Nevada are estimated at quite high levels, but the most economically viable deposits are in depletion. Many known resources are deep or remote. Finished product shipped from the Nevada mills in 2023 totaled 347 kt and although figures for 2024 are not yet available, the numbers are likely to be similar. The estimated U.S. demand in 2024 of 2.24 Mt was sourced mostly in India, China Morocco and Mexico. No new miners or grinders have appeared in Nevada since Baker Hughes Co. sold its processing assets to I-80 Gold for water and rail access, and ceased mining.

Figure 1 shows U.S. barite imports in 2024. The Mexican-sourced barite mostly comes to West Texas and New Mexico by rail or truck in powder or lumps. Barite from China, India and Laos typically ships in lump form via dry bulk ocean vessels, typically

in Panamax-sized cargoes of 58 to 75 kt. Moroccan cargoes more often arrive in 35- to 45-kt cargoes.

The destination ports are in Louisiana and Texas at or near where mills are located. Most mills are rail- or barge-served, allowing economical inland bulk freight from there to the drilling basins. The demise of most U.S. Gulf offshore drilling has led to an overcapacity of grinding assets in the New Orleans to Brownsville arc.

Although more U.S. grinding capacity is not mathematically needed to serve the total market, location and logistics are critical factors. As a result, in 2024 two new grinding mills began operation in the Permian Basin of West Texas. One is in Pecos and the other in nearby Monahans. They are processing Mexican crude lump barite as well as some barite imported through Corpus Christi and railed to the mill.

Another trend since 2022 has been grade density. Prior to 2006, API had one official density spec: 4.20 g/mL, minimum. Operators and producers jointly realized that this universal requirement was at times overkill, and leading to an accelerated reserve depletion in Nevada and globally. The industry and API eventually adopted an optional 4.10 g/mL standard for many applications. As even simpler and cheaper mud systems have evolved in West Texas, the percentage of mud systems using sub-4.10 g/mL has grown. Densities of 3.90 g/mL barite may account for half or more of Permian activity.

However, Saudi Arabian drilling continues to have the toughest barite specifications in the world, sticking to API 4.20 g/mL grade density, super low U.S. offshore mercury and cadmium requirements, and even a 0.3 percent by weight iron (Fe), achievable rarely and only from India or Laos. Recently, Saudi Arabian Oil Co. (Aramco) has made some accommodations on density in certain applications but officially sees this as more an exception than the rule.

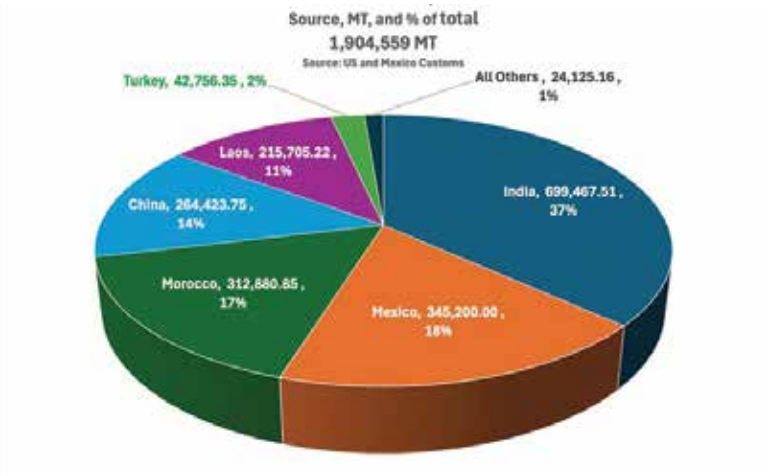
Outlook

2025 is going to be an interesting year in barite. Most industry followers see a flat demand but tightening supply. Chinese exports have drawn down very significantly in the last four to five years. This is partly due to significant mine closures, environmental restrictions and stronger domestic demand for drilling and chemical/fillers.

India had been rising to fill the void, but mid-2024 saw a series of challenges begin in the Andhra Pradesh state government Mangampet Mine and its owner, the Andhra Pradsesh Mine Development Co. (APMDC). The latest government tender cum auction for export quantities releases significantly less A-Grade (4.25 g/mL minimum) ore and limited 4.10 g/mL B-Grade. The tender auction process seeks to maximize prices that Indian processors or exporters are willing to pay. The auction, originally scheduled for January 2025, has been postponed several times.

Figure 1

2024 U.S. barite imports.



Laos is a relatively new source with very high-density barite ore needing no beneficiation, like China 30 years ago. Development has grown steadily but slowly, but only limited volumes are currently available.

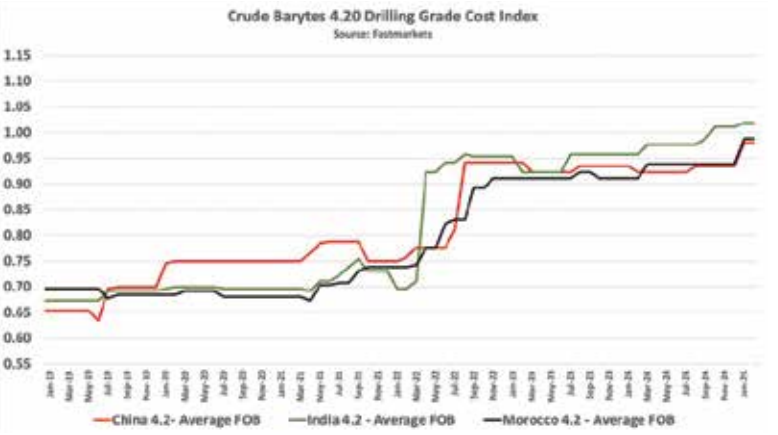
Mexico is an anomaly in that barite for domestic drilling in the southern Bay of Campeche depends on imports, with mine production in the north going to Mexican land drilling and exports to the United States. Much of the barite produced is sub-4.00 g/mL. Volumes exported have grown significantly over the last three years, but there is minimal potential for further near-term growth in exports.

Morocco has resources that many believe still have upside potential.

An element of uncertainty in 2025 is that of U.S. tariffs. China and Mexico are likely to be affected by the tariffs. At this writing, Chinese-origin barite has had 20 percent tariffs imposed, and since barite is a United States–Mexico–Canada Agreement (USMCA)

Figure 2

Monthly average prices of unground lump barite from China, India and Morocco (1.00 = the October 2013 average FOB price of $130/t; 0.95 = 5 percent lower; 1.05 = 5 percent higher).



commodity, Mexican barite is still moving without the threatened 25 percent tariff. It is unclear how long these rules will remain and whether the future potential tariffs will include other countries like India.

Fastmarkets IM publishes monthly average prices of unground lump barite meeting API specifications with specific gravity of 4.2 g/mL from the three leading exporting countries (Fig. 2) .

Conclusion

Barring an unforeseen drop in demand, the market ahead should produce great opportunities for entrepreneurs and investors in a commodity that has been anything but exciting since the mid-1990s.

BAUXITE AND ALUMINA

by Adam M. Merrill, National Minerals Information Center, U.S. Geological Survey

Production

During 2024, one alumina refinery produced alumina from imported bauxite in the United States. The 1.2-Mt/a refinery in Gramercy, LA, owned by Atlantic Alumina Co. LLC, produced alumina mostly for use in aluminum smelters, but also produced chemical-grade alumina. The United States is 100 percent net import reliant for metallurgical-grade bauxite. Small amounts of bauxite and bauxitic clays are produced in Alabama, Arkansas and Georgia for nonmetallurgical uses.

Consumption and end uses

In 2024, total domestic consumption of bauxite (in crude dry equivalents) was estimated to be 1.8 Mt, 12 percent less than in 2023. Of this, approximately 76 percent was consumed to produce alumina or alumina hydroxide, compared with 78 percent in the prior year. The remainder was used to produce abrasives, cement, chemicals, proppants, refractories and as a slag adjuster in steel mills. Total domestic consumption of alumina by the aluminum industry was estimated to be 1.4 Mt in 2024, 10 percent less than in 2023. Approximately 687 kt of alumina was consumed by other industries in the United States in 2024, 42 percent more than in 2023. Other uses of alumina included abrasives, cement, ceramics and chemicals.

Foreign trade

Bauxite. According to the U.S. Census Bureau, metallurgical-grade bauxite (crude dry) imports totaled 2.08 Mt in 2024, 13 percent less than in 2023. In 2024, the principal sources of metallurgical-grade bauxite were Jamaica (81 percent) and Turkey (17 percent). Imports of refractory-grade calcined bauxite in 2024 totaled 121 kt, 4 percent more than in 2023. China (53 percent) and Guyana (45 percent) were the principal sources of refractory-grade calcined bauxite imports. Imports of nonrefractory-grade calcined bauxite in 2024 totaled 367 kt, 13 percent more than in 2023. Australia (67 percent) and Guyana (27 percent) were the principal sources of nonrefractory-grade calcined bauxite.

Alumina. According to the U.S. Census Bureau, alumina imports totaled 1.34 Mt in 2024, compared with 1.36 Mt in 2023. Brazil (72 percent) and Jamaica (8 percent) were the leading sources of imported alumina. Exports of alumina in 2024 totaled 146 kt, 5 percent more than in 2023. The leading destinations of exported alumina were Mexico (26 percent), China including Hong Kong (20 percent), and Canada (15 percent).

Prices

According to the U.S. Census Bureau, values for imported bauxite varied depending on the source and grade. Average unit values on a free-alongside-ship (FAS) basis for crude dry bauxite imported to the United States from major suppliers in 2024 were $31/t from Jamaica (a 4 percent decrease from 2023) and $55/t from Turkey (double the 2023 amount); for imported refractory-grade calcined bauxite in 2024 were $441/t from China (4 percent increase) and $262/t from Guyana (26 percent decrease); and for imported nonrefractory-grade calcined bauxite in 2024 were $53/t from Australia (13 percent increase) and $190/t from Guyana (34 percent decrease). The average unit value, on an FAS basis, of alumina imports to the United States in 2024 was $579/t, 21 percent more than in 2023, while the value of alumina exports in 2024 was $3,960/t, 26 percent more than in 2023. Based on cargo sizes, export destinations and prices, it is assumed that most of the alumina exports in 2023 and 2024 were specialty grade alumina instead of smelter-grade alumina.

Outlook

Consumption of smelter-grade alumina in the United States was expected to remain static as no primary aluminum smelter restarts have been announced for 2025. Consumption of refractory-grade calcined bauxite is largely dependent upon steel production. The World Steel Association's short-term outlook anticipates domestic steel demand to increase slightly (by 2 percent) in 2025, and it is expected that consumption of refractory-grade calcined bauxite will follow this trend.

Consumption of alumina and nonrefractory-grade calcined bauxite is expected to follow the general growth of the construction, chemical, manufacturing and petroleum industries, which is projected to increase slightly (by 2.2 percent) in 2025.

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BENTONITE

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

Bentonite, a clay primarily consisting of smectite minerals (usually montmorillonite) with minor amounts of feldspar, biotite and quartz, is formed from the alteration of volcanic ash., First discovered in the late 19th century near Fort Benton, MT, bentonite is often called the "clay of a thousand uses." The physical and chemical properties of bentonite make it a highly absorbent and reactive material, which is useful in a range of industries including agriculture, construction, cosmetics, drilling, pet care and environmental remediation.

The 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 western states and can absorb several times its weight in water. Calcium montmorillonite, also referred to as nonswelling bentonite, is mostly produced in southern states. Bentonite, typically found in shallow deposits over expansive land areas, is primarily mined using openpit techniques. This versatile clay is found in a variety of colors including tan, gray-blue, olive, brown and white.

Production

In 2024, domestic bentonite production (the quantity sold or used by producers) was estimated to have increased by 10 percent to 4.8 Mt compared with 4.36 Mt in 2023. 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 2024, nonswelling and (or) swelling bentonite was 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 94 percent of swelling bentonite was produced in Wyoming, while Alabama and Mississippi, as in past years, led in the production of domestic nonswelling bentonite.

Bentonite is widely available in many countries around the world. In 2024, global bentonite production was estimated to be 21 Mt, compared with 20.3 Mt in 2023, with production from 50 countries. The United States continues to be the global leader in the production of bentonite, followed, in descending order, by India (estimated 3.7 Mt), Turkey (estimated 2.5 Mt) and China (estimated 2.1 Mt).

Consumption

Pet-waste absorbents (48 percent of sales) and drilling mud (23 percent) were estimated to be the leading domestic markets for bentonite in 2024. Bentonite was also 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 2024 was estimated to be $99/t compared with $102/t in 2023. That of exported bentonite was $257/t in 2024, compared with $237/t in 2023, and that of imported bentonite was $347/t in 2024, a decrease compared with $441/t in 2023. 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 748 kt, valued at $192 million, in 2024 compared with 785 kt, valued at $186 million, in 2023. The leading destinations for exports of bentonite in 2024 were Canada (49 percent), Japan (15 percent) and Mexico (9 percent). Lesser amounts were shipped to 73 other countries. Bentonite imports more than doubled in quantity to 48.6 kt valued at $16.9 million in 2024 compared with 21.7 kt valued at $9.57 million in 2023. Canada (38 percent), Mexico (28 percent) and Turkey (20 percent) were the leading sources of bentonite imports while 20 other countries provided lesser amounts in 2024.

Outlook

Bentonite's diverse applications ensure it remains a mature and stable industry. The trend toward sustainability and the use of eco-friendly products, such as bentonite, will sustain the demand

for bentonite. Pet-waste absorbents and drilling muds are expected to remain the leading uses of bentonite, continuing to influence its demand. The growing pet industry may result in increased consumption of bentonite for pet-waste absorbents. Additionally, bentonite production will be influenced by the natural-gas and petroleum well drilling industries, although this sector has a greater level of fluctuation compared to the pet-care industry.

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CEMENT

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

Portland, blended and masonry cement (cement) 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) to make cement. 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

In 2024, production of cement in the United States, excluding Puerto Rico, was estimated to be 86 Mt, a 4.4 percent decrease from an estimated 90 Mt in 2023. Production in 2024 was 13 percent lower than the record of 99.3 Mt set in 2005 (Fig. 1). Total world cement production in 2024 was estimated to be 4 Gt, a slight decrease from an estimated 4.1 Gt in 2023. China (1,900 Mt), India (450 Mt), Vietnam (110 Mt), the United States (86 Mt) and Turkey (82 Mt) continued to be the leading producers in 2024. The United States manufactured about 2 percent of cement produced worldwide.

In 2024, an upgrade and capacity expansion of a cement plant in Wyoming was announced and work progressed on plans to increase the capacity of cement plants in Missouri and Texas. Also in 2024, a cement plant in Indiana was repurposed into a slag-grinding facility and construction of a new slag cement facility in Texas continued. However, in 2022 and 2023 cement plant closures were announced at cement plants in California, Maine and New York; in 2024, the plant in Maine transitioned to a distribution center for imported material.

Consumption

Domestic cement consumption in 2024, as measured by sales to final customers, was estimated to have decreased by 6.3 percent to 104 Mt from 111 Mt in 2023 but was 19 percent lower than the 2005 record consumption of 127.9 Mt. The difference between consumption and domestic production in 2024 was met, in part, by imports, although total imports of hydraulic cement and clinker in 2024 were 5.4 percent less than the amount reported in 2023. Over the past 10 years, imports increased from 8.3 Mt in 2014 to 25 Mt in 2024, but imports in 2024 were still well below the record of 35.6 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 (or) unspecified uses.

Foreign trade

According to the U.S. Census Bureau, imports of cement and clinker by the United States, including Puerto Rico, in 2024 were 25 Mt, compared with 26.5 Mt in 2023. In 2024, Turkey (29 percent), Canada (19 percent), Vietnam (17 percent), Greece (7 percent) and Mexico (5 percent) supplied the majority of U.S. cement imports, with the remainder coming from several other countries. Exports of cement were 939 kt, a slight increase from 2023. Canada (82 percent), Mexico (6 percent) and the Bahamas (4 percent) received the majority of U.S. cement exports, with the remainder going to several other countries and localities.

Prices

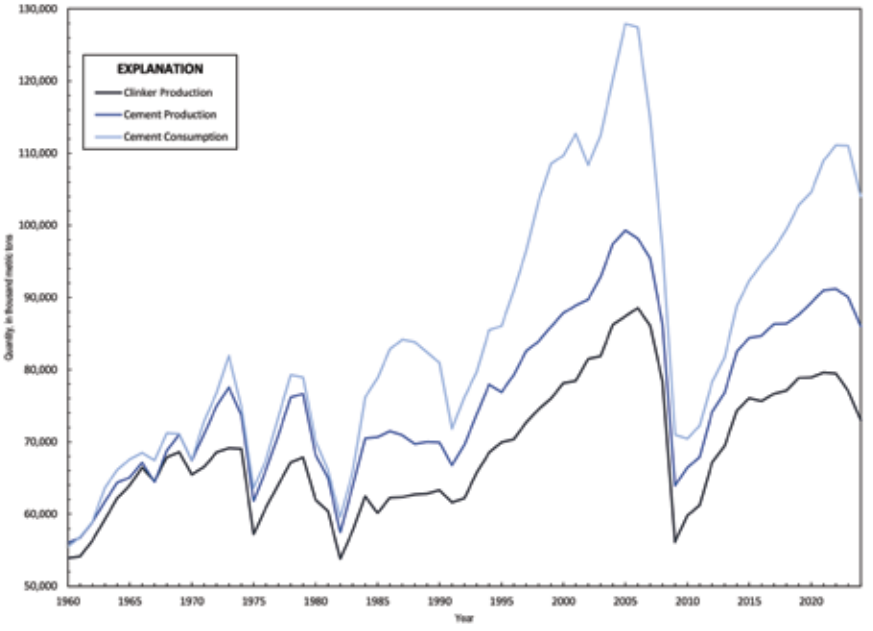
The average mill net value (price) of cement depends on application, quality, quantity purchased, source and type, and therefore encompasses a range of prices and was estimated to be $160/t in 2024. In recent years, increased prices have been partially attributed to increased costs of production, having increased from $125/t in 2020. During 2024, the overall estimated value of sales increased to a record-high $17 billion.

Environmental issues

Large quantities of raw materials (mainly carbonate rocks, especially limestone) and fuels are

Figure 1

U.S. clinker production, cement production, and cement consumption, 1960–2024.



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 carbon compounds and particulates. Increasingly, these emissions are being stringently regulated. The cement industry is one of the leading industrial emitters of CO_2, a greenhouse gas.

In April 2024, the Connecticut Department of Transportation approved the use of portland-limestone cement (PLC); PLC has become widely accepted by various authorities and has been approved for use by all 50 states and the District of Columbia. In 2024, blended cement accounted for 59 percent of total cement shipments and 97 percent of the blended shipments were estimated to be PLC (type IL). Additional company announcements aligned with sustainability and decarbonization efforts included the increased or enhanced use of alternative fuels and materials, carbon capture, utilization and storage projects, improved efficiency, renewable energy projects, and other innovations. Development of other low-carbon and (or) new blended cement product lines utilizing various SCMs, and innovative techniques, also progressed, including funding announcements to build two new novel cement manufacturing facilities.

Outlook

The decrease in reported consumption of cement in 2024 likely resulted from decreased construction starts of new housing units, as well as increased costs for energy, material and service inputs. Regulators continued to implement new measures designed to aid industry sustainability efforts, and several cement producers were awarded government funding for decarbonization initiatives. Additionally, funding from the November 2021 passage of the Bipartisan Infrastructure Law continued to be allocated to projects moving forward in each state. 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.

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CHROMIUM

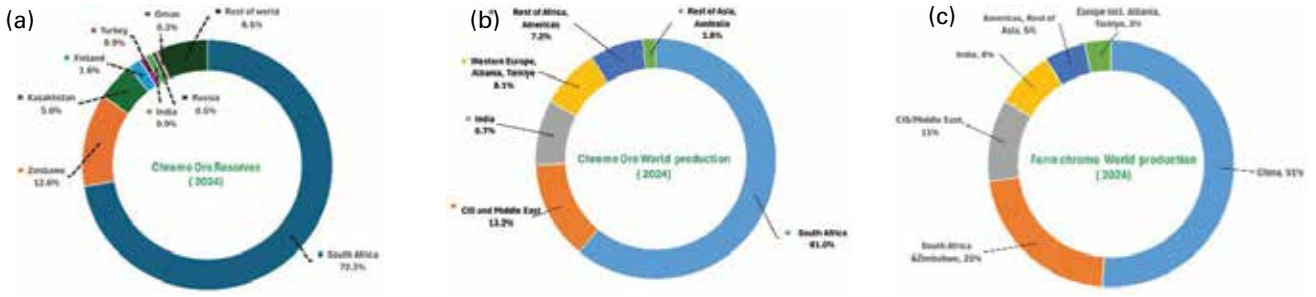
by Y. Rama Murthy, Research and Development Division, Tata Steel Ltd.

Chrome metal is the backbone of the steel and stainless-steel industry. The basic ore — metallurgical-grade chromite — is mined and concentrated in a beneficiation plant. The concentrated ore is smelted/reduced in a submerged arc furnace to different metallurgical grades: high-carbon (HC), low-carbon (LC) and medium-carbon (MC) ferrochrome.

Nearly 80 percent of the ferrochrome is used to produce stainless steel, special steels and alloys. Low-carbon and medium-carbon ferrochrome is used in the manufacture of special steels. Low-carbon ferrochrome (LC-Fe-Cr), with carbon content below 0.5 percent, is a ferroalloy used to regulate the ratio of chromium in steel production. It imparts the property to withstand extremely high temperatures and corrosive atmosphere. High-carbon ferrochrome is widely used as a raw material for stainless-steel production. High-carbon ferrochrome, with 60 to 70 percent chromium (Cr) content and 1 to 3 percent silicon (Si) content, is used as an alloying agent in ball-bearing steel (0.5 to 1.45 percent Cr), tool steel, mold steel (5 to 12 percent Cr) and high-speed steel (3.8 to 4.4 percent) improving the steel's hardenability, wear resistance and hardness. Medium-carbon ferrochrome is used to produce medium- and low-carbon structural steels, carburizing steel and in the manufacture of

Figure 1

Chrome ore resources, reserves and production in 2024. (Source: Investingnews.com) (a) Chromite reserves by country. (Source: ICDA, 2024) (b) Chrome ore world production. (c) Ferrochrome world production.



gears, high-pressure blower blades and more. Micro-carbon ferrochrome is used in the production of stainless steel, acid-resistant steel, heat-resistant steel and electrical heating alloys.

Noble ferroalloys are one of the vital additive inputs required to produce special steel. These ferroalloys are used in small quantities and are expensive compared to bulk ferroalloys. They include ferrovanadium, ferrotitanium, ferronickel, ferromolybdenum, ferrotungsten and ferroniobium. These alloys are generally used in turbine engines, power plants, furnaces and all pollution control equipment.

One of the most common alloys of chrome is chrome-nickel (CrNi) superalloy, also known as nichrome. Superalloys can withstand temperatures higher than 1,400 °C. This superalloy is manufactured using pure (99.5 percent) chrome metal. Chromium-containing superalloys can be split into four major groups: (1) high-performance alloys, (2) heat-resistant alloys, (3) corrosion-resistant alloys and (4) electronic alloys and soft magnetics. Apart from macro applications for chrome metal, there are also micro-level applications such as magnetic memory media, photo masks and integrated circuits.

Production and consumption

South Africa remains the major global producer and supplier of chrome ore, followed by Turkey, Kazakhstan, India and Finland. The mine productions of the top five countries were: South Africa, estimated 21 Mt; Turkey, estimated 8 Mt; Kazakhstan, estimated 6.5 Mt; India, 4.1 Mt; and Finland, 1.9 Mt. Globally, chromium production grew 1.8 Mt in 2024 to an estimated 47 Mt.

South Africa followed by Kazakhstan and India were the leading suppliers of ferrochrome. The supply of Reef Upper Group 2 (UG2) chromite, in addition to traditionally mined chrome ore, has changed the structure of the ferrochrome industry. Mining of chrome ore as well as ferrochrome production has seen a decreasing trend due to a sluggish market and cost pressures. The United States alone consumed an estimated 4 percent of world chromite ore for various applications, from raw chromite ore to chromium chemicals to chromium metal. Ferrochromium was consumed in the production of stainless steel and heat-resistant steel. Chromium material consumption decreased by 44 percent in 2023.

Markets, prices, economics and new applications

Demand for chromium driven by the automotive industry is increasing compared to construction and other industries that utilize it in various applications. Globally, the automotive and aerospace sectors are regarded as the primary drivers of growth for chromium industry. Use of chrome in new sectors like electric vehicles is expected to rise significantly in the future. At present, demand for chromium in these industries is strengthened by the development of new materials with low density, high-strength alloys and coatings, which enhance fuel efficiency and reduce emissions. The advent of better metallurgical technology and the discovery of new chromium-containing alloys have expanded their applications across various industries. Masteel achieved the production of high-chromium P91 steel grade (hard-to-weld steel grade, extensively alloyed with molybdenum and chromium to preserve mechanical resistance at high temperatures) in continuously cast blooms.

Trends and outlook

Continued demand for stainless steel in the construction, automotive and other industries is expected to be a key driver of chromite mining and chromium production and consumption. Chrome ore production has seen an increasing trend globally due to high prices and increased demand from China, and the Europe and Middle East regions' improved demand for local smelters, which led to an increase in demand for the ore. Ferrochrome production is picking up despite power-supply issues and slower markets due to the automotive and aerospace sectors, which are regarded as the primary drivers of growth. Europe's chromium pricing trends are deeply affected by its stringent environmental regulations and the push toward sustainable and recycled materials.

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COMMON CLAY AND SHALE

by Dibyajyoti Behera, Ashapura Group of Industries

Clay is a term used to loosely define a group of hydrous aluminum-silicate minerals. Clay sediment is the fine-grained earthy material that results from natural chemical weathering and hydrothermal rock alteration. Clay sediments are often characterized by high plasticity, or workability, that is useful for the manufacture of structural clay products such as brick and tile as well as pottery.

The U.S. Geological Survey (USGS) classifies clays mined in the United States into six categories: ball clay, bentonite, common clay, fire clay, fuller's earth and kaolin. In total, the United States produced around 26 Mt of these clays, including common clay and shale, with an estimated value of $1.7 billion. In 2019, common clay and shale made up 49 percent of the total clay production by volume but contributed only 12 percent of the overall value. By 2024, the United States had exported approximately 700 kt of bentonite and 1.6 Mt of kaolin, reflecting a modest decline from previous years.

Shale and shale gas

Shale is a fine-grained sedimentary rock formed by the consolidation of clay and silt-sized particles. Shales contain roughly 95 percent of the organic matter in all sedimentary rocks. However, this amounts to less than one percent by mass in an average shale. Shale gas refers to the methane trapped within these shale formations. Thus, shale acts as both the source and reservoir rock for extracting shale gas through hydraulic fracturing.

Outlook

The shale gas market size has grown rapidly in recent years. It is forecast to grow from $87.64 billion in 2024 to $100.44 billion in 2025 at a compound annual growth rate (CAGR) of 14.6 percent. The rapid pace of advancements in shale gas exploration and drilling technologies is boosting production volumes and reducing production costs, thereby contributing to market growth.

Shale gas enhances energy security by offering a reliable domestic or regional energy source. Countries with significant shale gas reserves can reduce their reliance on imported fossil fuels, minimizing exposure to geopolitical risks and potential supply-chain disruptions.

Key players

The global industrial common clay market is led by players including Imerys SA, KaMin LLC, BASF SE, Sibelco, Thiele Kaolin Co., Ashapura Group, LB Minerals Ltd., EP Minerals LLC, I-Minerals Inc., Active Minerals International LLC, Quarzwerke Group, Lhoist Group, SCR-Sibelco NV, Old Hickory Clay Co., Daleco Resources Corp., Wyo-Ben Inc., Bentonite Performance Minerals LLC, Burgess Pigment Co. and Ashapura Minechem Ltd.

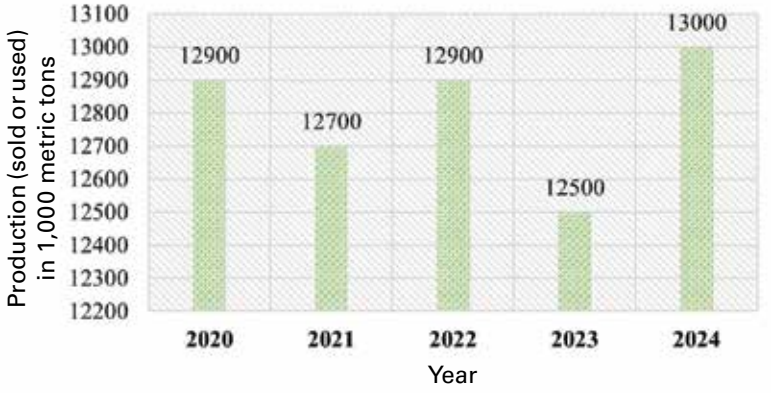
In the case of shale gas, Asia-Pacific was the largest region in the shale gas market in 2024. North America was the second largest, with Royal Shell PLC, Exxon Mobil Corp. and PetroChina Co. Ltd.

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Figure 1

Common clay production (sold or used) in the United States, 2020-2024. (Source: U.S. Geological Survey)



CONSTRUCTION AGGREGATES

by Venkata Aneesh Kona, Vulcan Materials Co.

Demand for sand, gravel and crushed stone is constant for urban and highway projects. Aggregates include coarse- to medium-grained materials vital to concrete and asphalt industries. In 2024, the industry faced complex demands, regulations and market trends.

Production and market overview

Construction aggregates are mined and crushed from various rock types, including limestone and granite. Some types, like shell and slate, generally do not meet specifications for plain cement concrete (PCC) and asphalt. Recycled materials contributed minimally to the total aggregates supply in 2024.

In 2024, the U.S. Geological Survey (USGS) reported aggregates production from 3,500 quarries and more than 6,500 sand and gravel pits. Top states for crushed stone included Texas and Florida. The USGS estimated 1.5 Gt of crushed stone were produced, valued at more than $26 billion — a 6 percent decrease in production but an 8 percent increase in value from 2023 (Fig. 1).

Regulatory landscape and testing

Aggregates must meet various state, federal and local standards. Physical testing, defined by ASTM International and the American Association of State Highway and Transportation Officials (AASHTO), ensures compliance. Agencies like the Federal Aviation Administration (FAA) and U.S. Army Corps of Engineers (USACE) have unique project-specific standards, such as the USACE "drop test" for armor stone. Railroad specifications also exist for ballast and traction sand.

Various tests determine aggregate suitability. The Los Angeles Abrasion (LA) test evaluates degradation. Sulfate soundness tests assess weathering. Skid resistance requires noncarbonate aggregates. The Micro-Deval test is gaining popularity. State variations exist: for example, New York requires a stringent 10-cycle magnesium sulfate test. Test results influence marketability; approved source status is an advantage.

Crushed stone, sand and gravel

The aggregates market serves applications from low-grade fill to high-grade PCC and asphalt. It is predominantly local due to transportation costs, with trucks handling about 85 percent of deliveries. The economical haul distance is 56 to 63 km, but urban congestion impacts freight rates. Most producers rely on contract haulers.

Geology dictates regional aggregates use. California's alluvial fans supply sand and gravel, while glacial deposits are mined in the Midwest. Crushed stone is preferred over crushed gravel for consistent performance in PCC and asphalt. Natural sand is favored over manufactured, but meeting ASTM C-33 specifications is difficult. In 2024, U.S. sand and gravel production declined 8 percent to 890 Mt, valued at more than $12 billion, primarily for PCC use.

Recycling and substitutes

Recycled asphalt pavement (RAP) and recycled concrete are increasingly used for base materials. However, they do not meet state specifications for approved PCC or asphalt mixes. Recycling is a small percentage of total aggregates consumption. Substitutes like iron slag present quality concerns. Asphalt producers recycle roofing shingles. Blending RAP with washed concrete-grade sand balances fines, increasing demand for washed sand. Other recycled materials like crushed glass are used. Meeting standards is the main challenge.

Health and safety

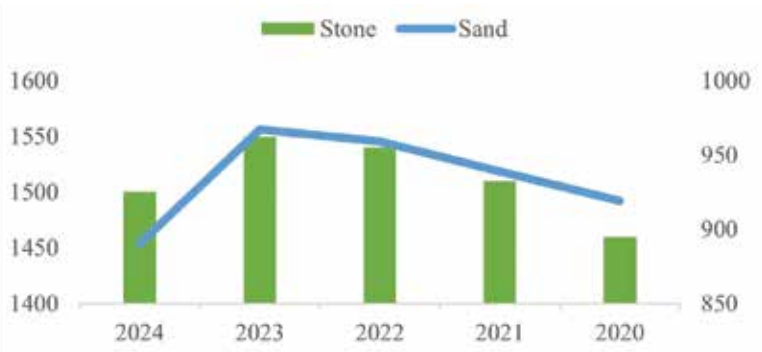
The U.S. Mine Safety and Health Administration (MSHA) actively enforces safety regulations. Crystalline silica is a key concern due to widespread quartz (SiO_2). In 2024, MSHA finalized a rule limiting miners' respirable crystalline silica exposure to 50 µg/m^3. Another 2024 regulation requires surface mines to implement written safety programs for mobile equipment hazards. MSHA prioritized training and safety alerts.

Transportation and market reach

Trucking accounts for 85 percent of aggregates transport. The 56-to-63-km cost-effective trucking rule is strained by urban congestion. Rail and barge transports offer alternatives, but accessibility is limited. Strategic facility placement reduces costs. Rail offers lower rates but requires sidings. Barge and ship

Figure 1

Aggregates production 2020-2024 (data in million metric tons).



transport are cost effective but need navigable waters. Unloading costs can increase final costs.

Innovation and sustainability

The industry embraces innovation for efficiency and sustainability. Autonomous hauling and increased use of recycled materials are rising. Artificial intelligence (AI) transforms quarry operations into data-driven systems, providing real-time insights and optimizing resource allocation. AI guides decision-making for safer, more efficient workflows.

Challenges and opportunities

The aggregates industry faces public opposition, leading to permit denials. Companies employ environmental managers and host open houses to educate the public. Despite progress on environmental concerns, truck traffic remains a significant challenge.

Acquisitions

In 2024, significant quarry acquisitions reflected consolidation. Arcosa acquired Stavola. Martin Marietta purchased 20 aggregate operations from Blue Water Industries. CRH acquired BoDean Co. and Ary Corp. Vulcan Materials acquired Whitaker Contractor and Wake Stone Corp. Granite Construction agreed to acquire Dickerson & Bowen. Summit Materials agreed to be acquired by Quikrete Holdings Inc. Metso acquired Diamond Z and Screen Machine Industries.

