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The high-stakes game of rare earths

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Industrial Minerals & Aggregates Division

Each year, a team of volunteers from SME's **Industrial Minerals & Aggregates Division** pulls together summaries of dozens of industrial minerals commodities for the July issue of *Mining Engineering*. This year the result is an impressive overview of 43 commodities that power the world. The editors of *Mining Engineering* would like to thank the committee for its hard work to make this issue possible each year. If you would like to contribute to next year's Industrial Minerals Review or if you would like to join the technical committee please contact Raghav Dube (raghav.dube@outotec.com) or Jim Norman (Jim.Norman@tetrattech.com) to inquire about becoming a vice chair or 2nd vice chair for this effort. A special thank you goes out to the Industrial Minerals Annual Review editor, to the **Industrial Minerals & Aggregates Division** Technical Committee chair and vice chairs, and to the authors of the individual commodity profiles. Jim Norman, member SME, of Tetra Tech Geo, is the industrial minerals annual review editor. Raghav Dube, member SME, of Outotec, is chair of the **Industrial Minerals & Aggregates Division's** Technical Committee. The technical committee vice chairs include:

- Tushar Gupta, member SME, Graduate Student at the University of Kentucky, Agricultural materials.
- Xihui Yin and Lauren Olsen, members SME, Kemira and Minerals Tech, respectively, Ceramic and Refractory materials.
- Riddhika Jain, member SME, of Outotec, Chemical raw materials.
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- Alind Chandra, member SME, of the University of Kentucky, Construction aggregates.
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- Kaiwu Huang, member SME, of Virginia Tech, Sorbents, filters and process aids.
- William Rapier, member SME, a consultant, Specialty minerals.

On behalf of ME readers, the editors thank them.



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In This Issue

In 2019, the estimated value of industrial minerals produced in the United States increased by 3 percent over 2018 to \$58.2 billion according to the U.S. Geological Survey. Beginning on page 30 of this issue you will be able to read annual reviews of 43 industrial mineral commodities. These are the minerals that make the world function. On page 100 you can read more about the complexities of the rare earth market. Cover design by Ted Robertson.

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Reversing the the myth of the resource curse; Evidence suggests that the long-held belief is not accurate



Robert W. Schafer
2020 SME President

Ever since I learned of the resource curse many years ago it seemed paradoxical that the populace and economy of nations with abundant mineral resources were somehow destined to stagnate in poverty, remaining less-developed as a result of development and utilization of the nation's mineral wealth. Finally, a scientific study has been published concluding that the "curse" is misconceived, and the negative propaganda promoted by antimineral nongovernmental organizations (NGOs) and prejudiced academics over the decades to suppress mining in less developed parts of the world has little empirical information to support it. The study, published in *Mineral Economics*¹ in 2019, is the result of research carried out at Lulea University of Technology in Sweden, a country well-known for its liberal thinking and environmental conscience.

This paper reports on an abundance of statistical analyses that convincingly evaluates the contribution of nonfuel mineral mining to the economies of 50 countries, from the wealthiest to the least developed, with a focus on mining's impact on less-developed countries where the resource curse should be most impactful. Using country-by-country data from 1996 to 2016 that included mineral production, prices, mineral rents, exploration expenditures, government revenues and employment, the study provides insights to the mining industries' contribution to each national economy and the change in mining's economic contribution over time. Taking it one step further, an assessment was made regarding the magnitude of each country's economic dependence on extractive resources.

Not surprisingly, coal, iron ore, copper and gold are the chief value contributors across all countries, providing about 80 percent of the annual \$1 trillion global business. Fertilizers provide about 5 percent of the economic contribution, and other metals (Zn, Ni chiefly) fill out the balance.

The study readily recognized that there is a true market failure when it comes to mineral exploration, something that I have realized through my career as an exploration geologist. Exploration activity and spending should be driven by expectations of future demand, mostly long term. However, the reality is that exploration spending in a given year closely

Safety share: Now, more than ever, supporting miner well-being is critical. As an industry, we can draw from research and lessons learned around healthier work design and organizational practices to support miners during COVID-19. Mainly, organizational support can be advanced by showing that health and safety is a true priority of the company. Ways to illustrate this message include the following: provide all employees fair treatment and equal opportunities; install adequate pay and benefits including paid sick leave; allow for more flexible work environments with increased opportunities for cross-training; and maintain consistent, open communication to facilitate trust.

Additionally, finding ways to increase employee involvement in decision-making authority through newly formed committees may result in an increased sense of control in a less certain environment. CDC has offered guidance on worker safety and support for a variety of occupations, including mining, available at: <https://www.cdc.gov/coronavirus/2019-ncov/community/miners.html>.

Submitted by Emily Haas, 2020 SME Health and Safety Division Chair Elect

correlates with metal prices of the preceding year. This means that the future demand for metals, which logically should determine the levels of exploration expenditures, is not the key driver at all.

Here's the meat: among the 20 less-developed and moderately developed countries that were profiled, the economies of 11 of these grew sufficiently to advance them at least one step in the World Bank's income-group classification scheme. Among the winners, Zambia, Ghana, Guyana and Mongolia graduated to Middle Income Economies. Peru, Suriname, Botswana and Namibia moved up to Upper Middle Income Economies, and Chile is now classified as an Upper Income Economy. On a regional basis, West Africa certainly improved the most, largely as a result of gold mining. Many factors certainly contribute to economic development, but for these countries, mining played a key role.

However, income is not the only or best way

(continued on page 17)



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ESG issues come to the forefront after caves destroyed

AS RIO TINTO works to contain the fallout from the destruction of two caves with cultural and historical significance to the aboriginal people in Western Australia, the company formed a board-led review of its heritage management processes into the incident and the communication it had with the Puutu Kunti Kurrama and Pinikura People (PKKP), the traditional owners of the lands and caves.

During expansion work at an iron ore mine in Juukan Gorge, Rio Tinto carried out a blast that destroyed two caves that showed evidence of continual habitation dating back 46,000 years.

Reuters reported that in 2013, Rio Tinto won state government approval to expand into areas where the caves were located. Rio Tinto said it believed it had consent from the PKKP, because they had not explicitly asked that the site not be mined, however, PKKP leaders disputed that claim.

“Our elders are deeply distressed about this,” Burchell Hayes, a director of the PKKP Corporation said to the

ABC in Australia. “For years, we have made mention how significant those sites were to the PKKP people. When we say that those sites are significant, we have an expectation that miners, in this case, Rio Tinto ... they don’t go and disturb that place.”

Rio Tinto apologized and said it would urgently review its plans for other sites in the area.

“On behalf of the Rio Tinto board, I would like to apologize to the Puutu Kunti Kurrama and Pinikura people. The decision to conduct a board-led review of events at Juukan Gorge reflects our determination to learn lessons from what happened and to make any necessary improvements to our heritage processes and governance,” Simon Thompson, chairman of Rio Tinto, said in a statement.

The issue comes as large investors in the mining industry are focusing more on environmental, social and governance (ESG) issues in making investment decisions.

“Managing social license to operate is crucial for all mining

companies,” Nick Stansbury, portfolio manager at Legal & General, the UK’s largest asset manager told *Reuters*. “We are disappointed by this incident and are concerned about the implications for the ongoing relationship with local communities.”

Some analysts believe that the backlash from the blasts could result in tougher heritage legislation, potentially slowing mine developments in Australia’s Pilbara Region. Rival miners BHP and Fortescue Metals Group have also secured state approval to destroy heritage sites in the region to make way for mines.

Australian legislation currently allows mining companies to apply for an exemption to destroy Aboriginal sites.

J-S Jacques, chief executive of Rio Tinto, said, “Our immediate priority is to regain the trust of Traditional Owners, starting with the Puutu Kunti Kurrama and Pinikura people. We very much look forward to incorporating the findings of the board-led review into our heritage processes and approach.” ■

US will look to expand strategic minerals initiative

THE U.S. STATE Department will look to expand the Energy Resource Governance Initiative (ERGI) with the hopes of ensuring supply chains for critical minerals used for renewable energy sources while reducing dependence on China for those minerals.

Reuters reported that a top U.S. diplomat told the news agency of the plan to expand the initiative among 10 countries including Canada, Australia and Brazil who joined the United States last year to form ERGI. As part of the initiative, the United States will share mining experience to help countries discover and develop minerals such as lithium, copper and cobalt.

ERGI, part of an effort to reduce the world’s reliance on China for the high-tech materials, is also

meant to provide advice to help ensure industries are attractive to international investors.

Next year, renewable power additions are forecast to rebound to the level reached in 2019.

Despite slower growth this year, construction delays and supply chain disruptions because of the COVID-19 pandemic, overall global renewable power capacity will grow by 6 percent in 2020, the International Energy Agency said late last month.

Next year, renewable power additions are forecast to rebound to the level reached in 2019.

“We are very much looking to expand ERGI to include other governments as well as governmental institutions,” Frank Fannon, the top U.S. energy diplomat, said in an interview.

Fannon said he has had conversations about ERGI with the European Commission. Increased participation in the group could include emerging-economy countries around the world, as well as Japan and other developed countries in Asia with strong energy demand, he said.

Fannon participated in a workshop on Tuesday with the International Renewable Energy Agency (IRENA), which said in a report that the attractive prices of renewables relative to fossil-fuel power generation could help governments embrace green economic recoveries from the pandemic.

The other ERGI members are Botswana, Peru, Argentina, Democratic Republic of the Congo, Namibia, the Philippines and Zambia. ■

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EPA will not object to Pebble Project proposal; Northern Dynasty Minerals announces performance dividend plan

A TOP OFFICIAL at the U.S. Environmental Protection Agency (EPA) informed the U.S. Army Corps of Engineers in Alaska that the EPA would not formally object at this point to the proposed Pebble Mine, according to the *Washington Post*.

Christopher Hladick, the EPA's regional administrator for Alaska and the Pacific Northwest, wrote to the Alaska district engineer, Col. David Hibner, that the agency still has serious concerns about the plan, but the agency would not elevate the matter to the leadership of the two agencies, which could delay necessary approvals for the project to advance. The EPA "appreciates the Corps' recent commitment to continue this coordination into the future," he wrote.

The Corps is set to decide this summer whether to grant a federal permit to the Pebble Partnership to move forward with the project. The EPA could still veto such a permit, and last year it sent the Corps a letter saying the project slated for southwest Alaska may harm "aquatic resources of national importance."

But the EPA had to determine

by whether the mine will cause such harm, and it opted not to do so — an indication that the environmental agency does not appear likely to block the mine.

Pebble Partnership chief executive officer Tom Collier hailed the decision in a statement as "another indication of positive progress for the project."

"Our core principle has always been for the project to be done in a way that does not harm the fishery or water resources in Bristol Bay. The draft EIS showed this, the Preliminary Final Environmental Impact Statement shows this and we are confident the final EIS will show this and demonstrate to Alaskans that this is an important project for the state's future," said Collier.

"Rich Nolan, president and chief executive officer of the National Mining Association, also welcomed the EPA's determination. "It is encouraging to see the permitting process proceeding as intended on this important project, especially after so many years of delay and inappropriate overreach," he said in an email.

In a bid to win over public support and in turn, earn a social license to operate the Pebble Mine, Northern Dynasty Minerals has launched a

profit-sharing plan for residents from the Bristol Bay region.

Pebble Partnership said in a statement that the Pebble Performance Dividend will share 3 percent of the net profits from the copper, gold and molybdenum mine.

Collier said the Pebble Performance Dividend helps fulfill a key promise made to local people: "When we rolled out our new, smaller mine plan in 2017, I made a commitment to find a way to share the opportunity Pebble represents with the residents of Bristol Bay. While not everyone will want to work at the mine, this ensures a direct way for everyone to participate.

"We're proud to offer this benefit to the people of Bristol Bay and hope and believe it will help make these villages and the Alaska Native culture they support sustainable for future generations," said Northern Dynasty president and chief executive officer Ron Thiessen.

The U.S.-based unit noted the revenue-sharing plan was intended to mirror Alaska's Permanent Fund, which distributed an annual dividend to the state's full-time residents based on revenue derived from natural resource activity. ■

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The Great Debate

BHP halts plans to mine near Aboriginal sites in Australia

BHP SAID IT HAS halted plans to expand a mine in Western Australia because of concerns it could destroy dozens of indigenous heritage sites, *BBC News* reported.

It follows a public outcry over the destruction of a 46,000-year-old site by another firm, Rio Tinto, last month.

BHP had been granted approval to work on up to 40 sites in the remote Pilbara region as part of its expansion of an iron ore mine. But it said it would consult further with Aboriginal groups.

"We will not disturb the sites identified without further extensive consultation with the Banjima people," BHP said in a statement.

"That consultation will be based on our commitment to understanding the cultural significance of the region," it added. "This will include further scientific study and discussion on mitigation and preservation."

It is not clear how the delay will affect the development of the AU \$3.6 billion (US \$2.5 billion) South Flank Mine, which is near the town of Newman.

It is due to start producing iron ore next year, local media report.

Western Australia's Aboriginal Affairs Minister Ben Wyatt said he had approved BHP's application to impact 40 heritage sites in the iron-ore-rich region. ■

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Colorado School of Mines, U of Arizona and Colorado State combine to create center of excellence for tailings dam research

THE COLORADO School of Mines, the University of Arizona and Colorado State University will develop a center of excellence dedicated to mine tailings research and education.

Officials from the three universities have signed a memorandum of understanding outlining the inter-university initiative. The center of excellence in mine tailings and waste management will focus on two main goals: the education of engineers to responsibly and sustainably manage mine tailings and the advancement of best practices in tailings management through applied science and engineering research, the Colorado School of Mines said in a press release.

“The mining industry is extremely concerned about the management of tailings, especially as companies increasingly rely on large-scale extraction of ever-lower-grade ore deposits, a process that yields large volumes of waste materials,” said Priscilla Nelson, professor of mining engineering at Colorado School of

Mines. “We hope that this center of excellence will serve as a center for coordination for all the international efforts that are going on in tailings management. Finding ways to sustainably manage tailings is a matter of social and corporate responsibility.”

Recent high-profile tailings incidents have made the center’s proposed work all the more important. The Brumadinho dam disaster in 2019, in which a tailings dam at Brazil’s Córrego do Feijão iron ore mine suffered a catastrophic failure and killed more than 270 people while contaminating a stretch of about 70 km downstream, brought the issue to global attention. Tailings dams fail at a rate about 10 times higher than comparable water storage embankments, creating concerns about the continued viability and acceptability of the structures and the need for more research in complex soil and tailings mechanics.

“The center is going to be interested in not just the safe disposal of mine tailings but also what we can do with the tailings that represent new

products. We have a group that’s planning a project to melt tailings and pull glass fiber that could be used in all sorts of applications,” Nelson said. “The idea of creating downstream projects would bring the mining industry more strongly into the global circular economy.”

Among the center’s priorities are to:

- Offer online and in-person short courses and workshops in tailings management for current mining professionals and engineers, as well as inter-university certificates in relevant areas of tailings and waste management.
- Serve as a nexus for the dissemination of best practices and industry benchmarks.
- Provide venues for graduate education focused on mine waste to support the development of uniquely qualified tailings engineers.
- Conduct fundamental and near-term research guided by industry needs. ■

Rare earths processing plant receives permits; Plant in Colorado will help US establish independent supply chain

USA RARE Earth LLC’s new rare earth and critical minerals pilot plant processing facility in Wheat Ridge, CO has received its required permits and its pilot plant is now being commissioned.

USA Rare Earth LLC, the funding and development partner of the Round Top Heavy Rare Earth and Critical Minerals Project in west Texas, made the announcement together with Texas Mineral Resources Corp.

Once fully commissioned, the plant will be focused initially on group separation of rare earths into heavy (dysprosium, terbium), middle, and light (neodymium, praseodymium) rare earth (REEs). The final phase of the pilot work will be the further separation of high-purity individual rare earth compounds.

At the same time, the pilot plant

will also be focused on recovery of non-REEs focusing on lithium, uranium, beryllium, gallium, zirconium, hafnium and aluminum, all of which are on the U.S. government critical minerals list. Confirming the recovery of these critical non-REEs will support upgrading the measured and indicated resources to proven and probable reserves (with no in-fill drilling required) and completion of the preliminary feasibility study (PFS).

“Establishing an independent domestic rare earth and critical minerals supply chain is monumental for USA Rare Earth and for the United States, overcoming reliance on China for materials and processing that are essential for defense applications and advanced technology manufacturing,” said Pini Althaus, chief

executive officer of USA Rare Earth.

“This is an important step toward USA Rare Earth’s objective to build the first rare earth and critical minerals processing facility outside China and to bring the Round Top project into full commercial production. Our Colorado pilot plant will have the ability to produce the full range of high-purity, separated rare earths as well as other critical minerals such as lithium,” Althaus continued.

With the Round Top project, the processing facility and the recent acquisition of the neodymium magnet plant formerly owned and operated by Hitachi, USA Rare Earth has a three-pronged mine-to-magnet strategy to establish a resilient, 100-percent domestic supply chain for rare earth magnets. ■



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Researchers create map to target resources on the moon; Mapping model was inspired by mining industry's exploration

INSPIRED BY on-earth exploration methods for mineral deposits, a team of researchers at the University of Central Florida (UCF) have created a model that they hope will help find deposits of ice on the surface of the moon.

Deep-space exploration will require off-earth resources, like water and ice, that can be turned into fuel for space missions. These resources will have to be mined and a team lead by planetary scientist Kevin Cannon has created an Ice Favorability Index. *Phsy.org* reported that the geological model explains the process for ice formation at the poles of the moon, and mapped the terrain that includes craters that may hold ice deposits. The model, which has been published in the peer-reviewed journal *Icarus*, accounts for what asteroid impacts on the surface of the moon may do to deposits of ice found meters beneath the surface.

"Despite being our closest neighbor, we still don't know a lot about water on the moon, especially how much there is beneath the surface," Cannon says. "It's important for us to consider the geologic

processes that have gone on to better understand where we may find ice deposits and how to best get to them with the least amount of risk."

The team was inspired by mining companies on Earth. Mining companies conduct field mappings, take core samples from the potential site and try to understand the geological reasons behind the formation of the particular mineral they are looking for in an area of interest. In essence they create a model for what a mining zone might look like before deciding to plunk down money to drill.

The team at UCF followed the same approach using data collected about the moon over the years and ran simulations in the lab. While they couldn't collect core samples, they had data from satellite observations and from the first trip to the moon.

In order for humans to explore the solar system and beyond, spacecraft have to be able to launch and continue on their long mission. Mining the moon could result in creating a fuel source that would help ease the cost of flights, since spacecraft wouldn't have to haul the

extra fuel.

Water and ice can be purified and processed to produce both hydrogen and oxygen for propellant, according to several previously published studies. Sometime in the future, this process could be completed on the moon, effectively producing a gas station for spacecraft. Asteroids may also provide similar resources for fuel.

Some believe a system of these gas stations would be the start of the industrialization of space.

Several private companies are exploring mining techniques to employ on the moon. Both Luxembourg and the United States have adopted legislation giving citizens and corporations ownership rights over resources mined in space, including the moon, according to the study.

"The idea of mining the moon and asteroids isn't science fiction anymore," said UCF physics professor and co-author Dan Britt. "There are teams around the world looking to find ways to make this happen and our work will help get us closer to making the idea a reality." ■

Fortescue Metals sets goal for net zero emissions by 2040; Goal will focus on its own operations

FORTESCUE METALS Group announced that it has set its own ambitious target to reach net zero operational emissions by 2040 as part of its climate change strategy.

The goal is about 10 years ahead of the company's rivals, such as BHP, Vale and Rio Tinto, and will focus on the reduction of Scope 1 and 2 emissions from existing operations by 26 percent from 2020 levels by 2030. Scope 1 and 2 emissions include those generated by an organization as well as indirect emissions from the power it buys to run those operations.

"Fortescue has a proud history of setting stretch targets and our 2030 emissions reduction commitment,

together with our goal to achieve net zero operational emissions by 2040, positions Fortescue as a leader in addressing the global climate change challenge," Fortescue chief executive officer, Elizabeth Gaines, said.

"Fortescue supports the Paris Agreement long-term goal of limiting global temperature rise to well below 2 °C above pre-industrial levels, and our emissions reduction targets align with this international objective. Our success will be founded on practical initiatives that will allow us to deliver on our targets in an economically sustainable manner.

"Since October 2019, Fortescue and our partners have announced

investments in excess of \$800 million in significant energy infrastructure projects which will increase our use of renewable energy and will be a key contributor to our pathway to achieve our emissions reduction targets."

"The Chichester SolarGas Hybrid Project, announced with Alinta Energy in October 2019, is well advanced for the installation of 60 MW of solar generation. More recently, Fortescue announced the \$700 million investment in the Pilbara Energy Connect program which, together with the Chichester SolarGas Hybrid Project, will deliver 25-30 percent of our stationary energy requirements from solar power," said Gaines. ■

Diamond industry stuck holding gems; Supply worth billions of dollars has not moved during COVID-19

COUNT THE DIAMOND

industry among those devastated by the COVID-19 outbreak.

Bloomberg reported that because of restrictions on travel and in-person meetings, diamonds and gems worth billions of dollars have remained in storage for months. DeBeers and Alrosa are among the companies trying to figure out how to move some of the stockpile without undermining the nascent recovery.

Because of the pandemic, jewelry stores closed their doors, India's cutting and polishing artisans were forced to stay home and De Beers had to cancel its March sale because buyers couldn't travel to view the merchandise.

Alrosa said its diamond inventories could rise to 30 million carats by the end of the year

De Beers and Alrosa have moved to defend their market. The miners refused to cut prices, instead allowing buyers unprecedented freedom to renege on contracts to buy stones. They've also reduced production in an effort to control stock levels. Yet the diamonds keep piling up.

The five biggest producers are probably sitting on excess inventories worth about \$3.5 billion, according to

Gemdax, a specialist advisory firm. The figure could reach \$4.5 billion by the end of the year, or about one-third of annual rough-diamond production.

"They've tried to restrict rough-diamond supply to protect the market and protect value," said Gemdax partner Anish Aggarwal. "The question will be, how does this destocking occur? Can miners destock and keep protecting the market?"

While De Beers and Alrosa have stood firm on pricing — even refusing approaches from customers offering to buy at special terms — smaller diamond producers have dropped their own prices, according to people familiar with the matter.

Junior miners, some of which were fighting for survival even before the pandemic, have been offering steep discounts of as much as 25 percent in trading centers such as Antwerp, the people said. That could make it tough for the large companies to convince big buyers to come to the table.

Diamond miners face "a double whammy of weak prices and a sharp decline in sales volumes on a scale reminiscent of the 2008-2009 crisis," Societe Generale analyst Sergey Donskoy said this week.

Managing supply has been a constant headache for the diamond industry ever since De Beers ended its monopoly. The company spent the early 2000s running down about \$5 billion in stock, and industry inventories ballooned during the global financial crisis and again in 2013. Each time, selling down the stockpiles has caused buildups of polished diamonds, putting huge pressure on the cutters, traders and manufacturers that buy from them.

There are some signs of recovery. Chinese retailers are open again and India has allowed manufacturing to restart in the key Surat polishing hub, albeit at only 50 percent of capacity. The main Indian trading offices are allowed 10 percent of employees on site.

Still, manufacturers bought heavily in the first two months of the year in anticipation of a recovery in the market. With cutting centers shut for the past two months, that inventory is expected to last until July or August. That's left little need to buy now.

"At this stage it's hard to speculate on what the recovery curve will look like," said Aggarwal. "What we're not expecting is an immediate jump back in consumer demand." ■

Rule limits states' power to deny permits for energy projects; EPA will limit the powers under the Clean Water Act

U.S. ENVIRONMENTAL

Protection Agency (EPA) chief Andrew Wheeler signed a rule that will strip states of the ability to block a federal water permit for any reason other than direct pollution to state waters.