Outlook

The industry closed 2024 with strong demand but faced weather and regulatory pressures. 2025 brings cautious optimism for continued strength, driven by improved interest rates and merger & acquisition (M&A) integration.

Uncertainty remains regarding funding and pricing. Growth projections are modest, with ongoing permitting, zoning and environmental hurdles. Material shortages, due to urban land constraints, will likely push new quarries farther from cities, increasing regional prices via higher transport costs. The future of infrastructure funding after the Infrastructure Investment and Jobs Act (IIJA) is a key question. Major metropolitan areas like Atlanta and Dallas–Fort Worth will continue to drive demand.

Figure 2

2024 Construction Materials Index (CMI) versus Dow Jones Industrial Average (DJIA) and S&P 500. (Source: S&P Capital IQ)



Figure 3

National impact of the aggregates industry (conservative). (Source: Phoenix Center, The Economic Impact of the Natural Aggregates Industry: A National, State, and County Analysis).

	Aggregate Industry	Type II Multipliers	Impact on Other Industries	Total Impact
Jobs	104,841	4.35	351,640	456,481
Earnings	$9.2 billion	3.74	$25.2 billion	$34.4 billion
Sales	$27.2 billion	2.86	$50.6 billion	$77.8 billion

Conclusion

The aggregates industry is evolving. Future success relies on collaboration, innovation and sustainability. Stakeholders must prioritize safety, public perception and new technologies. A key concern for 2025 is sustained pricing momentum. Fortunately, all three primary end markets show favorable conditions:

- Infrastructure: The IIJA continues robust demand, with only 20 percent of funds spent as of April 2024, extending demand beyond the program's expiration,
- Residential: Tight housing supply and expected interest rate declines boost outlook.
- Nonresidential: Some leaders see stabilization or growth in 2025.

Producers should prepare for regional supply challenges, monitor regulatory changes and track evolving demand. Figure 2 shows how the Construction Materials Index (CMI) compares against the Dow Jones Industrial Average and S&P 500. The CMI includes Arcosa Inc., Buzzi S.p.A., CEMEX S.A.B. de C.V., Construction Partners Inc., Eagle Materials Inc., GCC S.A.B. de C.V., Granite Construction Inc., Heidelberg Materials AG, Holcim Ltd., Knife River Corp., Martin Marietta Materials Inc., Summit Materials Inc., The Monarch Cement Co., Titan Cement International S.A. and Vulcan Materials Co. Figure 3 shows the economic impact of the aggregates industry.

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

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 2024 was estimated to be 880 kt, an increase of 4 percent from 849 kt in 2023. 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 in 2024 were 63.3 kt. Diatomite imports were 14.2 kt, about one-fourth of the amount of exports. Total world production of diatomite was an estimated 3 Mt in 2024. Following the United States in diatomite production, other significant producers in 2024 were Denmark (530 kt), China (370 kt), France (250 kt), Turkey (240 kt) and Argentina, Mexico and Peru (each with 100 kt). 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 2024. The estimated annual average unit value of diatomite in 2024 was $590/t, slightly more than in 2023. Diatomite used as an absorbent and as a lightweight aggregate in cement was priced at approximately $10/t, but specialty grade diatomite, used in art supplies, biomedical applications or cosmetics, could be priced above $1,000/t.

Consumption

Domestic apparent consumption in 2024 was estimated to be 830 kt, an increase of 23 percent from 2023. 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 2024, approximately 65 percent of diatomite was utilized in filter aids. The remaining 35 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 sales of natural and synthetic substitute materials into diatomite markets have 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. The substitution for diatomite by more advanced filtration products, including carbon membranes, ceramics and polymers, was not a concern in 2024. 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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FIRE CLAY

by Dibyajyoti Behera, Ashapura Group of Industries

Fire clay refers to a group of refractory clays capable of withstanding temperatures above pyrometric cone equivalent (PCE) 19. Two key properties that determine the suitability of fire clay for manufacturing refractory bricks are refractoriness and plasticity. Refractory manufacturers prefer fire clay, which is high in alumina and low in impurities such as iron oxide, lime, magnesia and alkalis. The aluminous (kaolinitic) variety of fire clay is particularly valued for its higher refractoriness, which is attributed to its hardness, density and low iron content. This variety also exhibits a white-burning color upon firing, further indicating its purity.

Production

In 2024, the United States produced an estimated 670 kt of fire clay (Fig. 1).

Exports and imports

The fire clay market is mainly driven by the growths of the steel and construction industries. These sectors require heat-resistant materials, like fire clay, for lining furnaces, kilns, incinerators and other high-temperature equipment. As steel production and construction activities expand, the demand for fire-clay-based refractory products also rises.

In 2024, 140 kt of fire clay were exported; import figures for fire clay were not available from the U.S. Geological Survey. In January 2025, the United States exported $3.35 million worth of fire clay and imported $97,300, resulting in a trade deficit of $3.25 million. Compared to December 2024, U.S. exports increased by 69 percent (from $1.98 million to $3.35 million), and imports rose by 34.2 percent (from $72,500 to $97,300). The top export destinations were Mexico ($1.74 million), Canada ($412,000), Japan ($376,000), Australia ($279,000) and South Korea ($176,000). Most imports came from China ($66,500) and Canada ($30,700).

Outlook

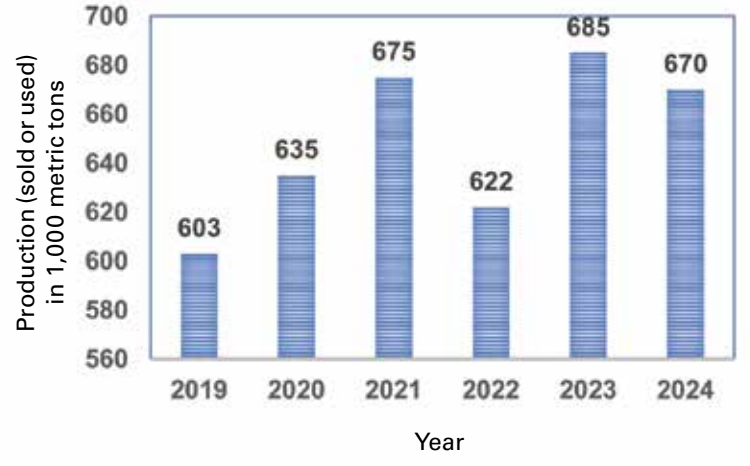
The global fire clay market is expected to witness significant growth over the forecast period, owing to increasing use as fire bricks and in metalworking industries. Its major application is in chimney linings, boiler, glass melting, pottery kilns, and blast and reheating furnaces. It is used as a protective shield in heat-generating machinery installed in places such as power plants and households with fireplaces. Fire clay is applied in these furnaces because of its high melting point (1,515 to 1,775 °C) and its plasticity. The rising number of power plants in India, China, the United States, South Africa and Brazil, the result of increasing energy demand by their populations and rapid industrialization, is expected to fuel fire-clay demand over the forecast period. Furthermore, it is also being increasingly used in construction projects to make the buildings fireproof. This is expected to be fueled by infrastructural developments in China, India, the United States, Saudi Arabia and the United Arab Emirates, backed by rising disposable income.

Key players

The leading companies in the industry include Claymont Fire Co. Inc., Fire Clay Minerals Inc., Fireclay Tile Inc., Leeds Fireclay Co. Ltd,, Mohawk

Figure 1

Fire clay production (sold or used) in the United States, 2019-2024. (Source: U.S. Geological Survey)



Industries Inc., Porcelanosa Grupo, RAK Ceramics PJSC, Rutland Fire Clay Co., Shandong Fire-Proof Materials Group Co. Ltd. and Wortley Fire Clay Co.

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FRAC SAND

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

In 2024, the hydraulic fracturing sand (commonly known as frac sand) market was valued at around $8.1 billion globally, with U.S. demand reaching an all-time high. The Permian Basin continues to be the busiest region; however, spot pricing in the Permian was down about 40 percent year over year due to oversupply.

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 sizes. By convention, the size range includes particles small enough to pass a sieve indicated by the first number but are retained on the 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 natural 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 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 very 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

Demand for U.S. frac sand reached an all-time high in 2024, according to estimates from Lium Research, an energy market research firm. Lium estimates that U.S. frac sand pumped increased to 112 Mt for the year. The busiest region continues to be the Permian Basin, where 65 Mt of frac sand were consumed, according to Lium, mostly sourced from local frac sand mines operated in the West Texas region since 2017.

The total North American drilling rig count decreased again in 2024, based on data from Baker Hughes (Fig. 1). March saw a maximum of 625 rigs, which fell to 589 by the end of the year. The second quarter saw a consistent decline, with July marking the annual low. The rig count bounced back sharply in August and remained stable for the rest of the year, yet still about 200 rigs below the high in January 2023. The total rig count is typically an indicator of the overall health of the oil and natural-gas industry, and therefore by extension the frac sand industry. This year however, the frac sand market appears to be improving despite the rig count continuing to decline.

The price of oil can also be an indicator of frac sand market health. West Texas Intermediate (WTI) oil prices increased during the first quarter, reaching an annual high of $87 per barrel in early April. Prices consistently fell for the remainder of the second quarter before recovering slightly in late June and early July. WTI prices ended the year around where they started, at $72 per barrel, according to data from www.macrotrends.net.

Prices

While frac sand demand has been reaching new all-time highs, spot prices (especially in the Permian) have been under pressure over the past several years because supply growth has overshot demand. In the Permian Basin, Lium assessed 2024 spot prices at $18/t on a free-on-board basis from the mine in the Permian Basin, down about 40 percent year over year. In other frac sand production zones, such as the Northern White Sand corridor in Wisconsin and Minnesota, and the Eagle Ford Shale Basin in South Texas, frac sand producers enjoyed more price stability during 2024, according to Lium.

Figure 1

Total U.S. rig count, 2024.



Trends and outlook

The market research firm IMARC Group projects a frac sand market compound annual growth rate of 7.06 percent during 2025 to 2033, bringing the market to an estimated $16.1 billion by 2033. North America leads the market; however, China and Australia continue to explore their shale reserves, increasing the demand for frac sand in the Asia-Pacific region, according to IMARC.

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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 2024 was estimated by the U.S. Geological Survey (USGS) to be $10 million, unchanged from 2023. 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 the cutting of large diamonds.

During 2024, each of the 50 states were estimated to produce at least $1,790 worth of gem materials. Ten states accounted for 90 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 2024, 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 $63 million in 2024. Reported output of synthetic gemstones was from eight companies in North Carolina, California, Oregon, Maryland, New York, South Carolina, Wisconsin and Arizona, in descending order of production value. Production included the manufacture of 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 2024. U.S. apparent consumption of unset gemstones in 2024 decreased by 15 percent over the previous year to an estimated $18 billion. About 82 percent of the 2024 U.S. gemstone apparent consumption was unset gem-quality diamond, and the remaining 18 percent was unset nondiamond gemstones. 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. During 2024, total U.S. gemstone trade with all countries and localities was about $21 billion ($19.1 billion in imports plus $1.88 billion in domestic exports). In 2024, U.S. domestic exports of diamond were valued at $1.37 billion. U.S. domestic exports of gemstones other than diamond were valued at $516 million. U.S. imports of diamond were valued at $15.9 billion, and U.S. imports of gemstones other than diamond were valued at $3.21 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 or foreign exports shipped to other centers is one measure of the significance of the United States in the worldwide diamond supply network.

In a four-year (2020-2023) average of U.S. import sources by value, the leading gemstone sources were India, 47 percent; Israel, 26 percent; Belgium, 11 percent and South Africa, 5 percent. Diamond imports accounted for an average of 83 percent of the total value of gemstone imports during 2024.

In April 2022, the U.S. government banned the import of rough and finished gem-grade diamonds from Russia, and the U.S. Department of the Treasury placed sanctions on the Russian state-owned diamond mining company to prevent diamond revenues from funding the conflict with Ukraine. The Group of Seven (G7; representatives of the seven leading industrial nations) also announced a ban on Russian diamonds in December 2023, with the goal of limiting Russia's ability to fund its conflict with Ukraine through diamond sales. The European Union (EU) included the G7 diamond ban into its sanctions package against Russia, making it legally binding on EU member states. The EU ban included diamonds processed in third countries and went into effect on March 1, 2024.

Outlook

During 2024, U.S. jewelers continued to expand their online business and sales from their websites. 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 emerge to serve the diamond and gemstone industries, partially replacing "brick-and-mortar" store sales. Online auctions continued gaining a higher share of rough diamond sales. The major U.S. gemstone trade shows are being held again.

During 2024, world gem-quality natural diamond production was an estimated 72 million carats compared with 71.8 million carats in 2023. By 2025,

several large mines will reach the ends of their mine life, while only a few new projects are currently being developed.

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.

High-purity natural and synthetic graphites have played an important role in the emerging nonhydrocarbon energy sector and have been 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 purified graphite (SPG), expanded graphite and graphene.

Production

No natural graphite was mined in the United States in 2024, but five natural graphite projects were under development.

In October, South Star Battery Metals Corp. announced results of the preliminary economic assessment for the BamaStar graphite project in Alabama. Planned production was an average 47 kt/a of graphite concentrate over a 19-year mine life. Titan Mining Corp. continued development of the Kilbourne graphite project, located in St. Lawrence County, NY. In December, the company released the results of the maiden mineral resource estimate. Using a cutoff grade of 1.50 percent, inferred resources were an estimated 20.3 Mt of 2.91 percent graphitic carbon (C_g) for 592 kt of graphite content. In Alaska, Graphite One Inc. continued to progress a feasibility study for its Graphite Creek project. Two additional companies, Reflex Advanced Materials Corp. and Westwater Resources Inc., continued development of natural graphite projects in Montana and Alabama, respectively. In February 2024, Syrah Resources Ltd. began production of natural graphite battery anode material (BAM) at its new facility in Vidalia, LA. Capacity was planned to be 11.25 kt/a of SPG initially, with a potential expansion to 45 kt/a. Syrah supplied the graphite concentrate feedstock from its Balama Mine in Mozambique. Westwater Resources continued construction of a natural graphite BAM facility in Kellyton, AL. An additional nine natural and synthetic graphite BAM plants were under early development in the United States.

World production of natural graphite in 2024 was an estimated 1.6 Mt compared with 1.53 Mt in 2023. The leading producers of natural graphite in 2024 were China, 1.27 Mt; Madagascar, 89 kt; Mozambique, 75 kt; and Brazil, 68 kt. These four countries contributed approximately 94 percent of the global natural graphite production. China was also the leading supplier of BAM. China exported 42 kt of natural graphite BAM in 2024, compared to 55.7 kt in 2023, a decrease of 25 percent. Top destinations in 2024 were the Republic of Korea (44 percent), the United States (23 percent), Japan (23 percent) and Indonesia (10 percent). In 2024, China exported 81.3 kt of synthetic graphite BAM, compared to 75.6 kt in 2023, an increase of 8 percent. Top destinations of synthetic graphite BAM in 2024 were the United States (37 percent), Japan (16 percent), Hungary (16 percent) and the Republic of Korea (11 percent).

Consumption

U.S. consumption of natural graphite was approximately 52 kt in 2024 compared with 66 kt in 2023. The major uses of natural graphite in 2024 were batteries, brake linings, lubricants, powdered metals, refractory applications and steelmaking. The major uses of synthetic graphite in 2024 were batteries, electric motor brushes, electrodes and graphite shapes.

Prices

Prices for natural graphite largely depend on flake size, size distribution and carbon content. Prices for individual flake mesh sizes were unavailable. The estimated unit values of imports in 2024 were $640/t for amorphous, $1,070/t for flake and $2,900/t for vein graphite from Sri Lanka. According to China customs data, prices for uncoated spherical graphite exported to the United States were $4,030/t in 2024 compared with $4,390/t in 2023, a decrease of 8 percent. Prices for synthetic graphite anode material decreased by 16 percent to $4,420/t in 2024 from $5,250/t in 2023.

Foreign trade

U.S. trade data are from the U.S. Census Bureau and were analyzed by the U.S. Geological Survey (USGS). The data presented in this section are updated trade statistics and were not derived from the 2025 Mineral Commodity Summary. Total U.S. graphite exports decreased by 19 percent in tonnage to 35.8 kt valued at $249 million in 2024 from 44.5 kt valued at $242 million in 2023. Total graphite export tonnage was 24 percent natural graphite and 76 percent synthetic graphite. Total U.S. natural graphite imports were 73.9 kt in 2024 compared with 73.5 kt in 2023, and the value decreased by 9 percent to $142 million in 2024 from $157 million in 2023. Quarterly imports averaged 16.1 kt during the first three quarters of the year but increased to 25.5 kt in the fourth quarter. Principal import sources of natural graphite, by tonnage, were China (48 percent), Canada (14 percent), Madagascar (11 percent), Mozambique (10 percent) and Mexico (10 percent).

Total U.S. synthetic graphite imports increased by 3 percent in tonnage to 128 kt in 2024 from 124 kt in 2023, and the value decreased by 15 percent to $488 million in 2024 from $575 million in 2023. Imports from China increased by 16 percent in tonnage and the total value decreased by 12 percent. Principal import sources of synthetic graphite, by tonnage, were China (68 percent), Mexico (8 percent), Republic of Korea, France and Spain (4 percent each).

In 2024, U.S. imports of BAM, combined natural and synthetic, was approximately 48 kt, an increase of 23 percent compared with approximately 39 kt in 2023. Most of this material came from China, with the rest coming from Indonesia, Japan and the Republic of Korea.

In December 2024, a coalition of graphite producers in North America petitioned the U.S. Department of Commerce and the U.S. International Trade Commission (ITC) to investigate the graphite trade practices of China. The filing claimed that China had been dumping graphite BAM into the United States at prices below fair market value. In January 2025, the ITC voted to continue its investigation after finding a reasonable indication the BAM industry in the United States was being negatively affected.

Industry news

In Brazil, South Star began commercial production at the Santa Cruz Mine, located in Bahia. Phase one capacity was 12 kt/a, phase two was 25 kt/a, and phase three was 50 kt/a. In Tanzania, Walkabout Resources Ltd. began commissioning the Lindi Jumbo graphite mine. In November, the company entered voluntary administration, but stated operations would continue in the meantime. Initial mine capacity was 40 kt/a of graphite concentrate.

In Indonesia, BTR New Material Group Co. Ltd. (Shenzhen, China) began commercial production of BAM at its new facility. Production capacity of the new facility was 80 kt/a of BAM in phase one, expandable to 160 kt/a in phase two. The company planned to produce natural and synthetic graphite BAM in addition to silicon-based BAM.

In 2024, Graphjet Technology began commercial operations at its new synthetic graphite facility in Malaysia. The facility would produce up to 3 kt/a of synthetic graphite from about 9 kt/a of palm kernel shells. Palm kernel shells are an agricultural waste byproduct generated during the production of palm seed oil. The company also planned to produce hard carbon, which would be shipped for use as feedstock at a planned synthetic graphite facility in Nevada. The company planned to begin production at the Nevada facility in 2026 with an initial capacity of 10 kt/a of synthetic graphite.

In Norway, Vianode AS commissioned Via ONE, a new synthetic graphite facility located in Heroya. The new facility was designed to produce up to 2 kt/a of synthetic graphite BAM. The company had been producing BAM at a pilot plant in Kristiansand since 2021.

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, much of it focused on Africa. Projects were 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. Forty-seven companies mined gypsum in the United States in 15 states. Production of crude gypsum in the United States during 2024 was estimated to be 22 Mt, slightly more than in 2023. The average price of mined crude gypsum was $13/t. Sales of synthetic gypsum, most of which was generated as a flue-gas desulfurization product from coal-fired electric power plants, in 2024 were estimated to be 15 Mt and priced at approximately $10/t.

World production of gypsum in 2024 was estimated to be 160 Mt, slightly more than in 2023. The United States was the largest producer of natural gypsum in 2024 with an estimated 22 Mt, followed by Iran with an estimated 16 Mt, Oman with 14 Mt, China with 12 Mt, Spain with 11 Mt and Turkey with 10 Mt. Crude gypsum production was reported or estimated in 78 countries or localities in 2024.

Consumption

Apparent consumption of crude gypsum was an estimated 44 Mt in 2024, compared with 44.6 Mt in 2023. An estimated 2.8 billion m^2 of gypsum-derived wallboard products were produced in 2024 domestically. Synthetic gypsum accounted for 34 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 of gypsum scrap that was generated by wallboard manufacturing, wallboard installation and building demolition was recycled. That quantity included an estimated 600 kt of preconsumer wallboard waste recycled by wallboard manufacturers, coupled with an estimated 100 kt 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. According to the U.S. Census Bureau, U.S. gypsum imports totaled 7.13 Mt in 2024, 8 percent less than in 2023. Exports totaled 45.1 Mt, slightly more than in 2023. 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. For the same reason, Canada and Mexico were the top two recipients of gypsum exports from 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 power generation plants to natural 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.

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INDUSTRIAL DIAMOND

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

Production

During 2024, world production of natural and synthetic industrial diamond was estimated to be 15.5 billion carats, most 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 41 million carats were produced in 2024, unchanged from production in the previous year. The leading five natural industrial diamond producing countries in descending quantity order were Russia, Botswana, Congo (Kinshasa), Zimbabwe and South Africa, accounting for 97 percent of global production.

Synthetic industrial diamond was produced in eight countries during 2024. About 99 percent of the combined natural and synthetic global output was produced (in descending order of production) in China, the United States, Russia, Ireland and South Africa. During 2024, China was the world's leading producer of synthetic industrial diamond followed by the United States and Russia. In 2024, the two U.S. synthetic producers, one in Pennsylvania and another with facilities in Florida and Ohio, produced an estimated 160 million carats, valued at about $53 million. This production was entirely synthetic diamond bort, dust and powder, and grit. Also in 2024, 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 15 million carats of used industrial diamond, valued at about $660,000, was recycled in the United States during 2024. Of this total, an estimated 77,000 carats were recycled diamond stone with a value of $120,000 and the remainder was diamond bort, dust and powder, and grit. Diamond stone recycling operations have decreased in number and scale 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 opto-electronic 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, 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 2024. Estimated U.S. apparent consumption of natural and synthetic industrial diamond bort, dust and powder, grit and stones was 330 million carats, valued at $60 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 2024, more than 99 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 2024, the average unit value for diamond bort, dust and powder, and grit material produced in the United States was $0.33 per carat. According to the U.S. Census Bureau, U.S. imports of all types of industrial diamond had an average unit value of $0.21 per carat in 2024. These imports were a combination

of natural and synthetic diamond stone that had an average unit value of $10.87 per carat and natural and synthetic diamond bort, dust and powder, and grit that had an average unit value of $0.19 per carat.

Foreign trade

Trade data in this report are from the U.S. Census Bureau. During 2024, U.S. imports of industrial-quality diamond stones (natural and synthetic) were 401,000 carats valued at $4.36 million from 13 countries or localities. The leading import sources were India with 37 percent, South Africa (30 percent), Botswana (17 percent) and Canada (6 percent). U.S. imports of industrial-quality diamond bort, dust and powder, and grit (natural and synthetic) were 238 million carats valued at $44.9 million from 21 countries or localities. The leading import sources were China with 75 percent, South Korea (8 percent) and Ireland (5 percent). During 2024, U.S. exports of industrial diamond dust, grit and powder (natural and synthetic) were about 73.2 million carats valued at $42.2 million to 40 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 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 that 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 natural diamond production is expected to continue declining further in quantity, and the global supply of rough natural diamond is forecasted to steadily decrease.

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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 to those properties, garnet is free of crystalline silica and can be recycled. Garnet is the 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 as 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 2024, industrial garnet was mined by three firms — one in Montana and two in New York. In 2024, U.S. production of crude garnet concentrate for industrial use (industrial garnet) was estimated by the U.S. Geological Survey (USGS) to be 80 kt valued at $17 million, a 12 percent increase in both quantity and value compared with 2023 production. Most of the 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 140 kt valued at $50 million, a 15 percent decrease in quantity and a 14 percent decrease in value compared with 2023 production.

Total world industrial garnet production was estimated to be 980 kt, compared with 972 kt in 2023. Australia (390 kt), China (310 kt) and South Africa (180 kt) were the leading producers in 2024. The United States produced about 8 percent of the industrial garnet mined worldwide.

Recycling

Garnet can be recycled multiple times without significant degradation of its quality. Most recycled garnet is from blast cleaning and water-jet-assisted cutting operations. Garnet was recycled in Oregon and Pennsylvania, at plants with capacities of 16 and 25 kt, respectively, per year.

Consumption

In 2024, apparent consumption of industrial garnet in the United States was estimated to be 160 kt, accounting for 16 percent of global garnet production. U.S. apparent consumption decreased by 21 percent compared with 2023.

Major applications 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, hydrocarbon reservoir-fracturing proppants, 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, natural-gas and petroleum industry, shipbuilders, textile stone washing, water filtration plants and wood-furniture-finishing operations.

Prices

Prices for industrial garnet cover a range depending upon application, quality, quantity purchased, source and type. During 2024, estimated domestic values of industrial garnet crude concentrate averaged $220/t. The average unit values of refined garnet sold in the United States during the year averaged $350/t. The average customs unit value of U.S. garnet imports in 2024 was $270/t, an increase of 28 percent compared with 2023.

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, the United States has become increasingly dependent upon foreign sources of industrial garnet.

According to data from the U.S. Census Bureau that was adjusted by the USGS, imports for consumption in 2024 were received from 12 countries or localities and totaled 155 kt, a slight increase from 2023. In 2024, South Africa (54 percent), Australia (29 percent), China (9 percent) and India (6 percent) were the leading suppliers of imports to the United States. U.S. exports were shipped to 55 countries or localities and totaled 24 kt, an increase of 22 percent compared with 2023. U.S. exports of industrial garnet were shipped to Canada (57 percent), Mexico (21 percent) and the Netherlands (4 percent), with the remainder going to several other countries and localities.

Outlook

Industrial garnet consumption 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 media 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. Census Bureau and Trade Mining LLC; data adjusted by the U.S. Geological Survey

INDUSTRIAL SAND AND GRAVEL

by Robert C. Goodin, National Minerals Information Center, U.S. Geological Survey

Industrial sand and gravel, often called silica, silica sand or quartz sand, includes sands and gravels with high silicon dioxide (SiO_2) content. These sands are used for foundry, glassmaking, hydraulic fracturing (fracking) and many other industrial applications.

Production

In 2024, U.S. industrial sand and gravel sold or used was an estimated 130 Mt valued at an estimated $5.1 billion. The quantity of industrial sand and gravel sold or used decreased slightly, and the value decreased by 12 percent compared with 2023. The estimated average unit value of domestically produced industrial sand and gravel in 2024 was $39/t compared with $43.40/t in 2023. Industrial sand and gravel was produced by 133 companies from 216 operations in 33 states in 2024. The leading producing states were, in descending order of production, Texas, Wisconsin, Illinois and Oklahoma. Combined production from these states accounted for 78 percent of total domestic sales and use.

In February, Atlas Energy Solutions Inc. purchased High Crush Inc. In June, Covia Holdings LLC completed a separation of its energy businesses to become Covia Energy LLC. In July, U.S. Silica Holdings Inc. was acquired by Apollo Global Management Inc. In November, Covia Energy LLC and Black Mountain Sand Holdings LLC merged to create Iron Oak Energy Solutions LLC.

World production of industrial sand and gravel was estimated to be 440 Mt in 2024. The United States was the world's leading producer and consumer of

industrial sand and gravel based on estimated world production figures.

Consumption

U.S. apparent consumption of industrial sand and gravel was estimated to be 120 Mt in 2024, a 5 percent decrease from 2023. The most important driving force in the industrial sand and gravel industry remained the production and sale of frac sand. In recent years, the consumption of frac sand increased as hydrocarbon extraction from shale deposits increased and the quantity of frac sand used per well increased in the United States. In 2024, domestic industrial sand and gravel consumption decreased due to an oversupply of frac sand leading to lower prices, which caused many industrial sand and gravel companies to decrease production or idle operations.

Approximately 83 percent of the U.S. tonnage was used as hydraulic-fracturing sand (frac sand) and well-packing and cementing sand, and 7 percent as glassmaking sand. Other common uses were, in decreasing quantity of use, foundry sand, whole grain fillers for building products, filtration sand and recreational sand, which accounted for 6 percent combined. Other minor uses were, in decreasing quantity of use, roofing granules, chemicals, abrasives, silicon and ferrosilicon, ceramics, fillers, traction, filtration gravel, metallurgic flux and other unspecified uses, which together accounted for 4 percent.

Foreign trade

According to the U.S. Census Bureau, the United States remained a net exporter of industrial sand and gravel, shipping it to almost every region of the world. High global demand for U.S. industrial sand and gravel can be attributed to the high quality and advanced processing techniques used in the United States for many grades of industrial sand and gravel, meeting specifications for virtually any use. Imports of silica are generally of two types — small shipments of very high-purity silica or a few large shipments of lower-grade silica shipped only under special circumstances (for example, very low freight rates). Imports of industrial sand and gravel in 2024 were an estimated 300 kt, a 42 percent increase from 2023. U.S. exports of industrial sand and gravel were an estimated 8.3 Mt, a 16 percent increase from 2023.

Outlook

The industrial sand and gravel industry continued to be concerned with safety and health regulations and environmental restrictions, especially those concerning crystalline silica exposure. Local shortages of industrial sand and gravel were expected to continue to increase owing to land development priorities, local zoning regulations and logistical issues. These factors may result in future sand and gravel operations being located farther away from high-population centers. Increased efforts to reduce cost, emissions, and the risk of exposure to crystalline silica have led to an increase of in-basin "dry sand" and undried "wet sand" being sold or used as frac sand instead of conventional "dry sand" from out-of-basin sources.

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KAOLIN

by Debashis (Deba) Das, 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 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 (USGS) Mineral Commodities Summary, domestic clay production in 2024 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 4.5 Mt, 17.3 percent of all clay materials recovered in the United States. Half the total kaolin (about 54 percent) went into developing coatings, fillers, extenders and binders, while about 23 percent was used in ceramic products.

Exports and imports

In 2024, according to the USGS, the United States exported about 1.6 Mt of kaolin minerals, mainly as components in coatings, extenders and fillers, and as ceramics, to Mexico, China and Japan. Compared to 2023, total clay and shale exports increased by 2.4 percent. By comparison, in 2024, only 130 kt of kaolin was imported into the United States. Kaolin exports accounted for $288 million and imports $24 million, resulting in a positive U.S. trade balance of $264 million.

Trends and outlook

According to Grandview Research, 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 and increasing demand for paints and coatings, ceramic-based products and cement will drive market growth.

Emphasis on green construction will also drive the kaolin market. According to the World Bank's IFC report, 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 propelling demand for kaolin. Plastics are used in façade panels, exterior coatings and carpentry, and the rising number of nuclear families in India and China is promoting demand for plastics.

However, market growth can be impeded by stringent regulations against kaolin mining. Many kaolin mines are near biodiversity hotspots, potentially degrading water and air bodies. Introducing suspended particles into the air can cause respiratory problems, and mining operations can affect the pH level in nearby water and potentially impact the aquatic flora and fauna. *(References available upon request)*

KYANITE, ANDALUSITE AND SILLIMANITE

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

Economic deposits

The sillimanite minerals group includes the minerals kyanite, andalusite and sillimanite. These naturally occuring minerals are polymorphic (Al_2SiO_5) but have differences in their respective physical, thermodynamic and crystalline structure properties. They occur as accessory minerals associated with high-grade regional or contact metamorphism. Stratiform replacement deposits also occur through alumina enrichment of silica-rich metasedimentary and metavolcanic rocks via hydrothermal alteration. Sillimanite may occur within mineralized quartz veins and pegmatites. As unconsolidated deposits, these minerals can occur in heavy mineral beach and stream placers.

The Appalachian region of the southeastern United States hosts economic and sub-economic concentrations of kyanite, andalusite and sillimanite. Other known occurrences are in Alaska, California, Florida, Idaho, Nevada and New Mexico. Economic deposits outside of the United States occur in 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 the sillimanite group minerals make them useful for highly heat-intensive refractory applications, metallurgy, investment casting molds, glass manufacturing and ceramics. High-quality specimens have a market for 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.

Most mined sillimanite group minerals are used in refractories, predominantly for steel and iron manufacturing, which can be used as a indicator of global mineral production.

Other refractory uses include insulating brick, firebrick, refractory concrete, kiln furniture, mortar and gunning mix.

Additional end products and uses include ceramics, glass, nonferrous metals, cement, brake shoes and pads, abrasive products, electrical insulators, additives, fillers and filtration of aluminum slag and impurities.

Production and consumption

In 2024, global production was estimated at 432 kt, lower than the previous five-year average of 524 kt (2019-2023), according to revised U.S. Geological Survey (USGS) estimates. The 2024 estimate includes 150 kt of andalusite from South Africa, 100 kt of andalusite from China, 78.6 kt of kyanite and calcined kyanite from the United States, 60 kt of andalusite from France, 40 kt of andalusite from Peru, and 3.6 kt of combined sillimanite and kyanite from India (not including reclassified beach deposits). 2024 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 2024, KMC reported production of approximately 78.6 kt of combined kyanite and mullite product, with an international and domestic customer base estimated at 55 and 45 percent for KMC's products, respectively. 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.

The USGS reports that two companies, based in Alabama and Georgia, produce synthetic mullite from a combination of feedstock materials such as kyanite, kaolin, bauxite and bauxitic kaolin. 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. Additional details on production volumes from the above operations were not available and were not included in production estimates for the United States.

South Africa, China, France and Peru are the leading global producers for industrial-grade andalusite. Imerys Group conducts mining operations in the Brittany region of France (Glomel) and in South Africa (Thabazimbi). Since 1970, Imerys Group has been mining andalusite from highly weathered Ordovician-age schists adjacent to granitic rocks of the Armorican Massif. Imerys Group also mines andalusite from the Rhino Mine in South Africa, from deposits which are hosted in highly weathered pelitic rocks of the Pretoria Group associated with contact metamorphic rocks of the Bushveld Igneous Complex. In 2022, ARM Andalusite Resources (Pty) Ltd took ownership of an existing mine in the Thabazimbi area of South Africa that was previously operated by Andalusite Resources (Pty) Ltd. Andalucita S.A. has been recovering andalusite since 2009 in northern Peru, with an estimated production capacity of 50 kt as of 2018. In China, andalusite reserves were estimated at 361 Mt, according to details from a company website in 2023 (Xinjiang Xinrong Yilong Andalusite Co., Ltd). The website also stated that the company has an annual production capacity of 40 kt of andalusite products. Additional production information was not available.

India is the primary source for the global supply of sillimanite with operations in the states of Maharashtra, Andhra Pradesh, Odisha and Kerala. More than 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 of proven reserves. The ministry also estimates total resources of 105.7 Mt of kyanite, with 393 kt of proven reserves.

Foreign trade and prices

Import and export pricing for the sillimanite minerals group products are influenced by a variety of factors including ore grade and purity, quantity, particle (mesh) size, packaging, monetary exchange rates, source and destination. In 2024, the U.S. Census Bureau reported global exports of approximately 40.5 kt of kyanite and 17.5 kt of mullite, slightly down from 2023 exports. Kyanite was valued at $459/t, and mullite was valued at $525/t. According to the U.S. Census Bureau, imports of sillimanite minerals to the United States were estimated at 5.9 kt in 2024.

Trends and outlook

Trends in the market demand for the sillimanite minerals group are associated with global steel production, as the refractory uses of these minerals are critical for this industry. The World Steel Association estimated global steel production at 1,885 Mt in 2024. China led in total steel production (1,005 Mt), comprising 53 percent of the global output for 2024, followed by India, Japan, the United States and Russia, rounding out the top five producers. Steel production in the European Union was estimated at 130 Mt in 2024.

The United States will likely continue to experience an increased demand for steel for the vehicle manufacturing industry and ongoing infrastructure and construction improvements, but potentially at a slower rate than previous years if tariffs on steel imports are imposed and remain in

effect. Imposed tariffs on steel imports to the United States may encourage additional domestic steel production capacity, but downstream industries are expected to have higher manufacturing costs in the near term, which may affect overall demand for certain sectors.

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LIME

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

In 2024, 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 2024, an estimated 16 Mt of quicklime and hydrate was produced (excluding independent commercial hydrators), unchanged from 2023. At year-end, 26 companies were producing lime, including 17 companies with commercial sales and nine 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 26 companies operated only hydrating plants in nine states. In 2024, 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 third-ranked lime producer in the world after China and India.

Apparent consumption at 16 Mt was estimated to be unchanged from that in 2023. 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 increased by 5 percent to 362 kt in 2024 from 343 kt in 2023. Canada (96 percent) was the leading source of lime imports to the United States. U.S. lime exports decreased by 8 percent to 318 kt in 2024 from 344 kt in 2023. 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 estimated to be $190/t in 2024, 4 percent higher than in 2023, and that of hydrate sold or used was estimated to be $240/t, a slight increase from 2023.

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 lower 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 2024, 16 percent of domestic utility-scale electricity generation was from coal compared with 17 percent in 2023 as a result of increased electricity generation from renewable sources.

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LITHIUM

by Debashis (Deba) Das, RESPEC

In 2024, global lithium production experienced significant growth, with output increasing by 18 percent to approximately 240 kt of contained lithium, up from 204 kt in 2023. This surge was driven by heightened demand from the lithium-ion battery market and expansions in production capacity across various countries. Notably, Australia led the production with 88 kt, followed by Chile (49 kt), China (41 kt), Argentina (18 kt) and Zimbabwe (22 kt). The United States also contributed to global production; however, specific figures were withheld to protect proprietary company data.

The U.S. Geological Survey (USGS) reported that commercial lithium production in the United States was from a continental brine operation in Nevada. Lower prices in 2024 led to the idling of the brine-sourced waste tailings of a Utah-based magnesium producer. Two companies in the United States manufactured an array of downstream lithium compounds utilizing lithium carbonate, lithium chloride and lithium hydroxide sourced either domestically or through imports.

Consumption

The USGS reported that the world lithium consumption was about 220 kt of lithium contained in minerals and compounds, a 29 percent increase from the revised consumption figure of 170 kt in 2023. U.S. consumption data were withheld to avoid disclosing company proprietary data. The estimated global distribution for lithium used in 2024 was batteries, 87 percent; ceramics and glass, 5 percent; lubricating greases, 2 percent; continuous casting mold flux powders, 1 percent; air treatment, 1 percent; medical, 1 percent; and other uses, 3 percent. Lithium's important properties include low density, high specific heat, low coefficient of thermal expansion, high electrochemical potential and excellent thermal conductivity.

Prices

Despite the increase in production, lithium prices saw a considerable decline throughout 2024. According to the USGS, the annual average U.S. lithium carbonate price dropped by 66 percent from the previous year, settling at $14,000/t. In China, spot prices for lithium carbonate decreased from approximately $14,500/t in January to about $9,400/t in November. Similarly, lithium hydroxide prices fell from around $17,000/t to $9,900/t over the same period. Spodumene concentrate (6 percent lithium oxide) prices in Australia also declined, from approximately $1,250/t in January to about $730/t in November.

The decline in prices was attributed to several factors, including concerns over a short-term oversupply of lithium and weaker-than-expected electric-vehicle (EV) sales during the first half of the year. However, incentives and discounts led to a significant increase in EV sales in the third quarter of 2024, particularly in Canada, China and the United States.

Recent developments and outlook

The United States has recently intensified efforts to develop its domestic lithium industry, aiming to reduce dependence on foreign sources, particularly China, and to support the growing demand for EVs and renewable energy storage. Key developments include significant mining projects, federal investments, and advancements in battery technology.

Major U.S. lithium projects

One of the most prominent initiatives is the Thacker Pass project in Nevada, operated by Lithium Americas. As announced by Lithium Americas in an October 2024 press release, the U.S. Department of Energy (DOE) finalized a $2.26 billion loan to support the construction of processing facilities for phase one of the project. This phase is expected to produce 40 kt of battery-quality lithium carbonate annually, sufficient for approximately 800,000 EVs per year.

In California, the Hell's Kitchen lithium and power project near the Salton Sea has received judicial approval to proceed. This integrated geothermal and lithium extraction project aims to produce up to 300 kt of lithium carbonate equivalent per year and generate 1,100 MW of baseload renewable power.

Additionally, the Rhyolite Ridge lithium-boron project in Nevada, developed by Ioneer Ltd., received final federal approval in October 2024. This project is expected to commence production by 2028 and aims to supply enough lithium for 370,000 EVs annually over a span of 20 years.

Federal policy and investment

The DOE has announced more than $3 billion in funding for 25 projects across 14 states to boost domestic production of advanced batteries and battery materials. This investment includes grants for lithium extraction projects, such as Standard Lithium's South West Arkansas project, which received a $225 million grant. The project, in partnership with Equinor, aims to use direct lithium extraction technology to produce battery-grade lithium carbonate.

Technological innovation and private-sector activity

According to renewable-energy reporter Zachary Visconti (2024), Tesla has commenced operations at its new lithium refinery in Robstown, TX. This facility is the first large-scale lithium refinery in the United States and is expected to produce enough lithium hydroxide to support the production of more than one million EV batteries annually.

As noted above, Standard Lithium and Equinor have also formed a joint venture, Smackover Lithium, to develop direct lithium extraction projects in southwest Arkansas and East Texas. These projects aim to tap into lithium-rich brine resources using innovative extraction technologies.

Supply-chain challenges and strategic outlook

Despite these advancements, the United States remains heavily reliant on China for critical minerals and battery components. China's recent export restrictions on rare earth elements and graphite have raised concerns about potential disruptions in the EV supply chain. Efforts to mitigate this dependency include the development of domestic mining projects, investment in alternative extraction technologies, and the establishment of battery recycling programs.

These initiatives reflect a concerted effort by the United States to build a resilient and sustainable lithium supply chain, essential for the nation's transition to clean energy and electric mobility.

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MAGNESIA

by Sharath Kumar Bhoja, Process Technology Group, Tata Steel Ltd.

Magnesia (magnesium oxide, MgO) is a critical, versatile industrial mineral sourced from seawater, brines, deep salt deposits and magnesite mining. The three main compounds are (1) caustic calcined magnesia (CCM), which are used in agriculture, animal feed, environmental applications and chemical

industries, (2) dead burned magnesia (DBM), which are primarily used in refractories for high-temperature applications, mainly in steel, cement and glass industries, and (3) fused magnesia (FM), which are also used in high-performance refractories, as well as electrical insulation (Fig. 1).

The importance of magnesia is underscored by its versatility and strategic value across both industrialized and emerging economies. As a critical input in advanced industries and basic infrastructure, magnesium compounds play a pivotal role in supporting sustainable development and industrial competitiveness worldwide.

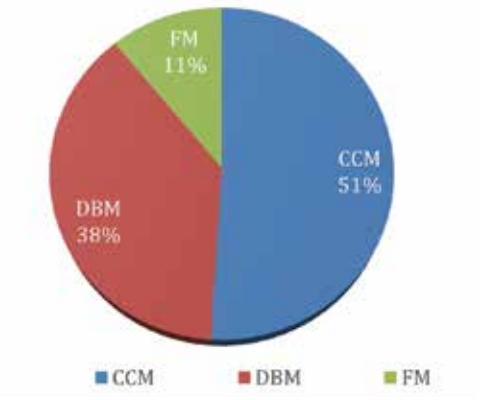
Production and capacity

The total world magnesite reserves exceed 8.5 Gt. Global production of magnesium compounds in 2024 was estimated at approximately 28 Mt (including all forms). Most of the production comes from natural magnesite, brine, dolomite and seawater. Major reserves are in China, Russia, North Korea, Turkey, Brazil and European Union (EU) countries such as Greece, Slovakia and Austria. Seawater and brine-derived magnesia, especially relevant in countries like the United States and Japan, are being promoted as sustainable alternatives to mined magnesite.

Untapped sources such as serpentine and brine reserves in the Dead Sea and Qinghai (China) represent significant potential. Technology improvements are enabling more economic extraction from these sources. As of early 2025, global production of magnesia was estimated at 23.7 Mt, with China continuing to lead production. China produced approximately 16.1 Mt, accounting for nearly 68 percent of global production. Notably, Greece and Australia have increased their magnesia output through investments in brine extraction and processing upgrades.

Figure 1

Proportions of CCM, DBM and FM production (estimated based on 2023 production data published in Euromines, 2025).



China dominates global production and exports of magnesia, with a significant concentration in Liaoning Province. According to the Euromines Project Blue 2025 report, 80 percent of Liaoning's production is expected to be controlled by five major producers by the end of 2025, indicating major industry consolidation.

Europe contributes about 7 percent to global production, with major producers in Greece, Slovakia and Austria. The region hosts about 25 percent of the world's magnesite reserves. However, import dependency, particularly from China, has raised strategic concerns in the EU.

The United States produced magnesium compounds valued at approximately $450 million in 2024, sourced primarily from seawater and natural brines, and from magnesite mined in Nevada.

Consumption and end uses

In 2024, global consumption reached 27.2 Mt, with primary demand from steel refractory manufacturing (36 percent), environmental and flue-gas desulfurization (22 percent), agriculture (15 percent), chemical processing (14 percent) and deicing (5 percent). The highest growth was observed in South and Southeast Asia, led by India and Vietnam, driven by infrastructure development and environmental controls.

The steel industry remains the largest consumer of magnesia, particularly for basic refractory products. More than 50 percent of magnesia consumption globally is tied to steelmaking.

CCM is used in wastewater treatment, flue-gas desulfurization, fertilizer production and as a feedstock in chemical industries. Magnesium hydroxide serves as a flame retardant and environmental neutralizer.

Increasing use in soil conditioning, animal feed additives and remediation applications has boosted magnesia demand in the agricultural and environmental sectors.

Exports and imports

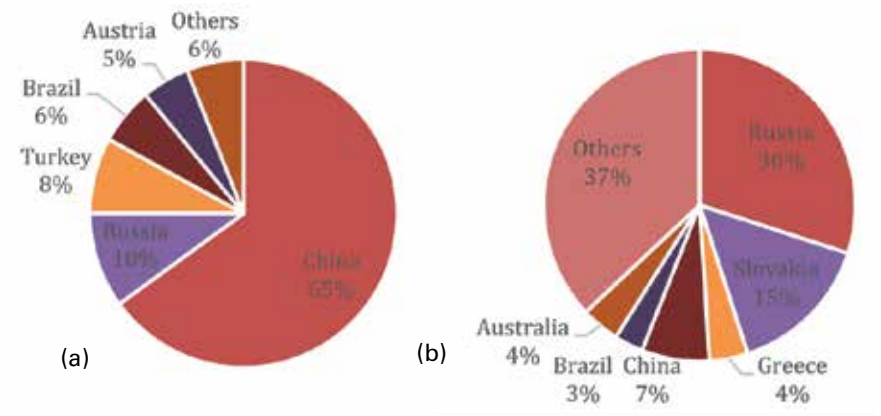
International trade in magnesium compounds is heavily skewed toward exports from China, accounting for more than 60 percent of global trade in 2024. Key importers include India, the United States, Germany, Japan and South Korea. Market reliance on China has prompted diversification efforts, with countries like Turkey and Brazil expanding their processing capacities to reduce dependency.

China remains the principal exporter of magnesia, supplying Japan, India, South Korea, the United States and several European countries. In 2024, Chinese exports exceeded 6.2 Mt, reflecting increased global demand.

The EU imports nearly 40 percent of its magnesia from China. This dependence has triggered supply

Figure 2

Proportions of (a) production and (b) reserves of magnesia and compounds by country, 2024. (Source: U.S. Geological Survey, Euromines)



security concerns, prompting EU policies to classify magnesite and magnesia as strategic raw materials.

The United States imported magnesium compounds valued at approximately $223 million in 2024. Major suppliers were China, Canada and Brazil.

Prices

Prices for key magnesium compounds remained under pressure in early 2024 due to oversupply, particularly in China. Fused magnesia, on a free-on-board (FOB) China basis, averaged $410/t in the first quarter of 2025, down from $440/t year on year. However, caustic-calcined magnesia saw a moderate price recovery in the EU and India, driven by strong agricultural and water-treatment demand.

Globally, prices have remained volatile, driven by demand fluctuations, energy prices and stricter environmental regulations. In early 2025, average FOB prices were $620 to 730/t for Chinese DBM and $1,120 to 1,350/t for FM. *(Price charts available upon request.)*

Environmental regulation enforcement and production consolidation in China have stabilized prices since late 2023, with only modest increases into early 2025.

Trends and outlook

- Market growth: The global magnesia market is expected to grow by $3.10 billion during 2024–2028 at a compound annual growth rate of 5.64 percent, led by Asia-Pacific due to robust demand in steel and manufacturing industries.
- Sustainability and supply security: Increasing focus on green mining, recycling of spent refractories, and circular economy frameworks are being implemented, particularly in the EU and developed economies.
- Technological innovations: Research and development in advanced magnesia-based refractories, carbon-capture applications, and magnesium-based nanomaterials is gaining traction, supported by industrial and academic collaboration. Countries are investing in domestic production capacity to mitigate geopolitical risks associated with heavy reliance on Chinese exports.
- Regionalization: The EU is actively pursuing initiatives to increase domestic production of critical raw materials, including magnesia, to reduce reliance on imports.
- Price volatility: Magnesia prices are expected to remain volatile in the near term due to factors such as Chinese production policies, energy prices and global economic conditions.
- Focus on high-grade magnesia: Demand is expected to increase for high-grade magnesia to meet growing Chinese demand for the material.

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MANGANESE

by Sharath Kumar Bhoja, Process Technology Group, Tata Steel Ltd.

Manganese (Mn) is a critical industrial metal primarily used in steelmaking and is increasingly vital for energy storage in electric-vehicle (EV) batteries. Despite global challenges in 2024 — such as the steel market's sluggishness and geopolitical disruptions — the manganese industry showed resilience, especially through strategic shifts toward sustainability and electrification.

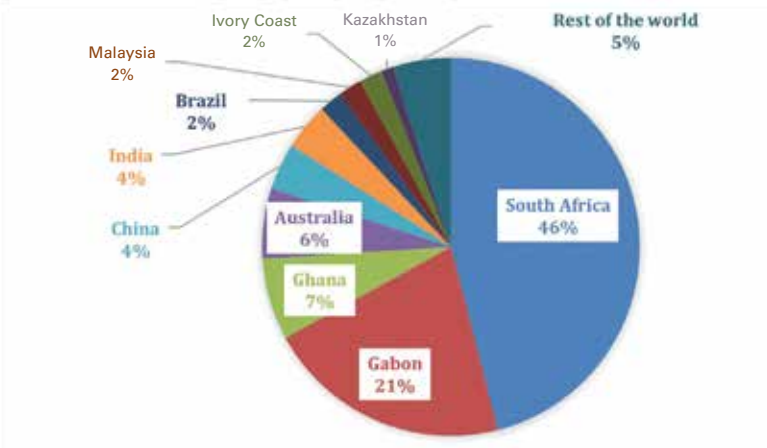
World resources and production

South Africa remains the largest global supplier, with countries like Brazil and Gabon having significant untapped resources. Projects in Botswana (Giyani), Kenya (Marula) and Peru (Benguela) show promise for battery-grade manganese.

In 2024, global manganese ore production was

Figure 1

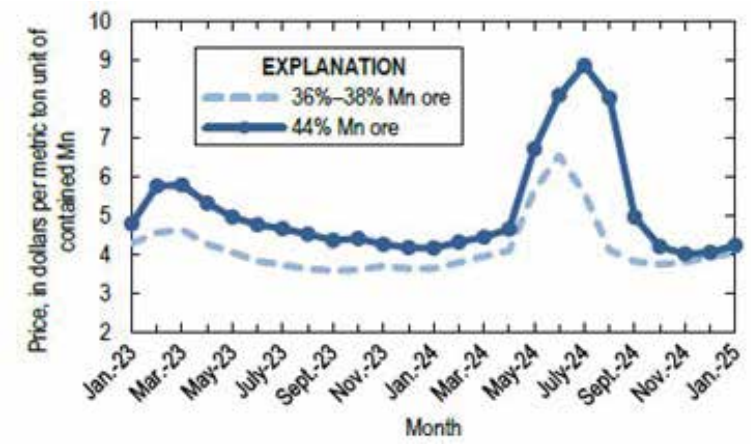
Top manganese ore producing countries in 2024.



19.8 Mt. Production of high-grade ore (more than 44 percent Mn) and low-grade ore (less than 30 percent Mn) expanded by 3 percent and 21 percent, respectively, while that of mid-grade ore (more than 40 and less than 44 percent Mn) fell sharply by 44 percent compared to the previous year. Production in Gabon contracted by 4 percent from the previous year, while production increased by 9 percent in South Africa and 64 percent in Ghana. Together, these three countries constitute the majority of global supply. The increases in South Africa and Ghana were offset by lower output in other producing countries like Australia (down 57 percent), India (down 4 percent), Brazil (down 35 percent), Malaysia (down 2 percent) and Ivory Coast (down 18 percent). In Australia, the suspension of South32's GEMCO facility after Cyclone Megan caused severe disruptions in late March 2024, with operations expected to resume only in 2025.

Figure 2

Price variation illustrating the volatility in 2024. (Source: IMnI Annual Review 2024)



Consumption and end uses

Consumption of manganese closely follows the steel industry, with 96 percent of manganese ore consumed in the steel industry. The World Steel Association estimated global finished steel consumption would decrease by 0.9 percent in 2024. In 2024, global steel output was 1.89 Gt, down 0.2 percent year over year, with China contributing 1.02 Gt, down 0.7 percent. Steel output in India grew by 5 percent, and it remains the most dynamic market. Battery-sector manganese demand also rose, accounting for 3 percent of ore use, primarily for high-purity manganese sulfate (HPMSM) in EVs and energy storage.

Imports and exports

In 2024 the top manganese ore importing countries were, in decreasing order, China, India, Norway, Japan, Indonesia, Malaysia, France, South Korea and the United States. *(Chart of top importing countries available upon request)* China reduced its imports of high-grade ore due to price spikes and inventory corrections. Ukraine resumed silico-manganese exports in the second quarter. India expanded its exports, particularly of SiMn and FeMn alloys. Freight rates fluctuated due to Red Sea conflicts but dropped 36 percent by October.

Prices

Manganese ore prices were highly volatile in 2024. The second quarter saw a rally driven by Chinese restocking and reduced African supply. Mid-grade ore prices hit highs; however, silico-manganese alloy prices fell, triggering smelter shutdowns. Amid the second-quarter manganese ore price rally, Chinese manganese alloy producers reduced high-grade ore usage to 15 to 20 percent, with 10 to 15 percent sourced from Gabon, down from at least 30 percent in past blends.

In January 2025, average spot prices of manganese ore deliveries to China were $4.01/t unit of contained manganese, 36 to 38 percent grade, and $4.22/t unit of contained manganese, 44 percent grade, slightly more and 4 percent more, respectively, than in December 2024 (Fig. 2). Compared with the monthly average values in January 2024, the January 2025 price for 36 to 38 percent grade was 10 percent more, while that for the 44 percent grade was slightly more.

Trends

In 2024, several significant regulatory changes impacted the manganese industry:

- The European Union's (EU) Carbon Border Adjustment Mechanism (CBAM) has started reporting duties for importers, a policy aimed at preventing carbon leakage. This policy affects International Manganese Institute (IMnI) members, particularly ferromanganese alloy producers, who import

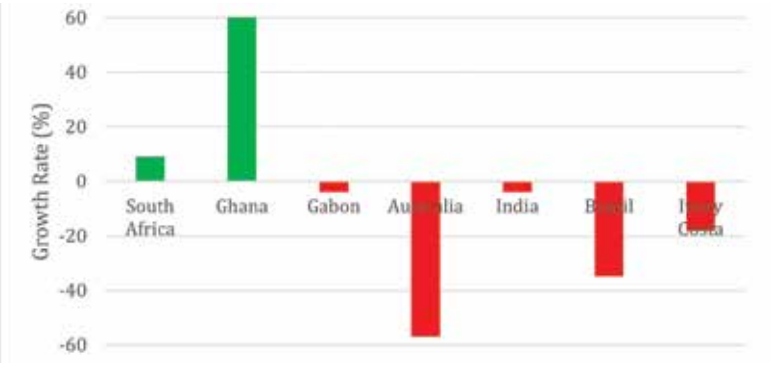
these products into the EU.

- The EU Council adopted the Critical Raw Materials Act in March 2024, ensuring a secure and sustainable supply of critical raw materials, including manganese. The act recognizes its importance in transitioning to a climate-neutral continent and aims to secure access to these materials.
- The EU revised its Classification, Labelling, and Packaging Regulation in October 2024, introducing new hazard classes and labeling requirements for chemicals with endocrine-disrupting properties, impacting human health and the environment.
- The U.S. Environmental Protection Agency (EPA) plans to assess manganese exposure through its Integrated Risk Information System (IRIS) program, with IMnI and the Manganese Interest Group (MIG) collaborating to ensure robust data for evaluation.
- The EPA funds the Cornwell Research Group in Newport News, VA, for manganese drinking water treatment (September 2024).
- The European Commission to start working on mining best available techniques — manganese included in the scope of the upcoming exercise (July 2024).

In 2024, Ghana recorded an impressive 64 percent growth in production, indicating strong operational expansion. Gabon saw a slight decline of 4 percent due to temporary production halts. Australia's output dropped by 57 percent due to the suspension of South32's GEMCO mine. India and Brazil also recorded declines due to policy and environmental constraints. Figure 3 shows the growth rates of manganese ore production across major producing countries in 2024.

Figure 3

Growth rates of manganese ore production by country in 2024. (Source: IMnI Annual Review 2024)



Outlook

In 2025, a recovery in manganese alloy markets, strong growth for battery-grade manganese, and a focus on circular economy through slag reuse and recycling are expected.

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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

In 2024, U.S. mine production of scrap and flake mica was an estimated to be 23 kt, a 38 percent decrease from 2023. Production of ground mica was an estimated 52 kt, 15 percent lower than in 2023. Mica was mined in Georgia and North Carolina. Production and consumption of scrap and flake mica decreased in 2024, owing in part to the closure of one mica facility in South Dakota and from storm damage to facilities in western North Carolina from Hurricane Helene in October 2024. Scrap mica was recovered primarily from mica and sericite schist and as a byproduct from the production of feldspar, industrial sand beneficiation, and kaolin. Ground mica was produced from domestic and imported scrap and flake mica. In 2024, world production of scrap and flake mica was estimated to have increased to 380 kt from 379 kt in 2023. Madagascar (85 kt), China (80 kt), Finland (50 kt) and the United States (23 kt) were the

leading producers. World production of sheet mica was unavailable in 2024, 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 39 kt, 26 percent lower than in 2023. Apparent consumption of sheet mica was estimated to have increased to 3,600 t in 2024 from 3,310 t in 2023, owing to a decrease in exports.

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 was 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 was used in decorative coatings on wallpaper, concrete, stucco and tile surfaces.

Ground phlogopite mica was 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, was 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 was added to latex balloons to provide a colored shiny surface.

Sheet mica was 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 $140/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 $310/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 $1.80/kg.

Foreign trade

According to the U.S. Census Bureau, U.S. imports and exports of scrap and flake mica were 19.7 kt and 4.16 kt, respectively, in 2024. Imports of scrap and flake mica increased slightly, and exports increased by 14 percent, compared with 2023.

In 2024, China (47 percent), Canada (36 percent) and India (6 percent) supplied most 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 (32 percent), Brazil (17 percent) and Canada (12 percent).

In 2024, U.S. imports and exports of sheet mica were 4.51 and 864 kt, respectively. Imports of sheet mica increased by 4 percent and exports decreased by 14 percent compared with 2023. In 2024, China (55 percent), Vietnam (26 percent) and Brazil (4 percent) supplied most U.S. imports of sheet mica, with the remainder from several other countries. Most U.S. exports of sheet mica went to Mexico (25 percent), Netherlands (13 percent) and Canada (12 percent).

Outlook

The major markets for ground mica — drywall joint compounds and paints — are mature and relatively stable industries, 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

Ammonia production in the United States was estimated to be 14 Mt of nitrogen (N) content in 2024, compared with 13.8 Mt of N in 2023. In 2024, U.S. producers operated at about 80 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 2024. The United States along with Russia were the world's third-ranked ammonia producers after China and India. Urea, ammonium nitrate, nitric acid, ammonium phosphates, and ammonium sulfate, in descending order of quantity produced, were the major derivatives of ammonia produced in the United States.

Ammonia was produced domestically by 18 companies at 37 plants in 17 states during 2024. About 55 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) was 1.7 Mt in 2024 compared with 1.72 Mt in 2023. Canada (52 percent) and Trinidad and Tobago (42 percent) were the leading sources of U.S. ammonia imports. U.S. ammonia exports decreased by 5 percent to 849 kt of N content in 2024 from 890 kt of N content in 2023. Ammonia exports were primarily shipped to Morocco (35 percent) and Norway (26 percent).

Prices

U.S. Gulf Coast ammonia prices in 2024 were estimated to average $440/st, 6 percent lower than the average in 2023. The Gulf Coast ammonia price was $478/st at the beginning of 2024, decreased to $364/st in late May and increased to $519/st by year-end.

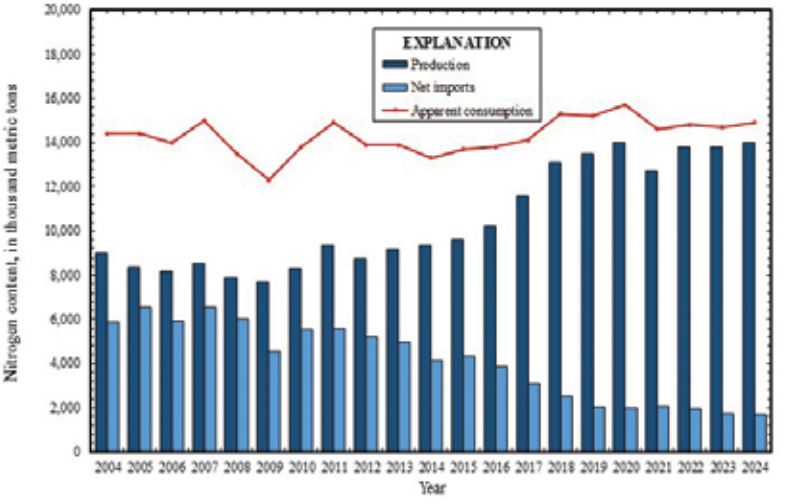
Natural gas is often used as the feedstock to produce ammonia fertilizers, and the cost of natural gas can account for 70 to 90 percent of the production costs. The Henry Hub spot price for natural gas ranged between $1.25 and $3.25/million Btu for most of the year, with an average of about $2.1/million Btu. Natural-gas prices in 2024 were lower than in 2023 — a result of above-average storage levels of natural gas and warmer-than-average winter weather. The Energy Information Administration, U.S. Department of Energy, projected that the Henry Hub spot prices for natural gas would average $3.1/million Btu in 2025.

Outlook

Low 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 in the next five years is expected to increase capacity by about 1.4 Mt/a, which includes decarbonized ammonia projects. Global ammonia capacity is expected to increase by a total of 7 percent during the next four years. Capacity additions were expected in places with low-cost natural gas such as Asia, Eastern Europe and North America. As part of the capacity increase, decarbonized ammonia plants have been proposed in several countries but mainly in North America. Consumption of ammonia for fertilizers is expected to

Figure 1

U.S. supply and apparent consumption of ammonia, 2004–2024. (Source: U.S. Geological Survey data)



increase in Latin America and eastern Asia.

Large corn plantings maintain the continued demand for nitrogen fertilizers in the United States. According to the U.S. Department of Agriculture, U.S. corn growers planted 37 million hectares of corn in crop year 2024 (July 1, 2023, through June 30, 2024), 3 percent less than in crop year 2023. Corn acreage in crop year 2025 is expected to decrease because of anticipated lower returns for corn compared with those of other crops.

Reference

U.S. Geological Survey, 2025, Mineral commodity summaries 2025—Nitrogen (Fixed)-Ammonia: U.S. Geological Survey, pp. 128–129, https://doi.org/10.3133/mcs2025

PEAT

by Gaurav Jha, Indian Institute of Technology (Indian School of Mines) Dhanbad

Peatlands are ecosystems that are present worldwide and are made up of water and land. Worldwide, peatland covers 3 percent of the Earth's land surface and harbors around storage of 600 Gt of carbon. Peat is a renewable, organic, natural, fibrous biomass material, which is a product of gradual decomposition of long-lying sedimentation of organic matter under anaerobic conditions.

Peatlands also act as a carbon sink that supports carbon-neutral goals; however, these peatlands require space and water bodies for growth that can be disastrous to water bodies. In 2023, the National Oceanic and Atmospheric Administration (NOAA) reserved a 55-acre peatland to support peat growth and to recharge water levels. Countries including Finland, Ireland and the United Kingdom are slowly phasing out peat harvesting/utilization for energy applications as their energy requirement is fulfilled by renewable sources of energy. Several conservation agencies, federal institutions and universities in the United States plan to decrease the use of peat and install water management infrastructure that can help in peatlands restoration. As an initiative, Ireland has planned to stop peat harvesting by 2030 completely. To achieve the goals of the Paris Climate Agreement requires the restoration/formation of 1 million hectares of peatlands in Europe every year, and the same must be done for the formation of 2 million hectares of peatlands worldwide.

Consumption and end uses

Approximately 70 percent of peat is used in agriculture globally, and the rest is utilized in other industrial applications. Peat has significant application in horticulture and agriculture as a plant growth and soil-amendment medium due to its fibrous and porous nature. Another area where peat is useful is in the industrial filtration process to remove toxic constituents in effluents from mine waste streams, municipal drainage and industrial process water.

Production, imports, exports and consumption

According to the U.S. Geological Survey's (USGS) 2025 Mineral Commodity Summary, peat production in the United States in 2024 was approximately 350 kt, and imports were 1.3 Mt. The top three producing states were Florida, Maine and Minnesota, which accounted for 52 percent of the quantity of peat sold. Exports from the United States in 2024 were approximately 50 kt. The value of domestic peat sold in 2024 was approximately $12 million in 2024. Apparent consumption of peat in the United States in 2024 was approximately 1.6 Mt.

World production was approximately 20 Mt in 2024, an increase of approximately 100 kt over 2023. Leading peat producers are Finland, Canada, Latvia, Belarus and Sweden. Approximately 83 percent of the global extraction of peat takes place in Europe.

Outlook

Concerns about climate change prompted several countries to plan to decrease or eliminate the use of peat, owing to peatland's ability to act as a carbon sink. Global attempts are being made to restore the peatlands to accelerate the carbon neutrality impact while limiting peat usage for horticulture and agriculture purposes. Peat is a renewable resource, continuing to accumulate on 60 percent of global peatlands. However, the volume of global peatlands has been decreasing at a rate of 0.05 percent per year owing to harvesting and land development.

Prices

The average domestic price for peat, free-on-board mine basis, was $24/t, an increase of $4/t over 2023.

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PERLITE

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

Perlite, an amorphous siliceous volcanic glass containing 2 to 5 percent water, is commonly light gray to black in its natural state. Found globally, it is most often extracted through openpit mining. When rapidly heated to about 900 °C, the contained water converts to steam causing the ore to expand up to 20 times its original size. The resulting material, which is lightweight and bright white, has many properties suited for multiple industrial applications.

Production

In 2024, domestic processed crude perlite sold and used was estimated to be 440 kt with a value of $33 million compared with 410 kt with a value of $30.3 million in 2023. The average unit value of processed crude perlite sold and used by U.S. operations in 2024 was $75/t compared with $74/t in 2023. 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 53 plants owned by 29 companies in 29 states. In December 2024, The Strong Co. Inc., headquartered in Pine Bluff, AR, announced the acquisition of all manufacturing assets of Ambient Minerals Inc. located in Benton, AR. Ambient Minerals Inc. specializes in perlite and vermiculite products. World production of perlite in 2024 was estimated to be 4.3 Mt, compared with 4.23 Mt in 2023.

Consumption

Expanded perlite's lightweight, porous structure, combined with its durability, fire resistance, inert nature, low acoustic and thermal conductivity, and excellent water retention, make it useful across many industries and applications. In 2024, construction-related uses, such as concrete aggregates, formed products, and masonry- and cavity-fill insulation led the expanded perlite market with 47 percent of total sales and use.

Horticultural uses by commercial growers and hobby gardeners followed with 16 percent of perlite consumption, while filter aid accounted for 14 percent. Usage data for fillers, previously a significant end use, was withheld starting in 2023 to protect proprietary company information. Fillers, along with various other uses for expanded perlite, comprised the remaining portion of its consumption. Domestic apparent consumption, defined as processed crude perlite sold or used by producers plus imports minus exports, increased in 2024 to an estimated 590 kt from 530 kt in 2023.

Substitutes

Substitutes for perlite vary depending on the application. In construction, materials such as diatomite, expanded clay and shale, pumice and slag can serve as alternatives. For horticultural uses, coco coir, pumice, vermiculite and wood pulp are alternative soil additives and are sometimes used in conjunction with perlite to enhance its effectiveness. Substitutes are chosen based on the specific demands of each application and their cost effectiveness.