Reuters reported that the rule was signed on June 3. The Trump administration has said some states have misused their authority under the Clean Water Act to prevent fossil fuel projects.

Under the rule the EPA will alter Section 401 of the federal water law to make it impossible for a state to block a water permit for a project for any reason other than direct pollution into state waters. It will also set a one-year

deadline for states to approve projects.

In the past, states have weighed broader factors, such as climate change, to determine quality and have taken years to make decisions on projects.

New Jersey and New York both denied a 401 permit to the Williams Co. \$1 billion Northeast Supply Enhancement pipeline project, citing both water quality and climate change concerns.

Wheeler said the change would prevent states from holding the nation's energy infrastructure projects hostage," deterring investors.

Interstate pipelines, coal terminals and other projects cannot proceed without a state agreeing to a water

permit or waiving its authority to issue a certification.

Several states, including Washington, have hinted that they would take legal action against the EPA if it moves to curtail state authority under the Clean Water Act.

"The Trump Administration's proposed rule would usurp state and tribal authority to regulate our waters, in violation of the law," Washington Attorney General Bob Ferguson said after submitting comments in October.

Washington denied a section 401 permit in 2017, effectively blocking the construction of a coal-export terminal that would have allowed western U.S. coal to be transported to Asia. ■



The Great Debate — Round Six

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Social and environmentally responsible mining and mineral processing are influential to national economies and to quality of life. Mines today must have closure plans started during early exploration and proceed throughout the life of the mine. It is no secret that rock chemistry and climate vary from mine to mine, but the one thing they almost all have in common is water. Water is essential to life and usually also essential in the mining and processing of mineral ores. The processes that use water include, but are not limited to, solution mining,

heap leaching, flotation and chemical process leaching. Each of these may result in waste streams and tailings impoundments that must be treated or recycled responsibly.

The environmental and health and safety sector is a diverse bunch, an incohesive mixture of professions that include natural resource scientists, engineers and sociologists. Our daily jobs may focus on things such as concrete as, well, concrete, or as abstract as “the acid-neutralizing capacity is equivalent to alkalinity but in solids, not liquids.” Yes, us environmental wackos must think in terms of chemistry and in guessing about things such as the potential of acid drainage based on other assumptions. We deal in data. Lots of it. Lots of numbers and chemicals. Which ones react, which ones don't react and how can I prevent these from reacting when I add those others?

We are geologists. The physical and mineralogical geology of the mine site dictates the extent of environmental contamination that

may occur as a result of human activity. Water pollution is affected by the natural environment and geology, the availability of water and oxygen, the final placement of rock material that may encounter the water, and the physical and chemical properties of the rock. Geology dictates the movement of groundwater. Environmental geologists work with mine engineers to develop structural controls that minimize the impact of mine-influenced water, lowering the risk of environmental pollution and litigation.

We are engineers. Preventing the impact of mine-influenced water during planning and design and throughout operation is much more effective before rather than waiting for later. Data from site exploration and materials and geochemical testing assist in determination of proper design, methods of mining and other operational considerations to minimize issues that will need to be addressed during closure. In addition, we are regulatory experts navigating the myriad local, state and federal regulations in managing tailings, dust, water treatment, discharges and runoff to prevent the release of harmful chemicals that may contaminate the surrounding air, water and soil.

We are consultants. We provide integrated services throughout our global networks of scientific and technical expertise. We bring in an outside view for a fresh look at your operation, enabling us to improve the design and performance. We are experts at handling mine waste, at water treatment, and at mine closure and remediation. We review regulation and permitting guidance on projects at any stage, from baseline studies to implementation, expansion, all the way to reclamation. Environmental consultants specialize in understanding local, state, federal and international regulations and communities.

Most important, we work closely with mining and mineral processing to minimize the potential of environmental mishaps and releases of contaminants into the environment.

While you may find deposits, mine the deposit and process the ore, we are the ones that provide you a safe, environmentally responsible industry. So, you're welcome.

To support those who support your environmental health and safety make your voice heard and donate at bit.ly/Gr8Deb8. Make your vote count. ■



The Great Debate is intended to be a good-natured debate about the mining industry with a goal of raising funds for the U.S. National Mining Hall of Fame and Museum. The opinions expressed here are those of the author and not necessarily of SME or *Mining Engineering*. Each edition of the Great Debate will be available on *Mining Engineering's* website. To get involved in the debate, visit <https://me.smenet.org/greatdebate/>.

President's Page: Countries with resources have improved over time

(continued from page 6)

to measure development and progress. Social and political development are also important. Improved human development, education and equality as well as political stability, rule of law and accountability are key socio-political considerations in realizing whether the resource curse exists. The United Nations' Human Development Index shows that countries with high economic contributions from mining showed larger improvements than those without mining. Similarly, considering all good governance indicators, mining countries have exhibited significantly better political development than non-mining countries. Interestingly, a number of oil-producing countries have actually regressed.

The result of this exhaustive study fails to support the view that

mineral resources create a difficult dependency, breeding poor social, political and economic development. Quite the opposite – less-developed countries with rich mineral endowments have a better chance for positive social and economic improvement than those without. The development or exploitation of mineral resources within a country does not create a resource curse in terms of a tragic dependency.

The ultimate conclusion is one that I believed from the first: it is unlikely that a country classified as a "low-income economy," relying heavily on mineral-resource-production revenues, is destined not to prosper. It is not the mining-based economy that is the problem, but rather it is the way economic benefits of mining are managed that underpins this issue. If

the economic benefit created from the mineral resource patrimony by the process of mining is not appropriately shared among the citizenry, there is a problem. The curse is that the economic benefits are sometimes kept by a privileged few, commonly within less-than-honorable governments or those with ties to such governments.

I now feel vindicated. My remaining hope is that those that are carrying out the mining activities are following the international guidelines set forth by the ICMM and are not in collusion with debased governments and its cronies. I hope that you are feeling better about this issue as well. ■

¹Ericsson, M. and Lof, O., 2019, Mining's Contribution to National Economies between 1996 and 2016, *Mineral Economics*, v.32, pp. 223-250.

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Coal has been in a decline since 2007; COVID-19 has only exacerbated the problems

by William Gleason, Editor



Through the past century, coal has been a dependable and affordable fuel source for much of the world. However, coal's position on top of the fuel chain has been eroding for more than a decade, losing ground to natural gas and renewable energy sources. The COVID-19 crisis has only made matters worse for the sector.

The International Energy Agency (IEA) released a report in May that found that the pandemic has set in motion the largest drop in global energy investment in history with spending expected to plunge in every major sector this year. Moody's Investors Services released a more dire outlook for the coal sector and predicted earnings for North American coal miners may plunge by more than 50 percent in 2020. This all comes as the industry continues to struggle with shrinking demand in the United States as utilities retire coal-fired power plants and turn to natural gas and renewable energy solutions.

"The effects from and the reaction to the COVID-19 pandemic were unimaginable a few months ago, not just to the coal industry but to almost every sector worldwide," said Eric Shereda, manager of Exploration and Applied Improvements for CONSOL Energy Inc., "The magnitude of impacts resulting from stay-at-

home orders and self-quarantining was largely unforeseen by most governments, companies, organizations and individuals."

In its report, the IEA looks at the entire energy sector, not just coal, and writes, "The unparalleled decline is staggering in both its scale and swiftness, with serious potential implications for energy security and clean energy transitions. At the start of 2020, global energy investment was on track for growth of around 2 percent, which would have been the largest annual rise in spending in six years. But after the COVID-19 crisis brought large swathes of the world economy to a standstill in a matter of months, global investment is now expected to plummet by 20 percent, or almost \$400 billion, compared with last year."

The pandemic brought everything from restaurants and offices to manufacturing plants around the world to a halt and with it demand for electricity plummeted.

"Initially, there was a lot of uncertainty and fear of the unknown surrounding COVID-19 across the entire country as evidenced in the daily news," said Shereda. "Producers have been challenged with finding ways to continue operations while minimizing the risk of potential exposure to their employees. Reduced demand

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for electricity has led to swollen inventories at coal plants causing some producers to scale back production.

“But it’s not all bad news,” Shereda said. “There has been growing consensus among the analyst community that natural gas prices could rebound as we head into 2021 due to a falloff in associated gas production and pullback in capital spending for new gas wells. We must be ready to quickly take advantage of any rebound in the market.”

Much of the mining sector in the United States, including coal mines, were spared from the shutdowns that swept across the planet in an effort to stop the spread of the coronavirus. In March, the Department of Homeland Security’s Cybersecurity & Infrastructure Security Agency issued an “Essential Critical Infrastructure Workforce” advisory list in which mining was included under the “Critical Manufacturing” category. That list included “Workers necessary for mining and production of critical minerals, materials and associated essential supply chains, and workers engaged in the manufacture and maintenance of equipment and other

infrastructure necessary for mining production and distribution.”

The critical industry designation allowed many mines to remain in production, often with self-imposed social distancing guidelines in place. This provided a lifeline for many metal mining companies; however, for a large part of the coal industry, it appears that it is not enough to stop the decline that the sector has been experiencing since 2007.

In June, the U.S. Energy Information Administration (EIA) reported coal consumption in the United States fell by nearly 15 percent in the fourth quarter of 2019 compared to 2018, down for the sixth year in a row and that for the first time since at least 1885 renewable energy sources have surpassed coal in energy generation in the United States.

Numerous coal mining companies in the United States have scaled back production, cut their workforce with layoffs of furloughs or have been forced into bankruptcy. Furthermore, a number of large-scale investors have pulled away from coal citing environmental, social and governance (ESG) issues. Norway’s sovereign

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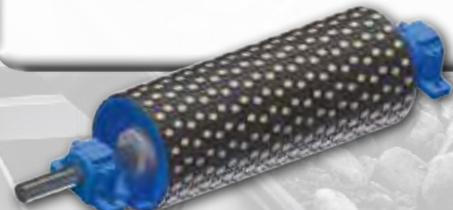
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wealth fund, a state-owned investment reserve worth \$1 trillion, is one of the most recent to exclude some of the world's biggest commodity companies from its portfolio due to excessive use and production of coal.

The changing landscape has impacted coal producers in the east as well as those in the Powder River Basin out west and is forcing the industry to adapt to a new reality.

"Reduction to coal inventories should provide relief in the short term, but for coal demand to stabilize long term, the cost to supply and generate electricity from coal must be low enough to allow the remaining coal-fired power plants to compete on the power grid against the gas power plants, which are now providing much of the baseload generation," said Shereda.

The coal industry could also experience some relief from the export market. While the United States and Europe have accelerated the transition from fossil fuels to renewable energy, emerging markets have seen a higher demand for coal including China and India.

E&E News reported that China permitted more new coal-fired power plants in March 2020 than it did in all of 2019. The new permits come on the heels of an uptick in coal plant construction last year — reversing a two-year slowdown in China's coal expansion.

China, which consumes more than half the world's coal

now has almost as much new coal generation in planning or construction (206 gigawatts) as the United States has in operation (235 GW at the end of 2019).

Innovation

It is clear that the coal industry will continue to change in the near future and will be forced to adapt to challenging market conditions as well as other unforeseen challenges. One of the ways to do that will be through the adaption of new technology and innovation.

Shereda said coal industry needs to innovate to create value and sustainability along all aspects of the coal value chain, from the coal mine to the power plant or the steel mill, and everything in between. And it is also very important to develop new end-uses for coal beyond traditional and metallurgical utilization.

The industry will need to turn to technologies such as automation, big data and advanced computing to find a way forward. Shereda pointed out that Consol is working on a number of projects including the manufacturing of high-performance carbon foam products used in the aerospace sector and the development of coal plastic composites for decking. Other innovations include longwall shearer automation and the use of big data for increased productivity.

In addition to improved technologies the coal industry must improve the perception the public has of the industry and educate future engineers.

Heather Trexler a project manager for coal mining, natural gas and environmental projects with Tetra Tech, Inc. emphasized the importance of public perceptions. "There is always a fight for public support," she said. "We need to work to change the perception of mining and to educate people about the benefits of coal."

Trexler and Shereda both noted that coals availability, especially in times of extreme weather disturbances, its abundance and affordability are benefits that should be promoted to the public and politicians responsible for policy. ■

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Coal mining in extreme conditions; Alaska's winters present unique challenges

by Caroline Schweitzer



The Usibellis coal mine in Alaska creates challenge conditions for coal mining. Photos courtesy of Hitachi.

Winters in Healy, AK, are not for the fainthearted. Located just outside Denali National Park and Preserve, the daylight is short and the cold lingers into spring. Sometimes, temperatures plummet to as low as -60 °F. Amidst these harsh temperatures, the work must go on at Usibelli coal mine.

“We work in extreme conditions,” said Alex Legrismith, Usibelli mining engineer. “Steel can shatter in these low temperatures.”

Not only does the work continue through the winter, but for Usibelli, it's peak season.

“The middle of the winter is our largest production time,” Legrismith said. “Fairbanks is just up the road, and it's the coldest city in the United States. Our coal keeps Fairbanks warm.”

Usibelli is a family-owned mine started in 1943 by Emil Usibelli. Not only does the mine singlehandedly heat Fairbanks, but its production has increased steadily through the years. Today, the mine outputs 1 to 2.2 Mt/a (1.2 to 2 million stpy) of coal.

“We're all about production,” Legrismith said. “And we've worked to make our operation as efficient as possible to output

more high-quality coal.”

Productivity through reliability

Usibelli utilizes one powerful Hitachi excavator – an EX1900-6 – to output about 50 percent of the mine's production. The machine was purchased in 2012 and has been a workhorse ever since.

“It's just so reliable,” said Robert Bohanon, Usibelli operator. “I've run plenty of other machines. The Hitachi is smoother and has more power.”

Legrismith echoed the machine's reliability.

“Our EX1900 excavator is one of the most reliable pieces of equipment we have on the mine,” he said. “It's had almost no mechanical issues. It's always running. Its motto should really be, ‘Productivity through reliability.’”

With a customized 19.5 cubic-yard bucket, it not only boasts big productivity, but also a comfortable working environment.

“With our operators spending so much time in the cab, it's important that the cab is comfortable,” Legrismith said. “With the EX1900, the ergonomics and visibility from the cab are much better than other pieces of equipment.”



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"As the story goes, our primary coal loading operator, who has been here for more than 30 years now, says the EX1900 is the only

machine that doesn't leave him with a stiff neck at the end of the day," Legrismith said. "I think the visibility is so much better than other machines, and it runs smoother, which leaves our operators feeling way better."

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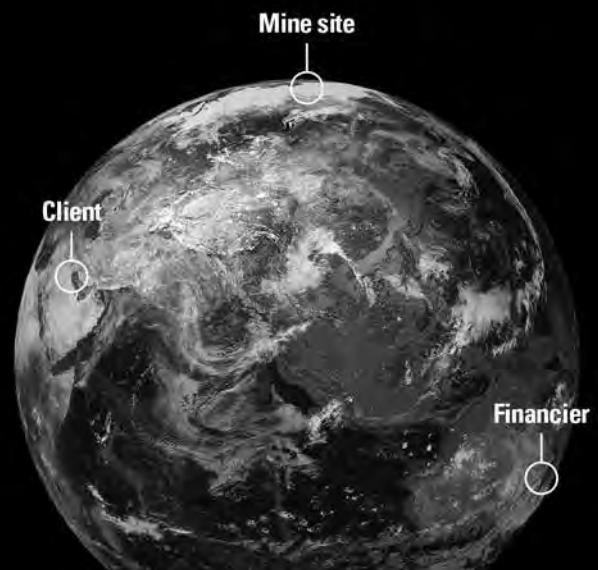
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Working in conjunction with the EX1900-6, drone surveying has recently revolutionized Usibelli's mining process, streamlining it for efficiency and quality. Legrismith spearheaded the efforts to bring drone surveying to the mine and has experienced positive results since.

"Drone surveying is safer and more efficient," Legrismith said. "Before, we used GPS and had to walk around, getting to the crests by foot. Now, we just set out some control points and fly the drone. The result is a perfect survey of the area in very little time."

One of the biggest advantages to drone surveying is to pinpoint where the "good coal" is located so operators can dig in more precisely. This is especially important in Usibelli's challenging environment.

"We're mining coal that has a parting or 'seam' about halfway through it," Legrismith said. "The drone survey allows us to have great elevation control and hone-in on where this parting is, and where it will be projected in the future. All of this quality variation occurs within 10 m (30 ft). We've got our Hitachi excavator in these pits, and it's been doing great because we've been able to selectively mine the coal."

While this drone surveying push is a great advancement, Legrismith is always looking ahead, eager to utilize technology and keep the mine moving forward.

"Next, I would love to see machine control, or have an autonomous truck," Legrismith said.

So far, Legrismith has only noticed one downside.

"I used to get some exercise surveying and getting outside," Legrismith smiled. "But then I got the drone and need to get to the gym."

Excavators for the last frontier

As Legrismith anticipates the future of mining, there's one piece of equipment he wants to see stick around for years to come.

"With the performance we've seen from the Hitachi, we trust the brand," Legrismith said. "The next piece of equipment I would love to see here at Usibelli Coal Mine is another Hitachi shovel. I think for the mining we have coming up in the next five to ten years, it would be perfect for us."

When Usibelli decides to

purchase equipment, they turn to their dealer, Construction Machinery Industrial (CMI).

"Our relationship with CMI has been wonderful," Legrismith said. "They've done nothing but stick by us. They are always extremely fast in getting us what we need to keep us running, and they know the community and mining industry."

Working with a company that values the community connection is no surprise, as Usibelli has gained brand recognition locally by giving back through sponsoring scholarships and grants to more than 80 organizations annually.

"Growing up in Alaska, you learn to love it and its community," Legrismith said. "It's the last frontier, and it takes a special type of person to love the lifestyle."

Luckily for Legrismith, he's found the right fit at a company with more than 115 employees who live for the community and outdoor atmosphere like him.

"We've been family-owned and run for going on 76 years now," he said. "Working here is like working for a giant family."



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Komatsu Mining allowed to pursue actions on two shovels; Shovels are operating at two coal mines in Wyoming

A **FEDERAL** bankruptcy court has ruled that Komatsu Mining Corp. can begin foreclosure procedures for two shovels currently operating at Eagle Specialty Materials' Eagle Butte and Bell Ayr mines in the Powder River Basin.

Judge Benjamin A. Kahn of the U.S. Bankruptcy Court for the Southern District of West Virginia denied requests from both Eagle Specialty Materials and Blackjewel LLC to hold an evidentiary hearing on Komatsu's claims that it's owed millions of dollars on a broken maintenance contract for the shovels — called Shovel 12 and Shovel 13 in court documents.

Eagle Specialty Minerals purchased the mines for \$40.2 million following the bankruptcy of previous

mine owner Blackjewel in 2019. The shovels were not included in the sale but Komatsu contends that the mines' current and previous owners owe millions of dollars on a maintenance contract for the shovels, the *Gillette News Record* reported.

Eagle Specialty Materials and Blackjewel don't dispute that they owe on the shovels. The question is how much, Eagle Specialty Materials attorney Steven L. Thomas said in court.

The two mines closed when Blackjewel filed for bankruptcy last July, putting more than 500 miners out of work. The bankruptcy, which also put miners out of work in Appalachia, was among the more disruptive amid several in the U.S. coal industry due to declining use of

the fossil fuel.

Eagle Specialty Materials and Komatsu planned to negotiate a resolution to the shovel dispute after the mines' sale, Blackjewel attorney Stephen Lerner said.

They haven't reached agreement. Eagle Specialty Materials and Blackjewel shouldn't be expected to pay a bill without seeing justification for how much they owe, Thomas said.

"They can't just file something and say we're owed millions of dollars and everybody just says, 'Well, you must be right because you're Komatsu,'" Thomas said.

Blackjewel still holds title to the shovels even as Komatsu has a valid lien and Eagle Specialty Materials continues to use the equipment, said Parks, the Komatsu attorney. ■

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Colorado coal mine expansion approved by BLM

THE U.S. BUREAU of Land Management announced that it had approved GCC Energy's lease for its expansion of the King II coal mine near Durango, CO.

The *Durango Herald* reported that the lease is for a 981-ha (2,426-acre) expansion for the mine about 32 km (20 miles) west of Durango and is estimated to contain about 8.6 Mt (9.5 million st) of recoverable coal.

"The coal reserves in this tract are important for infrastructure projects and will generate millions of dollars for Colorado's economy," the BLM's Colorado Director Jamie Connell said in a statement. "BLM supports working landscapes across the West and issuing this lease is a fine example of that."

GCC Energy has operated the coal mine near Hesperus since 2007. But in preparation for its coal reserves to run out, it asked the BLM for the expansion to extend the life of the mine by about 20 years.

The BLM approved the expansion in October, but as a formality, was required to go through a bidding process. In April, only one bid was received, from GCC Energy, for \$3,434,400.

With the lease, the BLM said GCC Energy will pay an annual rental of \$3 per acre, along with a royalty payment of 8 percent of the value of coal produced. Company officials have previously said the mine pays \$5 million a year in local, state and federal taxes. ■

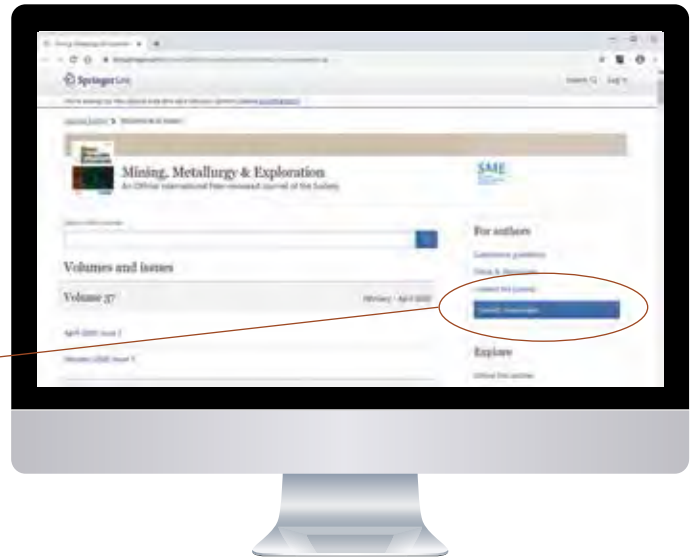
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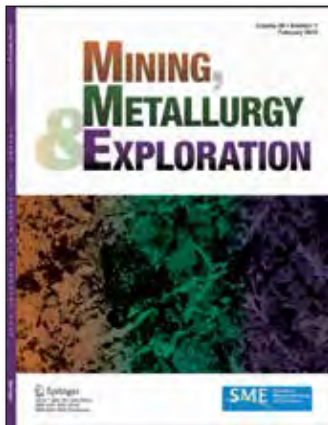
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MME Special Issue on Tailings Management

A waste product of mineral processing, tailings are the necessary result of successful mining. Recent tailings dam failures have required the industry to rethink its approach to tailings management. The impending Global Tailings Standard (GTS) will support this push. This special issue aims to disseminate state-of-the-practice research, experience and case studies regarding tailings characterization/behavior (such as brittle failure modes), monitoring technologies, risk assessment/management, advancements in dewatering technologies, closure and innovative tailings management approaches.

Guest Editor: Kimberly Morrison, PE, RG – Newmont

Submit by September 30, 2020. Email Chee Theng at theng@smenet.org if you have any questions or need any help.

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Industrial Minerals review 2019

2020 Vision for Industrial Minerals

by Mike O'Driscoll*

Writing this mid-May sees the world still grappling with the impact of the COVID-19 pandemic, which will continue to affect mineral operations and consuming market sectors for the next few months, if not the remainder of the year, and a global economic recession is more than likely.

China was already getting back on track by mid-March, albeit initially hampered by internal logistics restrictions, and by July and August it is hoped that lockdown restrictions will have eased for most western operations.