Foreign trade

Trade data for perlite are not collected as a separate category by the U.S. Census Bureau but are included within the group "vermiculite, perlite and chlorites, unexpanded." Domestic exports and imports for consumption of perlite were estimated based on information published by the U.S. Census Bureau and adjusted by the U.S. Geological Survey based on average unit value, countries known to produce perlite, and likely port destinations to eliminate other minerals reported in the same group. An estimated 220 kt of perlite valued at $21 million was imported into the United States during 2024 compared with 140 kt valued at $19 million in 2023. The estimated average unit value of imported perlite in 2024 was $93/t, compared with $133/t in 2023. Most imports were estimated to have originated from Greece (97 percent). In 2024, exports of perlite were estimated to have increased to 26 kt valued at $4.3 million compared with 18 kt valued at $3.4 million. The estimated average unit value of exported perlite was $165/t in 2024 compared with $185/t in 2023. An estimated 99 percent of exports were shipped to Canada.

International

In 2024, global production of perlite was estimated to be 4.3 Mt compared with 4.23 Mt in 2023. The world's leading producers were, in descending order of production, China (1.5 Mt), Turkey (1.2 Mt), Greece (850 kt), and the United States (440 kt). Most of China's perlite production was presumed to be consumed internally while Greece and Turkey were the leading exporters of perlite.

Imerys finalized the purchase of Chemviron's European diatomite and perlite operations, a subsidiary of Calgon Carbon Corp., on Jan. 6, 2025. As part of the acquisition, Imerys took ownership of a perlite processing plant in Foggia, Italy.

Outlook

The perlite industry is well established and

stable. The utilization of perlite is anticipated to stay consistent. Construction market fluctuations could affect consumption in related uses. The diverse properties of perlite continue to drive the exploration of innovative and emerging issues.

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Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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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 2024, phosphate ore was mined by five companies at 10 mines in four states for an estimated 20 Mt of marketable product (representing 64.3 percent of the domestic production capacity of 31.1 Mt), making the United States responsible for 8.3 percent of the world production of 240 Mt (Table 1). Calendar year 2024 production quantities were similar to 2023 production quantities.

The last five years of phosphate production for China, Morocco and the United States are presented (Table 1).

Exports and imports

There were no reported U.S. exports of phosphate rock in crop year 2024 nor any reported exports of phosphate rock since crop year 2004. Approximately 25 percent of the diammonium phosphate (DAP), monoammonium phosphate (DAP) and triple super phosphate TSP fertilizer produced in calendar year 2024 was exported.

Imports of phosphate rock in calendar 2024 are estimated by the U.S. Geological Survey (USGS) at 3.39 Mt as compared to 2023 imports of 2.59 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

The 2024 calendar year average price at the mine was reported at $129.09/t, which is 12.4 percent lower than the calendar year 2023 average price of $147.32/t (Table 2).

The value of the imported phosphate in calendar year 2024 of $128.91/t also decreased from $147.32/t in the prior calendar year (Table 2).

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, Itafos and J.R. Simplot, which are operating five mines. One new mine has opened, and another has been permitted,

Table 1

Major phosphate producers. (Source: Stephen M. Jasinski, USGS Mineral Commodity Summaries, January 2025, pp. 134-135, Phosphate Rock)

World Production[1]							
Calendar year	Tons[1,2]				China (percent)	Morocco[3] (percent)	US (percent)
	World	China	Morocco[3]	US			
2020	219.0	88.0	37.4	23.5	40.18	17.08	10.73
2021	223.0	90.0	37.0	21.6	40.36	16.59	9.69
2022	228.0	93.0	39.0	19.8	40.79	17.11	8.68
2023	233.0	105.0	33.0	19.6	45.06	14.16	8.41
2024	240.0	110.0	30.0	20.0	45.83	12.50	8.33

[1]Estimated for 2022, 2023 and 2024 [2]Million metric tons [3]Includes Western Sahara

but little construction has occurred.

Saudi Arabia's Ma'aden's phosphate mine is currently producing up to 5 Mt/a of concentrated phosphate rock from the beneficiation plant. Peru is also producing close to 5 Mt/a. Mosaic sold its interest in Ma'aden in exchange for shares of Ma'aden. In addition, Mosaic has signed an agreement to sell the idled Patos de Minas phosphate mine in Brazil.

Environmental, regulatory and reclamation issues

Several Florida phosphate mines, chemical plants and fertilizer shipments were idled for several weeks in September and October of 2025 because of storm damage from Hurricane Helene and Hurricane Milton.

Trends and outlook

Global phosphorus pentoxide (P_2O_5) production is expected to increase from 47.5 Mt in 2024 to 51.8 Mt by 2028. The leading growth regions are forecasted to be Asia and South America.

Canada has two new mines and associated purified acid plants under development to produce lithium-iron-phosphate battery cathode active material (CAM) and produce iron phosphate for the manufacture of lithium batteries.

Table 2

Phosphate rock prices. (Source: USGS Mineral Industry Surveys, Stephen M. Jasinski, Mineral Industry Survey Marketable Phosphate Rock in January 2024, Tables 2 and 3, and 2024 Annual Phosphate Rock, pp. 134 and 135)

Phosphate use	Calendar year				
	2020	2021	2022	2023	2024
Domestic production (FOB mine[1])	$75.50	$84.80	$136.00	$147.32	$129.09
Exports (FOB port[1])	N/A	N/A	N/A	N/A	N/A
Imports (CIF[1])	$74.55	$84.80	$135.60	$147.32	$128.91

[1]Price (U.S. dollars per metric ton), FOB = free on board, CFI = cost, insurance, freight

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Data compiled predominantly from personal knowledge, contacts in the industry, U.S. Geological Survey (USGS) Mineral Industry Surveys: USCOE and BLM EIS documents; personal communication with Stephen Jasinski, USGS, Bill Stout, 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 various other 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, can also 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 ($K_2SO_4 \bullet 2MgSO_4$ or langbeinite or double sulfate of potash magnesia).

Muriate of potash (MOP) for fertilizer use is an agriculturally acceptable mix of KCl (95 percent pure 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 2024, U.S. potash production was estimated to be 420 kt of K_2O equivalent, 8 percent higher than in 2023 and was valued at an estimated $530 million, 6 percent higher than in 2023. Domestic sales were estimated to be 440 kt of K_2O equivalent, 10 percent higher than in 2023. 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 2024.

World production was estimated to be 48 Mt of K_2O equivalent, 11 percent higher than in 2023. Canada (15 Mt), Russia (9 Mt), Belarus (7 Mt) and China (6.3 Mt) were the leading producers, accounting for 78 percent of total production. Canada, the leading potash-producing country and exporter in the world, accounted for 38 percent of global capacity. All production in Canada was from Saskatchewan in 2024. 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.

Belarus production nearly returned to pre-2022 levels, when the European Union and the United States placed sanctions on the state-run Belarusian potash-exporting company. Exports from Belarus,

however, were still much lower than before 2022, when Lithuania terminated the rail contract that allowed Belarus to send potash to the Baltic Sea port of Klaipeda for export. In 2024, Belarus exported potash via several Russian ports. It also sent shipments by rail, primarily to China and Iran.

Consumption

U.S. potash consumption was estimated to have increased by 8 percent to 6,400 kt of K_2O equivalent compared with 5,900 kt of K_2O equivalent in 2023. The increase in consumption of potash was attributed mainly to lower potash prices and favorable weather conditions in the planting season compared with 2023.

According to a report from the International Fertilizer Association, world consumption of potash fertilizers in 2024 was estimated to have increased to 38.8 Mt from 37.5 Mt in 2023. 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 5 percent to 5.97 Mt of K_2O equivalent in 2024, compared with 5.68 Mt of K_2O equivalent in 2023, The United States was 93 percent net import reliant for potash in 2024. Canada (79 percent), Russia (15 percent) and Israel (3 percent) were the leading suppliers for all forms of potash combined. The United States is not a significant exporter of potash. In 2024, exports decreased to 100 kt of K_2O from 165 kt of K_2O in 2023.

Prices

The Vancouver, British Columbia, Canada spot price for standard potash began the year averaging $287/t ($261/st) and ended the year at $260/t ($236/st). The U.S. price for SOP began 2024 in the range of $640 to $680/st and ended the year in the range of $600 to $630/st. The U.S. price for SOPM, free on board Carlsbad, NM, began the year in the range of $290 to $330/st and ended the year in the range of $325 to $365/st.

Outlook

Potash is an essential fertilizer nutrient for which no substitute exists. A 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 76.0 Mt in 2028 from 65.2 Mt in 2024. 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 2028. The conflict between Russian and Ukraine, coupled with sanctions on Belarus, may lead to a shift in world potash supply patterns.

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Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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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 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 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 price

Mine production of pumice in the United States during 2024 was estimated to be 450 kt, 3 percent more than in 2023. The unit value of pumice was estimated to be $42/t in 2024, slightly higher than in 2023. 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 11.2 kt, 5 percent more than in 2023. Imports totaled 150 kt, almost three times more than 53 kt imported in 2023.

World resources of pumice are adequate for the foreseeable future. However, transportation costs may encourage development of deposits closer to markets. Total world production of pumice was estimated to be 18 Mt in 2024, 3 percent more than in 2023. 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 estimated top world producers in 2024 were: Turkey (8.2 Mt), Greece (1 Mt), Saudi Arabia (980 kt), Algeria (900 kt), Uganda (830 kt) and Ecuador (800 kt).

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 2024, 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 block (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 and major markets located in the eastern states. 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.

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SALT

by Cody Vining, 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.

Production

Domestic annual salt production in the United States differs from year to year and is estimated at approximately 40 Mt in 2024, which is slightly less than the estimated 42 Mt in 2023 and is in line with the five-year and 10-year averages of approximately 41.9 and 42.5 Mt, respectively. At the beginning of 2024, 64 salt-producing plants existed in 16 states, one more than reported in 2023, with approximately 95 percent of the total production coming from Kansas, Louisiana, Michigan, New York, Ohio, Texas and Utah.

Total world production in 2024 is estimated at 275.4 Mt, which is approximately 10 Mt more than the revised 2023 production of 273.7 Mt (Table 1). China remains the world's largest salt producer at approximately 55 Mt, while the United States and India (the world's second- and third-largest producers, respectively) produced an estimated 40 and 28 Mt in 2024, respectively. These three countries combined account for 45 percent of the total world production, while other countries collectively produce a total of approximately 157 Mt (55 percent of the total world production).

Consumption

For 2024, the total U.S. salt apparent consumption (domestic sold or used minus exports plus imports) is an estimated 51 Mt. This is consistent with the previous three years with apparent consumption in the range of 55 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 2024 was salt in brine (42 percent), rock salt (40 percent), vacuum pan salt (9 percent) and solar salt (9 percent).

Exports and imports

Most of the domestic production (95.25 percent)

Table 1

Estimated world production of salt, 2024.

Country	Production (1,000 metric tons)		
	2022	2023	2024
China	54,000	53,000	55,000
United States	41,000	42,000	40,000
India	30,000	30,000	28,000
Germany	15,000	15,000	16,000
Australia	13,000	14,000	13,000
Canada	12,000	12,000	12,000
Chile	9,000	9,200	11,000
Mexico	8,700	9,000	9,000
Turkey	9,100	9,000	9,000
Russia	8,000	7,000	8,000
Brazil	6,600	6,600	6,600
Netherlands	5,900	6,000	6,000
France	5,500	5,500	5,000
Poland	4,000	4,200	4,600
Spain	3,900	4,000	4,000
Pakistan	3,300	3,000	3,000
Bulgaria	3,300	3,300	3,000
United Kingdom	2,400	2,300	2,800
Iran	2,700	2,700	2,700
Saudi Arabia	2,400	2,500	2,400
Egypt	2,300	2,300	2,300
Belarus	2,000	2,100	2,100
Italy	1,900	2,000	1,900
Djibouti	0	0	0
Ukraine	1,000	0	0
Other countries	32,000	27,000	28,000
World total (rounded)	279,000	273,700	275,400

was consumed within the United States in 2024, with approximately 1.9 Mt exported. The estimated 2024 exports are less than 2.3 Mt exported in 2023 and are aligned with the five-year average for exports, which is approximately 1.3 Mt. To meet demand in 2024, the United States imported an estimated 14 Mt of salt (27.5 percent of total apparent consumption). These imports originated from Canada (29 percent), Chile (27 percent), Mexico (14 percent), Egypt (8 percent) and several other producing countries (22 percent).

Prices

The total value of U.S. salt sales in 2024 was estimated to be $2.5 billion, a slight decrease from $2.6 billion in 2023. The average price of vacuum pan salt in 2024 was $230/t, a modest price increase from $200/t in 2017 and a $10/t increase from 2023. The average price of solar salt was $140/t in 2024, the same as in 2023 but a 40 percent increase from $100/t in 2017. The average price of rock salt was $56/t in 2024, a decrease from the five-year high of $61/t reported in 2023. The price of salt in brine matched a 10-year high of $10/t in 2024.

Outlook

The U.S. Geological Survey (USGS) expects demand for salt in brine, which is used in the chloralkali industry, to continue to increase 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 U.S. Geological Survey (USGS), and the key document referenced was: U.S. Geological Survey, 2025, Mineral Commodity Summaries 2025, https://pubs.er.usgs.gov/publication/mcs2025

SODA ASH

by Debashis (Deba) Das, RESPEC

Production

According to the U.S. Geological Survey, domestic soda ash (sodium carbonate) produced in 2024 was estimated at 12 Mt for a total market value of $2.5 billion, 10 percent more than in 2023. 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. Their combined nameplate capacity was 13.9 Mt/a. China was the world's largest producer of soda ash (36 Mt, mostly synthetic), followed by the United States and Turkey. These three countries produced around 81 percent of the world's soda ash in 2023.

Consumption and end uses

The reported consumption of soda ash in the

United States in 2024 was around 4.2 Mt, down 6 percent from 2023. An estimated 45 percent of the total soda ash produced in 2024 went into glass products, with about 29 percent used in chemicals and the remaining for soaps/detergents, flue-gas desulfurization, distributors, paper and other miscellaneous uses.

Exports and imports

In 2024, the United States exported about 7.4 Mt of soda ash, more than one-half of its total production, and imported around 10 kt, mostly from Turkey.

Prices

Soda ash prices, on a free-on-board plant basis, in the United States increased from $211/t in 2023 to an estimated $220/t in 2024. As of April 2025, soda ash prices in the United States have shown a steady upward trend, reflecting a recovery from the declines seen in 2023, according to Procurement Resource.

Trends and outlook

According to OpenPR, the global soda ash market is projected to grow at a compound annual growth rate of approximately 4.1 percent from 2024 to 2031, reaching an estimated value of $26.64 billion by 2031. This growth is primarily fueled by increased demand for soda ash in the glass industry, solar energy and water treatment.

WE Soda completed the acquisition of two large soda ash facilities in Wyoming, increasing its total capacity to 9.5 Mt/a. Plans are underway to expand the Westvaco facility by an additional 1 Mt to 1.5 Mt/a.

According to Mills (2024), approximately 18 Mt of new soda ash capacity are expected to be added globally between 2023 and 2028, with 61 percent of this expansion occurring in China and 34 percent in the United States.

These developments indicate a robust growth trajectory for the soda ash industry, driven by technological advancements, environmental initiatives and increasing demand across various sectors.

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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 wide variety of mineral habitats in association with other minerals like carbonates and chlorite. In addition, atoms such as 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 are several ways talc can be classified; the natural crystal size of the talc is an example. Microcrystalline talc has a natural crystal size of 5 to 45 µm and macrocrystalline talc crystals are 50 to 150 µm. The macro grades have been repeatedly sheared in geological time, resulting in larger, more planar structure. The micro grades are particularly good absorbents for paper pitch control, 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.

Production and consumption

Three companies operated five talc producing mines in the United States in 2023, with production estimated to have increased to 530 kt. Magris Talc operated one mine in Montana and one in Vermont; Barretts Minerals operated two mines in Montana and

Table 1

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

Year	2019	2020	2021	2022	2023	2024
U.S. mine production	578	491	577	511	508	530
Mill and ore sales	515	461	556	548	530	510
Imports	280	189	278	346	235*	210*
Exports	229	196	236	203	204	200
Apparent consumption	566	454	598	691	561*	520*

*Due to potential errors in import volumes, these values may be incorrect.

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	2024
U.S. mined ore	38	41	45	45	44	51
U.S. milled product	240	265	321	303	304	333
Exported product	512	503	503	614	564	597
Imported ore	259	293	297	274	338*	292
Imported product	599	635	628	714	695	796

*Due to potential errors in import volumes, these values may be incorrect.

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 froth floatation at its plant in Dillon, MT. RT Vanderbilt and Resco Products operated pyrophyllite mines in North Carolina and Trinity Resources recovers the mineral from old tailings in Newfoundland. Pyrophyllite production data were not reported by the U.S. Geological Survey (USGS).

Cimbar Performance Minerals mills processed 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 210 kt in 2024, a decrease from the 235 kt reported in 2023. However, there are indications that both these values are underreported. (The imports to the United States do not match those reported by the exporting countries, and the biggest U.S. markets in plastics and paint were strong in 2023 and 2024.) 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 200 kt of talc in 2024, with Mexico, Canada and China being the major destinations. Exports decreased slightly from 2023.

The average value of U.S. mined talc ore was $51/t and the average for domestic products from the mills was $333/t. The average value of imported ore was $292/t and that of finished product $796/t. The average value of exported products (almost all finished) was $597/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.

Uses and applications

According to the U.S. Geological Survey, the major uses for talc mined and sold in the United States were plastics (32 percent), ceramics (21 percent), paint (18 percent), paper (9 percent), roofing (8 percent) and rubber (6 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 such as bumpers, interior panels, under-the-hood parts, and trim. It is also used in rigid packaging and for reinforcing polyvinyl chloride (PVC) 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.

Business developments

In May, Minerals Technologies announced the sale of its Barretts Minerals subsidiary to Chicago-based private equity firm Riverspan Partners for $32 million. The company continues to operate as Barretts Minerals.

In September 2024, a Massachusetts jury awarded a private party a $39 million verdict against privately owned talc importer Cimbar Performance Minerals. The private party alleged that talc supplied by Cimbar, used in a medical procedure, had caused mesothelioma and subsequent death.

Regulatory

In April 2023, the U.S. Food and Drug Administration (FDA) released its report on annual testing of consumer products containing talc for asbestos. No asbestos was detected in 50 products tested. On Dec. 26, 2024, the FDA issued a proposed

rule for testing of talc products to be used in cosmetics. The rule would require all products to be tested by polarized light microscopy (PLM) and transmission electron microscopy (TEM) to ensure the absence of asbestiform materials. This was required as part of the Modernization of Cosmetics Regulatory Act (MOCRA). In the United States, talc retains its "generally recognized as safe" (GRAS) status.

There was also significant regulatory action internationally. In July, the Lyon, France-based International Agency for Research on Cancer (IARC) reclassified talc into group 2A, or "probably carcinogenic to humans." This was a controversial ruling as there is very limited medical mechanistic evidence of carcinogenicity. Some commentators have surmised that it is a reflection of the agency understanding that much of the talc used in the underdeveloped world contains asbestos.

In September, the risk assessment committee of the European Chemicals Agency recommended that talc should be categorized as a class 1B carcinogen and STOT-RE1. This means it would be treated as a probable human carcinogen and the STOT (specific target organ toxicity) rating is for damage to lungs on repeated inhalation. If confirmed, this would almost certainly lead to the banning of talc in cosmetics within a few years in the European Union and pressure to remove it from many consumer products.

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TIN

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

Tin is a silvery-white, soft and highly crystalline metal known for its malleability, ductility and excellent resistance to corrosion. With an atomic number of 50 and the symbol Sn (from the Latin *stannum*), tin has played a crucial role in human technological development. It continues to be indispensable in many modern applications. Historically, tin was a key component in one of humanity's earliest and most transformative technological advances: the Bronze Age. Around 3,000 BCE, tin was alloyed with copper to produce bronze — a harder and more durable metal used to make weapons, tools, armour and ceremonial objects. This innovation marked a significant leap in material science and civilization. In the modern era, tin continues to hold industrial significance, particularly due to its nontoxic nature and chemical stability. The most prominent use of tin today is in soldering, especially in electronics, where tin-based solders (often alloyed with lead or silver) are used to join metal components. Tin also finds applications in plating (tinplate), alloys, chemical industry, glass manufacturing and decorative arts, among others.

Occurrence

Cassiterite, the principal ore of tin, is found in both alluvial (placer) and primary hard-rock deposits. Alluvial deposits are formed through the weathering of tin-bearing rocks, followed by the transport and accumulation of cassiterite in riverbeds and sediments. These deposits are especially prevalent in Southeast Asia, with major occurrences in Malaysia, Indonesia and Thailand. In contrast, primary hard-rock deposits are typically associated with late-stage granitic intrusions. Here, cassiterite occurs in veins and fissures within granites and surrounding country rocks. Such deposits are predominantly found in China, South America and Australia. Globally, tin reserves are estimated at approximately 4.3 Mt, with significant concentrations in China, Indonesia, Brazil, Bolivia, Russia, Peru, Malaysia, Australia and Thailand.

Production

In 2024, global refined tin production declined by 2.7 percent year over year to approximately 371,200 t, primarily due to significant supply disruptions in key producing regions. One of the major setbacks was the continued closure of the Man Maw tin mine in Myanmar, which had been suspended in August 2023 for an industry audit and remained nonoperational throughout 2024. This closure drastically reduced tin concentrate exports to China, tightening global supply. Additionally, tin production in the Democratic Republic of the Congo (DRC) was impacted by armed conflict, with the Bisie Mine, responsible for around 6 percent of global tin output in 2023, facing temporary shutdowns due to the advance of the M23 rebel group. Indonesia, another major producer, also saw its output drop from 70 kt in 2022 to 52 kt in 2023, largely due to regulatory and environmental challenges. Despite these setbacks, China, Myanmar, Indonesia, Peru, the DRC and Brazil remained leading contributors to global tin output. Meanwhile, market forecasts indicate moderate growth, with tin demand expected to rise in sectors such as electronics, renewable energy and electric vehicles, although future supply will remain vulnerable to geopolitical, regulatory and environmental factors.

Consumption

Tin consumption shows variability across industries over time. During the 1970s, significant quantities of tin were consumed by tin plate industries

in the U.S. and European countries, although consumption rates in these sectors were either stable or declined 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 (SnO_2) is the primary mineral from which tin is economically extracted, typically found in both placer (alluvial) and hard-rock deposits, often associated with lighter gangue minerals. Beneficiation of cassiterite predominantly involves gravity concentration methods such as jigs, spirals and shaking tables. Enhanced gravity concentrators have been developed to improve efficiency, particularly for finer particles. To maximize tin recovery, flotation techniques are employed to recover fine cassiterite from gravity tailings, using selective collectors and specialized reagents that have evolved over time. These beneficiation processes have undergone significant advancements, including modifications to flowsheets, incorporation of high-efficiency equipment, and adoption of novel chemical reagents. Once a tin concentrate is produced, it undergoes smelting and refining. The most common refining method is pyrometallurgical, where tin concentrate is reduced with carbon at high temperatures in a furnace to produce crude tin. This crude tin is then refined further using processes such as liquation, electrolytic refining or vacuum distillation to remove impurities like iron, lead and arsenic for the production of high-purity tin suitable for industrial applications such as soldering, plating and alloy production.

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TITANIUM

by Deepak Nayak, Mineral Processing Department, CSIR-Institute of Minerals and Materials Technology

Titanium minerals that are economically important include ilmenite, leucoxene and rutile. Titanium itself is widely recognized for its corrosion resistance and high strength-to-weight ratio. About 90 percent of titanium is used in the form of titanium dioxide (TiO_2), which serves as a white pigment in paints, paper and plastics. The quality of TiO_2 pigment is determined by its purity, refractive index, particle

Table 1

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

Country	Production (kt of TiO_2 equivalent)	
	2023	2024[e]
Australia	400	400
Canada[1]	350	350
China	3,250	3,300
India	210	210
Madagascar[1]	300	240
Mozambique	1,860	1,900
Norway	360	360
Senegal	260	300
South Africa[1]	1,260	1,300
Ukraine	130	120
United States[2]	100	100
Other countries	360	330
Total (rounded)	**8,840**	**8,900**

[e]Estimated
[1]Mine production of titaniferous magnetite is primarily used to produce titaniferous slag.
[2]Rounded to the nearest 100,000 tons to avoid disclosing company proprietary data. United States rutile production and reserves data are included with ilmenite.

size and surface properties.

Production

Global production of titanium mineral concentrates in 2024 was estimated to be 9.35 Mt of contained TiO_2, slightly less than in 2023 (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 100 kt of contained TiO_2. The Chemours Co. produced titanium mineral concentrates in the United States 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 2024 was estimated to be 850 kt, about 8 percent less than in 2023. Domestic consumption was estimated to have been 740 kt in 2024, a 14 percent decrease from 859 kt in 2023. 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 sponge production in 2024, excluding the United States, where production data were withheld to avoid disclosing company proprietary data, was estimated to be 320 kt, unchanged from 2023 (Table 3). In the United States, titanium sponge was produced by Honeywell Electronic Materials Inc. in Utah. The 500-t/a plant supported the production of high-purity titanium in Fombell, PA.

Foreign trade

U.S. imports of titanium mineral concentrates included ilmenite, rutile, synthetic rutile and titanium slag. The United States was heavily reliant on imports of titanium mineral concentrates because domestic consumption of titanium minerals greatly exceeded domestic production capacity.

U.S. imports were 600 kt based on estimated TiO_2 equivalent, and the leading import sources were South Africa (32 percent), Madagascar (16 percent), Canada (13 percent) and Australia (11 percent). The United States was a net exporter of TiO_2 pigments, exporting 360 kt in 2024 based on TiO_2 equivalent.

U.S. producers of titanium ingot and downstream products depend on imports of titanium sponge and scrap. In 2024, titanium sponge imports were estimated at 40 kt, nearly matching the previous year's high of 40.4 kt. The main sources of sponge imports were Japan (67 percent), Saudi Arabia (23 percent) and Kazakhstan (7 percent). Titanium scrap imports were estimated at 28 kt, primarily sourced from the United Kingdom (17 percent), Germany (12 percent), France and Japan (11 percent each), and Canada and South Korea (9 percent each).

Prices

According to data from the U.S. Census Bureau, which outlines imports for consumption, the average

Table 2

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

Country	Production (kt of TiO_2 equivalent)	
	2023	2024[e]
Australia	200	200
India	12	12
Kenya	47	40
Mozambique	8	8
Sierra Leone	110	60
South Africa	100	100
Ukraine	95	10
Other countries	20	20
Total (rounded)	**590**	**450**

[e]Estimated

Table 3

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

Country	Production (kt)	
	2023	2024
China	220	220
India	0.3	0.3
Japan	57	55
Kazakhstan	14	14
Russia	20	20
Saudi Arabia	11	15
United States[1]	—	—
Total (rounded)[2]	**320**	**320**

[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, 2014-2024. (Source: U.S. Census Bureau)

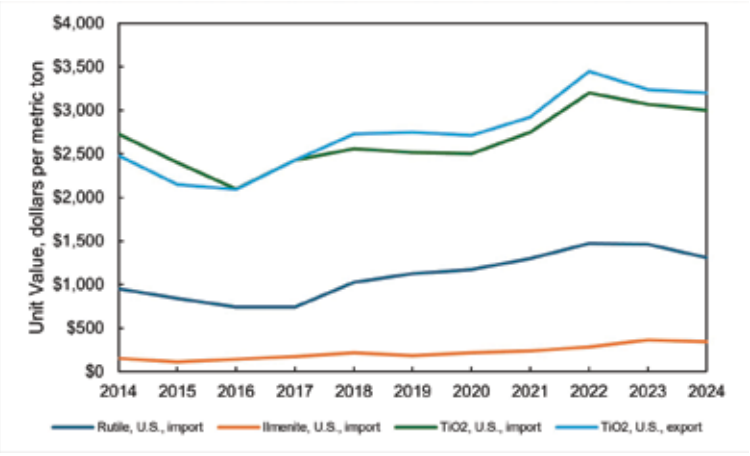
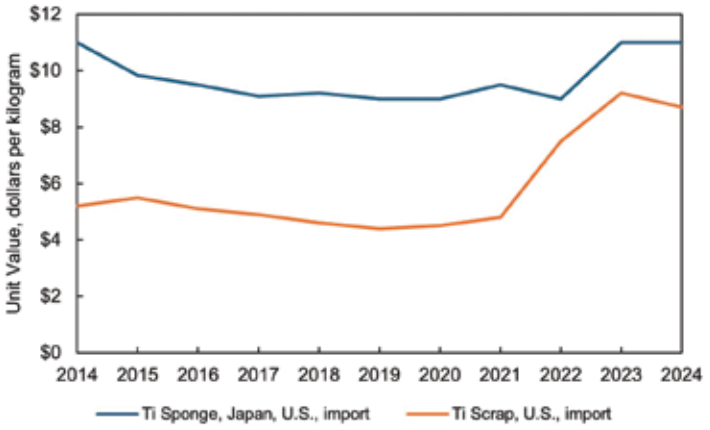


Figure 2

Average annual prices (unit values) for titanium sponge and titanium scrap, 2014-2024. (Source: U.S. Census Bureau)



annual price (unit value) for ilmenite was $340/t in 2024, a decline of 7 percent compared to 2023. The price for bulk rutile was $1,310/t, a decrease of 10 percent. The U.S. import and export prices for TiO_2 pigments decreased by 2 percent and 1 percent, respectively (Fig. 1).

The average annual price for titanium sponge imported from Japan remained relatively stable, whereas that for titanium scrap was $8.7/kg, a decrease of 5 percent compared to 2023 (Fig. 2).

Outlook

The consumption of titanium mineral concentrates plays a crucial role in the production of TiO_2 pigments, which are essential components in a variety of products, including paint, paper and plastics. The demand for these key applications is closely tied to fluctuations in the gross domestic product, as economic growth often drives increased manufacturing and consumption rates.

In 2024, it was estimated that the domestic apparent consumption of titanium mineral concentrates remained steady compared to 2023, indicating a stable market for these materials despite external economic factors. Meanwhile, exports of titanium mineral concentrate experienced a decline; this decrease included mixed concentrates sourced from mine tailings, highlighting the industry's ongoing challenges in balancing supply and demand.

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TUNGSTEN

by Surya Kanta Das, CSIR-Institute of Minerals and Materials Technology

Tungsten, also known as wolfram, is a critical metal known for its exceptional properties, including the highest melting point of all metals at 3,422 °C, remarkable hardness, high density of 19.25 g/cm³ and a low coefficient of thermal expansion. These characteristics make it indispensable in various applications. Primarily, tungsten is used in the form of tungsten carbide, essential to various industries such as mining, ordnance, aerospace, automotive, construction and metalworking. Additionally, tungsten-bearing alloys are employed in the manufacturing of electronics, power engineering tools, medical equipment, heating elements and filaments.

Occurrence

As of 2024, global tungsten reserves are estimated at 4.6 Mt. The average abundance of tungsten in the Earth's crust is about 1.5 ppm. Tungsten-bearing minerals are typically found in compound forms attached to various silicates, oxides and halides. These minerals are generally located in diverse types of deposits, including skarn, vein/stockwork, porphyry, greisen, disseminated, stratabound, brine, placer and breccia formations. Despite the existence of numerous tungsten-bearing minerals worldwide, only scheelite ($CaWO_4$) and wolframite ($(Fe, Mn)WO_4$) are considered primary sources for tungsten extraction.

Significant tungsten deposits are situated in the fold belts of the Far East (including South China, Thailand, Myanmar, South Korea and Japan), the Asiatic regions of the former Soviet Union (such as South Siberia, Kazakhstan, Uzbekistan, Kyrgyzstan and the Caucasus), the eastern coastal belt of Australia, the Alpine fold belt extending from France to Turkey, Western Europe (notably the Variscan belt arcs from Germany and the Czech Republic through France and southwest England into Spain and Portugal), and the United States (notably the Rockies and Andes). Additional deposits are also present in Canada, Bolivia and Peru.

Production

Global tungsten production experienced an increase from 79,500 t in 2023 to 81 kt in 2024. China continues to dominate global tungsten production, contributing approximately 67 kt in 2024, which accounts for more than 80 percent of the global production. Vietnam follows as the second-largest producer, with an output of about 3,400 t in 2024. Other notable producers include Russia (2,000 t),

Austria (800 t), Rwanda (1,200 t), Bolivia (1,600 t) and Spain (700 t).

In addition to the primary mining production, a significant portion of tungsten is sourced from recycling efforts. Approximately 35 percent of tungsten metal is reclaimed from recycled scraps, such as metal drills, superalloys and tungsten carbide, and reintegrated into various end-use applications.

Outlook

Tungsten demand is closely linked to global economic conditions, with primary consumption in cemented carbides across industries such as automotive, aerospace, mining, construction and electronics. Market growth is driven by increasing demand in these sectors, along with expanding applications in medical, defense and electronics industries. Tungsten carbide remains the leading segment, widely used in cutting and drilling tools, while mill products like electrodes and filaments are also gaining importance, particularly in the electronics industry.

China remains the dominant global supplier of tungsten, though production has been rising in countries such as Austria, Portugal, Russia, Spain and Vietnam. Additionally, tungsten recycling is becoming more prominent, supported by ongoing research into recovering tungsten from tailings and extracting values from low-grade resources. The growing adoption of electric vehicles and advancements in 3D printing further highlight the strong growth potential of the tungsten market.

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 2024, most of the world's vanadium supply came from either vanadiferous titanomagnetite (VTM) mineral concentrates or from steelmaking slags, which are generated during the production of steel from VTM.

Production

Industry convention for describing vanadium production typically applies the terms primary production (from mined ore as mineral concentrates from VTM or sandstone-hosted vanadium (with or without uranium)), joint production (from vanadium slags that are produced during steelmaking), and secondary production (from residues, industrial waste materials and spent catalysts) based on the source material for production. The United States did not produce any primary vanadium in 2024. 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. In 2024, domestic secondary vanadium production was an estimated 8.2 kt of contained vanadium, a 26 percent increase from 2023. Secondary production was from processed waste materials to produce FeV, a variety of vanadium-bearing chemicals, specialty alloys and V_2O_5.

In 2024, world production of primary vanadium — from ore, concentrate and slag — was 104 kt with the dominant producers being China, accounting for 67 percent of global production and Russia, accounting for 20 percent. South Africa (8 percent) and Brazil (5 percent) were the other global producers.

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. Energy Fuels did not produce or sell any vanadium in 2024 and had approximately 410 t of V_2O_5 in inventory.