Regarding market demand, right now it is a mixed bag: with some sectors undergoing a dramatic decline (e.g., oilfield — drilling minerals), others suffering what is hoped to be a temporary dip (e.g., steel — refractory, flux minerals; construction — building materials, glass minerals), while a few are actually seeing a boost (European Union do-it-yourself market (popular in lockdown) — paint minerals).

That said, as most companies have now taken action or are readjusting accordingly; they are beginning to take stock, look ahead and strategize for their emergence on the other side of this crisis.

If anything, the ramifications of the COVID-19 pandemic has put into sharp focus certain trends which were already emerging for the industrial minerals sector, as well as salient reminders as to their overall importance to industry and everyday life. These factors could, and should, shape the industry for the better going forward.

Industrial minerals are essential — it's official. In response to the COVID-19 lockdown, on March 19, 2020, then updated March 28, 2020, the U.S. Cybersecurity & Infrastructure Security Agency (CISA) classified a range of industrial sectors as "essential critical infrastructure," many of which rely on the supply of industrial minerals.

The subsequent CISA update then included industrial minerals in their own right. This was a welcome result for U.S. industrial minerals operations but also a solid message to the populace and government as to the important role of industrial minerals in supporting the economy (similar decisions were rolled out in other countries re: mineral operations).

Hopefully this will help support plans for future mineral projects and increase investors' (and the public's) recognition and confidence in the value of industrial minerals.

Perhaps the single most obvious factor that emerged from the start of the crisis was the world's (over-)reliance on sourcing minerals (and many other items) from China.

It had happened a few times before: during the

SARS outbreak of 2003, the Beijing Olympics of 2008, and most recently the 2017-19 anti-pollution drive (continuing) within China, but this time the impact has been felt deeper and wider and, crucially, perhaps for a longer term.

The subsequent New Year clampdown on movement within China paralyzed mineral supply to global markets during the first quarter of 2020 from the world's largest industrial mineral exporter.

Mineral consumers in the West, particularly refractory and ceramic manufacturers, became very short on stock and needed all their lateral thinking powers to secure alternative and sufficient raw material supplies from elsewhere.

China is supremely gifted with large natural resources and commands a dominant position in world supply of industrial minerals. In value terms, China accounts for nearly US\$4 billion or 8 percent of global industrial mineral exports, representing at least 68 Mt.

Of significance is China's leading role in world exports of key industrial minerals including graphite (60 percent), magnesias (57 percent), barite (36 percent), mica (35 percent), limestone (25 percent), quartz (23 percent), fluorspar (16 percent) and vermiculite/perlite (10 percent).

After Japan, the United States is China's second largest export market for industrial minerals (other primary market destinations are Europe (via the Netherlands) and Asia — South Korea, Taiwan, India and Indonesia).

In 2019, according to the U.S. Geological Survey (USGS), the United States had an import reliance of ≥ 20 percent for some 28 industrial minerals, 23 of which the United States was ≥ 50 percent import-reliant.

Of the 28 minerals, the majority (20) were imported from China, 16 of which the United States was ≥ 50 percent import-reliant. These include minerals, and some termed critical, on which the United States is 100 percent reliant: bauxite, fluorspar, graphite, mica, rare earths, scandium and yttrium.

Additional minerals from China on which the United States is ≥ 50 percent import-reliant include barite, antimony, fused alumina, garnet, silicon carbide, diamonds, iron oxide pigments and magnesia.

The upshot is that United States and world consumers of these Chinese minerals suffered supply shortages March to May at the least, and perhaps through to June/July as mines, plants and transport networks slowly got back to business (although western demand sharply dropped as E.U./U.S. manufacturers entered lockdown).

This latest impact on Chinese mineral supply, and coming straight after the (ongoing) ramifications (i.e., mine/plant closures) of domestic pollution control instigated in 2017, has further exposed global markets' somewhat risky high import reliance on China and

revived the drive to seek alternative sources of supply.

The situation has forced an entire rethink and assessment of adapting to alternative options in global mineral supply chains.

And this is not just restricted to exploring for and evaluating alternative mineral sources, but also in logistics, working practices, sustainable development, recycling, increased remote online/digital methods — and some most likely for the better.

Indeed, the industry may go from temporarily adapting to permanently adopting some of these measures for more efficient and secure working in the future.

Security of consistent supply — in terms of both volume availability and desired quality — for industrial mineral consumers is imperative.

There is now much talk of an economic decoupling of China from traditional supply chains by some countries and the next few years may see a major change in mineral sourcing options.

With this latest stimulus, the start of the 2020s may well herald a surge in global mineral project development, especially in critical minerals, in order to lessen markets' reliance on China's mineral resources. Along with this quest for alternative sources to China will be a boost for the already fast-evolving mineral recycling sector.

According to European Commission research, global raw-material extraction has grown 14 times from 6 Gt in 1900 to 84 Gt in 2015, with the sharpest increase in industrial minerals at 45 times.

Global resource extraction was projected to increase 119 percent from 2015 to 2050, to 184 Gt in

total, including an estimated increase in industrial minerals extraction of 168 percent. Sustainable development and increased recycling will come to the fore.

Industrial waste resources will soon emerge as the new alternative mineral resource and eventually become the new normal supply chain option for mineral consumers.

Not only will more recycling processors emerge, but also we may begin to see more primary mineral mining producers involve themselves with recycling tailings and other waste sources in order to offer a wider range of products with very much a welcome green tinge to their portfolio.

Key among the evolving new supply chains incorporating more recycling will be a drive to change product formulations to permit easier end-of-life recyclability, better harmonization of waste legislation to help logistics, increasing economic alliances between waste sources and recyclers and investment in suitable processing and accurate sorting technology.

All we can do is to stay calm, stay well and create new solutions and opportunities in adapting to new mineral supply options. ■

**Director and co-founder of IMFORMED — Industrial Mineral Forums & Research Ltd, UK; "2020 Vision for Industrial Minerals" is the theme for IMFORMED's Rendezvous conference on industrial minerals outlook now postponed to April 12-14, 2021 in Amsterdam. Contact mike@imformed.com or www.imformed.com*

Editor's note: Throughout this review, all measurements are expressed as metric units.

ANTIMONY

by Jack Bedder and Nils Backeberg, Roskill Information Services

Native antimony metal is rare and antimony generally occurs together with gold, lead, copper and silver. There are more than 100 antimony minerals, although the sulfide mineral stibnite is the main economic mineral.

Antimony is mostly consumed in flame retardants (nonmetallurgical antimony) and lead-acid batteries (metallurgical antimony), accounting for 81 percent of antimony demand in 2019. Consumption trends in these two critical applications for antimony thus shape overall demand dynamics. In both cases, a similar situation prevails: while overall demand (for flame retardants and lead-acid batteries) has been steadily increasing, the antimony loading within these applications has been reducing. In flame retardants, this was mainly because of high antimony prices prompting substitution for antimony, and more recently legislative

requirements forcing changes to flame retardant formulas. In batteries, lead-calcium-tin alloys are increasingly being used instead of antimonial lead in battery grids for sealed-for-life, maintenance-free automotive batteries, also called valve-regulated lead-acid (VRLA) batteries. Other end uses include plastics and heat stabilizers, ceramics and glass (specifically solar panel glass) and a variety of metallurgical applications.

Antimony enters the supply chain either as a result of mining (primary production) or recycling (secondary production). For secondary antimony, antimonial lead is produced in a number of countries, mainly in secondary lead smelters. The antimony recovered from this product is mainly recycled back into metallurgical applications. Because of the declining demand for antimony in lead-acid batteries

and the growing supply from secondary sources, there will be a fundamental shift in the antimony market in the mid-2020s, when metallurgical demand for antimony becomes self-sufficient with supply from recycled antimony units, requiring little or no primary supply. As a result, Roskill forecasts that the primary supply of mined antimony will be entirely underpinned by nonmetallurgical applications, specifically flame retardants.

For mine production, China has by far the largest antimony resources and has, as a result, been the world's center for antimony mine and refined production. While China remains the leading primary producer in 2019, declining reserves, market consolidation and regulatory inspections across China leading to closures of facilities have caused a significant decrease in Chinese output from more than 80 percent of global production in 2010 to around 50 percent as of 2018 and 2019.

Ores are mainly converted into antimony ingot, which forms the feedstock to produce refined antimony compound, including antimony trioxide used in flame retardants. While China has lost a significant market share in ore supply, the country remains the largest producer of ingots (76 percent of global production in 2019). As a result, China has sourced growing volumes of primary antimony units through imports. Russia and Tajikistan are the next largest producers of antimony after China, both ramping up production in recent years to fill the gap left by China. China, Russia and Tajikistan have consistently accounted for around 85 percent of global mine supply since 2015.

In 2018, Russian supply of antimony leapfrogged ahead of Tajikistan with Russian company Polyus, one of world's leading gold producers, supplying by-product antimony from the Olimpiada Mine, equivalent to 15 percent of global mined antimony supply. As a result, the antimony market balance has remained in a sustained structural surplus, mitigated only by a select few processing plants in China having the capability to process the lower-grade gold-bearing

antimony concentrates from Polyus. Typical antimony concentrates imported into China, to which the processing plants have been designed, include either high-grade antimony with negligible gold or high-grade antimony with high grades of gold. Most gold-bearing ores are sourced from Russia, Australia and Bolivia, though more than 80 percent of the concentrates processed in China are non gold-bearing ores (including Chinese and Tajik ores).

Even with further declines in Chinese supply, the antimony market balance is expected to remain in surplus for much of the 2020s. In addition, growing secondary supply from antimonial lead will provide a new excess antimony supply over the second half of the 2020s. While currently not commercially viable to meet flame-retardant-grade antimony trioxide specifications, research is continuing to remove impurities to meet these specifications and utilize this source in the production of nonmetallurgical compounds.

The outlook for nonmetallurgical antimony demand seems broadly positive when considering construction and plastics trends, which suggests demand for flame retardants will increase. Antimony demand in glass is far smaller but could potentially have a high growth rate due to use in photovoltaic panel production. In terms of market share in flame retardants, however, there is potential for antimony to lose out as a result of safety concerns and regulatory pressures. Current scrutiny of antimony largely stems from the fact that it is metalloid in nature — there being a general perception that metals may pose particularly high risks to consumers and workers. Antimony trioxide is classified as a GHS category-two suspected carcinogen and is closely associated with halogenated flame retardants, some classes of which have been phased out over their own safety issues. Most recent and ongoing regulatory scrutiny is centered on the North American and European market. As such, over the outlook period, the total volume of antimony used in flame retardant applications is predicted to show a slow growth but tracking below overall growth in the flame-retardant industry. ■

BALL CLAY

by Jason Christopher Willett, National Minerals Information Center, U.S. Geological Survey

Since 1990, domestic ball clay production (the quantity sold or used by producers) increased from 788 kt to a record high of 1.31 Mt in 2003. U.S. housing construction, a leading market for ball clay-based ceramics and sanitaryware, declined after 2005, which resulted in a considerable decrease in ball clay sales that continued through the economic recession of 2008 and 2009. After decreasing to 831 kt in 2009, ball clay sales steadily increased until 2018. Sales decreased by 12 percent in 2018 from that of 2017. Estimated sales in 2019 were essentially unchanged from 2018 but were 40 percent higher than those in

1990 and 16 percent lower than those in 2003.

Six companies (Covia Holdings Corp., Gleason Clay Co., H.C. Spinks Clay Co., Imerys S.A., Old Hickory Clay Co., and US Mine Corp.) mined ball clay in the United States during 2019. An estimated 1.10 Mt valued at \$61 million was sold or used by domestic producers, essentially unchanged from that in 2018. Tennessee was the leading producer and accounted for nearly 70 percent of total estimated ball clay output, followed by, in descending order of tonnage, Texas, Mississippi, Indiana and California. Production data were estimated based

on current and previous producer reports as well as employment hours published by the Mine Safety and Health Administration. Reliable data on global production of ball clay are not available because many countries combine ball clay production with that of other clays.

Consumption

The two principal markets for U.S. ball clay in 2019 continued to be ceramic floor and wall tile (54 percent of sales) and sanitaryware (17 percent of sales). Ball clay was also sold for the manufacture of bricks, electrical porcelain, fine china, pottery, refractory products, roofing granules and other types of ceramics. Although sales for fiberglass and filler, extender and binder applications have been reported in recent years, these were likely to have been kaolin-mined or purchased by the ball clay producers.

Historical sales of domestic ball clay have strongly correlated with construction activity. In 2019, housing starts increased by 3 percent to 1.29 million units, but the Tile Council of North America reported in mid-2019 that U.S. shipments of ceramic tile were down compared with those in 2018. Consequently, ball clay sales may have been greater than the estimate presented above, but the

available information was insufficient to confirm this inference.

Prices

Unit values for most of the individual U.S. ball clay operations in 2019 were estimated to range from \$30 to \$100/t, with an average unit value of \$55/t. The average free alongside ship (f.a.s.) value for exported ball clay increased to \$191/t in 2019 as compared with \$169/t in 2018, and the average customs value for imported ball clay decreased to \$213/t from \$217/t. Average unit values for exports and imports fluctuate much more than the average value of domestic production owing to the influence of small, high-value shipments.

Foreign trade

According to the U.S. Census Bureau, ball clay exports were 85.3 kt valued at \$16.3 million in 2019, a decrease in quantity of 5 percent from 89.8 kt valued at \$15.2 million in 2018. Based on import trade statistics published by Mexico's Ministry of the Economy in recent years, a sizable tonnage of United States ball clay exports shipped to Mexico may have been classified as kaolin. Exports of ball clay in 2019 were primarily sent to Mexico (80 percent), Guatemala, China and Japan (in descending order



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of quantity, about 3 percent each). Ball clay imports totaled 679 t valued at \$145,000 compared with 433 t valued at \$94,000 in 2018. The majority of imports originated from the United Kingdom (50 percent), Portugal (31 percent) and Canada (18 percent).

Outlook

In December 2019, an outbreak of a novel coronavirus (COVID-19) was first identified in China. The World Health Organization declared that

COVID-19 was a global pandemic on March 11, 2020. Measures instituted to mitigate the spread of the pandemic, such as closures of nonessential businesses, are likely to cause disruptions in the mining industry across the United States and around the world. The duration and the outcome of the COVID-19 pandemic remains uncertain, but it is expected that the economies of the United States and the world as a whole will likely be negatively affected, which could influence the performance of the ball clay industry. ■

BARITE

by Michele E. McRae, National Minerals Information Center, U.S. Geological Survey

An estimated 2.5 Mt of barite (from domestic production and imports) was sold by crushers and grinders operating in eight states in 2019, an increase of 3 percent as compared with that in 2018. One company opened a second barite processing plant in Ohio and another company planned to build a plant in the northeastern United States. Domestically mined barite was estimated to account for approximately 16 percent of ground barite sales (Fig. 1). Four companies, three in Nevada and one in Georgia, accounted for all U.S. mine production. One mine was idled but continued to work on an expansion project. Mine production was estimated to have increased to 390 kt, but was less than the 433 kt mined in 2015, prior to the downturn in oil and gas drilling that led to historically low domestic production of mined and ground barite in 2016 (Fig. 1). World production of barite in 2019 was estimated to have increased slightly to 9.5 Mt. China, India and

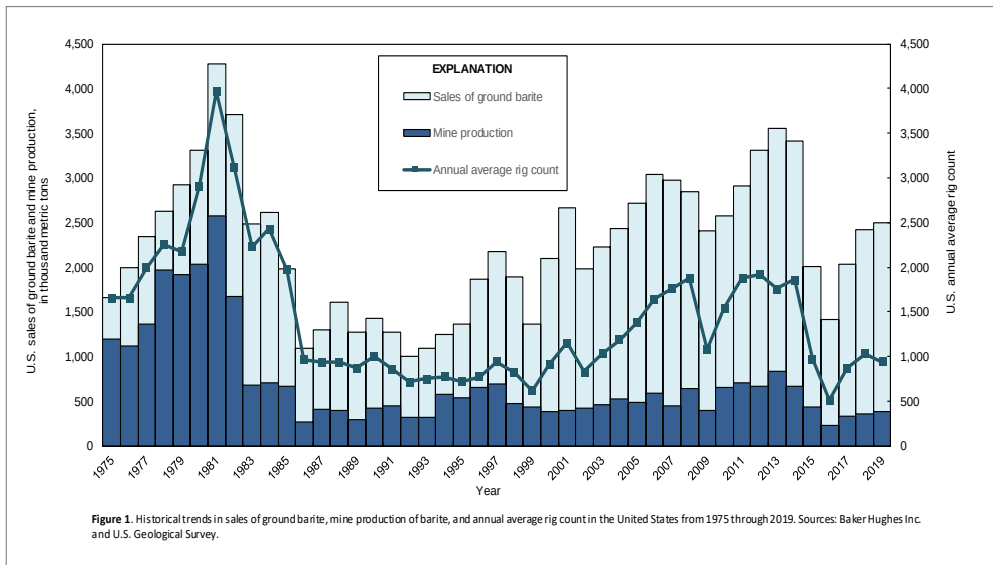
Morocco accounted for approximately 65 percent of world production.

Because of high specific gravity, barite is the weighting agent of choice in oil and natural gas drilling fluids, used to suppress high formation pressures and to prevent blowouts. In the United States this application accounts for more than 90 percent of barite sales. Barite also is used in radiation-shielding concrete, as a contrast medium in medical X-rays, and as filler, extender or weighting agent in products such as paints, plastics and rubber.

The United States continued to be the world's leading barite consumer. Domestic apparent consumption averaged approximately 30 percent of world production over the past 10 years. Nearly one-half of ground barite sales were from plants in Texas, where the Permian Basin continued to be the focus of domestic drilling activity.

Figure 1

Historical trends in sales of ground barite, mine production and annual average rig count in the United States from 1975 through 2019. Source: Baker Hughes Inc. and U.S. Geological Survey.



Foreign trade

In 2019, U.S. barite imports were 2.56 Mt, a 4 percent increase compared with those in 2018. Imports from India increased by 45 percent to 829 kt, surpassing those from China. Imports from China, which had been the leading source of domestic imports since 1980, decreased by 38 percent to 755 kt. Imports from Mexico were 396 kt and those from Morocco were 378 kt. Together, these four countries accounted for 92 percent of domestic imports.

Industry news

Changes in domestic import sources were likely related to policy and

production changes in leading exporting countries. Barite production in China was essentially unchanged from that of 2018, despite the reported closure of 50 to 70 percent of mines owing to new environmental regulations. However, mine closures coupled with increased consumption in China likely constrained the amount of barite available for export. This supply limitation was offset by production in India, where improved beneficiation of low-grade ore contributed to production exceeding 2 Mt for the second consecutive year.

Outlook

The number of active drilling rigs has been used as a barometer of barite consumption. In 2019, the U.S. monthly average rig count decreased continuously throughout the year. A continued

downward trend in rig count would be expected to adversely affect domestic consumption and world production of barite.

In December 2019, an outbreak of a novel coronavirus (COVID-19) was first identified in China. The World Health Organization declared that COVID-19 was a global pandemic on March 11, 2020. Measures instituted to mitigate the spread of the COVID-19 pandemic, such as closures of nonessential businesses, are likely to cause disruptions in the mining industry across the United States and around the world. The duration and the outcome of the COVID-19 pandemic remains uncertain, but it is expected that the economies of the United States and the world as a whole will likely be negatively affected, which could influence the performance of the barite industry. ■

BAUXITE AND ALUMINA

by E. Lee Bray, National Minerals Information Center, U.S. Geological Survey

Two alumina refineries produced an estimated 1.6 Mt of alumina from imported bauxite in the United States in 2019. The 500-kt/a refinery in Burnside, LA, produced specialty alumina used in the abrasives, ceramics, chemical and refractory industries. In June, Almatix Inc. sold the Burnside refinery to Arthur Metals LLC. The 1.2-Mt/a refinery in Gramercy, LA, owned by Noranda Alumina LLC, produced alumina mostly for use in aluminum smelters, but also produced specialty alumina. A project at the Gramercy refinery was increasing its capacity, but a completion schedule was not available. The amount of new capacity was not disclosed but it would be used to produce nonmetallurgical grade alumina. Alcoa Corp. announced in December 2019 that the shutdown of the 2.3-Mt/a refinery in Point Comfort, TX, which was temporarily shut down in March 2016, would be permanent.

Production and trade

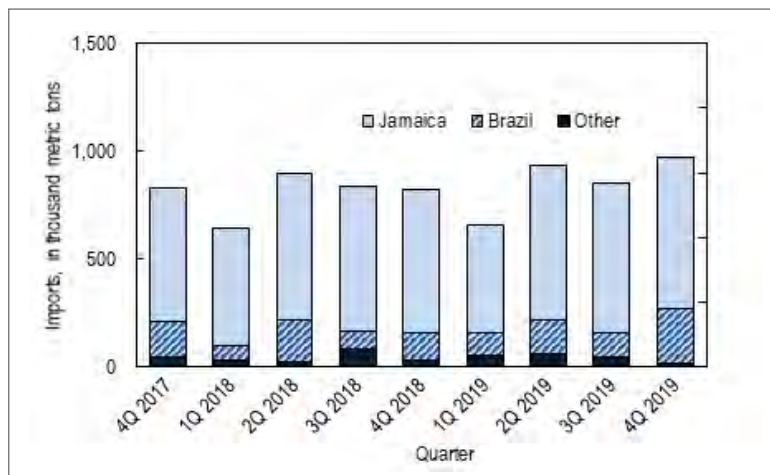
Bauxite. The United States is 100 percent net import reliant for metallurgical-grade bauxite. Small amounts of bauxite and bauxitic clays are produced in Alabama, Arkansas and Georgia for nonmetallurgical uses. Metallurgical-grade bauxite (crude dry) imports in 2019 totaled 3.71 Mt, 6 percent more than the quantity imported in 2018. In 2019, the leading suppliers were Jamaica (70 percent), Brazil (22 percent) and Turkey (6 percent). Imports from Brazil increased by 169 kt (27 percent), imports from Jamaica increased slightly by 43 kt, and imports from Turkey increased by 154 kt (183 percent) (Fig. 1). The bauxite from Turkey was believed to have been used for nonmetallurgical uses based on the destination ports. In 2019, 69 kt of refractory-grade calcined bauxite was imported, a 32 percent decrease

compared with imports in 2018. Guyana (74 percent) and China (24 percent) were the principal sources of refractory-grade calcined bauxite imports. Imports of nonrefractory-grade calcined bauxite in 2019 totaled 361 kt, 32 percent more than the quantity imported in 2018. Australia (59 percent) and Guyana (37 percent) were the leading sources.

Alumina. Domestic production of alumina in 2019 was estimated to be 1.6 Mt, slightly more than that in 2018. Imports of alumina totaled 1.94 Mt in 2019, 27 percent more than imports of alumina in 2018. Brazil (52 percent), Australia (24 percent)

Figure 1

U.S. imports for consumption of crude and dried bauxite from the fourth quarter 2017 through the fourth quarter 2019. Source: Jamaica Bauxite Institute and U.S. Census Bureau.



and Jamaica (12 percent) were the leading sources. Exports of alumina totaled 200 kt in 2019, 31 percent less than exports in 2018, with Mexico (21 percent), Canada (15 percent), Iceland (10 percent), Venezuela (10 percent) and the Netherlands (7 percent) as the leading destinations.

Consumption

Total domestic consumption of bauxite (in crude dry equivalents) was estimated to be 5.1 Mt in 2019, 31 percent more than that in 2018. Of this total, approximately 74 percent (3.77 Mt) was used for producing alumina, slightly more than in the prior year. Other uses of bauxite included abrasives, cement, chemicals and refractories, as well as uses in the petroleum industry, steel production and water treatment. Total domestic consumption of alumina by the aluminum industry, which increased for the second consecutive year, was 2.19 Mt in 2019, 23 percent more than that in 2018. Approximately 1.15 Mt of alumina was consumed by other industries in the United States in 2019, 13 percent more than the amount in 2018. Other uses of alumina included abrasives, cement, ceramics and chemicals.