Global vanadium projects in different stages of development included Australia Vanadium Ltd.'s project in Australia, Richmond Vanadium Technology's Richmond-Julia Creek project in Australia, Ferro-Alloy Resources Group's Balasausqandiq project in Kazakhstan and Vanadium Resources' (VR8) Steelpoortdrift project in South Africa.

Bushveld Minerals Co. implemented significant operational changes in 2024, resulting in reduced vanadium production at its South African facilities, Vametco and Vanchem. Glencore plc's Rhovan operation in South Africa was expected to maintain production, while secondary vanadium production was anticipated to continue to play an increasingly important role in the global supply of vanadium.

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 for vanadium 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.

The use of large-scale energy storage systems, which utilize vanadium in batteries, is expanding owing to the rise in energy production from renewable sources. The vanadium redox flow battery (VRFB) stores energy in a liquid electrolyte solution containing vanadium ions in different oxidation states. VRFB technology has become an increasingly crucial component of large-scale energy storage, offering the ability to store energy over medium to long durations in a safe manner, with a high safety rating.

Prices

In 2024, according to Argus Metals International, the average Chinese vanadium pentoxide price (98 percent V_2O_5) was $5.44/lb of contained vanadium, a 27 percent decrease compared with $7.50/lb in 2023. The annual average U.S. ferrovanadium price (78 to 82 percent V) decreased by 21 percent to $13.05/lb of contained vanadium in 2024 compared with $16.42/lb in 2023.

Foreign trade

The United States continued to be a net importer of many vanadium materials in 2024. According to the U.S. Census Bureau, the United States imported (vanadium content) 1,750 t of FeV, 2,360 t of V_2O_5, and 139 t of other oxides and hydroxides of vanadium. Total imports for consumption of all vanadium-bearing materials decreased by 23 percent from 2023. In 2024, the United States exported (vanadium content) 67 t of FeV, 93 t of V_2O_5 and 427 t of other oxides and hydroxides of vanadium. Total exports of all vanadium-bearing materials increased by 32 percent from 2023.

Outlook

The majority of vanadium is used in steel production with consumption trends closely tied to fluctuations in steel production. As steel consumption grows and more specialized applications are required, the variety of steel grades containing vanadium continues to expand. The consumption of HSLA steels is expected to increase as the construction industry seeks to reduce the amount of steel required in its overall infrastructure projects, and therefore carbon emissions, while simultaneously enhancing strength and reducing weight. 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 global environmental regulations tighten on fuels and waste, the recovery of elements like vanadium from spent catalysts and fossil fuel residues is anticipated to rise.

While the steel industry remains the dominant consumer of vanadium, VRFBs are increasingly being deployed for large-scale energy storage solutions. As many countries work toward achieving renewable energy targets, VRFB storage presents a promising solution with the growing commercialization of VRFB technology; however, high capital and operating costs as well as limited vanadium feedstock availability and highly concentrated production in only a few countries remain the main drawbacks of VRFB technology. Alternate battery chemistries including lithium-ion, lead-ion and sodium-ion are being developed, but many of these are still in the early stages of research compared to the more established VRFB.

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VERMICULITE

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

Vermiculite, a hydrated magnesium-aluminum-iron silicate, is extracted from near-surface deposits. In its raw form, vermiculite resembles mica and contains water molecules within its structure. It can appear in various colors, from black to shades of brown and yellow. When heated quickly to temperatures above 870 °C, the intermolecular water flashes into steam, causing the flakes to expand into gold- or bronze-colored, accordion-like particles. This process, known as exfoliation, results in an ultra-lightweight, chemically inert, fire-resistant and odorless material.

Vermiculite was discovered in 1824 by Thomas H. Webb; however, the first successful commercial vermiculite mine did not begin production until the 1920s, when the Zonolite Co. began mining vermiculite in Libby, MT. Currently, 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 traditional openpit methods.

Production

In 2024 an estimated 100 kt of vermiculite was produced in the United States from two mining companies: Specialty Vermiculite Corp. (a subsidiary of Dicalite 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 proprietary company data.) An estimated 70 kt of vermiculite ore was exfoliated in 2024, a 19 percent increase from 59 kt in 2023. Exfoliation was performed by 11 companies operating 12 plants in seven states (Arizona, Arkansas, Massachusetts, New Jersey, Ohio, Pennsylvania and South Carolina). In December 2024, The Strong Co. Inc., headquartered in Pine Bluff, AR, announced the acquisition of all manufacturing assets of Ambient Minerals Inc. located in Benton, AR. Ambient Minerals Inc. specializes in perlite and vermiculite products.

Consumption

Unexpanded vermiculite concentrate is predominantly utilized in fire protection products, although the majority of vermiculite is used in exfoliated form. Exfoliated vermiculite is valued for its diverse applications due to attributes such as fire resistance, high-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 2024. When combined with peat, bark or compost, vermiculite enhances aeration and moisture retention, fostering rapid plant growth. Additional notable applications encompass aggregates (concrete, plaster and premixes), insulation (loose-fill, block, high-temperature and packing insulation) and sealants.

Substitutes

There are numerous alternatives to vermiculite. Expanded perlite, along with more cost-effective options like expanded clay, shale slag and slate, can replace exfoliated vermiculite in lightweight concrete and plaster. In the agricultural sector, substitutes include bark, other plant materials, peat, perlite, sawdust and synthetic soil conditioner. For loose-fill fireproofing insulation, alternatives include fiberglass, perlite and slag wood.

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 group "vermiculite, perlite and chlorites, unexpanded." Domestic exports and imports for consumption of vermiculite were estimated based on information published by the U.S. Census Bureau and adjusted by the U.S. Geological Survey based on average unit value, countries known to produce vermiculite, and likely port destinations to eliminate other minerals reported in the same group. An estimated 40 kt of vermiculite valued at an estimated $18 million were imported into the United States in 2024. The majority of these imports, (85 percent) came from Brazil and South Africa. 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 an estimated $1.9 million in 2024 with Canada being the leading destination.

International

Global production of vermiculite was estimated to be 460 kt in 2024 compared with 458 kt in 2023. South Africa continued to be the leading vermiculite producing country followed, in descending order, by the United States and Brazil.

Outlook

The global production capacity of vermiculite consistently surpasses consumption. Notably, the production capacity for finer grades of vermiculite greatly exceeds that of coarser grades. Even though some consumers have turned to alternative materials in recent years, the global demand for vermiculite is expected to remain strong. Exploration and development of vermiculite deposits of all grades are anticipated to persist, while producers are likely to continue exploring innovative applications for vermiculite, particularly finer grades in high-value markets.

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ZEOLITES

by Wilfrid Balmer, Alcimex and Daniel T. Eyde, Cheto Partners

Global market overview

In 2024, the global natural zeolite market reached a value of about $1.77 billion, with a projected annual growth rate of 6 percent from 2025 to 2030. This growth is fueled by rising demand in water treatment, agriculture and industrial applications. Outside of the

United States, there is a robust natural zeolite industry 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 wide range of product offerings.

Global production has stayed around 1 Mt annually, with the major producers being Slovakia (220 kt), China (150 kt), Indonesia (120 kt), Cuba (78 kt), the United States (81 kt) and Turkey (70 kt). It should be noted that these figures are largely underestimated and mainly take into account agricultural and environmental applications. In many regions of the world, particularly China and Eastern Europe, natural zeolites are primarily a raw material in the manufacture of cement. The quantities involved in this industry alone would be several million tonnes. In U.S. Geological Survey (USGS) statistics, cement applications are reported under pozzolan applications.

U.S. industry changes

In 2024, seven companies operated nine zeolite mines in six states and produced an estimated 81 kt of natural zeolites. Though 81 kt of zeolites were reportedly produced in 2024, sales totaled 73 kt, down about 3 kt from 2023. Animal feeds at 46 percent and odor control applications at 12 percent were the two largest markets. The major producers in the United States are St. Cloud Mining, Zeotech, Bear River Zeolites, KMI Zeolites, Teague Mineral Products and UOP LLC. Kirkland Mining Products and Zeodorizer produce zeolitized volcanic ash products.

There were significant changes in the U.S. market in 2024. St. Cloud Mining Co. was acquired by Equalizer Inc., a distributor of bulk, feed and agricultural chemicals and petrochemical products through four distribution terminals in Texas and Nebraska. The purchase price was not disclosed. Bear River Zeolites is apparently on the hunt for acquisitions as well, though no specific targets have been mentioned. KMI Zeolites is in the process of closing its processing facility at Ash Meadows, CA. It plans to use a toll facility being constructed in Pahrump, NV. Teague Minerals and Zeotech may also decide to sell their operations.

Prices

Clinoptilolite remains the primary product at more than 90 percent of U.S. production. Chabazite remained at about 5 to 6 percent of production in 2024, with the remainder principally mordenite, phillipsite and ferrierite. Prices are generally negotiated; consequently, there are no published price quotes, though Bear River reports its average sales price per ton in the annual report of its parent company, US Antimony, and is a good benchmark for the industry. In 2024, Bear River produced 10,086 t at an average sale price of $291.50/t for clinoptilolite products, up from $267.30/t on 10,145 t in 2023.

European producers

Zeocem in Slovakia and Rota Mining in Turkey are the main European clinoptilolite producers. Zeocem is permanently investing to reduce its environmental impact, with a new phase of solar panel deployment. Its goal is to become the world's leading eco-producer of natural zeolites.

Other strategic investments concern production dedicated to the construction industry, particularly a wide range of micronized zeolites. European producers have suffered from the sharp increase in energy costs over the past three years. This is reflected in the ex works price, which has increased by an overall 40 percent. Added to this is the cost of freight, which has increased by almost 45 percent over five years and has a significant impact on the bill.

With the exception of Zeocem, which is well developed in exports, and Rota Mining, whose location on the Mediterranean Sea opens the doors to the North African and Middle Eastern markets as well as European coastal areas, there has been a contraction in sales for most other producers, with relative stagnation for Italian chabazite/phillipsite producers (Verdi, IZ and ATZ) and most European producing countries.

In 2024, Josab Hungary virtually stopped production in Ratka, and the company is reportedly for sale. Changes of ownership are also expected in Turkey. Alcimex in France has opted for a range of high-end products by offering its own formulations with a high level of technicality for the industry and elite sports fields.

Markets

Agriculture accounted for about 29 percent of the global market, with natural zeolites used as soil conditioners and fertilizers to enhance nutrient retention and improve crop yields.

Animal feed accounted for 23 percent of the global market but nearly 46 percent of the U.S. market, driven by the inclusion of zeolites in livestock diets to improve digestion and feed efficiency. Feed lots and other large concentrations of animals are point sources of several effluents, odors and waste runoffs. There will be increasing regulatory pressure to mitigate the impact of these facilities.

The water treatment segment is expected to grow at a rate of 6.4 percent over the next decade. Natural zeolites are valued for their ability to remove contaminants like heavy metals and ammonium from water due to their strong ion-exchange properties. The use of natural zeolites is increasingly widespread in Europe in water treatment. The European Committee for Standardization has established the EN 16070 standard, which specifies the characteristics of natural

zeolites used in the treatment of water for human consumption.

Cement, pozzolans and concrete additives make up the largest application segment, constituting 55 percent of the global market, in which zeolites are incorporated into lightweight concrete and cement to enhance strength and thermal insulation. This is a developing market in the United States and will probably be a western regional market, as the available resources are in the western states and not always well located to enable reasonable transportation costs.

Other lesser markets include micronized zeolite, synthetic turf, odor and pollution control, and nuclear applications.

Outlook

Interest in natural zeolites and their integration into building material formulations has been growing steadily over the past two decades, driven by economic constraints and the need to develop materials with low carbon footprints and high durability. Today in Europe, maritime infrastructures integrate clinoptilolite-based concrete, reducing the penetration of chlorides into concrete exposed to seawater. Their use in road and hydraulic concrete has improved sulfate resistance and reduced plastic shrinkage. Restoration mortars based on chabazite/phillipsite are used on historical monuments, for their mineralogical compatibility and for their ability to limit saline efflorescence and salt migration. In the case of activated concretes and geopolymers, micronized zeolite activated by alkaline solutions rapidly release aluminosilicate species, participating in the formation of sodium alumino-silicate hydrate (NASH) or calcium alumino-silicate hydrate (CASH) gels in geopolymers and activated concretes. The incorporation of natural zeolites, raw or calcined, densifies the matrix, reduces porosity and increases mechanical strength.

It is remarkable to note that Europe has followed a trajectory mainly focused on the technological and industrial development of the applied products, unlike other countries like the United States and China, which are particularly active in academic research. This contrast can be explained by several factors:

- Strong economic constraints, particularly the high cost of energy in Europe, have led manufacturers to prioritize low-carbon solutions and optimize the use of local natural resources such as zeolites.
- A demanding environmental regulatory framework favors the integration of natural and ecological materials, as buildings are responsible for approximately 50 percent of resource extraction and consumption and more than 30 percent of the total waste produced each year in the European Union (EU).
- The development of advanced technological process with, notably, the mastery of micronization and activation of natural zeolites.

The positioning of European companies is therefore based on a pragmatic and innovative approach, where constraints have become drivers of development. This can be illustrated by the development of "low-carbon" cements. The EU aims for climate neutrality by 2050 with a net-zero greenhouse-gas-emissions economy. The cement industry alone accounts for 6 to 7 percent of global anthropogenic emissions. Therefore, the solution to the problem lies largely in the search for effective substitutes to replace part of the clinker in portland cement with secondary components, while optimizing the granulometry and composition of the cement. These efforts have led to a modification of the European standard EN 197-1 for general-purpose cements, which introduces new types of composite cements. These new types can contain from 6 to 80 percent of mineral additives, unlike traditional portland (CEM I), which is limited to 5 percent. This development leaves a prominent place for natural zeolites. However, this is only possible thanks to the development of processes like micronization. Current processes make it possible to obtain median diameters between 3 and 5 µm.

ZIRCONIUM

by Gaurav Jha, Indian Institute of Technology (Indian School of Mines) Dhanbad

Zirconium is the 20th most abundant metal in the Earth's crust and is mostly found in the form of silicates ($ZrSiO_4$). Zirconium is a lustrous, gray-white metal mainly obtained from zircon sand. Zircon exhibits excellent corrosion resistance and high strength properties, which makes it workable in marine, industry and other metallurgical environments. Zirconium is found to be associated with heavy minerals such as ilmenite, rutile and monazite. Zirconium is extracted as a product or byproduct during the processing of heavy minerals containing beach sands. The major uses of zircon are in ceramics, foundry sands, opacifiers and refractories, and corrosion-resistant applications in the chemical processing industry. The major applications of zirconium metal are in the nuclear sector, where it is used to clad fuel rods, and in the chemical processing industries. Global resources of zirconium stand at 68

Mt, of which U.S. reserves are around 14 Mt. Australia has major reserves of around 50 Mt.

Production and consumption

Global zirconium production stands at around 1.5 Mt/a, with Australia, South Africa and China as major producers. Australia has led production numbers for many years due to its huge reserves. China, the European Union and the United States are key consumers, using zirconium in ceramics, refractories, chemicals, nuclear reactors and biomedical devices. Less than 0.1 Mt of ZrO_2 was produced in the United States in 2024, similar to 2023. Domestic consumption of zirconium has been unchanged from 2019 to 2024.

Exports and imports

The United States exported 16 kt of zirconium oxide and imported 19 kt in 2024, down from 40.5 kt of exports and 22.6 kt of imports in 2019. Major import sources were South Africa, Australia and Senegal.

Outlook

Globally, production grew from 1.44 Mt to 1.5 Mt. Countries like Australia, Madagascar, Mozambique and Tanzania are taking several exploration and development initiatives. Attempts are also ongoing to recycle the spent zirconium, though the quantification is not yet achieved.

Prices

According to U.S. Geological Survey 2024 data, the price of zircon was $2,000/t in 2024, up significantly from $1,620/t in 2019. According to Shanghai Metal Exchange data, zirconium carbonate was priced at $2,623/t in May 2025. ■

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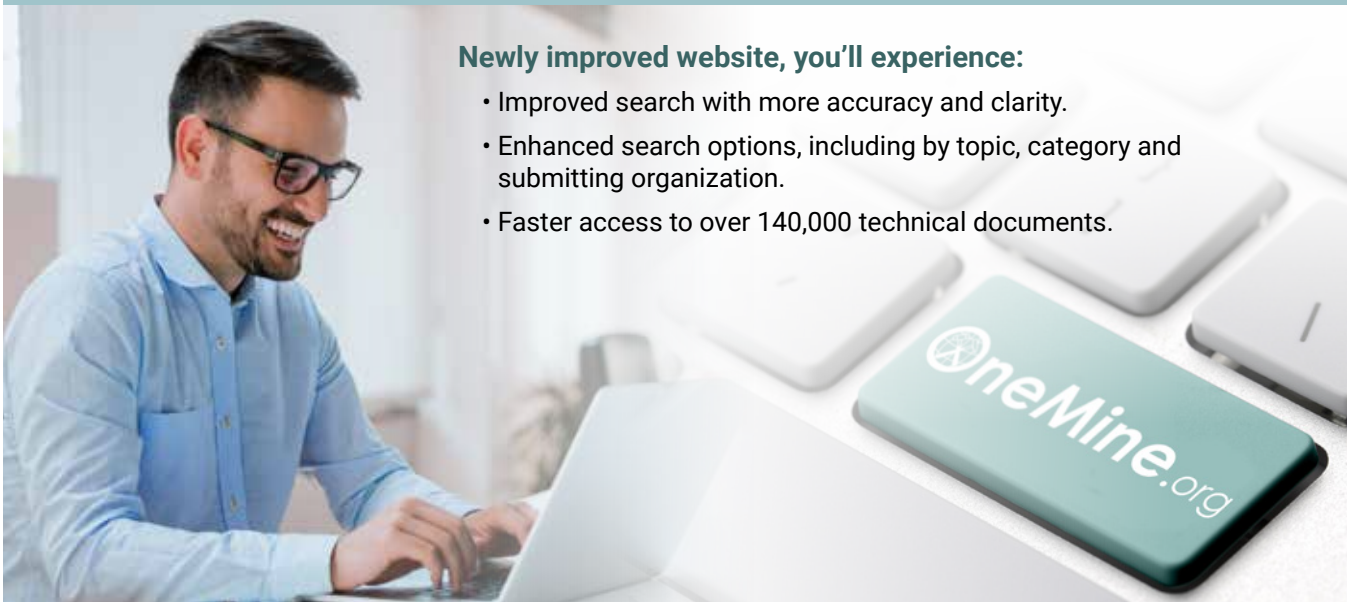
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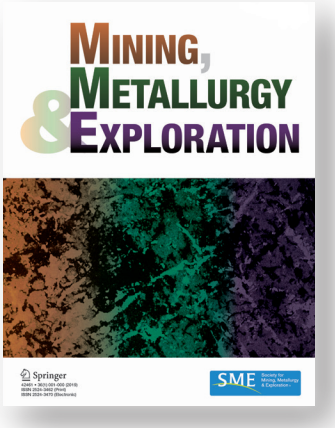
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Invited Extended Abstracts

Collection on Geometallurgy

Rock strength distribution modeling for predictive geometallurgical modeling

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Keywords: Geometallurgy, Ore characterization, Rock strength measurement, Milling energy, Fracture energy

The competence of mined rock is a key property that determines the amount of energy required to grind the ore and the throughput of the process plant. Existing empirical geometallurgical models cannot predict outside the tested ore base or account for changes to the grinding circuit. A new approach is introduced which provides a precise measure of rock fracture energy distribution related to the rock mineralogy, specifically degree of alteration of a porphyry copper. A relationship between mineralogy and rock strength allows the rock crushing and milling energy to be mapped into the orebody based on the geological map of the deposit, rather than requiring extensive, and expensive, breakage testing and the use of unreliable proxy values. This study presents a viable method to quantify the distributed and widely varying rock properties of mineral resources in a more cost-effective manner than traditional independent rock strength testing methods, by using automated core-scanning technology to relate mineralogy and texture to rock strength. Recent development in more rapid and cheaper, but still accurate, ore breakage characterization may propel this methodology into standard geometallurgical modeling practice.

Introduction

We address the challenge of developing a method to map

ore competence based on the varying mineralogy of an orebody, by directly relating breakage properties to a specific mineral composition. Current methods discard the rich data of geological mapping that can be constantly upgraded with core data, instead using statistical methods to map ore competence between a few measured composite lengths along cores. Geometallurgical modeling tends to use only assay data to relate to competence — with the data averaged to match the low sampling resolution of the competence tests or uncertain correlations to mill throughput. The proposed improved option is to leverage off new core scanning methods by relating specific mineralogy to breakage properties, then mapping that back into the orebody via the measured and mapped mineral composition.

Rock is a brittle material with strong heterogeneity and anisotropy giving a wide distribution in breakage properties, thus rock strength distribution of a given lithology and alteration type, rather than an average, is an appropriate measure. Preliminary work highlighted a likely relationship between degree of alteration and ore competence of porphyry coppers, providing a well-defined test case for trialing the proposed methodology based on the relationship between strength and phyllic alteration.

Relating rock strength to mineral structure. The process alteration index (PAI) incorporates both the lithological variability and the degree of alteration during copper mineralization to quantify the degree of alteration:

$$\mathbf{PAI_{(plg)}} = \frac{\mathbf{Plg(org) - Plg(alt)}}{\mathbf{Plg(org)}} * 100$$

where org = mineral content of host rock, plg = plagioclase content, and alt = mineral content after alteration. The same can be applied to quartz content.

Using drill cores to quantify rock strength as a function of alteration mineralogy:

1. Group identified mineralogies:
   - Average lithology from standard core logging lengths are NOT used.
   - Quantified differentiation of mineral type, grain size and association.
   - Automated core logging.
   - Select and group identified zones into samples of about 1 kg.
2. Breakage test requirements:
   - High precision to differentiate between rock types.
   - Rock strength distribution.
   - Short impact load cell (SILC) suits this.

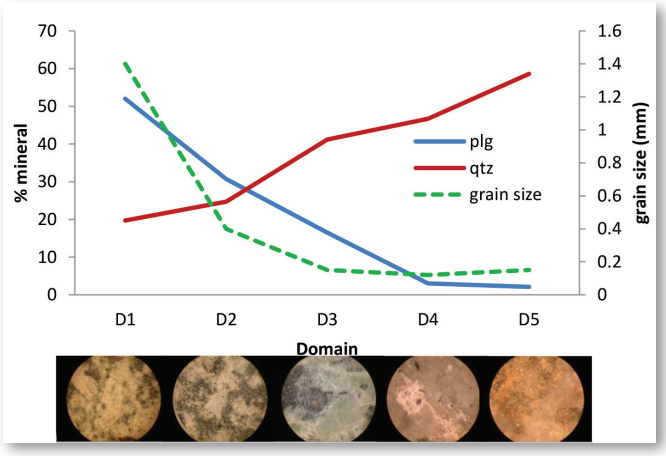


Fig. 1 Textural changes: QXRD of plagioclase and quartz relating to the degree of alteration.

Testing

Anglo American's Los Bronces porphyry copper mine in Chile contributed core samples selected by geologists for discrete mineralogy and alteration domains. The samples of five selected degrees of alteration were each combinations from spatially different sections of core, ensuring tightly defined mineralogy to avoid the diluting effect present in previous studies. Domains were confirmed through optical microscopy (QXRD), automated core logging and mineral liberation analysis (MLA), eliminating the subjective nature of geological logging.

Texture changes are defined as mineralogical transformation of the original texture during hydrothermal alteration. Texture is unrecognizable when intensely altered, so grain size of key minerals is used as a proxy, with plagioclase grain size decreasing with alteration. Texture is an essential identifier, which was missing in the core scanning, so it was quantified using optical microscopy to measure the axis of plagioclase crystals.

Cores were lightly crushed to provide large particles, which were then gently rounded in a small autogenous mill to provide smoothed particles for testing (the process is covered in the full paper). For more precise measures, mini-cores, 6 × 10 mm (D×L), were extracted to provide a controlled geometry, eliminating particle shape to provide a narrower range of rock strength measures.

The SILC impact loadcell methodology provides the input energy, absorbed energy, force to fracture, initial fracture energy and total fracture energy of every particle. The absorbed energy provides a direct measure of the breakage strength, from which a strength distribution is derived. The cumulative strength distribution and median strength provide a distinctive signature for each rock type, independent of comminution devices (such as mill or crusher). The distribution of rock fracture energy, described by the log-normal function, is used to derive E_{50}, the median fracture energy, providing a strength value. Tavares has developed mill models based on this primary fracture energy.

Results

Figure 1 shows the quartz–plagioclase relationship and texture measure across each domain. The breakage results in Fig. 2 demonstrate a significant 24 percent difference in median fracture energy. The overlapping of D2 and D3 may indicate uncertainty in classification of this intermediate degree of alteration, or insignificant difference in their fracture strengths.

Application

The relationship between E_{50} and PAI in Fig. 3 supports this detailed measurement approach, which has not previously been applied in geometallurgical modeling [1]. There

is a 30 percent difference from unaltered to full phyllic alteration, with a conveniently linear trend.

The relationship between rock strength and mineralogy needs to be established for the major orebody domains. In application, core logging with textural analysis can provide automated selection of alteration zones. The strength versus alteration can be mapped into the geological model to propagate a map of strength as a function of mineralogy — eliminating the need for detailed breakage testing on all the cores. Scoping work on the competence of different definable domains can establish the required number according to competence, volumetric fraction and probable maximum fraction in the feed over mine life. High competence domains have a disproportionate impact on mill throughput, so should be included even if they are a low fraction.

Translating this to milling circuit throughput requires appropriate crushing and mill models. A simplified method is to correlate the rock strength values directly to mill throughput, being cautious of the nonlinear effect of blending by competence. Alternatively, map the E_{50} against standard breakage indices, such as A×b. Additionally, it is viable to develop an empirical relationship between E_{50} and milling power requirement, through a well-implemented geometallurgy program. A more recent method of applying breakage outputs to mill performance predictions is using size specific energy (SSE) — the energy required to produce final product, such as minus 100 µm [2].

Rather than scaling off existing circuits, the extension of this is to incorporate changes in circuit or operational efficiency to update the comminution models and thus generate an updated throughput prediction with circuit changes and improvements.

Recent development in testing methods has provided a pathway to simpler and faster measurement of the rock strength than the detailed SILC method. The Geopyörä breakage test provides similar data of force to fracture and E_{50}, plus A×b and BWi values. Linked to core scanning, this faster and cheaper method provides a viable pathway to implementation. ■

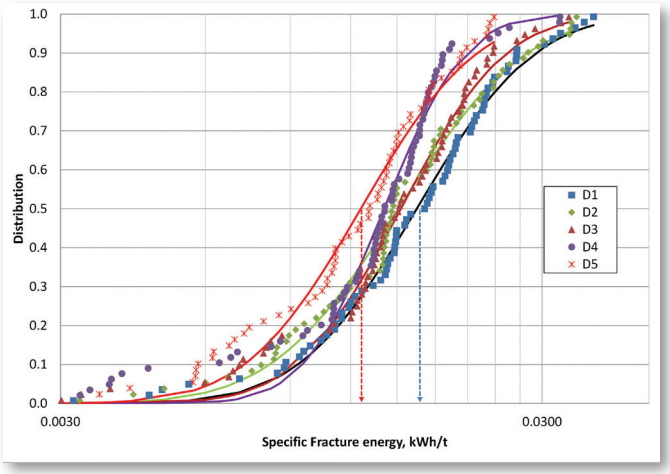


Fig. 2 Mini-core SILC results.

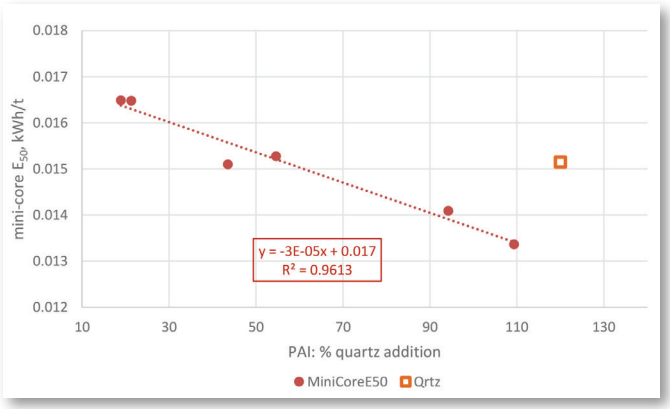


Fig. 3 Rock median strength as a function of the PAI — degree of phyllic alteration.

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Drill and blast in gypsum quarries: Optimization of technical, economic and safety aspects in Monte Tondo midmountain case study

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Keywords: Blasting design, Fragmentation, Gypsum quarry, Kuz-Ram

Drilling and blasting operations are one of the common operations in openpit mining. Recently, mathematical rigorous patterns are attracting attention, and digitalization and optimization of mining operations are highly suggested. In this work, drilling and blasting operations are modeled and various optimization scenarios are simulated. The aim is to improve the blasting efficiency in quarrying through proper understanding of the fracture mechanisms and optimization of blasting alter-

natives. The analysis was developed over the Monte Tondo gypsum quarry, owned by Saint-Gobain Italia. The case study was modeled by the openpit blasting software O-Pitsurface.

Background

Studies over fragmentation prediction account for managing both controllable and uncontrollable parameters. Kuznetsov developed a mathematical equation based on the relationship between the mean fragment size and the specific charge [1]. Cunningham used the Rosin and Rammler distribution function and the Kuznetsov model to develop a new model (Kuz-Ram) to predict rock fragmentation curve by blasting [2], later improved in 1987 [3]. The current challenge is how to adapt the modified Kuz-Ram model to the topographical, geological and blast design setting of each mine and quarry operations. In recent years, blasting softwares such as O-Pitsurface have undertaken this task, and the fragmentation can now be predicted. Many parameters are considered, such as the different free faces, the blasting pattern design, the imposed delays and the overall mutual interactions among blasts of single blastholes [4].

This work presents blasting optimization strategy using the modified Kuz-Ram model implemented in O-Pitsurface, conducted over the gypsum openpit Monte Tondo quarry in Italy. The stable geological conditions allowed the use of the Kuz-Ram approximation. The quarry occupies around 374,500 m^2, with a mountain peak of 436.5 m. The current gypsum exploitation extends from 200 to 320 m above sea level. The quarry is located beside the Gypsum Vein of Romagna Regional Park, an area classified as a UNESCO natural World Heritage site in 2023, thus it is subjected to strict environmental rules. The gypsum grade highly varies in the area, according to the geological strata. The highest grades (up to 90 percent) can be found in the layers III, IV, V and VI (Fig. 1).

The target blasting fragmentation sizes for the Monte Tondo gypsum exploitation are: (1) 600 mm: maximum dimension for the fragmented material entering the crusher and (2) 1,000 mm: maximum dimension for guaranteeing the safety of operations.

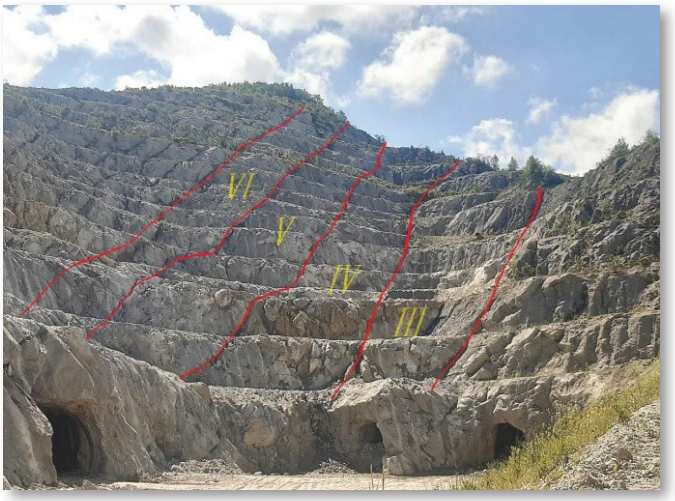


Fig. 1 Monte Tondo gypsum quarry and geological strata with highest grades.

All fragmented materials exceeding the thresholds must be treated with a jackhammer, and this affects the excavation procedures and materials managements. Moreover, such a situation poses a serious threat to operators during the moving, loading and hauling phases. The quarry process, with the potential achievable time savings if blasting was optimized, is presented in Fig. 2.

Validation of model with current blasts

The blasting pattern model in O-Pitsurface was created based on three real blasts conducted between March and June 2023. Table 1 reports the features of each blast.

Table 1 – Blasts used as a benchmark for model realization.

No.	Date	Bench altitude (m)	Number of blastholes	Blasthole length (m)	Blasthole angle (°)	Spacing (m)	Burden (m)
1	24.03.2023	290	7	13	24	3.5	3.8
2	07.04.2023	300	14	16	24	3.5	3.8
3	01.06.2023	290	12	13	24	3.5	3.8

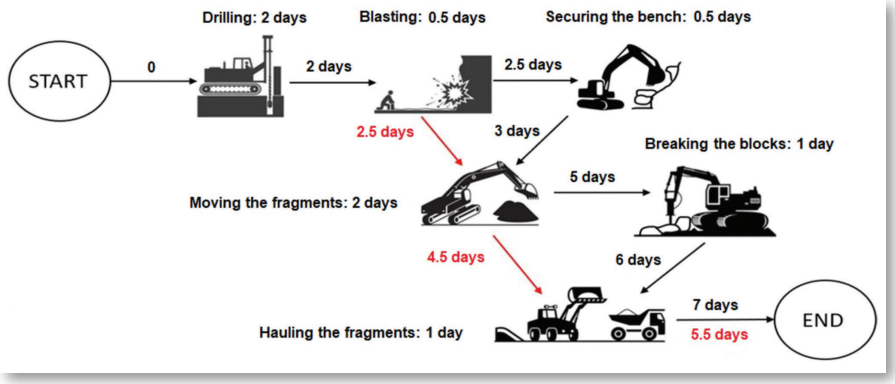


Fig. 2 Current process of the Monte Tondo gypsum quarry, with potential time savings due to blasting optimization.

The topography was reproduced by inserting the digital terrain model (DTM) relating to 2023. Afterwards, the three blasthole schemes were inserted on the model, with proper charges, detonating types and delays. The geomechanical information was obtained by both historical data and new measurements on blast fragments made in the Geoengineering and Natural Resources Laboratory of Bologna University (LAGIRN), while specific on-site surveys allowed to the obtaining of an indication of the fractures and discontinuities of the in situ rocks.