Prices

Prices for imported bauxite varied depending on the source and grade. Average unit values (c.i.f.) for imported crude dry bauxite from major suppliers in 2019 were \$55/t from Brazil (5 percent decrease), \$37/t from Guinea (no imports in 2018), \$25/t from Jamaica (unchanged) and \$49/t from Turkey (8 percent increase). Average unit values (c.i.f.) for imported refractory-grade calcined bauxite in 2019 were \$461/t from China (15 percent increase) and \$344/t from Guyana (19 percent decrease). Average unit values (c.i.f.) for imported nonrefractory-grade calcined bauxite from the principal sources were \$482/t from China (5 percent increase) and \$111/t from Guyana (16 percent increase). The average unit value (c.i.f.) for alumina imported in 2019 was \$480/t, 22 percent less than that in 2018. The average unit value (f.a.s.) for alumina exported from the United States increased to \$2,080/t, a 53 percent increase compared with the price in 2018.

Lower alumina import prices in the United States in 2019 were influenced by two events involving

major producers in other countries. Sanctions imposed by the United States on a company in Russia in April 2018 were lifted in January 2019. In May 2019, an alumina refinery in Brazil restarted 3.15 Mt/a of capacity that had been shut down since February 2018. Environmental regulators ordered the shutdown after heavy rainfall caused concerns about leaks from waste impounds. Both events contributed to higher alumina prices in the world market during 2018, but with their resolutions, alumina prices generally decreased in 2019.

Outlook

In December 2019, an outbreak of a novel coronavirus (COVID-19) was first identified in China. The World Health Organization declared that COVID-19 was a global pandemic on March 11, 2020. Measures instituted to mitigate the spread of the COVID-19 pandemic, such as closures of nonessential businesses, are likely to cause disruptions in the mining industry across the United States and around the world. The duration and the outcome of the COVID-19 pandemic remains uncertain, but it is expected that the economies of the United States and the world as a whole will likely be negatively affected.

Alumina consumption in the United States in 2020 would be dependent upon primary aluminum smelters being able to remain open, although decreasing aluminum prices in the first quarter of the year call that into question. Production of alumina for aluminum smelters is expected to remain stable in the United States in 2020 despite the economic impact of COVID-19 as decreased shipments to domestic smelters could be offset by exports to smelters elsewhere. Production of alumina for specialty markets is expected to decrease significantly with declining economic activity.

Imports of refractory-grade calcined bauxite, which are largely dependent upon steel production, are expected to decrease significantly if domestic steel production decreases. Consumption of nonrefractory-grade calcined bauxite is expected to decrease in 2020 if consumption for cement used in construction decreases. Consumption of bauxite for use in abrasives and other products is also expected to decline. ■

BORON

by A.S. Brioché, National Minerals Information Center, U.S. Geological Society

Four minerals account for 90 percent of the natural borates used by industry worldwide — the sodium borates, tincal and kernite; the calcium borate, colemanite; and the sodium-calcium borate, ulexite. Deposits of borates are associated with

volcanic activity and arid climates, with the largest economically viable deposits in the Mojave Desert of the United States near Boron and Trona, CA, the Alpid belt in southern Asia and the Andean belt of South America. Borax, a white crystalline substance

chemically known as sodium tetraborate decahydrate, is found naturally as the mineral tincal. Boric acid (hydrogen borate) is a colorless crystalline solid sold in technical, national formulary and special quality grades as granules or powder and marketed most often as anhydrous boric acid. Ore quality is typically measured as a function of its diboron trioxide (B_2O_3) equivalent content. Major end-use industries for boron include detergent, fertilizer, glass and ceramics.

Production

U.S. production of boron minerals and compounds decreased slightly in 2019 from that of 2018; the actual data are withheld to avoid disclosing company proprietary data. Two companies in southern California produced boron minerals, primarily sodium borates. U.S. Borax Inc., a wholly owned subsidiary of United Kingdom-based Rio Tinto Minerals plc, extracted kernite and tincal by openpit methods at its operation in Boron, CA. The minerals were processed into boric acid or sodium borate products in a refinery adjacent to the mine and shipped by railcar or truck to North American customers or distributed internationally through the Port of Los Angeles. Specialty borates, such as agricultural, flame-retardant and wood-preservative products, are made at Borax's Wilmington, CA plant. Searles Valley Minerals, Inc. (SVM), headquartered in Overland Park, KS produced borax and boric acid from potassium and sodium borate brines at its Searles Lake operation near Trona, CA. The brines were refined into anhydrous, decahydrate and pentahydrate borax in SVM's Trona and Westend plants.

Consumption

In 2019, the glass and ceramics industries remained the leading domestic users of boron products, consuming an estimated 60 percent of total borate consumption. Boron also was used as a component in abrasives, cleaning products, fertilizers, insecticides and in the production of semiconductors. Boron was the most widely used micronutrient in agriculture, applied primarily to promote seed production. Boron fertilizers were mostly sourced from borax and colemanite owing to their high solubility in water, allowing boron fertilizers to be delivered through sprays or irrigation water.

Foreign trade

U.S. exports of refined borax were 598 kt in 2019, a slight decrease from 610 kt in 2018. China, India, Indonesia, Malaysia and the Netherlands imported the largest quantities of refined borates from the United States. The average unit value for refined borate exports was \$449/t in 2019, a 5 percent decrease from \$472/t reported in 2018. Boric acid exports of 332 kt in 2019 represented an increase of 28 percent from 260 kt in 2018. Imports of boric acid in 2019 were 41 kt, about

20 percent lower than those of 2018. Approximately 63 percent of imported boric acid came from Turkey in 2019. The average unit value for boric acid imports was \$587/t in 2019, a 3 percent increase from \$570/t reported in 2018. The average unit value for refined borate imports was \$0.34/t in 2019, a 3 percent decrease from \$0.35/t reported in 2018.

International

Chile, Turkey and the United States led the world in the production of borates in 2019. Chile was the leading borate producer in South America. China mined more than 100 borate deposits in 14 Provinces. Boron resources in China, however, are of low quality, averaging around 8.4 percent B_2O_3 , in comparison to reserves in Turkey and the United States, which have grades ranging from 26 percent to 31 percent and 25 percent to 32 percent B_2O_3 , respectively. China has become more import reliant on borate products from South America, Turkey and the United States. Turkey's state-owned mining company signed a cooperative agreement with a company from China to build a 1.5 kt/a boron carbide plant in Balıkesir. Construction of the \$70 million plant began in October 2019 and was anticipated to be completed in two years. This plant was intended to expand Turkey's national defense manufacturing and will process boron carbide for military applications.

Outlook

Consumption of borates is expected to increase, spurred by strong demand in the agriculture, ceramic and glass markets in Asia and South America. Demand for boron-based fertilizers was expected to rise as a result of an increase in demand for food and biofuel crops. Higher crop prices have enabled farmers to invest more capital in advanced farming techniques and higher-grade fertilizers. The expectation of increased boron demand prompted several companies to perform prefeasibility studies at new boron mine prospects in a few countries, including the United States and Serbia. One company is expected to begin construction at a boron deposit in southern California when necessary permits are approved in 2020.

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BROMINE

by Emily K. Schnebele, National Minerals Information Center, U.S. Geological Survey

Two companies in Arkansas accounted for all of U.S. production of bromine in 2018. The bromine was recovered from underground brine wells in Arkansas at depths of about 2,400 m (7,900 ft) with bromine concentrations of 3,000 to 5,000 ppm. Domestic production data for elemental bromine are withheld to avoid disclosing company proprietary data. However, the United States was one of the top four producers in the world along with China, Israel and Jordan. World production of bromine in 2018, excluding the United States, was estimated to have decreased slightly to about 380 kt compared with 388 kt in 2017.

Consumption

Brominated flame retardants, intermediate compounds and industrial uses were the leading global applications for bromine. Bromine compounds also were used in a variety of other applications, including drilling fluids and industrial water treatment. U.S. apparent consumption of bromine in 2018 was estimated to be greater than 2017.

Foreign trade

In 2018, U.S. imports of bromine and bromine compounds were 70.1 kt, gross weight, a 7 percent increase from 65.3 kt in 2017. The average cost, insurance and freight price of elemental bromine imports in 2018 was \$3/kg compared with \$3.43/kg in 2017. Israel was the leading source of bromine imports into the United States, accounting for 77 percent of the total quantity imported on a gross weight basis. Exports of bromine and bromine compounds were 49.5 kt, gross weight, a 6 percent

decrease from 52.7 kt in 2017. The average unit value of exported elemental bromine in 2018 was \$2.63/kg compared with \$1.76/kg in 2017. Methyl bromide, a broad-spectrum pesticide, was the leading exported product in terms of gross weight, accounting for 53 percent of exported materials in 2018. The primary recipient of exported methyl bromide in 2018 was Mexico, which accounted for 91 percent.

Industry news

New environmental regulations initiated by the government of China in late 2017 continued in 2018. This led to the temporary shutdown of many industrial manufacturing plants for rectification and improvements, including bromine production facilities in Shandong Province. As a result, bromine production in China was estimated to have decreased in 2018 compared with 2017 production and the price of elemental bromine in China remained high throughout the year.

Outlook

Global consumption of brominated flame retardants (BFRs), particularly in the automotive, construction and electronics industries, remained strong in 2018, although environmental and toxicological concerns regarding some BFRs continued to be assessed. Questions of balancing fire safety with environmental and human health, in relation to BFRs, will likely continue to be examined in coming years.

Future bromine use in clear, brine drilling fluids will continue to be dependent on fluctuations in the business cycle for the oil- and gas-well drilling industry. ■

CEMENT

by Kenneth C. Curry, 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 makeup by weight. Cements are made from a material called clinker, which is ground into a powder and mixed with a small amount of gypsum and potentially a few supplementary cementitious materials to make cement. Clinker is produced from a precise combination of calcareous, aluminous, ferrous, and siliceous materials, which are combined through pyroprocessing of the requisite materials in a rotary kiln.

Production

In 2019, production of portland and masonry cement in the United States, excluding Puerto Rico, was estimated to be 88.5 Mt with a mill net value of about \$12.5 billion, a 2 percent increase in quantity and a 5 percent increase in mill net value from 86.4 Mt and about \$11.9 billion in 2018 respectively. Production in 2019 was 11 percent lower than the record of 99.3 Mt set in 2005 (Fig. 1).

Total world cement production in 2019 was estimated to be about 4.1 Gt, a slight increase from 4.05 Gt in 2018. China (2,200 Mt), India (320 Mt), Vietnam (95 Mt), the United States (89 Mt), and Egypt (76 Mt) were, in descending order of tonnage,

the leading producers in 2019. The United States manufactured about 2 percent of cement produced worldwide.

Consumption

Domestic cement consumption in 2019, as measured by sales to domestic final customers, was estimated to have increased by 4 percent to 102 Mt from 98.7 Mt in 2018, but was 20 percent lower than the 2005 record consumption of 127.9 Mt. The difference between consumption and domestic production in 2019 was met, in part, by an 8 percent increase in cement imports. The major end uses for cement in the United States are, in descending order by estimated market share, ready-mixed concrete, road paving, precast and prestressed concrete, building materials, brick and block, soil cement and oil-well drilling.

Environmental issues

Large quantities of raw materials (mainly carbonate rocks, especially limestone) and fuels are burned at high temperatures to make clinker, resulting in emissions of large quantities of carbon dioxide (CO₂) 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 CO₂, a major greenhouse gas.

Prices

The mill net value (price) of cement depends on application, quality, quantity purchased, source, and type, and therefore encompasses a range of prices. During 2019, the estimated domestic value of cement was \$12.5 billion with a unit value of \$123.50/t. This was a 5 percent increase in value compared with \$11.9 billion with a unit value of \$121/t in 2018.

Foreign trade

U.S. imports of cement, including clinker, in 2019 were 15.9 Mt, an increase of 8 percent from 14.7 Mt in 2018. Imports of cement in 2019 were still well below the record of 35.6 Mt in 2006. In 2019, Canada (33 percent), Turkey (23 percent), Greece (12 percent), and Mexico (8 percent) supplied the majority of U.S. cement imports, with the remainder coming from several other countries. Exports of cement were 1 Mt, an increase of 7 percent compared with 940 kt in 2018. Canada (80 percent), Mexico (8 percent), the Bahamas (6 percent), and Japan (2 percent) received the majority of U.S.

cement exports, with the remainder going to several other countries.

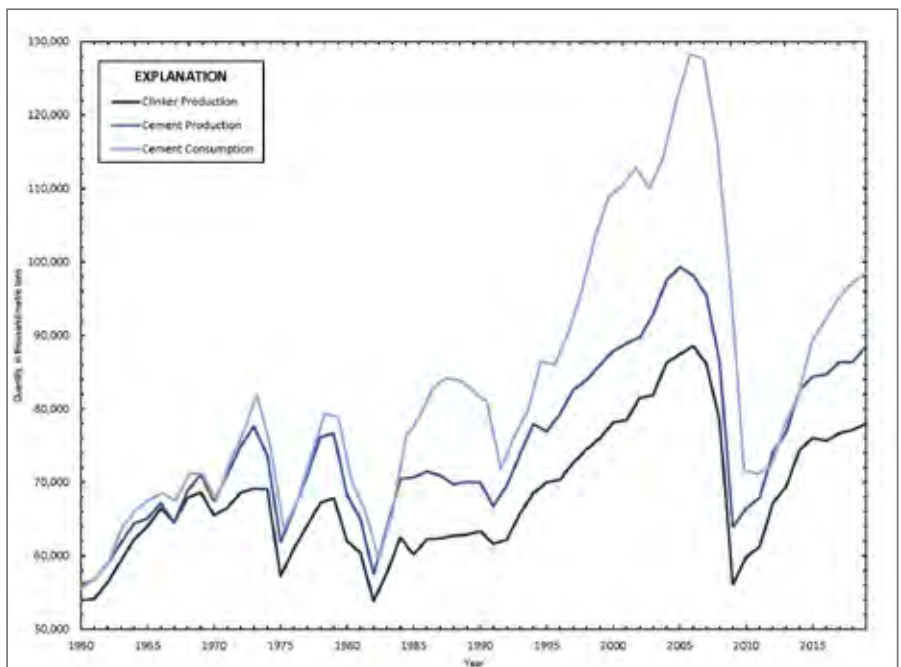
Outlook

The domestic cement industry is expected to continue to grow, albeit at a slower pace than the past few years. Volatility with the construction industry and continuing impacts from recently assessed tariffs are the limiting factors to further growth. One potential factor that could boost the industry is the need for increased public sector construction spending to replace the aging infrastructure in the United States. Imports are likely to continue to increase as cement manufacturer augment their cement supply to counteract reduced domestic production capacity resulting from kilns being idled owing to environmental concerns.

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Figure 1

U.S. clinker production, cement production and cement consumption, 1960-2019.



CHROMIUM

by Dr. Nils Backeberg, Roskill Information Services Ltd.

Chromium is sourced from the mineral chromite, its only currently economic occurrence. Chromite is used directly in industrial foundry and refractory sands or converted into sodium dichromate for further refinement into other chemicals and chromium metal, but the main consumption is in ferrochrome furnaces to produce an alloy used by the steel industry. More than 95 percent of chromium consumption is attributable to metallurgical applications, with stainless steel alone representing 78 percent of consumption in 2019. Trends in stainless steel production are, therefore, the main determinant for chromium demand. After several years of 4-10 percent/year growth in demand driven by stainless steel production, the longer-term chromium market is forecast to move into a period of more modest demand growth of 2-3 percent/year.

The niche chromium chemical and refined metal markets accounted for just below 3 percent of the total market in 2019. Prices for these niche products have followed different trends than chromium ores and ferrochrome, with chromium metal having reached a potential price floor in Q1 2020. The low metal price together with surplus chromium chemical supply saw sodium dichromate prices correct downward, after following a steady upward trend since 2017.

South Africa hosts more than 75 percent of the world's chromite reserves and resources and accounts for approximately 60 percent of annual global chromium ore production. Kazakhstan, India, Turkey, Finland and Zimbabwe together account for more than 30 percent of global chromite supply, making up the rest of the key producers. High prices in early 2017 encouraged large volumes of additional supply from South Africa, and during the three years that followed production increases have outpaced the growth in demand from the steel sector, solidifying a structural surplus that has suppressed prices.

Prices for chromite and ferrochrome have seen prices decline steadily during 2019, falling out of balance with the fundamentals of the cost curve. Prices for both products have fallen to below the 50th percentile of their respective cost curves toward the end of 2019, making the majority of production unprofitable. The low prices have been underpinned by weak markets and growing stainless steel inventories and by additional low-cost by-product chromite, extracted from tailings of the platinum group metal (PGM) UG2 reef mined from South Africa's Bushveld Igneous Complex. UG2 chromite

supply grew at double-digit rates for a second consecutive year in 2019, while primary chromite production in South Africa declined for the first time since 2011.

The growth in chromite supply during the last two decades has closely followed developments in China, where increasing ferrochrome capacity (requiring imported feed) to service the country's stainless steel industry has outpaced other producing regions. China has grown to account for 45 percent of global ferrochrome production in 2019 and Roskill forecasts its market share to jump to more than 50 percent as non-Chinese stainless steel production stagnates and existing ferrochrome producers outside of China face challenges from declining markets, climbing electricity prices and, looking forward, potential competition from Chinese producers.

South Africa, which led global ferrochrome production prior to China taking the lead in 2012, is facing ongoing challenges for its ferrochrome furnaces. Rising electricity tariffs have switched the country from being one of the cheapest producers a decade ago to one of the higher-cost producers. The headwinds have caused a consolidation of the ferrochrome industry in South Africa and several plants remain offline amid weak market conditions and low prices. South Africa is expected to continue to lose market share in the ferrochrome market, and Glencore is expected to lose its leading position as the world's largest ferrochrome producer in 2020, giving way to ERG's Kazchrome in Kazakhstan, closely followed by rising capacity of China's leading ferrochrome companies.

The chromite and ferrochrome markets were forecast to rebalance in 2020, following closures and cutbacks in production from key producers as low prices persisted throughout 2019. The outbreak of COVID-19 in Q1 2020 has already begun to ripple through the chromium industry. With the Chinese steel industry returning its furnaces into operation, available chromite stocks will only account for three months of demand, should supply be limited from South Africa and other producers moving into lockdown in order to curb the spread of COVID-19. Even if the lockdown period can be limited, the impacts of COVID-19 will likely accelerate the rebalancing expected for the chromium industry in 2020. The long-term fundamentals of the chromium industry cost curve will be underpinned by the growth-potential of byproduct UG2 chromite, which is linked to the performance of the PGM industry. ■

CONSTRUCTION AGGREGATES

by Mark J. Zkunczyk, consulting geologist

Construction aggregates is a general term used to describe crushed stone, sand and gravel, steel and iron slag, recycled asphalt pavement (RAP), recycled concrete and various other natural materials used by the construction industry. These materials are used in Portland cement concrete (PCC), bituminous concrete (asphalt) for roads and bridges, concrete blocks and pavers and other building materials.

In 2019, the U.S. Geological Survey (USGS) estimated that 1.53 Gt of crushed stone valued at more than \$18.7 billion was produced by an estimated 1,430 companies in 3,440 quarries and/or sales and distribution yards. The top 10 states were: 1) Texas, 2) Pennsylvania, 3) Florida, 4) Missouri, 5) North Carolina, 6) Ohio, 7) Georgia, 8) Virginia, 9) Illinois and 10) Kentucky. In 2019, Missouri replaced North Carolina for fourth position and North Carolina fell to number five. Ohio replaced Missouri as number six, Georgia and Virginia remained seven and eight respectively. Illinois replaced Tennessee at number nine and Kentucky replaced Illinois at number 10.

Total production of crushed stone increased approximately 9 percent from 2018, but the number of producing companies decreased from 1,465 in 2018 to 1,430 in 2019. Operating quarries decreased as well from 3,710 in 2018 to 3,440 in 2019. The USGS does not indicate why these decreases occurred. Distribution and/or sales yards remained the same.

The USGS estimates that 69 percent of crushed stone was produced from limestone and dolomite, about 15 percent from granite or granitic-type rocks such as gneiss and granodiorite, about 6 percent from traprock such as basalt, diabase and gabbro, 5 percent from miscellaneous stone, about 3 percent from sandstone and quartzite and 2 percent from marble, volcanic cinder such as scoria and pumice, calcareous marl, slate and shell material. The low-percentage rock types are generally of too poor a quality to meet state departments of transportation (DOT) specifications for PCC or asphalt aggregate, and therefore are not widely used. Volcanic cinder is used in some concrete blocks or lightweight aggregate, marble can be crushed to sand size (4.75-150 mm) that sometimes meet some DOT's specifications for concrete grade sand. Some shale can be expanded by heat in a kiln and used as a light-weight aggregate. Otherwise, shale does not meet specifications for any state approved aggregate source.

Crushed stone aggregates must conform to certain standards set forth by the American Association of State Highway Transportation Officials (AASHTO), ASTM, U.S. Army Corp of Engineers, the Federal Aviation Administration (FAA), railroads and private

industry engineers or architects.

Some of the most common tests are grading (size restrictions), resistance to abrasion and degradation, resistance to freezing and thawing, resistance to disintegration by sulfates, particle shape, specific gravity and absorption, alkali reactivity (silica and carbonate), deleterious material, petrographic examination for asbestiform and nonasbestiform minerals, sulfide minerals such as pyrite, pyrrhotite, arsenopyrite and chalcopyrite as well as foreign/deleterious material in fine or coarse aggregate.

Testing procedures and specifications vary from state to state. Most state DOTs follow ASTM and AASHTO procedures and specifications. The Army Corps of Engineers, FAA and railroads follow their own in-house testing and specifications. One test that seems to differ from state to state is the requirements for skid resistance (antiskid) or high friction aggregate. Skid-resistance aggregate is used in concrete and asphalt for the top course of heavily traveled roads. Studies have shown that limestone and some dolomites polish as traffic wears the surface of the road. When the road is wet, the polished aggregate allows more skidding before braking. Skid-resistant aggregate include sandstone, granite and traprock. However, these rock types must meet the normal physical testing required by each state. In the states where limestone and dolomite are commonly mined for crushed stone, the acid insoluble test is generally used to determine the amount of residue left after the rock is subjected to an acid bath. The amount of residue left determines if the limestone or dolomite can be used as skid-resistant aggregate.

Many aggregate producers test for asbestiform and nonasbestiform minerals in their quarries. This is sometimes difficult to delineate in the quarry without closely spaced core drilling. This is not only expensive but may not adequately delineate these minerals in the deposit. Many producers use a protocol to collect crusher dust at certain intervals during the production season. The dust is then sent to an authorized laboratory for identification of these minerals.

One quality issue which made national television and newspapers in 2019 and 2018 was the slow crumbling of concrete foundations in Connecticut and Massachusetts caused by pyrrhotite. Pyrrhotite is a sulfide mineral that when exposed to air and moisture on the surface of concrete begins to oxidize. During this process, cracks occur in the concrete caused by swelling, eventually leading to failures in the concrete foundation. Common sulfide minerals in aggregates are pyrite (FeS_2), chalcopyrite (CuFeS_2), arsenopyrite (FeAsS) and marcasite (FeS_2). Most of these sulfide

minerals occur as fine grains in the rock and are weak or brittle, so that they are generally removed during the crushing, washing and screening process. In the case of Connecticut and Massachusetts, pyrrhotite was contained in the sized aggregate used in the concrete for the foundations. Similar situations have occurred in Ohio, West Virginia, Pennsylvania, Missouri, Kansas and Kentucky.