Parameters for optimization scenarios

After the model calibration over the quarry real operation, the optimization phase began, with the targets of: time saving, economic saving, and improvement of safety conditions. All optimization scenarios considered do not increase the drilling time or the

costs of explosives. The main constraint of such optimization is geometrical as the quarry geometry and scheme, and the width of the benches, cannot be changed. Three indexes were used to evaluate the quality of the optimization, by respecting the constraints. The time saving index, TSI (h/t), is related to the time necessary for exploiting 1 t of material; the cost saving index, TCI (€/t), is related to the cost of 1 t of blasted material; and the safety upgrade index, SUI (percent/t), is related to the percentage of retained material having dimensions greater than 1,000 mm, as larger blocks put the operators at risk. The higher the index value, the worse blasting results are expected. Because the three indexes have different units, a quality matrix was introduced to compare the optimization scenarios. The best hypothesis was finally selected, based on time saving of 145 h/y of work related to drilling and breaking; economic saving of €24,150/y, due to the reduced number of blastholes and diminished use of jackhammers; and improvement of safety conditions by 12 percent thanks to lower dimension of fragments, which leads to easier and safer management. This scenario concerns the use of a different type of explosive and a slightly improved blasthole pattern. The quarry process was then modified accordingly (Fig. 3).

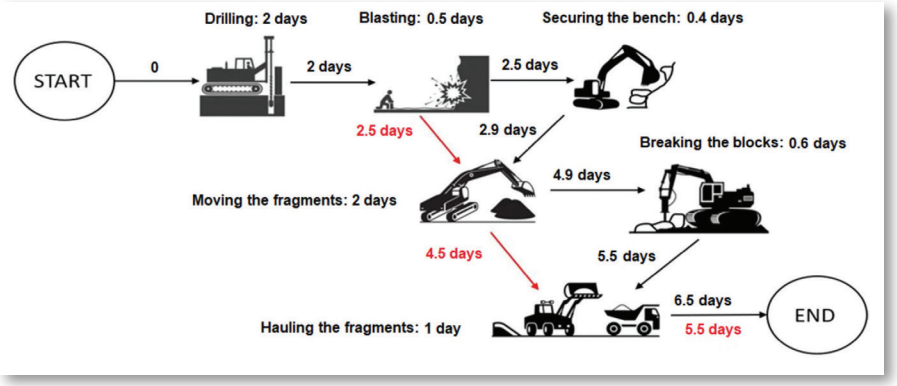


Fig. 3 Prospected modified process of the Monte Tondo gypsum quarry, due to the blasting optimization results.

Discussion and conclusions

The obtained results are inevitably influenced by the geological uncertainty of the gypsum body, which affects the rock parameters and then the rock factor used in the Kuz-Ram model. Due to this, a sensitivity analysis was conducted in order to understand how an error on the rock parameters measurement and estimation could affect the model result. The software O-Pitsurface was used as well to perform such analyses. As expected, an increase of rock factor causes an increase of retained material, due to the reduced effect of the explosives. However, it is worth noticing that the increase of retained materials greater than 1,000 mm is much higher, in percentage variation, than those greater than 600 mm. With the proposed optimization scenario then, an error in the definition of the rock factor provokes notable variations in blasting results, while the current scenario gives more margins for geological investigation errors. This aspect must be carefully considered in the next decisional steps for the prosecution of the gypsum exploitation. ■

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Mechanisms and measurements of destressing in underground mines: A state-of-the-art review

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Keywords: Destressing, Preconditioning, Destress excavations, Stress reduction, Deep mining

Mining operations in the 21st century will be conducted at increasing depths within very high stress environments. Destressing and preconditioning are traditional control techniques that have already been used in past decades but will be relied upon on a regular basis under those conditions. Destressing activities are currently designed based on an empirical approach, and the use of numerical modeling is limited to a back analysis of previous applications. In this study, an extensive overview is conducted of destressing in underground hard rock mines and collieries with stiff formations, as well as caving operations where preconditioning is applied. The underlying mechanisms proposed by numerous authors are categorized into several schools of thought, and measurements obtained from case-study mines are summarized based on the purpose of destressing, operational depth, and the mechanisms involved. The various summary tables

provide an updated database for empirical design and can be used as a foundation for calibrating numerical models where destressed rock mass is simulated.

Background

Destressing and preconditioning are techniques that have been used in the mining industry for the past 75 years. They consist of specialized blasting and full excavations that either create a weaker rock mass or remove it altogether, respectively, thus creating a stress shadow in the immediate vicinity. With the future of mining lying at further depth within very high stress environments, the need for destressing and preconditioning will increase significantly. Numerical modeling is a powerful tool that is regularly used in the industry, and its computational power can be harnessed to assess the impact of destressing. However, it is currently used mostly to back analyze previous applications of the technique, and to deduce its impact on the rock mass properties.

In this study, an extensive literature review is conducted of field measurements and observations from the application of destressing and preconditioning in underground hard-rock mines, coal mines with stiff geologic formations, and caving operations.

In addition, mechanisms put forward by multiple researchers are categorized to provide a basis for future numerical analysis. Finally, field data from case-study mines are summarized to provide a robust empirical database that can be used for design purposes.

Table 1 – Mines where new fracture formation or network densification was observed.

Mine	Depth (m)	Destressed region	Reference
3 large copper mines	870	Dolomite formations in the roof	163
Blyvooruitzicht	2,500	18-13W stope	44, 48
Brunswick	1,000	North and south regional pillars; panel destressing in 29-9 pillar	30, 110-112
Budryk and Pniówek	880 to 1100	401 and 404/1 coal seams	176
Coal mine in Colorado	650		164
Coal mine in Pennsylvania	245 to 275	Hydraulic fracturing in sandstone roof	215
Creighton	1,175; 1,645 to 2010; 2,070	Sill developments in 400 orebody; corners of working faces; drifts, a shaft, and rib pillars	100, 106-108
Falconbridge	1,225	4002 27-31 stope	94
Fraser Copper	1,260	42-1-080 pillar	30, 104
Galena	1,460; 2,000	Stope pillar; stope 40-135E, 21-m high pillar, 46-99 stope	81, 82, 85, 86, 88
Garson	1,525	Development through a dyke	103
Hongqinghe	700	Abutment	213
Huize	1,500	Drift development through highly stressed rock mass	195
Kirkland Lake area		Development headings, shafts, raises, pillars and stopes	12
Lake Shore	1,625; 1,770	2 stopes next to a fault; 58-40 stope crown pillar	14, 27
Lazy	720; 740; 800	Panel no. 140914 of no. 504 coal seam; coal seam no. 40; roof strata in longwall no. 140704	181, 184, 185
LGOM	830; 1,000; 1,100; 1,160	Simultaneous blasting at faces, in roof and in floor	152-162
Macassa	1,950; 2,050	58-40 stope crown pillar; small pillar in the 61/38 stope	5, 27
Moonee	160	Conglomerate roof	216-218
Narrabri	150	Strong roof rock	212
Onaping	1,500	Waste pillar	116
Pingdingshan area	740; 800	Roof cutting, destress blasting with hydraulic fracturing	188, 191
Pyhäsalmi	660	Stope R21	139, 144, 145
Red Lake	495 to 855	1470 stope access drift; sill, crown, and boxhole pillars; 1604E stope	14, 91, 95
Sigma	1,500	Sill pillar on the 34 level	99
South Deep	2,600	Four- versus five-hole preconditioning	41, 42, 66, 70, 71
Star-Morning	2,350	Between two crosscuts	7-9, 11, 83, 89
Strathcona	720 to 760	25-39-D4 stope	98
Thierry		Shaft	209
West Driefontein Gold	1,575	32-12W stope	44, 48
Xstrata Nickel Fraser	1,260	42-1-1620 D7 lens	116
USCB mines	910; 1,050	Coal seams nos. 504, 506, 507, 510	170-175

Table 2 — Mines where either slippage on pre-existing fractures or both new fracture generation and slippage on pre-existing ones were observed.

Mine	Depth (m)	Destressed region	Reference
Slippage on pre-existing fractures only			
Driefontein	1,600	18-23 pillar	54
Kiirunavaara	1,350		148
Laisvall	220; 300	Above a rib pillar	19, 138, 139
Mponeng	2,500; 2,900	Stope faces; 87-49W stope	46, 47, 63, 64
Star	2,100	Sill pillar on 6900 level	90
USCB mines	730		179
Both new fractures and slippage on pre-existing ones			
Blyvooruitzicht	1,850; > 1,900	Pillar near the 17-24W stope; pillars, remnants; 17-24W stope	29, 48, 50, 55, 56
Carltonville, Klerksdorp areas	2,100; 2400		39
Mponeng	2,000; 2500	Remnant pillar	45
Mt Charlotte	780	Rib and abutment pillars of ROB and CDOB orebodies	17, 133-135
Red Lake	765	1670W stope crown pillar	14
South Deep	2650	Near a dyke	37, 67, 211
Unspecified Australian mine	600	Parallel twin tunnels	137

Methodology

More than 350 references were obtained and reviewed for the preparation of this literature review. The focus was on hard-rock mine environments, but collieries with stiff geologic formations were also included as well as caving operations where preconditioning is commonly used. Case-study mines were categorized based on their geographic area first, followed by the type of destressing adopted — blasting or excavations — and the depth of implementation. In the following stage, theoretical postulations and various mechanisms proposed by numerous researchers were categorized. These were then compared to field measurements and observations from mines and other projects.

The data are presented in summary tables based on the mechanisms involved, where the depth and region of destressing are also indicated. In addition, changes in rock mass properties such as deformation modulus, compressive strength, seismic wave velocity, stress decrease, closure and seismic activity are summarized. Destressing and preconditioning applications are categorized based on ore production and development excavations in hard-rock mines, with similar summaries for coal and caving operations.

Results

The geographical distribution of destressing and preconditioning applications was found to extend to Canada, the United States, South Africa, Australia, Sweden, Finland and Poland. Coal mines in the Czech Republic, Poland, China and the United States were also observed to have implemented the technique extensively. A summary timeline of the various geographic regions and the destressing approach used is provided in Fig. 6 in the full paper. In addition to South African mines, preconditioning was adopted especially in caving operations — mostly in Australia and Chile — to improve fragmentation and ore flow, as well as to control seismicity.

Researchers agreed that destressing resulted in a reduction of rock mass properties such as deformation modulus, compressive strength and stiffness. They also noted that stress transfer to adjacent regions occurred as a result, which translated into a reduction in its magnitude, the release of stored strain energy, and deformation. Two main mechanisms for destressing were postulated by numerous authors throughout the decades. The first was the creation of new fractures or extension of existing networks, which was mostly held by North American researchers, as summarized in Table 1. The second was slippage of rock blocks along pre-existing fractures, put forward by many South African and Scandinavian authors, as presented in Table 2. Around the turn of the century, a balanced approach was proposed by others, which allowed for both mechanisms to potentially occur based on the specific geologic environment where destressing was applied.

Field measurements and observations from case-study mines around the world provided support for both mechanisms, and these are summarized in table form, where the depth and region of application within the mine are indicated. Other effects on rock mass properties, such as modulus changes, strength and stress reductions, closure rates, and a decrease in seismicity and seismic velocity are also tabulated for reference purposes.

One of the key outcomes of this work is the development of an empirical database where the objective of destressing is used as a categorization tool. Hence, all the case-study mines are tabulated separately depending on whether destressing was used for stoping (ore production) or development purposes. Descriptions of the location, depth, mine name and country are provided for each of the two categories, in addition to separate tables for coal and caving mines. Finally, a single figure is presented, providing a graphical indication of

the depth — ranging from approximately 100 to 3,650 m — at which destressing or preconditioning took place at these mines, as well as the mechanisms involved in the process (Fig. 21 in the full paper).

Conclusions

This literature review provides a comprehensive evaluation of publications on destressing and preconditioning during the past 75 years.

It categorizes their application in underground mines based on the mechanisms invoked, various types of measurements obtained and the operational purpose of the exercise. As empirical design processes are used for destressing, the multiple summary tables that were generated can be used as an ideal database in this regard. In addition, they can provide a baseline for numerical model calibration where destressed rock masses are simulated. ■

References

A list of all references is available in the full paper. The numbers indicated in the tables in this abstract refer to those in the full paper.

Perspectives of mining personnel on adopting occupational exoskeletons: Comparisons between a developed and a developing country

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Keywords: Work-related musculoskeletal disorders, Mining industry, Intervention, Technology adoption, Exoskeleton

Occupational exoskeletons (EXOs) have received growing attention as a new ergonomic intervention to reduce physical demands in various industries, such as manufacturing, logistics, construction, and agriculture. However, their potential use in mining has not yet been reported. Survey data were obtained from mining workers in the United States and Indonesia. Both U.S. and Indonesian respondents reported potential benefits of EXOs for physically demanding tasks such as lifting and overhead work, and they shared concerns about adaptation, uncertainty or lack of knowledge, confined spaces, device weight, potential failure or damage, and costs. However, some key differences also emerged: U.S. respondents were more likely to consider using arm-support EXOs and back-support EXOs, despite expressing concerns about their use, while Indonesian respondents, although they reported more existing health and safety hazards, appeared more hesitant about adopting EXOs, possibly due to these additional hazards. These results demonstrate that miners appear to have an interest in EXOs but also emphasize the need to ensure task compatibility, comfort and affordability to ensure the safe and effective adoption of EXO technology in mining in both developed and developing countries.

Background

Work-related musculoskeletal disorders (WMSDs) remain a major health concern worldwide in the mining sector. In the United States, for example, the incidence rate of WMSDs in mining was 31 per 10,000 full-time employees in 2020, higher than the 25.4 combined rate of other industries, with the back and shoulder being the most affected areas [1]. Developing countries may face greater challenges due to different work conditions and cultures. While diverse controls have been implemented, their practical effectiveness is often limited. EXOs have emerged as a promising approach for reducing WMSD risks in multiple industries, but specific evidence or practical guidelines to support the safe adoption and effective implementation of EXOs in mining is limited.

EXOs are wearable devices designed to assist/support the wearer during various physical activities. Arm-support exoskeletons (ASEs) alleviate shoulder loads, and back-support exoskeletons (BSEs) support the lower back and hips through passive mechanisms. Existing evidence indicates that short-term use of EXOs can reduce physical demands and potentially improve task performance during overhead work and repetitive lifting [2,3]. Such benefits, however, are contingent upon the specific EXO design and work task characteristics. EXO use may also have adverse effects, highlighting the need to consider both potential benefits and limitations before workplace implementation.

This exploratory study compared the perspectives regarding the facilitators of and barriers to EXO adoption among mining personnel in the United States and Indonesia, representing a developed and developing country, respectively. This work also examines how the perceived likelihood to use an EXO differed between the two countries.

Materials and methods

Miners completed a self-administered online survey that had 87 closed and open-ended questions covering EXO knowledge, job task characteristics, perceived benefits,

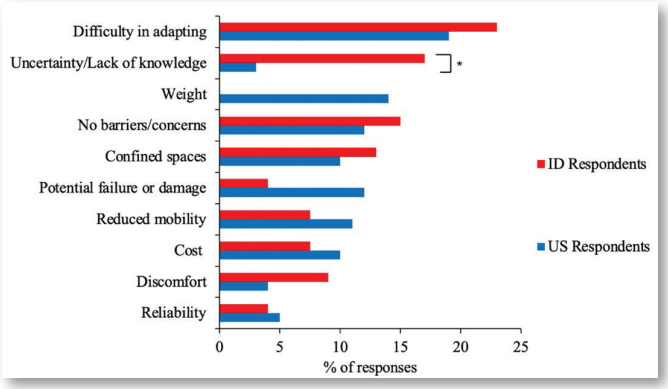


Fig. 1 U.S. (US) and Indonesian (ID) respondents' concerns about adopting and using EXOs. The symbol * denotes a significant difference between countries.

health and safety concerns, and promoters of and barriers to EXO use and adoption. Before the survey, participants watched a five-minute video on occupational EXO technologies and types. Participants were recruited through industry contacts, referrals and social media. Qualitative and frequency analyses were used to summarize and compare respondents' feedback. Beta regression analyses were also used to examine whether the perceived likelihood to use ASEs or BSEs differed by country, demographics or perceptions regarding EXOs.

Results and discussion

A total of 138 respondents completed the survey; three respondents from other countries were excluded from the analysis, leaving a total of 135, whose demographics and job characteristics are summarized in Table 1.

Among all predictors, years of experience was the only predictor that affected perceived barriers and the likelihood to use a BSE, while country was the only significant predictor of perception scores. However, we found significant differences in the reported likelihood to use ASEs between age groups and across mining commodities. Beyond these predictors, both the U.S. and Indonesian respondents expressed concerns about adaptability to EXO use over time (Fig. 1). These adaptability concerns may have been influenced by other concerns, such as uncertainties about reliability, ease of use, training or task compatibility. While Indonesian respondents reported more uncertainty and challenges with confined spaces, U.S. respondents were more concerned about reduced mobility and EXO weight. However, potential failure or damage concerns were expressed by both groups and may have been influenced by several factors, including high expectations for reliability and awareness of safety or financial implications.

Both U.S. and Indonesian respondents also reported some common risk factors in mining as concerns related to EXO adoption. Indonesian respondents reported more "Yes" across various factors, compared to U.S. respondents who reported "No" more frequently. The difference in response patterns may be due to the presence of distinct risk factors in their respective workplaces. Perceptions about EXO affordability also differed. Indonesian respondents cited financial constraints, whereas U.S. respondents focused more on productivity and safety benefits. Despite these concerns, both groups identified tasks (Fig. 2) that could benefit from ASE and BSE use. Lifting tasks were mentioned as suitable for BSEs, and overhead tasks were mentioned for ASEs, which align with typical identified use cases for ASEs and BSEs.

Some respondents in both groups also mentioned the knee as a body part that could benefit from EXOs. More broadly, a majority of both U.S. and Indonesian respondents

Table 1 — Summary of demographics and job characteristics of U.S. (US) and Indonesian (ID) respondents.

US	n (%)	ID	n (%)
Gender (n = 78)		**Gender (n = 57)**	
Male	73 (94)	Male	57 (100)
Female	5 (6)		
Age (n = 78)		**Age (n = 56)**	
18–24 (Young adults)	4 (5)	18–24 (Young adults)	15 (27)
25–44 (Middle-aged)	56 (72)	25–44 (Middle-aged)	40 (72)
45–64 (Older adults)	18 (23)	45–64 (Older adults)	1 (7)
Years in mining (n = 77)		**Years in mining (n = 57)**	
0–3 (Novice)	18 (23) 0–3	(Novice)	20 (35)
4–9 (Experienced)	32 (42)	4–9 (Experienced)	23 (40)
10 + (Highly experienced)	27 (35)	10 + (Highly experienced)	14 (25)
Years in current job (n = 78)		**Years in current job (n = 57)**	
0–3	34 (44)	0–3	26 (46)
4–9	35 (45)	4–9	20 (35)
10 +	9 (11)	10 +	11 (19)
Job roles (n = 76)		**Job roles (n = 57)**	
Operational staff	18 (24)	Operational staff	12 (21)
Technical staff	12 (16)	Technical staff	28 (49)
Management team	5 (6)	Management team	6 (11)
Others	41 (54)	Others	11 (19)
Mining operations (n = 78)		**Mining operations (n = 57)**	
Underground	43 (55)	Surface 54 (95)	
Surface	29 (37)	Others 3 (5)	
Processing	plant 3 (4)		
Others	3 (4)		
Mining commodities (n = 78)		**Mining commodities (n = 57)**	
Stone	34 (44)	Coal	44 (77)
Coal	15 (19)	Metal	11 (19)
Metal	14 (18)	Non-metal	2 (4)
Non-metal	13 (17)		
Sand and gravel	2 (2)		

indicated potential benefits of EXOs related to reducing muscle fatigue and improving work efficiency. Consistent with these benefits, both groups emphasized the importance of comfort, safety features and ergonomic design. Interestingly, U.S. surface mine workers' views remained consistent with those obtained from the overall U.S. mining cohort.

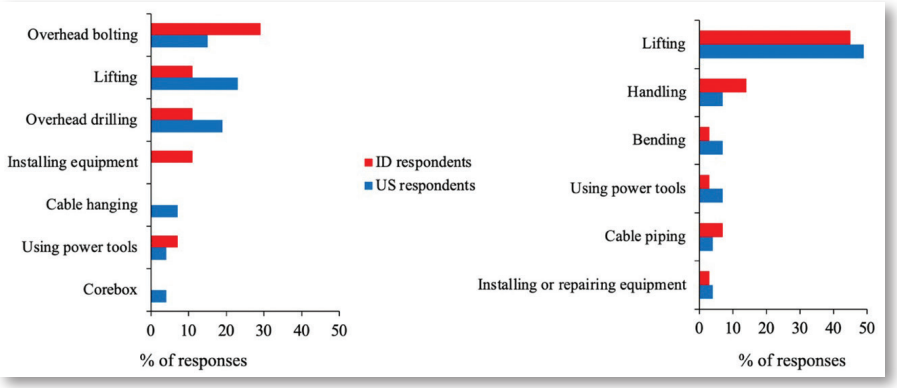


Fig. 2 U.S. (US) and Indonesian (ID) responses regarding mining tasks that could benefit from using ASEs (left) and BSEs (right).

Conclusions

Our results highlight shared perspectives between U.S. and Indonesian mining personnel on EXO adoption and use, with both groups recognizing benefits for lifting and overhead tasks and expressing concerns about usability, safety and cost. However, U.S. respondents indicated being more likely to use BSEs despite concerns, while Indonesian respondents were more hesitant despite reporting more workplace hazards. To facilitate effective adoption, EXOs must be compatible with mining tasks, comfortable, easy to use and affordable. Training and further research are also recommended to support the safe and effective use of EXOs in mining. Overall, there is strong potential for integrating EXOs into mining operations in developed and developing countries. ■

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Selected Abstract

Advance development in natural graphite material and its applications: A review

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Keywords: Natural graphite, Refinement, Materialization, Utilization of energy

Graphite is a promising and forward-looking mineral expected to drive not only technological advancements but also cultural shifts in the future. It has numerous applications and is particularly critical for electric-vehicle batteries, which has significantly increased its demand. However, the beneficiation of graphite ore is crucial as it determines the quality, market value, and suitability for various technological applications, including thermal conditions, graphite battery electrode production, and the nuclear sector. Given that graphite is naturally hydrophobic (similar to coal), its carbon content is a key factor limiting its utility. The removal of contaminants from high-grade graphite minerals poses a significant challenge. This review briefly introduces standard graphite refinement techniques, including gravity, magnetic, electric, flotation separation and thermochemical purification methods at high temperatures, as reported by various research groups worldwide. Finally, the key energy storage applications, such as supercapacitors and batteries that utilize graphite-based materials, were discussed with a focus on their roles in thermal management, graphite-based cement composites, dual-ion batteries, bipolar plates, nuclear graphite, moderators and reflectors, and high-performance energy storage devices. The primary aim of this review is to provide a comprehensive overview of the latest advancements in natural graphite materials. The review seeks to highlight the progress in the synthesis, modification and characterization of natural graphite, along with its emerging applications across various fields. The review aims to explore the potential of natural graphite in addressing challenges related to energy storage, environmental sustainability and technological innovations. ■

Stalwart support of Minnesota Section rewarded with selection of

Hibbing for MEC Partnership Award

by Kurt Doran, Minerals Education Coalition (MEC) Chair

The Minerals Education Coalition (MEC) awards SME members, internal organizations, student chapters and related organizations for outreach efforts that advance mineral education for the public and especially K-12 students, promote high-quality careers in the mining industry, and more broadly, tell a factual and important story about the impact the mining and minerals industry has on human society.

MEC's Partnership Award specifically acknowledges a non-SME individual or organization that has exemplified support for the MEC's mission, either through the development and use of educational materials with K-12 teachers and students, or public outreach and awareness about mining and minerals.

In 2025 the City of Hibbing, MN and Hibbing Area Tourist and Senior Center was selected for this award. Years of volunteer time and financial support from the Minnesota Section and Northern Minnesota Subsection of SME went into this collaboration.

The Hull Rust Mine View was relocated from its long-tenured location in North Hibbing to an adjacent stockpile approximately one mile away, allowing Cleveland-Cliffs' Hibbing Taconite Co. access to mine the underlying taconite. The mine view serves as a physical window into the Mesabi Iron Range's storied Hull Rust mine pit complex, where more than 800 Mt (880,000 st) of U.S. iron have been produced since 1891. The mine view attracts 30,000 visitors annually from May through September. Sitting more than 5 m (600 ft) above the bottom of the pit, it gives an unparalleled view of Iron Range taconite mining operations, with breathtaking, 360-degree visages of the Mesabi and surrounding communities and landscape.



The Hull Rust Mine View attracts 30,000 visitors annually from May through September.

The site is enhanced with historical mining equipment linked by short walking paths, including a production truck that visitors can climb into and interact with. Also presented at the mine view is content describing the significance of the Mesabi for the Anishinaabe people, as well as a viewpoint of a unique geographic and culturally prominent location known as the "Hill of Three Waters," where three significant continental watersheds — the Mississippi River, Hudson Bay and Great Lakes/St. Lawrence River — converge.

This year, the City of Hibbing and Tourism Center held a ribbon-cutting ceremony on May 9 to officially open the facility. Amid temperatures in the 70s and bright sunshine, a great turnout of representatives from SME, Hibbing Taconite Co., state and county agencies, and local communities gathered to celebrate the next chapter of an Iron Range commitment to promoting mining and minerals through educational outreach. ■

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SME Minnesota Section members and other attendees at the ribbon-cutting ceremony.

Explain business (mining) ethics

and how they are applied today

by Russell J. Sheets, P.E., SME RM, Assistant Vice Chair for Program Planning, Mining & Exploration Division Executive Committee

Some of us of a particular mid-range experience age will recall the 1990s instant classic movie *Billy Madison*. Very briefly, the plot includes Billy Madison going back to school, completing each grade in two weeks, to show he is worthy of taking over the Madison Hotel empire. Due to some shenanigans by Eric Gordon — an advisor to Billy's father — Billy does not complete the challenge but then challenges Eric to an academic decathlon. The last event is a quiz show-type contest where Billy and Eric pick the topic the other must answer. After Billy provides an inspirational discussion as to how "The Puppy Who Lost His Way" is symbolic of industrialization and was unjustly and harshly judged, he picks the topic for Eric. The topic Billy chooses is "Business Ethics," which Eric is unable to coherently answer. Ultimately, this proves to everyone that he is a sleazeball. Because Eric does not practice ethically, he is incapable of explaining ethics. Billy wins and ultimately foregoes taking over the company to continue school to become a teacher.

This brings me to pose an open question to everyone: "Explain mining ethics and how they are applied today?"

Code of ethics

Each engineering association or society has developed a code of ethics and/or fundamental canons for those who serve and practice to follow. SME is no different. There is a stated code of ethics with which all SME Registered Members are to comply. The codes follow a similar progression of responsibility and priority, starting first and foremost with the safety and health of the public and the community. For example:

- Act with honor and integrity, while performing work only in your area of competence.
- Build your own reputation on actual merit rather than the tearing down of others to appear "better."
- Apply your knowledge in the interest of your employer or client, as faithful representatives.
- When expressing opinions or making statements, be objective and truthful based on knowledge.
- Continue your own professional development and support those under your direction.

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 2025 is Jenessa L. Haarala.**

SME has also included one more item that specifically addresses our role in mineral reporting.

Although the SME code of ethics targets Registered Members, I strongly encourage all members to read and strive to follow the code, which can be found at: https://www.smenet.org/membership-benefits/membership-categories/code-of-ethics.

Communication

One of the first chief engineers that I worked under explained that my responsibility, granted with a focus on geotechnical risk, is to let him know what I know and when I know it, to the best of my ability based on the information available; explain what the potential risk and impact could be, and what information could help understand or refine that interpretation; and if the condition and/or risk changes, be sure to provide updates accordingly. So, tell people what they need to hear, when they need to hear it. They, or their supervisors, would be making decisions that impact a wide range of stakeholders. Even if it is bad news, knowing it in time to try and potentially address the risk before it progresses can be critical.

The converse of this approach is one where the truth or facts are not communicated or discussed: Maybe to downplay the actual risk? Maybe to stick with the previously accepted "story" of the situation? This can be observed as limiting discussion; restricting access to discuss with those that can positively impact the situation; or an extreme case of minimizing documentation.

Take-home assignment

When I was developing this idea for a "Rock in the Box" article, one thing was clear to me — the space for this article is not long enough to properly discuss the topic. I suspect that it can be hard to concisely explain "ethics" and how to apply them. However, I am certain that it is one of those principles where you know it when you see it, when you experience it, when you live it — both the positive and negative examples.

Therefore, your take-home assignment is to discuss the original question with your team: "Explain mining ethics and how they are applied today?"

Just pose the question and see where it goes. Then discuss with your team your own experiences, thoughts and maybe some of your lessons learned. ■

(Russell Sheets has been a member of SME since 2005 and a Registered Member since 2014. He currently serves as the Assistant Vice Chair for Program Planning on the Mining & Exploration (M&E) Division Executive Committee and sits on SME's Professional Engineer (PE) Committee. For more information on how to get involved in the M&E Division or the PE Committee, email him at rsheets@barr.com.)

Colorado MPD marks 74th meeting

in The Broadmoor with "Mineral Processing's Got Talent"

by Adam House, Technical Progam Associate, Mineral & Metallurgical Processing Division Executive Committee

The Colorado Mineral & Metallurgical Processing Division Subsection (Colorado MPD) of SME held its first meeting in 1949 at The Broadmoor in Colorado Springs, CO. This year marked the 74th year of the conference and took place May 1-3. It has always been the goal of this meeting to bring together those from operating companies, engineering, academia, and equipment or service suppliers in a setting that would provide an atmosphere of professionalism combined with a relaxed "get together" attitude to facilitate the exchange of ideas, knowledge and experience.



(Left to right) Richard Waller, Erich Dohm (winner of Lou Cope Award for best presentation) and Mark Jorgensen.



(Left to right) Stephen Hearn receiving the Arthur C. Daman Lifetime Achievement Award from Brett Berg.

The MPD meeting was also designed to provide invaluable contact and networking possibilities for attendees in a forum that attracts those from upper-level positions of companies. It is a great opportunity to rekindle old friendships and establish new ones. For the main social events this year, participants enjoyed some high-stakes action at the Thursday Casino Night while dressing in their Derby best for dinner on Friday, prior to the running of the Kentucky Derby on Saturday.

The meeting structure provides a comfortable setting in which participants may attend technical sessions in a somewhat informal setting. Themes and topics of the meeting and technical papers are adjusted annually to be current with social, economic, environmental, operational and financial concerns within the industry, while staying within the general topic of mineral processing. The theme for 2025 was "Mineral Processing's Got Talent," which once again showcased an outstanding program.

The Lou Cope Award is given for the best presentation at the conference. The quality of the program makes it more challenging to select a winner each year. This year, the award went to Erich Dohm from Eriez who presented on "Maximizing Net Metal Production in Copper Cons with Coarse Particle Flotation."

John Wilmot, general manager of Colorado operations for Climax Molybdenum, served as the event keynote speaker. Wilmot delivered an excellent presentation titled "Forward Thinking to Tackle the Challenges in Attracting and Retaining Qualified Labor." The presentation highlighted some of the innovative measures being implemented by the Climax team to ensure they are able to find and keep talented personnel. Included in the discussion were operations in spectacular and scenic locations as well as affordable housing, particularly important for young engineers just beginning their careers.

Supporting the next generation of mineral-processing engineers remains a key focus of the Colorado MPD. The MPD supported three students to attend and present at the 2025 conference. The students all receive an award for their presentations; in addition, this year, the best student presentation went to Matthew Mettler from the Colorado School of Mines for his presentation on "Tailings Take Center Stage: Showcasing the Hidden Talent of Pyrrhotite."

The committee also selects a recipient for the Len and Rosa Harris Student Award, which supports promising young engineering students from the Colorado School of Mines who just might be persuaded to stick with mineral processing/extractive metallurgy. The program targets students beginning their sophomore year and continuing through their senior year, ultimately leading to three potential students receiving the award in a given year. The recipient this year is Lunaya Barnhart, who was working hard on her finals and unable to attend. Kagan Killough

(continued on page 102)

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As temperatures start to climb, we need to be

mindful of heat-related illnesses

by Matt Main, Communications Chair, Health & Safety Division Executive Committee

With the summer upon us and high temperatures the norm, the mining industry faces significant challenges related to heat stress and heat-related illnesses. These conditions can severely impact the health and safety of miners, making it crucial to understand, prevent and manage heat-related illnesses effectively. Understanding the types of heat-related illnesses and the differences between them is the first step in recognizing the hazards.

Heat-related illnesses range from mild conditions like heat rash to severe and potentially fatal conditions like heat stroke. The primary types of heat-related illnesses include:

- Heat rash — This condition occurs when sweat ducts become blocked and sweat cannot evaporate from the skin. It is characterized by red clusters of pimples or small blisters, usually on the neck, upper chest, groin, under the breasts and in elbow creases.
- Heat cramps — These are painful muscle spasms that occur due to the loss of salt and electrolytes through sweating. Heat cramps typically affect the abdomen, arms and legs.
- Heat exhaustion — This is a more severe condition caused by excessive loss of water and salt through sweating. Symptoms include heavy sweating, weakness, dizziness, nausea, headache and muscle cramps. If untreated, heat exhaustion can lead to heat stroke.
- Heat stroke — The most serious heat-related illness, heat stroke occurs when the body's temperature regulation system fails, and body temperature rises to dangerous levels. Symptoms include confusion, loss of consciousness, hot and dry skin, and seizures. Heat stroke is a medical emergency and can be fatal if not treated promptly.

Preventing heat-related illnesses requires a combination of environmental controls, personal protective measures, and proactive monitoring, including paying attention to the warning signs. Key prevention strategies include:

- Environmental controls — Implementing measures to reduce heat exposure in the workplace is essential. This includes providing shaded areas for breaks, ensuring adequate ventilation and using cooling systems to lower ambient temperatures.
- Hydration — Encouraging miners to drink plenty of water throughout the day is crucial. Access to cool drinking water should be readily available, and miners should be reminded to hydrate regularly, even if they do not feel thirsty. Drinking caffeinated beverages such as soda, energy drinks or coffee do not replace water for staying hydrated and can actually lead to dehydration more quickly.
- Work scheduling — Adjusting work schedules to avoid high-impact work during the hottest parts of the day can significantly reduce heat exposure. Physically demanding tasks should be scheduled during cooler times, such as early morning or late afternoon.
- Personal protective equipment (PPE) — Providing appropriate PPE, such as lightweight and breathable clothing, can help minimize heat retention. Cooling vests and other specialized gear can also aid in regulating body temperature.
- Training and awareness — Educating or refreshing miners about the risks of heat-related illnesses and the importance of prevention is vital. Training sessions should cover the symptoms, prevention strategies and emergency response procedures for heat-related illnesses.
- Monitoring and early intervention — Regularly monitoring miners for signs of heat stress and intervening early can prevent the progression of heat-related illnesses. Supervisors should be trained to recognize symptoms and take appropriate action, such as providing rest breaks and hydration.