Construction aggregates markets can range from low-grade material such as fill, road base and miscellaneous products, to washed and sized aggregate sold to the ready-mix concrete and asphalt producers. The three major markets are residential buildings, nonresidential buildings (airports, federal and state buildings hotels), and nonbuilding construction (roads and bridges). The market area is generally within trucking distances, as trucks transport about 85 percent of aggregates in the United States. Rail and barge or ship together total about 15 percent. As an industry rule of thumb, trucks can generally travel 56 to 64 km before transportation costs increase significantly. However, where aggregate shortages occur, such as for PCC sand and certain size aggregates, 95 to 145 km transportation distances are not uncommon. The transportation costs depend on many factors, such as road conditions, traffic, tolls, bridges, back hauls and weight laws. For example, relatively straight roads with limited traffic signals can allow trucks to carry material much farther than 64 km at low rates. Conversely, in areas near New York City, Atlanta, GA, Dallas/Forth Worth, TX, Los Angeles, CA and other major cities, trucks are slowed by traffic congestion and thus freight rates are much higher. In these cases, many of the trucks charge an hourly rate. Generally, all shipments or deliveries are based on a ton-mile basis. All these charges vary from state to state or region to region in the United States.

Rail rates are lower than trucking rates, but rail has limited areas of service. The producer using rail generally owns or leases a siding on the production end and a distribution yard on the delivery end. In addition, the producer typically either owns or leases the 90-to 113-t hopper cars needed for transport. A unit train generally contains 50 cars minimum for aggregate transport. However, the more rail cars used, the lower the transportation costs. Extra costs include storage, loading and unloading. Additional handling results in costs added to the aggregate at the final destination. Many producers with rail access participate in the ballast-stone market, as railroads sometimes send their own hopper cars to be loaded. Crushed stone aggregate is railed from producers in areas deficient in quality aggregate. For example, crushed stone is railed from the piedmont regions of Georgia, North Carolina and South Carolina to the coastal plain regions of those states and to Florida, which is deficient in skid-resistant or friction aggregate and/or quality aggregate. In the western states rail is used at some quarries that

are outside the distance for reasonable truck delivery rates.

Barges and ships are used on the east and west coast, Mississippi, Missouri, Ohio and Columbia Rivers, intercoastal waterways and the Great Lakes. Water aggregate shipments generally are less costly than rail, but extra costs are added at the dock for demurrage or the time it takes to unload or load the material.

Construction aggregates are sold on a free on board (f.o.b.) basis. Quarry or sand and gravel pit prices are listed at the scale house or provided by salespeople. The f.o.b. prices do not necessarily reflect the price to the contractor, bid work or to those companies that buy in large volumes. Prices vary regionally in the United States. In addition, when a producer is vertically integrated, its price from its quarry or sand and gravel pit to its asphalt plant or concrete batch plant may be the f.o.b. price or lower depending on which business unit needs to be profitable. This is sometimes called a transfer number for internal use only. Where aggregate is needed, f.o.b. prices are generally higher than areas where aggregate is abundant. For example, in Charleston, SC f.o.b. prices for crushed aggregate of any type is generally higher than Anderson, SC because quality aggregate must be railed from Rockingham, NC or near Anderson and Columbia, SC or shipped from the Bahamas or Nova Scotia, Canada. The same holds true for the Houston, TX market, as aggregate is brought in by rail and barge from great distances.

The marketability of the aggregate depends upon the results of some or all physical testing. However, there are many producers whose aggregate does not meet certain specifications and are sold for low-grade construction products or nonstate specification stone. Some producers in the United States sell more nonspecification aggregate by volume than state-approved aggregate. It is usually advantageous to be a state-approved source for crushed stone or sand and gravel aggregate.

Sand and gravel as construction aggregate are used for many of the same purposes as crushed stone. There are some differences which are mostly geologic and geographic in nature. In the aggregate industry, geography and geology play important and different roles between the two aggregate sources. Where there are large deposits of sand and gravel, such as the large alluvial fans of California or the glacial deposits in the northeast and north-central states, sand and crushed gravel is widely used. Where there are large deposits of rock, crushed stone is generally used, such as in the Atlanta, GA area. There are two exceptions. Natural sand is preferred over manufactured or stone sand by most ready-mix concrete and asphalt producers, and crushed stone is preferred over crushed gravel for the same use. Crushed stone is also preferred in asphalt. In both PCC and asphalt, crushed stone is more uniform, generally having one rock type while crushed gravel

may contain several lithologies or rock types. In ready-mix concrete and asphalt, some rock types may absorb more water or react differently to the cement additives or liquid asphalt, therefore resulting in poor-quality concrete or asphalt. The use of natural sand for PCC is not typical as it requires a certain size gradation. Much of the natural sand found is too fine-grained to meet the size specifications. This has caused a shortage in some areas of the country.

In 2019, the USGS estimates 960 Mt of construction sand and gravel were produced in United States. The top 10 states producing sand and gravel were Texas, California, Arizona, Minnesota, Michigan, Washington, Ohio, New York, Utah and Colorado. The top five states changed since 2018. Texas replaced California at number 1, Arizona remained number 3, Minnesota was 4, replacing Washington, which dropped to number 6, and Michigan remained at number 5. According to the USGS, the top 10 states together accounted for about 55 percent of the total production in the United States. Most of the sand and gravel production in 2019 was used in concrete. The leading producing states have abundant mines in alluvial fans, colluvium, river deposits and glacial deposits. However, natural concrete sand is not as abundant in some states because the sand is too fine-grained to meet state specifications. Most, if not all, the specifications required by states for crushed stone are the same for sand and gravel aggregates. Some states do not accept natural gravel (noncrushed) for use in PCC or asphalt products. Most states require two or more fractured faces of the sized gravel in order to be approved as coarse aggregate. Natural gravel is generally used for landscape products, flat commercial roofing material or other commercial products. This is generally low-volume, high-price material.

Recycling has increased in recent years. Recycled concrete and RAP are generally used for base materials, as they do not meet many state specifications for state-approved PCC or asphalt aggregate. Recycled construction materials have not yet become significant in the marketplace. The USGS reports that recycling remains a small percentage of aggregate consumption. However, many states are experimenting with recycled aggregates on certain roads. Other substitutes such as slag have quality issues that prevent major use in the industry, especially for steel slag. Steel slag reacts with cement to cause expansion in concrete, but iron slag is a good source of friction material when available. Slag also has environmental concerns perhaps from leaching of certain metals. Asphalt shingles are recycled at an asphalt plant where it is sometimes mixed with RAP to minimize the use of the liquid asphalt. All recycled material use depends on the mix design of the asphalt or concrete. In the past, sand used in asphalt generally had liberal specifications. Asphalt sand was only used as a filler. Recently, asphalt producers have been using washed PCC sand to blend with their RAP stockpiled

on site. RAP has an abundance of fine material that requires blending with sand so that the sand gradation has less fines to meet state specifications. In some areas of the country, concrete sand producers are providing washed sand to both ready-mix concrete and asphalt producers, creating more of a shortage of specification concrete sand.

There are many issues facing the construction aggregates industry. Since many rock quarries and sand gravel pits need to be near urban areas in order to get their products to the market at competitive prices, the general public is exposed to their operations more than any other mining industry. The industry has come a long way in mitigating many environmental concerns of the local citizens. Today, all major companies and most of the other aggregate-producing companies have environmental issues. Because about 85 percent of aggregate production is transported by truck, truck traffic remains a concern to the local citizens and is difficult to mitigate. Dust, noise, blasting, wetlands issues and other issues have through the years been widely mitigated in most operations. Still, the fact remains that opposition from not-in-my-backyard (NIMBY) protest cost the industry undue expense in permitting or expanding quarries or sand and gravel operations.

To further emphasize permitting issues, Cemex Construction Materials in 2019 was still fighting for expansion of its rock operation in Hernando County, FL. Martin Marietta Materials Inc. applied to expand its quarry in Parkdale, CO onto Bureau of Land Management lands. In East Rockhill, PA, Hanson Aggregates continues to battle opposition over its expansion of their quarry at that location. Martin Marietta was halted in expanding its Missouri rock operation in Cass County. Finally, American Aggregates of Michigan was denied a permit to mine sand and gravel in Metamora Township, Michigan. These are only a few examples of what appears to be happening in all states.

Safety in aggregate operations is a major concern. Many of the producers have strict requirements for their workers, consultants, visitors and management within and around their operations. This includes wearing highly visible colored clothing, steel-toe boots/shoes, hard hats, safety glasses and having limited access to the active site or being escorted by company personnel. In the operating plant there are many safety requirements including emergency shutoff on crushers, screens and other movable machinery within the operating plant. Service trucks have blinking lights and/or highly visible color flags attached high above the frame of the vehicle. Haul trucks, front-end loaders and the like are equipped with back-up alarms, strobe lights and emergency stop controls.

Acquisitions continued in 2019, they include the acquisition of United Materials by Votorantim Cimentos; Windsor Rock Products by River Bend Materials; Colorado River Concrete by LaFarge Holcim; Yager Materials by Carmeuse S.A.; Transit Mix Concrete by Aggregate Industries; and JSL Materials (John S. Lane and Sons) by Peckham Materials. ■

DIATOMITE

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

The United States continues to be the world's leading producer and consumer of diatomite. Production of diatomite in the United States during 2019 was estimated to be 980 kt, slightly more than that in 2018. Six companies operated 12 mines and nine processing facilities in California, Nevada, Oregon and Washington. U.S. diatomite exports were 68 kt. Imports were much lower at approximately 10 kt. Total world production of diatomite was approximately 2.9 Mt in 2019. Following the United States in diatomite production, other significant producers in 2019 were Denmark (440 kt), China (420 kt), Turkey (170 kt) Republic of Korea (130 kt), Peru (110 kt) and Mexico (100 kt). World resources of crude diatomite appear to be adequate for the foreseeable future. However, transportation costs may encourage development of sources of material closer to markets.

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.

Prices

The unit value of diatomite varied widely by end use in 2019. Since 2014, the average unit value of diatomite has increased by nearly 29 percent. Diatomite used as an absorbent was priced at \$10/t, but specialty-grade diatomite, used in art supplies, cosmetics or biomedical applications, was priced as high as \$10,000/t. Since 2014, the average unit value of diatomite has increased to \$360/t from \$280/t.

Uses

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 2019, approximately 60 percent of diatomite-derived products was utilized in filter aids. The remaining 40 percent was used in absorbents, fillers, lightweight aggregates and other applications. A small amount, less than 1 percent, was used for specialized pharmaceutical and biomedical purposes.

Processing

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.

Substitutes

Many materials can be substituted for diatomite, especially for lightweight aggregate 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, perlite, talc, vermiculite, ground limestone, mica and silica sand. For thermal insulation purposes, materials such as specialty brick, various clays, mineral wool, expanded perlite and exfoliated vermiculite may be used. Many alternatives exist for diatomite as a pozzolan, but its use as an ingredient of portland cement has increased in recent years. The encroachment of natural and synthetic substitute materials into diatomite markets has not been significant.

Outlook

In December 2019, an outbreak of a novel coronavirus (COVID-19) was first identified in China. The World Health Organization declared that COVID-19 was a global pandemic on March

11, 2020. Measures instituted to mitigate the spread of the COVID-19 pandemic, such as closures of nonessential businesses, are likely to cause disruptions in the mining industry across the United States and around the world. The duration and

the outcome of the COVID-19 pandemic remains uncertain, but it is expected that the economies of the United States and the world as a whole will likely be negatively affected, which could influence the performance of the diatomite industry. ■

DIMENSION STONE

by Thomas P. Dolley, National Minerals Information Center, U.S. Geological Survey

Dimension stone can be defined as natural rock material quarried for the purpose of obtaining blocks or slabs that meet specifications as to size (width, length and thickness) and shape for architectural or engineering purposes. Color, grain texture and pattern, and surface finish of the stone are also normal requirements. Durability (essentially based on mineral composition, hardness and past performance), strength and the ability of the stone to take a polish are other important selection criteria. Although a variety of igneous, metamorphic and sedimentary rocks are used as dimension stone, the principal rock types are granite, limestone, marble, sandstone and slate.

Production

Approximately 2.7 Mt of dimension stone, valued at \$440 million, was produced domestically in 2019. Dimension stone was produced by 197 companies operating 250 quarries in 33 states. Leading producer states, in descending order by tonnage, were Texas, Wisconsin, Indiana, Georgia and Vermont. These five states accounted for 68 percent of the tonnage and contributed about 56 percent of the value of domestic production. Approximately 50 percent, by tonnage, of dimension stone sold or used was limestone, followed by sandstone (20 percent), granite (18 percent), miscellaneous stone (8 percent) and marble and slate (2 percent each). By value, the leading sales or uses were for limestone (45 percent), followed by granite (25 percent), sandstone (11 percent), miscellaneous stone (9 percent), slate (6 percent) and marble (4 percent). Rough stone represented 54 percent of the tonnage and 47 percent of the value of all the dimension stone sold or used by domestic producers, including exports. The leading uses and distribution of rough stone, by tonnage, were in building and construction (53 percent), and in irregular-shaped stone (35 percent). The leading uses and distribution of dressed stone, by tonnage, were in ashlar and partially squared pieces (41 percent), slabs and blocks for building and construction (12 percent) and curbing (11 percent).

Apparent consumption of all dimension stone in the United States in 2019 was valued at \$2.2 billion — down by 9 percent from that of 2018. This included apparent consumption of granite that

was estimated to be \$960 million — a decrease of 4 percent from that of 2018.

Foreign trade

In 2019, the value of total imports into the United States was \$1.86 billion — down by 11 percent from the \$2.09 billion value of 2018. Of the \$1.86 billion import value, dimension granite accounted for about \$863 million. Principal import sources for dimension stone were, in descending order of value, Brazil, China, Italy and India. The value of U.S. exports in 2019 decreased to \$57 million — down by 19 percent from that of 2018. Principal export destinations for dimension stone were, in descending order of value, Canada, Italy and China.

Consumption

The United States is one of the world's leading markets for dimension stone. In 2019, steady activity in new residential construction resulted in a slight increase in domestic production of dimension stone compared with that of the previous year. Dimension stone for construction and refurbishment was used in commercial and residential markets; in 2019, the renovation market for existing homes remained steady and unchanged compared with that in the previous year.

Government and regulatory activity

The dimension stone industry continued to be concerned with the safety and health regulations and environmental restrictions in 2019, especially those concerning crystalline silica exposure. Beginning in 2016, the U.S. Occupational Safety and Health Administration (OSHA) finalized new regulations to further restrict exposure to crystalline silica at quarry sites and other industries that used materials containing it. Phased implementation of the new regulations was scheduled to take effect through 2021, affecting various industries that use materials containing silica. Most provisions of the new regulations became enforceable on June 23, 2018, for general industry and maritime operations. On Aug. 14, 2019, OSHA requested comment and information to enable the agency to consider new developments and enhanced control methods for equipment that generates exposures to silica.

Outlook

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of nonessential businesses, are likely to cause disruptions in the mining industry across the United States and around the world. The duration and the outcome of the COVID-19 pandemic remains uncertain, but it is expected that the economies of the United States and the world as a whole will likely be negatively affected, which could influence the performance of the dimension stone industry. ■

FIRE CLAY

by Jason Christopher Willett, National Minerals Information Center, U.S. Geological Survey

Fire clay was the dominant clay type mined in the United States prior to the 1940s and accounted for nearly 70 percent of total clay tonnage produced from 1900 through 1939. Domestic production of fire clay (quantity sold or used by producers) increased sharply from the beginning of the United States' involvement in World War II through the immediate post-war period, peaking at 10.8 Mt in 1951. After 1956, production began to steadily decrease. In every year since 1986, fire clay sales have been lower than those in 1900. Much of the decline was attributed to greater use of higher-alumina clays, nonclay refractory products and monolithic refractory products in order to reduce fuel costs and adapt to changing furnace operation requirements.

Six companies (Belden Brick Co.; Christy Minerals Co.; Elgin-Butler Co.; General Shale Brick, Inc.; HarbisonWalker International and Triangle Brick Co.) were thought to mine fire clay in the United States during 2019. Other companies may or may not have produced fire clay because year-to-year output has become variable in recent years as common clay producers entered and exited the market in response to short-term customer demands. In 2019, fire clay production was an estimated 556,000 t valued at \$6.4 million. Fire clay was produced in five states, the leading producer being Missouri. Preliminary production data for 2019 were estimated based on current and previous producer reports as well as employment hours published by the Mine Safety and Health Administration. Reliable data on global output of fire clay are not available because many countries either do not report clay production or do not distinguish between fire clay and other clay types.

Consumption

Domestic markets for fire clay in 2019 were, in descending order of tonnage, portland cement, common brick, firebrick and a small amount in ceramic floor and wall tile, miscellaneous ceramics, pottery and miscellaneous refractories. Fire clay sales data were mostly withheld to avoid disclosing company proprietary data, but heavy-clay products (common brick and portland cement) represented

nearly 70 percent of sales, and refractories accounted for most of the remaining consumption.

Prices

The average unit value of fire clay was estimated to be \$11/t in 2019, with unit values for individual operations ranging from \$9 to \$15/t. The price of fire clay has trended downward since 2007, when the average unit value was \$42/t. The average free alongside ship value of exported fire clay was estimated to be \$251/t in 2019 and the average customs value of imported fire clay was \$482/t. Average unit values for exports and imports typically fluctuate from year-to-year owing to the influence of small, high-value shipments.

Foreign trade

Fire clay exports were estimated to have decreased by 22 percent in 2019 to 194,000 t valued at \$48.7 million from an estimated 250,000 t valued at \$60.8 million in 2018. The principal destinations for U.S. exports of fire clay and refractory kaolin in 2019 were the Netherlands (36 percent), Mexico (20 percent), Japan (14 percent) and Taiwan (8 percent). Imports of fire clay totaled 20,600 t valued at \$9.9 million, a decline of 40 percent from 34,100 t valued at \$15.7 million in 2018. Fire clay imported into the United States primarily originated in China (94 percent) and Canada (5 percent).

Outlook

In December 2019, an outbreak of a novel coronavirus (COVID-19) was first identified in China. The World Health Organization declared that COVID-19 was a global pandemic on March 11, 2020. Measures instituted to mitigate the spread of the COVID-19 pandemic, such as closures of nonessential businesses, are likely to cause disruptions in the mining industry across the United States and around the world. The duration and the outcome of the COVID-19 pandemic remains uncertain, but it is expected that the economies of the United States and the world as a whole will likely be negatively affected, which could influence the performance of the fire clay industry. ■

FLUORSPAR

by Peter Huxtable, Huxtable Associates, United Kingdom

World fluorspar demand weakened from mid-2019 due to the reduced global demand from the automotive industry, which accounts for a significant input from fluorspar. Supply remained tight due to further production shutdowns in China as a result of the continued environmental measures — and only limited new production output. China became a net importer of the material, most originating from Mongolia but also from Myanmar and Mexico. This resulted in higher prices for acidspar, which remained around \$400/t f.o.b. China as in 2018.

Fluorspar (CaF_2) consumption in the United States is essentially all from imports. Hastie Mining and Trucking Co. produce some fluorspar as a byproduct of its limestone quarry operations in Illinois. In addition, a small amount of usable synthetic fluorspar was produced from industrial waste streams.

World production output has slipped since 2011 (7.3 Mt) to 6.32 Mt in 2017 but has shown recovery in the last two years to 6.8 Mt in 2019 due to a significant increase in output from Mongolia.

China remains the dominant producer (54 percent), followed by Mexico (16 percent) and Mongolia (11 percent). South Africa, Europe and Vietnam together contributed in roughly equal parts another 11 percent.

The new SepFluor Ltd. Nokeng operation in South Africa commenced operation in September with the first 10 kt shipment in December. Both SepFluor and Canada Fluorspar in Newfoundland (which commenced output in August 2018) have an eventual expected output of 200 kt/a each when fully operational.

Trade

In 2019, U.S. fluorspar imports totaled 427 kt, which included 369 kt of acid-grade fluorspar (acidspar) and 55 kt of metallurgical-grade fluorspar (metspar). This was a decrease of 8 percent compared with 2018 due to lower imports of both acidspar (3 percent) and metspar (29 percent). Mexico was the leading supplier of fluorspar to the United States, accounting for 67 percent of total imports, followed by Vietnam (12 percent), China (12 percent), South Africa (4 percent), Spain (2 percent) and Canada (1 percent).

Leading imports, in descending order of quantity, were from Mexico: 235 kt of acidspar and 54 kt of metspar, Vietnam: 53 kt of acidspar, China: 51 kt of acidspar and 1 kt of metspar, South Africa: 17 kt of acidspar, Spain: 10 kt of acidspar, Canada: 5 kt of acidspar and 1 kt from Mongolia. Fluorspar exports totaled 17.7 kt in 2019,

85 percent as metspar with 15.4 kt to Canada and 1.3 kt to Mexico. Most were re-exports of imported fluorspar.

Net imports of hydrofluoric acid (HF) were 105 kt, much the same as in 2017/2018 and mainly imports from Mexico. There were 14 kt exported to Canada and imports of electronic grade material from South East Asia (7 kt) and Europe (3 kt). Net imports of aluminum fluoride (AlF_3) were up to 18 kt (5 kt in 2018) with 72 percent from Mexico and the remainder from Canada, Italy and Jordan. This indicates an improvement in aluminium production but still lower than pre-2014 levels of 40 kt/a.

Consumption and uses

Apparent U.S. consumption of fluorspar in 2019 was 406 kt, a decrease from 438 kt in 2018 due to a 3 percent decrease in acidspar consumption and 55 percent in metspar use.

Worldwide, the largest traditional markets for fluorspar are for the chemical industry and the production of HF (40 percent), AlF_3 and synthetic cryolite (both used in aluminum smelting) (25 percent); and in steelmaking (30 percent). In the United States there is no longer any production of AlF_3 .

The major end use for HF is in the manufacture of fluorocarbons used predominantly as refrigerants, air-conditioning and foam-blowing agents, in the production of fluoropolymers and fluoroelastomers, chemical derivatives and for petroleum alkylation, uranium processing, stainless steel pickling and other diverse uses. In the electrolytic reduction and refining of aluminum, AlF_3 is used as a flux to improve efficiencies by lowering the melting point of the electrolyte mix. HF overall requirement remained steady at 1.2 Mt in 2019. China still provides 45 percent of world output, North America 25 percent and Europe 13 percent. China continues to export 0.25 Mt a year, mainly to Japan, South Korea and other southeast Asia countries.

AlF_3 worldwide demand remained essentially

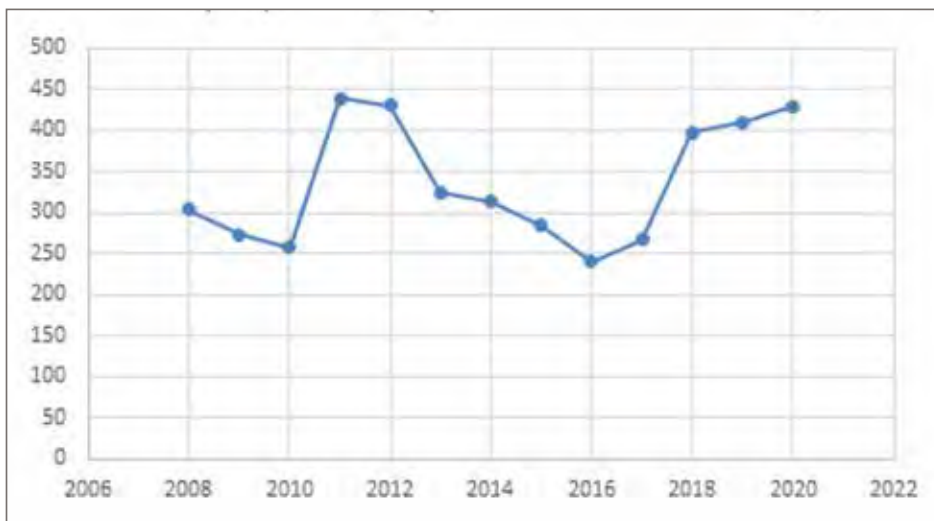
Table 1

World fluorspar demand.

World demand, Mt	2015	2016	2017	2018	2019
Acidspar	4.16	4.31	4.16	4.15	4.21
Metspar	2.33	2.31	2.16	2.45	2.59
Total	6.49	6.62	6.32	6.60	6.80

Figure 1

Acidspar prices \$US/t f.o.b. China 2008-2020 Q1.



steady at 1.1 Mt. China produced 65 percent of world output but only 56 percent of the aluminium production. It exported 12 percent of its output.

Future fluorspar demand is closely linked to the health of international economies, although the fluorocarbon market is more problematic as both the European Union (EU) and the United States introduce more restrictions on the use of certain hydrofluorocarbons (HFCs) and chlorofluorocarbons (HCFCs) due to their global warming potential (GWP). The low GWP hydrofluoroolefin refrigerant HFO-1234yf remains the preferred replacement for HFC-134a by both the U.S. Environmental Protection Agency (EPA) and the European Union.

World fluorspar markets have been on a roller coaster in recent years — strong demand and high prices leading up to the 2008-2009 recession, a major slump during the recession, a strong rebound in 2011-2012, then a steady fallback until the supply disruptions in China as a result of the environmental inspections and plant closures from late 2017.

Prices

Worldwide acidspar prices based on China f.o.b. material weakened after the heights of 2011-2012 when they reached \$440/t. and continued to fall to a low of \$241/t in 2016 but recovered to \$398/t in 2018 and \$410/t in 2019.

Industry news

Fluorspar was excluded from the U.S. Department of the Interior duties on Chinese imports — and imports were 53 kt compared to 1kt in 2018. However, HF and AlF_3 were included and in the further increases imposed in May and August, but domestic requirements were easily met from Mexico.

In Vietnam, Masan Resources' Nui Phao tungsten, copper, fluorspar and bismuth mining project, commissioned in 2014, continued fluorspar shipments to major markets of 240 kt in 2019.

Canada Fluorspar's Newfoundland acidspar

operation commissioned late 2017 remained well below the planned 200 kt/a level.

SepFluor commissioned its Nokeng Mine and 180 kt/a acidspar and 30 kt/a metspar plant in South Africa in September and the first 10 kt shipment was made in December.

Mexichem changed its name to Orbia — and their fluorine subsidiary business to Koura Fluor in September.

GFL (Gujarat Fluorochemicals Ltd) GM Fluorspar SA 40 kt/a acidspar operation at Taorirt, Morocco commissioned in 2018 is expanding production to 60 kt/a due on-stream in 2020.

Trends and outlook

The outlook for steel and aluminium remains strong but for the chemical industry there still remain environmental concerns for fluorine products, most particularly in Europe through the 2014 F-Gas Regulation that aims to reduce F-gas emissions (from high GWP HFCs, PFCs and sulfur hexafluoride (SF_6)) by two-thirds of current levels by 2030. This will inevitably lead to some not-in-kind replacements. The EPA SNAP (Significant New Alternatives Policy), effective 2016, placed restrictions on the use of several HFCs and HCFCs. Further and wider restrictions on the use of HFCs were agreed by 200 countries at the Montreal Protocol meeting in Kigali, Rwanda in 2016. The United States and European Union agreed to reduce emissions by 10 percent of 2011-2013 levels by 2019 and 85 percent by 2036.

The acceptance in the European Union, United States and by the International Panel on Climate Change of refrigerant gas HFO-1234yf with a GWP lower than CO_2 as the preferred car air-conditioning replacement for HFC-134a (banned on new vehicles from January 2017) developed jointly by Chemours and Honeywell has encouraged Honeywell to expand production at Geismar, LA, and Arkema to bring capacity on-stream in Asia and Europe. Chemours' new plant in Wilmington, NC commenced operations in February tripling its output of HFO-1234yf, the largest plant in the world. Arkema continues to expand fluoropolymer PVDF production in Calvert City, KY and Pierre-Benite, France; and a further 50 percent expansion in Changshu, China scheduled for 2020.

The growth of fluoropolymers that have captured fluorine in their products, and are outside environmental constraints, remains strong and into fast-growing sectors, which include Li-ion batteries, electronics and solar panels. However, there are concerns and increasing restrictions on the use of grease-repellant perfluorinated chemicals (PFCs) in fast-food packaging and drinking water.

The use of byproduct fluorosilicic acid (FSA) from phosphate production for both AlF_3 and HF production remains a long-term potential competitor but there is only some 15 percent of FSA being used currently mainly in AlF_3 manufacture.

2020 started slowly with large producer stocks and continued weak demand. The coronavirus COVID-19 pandemic severely impacted China's output and the demand from industry for fluorspar. Some other

producers also closed during the pandemic including SepFluor. The immediate implications are uncertain including the possibility of a global recession. However, the longer-term demand for fluorspar in the diverse and many fast-growing products is secure. China will be a diminishing player for feedstock and the new producers in Canada and South Africa will assist in balancing the requirements along with expansions in Southeast Asia and Africa. ■

GEMSTONES

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

The estimated value of natural gemstones produced from U.S. deposits during 2019 was \$9.8 million, a 3 percent increase from that of 2018. U.S. natural gemstone production included agate, beryl, coral, diamond, garnet, jade, jasper, opal, pearl, quartz, sapphire, shell, topaz, tourmaline, turquoise and many other gem materials.

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

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

During 2019, each of the 50 states produced at least \$1,600 worth of gem materials. Thirteen states accounted for 95 percent of the total value, as voluntarily reported to the U.S. Geological Survey by survey respondents. These states were, in order of descending value of production, Arizona, Oregon, Nevada, California, Montana, Maine, Arkansas, Colorado, Utah, Idaho, North Carolina, Tennessee and New York. Some states are known for the production of a single gem material, such as Tennessee for freshwater pearls. Other states, including Arizona, California, Idaho, Montana, Nevada and North Carolina, are known for producing a variety of gemstones. North Carolina is the only state with identified deposits of all four of the most popular precious gemstones: diamond, emerald, ruby and sapphire.

The estimated value of U.S. synthetic or manufactured gemstone production was \$65 million

in 2019. Reported output of synthetic gemstones was, in order of decreasing production value, from four firms in North Carolina, California, Maryland and Arizona. Production included the manufacture of azurite, malachite, diamond, moissanite and turquoise.

Consumption and uses

Although the United States accounts for only a small portion of the total global gemstone production, it is the world's leading gemstone market. U.S. gemstone markets were estimated to account for more than 35 percent of world gemstone consumption in 2019. The U.S. apparent consumption for unset gem-quality diamond during 2019 was estimated to be about \$19.7 billion. U.S. apparent consumption for unset nondiamond gemstones totaled about \$2.01 billion. The major uses for gemstones in the United States were in jewelry, for carvings, and in gem and mineral collections.

Prices

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

Imports and exports

During 2019, total U.S. gemstone trade with all countries and territories was about \$40.7 billion (\$22.4 billion in imports plus \$794 million in domestic exports and \$17.4 billion in reexports). In 2019, U.S. domestic exports of diamond were valued at \$529 million and reexports were valued at \$17.2 billion. U.S. domestic exports of gemstones other than diamond were valued at \$265 million and reexports were valued at \$269 million. U.S. imports of diamond were valued at \$20.2 billion, and U.S. imports of

gemstones other than diamond were valued at \$2.26 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 re-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 average of U.S. import sources by value, the leading gemstone sources were India, 37 percent; Israel, 33 percent; Belgium, 14 percent and South Africa, 4 percent. Typically diamond imports accounted for 90 to 95 percent of the total value of gemstone imports.

Outlook

As domestic and global luxury spending increases, sales of gemstones and jewelry are expected to increase also. Internet sales of diamonds, other gemstones and jewelry increased during 2019. They are expected to continue to increase in acceptance, along with other forms of electronic commerce (e-commerce) that emerge to serve the diamond and gemstone industries, as the gemstone industry and its customers become more comfortable with and learn more about new e-commerce tools. Internet sales are expected to add to

and partially replace brick-and-mortar store sales.

Global diamond production is expected to decrease during the next five years as new projects and expansions fail to offset lost output from mine closures. By 2025, several large mines will reach the end 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 transparent industry trade standards to maintain customer confidence.

Recent global developments, however, may affect the gemstone industry, at least in the near term. In December 2019, an outbreak of a novel coronavirus (COVID-19) was first identified in China. The World Health Organization declared that COVID-19 was a global pandemic on March 11, 2020. Measures instituted to mitigate the spread of the COVID-19 pandemic, such as closures of nonessential businesses, are likely to cause disruptions in the mining industry across the United States and around the world. The duration and the outcome of the COVID-19 pandemic remains uncertain, but it is expected that the economies of the United States and the world as a whole will likely be negatively affected, which could influence the performance of the gemstone industry. ■

GRAPHITE

by Andrew Scogings, KlipStone Pty Ltd.

Graphite is an allotrope of carbon, characterized by a hexagonal structure that facilitates easy cleavage, which makes it one of the softest substances known. Graphite is grey to black, opaque, very soft, has a low density and a metallic luster. It is flexible and exhibits both metallic and nonmetallic properties,

making it suitable for diverse industrial applications. Physical properties include specific gravity of 2.2 and Mohs hardness of 1-2.

Natural graphite occurs in several forms, described as amorphous, flake and vein. Graphite may also be manufactured synthetically from carbon-bearing raw materials such as petroleum coke and tar pitch.

Production of natural graphite

Flake graphite deposits typically have tabular or lens-like geometry and are hosted in metamorphic rocks such as gneiss and schist (Fig. 1). It is and generally mined opencast, though some high-grade flake graphite deposits were mined underground in Germany and Norway. Most flake graphite deposits being mined opencast contain between about 5 and 15 percent graphite, whereas underground mines have grades of around 20-30 percent graphite.

Vein deposits have complex geometry, are generally less than a meter in width and are selectively mined underground in Sri Lanka. Amorphous graphite is mined underground and usually extracted using selective room-and-pillar mining methods, similar to coal mining.

Natural graphite products generally contain

Figure 1

High-grade flake graphite ore from a mine in Heilongjiang Province, China. Photograph: Andrew Scogings.



Table 1

Examples of refractory products and graphite specifications. Source: Christoph Frey, Pro-Graphite (IM Graphite and Graphene Conference 2014).

Product	Flake size	Flake graphite quality (% carbon)
Unshaped refractories	> 150 micron	85-94
Graphite-containing crucibles	> 150 micron	85-96
Magnesia/dolomite carbon bricks	< 150 to > 300 micron	90-95
Alumina magnesia carbon bricks	< 150 micron	92-94

associated mineral impurities, known as ash. These impurities may include silicate and sulfide minerals such as quartz or pyrite in the case of flake graphite. Amorphous graphite may contain sedimentary rock impurities such as shale, sandstone, quartzite or limestone.

The most commonly used beneficiation method for flake graphite is flotation, and acids may be used to leach out impurities. The graphite ore is crushed and ground in rod mills in closed circuits with screens, before rougher flotation, followed by several regrind and cleaner flotation stages and final drying, screening and packaging.

Global annual natural graphite production is around 1.1 Mt. Flake graphite is estimated to account for about 800 kt, amorphous graphite about 320 kt and vein graphite around 4 kt.

According to U.S. Geological Survey (USGS) data, China was the world's leading producer of natural graphite in 2019 and supplied about 700 kt, followed by Mozambique (100 kt), Brazil (96 kt), India (35 kt) and Russia (25 kt). The USGS reports Madagascan production of 47 kt; however, the author's opinion is that Madagascan production may have been lower than this.

Downstream production is carried out in the United States by specialist processors such as Asbury Carbons, Superior Graphite and GrafTech International. For example, Asbury processes, upgrades and trades many types of carbons, including natural and synthetic graphite and sells to a range of end markets, including lubricants, refractories and foundry industries. Superior Graphite specializes in electro-thermal purification technologies, engineered graphite electrodes, advanced ceramic shapes and powders, precision particle processing and carbon coatings. GrafTech International is focused on synthetic graphite products and markets, particularly electrodes but the company also manufactures products based on natural graphite for thermal applications in the electronics industry and for sealants. The company buys flake graphite from sources around the world to manufacture into expandable graphite.

Most spherical graphite for lithium-ion battery anodes is manufactured in China and then exported to Japan or Korea for final coating. An Australian company that produces graphite at Balama in Mozambique has established a battery-anode material (BAM) plant in Vidalia, LA and announced the first production of purified spherical graphite in late 2019.

Consumption, uses and specifications

The major usages of graphite are in refractories, batteries, expandable graphite, plus brake linings, steelmaking and foundry operations.

The largest end market for natural graphite

is in refractories, foundries and crucibles used in high-temperature environments such as steel, glass and cement production. These markets account for around 40 percent of total graphite consumption; predominately consuming flake and vein graphite.

Metallurgy is the second largest market for natural graphite, which is used in metal production, particularly as a re-carburizer in steel, consuming mainly amorphous graphite or fine flake. This accounts for approximately 30 percent of total natural graphite output.

The third largest market for both flake and amorphous graphite is in parts and components; this range of products includes motor vehicle brake pads, carbon brushes for electric motors and pencils. As a group, it is believed to consume about 10 percent of total output.

Batteries are the fourth largest graphite market. Although only consuming around 10 percent of worldwide graphite production, it is potentially the fastest-growing market. Chinese producers use minus 100-mesh (94 percent C) small flake for making spherical graphite (for battery anode applications). Anode manufacturers typically blend natural spherical graphite ~50:50 with synthetic graphite.

Solid lubricants based mainly on amorphous graphite consume a further 10 percent of production, having been a classic use for centuries.

Expandable graphite is another market that is anticipated to grow, for applications such as fire retardation to replace halogenated retardants,

Table 2

China national standards: flake graphite products categorized by carbon content. Source: GB/T 3518-2008 flake graphite standards.

Category	Lower limit (% carbon)	Upper limit (% carbon)
LC (high purity)	≥ 99.9	100
LG (high carbon)	≥ 94.0	< 99.9
LZ (intermediate carbon)	≥ 80.0	< 94.0
LD (low carbon)	≥ 50.0	< 80.0

Table 3

Publicly reported mineral resource estimates for flake graphite projects, by country. Note: differences in tonnages and grades may occur due to rounding. Compiled by Andrew Scogings.

Country	Mineral resource	Graphite grade	Contained graphite
	Mt	%	Mt
Mozambique	3,002	10	311
Tanzania	978	6	59
Canada	368	6	23
United States	332	4	14
Madagascar	171	6	11
Australia	149	9	13
Russia	116	13	15
Malawi	115	7	8
Sweden	58	16	9
Finland	19	5	1
Total	5,308 Mt	9	464 Mt

insulation and heat transmission applications (e.g. graphite foil). These markets require large flake products generally >80 mesh. Lower product purity is acceptable for the construction industry, compared with graphite foils which require high purity.

Graphite is typically specified at a minimum by particle size and carbon content (Table 1). There are no set industry specifications, although in countries such as China the government has established national standards (Table 2). Other specifications may include bulk density, crystallinity, or expansion volume.

Trade

The major primary producing and exporting countries include China, Brazil, India, North Korea, Mexico, Mozambique and Canada. Imports are dominated by the United States, China (from Korea and Mozambique), Germany, Japan and India.

Sri Lanka has exported around 4 kt/a of vein graphite in recent years at prices exceeding \$1,600/t according to UN trade data.

U.S. natural graphite imports were approximately 58 kt in 2019 compared with 71 kt in 2018 and 52 kt in 2017. The imports were described by the USGS as being 65 percent flake, 34 percent amorphous and 1 percent lump and chip graphite. China, Canada, Brazil and Madagascar supplied most of the flake graphite; Mexico provided all amorphous graphite and Sri Lanka provided all the lump and chip (USGS, MCS-2020).

The USGS noted that sources of imported natural graphite from 2015 to 2018 into the United States were as follows: China, 33 percent; Mexico, 24 percent; Canada, 16 percent; India, 9 percent and

other, 18 percent. Sri Lanka was the sole source of lump and chip graphite.

Mozambique joined the ranks of major exporters in 2019. Publicly available data from the Balama Mine in Mozambique indicates production of 152 kt and sales of 163 kt of flake and fine graphite during 2019, at an average selling price of \$443/t CIF. The Balama Mine reduced production by about two-thirds in the final quarter of 2019, in response to global oversupply and in an effort to stabilize graphite prices.

Prices

The *USGS 2020 Mineral Commodity Summary* estimated import prices into the United States during 2019 as \$1,300/t for flake; \$2,370/t for Sri Lankan lump and chip, and \$438/t for amorphous graphite. By comparison, prices during 2018 were \$1,520/t for flake; \$1,890/t for Sri Lankan lump and chip, and \$310/t for amorphous graphite.

One graphite price not generally quoted is for Jumbo flake, a term that describes flakes +35 mesh size or larger. Trade is believed to be relatively limited and prices may have been around \$2,000/t in 2019.

Spherical graphite is another product for which prices are not widely publicized. However, according to China Customs data, prices for uncoated spherical product range around \$3,000/t while coated spherical graphite is believed to sell for ~\$7,000-\$10,000/t.

Geologic settings and mineral resources

Economic natural graphite deposits occur in three main geologic types: flake graphite disseminated in metamorphosed sedimentary rocks, amorphous graphite formed by metamorphism of coal or carbon-rich sediments, and veins or lump graphite filling fractures in granitic country rock.

The USGS estimated 300 Mt of global reserves in 2019. The reserves were predominantly accounted for by Brazil (72 Mt), China (73 Mt), India (8 Mt), Madagascar (1.6 Mt), Mexico (3.1 Mt), Mozambique (25 Mt), Tanzania (18 Mt) and Turkey (90 Mt). The USGS noted that U.S. resources of graphite are relatively limited, but that the inferred resources in the rest of the world exceeded “800 million tons of recoverable graphite.”

The past few years have seen intensive exploration for graphite by both private and publicly listed companies, with most exploration aimed at flake graphite deposits. Australia, Canada, Mozambique and Tanzania were the main hotspots, with the biggest resources discovered in northern Mozambique and southern Tanzania. Other target countries have included Brazil, Finland, Madagascar, Malawi, Sweden and the United States.

Mineral Resources for flake graphite projects reported by publicly traded companies totaled more

than 5.3 Gt at grades ranging from approximately 2 to 30 percent graphitic carbon for an average grade of ~ 9 percent graphitic carbon (Table 3). The contained (in situ) graphite content is estimated to be approximately 464 Mt. The largest publicly reported mineral resources are concentrated in East Africa, mainly in northern Mozambique and southern Tanzania (Table 3). Most of the published mineral resources were reported in terms of international codes, for example NI 43-101 and JORC.

Recycling and environmental

There are no graphite mines in the United States, hence no regulatory or reclamation issues arise. According to the USGS, refractory products led the way in recycling of graphite products, with material being recycled into products such as brake linings and thermal insulation.

Outlook

Global natural graphite production is expected to increase due to increased demand for electric vehicle batteries. The Balama flake graphite mine (owned by Syrah Resources Ltd.) in northern Mozambique came on stream during late 2017 and produced 256 kt in 2018-2019. Production was reduced in the fourth quarter 2019 and temporarily suspended in March

2020 due to restrictions related to the COVID-19 pandemic. It's unknown when production will be re-started.

Other graphite mines in northern Mozambique are likely to be developed within the next few years, possibly in the Balama and Ancuabe areas. Tanzanian projects have been delayed over the past two years resulting from a change in government and mining regulations; however, these issues are now apparently resolved and it is anticipated that mines are likely to be developed in the central and southern part of the country.

While most graphite markets are forecast to remain static, growth is expected to come from the battery-anode and expandable-graphite markets. The battery market for natural graphite used in spherical graphite has been forecast by various researchers to grow at a compound annual growth rate of around 15 percent, from a base of 60 kt in 2016 to 220 kt by 2025. The conversion rate of natural graphite to spherical graphite is about 40 percent, which means that there will be 60 percent of the feed graphite available for other applications.

Between traditional markets, battery markets and expandable graphite markets it may reasonably be expected that additional demand may exceed 300 kt flake graphite extra per year by 2025. ■

GROUND CALCIUM

by Lauren Olsen, Minerals Technologies Inc. (MTI)

Ground calcium carbonate (GCC) has a wide variety of applications in the industry. It is used in construction, paper, plastics, paints, food, personal care, agriculture and more. The minerology of a GCC comes from the calcite mineral, CaCO_3 , which is sourced from high quality limestone and marble deposits. The economic value of a deposit depends on the purity, accessibility, proximity to the customer, and any local environmental considerations.

Ground calcium carbonates of sedimentary and marble deposits are the dominant and economically important deposits to sources. Limestone is a sedimentary rock that forms in a shallow marine environment composed mostly of biologically deposited calcium carbonate organisms, clays, sands, organics and other impurities. The purest limestone deposits form in high-energy environments where there is constant oceanic flow, which would limit the amount of impurities deposited compared to a stagnant basin. This is important to the economic value of a deposit, as the particle size, texture and chemical purity play a role in determining its worth.

A limestone that undergoes metamorphism will eventually form a marble deposit. Metamorphism is the increase of temperature and/or pressure due to burial, convergence of plate boundaries, or

even a localized heat source that allows the calcite crystals in the limestone to become denser, often interlocking and even growing over time. A high-purity limestone will then become a high-grade marble that will change and enhance the properties of the calcium carbonate minerals that will be mined for GCC applications. According to the *7th Edition IMAR, Limestone and Dolomite*, "A practical chemical classification considers that an ultra-high calcium limestone is more than 97.5 percent CaCO_3 , high-calcium limestone is more than 95 percent CaCO_3 , and high-purity carbonate rock is more than 95 percent combined CaCO_3 and MgCO_3 ."

GCCs are used in many markets such as construction applications, cement, adhesives, caulks and sealants (ACS), paints, polymers and paper. They also play a role in food, personal care and calcium supplements. GCCs have a variety of qualities that make it economical in the calcium carbonate market. The inherent grain size of the GCCs can also enhance a product brightness, color, strength and smoothness. Processed GCC products can have particle sizes that range from as low as 1.0 micrometer up to relatively larger chips as applicable to many different specialty applications. GCCs have a basic pH which can be used to neutralize odors and to increase the pH of soils or water.

Production and use

Overall, production and consumption of GCCs have a constant industry growth of approximately 1 percent per year and some market reviews suggested that new applications for GCCs will continue to develop in the upcoming years. Key suppliers in the industry for GCCs include Omya, Imerys, J.M. Huber, Specialty Minerals Inc. (SMI), Mississippi Lime Co., Carmeuse, Sibelco, Lhoist and other smaller local companies. While there is an abundance of calcium carbonate deposits, high-purity white products without beneficiation or additional processing are rare and are controlled by just a few producers. Additionally, GCCs have increased economic value dependent upon the distance traveled and the means of transportation to end use customer markets.

GCCs are used in construction nearly everywhere including Portland cement, ACS and paint. In cement GCCs influence the performance of the reaction, setting times and strength. Ideally very fine grain particle size is used in cement mix applications. The properties of GCCs used in ACS enhance the flow of the material, strength and whiteness. Paint applications use GCCs for densifying and extending the formulation in addition to reducing or enhancing gloss.

Specialty applications for GCCs include fillers and coatings pigments for paper. Utilizing industrial minerals decreases the cost for paper production, improves the writing surface, opacity and whiteness. They are used in filler loading for pigments in printing paper, writing paper, newsprints, coated mechanical papers, and wood-free coated and uncoated papers. As the paper industry has moved from acid to alkaline paper production, industrial mineral fillers, like GCCs, are used to cut cost on the expensive paper fibers, increase brightness and strength. Due to expensive transportation costs the utilization of GCCs is often based on proximity to the source.

Major growth markets include Asia, which China is continuing to build satellite GCC plants. Other uses of GCCs include agriculture, food and personal care products. In agriculture, GCCs are used to neutralize soils and can be a carrier to transport chemicals to crops. Similarly, GCCs are considered a source of calcium for supplements and to enhance foods. They are used in antacids, to relieve indigestion, heart burn and upset stomachs. Other competitive fillers include, kaolin clays and precipitated calcium carbonate.