Proactive measures are essential in creating a safe working environment and preventing heat-related illnesses. By implementing comprehensive prevention strategies and fostering a culture of safety, mining operations can protect the well-being of their workforce and maintain productivity.

Health monitoring and fit-for-duty evaluations can help detect elevated risk for heat-related illnesses, but they are not foolproof. Mine operators should have comprehensive emergency preparedness plans to respond to heat-related illnesses. Early intervention is key to stop the progression of heat-related illnesses.

Heat-related illnesses pose a significant risk to miners, especially during the warmer months. Understanding the types, symptoms and prevention strategies is crucial for safeguarding the health and safety of the workforce. By implementing proactive measures, providing adequate training and fostering a culture of safety, we can effectively manage heat stress and protect our most valuable asset — people. Remember that being proactive in managing heat-related risk factors through early intervention is far better than managing emergency situations reactively. ■

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Call for abstracts for Resilient Energy in Mining Symposium

by Lisa Gonzales, Symposium Chair, and Jen Pepe and Annelia Tinklenberg, Vice Chairs

The Resilient Energy in Mining Symposium will be held during the MINEXCHANGE 2026 SME Annual Conference & Expo in Salt Lake City, UT. The symposium aims to harmonize the longstanding traditions of mining with the imperative need for sustainable practices and renewable energy sources. By exploring strategies for carbon emission reduction, energy transition and the integration of renewable power solutions, participants will engage in constructive discussions to pave the way for a more sustainable energy landscape. We are soliciting abstracts for presentations focused on navigating the complexities of tradition and transition to meet the requirements for ESG (environmental, social and governance) reporting.

Sessions will be chaired by various SME Divisions:

- Coal & Energy Division — Leveraging Opportunities and Managing Risk: A Holistic Approach for Coal's Sustainable Future.
- Mineral & Metallurgical Processing Division — Processing Powers Progress.
- Mining & Exploration Division — Opportunities and Challenges for the Mining Industry to Leverage Technology and People to Drive Operational Performance and ESG Impacts.
- Environmental Division — Harnessing Green Mining: Sustainable and Resilient Solutions for the Energy Transition.

Requirements for submissions:

- Authors/speakers are required to submit an extended abstract, which will be published in the symposium proceedings.
- Abstract Central (https://sme2026.abstractcentral.com/) will be accepting abstracts beginning May 30, 2025, and ending Aug. 1, 2025.
- Extended abstracts are due Oct. 31, 2025, to allow the proceedings to be published and available for distribution at MINEXCHANGE 2026. ■

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Central Wyoming Section awards scholarships

In May, the Central Wyoming Section met in Glenrock, WY, where nine students were awarded scholarships totaling more than $16,000.

The Section presented the Coates, Russel, Wolff & Swank scholarships to six college students and three high school graduates interested in pursuing a career in a mining-related discipline. Each student had submitted an essay related to the "Importance of Mining in Wyoming." The college recipients, all of whom are students at Wyoming schools, including the University of Wyoming and Casper College, are Jack (John) Larson, Conner Stafford, Maddison Linam, Bradyn Adels, Kolten Harmsen and Dezirea Tatro. The graduating high school student recipients are Calvin Kost, Dylan Johnson and Sarah Slaugh.

The Central Wyoming Section is committed to supporting a sustainable mining industry in Wyoming and the United States by providing scholarships and awards to those interested in promoting or pursuing a mining-related career. Based in Casper, WY, it has provided scholarships to teachers, high school students and college students for the past 40 years, with a cumulative total of more than $430,000. ■



Central Wyoming Section with four scholarship recipients: (center-front, left to right) Sarah Slaugh, Dylan Johnson, Dezirea Tatro and Conner Stafford.

WAAIME Division Student Reception at MINEXCHANGE 2025: Oh, what a night!

by Margaret Mansanti, WAAIME Past Chair

Oh, what a night it was! The WAAIME Division Student Reception, held Feb. 24, 2025, at the Hyatt Centennial Ballroom in Denver, CO brought the mining community together for an evening full of energy, excitement and unforgettable connections.

Held during the MINEXCHANGE 2025 SME Annual Conference & Expo, the reception drew a record-breaking crowd. More than 320 students and industry professionals filled the room, making it the largest and most lively WAAIME student reception to date.

From the moment the doors opened, the room buzzed with conversation and laughter as students mixed and mingled with industry leaders, future colleagues and new friends. Games, raffles and the ever-popular selfie-tag contest added to the fun, and 21 lucky winners walked away with Amazon gift cards.

But beyond the games and giveaways, the night was all about building bridges between students and professionals. In the crowd were SME Executive Director David Kanagy and an impressive lineup of past, present and future SME Presidents: Ihor Kunaz (1998), joined by his wife, Zenia Kunaz, this year's WAAIME Founder's Award recipient; Barbara Filas (2005); John Mansanti (2017); Barbara Arnold (2018); Marc LeVier (2023); Marc Herpfer (2024); and Bill Hancock (2025). Their presence and conversations throughout the night highlighted the welcoming spirit of the mining industry.

Of course, a night this successful does not happen by accident. Thoughtful planning and teamwork by WAAIME staff liaison Rachel Grimes and the SME meetings and exhibit team led by Cori Knasinski and meeting planner extraordinaire Hannah Harriman ensured a fun, festive and welcoming atmosphere.



The WAAIME Division Student Reception was all about building bridges between students and professionals.

The success of the reception was further strengthened by generous industry support. With sponsorship secured for the second year in a row through the efforts of incoming WAAIME Chair Barbara Filas and Emma Li Salditt, SME's Manager of Partnership Development, the reception was made even more impactful. Gold sponsors NewFields and Paterson & Cooke USA, along with sponsors Brooks & Nelson, Energy Fuels, Hecla Mining, Knight Piésold, NexGen Resource Corp., Orla Mining and RWI Enhanced Evaporation not only contributed financially but most sent representatives to meet and encourage students.

The 2025 WAAIME Student Reception was a true celebration of community, connection and celebration, one that reflects WAAIME's mission to support and inspire the next generation of mining professionals.

We look forward to making even more memories next year at MINEXCHANGE 2026 in Salt Lake City, UT. ■

WAAIME Wire **serves as a forum for the presentation and discussion of facts, ideas and opinions pertaining to the interests and technology of the WAAIME 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 2025 is Barbara Filas.**

Upcoming SME Events

UCA Cutting Edge Conference
November 3-5, 2025
Norfolk, VA

Extraction 2025
November 16–20, 2025
Phoenix, AZ

MINEXCHANGE 2026 SME Annual Conference & Expo
February 22-25, 2026
Salt Lake City, UT

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

Corporate Roundtable Partnership:
Benefits and opportunities

by Lorie Laessig, SME Foundation Specialist

Established in 2013, the SME Foundation (SMEF) Corporate Roundtable Partnership has welcomed numerous companies to participate, contribute and support SMEF programs. The Corporate Roundtable Partnership serves as a strategic investment for businesses in the mining and minerals industry, fostering world-class mineral education and inspiring the next generation to pursue careers in mining.

The Corporate Roundtable Partnership thrives on the support of forward-thinking companies that align with the SMEF's vision to inspire the next generation to meet the needs of a mineral-dependent future for a better world. Businesses in the mining and minerals industries are invited to join as Corporate Roundtable Partners with an annual commitment of $25,000 or more. Currently, 17 companies contribute at this level or higher, united by a shared investment in the talented individuals who drive both their success and the future of the industry.

Corporate Roundtable Partners receive several benefits that include:

- Recognition and acknowledgment in SMEF materials and at SMEF events.
- Acknowledgment in the SME Drift and *Mining Engineering* magazine.
- Complimentary seating at the SMEF Gala Dinner (minimum $50,000 Corporate Roundtable Partner level and above).
- Signage at the MINEXCHANGE SME Annual Conference & Expo, including at the SMEF Gala Dinner and in your MINEXCHANGE exhibit booth (if applicable).
- 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 Leadership Luncheon, bringing together SME leadership and corporate partners.

For more information on Corporate Roundtable Partnership opportunities and a full list of benefits, please visit https://community.smenet.org/smefoundation/crp/home, or contact Megan Martin, SME Foundation Manager at martin@smenet.org. ■



Crundwell wins SAIChE Gold Medal

The South African Institution of Chemical Engineers (SAIChE) has awarded Frank Crundwell the 2024 Bill Neale-May Gold Medal at its recent annual meeting. The award is the highest accolade presented by SAIChE, celebrating remarkable contributions made by chemical engineers to the industry and their profession. Crundwell's award recognizes his exceptional achievements and significant contributions to the fields of chemical and metallurgical engineering.

Crundwell is a global expert in mineral dissolution and leaching, with applications spanning metal extraction to dentistry. He is the founder of CM Solutions Metallurgical Consultancy and Laboratories and a Fellow of several institutions including SAIChE, the Southern African Institute of Mining and Metallurgy (SAIMM) and Institution of Chemical Engineers (IChemE). His groundbreaking research has garnered international recognition, including SME's Milton E. Wadsworth Award. In 2023, he was elected an international member of the U.S. National Academy of Engineering. ■



Summer scavenger hunt ideas

by Rebecca Smith, Curriculum Coordinator — Minerals Education Coalition

Continuing educational pursuits in the summer can give your children and grandchildren a leg up in school and can also be enjoyable for you. The Minerals Education Coalition (MEC) has items and activities that are fun and educational, perfect for summer vacation, camp, picnics and rainy days. Take a scavenger hunt around your house, or any area in your town or vacation destination, and try to list everything made from rocks and minerals. Use one of MEC's posters or books to take a guided tour of the products of rocks and minerals around your area.

The following resources are great options to help you in your hunt:

- "Everything is Made from Something" poster — From the walls to the plumbing to the wiring, buildings require many different rock and mineral products, and roads require tons of materials.
- "Industrial Minerals" poster — Identify numerous items around your house made with industrial minerals. Then, use the back of the poster to see some places industrial minerals are mined in the United States and finish by doing some of the activities on the back of the poster.
- "Everything We Use" poster — Learn important facts about the rocks and minerals used in the things on your hunt and throughout your life.
- *Mined Minerals in My Day* coloring and activity book — Mined minerals are in your meals, house and community. This is a great resource for your scavenger hunt, and it is also fun to color if the weather keeps you indoors.



- *Minerals Work for Us!* book — Hunt for items shown in the book, such as bicycles, pencils, kitty litter or paper, and learn about the important materials that go into making them work.

In addition to these posters and books, gold-panning resources and other materials for summer activities are available in the MEC online store at MineralsEducationCoalition.org/store, and you can find more activities and crafts for summer fun at MineralsEducationCoalition.org/summerfun. ■

Fine Grind

(Continued from page 97)

received his award and attended the conference for the second year. None of the student initiatives would be possible without the financial support of sponsors and attendees.

The Arthur C. Daman Lifetime Achievement Award is presented annually to someone with at least 20 years in the mining industry who is primarily based in Colorado and is active in one or more mining associations in the Colorado area. The individual must have also made significant impacts on the mining industry and project an image that is beneficial to the industry. And finally, the individual's character must be above reproach. The 2025 recipient of this award is Stephen (Steve) Hearn. Hearn earned his degree in metallurgy from the University of Nottingham and later earned an MBA from the University of Cranfield. With a career spanning more than 40 years, Hearn spent the last 22 years working in Colorado before retiring from Huntsman Chemical in 2020. He and his wife Lynne were also longtime members of the Colorado MPD committee.

It was with great sadness that we were informed of the passing of another industry giant just prior to this year's conference. Frank Seeton, a proud fourth-generation Coloradan and one of the founding members of the Colorado MPD Conference, passed away just shy of his 101st birthday. Seeton was instrumental in the success of the conference for many years and was among the first recipients of the Arthur C. Daman Lifetime Achievement Award. We also remembered Len Harris as we marked the one-year anniversary of his passing. Len and his wife Rosa created a legacy that will allow us to pay tribute to Len's memory through the next generation of mineral-processing engineers with the Harris Award.

Mark your calendars for April 23-25, 2026, when we will be celebrating the 75th Annual Colorado MPD Conference. The committee is already working hard on some big plans to make 2026 extra special. Congratulations to all of our presenters and award recipients. We look forward to seeing everyone again in 2026. ■

Anne L. Williamson is the nominee for SME President in 2027

ANNE L. WILLIAMSON'S 40-year career with mining and global engineering firms has spanned from boots-on-the-ground exploration to executive leadership. Starting in gold exploration in the Midwest and Western United States, she then worked nearly 10 years with Phelps Dodge Morenci, where she transitioned into hydrogeology and environmental permitting, compliance and remediation. As a passionate supporter of the mining industry, she subsequently expanded her roles at other organizations to include corporate sustainability, community relations, government affairs and enterprise risk management. She has held management positions at Phelps Dodge Corp., URS, Twin Metals Minnesota, Wood and WSP.

Starting her SME journey as a student member 43 years ago, Williamson has served on the SME Board of Directors, the Environmental Division executive committee, Morenci Section executive committee, Government and Public Affairs Committee and multiple strategic committees. She chaired technical sessions and presented at numerous SME conferences. She is an SME Fellow, recipient of the SME Environmental Division Distinguished Service and Benefactor awards, and a member of the inaugural class of SME Young Leaders.

Williamson is currently senior vice president, Corporate Sustainability at WSP, one of the world's largest mining professional services providers, where she manages sustainability risks and embeds resilient practices in WSP's U.S. business. She also provides mining clients with strategic advisory on permitting and sustainable development.


Anne L. Williamson

In addition to SME, she is a member of Women in Mining, served as a board member and vice president of the Mining Minnesota trade association, and as board advisor to Jobs for Minnesotans. She holds a master of science degree from New Mexico State University and a bachelor of science degree from the University of Minnesota Duluth, both in geology.

Anne is also proud to be the great-granddaughter of a Pennsylvania coal miner. ■

Nominees for the 2026 SME Board of Directors

EMILY J. HAAS, Ph.D., brings almost 15 years of leadership in occupational safety and health research (OSH) and innovation to the mining industry. Haas currently serves as the associate director for science at the National Institute for Occupational Safety and Health's (NIOSH) Division of Safety Research. In this role, she provides strategic and operational leadership to enhance the effectiveness and relevance of high-impact OSH research. Her own work has focused on risk identification and mitigation across high-hazard industries, with a strong emphasis on mining, construction and public safety.

Haas has authored more than 100 publications, delivered more than 150 technical presentations and is widely recognized for her contributions to improving technology adoption and safety culture through behavioral and human-centered design.


Emily J. Haas

Within SME, Haas has made consistent contributions. After entering the Health & Safety Division's executive committee in 2017, she served two consecutive terms as Division Chair (2022–2024), during which she launched a student scholarship program, led the development of SME's *Mine Safety & Health Handbook*, which was published in 2024, and contributed to the redesign of the National Mining Association's CORESafety program. She is a member of SME's Environmental, Social and Governance (ESG) Committee and the current Chair of the Industry Innovation Strategic Committee (2023–2026). Her work has been honored with the Arthur S. Flemming Award, the Presidential Early Career Award for Scientists and Engineers, selection as one of the Top 100 Global Inspirational Women in Mining (2022), and several SME awards.

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.

Her early interest in health and safety began after losing her cousin in a motorcycle accident. That tragedy sparked a career-long dedication to understanding the behavioral factors behind risk and developing science-backed communication and engagement strategies. She earned her Ph.D. in health communication from Purdue University and continues to mentor emerging professionals committed to transforming workplace safety across the mining industry and beyond.

STEVEN SCHAFRIK, Ph.D., is an associate professor and director of graduate studies for mining engineering and a faculty fellow of the James B. Beam Institute for Kentucky Spirits at the University of Kentucky.

He currently teaches programming, mine design, ventilation and automation at the undergraduate and graduate levels. His research is in automation, communication, ventilation and training. He has two patents for dust filtering technologies and one pending for recycling solar cells.


Steven Schafrik

Schafrik is engaged with high schools, working with the technology courses at the Pineville Independent School and the FIRST Tech Challenge team at the Craft Academy. He is the founding secretary/treasurer of the Eastern Collegiate Mine Rescue Organization and faculty advisor for the University of Kentucky RescUKats.

Schafrik is very active in SME. His range of activities include Past Chair of the Coal & Energy Division, Chair of the *Mining Engineering* Committee and former Chair of the Central Appalachian Division. ■

Coal & Energy Division officer nominees

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.


Sam Baker

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), vice chair of the YLC and C&E Division technical session chair. He is a member of the board of the SME Pittsburgh Section.

VICE CHAIR


Jim Haughey

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.

SECRETARY/TREASURER

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.


Jon Bobbera

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.

PROGRAM COMMITTEE CHAIR

ERIC HOWE is the engineering manager at Alliance Resource Partners' Tunnel Ridge Mine. A graduate of


Eric Howe

West Virginia University with a B.S. in mining engineering, his career experience has largely been focused on the underground coal mining industry. In his current role, he is responsible for managing the underground and surface engineering activities, major capital projects, tailings disposal facilities and coal preparation plant. He is a registered Professional Engineer in West Virginia.

Howe is a long-time member of SME. Currently, he serves SME as the program vice chair of the C&E Division Executive Committee and as a member of the Stefanko Best Paper Award Committee.

PROGRAM COMMITTEE VICE CHAIR

ASHISH R. KUMAR is an assistant professor of mining engineering in the Department of Energy and Mineral Engineering at The Pennsylvania State University. Previously, he was an assistant research professor at Missouri University of Science and Technology, Rolla in the Department of Mining and Explosives Engineering. He also held a postdoctoral scholar position at the University of Kentucky. He obtained his M.S. and Ph.D. from the University of Kentucky and his undergraduate degree from Indian School of Mines. His research interests include battery safety, mining process automation and control, in situ resource utilization, and computational fluid dynamics applications in mining engineering. He has worked as the PI/co-PI of several federally funded research projects. He is a registered Professional Engineer in Kentucky and holds two U.S. patents on nonclogging dust filters.


Ashish R. Kumar

Kumar was a member of SME's Young Leaders Committee, and the C&E Division's Membership Committee and Mine Operations Unit Committee.

Environmental Division officer nominees

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.


Amar R. Patel

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, in subcommittee leadership roles and as an SME division/strategic committee representative.

VICE CHAIR

HEATHER HALDERMAN is a senior project manager with Knight Piésold. She has more than 29 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 (GISTM) auditing, and hazardous-waste projects.

Halderman has extensive experience in project management and execution, including regulatory analysis and negotiation, data interpretation, cost estimating and risk analysis. She has served as chair on several Environmental Division committees. Besides SME, she is also a member of Women in Mining and is a Professional Engineer in Colorado.


Heather Halderman

SECRETARY/PUBLICATIONS

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.

Sutton has been with The Doe Run Co. since 2011, filling various key roles in the environmental and remediation departments.


Genevieve M. Sutton

Currently, she holds the role of EHS manager for the remediation, exploration and R&D groups and historic properties, in addition to overseeing all active remediation projects in the Old Lead Belt and Viburnum Trend. 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. She was invited to participate on the Missouri S&T Mining Engineering Department's advisory board in 2015 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 She has served as local section chair for multiple terms, on the SME Structure & Governance, Products & Services and Association Growth strategic committees, and on an ad hoc committee to improve relations between local sections and the broader SME organization. She is an active member of the Environmental Division and the SME PE Committee.

PROGRAM CHAIR

NINA ASTILLERO currently works for ERM in Nevada as a principal consultant managing sustainability planning and environmental compliance projects.

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 14 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 actively serves in Women in Mining USA 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.


Nina Astillero

PROGRAM PLANNING CHAIR

STEVE BOGART is a principal civil engineer with Arcadis U.S. Inc. Since joining Arcadis in 2012, his work has focused primarily on reclamation and remedial design. He has led design projects and overseen construction involving land restoration, environmental capping, hazardous waste landfills, geotechnical stabilization, mass earthwork/grading, flood protection/mitigation and stormwater management. Outside of design engineering, he also has extensive experience with environmental compliance, permitting and risk management. He currently leads a civil engineering team based in Syracuse, NY with projects throughout the United States and Canada.


Steve Bogart

Health & Safety Division officer nominees

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.


Amy J. Richins

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.

VICE 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. Gregor is


Adam Gregor

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 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.


Lara Sims

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.

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, Reno.

PROGRAM VICE 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 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

COMMUNICATIONS CHAIR

SIGRID-AUDREY RICHARD is a chemical engineer with more than 20 years of experience in high-risk industrial sectors, including oil and gas, mining and metallurgy.

She earned her bachelor's degree in unified engineering with a major in chemical engineering and a certificate in environmental sciences from the Université du Québec à Chicoutimi in 2003, followed by a master of business administration from Université Laval in 2012.


Sigrid-Audrey Richard

Her career began at Tetra Tech, where she worked as a process engineer from 2004 to 2011. In 2011, she joined Rio Tinto Kennecott Copper in Magna, UT, as the company's first process safety engineer, playing a pivotal role in developing and implementing process safety management (PSM) programs across Rio Tinto's global operations, particularly within the copper and diamonds division.

Since March 2022, Richard has been serving as the director of process safety management at Coeur Mining Inc., where she leads the development and implementation of PSM strategies across Coeur's operations.

Industrial Minerals & Aggregates Division officer nominees

CHAIR

TUSHAR GUPTA is a senior metallurgical engineer at MP Materials, where he leads research and development efforts to advance the recovery of rare earth elements (REEs) at Mountain Pass, CA. With more than eight years of experience in mineral processing, his expertise spans froth flotation, comminution, magnetic and gravity separations, and ore sorting.

Among his key accomplishments, Gupta spearheaded initiatives that increased REE concentrate production by more than 20 percent and successfully implemented the novel Concorde flotation technology to enhance fine particle recovery. His innovative approach to the gravity separation of REE minerals unlocked access to more than 20 million tons of previously untreatable ore — significantly extending mine life and improving operational efficiency.


Tushar Gupta

Gupta earned his Ph.D. in mining engineering from the University of Kentucky, where his

Division Officer Nominations

research focused on oxidation pretreatment to improve REE extraction from unconventional feedstocks. He also holds advanced degrees from the University of Alaska Fairbanks and the Indian School of Mines, Dhanbad. Prior to joining MP Materials, he worked as a research scientist at Columbia University, where he led projects in fine particle flotation for base and precious metals. Gupta merges academic rigor with industrial innovation — driving sustainable solutions that maximize resource utilization and shape the future of critical mineral recovery.

VICE CHAIR

HIMESH PATEL is a research and 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, he 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 & Aggregates 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.

SECRETARY/TREASURER

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.



Jack Sackrider

PROGRAM CHAIR

RUDRAJIT MITRA is an associate professor and Syd & Felicia Peng Professor in Mining Engineering at 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 areas of expertise include rock mechanics, mining systems engineering focusing on resource efficiency through the use of digitalization,virtual-reality applications in mining, and innovation in learning and teaching.



Rudrajit Mitra

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 SME, ARMA, MMSA (QP—Mining), AusIMM, SAIMM and SOMP. He is on the editorial boards of multiple journals and has been responsible for organizing various international conferences.

TECHNICAL COMMITTEEE CHAIR-ELECT

SUNIL TRIPATHY is a senior research scientist at the Natural Resources Research Institute (NRRI), University of Minnesota. Currently, he is involved in different projects on the decarbonization of the mining and metal industries. With more than 16 years of experience across India, France and the United States, his research focuses on the extraction of lithium, chromite, manganese, iron and dolomite. He has published more than 100 peer-reviewed articles and delivered 37 presentations at international conferences. Tripathy holds seven granted patents, with nine more filed, underscoring his contributions to processing technologies for industrial minerals. He serves on the editorial boards of various journals: *Mining, Metallurgy & Exploration, Mineral Processing* and *Extractive Metallurgy Review, Mineral Processing and Extractive Metallurgy (IMM Transactions section C)*, *Minerals*, *High-Temperature Materials and Processes* and *Transactions of the Institution of Mining and Metallurgy*. He is also active on



Sunil Tripathy

IM&AD committees, representing the Division in GPAC.

SCHOLARSHIP COMMITTEE CHAIR

NATHAN MANSER is a senior lecturer of mining and geological engineering at Michigan Technological University. His teaching and research activities focus on developing "mines of the future" by proving novel and improved technologies that reduce carbon and use water more effectively for the extraction, recovery and management of critical elements from mineral resources. Currently, he has investigations ongoing related to decarbonized lithium separations from hard-rock and clay hosts using biologically engineered approaches.



Nathan Manser

Manser is a registered Professional Engineer in the state of Michigan and has been chair of the Upper Peninsula Section of SME since 2019.

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

AARON NOBLE is a professor and the head of the Department of Mining and Minerals Engineering and the Interim Department Head of Materials Science and 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 50 journal papers, delivered more than 130 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 Outstanding Young Engineer Award (2018), the Rossiter W. Raymond Award (2017), the Stefanko Best Paper Award (2014) and Henry Krumb Lecturer (2016 and 2018).

ASSOCIATE 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 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.

FIRST VICE CHAIR

NICK GOW is the 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 conference. 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.

SECOND VICE CHAIR

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 in consulting roles, for Augusta Gold as vice president of operations and for Wood Group USA as manager, process engineering. Wickens is now consulting privately and remains 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.

SECRETARY-TREASURER

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 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. House 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 Committe and serves as secretary for the Colorado MPD Committee.

TECHNICAL PROGRAM ASSOCIATE

ZACHERY ZANETELL serves as interim director of metallurgical services at Newmont Corp.'s global technical center in Englewood, CO. With nearly 18 years of industry experience, he has led and contributed to a wide range of technical and operational initiatives across metallurgical laboratories, mine sites and corporate teams.


Zachery Zanetell

Zanetell holds a B.S. in chemistry from the University of Northern Colorado and an M.S. in metallurgical engineering from the Colorado School of Mines. His expertise centers on advancing metallurgical innovation — particularly in the testing and scale-up of emerging technologies, from early-stage concept through pilot-plant validation.

In 2020, he received the MPD Outstanding Young Engineer Award, recognizing his leadership and technical contributions to the mining sector. He also plays an active role in his local professional community as member of the Colorado MPD division, where he supports knowledge sharing and cross-industry collaboration.

MEMBERSHIP ASSOCIATE

MICHAEL SPICHER is a project and metallurgical


Michael Spicher

consultant under his Rocking S Extractive Services LLC, based in Meridian, ID. He is primarily employed by Perpetua Resources to oversee piping, mechanical, water treatment and process design support on the Stibnite Gold Project.

Spicher received a B.S. in metallurgical and materials engineering from Montana Tech. His career has taken him to sites including Nevada's Cortez Mine, South Carolina's Haile Gold Mine, multiple copper concentrators across Arizona and New Mexico and the DeLamar project in Idaho, gaining experience as a plant metallurgist, process operations supervisor, water management supervisor, process optimization engineer and engineering manager. He has been involved with projects from the PFS level all the way to operations. Spicher has served on the MPD Plant Design Unit Committee for nearly 10 years, chairing sessions, and was honored to receive the MPD Outstanding Young Engineer Award in 2021. He has also been involved with the SME Boise chapter as an executive committee member, successfully leading a major effort to increase fundraising and sponsorships.

Mining & Exploration Division officer nominees

CHAIR

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 in Lubbock, TX. He 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 Mining & Exploration (M&E) Division in 2018. He was appointed to the M&E Executive Committee in 2021 and was 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.


Lia Walker

CHAIR-ELECT

LIA WALKER is the manager of innovation for Freeport-McMoRan Inc., where she is the business leader for integrating data-driven innovation solutions that amplify business growth and profitability. She has an M.S. and more than 25 years of experience in the mining industry, functioning in various roles throughout her career and inspired by innovation, invention and collaboration. Some of her key contributions are inventor, digital-solutions innovator, quality leader, innovation engineering, change-management advocate and enterprise product management. Walker is committed to SME's vision and has served in diverse positions.

VICE CHAIR-PROGRAMS

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 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.


Katie Robertson

VICE CHAIR-PROGRAM PLANNING

RUSSELL SHEETS has 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 six years, Sheets' 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


Russell Sheets

on the GEOE Industry Advisory Board for many years, including as chair for the past few 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.

ASSISTANT VICE CHAIR-PROGRAM PLANNING

ROSA ROJAS 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 Rojas

Rojas 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.

Rojas is currently an independent director of Arizona Metals Corp. She 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).

SECRETARY

JENNIFER BAAR is an economic geologist with 15 years of experience in mining. She graduated from University of Georgia with a B.Sc. in geology and earned an M.Sc. from Washington State University. She spent six years in underground gold mining in Elko, NV before moving to the openpit. Since then, she has worked in gold, polymetallic copper, lithium and silver. She specializes in production geology and currently works for Hecla as a senior geologist out of Coeur d'Alene. When not working, she enjoys traveling with her husband and watching their young child discover the world.


Jennifer Baar

UCA Division officer nominations

CHAIR

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.

CHAIR ELECT

COLIN LAWRENCE is a world-renowned tunnel


Colin Lawrence

engineer within the industry. He has recently served in an executive role and as a tunnel expert on several major projects as well as leading a tunnels practice globally for one of the world's preeminent tunnel consultants. A major achievement is being instrumental in the growth of the North American tunneling capability with the firm from inception through to its current standing in the industry. Additionally, using this approach for establishing new tunnel teams grown globally, for example, in Spain.

Lawrence has more than 42 years of experience including in some of the world's most challenging tunnel projects and has been involved in all aspects of underground project implementation from planning, design and project management through to construction management and project completion. His tunnel experience encompasses all types of tunnel projects in a variety of markets such as transportation, water, wastewater, oil and mining projects in a variety of challenging ground conditions in soil, rock and mixed-face conditions, in subaqueous, seismic and mountainous environments.

PAST CHAIR


Erika Moonin

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 in California and Nevada. She worked as a consultant in the beginning of her career and then for 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.

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 teams with major technically challenging underground and tunneling infrastructure projects.

WAAIME Division officer nominations

CHAIR

JACKIE HERRERA brings more than 25 years of experience in technical sales, operations, marketing and leadership across multiple industries, with broad experience in the mining and mineral processing industries. She holds a B.Sc. in metallurgical engineering, an M.Sc. in materials science and an MBA.

Herrera is a published author with the Minerals, Metals & Materials Society (TMS) on "Improvement of trihydrate classification in the Bayer process" and holds a U.S. patent for functionalized silicones used in froth flotation. Her career has spanned the bauxite and alumina sectors in South America, the Caribbean and the United States as well as global roles in copper and molybdenum markets. She is a member of the Society of Women Engineers and an independent board member at Energy Fuels, a global critical mineral company. She also volunteers with UNICEF and Water for People, delivering water treatment education in rural Latin America. As WAAIME Chair, she will be committed to advancing WAAIME's mission of supporting education in the extractive industries and is proud to contribute to SME's broader goals for the mining community.


Jackie Herrara

PAST PRESIDENT

BARBARA FILAS is a licensed professional mining engineer and a longtime member of SME. She made history as SME's first female President in 2005 and played a key role in launching the Environmental Division and Student Mentor Program. A former WAAIME Chair, she has also served on the boards of the SME Foundation and AIME, where she was vice president of finance.


Barbara Filas

Filas' career spans gold, coal, uranium and industrial minerals, with technical, operational and executive roles in consulting, public companies and nonprofits. She currently serves on the boards of two publicly traded companies and is the nominations chair and chair of the board of governors for the National Mining Hall of Fame.

As a 2025 SME Legion of Honor member, Filas remains committed to fostering future leaders in mining and is honored to continue supporting WAAIME and SME's shared mission.

The criticality of industrial minerals



William Gleason
Editor

In this issue of *Mining Engineering*, readers will find summaries of 40 industrial minerals as well as an overview of the often-underappreciated sector by Mike O'Driscoll. I would like to thank SME's Industrial Minerals & Aggregates Division for coordinating the editors and authors who make this section possible and especially Jim Norman of Tetra Tech, who has steered this project for decades, as well as Jack Sackrider of Westward Environmental.

The industrial minerals review annually gives readers a closer look at many of the minerals that are, in O'Driscoll's words, "often the unsung workhorse mineral commodities and specialist raw materials which frankly keep the world's manufacturing industries ticking over and everyday products we use in sound availability."

Some of these minerals are not as well known to most people as the higher-profile battery minerals such as lithium, cobalt or rare earths, but many of them are just as vital to the U.S. economy as well as the global energy transition that remains the driving force of the global mining industry.

I recently had the opportunity to speak with Theo Yameogo, EY America's Metals and Mining Leader about the rapidly changing landscape of the North American minerals sector. Yameogo is a professional mining engineer and advisor to C-suite leaders of metals and mining companies across the Americas. He is also a contributor to EY's annual report on "Top 10 Risks and Opportunities for Mining and Metals Companies."

In its outlook for 2025, EY noted that the energy transition would continue to disrupt the mining and minerals sector. It said the industry is challenged with meeting surging demand while achieving sustainable mining practices that meet high stakeholder expectations all while managing capital discipline.

Rare earths, lithium, gold and cobalt are often mentioned by investors, media and politicians when the issue of minerals is brought up. But in 2024, the industrial mineral sector once again accounted for the majority share of total mine production in the United States by value at $72.1 billion, or 54 precent.

Minerals that are deemed critical, as most readers are aware, receive that designation when a government determines that the mineral is essential to economic or national security and that the supply chain for that mineral is vulnerable to disruption. The debate around which minerals make the various lists of "critical minerals" and which ones do not is a topic for another column.

"The definition of critical minerals is always changing," said Yameogo, who noted the list of minerals considered critical by Canada is longer than the list created by the U.S. Geological Survey. But Yameogo said, "Industrially, they are all critical. It is society and the energy transition that are making governments rank each mineral. For example, we have an abundance of iron ore, but if we stopped producing iron ore the industrial world would come to a stop. And potash, which is considered a critical mineral in Canada is not included as a critical mineral in the United States, but if potash production stopped we would all be back to caveman-age agriculture."

For its 2025 report, EY surveyed senior mining and metals leaders globally from organizations with at least $1 billion in revenue, collecting 353 unique responses from industry leaders, 17 percent of whom are at board or C-suite level, to determine what they view as challenges and trends in the industry.

EY has published the report for more than 15 years, and each year there are some changes to the top 10 list, but what was striking about the outlook for 2025 was that there were four changes including at the top, which was occupied by capital, or more precisely the challenge of finding capital for the projects that are needed to meet the demands of the global energy transition.

Managing capital was at the top of mind for the executives, followed by environmental stewardship, geopolitics, resource/reserve depletion, licence to operate, rising costs, climate change, new projects, changing business models and innovation.

As global events continue to affect the mineral sector and continue to unfold rapidly (the war in Ukraine, increased tensions in the Middle East, climate change and the growing influence of artificial intelligence), the mining industry has opportunities and challenges ahead, and as Yameogo insisted, the mining industry and all of the minerals and metals it produces remain critical to the future of society.

"If you think about society as a whole, our job is to produce the metals and minerals that we all depend on," he said. "And if we don't produce these metals and minerals, everything stops." ■

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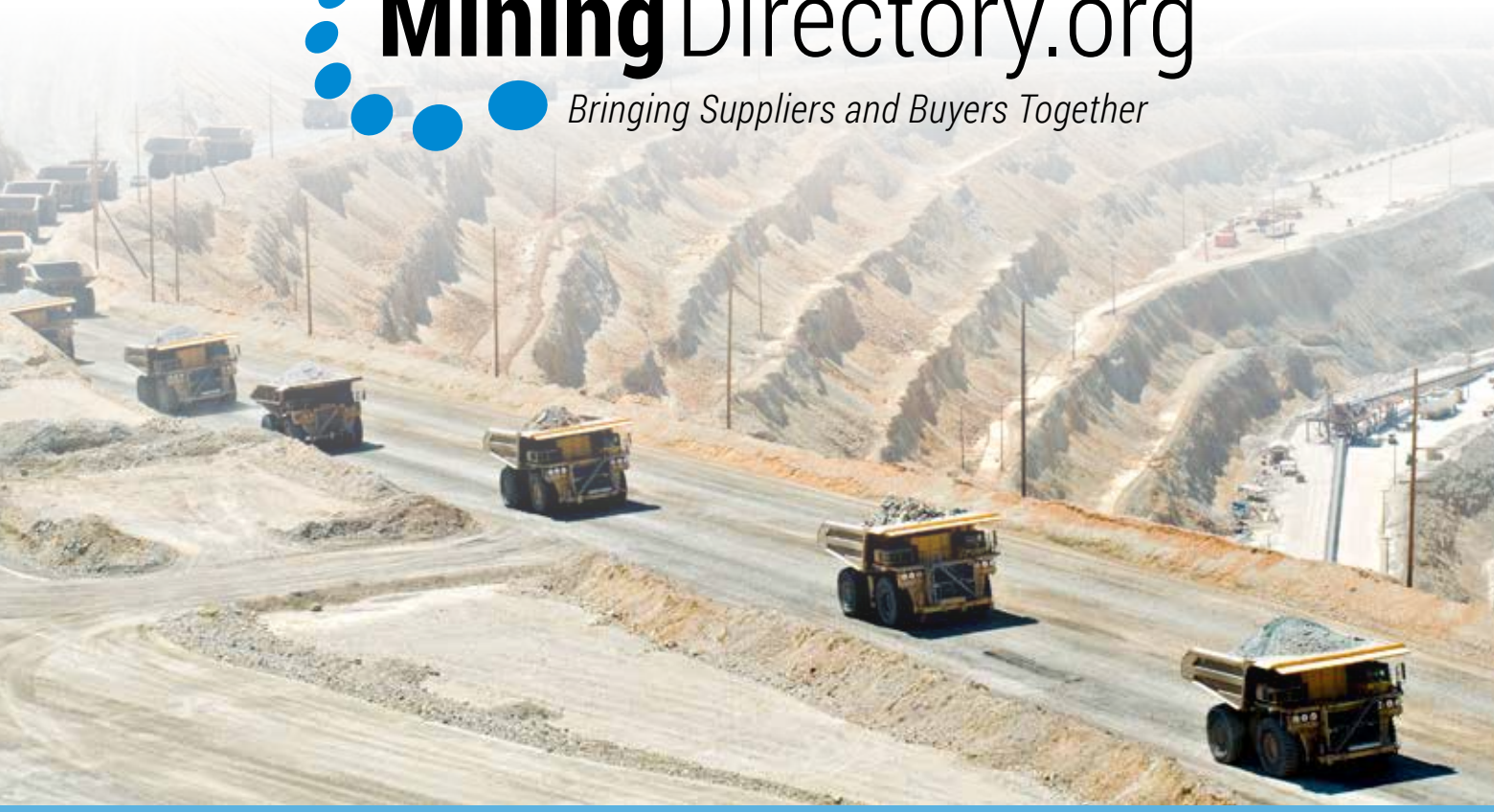
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Maptek™ is a global provider of innovative software, hardware and services. Founded more than 40 years ago to service the mining industry, Maptek offers a unique combination of domain knowledge, technical expertise and engineering resources. We incorporate automated workflows and optimised algorithms to collect, analyse and circulate critical information within the operational cycle, closing the loop between planning, production and results. With our digital mine solutions, operations can add value to projects. Maptek continually looks for new ways to extend the capability of the mining industry and develops reliable solutions that allow customers to improve safety, productivity and profitability.

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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-

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Iron Woman Mining Services, LLC

https://ironwomancon.com/

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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.

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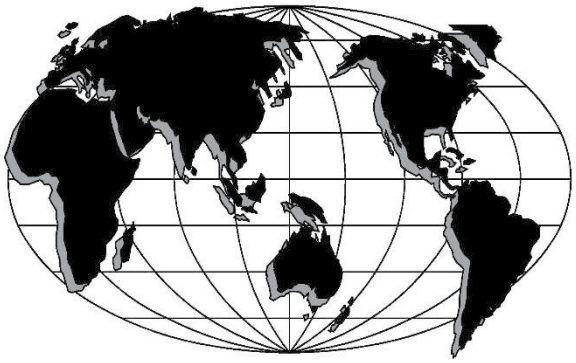
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The KCA Carbon Converter

Recover Gold From Your Carbon Fines On Site

Kappes, Cassiday & Associates (KCA) now has four Carbon Converters successfully operating at mines in Armenia, Argentina, Mexico and Nevada. These units take carbon fines and dirty, wet waste carbon at gold leach plants, thoroughly ash it and remove all mercury. Recovery of gold and silver into bullion is typically 99%. For waste carbon loaded to 200 grams gold per tonne, operating cost is $6.00 per gram, or 11% of the value of the recovered gold. Often waste carbons are loaded much higher - the cost per gram drops accordingly.

Mines with the Carbon Converter can recover their gold quickly without the Chain-of-Custody problems of shipping carbon to outside processors. Shipping mercury-contaminated wastes off-site incurs large risks of environmental contamination, and the Carbon Converter eliminates this risk.

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The installed cost of the Carbon Converter is about US$1 million including site services, a building, and infrastructure. For mines which generate at least 50 tonnes/year of carbon wastes and fines, payback is typically less than one year.

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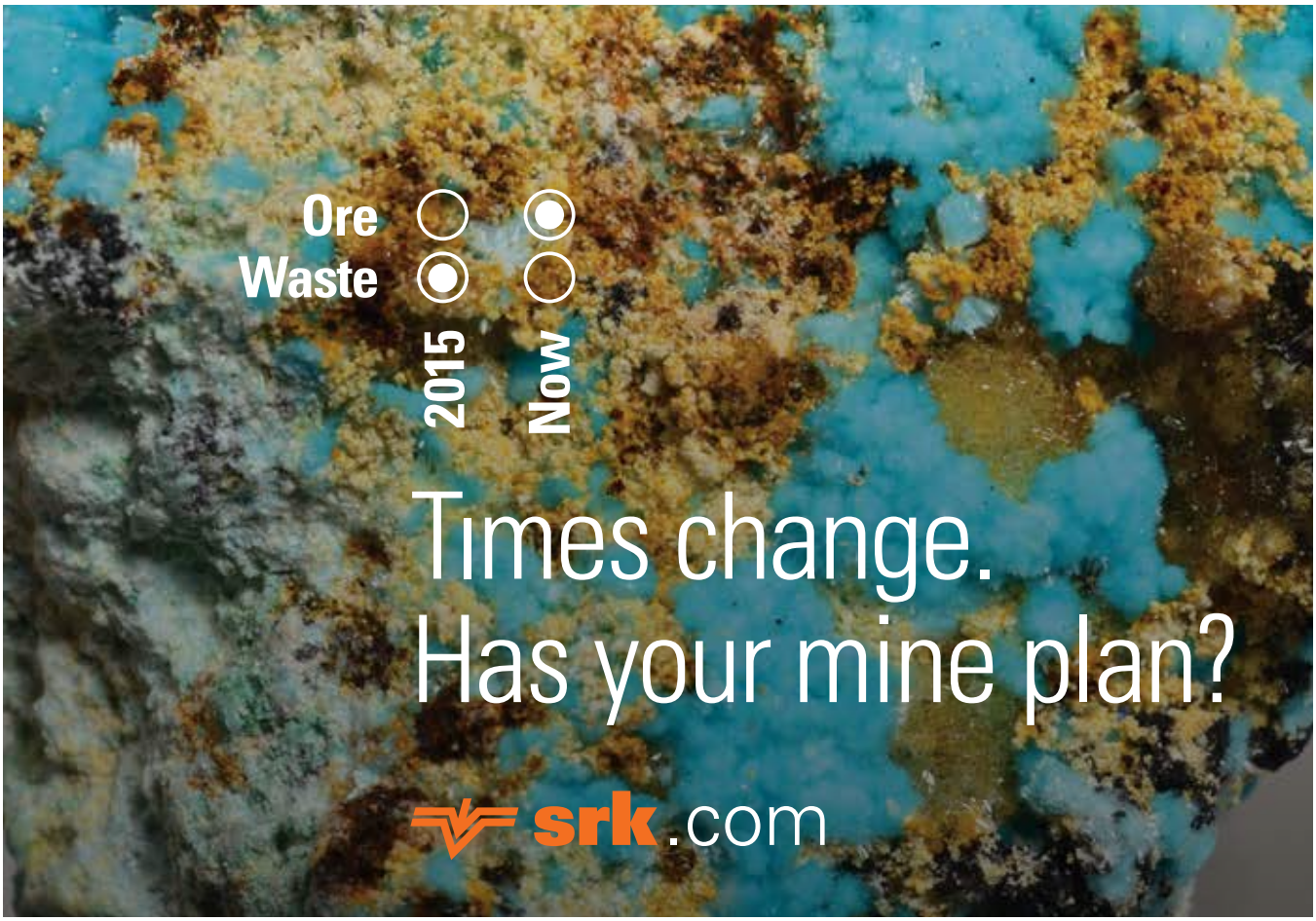
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CONVEYOR EQUIPMENT AND SYSTEMS

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Benetech, Inc. is the premier provider of best-in-class solutions for plant performance in industries experiencing dust control and material handling issues. Our Total Dust Management Solutions focus on providing products and services to improve overall dust control, material flow, performance, and safety. While our competitors focus on selling a product, Benetech focuses on providing solutions with the multiple technologies we can implement. Our mission is to "make a positive difference in our customer's lives by providing premier solutions for dust control and material throughput that add value, ensure efficiency, and help create a safe working environment." Benetech's commitment to total quality has served us with both customers and employees alike since 1983.

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RAM Enterprise, Inc.
ram-enterprise.com
RAM Enterprise, Inc. provides fixed maintenance and conveyor belt solutions, as well as manufacturing and distributing products to the bulk material handling industry. Through our commitments to safety, quality, and building strong teams, we aim to set new standards in the market for operational excellence. Founded in 1991 by Richard Milroy, Jr., RAM's core values have remained the same for nearly 35 years, aiming to succeed through responsiveness, being easy to do business with, and the mantra, "once a customer, always a happy customer." RAM Enterprise, Inc. is based out of Elko, NV, with other branches in Las Vegas, NV, Salt Lake City, UT, Odessa, TX, Gilbert, AZ, and Palmer, AK to serve the Western United States.

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Virta specializes in the custom design and supply of bulk material handling systems to industries worldwide, including overland & plant conveyors, feeders, chutes, transfer structures, crushing & screening plants, stockpile & reclaim equipment, and electrical & control systems. Our multi-disciplined, industry-renowned team offers complete system solutions for mines, mineral processing, ports & terminals, fertilizer & chemical plants, power plants, and steel mills, with expertise in the handling of ores, concentrates, chemicals, coal, coke and dry tailings. Belt conveyor expertise includes dynamic analysis, DEM, horizontal curves and regenerative systems. With international global supply chain and steel fabrication, and global affiliate offices, Virta executes projects worldwide including local engineering support, international logistics management, fast-track scheduling, and modularization capabilities.

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LIPPMANN

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MMD Mineral Sizing (America) Inc.

www.mmdsizers.com

MMD designs and manufactures innovative material processing equipment for the mining, quarrying, and recycling industries worldwide. Celebrating 40 years in the U.S., we offer a comprehensive range of Sizing solutions ranging from compact, road-transportable machines to complete In-Pit Sizing and Conveying (IPSC) Systems.

Our core technologies—such as the Mineral Sizer™ and Apron Plate Feeder—optimize material crushing and flow, supporting safer, more efficient, and cost-effective operations in many surface and underground environments. We continue to innovate and lead the way with advanced solutions like Bulk Ore Sorting and the Fully Mobile Surge Loader™, helping customers reduce emissions, lower energy and water use, while significantly increasing productivity.

By working in close collaboration with mining companies, engineering teams, and project developers, MMD delivers robust, scalable, and tailored systems. Our systems help support sustainable development and long-term performance across the mining, waste and recycling sectors.

STEDMAN MACHINE COMPANY, INC.

www.stedman-machine.com

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Stedman Machine Company offers a wide range of services for the aggregate industry by continuously creating and improving equipment to help increase production, decrease maintenance and improve overall efficiency.

A complete line of size reduction equipment provides access to the best equipment for the process, instead of modifying the process to fit the equipment.

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roxia.com

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Somerset International

Somersetinternational.com

Somerset International combines world-leading expertise with innovative technologies to deliver sustainable tailings management, resource tailings valorization, increased plant yield and enhanced environmental outcomes. Our globally recognized team comprised of a diverse skill base including project design, implementation, plant operation and optimization are leaders in mineral handling and processing, with decades of experience in North American, Australian, and Canadian resources industries.

We are committed to partnering with our clients to deliver Environmental, Social and Governance wins by delivering safer and more sustainable outcomes across the global mining industry. Through our beliefs in health and safety, environmental stewardship and ethical and honest business practices we improve resource utilization, reduce tailings waste, and improve management of water resources.

Our goal across all of our operations globally is to be a valued member of the communities in which we live and work by delivering results through our on-going investment in people, innovation and technology.

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DOORS & GATES

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Headquartered in Stoneboro, Pennsylvania, Supreme Manufacturing Inc. was founded in 1990. Supreme's main product and service lines are; floating clamshell dredges, floating and over-land conveyors, associated dredging equipment; clamshell, dragline, and drag-scraper buckets, rock barges, and service boats, as well as heavy-duty material handling equipment such as; overhead cranes, bins, and hoppers.

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Robit manufactures the competitive offering in drilling consumables for mining, surface drilling and foundation, underground construction, and well drilling. The company's offering is divided into three product and service ranges: Top Hammer, Down the Hole, and Geotechnical. The products are known for their high quality, excellent drilling results, and performance achieved by the latest technology. Drilling consumables are Robit's one and only focus. More at www.RobitGroup.com

Robit Inc.
Mikko Vuojolainen
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DRILLING CONTRACTORS

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For more information, contact marketing@boartlongyear.com

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Malcolm Drilling Company Inc.
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Jeff Harmston
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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.

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REI Drilling, Inc.

www.reidrilling.com

REI Drilling, Inc. (REI) operates a fleet of directional/core drills for 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 (now with geosensing), 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.

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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.

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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.

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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
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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.

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University of Arizona

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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.

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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.

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Virginia Tech Department of Mining and Minerals Engineering

www.mining.vt.edu

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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/

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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…

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www.geoforming.com

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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.

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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.
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www.chemgrout.com

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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.

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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.

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www.waites.net

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Weir MOTION METRICS™ is the Canadian technology division of ESCO®, and a world leader in delivering smart mining solutions that drive safer, smarter, and more sustainable operations. Headquartered in Vancouver, B.C., with offices worldwide, MOTION METRICS™ is Weir's first global Center of Excellence for Artificial Intelligence and Machine Vision Technology, setting the standard for innovation in modern mining.

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Nevada Gold Mines

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Redpath USA Corporation is a full-service underground mining contractor. Our expertise includes lateral development, shaft sinking, mechanized raise work, underground construction, and raise boring. Redpath USA Corporation is part of The Redpath Group, a multinational mining contractor with clients around the world. The company draws on a large network of multinational experts and over 60 years of service to the global mining industry. Our technical and operational expertise contributes greatly to our reputation for practical and innovative solutions.These are performed with the highest safety standards, resulting in the successful completion of complex mine development and construction. Redpath has worked in logistically and environmentally challenging areas including Alaska, Northern Washington, Montana and Northern Michigan. With Redpath you can "CONSIDER IT DONE — SAFELY".

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McDowell Brothers Industries Inc.

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McLanahan

McLanahan Corporation

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From crushing and screening to tailings management and water recycling, McLanahan offers solutions for nearly every stage of the minerals processing chain whether handling coal, iron ore, copper, lithium or other minerals. Known for its reliability and versatility, McLanahan's equipment is used in operations around the world to help deliver consistent, efficient performance.

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For more information, visit mclanahan.com.

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ME Elecmetal

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Metso is a frontrunner in sustainable technologies, end-to-end solutions, and services for the aggregates, minerals processing, and metals refining industries globally. We improve our customers' energy and water efficiency, increase productivity, and reduce environmental risks with our product and service expertise. From ore to metal, our combined offering includes industry-leading technology and comprehensive aftermarket solutions that will maximize performance at every stage of your operations. Metso is your partner for positive change in North America.

Metso is a global frontrunner in sustainable solutions for aggregates and minerals industries. Metso has 17,000 employees in 50 countries and sales in 2024 were approximately $5.4 billion USD. Metso is listed on the Nasdaq Helsinki.

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roytecglobal.com

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Website: www.terrasource.com

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SealRyt is the rotating shaft sealing expert. We utilize a wide range of patented products such as carbon polymer shaft stabilization bearings, gland followers, and braided packing to create custom sealing solutions for your critical equipment. We provide custom solutions that improve reliability and utilize less maintenance and manpower. Find out why reliability and maintenance managers are moving to our patented solutions. Suitable for outlet devices, agitators, soot blowers, vertical turbines, split case horizontal, slurry, condensate, and gear pump applications. We serve the mining, chemical, pharmaceutical, marine, power generation, refinery, biofuel, food or beverage, pulp and paper industries. Made in the USA.

SealRyt Corp.
64 Servistar Industrial Way
Westfield, MA 01085
413-564-5202

Tsurumi Pump

www.tsurumipump.com

Tsurumi Pump is a submersible pump manufacturer that supplies pumps worldwide for underground and open pit mine operations. Tsurumi pumps are capable of handling flows from 50 to 5000 gpm @ heads up to 750 feet. Parts are made of wear resistant materials capable of handling entrained solids commonly found in run of mine dewatering applications. Pump features such as dual inside mechanical seals (which do not require cooling from or come in contact with the abrasive liquid being pumped) is just one of the reasons Tsurumi Pump has become the pump of choice in mines throughout the world.

1625 Fullerton Ct Glendale Heights, IL 60139
Phone: (620)-793-0127
Fax: (630)-793-0146
info@tsurumipump.com
www.tsurumipump.com

VERTIFLO PUMP COMPANY

www.vertiflopump.com

Vertiflo Pump Company's vertical, horizontal and self-priming pumps are delivered fast, usually in half the typical lead time! Vertiflo's vertical sump pump line offers up to 3000 GPM, 250' Heads and 26' depth. The horizontal end suction pump line offers up to 3000 GPM and 300' Heads.

Vertiflo pumps are designed for nonresidential applications and currently over 20,000 are operating successfully worldwide. Vertiflo is recognized as a quality manufacturer of dependable pumps, and continues to grow and encompass new applications in the pump industry.

Vertiflo Pump Company, Inc. was established in 1979 to design, sell and build packaged lift stations. Since 1981, Vertiflo has concentrated on manufacturing vertical process pumps, sump pumps, end suction pumps and self-priming pumps in cast iron, stainless steel and special alloys.

VERTIFLO PUMP COMPANY
7807 Redsky Drive
Cincinnati, OH 45249
Telephone: 513-530-0888
Fax: 513-530-0893
E-Mail: sales@vertiflopump.com

Xylem

www.xylem.com

Xylem is a leading global water technology company dedicated to providing services and solutions that solve water challenges across all industries, including water management, water quality and sustainability for mine operations. For us, supporting open pit, underground and processing operations isn't about offering a few key pieces of equipment and leaving you to figure out how to integrate them into your operation. Xylem is committed to providing everything you need to transport, treat and test water throughout exploration, development, operation and reclamation. Then we put it together in new, more meaningful ways to make your job easier, and your mine more efficient.

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United States
Phone:856-467-3636
Email: support@xylemsales.com

REAGENTS - CHEMICAL AND FLOCCULANTS

Brenntag

www.brenntag.com/en-us/industries/mining

Brenntag is the global market leader in chemical distribution, supporting the mining industry with comprehensive solutions from extraction and recovery to water treatment. Operating a network of around 600 sites in over 70 countries, Brenntag employs more than 18,100 professionals and achieved EUR 16.2 billion in sales in 2024.

With a strong presence across North America, Brenntag's logistics infrastructure—including rail terminals, warehouses, tank monitoring systems, and a company-owned truck fleet—ensures safe, timely, and high-quality chemical delivery. The company also offers specialized equipment and storage tank programs to enhance operational efficiency and safety for mining customers.

Brenntag's global scale, technical expertise, and commitment to service excellence make it a trusted partner in the mining sector, delivering chemistry that drives performance and sustainability.

Alan Smith
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Reading, PA 19605
Alan.smith@brenntag.com

Evonik

www.mining-surfactants.com

Evonik has over 40 years of experience producing an array of performance chemicals that serve the global mining industry. At the core of that technical know-how is the production of high-quality reagents for reverse flotation of non-sulfide ores. Our Tomamine® and Arosurf® product lines of etheramines and fatty amines are designed specifically for this type of mineral flotation. Evonik's Shur-Flo® products help provide our customers free-flowing powdered solids. Evonik manufactures various surfactants for the formulation of dust control agents. We also supply emulsifiers for explosives and wetting agents for bio-hydrometallurgical processing. Evonik is well known for our broad range of foam control technologies. As different applications and minerals pose different extraction challenges, we can also tailor make formulations utilizing multiple chemistries to help optimize metal recovery, level of frothing and concentrate grade. We welcome the opportunity to discuss your specific application.

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HEXION INC.

www.hexion.com

Hexion's product portfolio includes flotation reagents that help customers in the mining industry improve productivity, maximize value, reduce treatment costs, and solve specific metallurgical

challenges. Our high-performance products are used in the processing of a variety of metals and minerals, are tailor made to address individual operational needs, and have been extensively tested and used in Australia and New Zealand. Hexion has been providing specialty chemicals to various industries globally for over 100 years

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Telephone: +1 888 443 9466
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NALCO WATER

www.ecolab.com/mining-and-mineral-processing

Nalco Water has been a global leader in water treatment and process optimization for the mining and mineral processing industry for over 50 years. We help mining customers meet their most pressing challenges by providing diverse products, on-site service, and technology to increase productivity, improve efficiency, decrease downtime, reduce total cost, and protect vital water resources. With our global network of technical experts, research and development laboratories, and world-class training, we provide our customers with unparalleled service and results.

With programs for base metals, precious metals, alumina, phosphate, and coal, our goal is to deliver a measurable return on investment in a safe and comprehensive approach. We can help you get the most out of your operation by offering innovative solutions for flotation, thickening and clarification, scale control, and more. Learn how we can help you in achieving your goals by contacting us at: GMCommunications@ecolab.com

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Nouryon

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Nouryon is your partner in essential solutions for a sustainable future. Harness our expertise in mining through our application know-how on flotation collectors, frothers, and depressants such as NaSH and Carboxymethyl cellulose (CMC); dewatering and anticaking processing aids; sulfidizing agents; hydrometallurgical oxidizing agents; organic peroxides; and thermoplastic microspheres. Learn how we can help you meet environmental regulations while enhancing metallurgical recovery and providing high-quality concentrate. Nouryon supplies essential solutions to consumers and markets around the world and our commitment to sustainability has earned us the EcoVadis Gold rating.

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Prasol Chemicals Ltd.

https://prasolchem.com/mining/

Enhance your mineral separation process with Prasol Chemicals Ltd., a safe, sustainable, and cost-effective manufacturer of flotation reagents. Our extensive portfolio of products for mineral processing is designed to optimize performance and efficiency. Improve the yield of your froth flotation process with our top-quality reagents.

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Syensqo

https://www.syensqo.com/en/solutions-market/resources-environment-energy/mining-solutions

Formerly part of the Solvay Group, Syensqo Mining Solutions is a leading reagent-solutions provider to the mining industry. The business serves a diverse range of markets, including copper, alumina, gold, moly, lithium, nickel, cobalt and phosphate, among others. Constantly adapting to changing markets and customer needs, Syensqo pushes the boundaries of science to deliver ever-more innovative, sustainable solutions.

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Tessenderlo Kerley, Inc: moleko

moleko.com

Moleko is a business unit of Tessenderlo Kerley, Inc. and offers customer focused solutions to the global industrial and mining markets, backed by experienced technical service. Tessenderlo Kerley, headquartered in Phoenix, Arizona, is a leading manufacturer and marketer of specialty Sulfur based derivative chemistry. Tessenderlo Kerley operates 13 manufacturing facilities in North America, in addition to an extensive supply chain network and is part of Tessenderlo Group.

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ROADHEADERS

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.

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.

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ROCK SPLITTING

Daigh Company, Inc.

www.Da-mite.com

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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.

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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.

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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.
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616-866-0815
williams@williamsform.com

SAFETY EQUIPMENT AND PRODUCTS

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
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Conveyor Components Company

conveyorcomponents.com
For 60 years, Conveyor Components Company has been a trusted manufacturer of high quality engineered products for the bulk handling industry worldwide. As a leader in conveyor safety, motion controls, level controls, and bin aerators, we are ISO 9001:2015 certified by NQA Global. Our commitment to quality ensures reliable products that meet customer needs, world class customer service and minimal lead times. We prioritize innovation, workplace safety, and ethical business practices, continually investing in resources and infrastructure for future growth. At Conveyor Components Company, we don't just make products. We make a promise: Ships on time | Works every time. Our name stands for quality, reliability, and an unwavering commitment to safety and performance.

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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™.

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https://minearc.com/
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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.

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joshua.hill@minearcusa.com

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.

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SAMPLE DEVICES

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Geotech Environmental Equipment, Inc.
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SCREENS

Derrick Corporation

www.Derrick.com

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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.

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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.

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GENERAL KINEMATICS

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Haver & Boecker Niagara
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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.

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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.

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Polydeck
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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.

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SEALS

GCP, a Saint-Gobain company
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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.

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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.

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Watershed Geo

https://watershedgeo.com

Founded in 1997 by civil engineers and based in Alpharetta, GA, Watershed Geo is an innovative environmental and civil technologies company specializing in engineered geosynthetic products that solve earth's greatest challenges with solutions that reduce risks, require virtually no maintenance and stand the test of time. Watershed Geo's solutions far exceed the performance of traditional methods, with validation through the highest levels of testing. Through best-in-class materials and extreme engineering, Watershed Geo's goal is to unearth solutions that eliminate plaguing industry issues that reduce environmental and financial liabilities. Watershed Geo has created and patented many engineered systems for erosion control, soil stabilization and waste containment including HydroTurf®, an engineered revetment armoring solution specifically designed to manage concentrated, high velocity surface water flow for mining applications.

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770-777-0386
info@watershedgeo.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 expertise is focused 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.

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info@ttcltd.org

SENSORS

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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.

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Sales@steinertus.com

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GEA
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GEA is a global leader in engineering solutions, leveraging decades of expertise to optimize mining processes with sustainability and efficiency at our core. GEA stands out as a go-to partner for mining companies looking to reduce environmental impacts, lower operational costs, and enhance productivity. Our technologies include crystallizers, dryers, and centrifuges solutions for the most demanding processes typically found within in the base/precious metal, rare earth, lithium, uranium, PGM industries. GEA's focus is to support process optimization with both global and local expertise, drive sustainability by and offering innovative technologies, and help our partners by supporting diverse applications within the mining sector such as ore beneficiation, crud treatment, extraction, tailings management, and water treatment to name a few.

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800 722-6622

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.

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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:

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- Chemical Technologies for Mine Backfill
- Admixtures for Concrete
- Thin Spray-on Liner (TSL)

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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.
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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.

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Shotcrete Technologies, Inc.

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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.

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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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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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TRAINING SERVICES

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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.

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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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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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Herrenknecht Tunnelling 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.

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Email: dube.seffen@herrenknecht.com

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www.messingerbearings.com
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Contact: Don Barnhurst
Phone: 215-824-4987
Email: dpb@kingsbury.com

Palmieri spa
www.palmierigroup.com
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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
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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

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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.

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www.asi-group.com

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http://www.robodrill-sa.com

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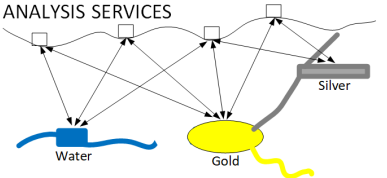
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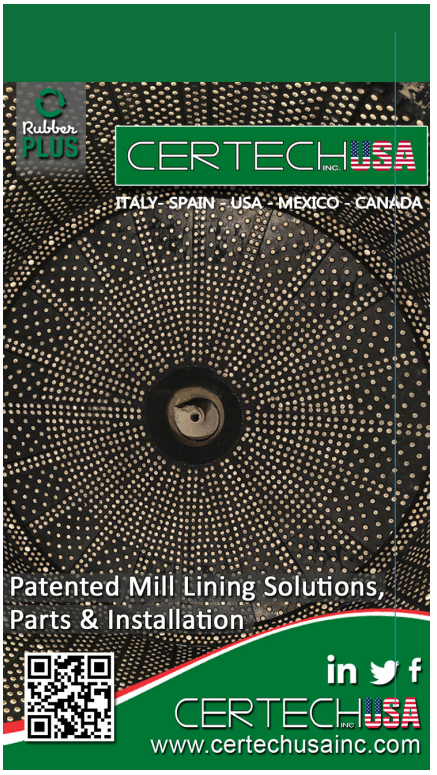
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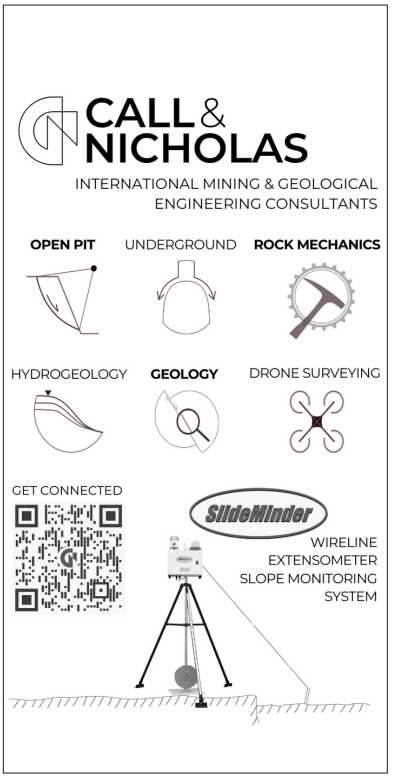


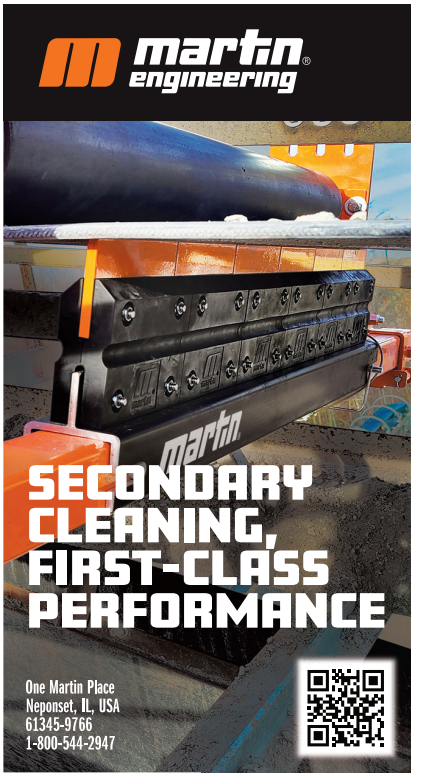
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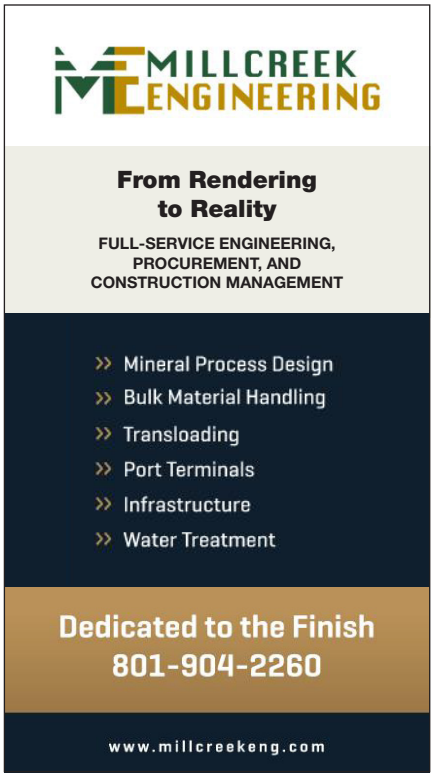

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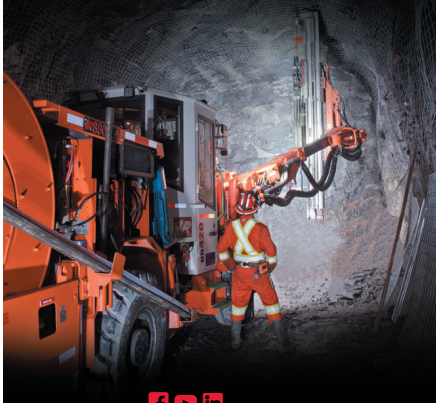
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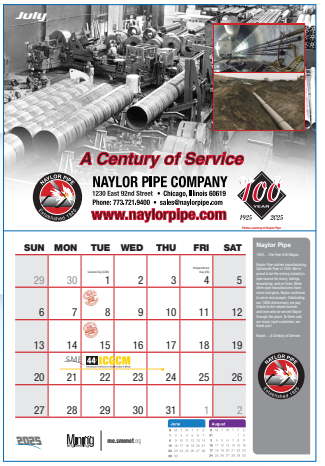
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