Specialty Minerals (SMI) segment of Minerals Technologies Inc. mines and processes its GCCs deposits located in the eastern and western parts of the United States. From 2017 to 2019, the company has seen an increase in net sales of its GCCs. SMI

sells into the paper, automotive, construction and household goods markets. The outlook for SMI is to utilize new GCC products in paints, coatings and packaging applications. J.M. Huber produces a high-purity GCC with low silica content which is preferred in ACS applications. Omya and Imerys provide a range of GCC products that are innovated to optimize particle-size distribution to improve opacity.

Pricing

From 2015 to 2019 the production of crushed stone has increased from 1,340 to 1,530 Mt accordingly. The average price for a metric ton of crushed stone in 2019 was reported by the USGS as \$12.26/t.

According to the *USGS Commodity Report*, "In 2019, 1.53 billion tons of crushed stone valued at more than \$18.7 billion was produced by an estimated 1,430 companies operating 3,440 quarries and 176 sales and/or distribution yards in 50 states. Of the total domestics crushed stone produced in 2018, about 69 percent was limestone and dolomite. It is estimated that 1.6 billion tons of crushed stone consumed in the United States in 2019, 72 percent was used as construction aggregate; 16 percent for cement manufacture; 8 percent for lime manufacturing; 3 percent for other chemical, special and miscellaneous uses and products; and 2 percent for agricultural uses."

Outlook and trends/new developments

In 2018, North America held the second largest GCC market compared to the Asian Pacific region which holds the largest market due to their regional growth in the paper industry and market demand. The North American market will continue to grow from the demand of plastics, paints and coatings in the United States. Part of the calcium carbonate market GCCs have shown growth in market shares in 2018 and are predicted to continue to grow.

In the United States there will continue to be a gradual demand for GCCs as industrial minerals in many industrial sectors due to demands for new and improved product performance in the construction and infrastructure sectors and for technological advancement in specialty materials. Increased demand for GCCs used in paper and plastic products may occur as a result of the recent COVID-19 pandemic due to the need for more single use products to avoid cross contamination and exposure. Many consumers seem to utilize online purchasing, which requires single-use paper products for delivery services, food and medical supplies. Overall, demand will continue to remain gradual, but across the globe other countries are continuing to develop new applications and technologies for GCCs. ■

GYPSUM

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

The United States is the world's leading producer and consumer of mined crude gypsum. Production of crude gypsum in the United States during 2019 was estimated to be 20 Mt, a 5 percent decrease compared with 2018 production. The average price of mined crude gypsum was \$8/t. Synthetic gypsum sales in 2019, most of which were generated as a flue-gas desulfurization product from coal-fired electric power plants, were estimated to be 16 Mt and priced at approximately \$5/t. Forty-seven companies mined gypsum in the United States in 16 states. Crude gypsum exports from the United States totaled 37 kt. Imports were 6.1 Mt.

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

World production of gypsum in 2019 was estimated to be 140 Mt, slightly less than that of 2018. The United States was the largest producer of natural gypsum in 2019 with an estimated 20 Mt, followed by China and Iran with an estimated 16 Mt, Turkey with an estimated 10 Mt, and Thailand with an estimated 9.3 Mt. Crude gypsum was thought to have been produced in 80 countries in 2019.

Consumption

An estimated 2.23 billion square meters of gypsum-derived wallboard products were produced in 2019. 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.

Trade

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. western seaboard. Large gypsum deposits occur in the Great Lakes region, the midcontinent region and several western states. Foreign resources are large and widely distributed; 80 countries are thought to produce gypsum.

Synthetic equivalents

Synthetic gypsum is very important as a substitute for mined gypsum in wallboard manufacturing, cement production and agricultural applications (in descending order of tonnage). In 2019, synthetic gypsum accounted for 38 percent of total domestic gypsum consumption.

Outlook

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 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.

The use of synthetic gypsum may continue to grow, albeit at a slower pace. As power companies convert coal-fired electrical generation plants to natural gas to take advantage of an abundant and inexpensive supply of shale gas, the production of synthetic gypsum could further decline because fewer coal-fired power plants would be operating. Nevertheless, the use of synthetic gypsum by U.S. wallboard manufacturers is likely to continue. Similarly, should the economy continue to expand, and if residential and commercial construction continues to increase, gypsum consumption is also expected to increase in the near future.

Recent developments, however, may affect the short-term outlook for the gypsum industry. In December 2019, an outbreak of a novel coronavirus (COVID-19) was first identified in China. The World Health Organization declared that COVID-19 was a global pandemic on March 11, 2020. Measures instituted to mitigate the spread of the COVID-19 pandemic, such as closures of nonessential businesses, are likely to cause disruptions in the mining industry across the United States and around the world. The duration and the outcome of the COVID-19 pandemic remains uncertain, but it is expected that the economies of the United States and the world as a whole will likely be negatively affected, which could influence the performance of the gypsum industry. ■

HYDRAULIC FRACTURING SAND

by Mark J. Zdunczyk, consulting geologist

In 2019, according to the U.S. Geological Survey (USGS), the estimated production of industrial silica sand was 110 kt of which approximately 73 percent was used for hydraulic fracturing sand (frac sand), well packing and well cementing sand. Therefore, somewhat less than 80.3 kt was used as frac sand taking into account well packing and cementing sand. This was a decrease of approximately 9 percent from 2018. This decrease is consistent with *World Oil* magazine forecast in September 2019 a slight decline in drilling in most basins. In addition, drilled wells are not always completed. These wells are called drilled uncompleted (DUCs). As of May 2019, operators working the U.S. shale plays have managed to archive 8,283 DUCs, with 48 percent of that total in the Permian Basin (*World Oil*, July 2019). In October 2019, the downturn in shale drilling continued as it was reported that well-stimulation companies (frackers) began parking unused equipment. During the same month, U.S. Silica Holdings Inc. announced plans to shut some sand mines in Wisconsin and the Permian Basin. Since the beginning of using local or regional sand, which may or may not meet American Petroleum Institute (API) or the International Standards Organization (ISO) for frac sand, Wisconsin/Northern White sand was only used in small amounts for blending with local or regional sand or in basins/plays where freight rates were reasonable. In late 2019, Hi Crush Proppants, Covia and Superior Silica Sands closed operations in Wisconsin. U.S. Silica reported that it had taken approximately 5 Mt of Northern White and regional sand capacity offline by idling plants and reducing plant operations hours. Superior Silica Sands filed for bankruptcy in late 2019.

The process of hydraulic fracturing (fracking) requires about 98 percent water and sand. Early fracking used nonwater-type fluids mixed with sand, which caused some environmental concerns. The objective of hydraulic fracturing an oil or gas well is to increase the productivity of the well by opening fractures in the rock extending for some distance into the formation. The fracture increases the area for drainage of the hydrocarbons into highly conductive channels leading to the well. Thus, the hydrocarbons can be produced at greater rates and at lower pressure than is possible from an unfractured well. The fractures will close under the normal reservoir horizontal pressure from the rock formations above. Therefore, it is necessary to introduce some type of particles to hold fractures apart and afford a highly permeable conductive channel from the formation to the well. The particles are called propping agents

or proppants, and consist of well-sorted sand, glass beads, walnut hulls and many other types of synthetic particles. Sand is less expensive, easy to handle and readily available, therefore widely used in the well-stimulation industry.

Similar to all industrial sand, as fracking with sand grew, recommended specifications were set forth by API and the ISO for frac sand. First and foremost, the sand should contain upward of 99 percent silica or quartz grains like all industrial sands. The sand should be a mixture of round or nearly rounded sand grains and grains which are spheres or nearly spheres. API and ISO specifications are based on the *Krumbein-Sloss Chart for Visual Estimation of Sphericity and Roundness from Stratigraphy and Sedimentation*, Second Edition, 1951 by W. H. Freeman and Co., New York, NY. Grain shapes above 0.6 roundness and 0.6 sphericity are recommended. The more rounded the grain, the more porosity the sand will have that is left between the grains, thus allowing the gas or oil to flow freely to the well head.

Grain size is another important recommended specification. Some standard sizes are:

- Sieve #20-#40 (0.84-0.42 mm)
- Sieve #30-#30 (0.59-0.29 mm)
- Sieve #40-#70 (0.42-0.21 mm)
- Sieve #70-#140 (0.21-0.10 mm)

Crushed resistance is also very important. As the sand is pumped down the well, it is subjected to pressures of 4,000 psi or greater and in horizontal fractures the sand must withstand the pressure of the fracture closing from the weight of the rock layers above. The quartz grains must withstand breaking down and producing fines. Fines will fill in the opening between the individual grains of sand causing less porosity, therefore less flow. Angular to subangular grain shapes will pack together and impurities such as feldspar, garnets, amphiboles and other minerals need to be limited because they break down under these pressures. Incipient fractures in the individual quartz grains can cause weak grains as well. Feldspar is one mineral impurity which is found in most sandstones and unconsolidated sand deposits that tend to break down along cleavage planes. Mineral impurities and grain shape characteristics may produce enough fines under pressure to allow packing, therefore slowing oil and gas flow. Some quartzose sandstones and other high-quartz-content unconsolidated sand deposits that do not meet crush resistance have been used and are currently being used in fracking operations. Other specifications such

as acid solubility and turbidity are somewhat less important. Turbidity can be resolved at the processing plant during washing, and most fracking operations are done with minor amounts of acid base chemicals, therefore carbonates in the sand have little effect on the process. Years ago, there were more acid base chemicals, and carbonate content in the sand diluted their performance. Acidizing the well increases permeability and dissolves limestone, dolomite and calcite cement between the sediment grains of the reservoir rocks. Hydrochloric acid is generally used. The use of hydrofluoric acid to increase permeability is called acid fracturing. This method removes sand and clay from the reservoir rocks.

Completion engineers are always skillfully trying to design and implement better ways to frac a well. The U.S. frac sand industry, along with these completion engineers, has made significant changes in these specifications to accommodate the market. The most significant change is the move from the use of Northern White or Ottawa sands and some of the Brady Brown sand to what the industry calls regional, local or in-basin sands. These sands are somewhat marginal compared with API and ISO recommended specifications which are based on Northern White sand.

Currently, roundness and sphericity of the individual quartz grains are not expected of a deposit being mined. The once specified 0.6 roundness and 0.6 sphericity is now more of a guide than a specification. Some regional and local sands can fall below this threshold and still be used by well service companies. Today the most common grain size used is sieve #40-#70 (0.42-0.21 mm) and sieve #70-#140 (0.21-0.10 mm) commonly called 100 mesh sand. Completion engineers find that pumping small-grain sized sand down the well enables entry into micro-fractures otherwise inaccessible to large grain particles, reducing the use of the once sought after #20-#40 (0.84-0.42 mm) when the frac sand “frenzy” started. It has been also suggested by some completion engineers that the sand pumped enters the fractures and bridges the fracture rather than filling the fractures. Bridging the fracture leaves spacing that allows oil and gas to flow freely to the well head. Therefore, there is no need for roundness and sphericity for porosity. Most regional and local sands have lower crushed resistance than Northern White sand. As put to this author by a major oil company, crushed resistance may not be an important specification for their particular completion efforts. However, well-completion engineers are always looking for ways to increase flow from an oil or gas well and recommend less expensive frac sand to control completion costs. Some engineers are still blending Northern White sand with local or regional sands, as they are not convinced that the local sand can perform as expected.

The geology of sand deposits has much to do with where frac sand is found and mined. The relaxed specifications discussed above have brought river, dune, alluvium and other unconsolidated/consolidated deposits to the market. These deposits were never exploited or had very limited production until costly freight rates and logistics from the Northern White mines changed conventional thinking. Presently the dunes and dune sheets in the Midland, TX region, river deposits on the Red River in Louisiana, Texas and Arkansas, and the Cimarron River in Oklahoma are being mined and used in various plays and basins. Unconsolidated sands of Cretaceous age are mined in east Texas and south of San Antonio. The Paluxy Formation, another Cretaceous-age unconsolidated sand, silt and clay is being mined in the Cleburne and Granbury, TX area. The Trinity/Antlers Formation is being mined in southern Oklahoma and northern Texas near the Oklahoma border.

At the start of 2018, there were approximately 30 operations providing in-basin sand to the Permian Basin wells. In late 2019, these mines created an oversupply of frac sand, weakening sales and prices. The oversupply and the fickle crude prices saw a dip in pricing to about \$20-\$30 or less per ton f.o.b. for frac sand. As one sand plant engineer reported, “It cost more to make the sand than the price we’re selling it for.” Northern White sand was not being used because of freight rates to the Permian and Eagle Ford basins. Reportedly, Wisconsin or Northern White sand prices fell to about \$20 to \$25 or less f.o.b. Most industry analysts report that the shift to local sand will erode the Northern White market. Freight costs from the Northern White mine to the Permian or Eagle Ford can be more than 65 percent of the sand costs. Since about 98 percent of well completion is frac sand, there is significant savings using in-basin sand. In 2019, more Northern White mines have been idled than 2018, but Northern White sand will still be used but at lower pricing and volume. Each shale play and/or basin has different characteristics which when designing a frac job and may call for the premier Northern White sand. In addition, some companies mining Northern White sands are vertically integrated, selling sand to their own well service company.

Issues facing the industry are like all surface and subsurface mines throughout the country. Air emissions of particulate matter (silica dust) are a substantial part of the permit process for dry-processing plants and there may be wetland, ground water, endangered species (especially Sagebrush lizard in the dunes near the Permian Basin) as well as other environmental issues. Truck traffic is the major transportation mode for the most recent mines opened in the Permian Basin. Trucks are

used to transport raw material from the mine site to the plant as well as to the “frac job”. Truck traffic is difficult to mitigate and generate many of the complaints for the new mines near Midland Texas. Rail transportation is not relevant when the mines are close to the customer.

Health and safety issues are also very similar to other mining industries across the country. One particular health issue which has dominated the industrial sand industry for decades is airborne silica. Especially during the drying process silica dust is emitted but also occurs during the entire

mining and processing steps. Breathing silica particles has long been known to cause silicosis. As long as the problem has existed, the industry has been proactive in mitigating this issue. Water suppression in the mine and plant areas is effective to mitigate airborne particles. In some plant areas employees are required to wear protective clothes and personal protection gear and are checked on a frequent basis for any health issues.

As reported in 2018, sand pricing remained the same or near the same as 2019 and possibly will trend lower in 2020. ■

INDUSTRIAL DIAMOND

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

Estimated 2019 world production of natural and synthetic industrial diamond was about 14.7 billion carats, the vast majority of which was synthetic. Natural diamond resources have been identified in more than 35 countries; natural industrial diamond was produced in at least 12 countries. At least 15 countries have the technology to produce synthetic diamond, and synthetic industrial diamond was produced in 11 countries during 2019. About 99 percent of the combined natural and synthetic global output was produced in China, Ireland, Russia, South Africa and the United States. During 2019, China was the world's leading producer of synthetic industrial diamond followed by the United States and Russia. In 2019, the two U.S. synthetic producers, one in Pennsylvania and another in Ohio, had an estimated output of 190 million carats valued at about \$86 million. This production was entirely synthetic diamond bort, dust and powder and grit. Also, in 2019, nine 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.

An estimated total of 38.4 million carats of used industrial diamond, valued at about \$972,000, was recycled in the United States during 2019. This was an estimated 38 million carats of recycled diamond bort, dust and powder, and grit with a value of about \$790,000 combined with an estimated 120,000 carats of recycled diamond stone with a value of \$180,000. Lower prices of newly produced industrial diamond appear to be reducing the number and scale of diamond-stone recycling

operations. 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.

Since the mid-1980s, CVD diamond technology has seen strong growth. The global market value of industrial diamond and diamond films and coatings was estimated to have been more than \$1 billion in 2019. Early applications for CVD diamond focused largely on thin- and thick-film PCD for cutting tools and dressing applications owing to the mechanical properties of diamond. Newer applications that use CVD diamond's mechanical properties include wear parts, such as watch gears and chemical mechanical polishing pad conditioners. CVD diamond is being used in microelectronic components, such as high-speed processors, medical devices, wide bandgap radio frequency and power conversion devices and optoelectronic devices (light-emitting diodes, laser diodes) that generate exceptionally high heat densities that require innovative approaches to thermal management. 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.

Historically, diamond has been perceived as an expensive material. Advances in CVD diamond manufacturing, like the development of microwave carbon plasma technology and the development of higher-throughput, hot-filament CVD diamond reactors, have significantly reduced diamond costs. This has led many industries to revisit development activities and actively pursue the use of CVD diamond for a growing number of applications. At least one U.S. company was developing projects in

2019 using single-crystal CVD diamond materials in high-voltage power switches, lasers, quantum communications and computing, and water treatment and purification.

Consumption

The United States remained one of the world's leading consumers of industrial diamond. Estimated U.S. apparent consumption of natural and synthetic industrial diamond bort, dust and powder, grit and stones was 420 million carats, valued at \$82 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 domestic industries that consume industrial diamond are construction, machinery manufacturing, mining services (drilling), oil and gas exploration (drilling), stone-cutting and polishing and transportation systems (infrastructure and vehicles). Stone cutting and highway building and repair together made up the largest usage of industrial diamond. During 2019, about 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 2019, the average unit value for diamond bort, dust and powder, and grit material was \$0.46 per carat. During 2019, U.S. imports of all types of industrial diamond had an average unit value of \$0.16 per carat. These imports were a combination of natural and synthetic diamond stone that had an average unit value of \$5.90 per carat and natural and synthetic diamond synthetic diamond bort, dust and powder, and grit that had an average unit value of \$0.14 per carat.

Foreign trade

During 2019, the United States led the world in industrial diamond trade. U.S. imports of industrial-quality diamond stones (natural and synthetic) were about 1.07 million carats valued at about \$6.32 million. U.S. imports of industrial-quality diamond dust, grit and powder (natural and synthetic) were about 310 million carats valued at about \$45.0 million. During 2019, the United States did not export industrial diamond stones. U.S. exports of industrial diamond dust, grit and powder (natural and synthetic) were about 114 million carats valued at \$56.9 million.

Outlook

The United States is expected to continue to be one of the world's leading consumers of industrial diamond into the next decade and likely will remain a significant producer and exporter of synthetic industrial diamond as well. U.S. demand is likely to continue increasing. 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.

In December 2019, an outbreak of a novel coronavirus (COVID-19) was first identified in China. The World Health Organization declared that COVID-19 was a global pandemic on March 11, 2020. Measures instituted to mitigate the spread of the COVID-19 pandemic, such as closures of nonessential businesses, are likely to cause disruptions in the mining industry across the United States and around the world. The duration and the outcome of the COVID-19 pandemic remains uncertain, but it is expected that the economies of the United States and the world as a whole will likely be negatively affected, which could influence the performance of the industrial diamond industry. ■

INDUSTRIAL GARNET

by Kenneth C. Curry, National Minerals Information Center, U.S. Geological Survey

Although garnet has been a popular gemstone since the Bronze Age, its angular fractures, relatively high hardness and specific gravity, chemical inertness, and nontoxicity make nongemstone-grade garnet ideal for many industrial applications. In addition, it is free of crystalline silica and can be recycled. Garnet is the general 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, and lower-quality garnet is used as a filtration medium because it is relatively inert and resists chemical degradation. Garnet is also being used as a proppant in oil and natural gas well drilling. It may be mixed with other proppants when high temperatures are encountered or in very deep formations.

In 2019, U.S. production of crude garnet concentrate for industrial use (industrial garnet) was estimated to be 93 kt valued at about \$21 million, an

Figure 1

U.S. production, imports and apparent consumption of industrial garnet, 1989-2019.



8 percent decrease in quantity compared with 2018 crude production. In 2019, industrial garnet was mined by four firms in Idaho, Montana and New York. The majority of industrial garnet mined in the United States was almandine (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 \$62 million, a 16 percent decrease in quantity compared with 2018 refined production. In mid-2019, a new refined garnet processing facility opened in Coos Bay, OR. The majority of garnet processed at this facility was imported in 2019.

Total world industrial garnet production was estimated to be about 1.2 Mt, 4 percent less than in 2018. Australia (400 kt), China (310 kt) and South Africa (190 kt) were, in descending order of tonnage, the leading producers in 2019. World production of industrial garnet decreased in 2019 owing to decreased production in India, South Africa and the United States. The United States produced about 8 percent of the industrial garnet mined worldwide.

Consumption

In 2019, apparent consumption of industrial garnet in the United States was estimated to be 290 kt, accounting for 24 percent of global garnet production. U.S. apparent consumption decreased by 15 percent compared with that of 2018 (Fig. 1). This decrease in apparent consumption can be attributed to a decrease in imports from South Africa, owing to a Pennsylvania processing facility reaching its storage capacity and curtailing imports at that site. The major end uses for industrial garnet in the United States are, in descending order by estimated market share, abrasive blasting media, waterjet cutting, water filtration,

abrasive powders and other end uses.

Domestically, the industrial sectors that consume industrial garnet include aircraft and motor vehicle manufacturers, ceramics and glass producers, electronic component manufacturers, water filtration plants, the petroleum industry, shipbuilders and wood furniture-finishing operations.

Prices

The price of industrial garnet depends on application, quality, quantity purchased, source and type and therefore prices encompass a wide range. During 2019, estimated domestic values of industrial garnet for different applications ranged from about \$200/t to \$240/t, with an average of about \$225/t. The average unit values of refined garnet sold in the United States for different applications during the year ranged from \$400/t to \$550/t, with an average of \$430/t. The average customs unit value of U.S. garnet imports in 2019 was \$210/t.

Foreign trade

The industrial garnet market is very competitive. Lower-priced foreign imports slowly began displacing U.S. production in domestic markets during the 1990s. Since that time, despite increasing domestic production in recent years, the United States has become increasingly dependent on foreign sources of industrial garnet to meet its needs.

U.S. imports in 2019 were estimated to be 208 kt, a decrease of 18 percent from the record high of 254 kt set in 2018. Exports were estimated to be 13 kt, a decrease of 11 percent compared with those of 2018. In 2019, South Africa (39 percent), China (35 percent) and India (20 percent) supplied the majority of U.S. industrial garnet imports, with the remainder from several other countries. U.S. exports of industrial garnet were shipped to Canada (31 percent), Mexico (25 percent), and Trinidad and Tobago (6 percent), with the remainder to several other countries.

Outlook

The domestic industrial garnet industry is expected to stabilize after the volatility of the past few years. However, 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 slowly increase, with the highest growth in consumption in waterjet cutting and abrasive blasting.

In December 2019, an outbreak of a novel coronavirus (COVID-19) was first identified in China. The World Health Organization declared that COVID-19 was a global pandemic on March 11, 2020. Measures instituted to mitigate the spread of the COVID-19 pandemic, such as closures of nonessential businesses, are likely to cause disruptions

in the mining industry across the United States and around the world. The duration and the outcome of the COVID-19 pandemic remains uncertain, but it is expected that the economies of the United States, and the world as a whole, will likely be negatively affected, which could influence the performance of the industrial garnet industry. ■

INDUSTRIAL SAND AND GRAVEL

by Thomas P. Dolley, National Minerals Information Center, U.S. Geological Survey

Production of industrial sand and gravel (also referred to as silica sand and gravel) in the United States decreased to an estimated 110 Mt in 2019, down by about 9 percent from that of 2018. The estimated value of production of industrial sand and gravel was \$5.7 billion in 2019. Hydraulic fracturing sand (frac sand) production remained a driving force in the industrial sand and gravel industry. Decreased oil and gas drilling and completion activity in North America triggered a concomitant decrease in the production of frac sand in 2019 compared with that of the previous year. Additionally, in any given year, more efficient hydraulic-fracturing techniques, which require more silica sand use per well (mostly for secondary recovery at mature wells) along with lower unit cost compared to other proppants tends to maintain demand for frac sand. Production of frac sand and well-packing and cementing sand in 2019 was estimated to be 80 Mt, about 10 percent less than that of 2018.

In 2019, industrial sand and gravel was produced by 191 companies with 308 operations in 35 states. The top 10 states for the production of industrial sand and gravel were, in descending order by tonnage, Wisconsin, Texas, Illinois, Missouri, Minnesota, Oklahoma, Mississippi, North Carolina, Iowa and Louisiana. Combined production from these states accounted for 85 percent of domestic production in 2019. World production of industrial sand and gravel was estimated to be 330 Mt in 2019. Based on estimated world production figures, the United States was the leading global producer and consumer of industrial sand and gravel with 33 percent of world production tonnage, followed, in descending order, by the Netherlands (54 Mt), Spain (36 Mt), Italy (14 Mt), Turkey (14 Mt), India (12 Mt), Malaysia (10 Mt), France (9.3 Mt), Germany (7.5 Mt), Bulgaria (7.3 Mt) and Indonesia (5.5 Mt).

Consumption

In 2019, consumption of industrial sand and gravel in the United States was about 105 Mt, a 9 percent decrease from that of the previous year, owing primarily to decreased activity in the oil and gas sector. Major markets for industrial sand and gravel were abrasives, ceramics, chemicals, fillers (ground and whole grain), glassmaking, filtration for swimming

pools, foundry uses, frac sand, other ground silica, recreational uses, roofing granules and fillers and well-packing and cementing applications.

Price

The estimated average unit value of domestically produced industrial sand and gravel in 2019 was \$50.40/t compared with \$56.40/t in 2018.

Foreign trade

The United States remained a net exporter of industrial sand and gravel even though exports decreased by 14 percent in 2019 to 5.6 Mt, with about 85 percent going to Canada. In 2019, imports decreased to about 389 kt from 392 kt in 2018. Imports of industrial sand and gravel are generally of two types — small shipments of very high-quality silica sand or a few large shipments of lower grade silica sand shipped under special circumstances (for example, very low freight rates). Major import sources for silica sand into the United States in 2019 were Canada, Taiwan and Turkey.

Outlook

Domestic mine output of industrial sand and gravel is sufficient to accommodate many end uses for the foreseeable future. In 2019, decreased oil and gas drilling in North America and oil well completion activity triggered a corresponding decrease in the production of hydraulic-fracturing sand in 2019 compared with that of the previous year. More efficient hydraulic-fracturing techniques, which require more silica sand use per well (mostly for secondary recovery at mature wells), tend to maintain demand for hydraulic fracturing sand. Additionally, frac sand's relative low cost when compared with that of other proppants tends to maintain demand for frac sand.

The industrial sand and gravel industry continued to be concerned with safety and health regulations and environmental restrictions in 2019, especially those concerning crystalline silica exposure. Beginning in 2016, the Occupational Safety and Health Administration (OSHA) finalized new regulations to further restrict exposure to crystalline silica at mine sites and other industries that use materials containing it. Phased implementation of the new regulations

was scheduled to take effect through 2021, affecting various industries that use materials containing silica. Most provisions of the new regulations became enforceable on June 23, 2018, for general industry and maritime operations. On Aug. 14, 2019, OSHA requested comment and information to enable the agency to consider new developments and enhanced control methods for equipment that generates exposures to silica. Local shortages of industrial sand and gravel were expected to continue to increase owing to land development priorities, local zoning regulations and logistical issues, including ongoing development and permitting of operations producing hydraulic fracturing sand. Natural gas and petroleum operations that use hydraulic fracturing may also undergo increased scrutiny. These factors may result

in future sand and gravel operations being located farther from high-population centers.

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IODINE

by Emily K. Schnebele, National Minerals Information Center, U.S. Geological Survey

In 2019, iodine was produced from brines in the United States by three companies operating in Oklahoma. U.S. iodine production in 2019 was withheld to avoid disclosing company proprietary data. As in recent years, Chile was the world's leading producer of iodine, followed by Japan and the United States. World production of iodine in 2019, excluding the United States, was estimated to be about 28.0 kt compared with 27.6 kt in 2018. Excluding the United States, Chile accounted for about 64 percent and Japan accounted for about 32 percent of world production in 2019.

Consumption

Globally, the leading uses of iodine and its compounds were X-ray contrast media, pharmaceuticals, liquid-crystal-display (LCD) screens and iodophors, in descending order of quantity consumed. Other applications of iodine included animal feed, biocides, fluoride derivatives, food supplements and nylon. Crude iodine and inorganic iodine compounds were thought to account for more than 50 percent of domestic iodine consumption in 2019. U.S. consumption of iodine in 2019 was estimated to be 4.8 kt, a 4 percent increase from the 4.6 kt consumed in 2018.

Foreign trade

In 2019, U.S. imports of crude iodine were 4.30 kt, a 13 percent decrease from the 4.93 kt imported in 2018.

The average unit value of crude iodine imports in 2019 was \$26.38/kg compared with \$22.46/kg in 2018. Chile was the leading source of crude iodine imports into the United States, accounting for 90 percent of the total quantity imported. Exports of crude iodine increased by 3 percent to 1.22 kt compared with 1.19 kt in 2018. The primary recipients of U.S. exported crude iodine in 2019 were India (21 percent) and Belgium (18 percent). The average unit value of exported crude iodine in 2019 was \$23.34/kg compared with \$19.83/kg in 2018.

Outlook

Growth in iodine consumption is expected and will likely be influenced by market demand for medical applications and LCDs because these are the primary consuming markets of iodine and iodine derivatives.

In December 2019, an outbreak of a novel coronavirus (COVID-19) was first identified in China. The World Health Organization declared that COVID-19 was a global pandemic on March 11, 2020. Measures instituted to mitigate the spread of the COVID-19 pandemic, such as closures of nonessential businesses, are likely to cause disruptions in the mining industry across the United States and around the world. The duration and the outcome of the COVID-19 pandemic remains uncertain, but it is expected that the economies of the United States and the world as a whole will likely be negatively affected, which could influence the performance of the iodine industry. ■

KAOLIN

by Jason Christopher Willett, National Minerals Information Center, U.S. Geological Survey

In 2019, U.S. kaolin production (the quantity sold or used by producers) decreased slightly to an estimated 5.50 Mt, valued at \$870 million from an estimated 5.53 Mt valued at \$860 million in 2018. Sales

from Georgia represented an estimated 90 percent of U.S. kaolin output and South Carolina accounted for 7 percent, followed by, in descending order of tonnage, Alabama, Arkansas, Florida, California and

Nevada. About 52 percent of all kaolin sold was water-washed, followed by airfloat (16 percent); calcined (15 percent); delaminated (12 percent); and unprocessed (5 percent). Production data were estimated based on current and previous producer reports as well as employment hours published by the Mine Safety and Health Administration.

World production of kaolin was an estimated 42 Mt in 2019, unchanged from 2018. The United States continued to lead the world in the production of refined kaolin, followed by Uzbekistan, Germany, India, Czechia, China, Ukraine and Brazil.

Consumption

The major domestic markets for kaolin were, in descending order of tonnage, paper coating (31 percent of domestic sales); miscellaneous ceramics (16 percent); refractory products (15 percent); paint (8 percent); and catalysts, rubber and miscellaneous fillers, extenders and binders (about 6 percent each). Smaller but significant domestic markets were adhesives, chemical manufacture, floor and wall tile, heavy-clay products (brick and portland cement), paper filling, plastics and sanitaryware. The leading export markets for kaolin were paper coating and filling.

Prices

The average unit value of kaolin in 2019 was estimated to be \$158/t, a slight increase from an estimated \$156/t in 2018. Unit values for individual kaolin types ranged from an estimated \$40/t for unprocessed kaolin to \$170/t for calcined kaolin. Estimated prices for kaolin from Georgia ranged from \$35 to \$900/t. The average free alongside ship value of

exported kaolin was \$242/t in 2019, a slight increase from \$238/t in 2018, and the average customs value of imported kaolin was \$125/t, up from \$120/t.

Foreign trade

Kaolin exports declined by 5 percent in 2019 to 2.27 Mt valued at \$550 million from 2.38 Mt valued at \$567 million in 2018. China received 19 percent of the U.S. export tonnage, followed by Mexico (18 percent), Japan (13 percent), Finland (7 percent), Canada (6 percent) and Taiwan (5 percent). Imports of kaolin totaled 321 kt valued at \$40.0 million, an increase of 8 percent from 297 kt valued at \$35.5 million during the prior year. Nearly all of the imported kaolin (92 percent) originated in Brazil. Based on entry and departure ports, refractory kaolin may have been exported under the category for fire clay and some imports from Brazil were likely destined for paper plants in Canada.

Outlook

In December 2019, an outbreak of a novel coronavirus (COVID-19) was first identified in China. The World Health Organization declared that COVID-19 was a global pandemic on March 11, 2020. Measures instituted to mitigate the spread of the COVID-19 pandemic, such as closures of nonessential businesses, are likely to cause disruptions in the mining industry across the United States and around the world. The duration and the outcome of the COVID-19 pandemic remains uncertain, but it is expected that the economies of the United States and the world as a whole will likely be negatively affected, which could influence the performance of the kaolin industry. ■

KYANITE, ANDALUSITE AND SILLIMANITE

by William L. Lassetter, Virginia Department of Mines, Minerals and Energy

Kyanite, andalusite and sillimanite are naturally occurring polymorphic minerals that have the same chemical composition, Al_2SiO_5 , yet differ in their crystal structures and thermodynamic properties. These minerals, collectively referred to as the sillimanite minerals group, are valued for their high alumina content, about 62.9 percent Al_2O_3 , and thermal and chemical stability in high-temperature industrial applications. The mineral mullite, $\text{Al}_6\text{Si}_2\text{O}_{13}$, is a closely related aluminum silicate with even higher alumina content, about 71.8 percent Al_2O_3 , and physical properties that add flexural and compressive strength at very high temperatures in ceramics. Mullite occurs rarely in nature with no known commercial deposits, but synthetic formulations are produced when sillimanite minerals are calcined. Apart from industrial uses, exceptional natural specimens of kyanite, andalusite

and sillimanite are highly valued in the gemstone jewelry industry and for their reported metaphysical properties.

Geology and economic deposits

Kyanite, andalusite and sillimanite occur as accessory minerals in metamorphic rocks derived from aluminous protoliths, typically making up a percent or two of the mineral composition of pelitic gneisses and schists. The predominance of one of the polymorphic minerals over another reflects the distinct stability fields of each mineral, defined by the pressure and temperature conditions under which the metamorphic rock formed. Andalusite is stable in rocks formed under relatively low pressure and low to moderate temperature conditions. These include hornfels and other thermally altered pelitic rocks within contact metamorphic aureoles. In

regional metamorphic terrains formed under high temperature and variably low to moderate pressure conditions, sillimanite is often the predominant mineral form. Kyanite, with the densest crystal structure of the polymorphs, is stable in rocks formed under relatively high pressure and low to high temperature conditions.

Economic deposits occur as massive segregations in metamorphosed aluminous sediments, as stratiform deposits often within quartzose rocks associated with meta-volcanic strata, mineralized quartz veins and pegmatites, and in residual soils. With specific gravity ranging from about 3.2 to 3.7, these minerals also occur in heavy-mineral placer deposits. Significant deposits of andalusite occur in hornfels and other thermally altered pelitic rocks within contact metamorphic aureoles adjacent to intrusive stocks. In the United States, economic and subeconomic concentrations of kyanite, andalusite and sillimanite occur in the Appalachian regions of Georgia, North Carolina, South Carolina and Virginia. Other known geologic occurrences are in Alaska, California, Florida, Idaho, Nevada and New Mexico. Outside of the United States, economic deposits occur in Australia, Brazil, Canada, China, Finland, France, India, Kenya, Nigeria, Norway, Peru, Russia, South Africa, Spain, Ukraine and Zimbabwe.

Industrial properties and uses

In metallurgical, glass manufacture and ceramics industries, the intrinsic refractory properties of kyanite, andalusite and sillimanite provide volumetric stability, resistance to thermal shock, low thermal conductivity, electrical insulation and resistance to chemical corrosion. The minerals convert to mullite and silica at decomposition temperatures ranging from about 1,250°C for kyanite, 1,450°C for andalusite, and 1,650°C for sillimanite. The percent volume expansion during the conversion is both predictable and irreversible. Calcined kyanite will expand in volume by an amount that is dependent on initial particle size. Very fine particles (325-mesh, 0.044 mm) increase volumetrically by about 3 percent, while coarser particle fractions (35-mesh, 0.5 mm) can potentially expand by about 25 percent. Calcined andalusite and sillimanite expand in volume by about 6 percent and 4 percent, respectively. Below temperatures of decomposition, the minerals have relatively low coefficients of thermal expansion. Synthetic mullite has an even higher thermal resistance (melting point about 1,840 °C), and crystallizes in interlocking forms with a high aspect ratio that enhances the mechanical strength of ceramic products.

The global iron and steel manufacturing industry consumes as much as 70 percent of the annual supply of sillimanite minerals produced by mining

operations. The minerals are used in refractories for firebrick, insulating brick, furnace and ladle lining materials, castables, mortar and many other high-performance heat- and corrosion-resistant products. Industrial ceramics and glass manufacture consume most of the remaining 30 percent of the annual supply, for kiln furniture, investment casting, monolithics, porcelain and sanitaryware, among other refractory materials. Other important end products include refractory additives and fillers, electrical insulators, ceramic tiles, brake shoes and spark plugs.

Global production highlights

The global supply of sillimanite minerals has historically come from mining operations in France, India, Peru, South Africa and the United States. The U.S. Geological Survey (USGS) estimated global production in 2019 to be more than 430 kt including about 190 kt of andalusite from South Africa, 91 kt of kyanite and calcined kyanite from the United States, 110 kt of combined sillimanite and kyanite from India, and 40 kt of andalusite from Peru (Ghalayini, 2020). Although there are no official mining statistics available for operations in China, estimates based on known geologic resources and company marketing materials indicate annual production of less than 50-60 kt of combined sillimanite minerals annually.

Kyanite Mining Corp. (KMC) is the world's largest producer of industrial-grade kyanite and calcined kyanite marketed under the trademark names Virginia Kyanite and Virginia Mullite, respectively. The company operates surface mines and processing facilities at the Willis Mountain mining complex near Dillwyn, VA. Ores extracted at the Willis Mountain and East Ridge quarries consist of kyanite-quartzite rocks associated with a sequence of interlayered metamorphosed felsic and mafic volcanic strata of Ordovician age. These rocks are mapped as part of the Chopawamsic Formation in Virginia's central Piedmont geological province. Ore-grade material contains 10 to 40 percent kyanite, averaging about 25 percent. The quarries, located about 1.25 miles apart east to west, are situated on opposing limbs of the Whispering Creek Anticline, where the kyanite-quartzite host rocks stand out as resistant topographic ridges. In 2019, the company reported annual production of about 91 kt of combined kyanite (80 percent) and calcined kyanite (20 percent). This represents an increase of about 2 percent over production in 2018. KMC states the annual production capacity at the Virginia operations is about 130 kt for commercial grade kyanite concentrates. The company markets a range of milled kyanite and calcined kyanite (>55 percent Al_2O_3 , <0.85 percent Fe_2O_3) products that are shipped mainly by truck to domestic customers and

port facilities for delivery to international customers. Exports currently account for about 50 percent of KMC's sales.

Elsewhere in the United States, Resco Products Inc. (Piedmont Minerals Division), acquired by Wellspring Capital Management LLC in 2011, operates a surface mine located in Hillsborough, NC that extracts pyrophyllite ($\text{AlSi}_2\text{O}_5(\text{OH})$) containing 15 percent to 20 percent disseminated andalusite. The mineralized zones were formed in structurally controlled, hydrothermally altered andesitic to dacitic metavolcanic rocks that are part of the late Precambrian Carolina terrane. The company produces high-purity alumina and silica mixes used in a range of castable refractory formulations, high-alumina brick, and specialty mineral products serving the foundry and ceramic industries.

Imerys, based in France, is the world's leading producer of industrial andalusite products for refractories, with major markets located in Western Europe, North America and emerging-market countries. In 2019, Imerys's Refractory Minerals business sector reported production of andalusite from mines in France and South Africa.

The Kerphalite Mine located just southwest of Glomel, France has been in operation since the 1960s and recovers andalusite from deeply weathered Ordovician-age schists proximal to granitic rocks of the Armorican Massif. Imerys markets andalusite products under the trademarked name Kerphalite KF for use as specialty foundry sand in moulding processes, in ceramics, and other refractory applications. In South Africa, surface mining operations in Mpumalanga Province include the Annesley Mine, north of Burgersfort, and the Rhino Mine at Thabazimbi in Limpopo Province.

In 2019, the former Krugerspost Mine, located about 19 km north of Lydenburg in Mpumalanga Province, remained in final closure and reclamation. These deposits occur in pelitic rocks of the Pretoria Group within the contact metamorphic aureole of the Bushveld Igneous Complex. Imerys markets a range of size-classified products under the trademarked names Durandal, Randalusite, and Purusite. Annual tonnages and capacities for the individual Imerys mine sites are not readily available but, based on the historic trend and apparent market conditions in 2019, production may have been somewhat lower compared to 2018. In its annual financial report for 2019, Imerys reported total mineral reserves for minerals for refractories (proven and probable at worldwide operations) of about 11,803 kt. Estimated total mineral resources (measured, indicated, inferred) for the same product were reported to be about 24,261 kt. These estimates include refractory mineral sources other than andalusite, such as bauxite and refractory clays.

Also in South Africa, Andalusite Resources

(Pty) Limited produces milled and run-of-mine andalusite products from surface mine operations at the Maroeloesfontein Mine located near Thabazimbi in Limpopo Province. The mineral deposit is on strike to the southwest of Imerys's Rhino Mine. Financial liquidity difficulties caused a month-long suspension of operations starting in June 2019 resulting in the loss of as much as 10 kt of mine output for the year. In 2017, the South African Competition Tribunal rejected a proposed acquisition of the company by Imerys. Andalusite Resources reports annual production capacity in excess of 70 kt, with reserves amounting to about 100 years of mining at that annual rate. The company globally markets a range of fine- and medium-grade products under the trade name Marlusite with average alumina content stated to be >57 percent Al_2O_3 .

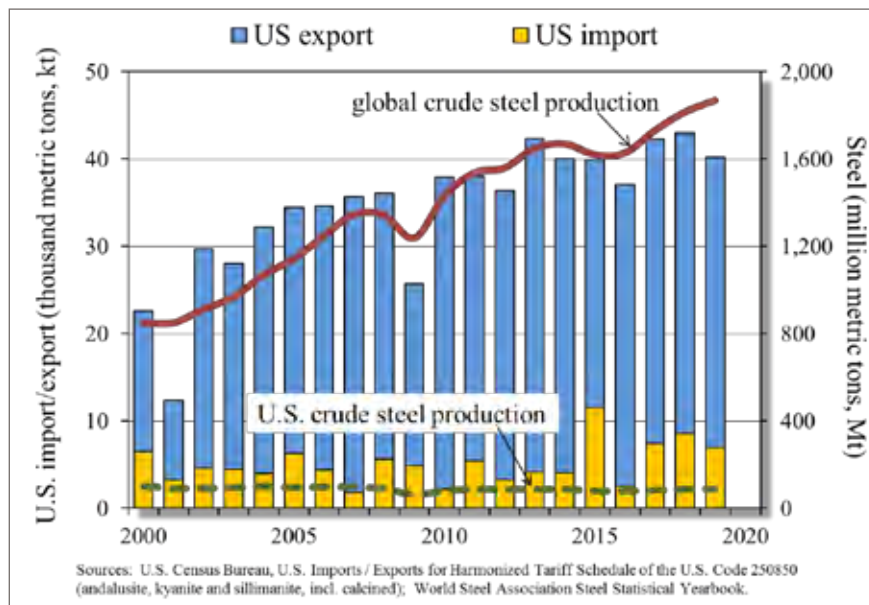
In northern Peru, Andalucita S.A. extracts andalusite from alluvial sediments in surface mining operations near the port of Paita. The company markets products ranging from fine (0-1 mm) premium-grade andalusite (58.5 percent Al_2O_3 , <0.75 percent Fe_2O_3) to coarse (3-6 mm) premium grade (58 percent Al_2O_3 , <1 percent Fe_2O_3) in 25-kg bags up to bulk quantities. The company reports annual production capacity at about 60 kt, with 100 years of mineral reserves.

With vast resources of sillimanite, India is the primary source in the global supply chain for this refractory mineral. Although production statistics for 2019 are not presently available, the Indian Bureau of Mines has estimated 70.2 kt of sillimanite geologic resources. About 73 percent of this resource is classified as granular high-grade material in heavy mineral-enriched beach sand deposits that also contain ilmenite, rutile, zircon, garnet and monazite resources. During 2017-18, more than 81 kt of sillimanite were produced mainly at four operations located in Andhra Pradesh, Odisha, Kerala and Maharashtra. About 20 percent of the total mineral produced was exported to China, Nepal and Germany, while the remainder served domestic refractory consumers. The Indian Bureau of Mines also estimated about 105 kt of kyanite resources in the country, of which less than 2 percent is classified as medium- to high-grade. During 2017-18, total production of about 8 kt of kyanite (>40 percent Al_2O_3) was reported by two operations located in Maharashtra. About 2 percent of this was exported, mainly to Greece. Estimated andalusite resources, classified in the reconnaissance category, stand at about 28.2 kt. There has been no reported production of the mineral since 1988.

Several mining operations in China produce sillimanite group minerals mainly for the domestic market. Nanyang Kaiyuan Cyanite Mining Company Ltd., mines kyanite in Nanyang City,

Figure 1

Sillimanite minerals foreign trade and steel production.



Henan Province. The company reports proven reserves of 34 Mt of ore averaging 28.38 percent Al_2O_3 , ranging up to 60 percent, with <0.5 percent Fe_2O_3 . The annual production capacity is stated to be about 50 kt of raw kyanite concentrate and 30 kt calcined kyanite. Shijiazhuang Mining Import & Export Trade Company Ltd., established in 2008, reports andalusite reserves in Xinjiang Province to be about 213 Mt. Xinjiang Xinrong Yilong Andalusite Company Ltd., reports production capacity of 40 kt/a. The company was initially founded in 2003 and briefly operated as a subsidiary of Imerys until 2018.

Prices

Sales prices for imported and exported minerals vary depending upon many factors including quantity, grade and purity, particle (mesh) size, packaging, monetary exchange rate, source and destination. The price of andalusite delivered from Europe was assessed in a range of \$357 to \$480/t; andalusite for delivery from South Africa was assessed at \$302 to \$381/t (Fastmarkets, 2019). The U.S. Census Bureau reports the average sales price for kyanite and calcined kyanite exported from the United States to be about \$358/t. The export price has remained relatively stable over the past five years, averaging about \$351/t. The average export price of sillimanite (56-60 percent Al_2O_3) f.o.b. from India in 2017-2018 was about \$140/t.

Trends and outlook

The strength of the global steel industry as measured by steel output has been a reliable indicator of the demand for refractories and the raw minerals used in their manufacture. Annual crude steel production statistics and annual exports

of sillimanite minerals from the United States since 2000 show a close positive correlation (Fig. 1).

The World Steel Association reported global steel production in 2019 reached 1,869.9 Mt, an increase of about 3.4 percent compared to 2018, setting a new record level. Increases in production were reported mainly in Asia and the Middle East, with China's output reaching 996.3 Mt, about 53.3 percent of the global total. Countries within the EU reported 159.4 Mt of crude steel, about 4.9 percent less production than in 2018. In North America, overall production was also somewhat lower, with only the United States reporting a 1.5 percent increase in steel output from 86.6 Mt in 2018 to 87.9 Mt in 2019.

Exports of sillimanite minerals from the United States in 2019 were about 40.2 kt, with primary destinations in Europe, followed by Asia and the NAFTA region. U.S. exports were 6.6 percent lower than in 2018, possibly a reflection of softer market conditions for refractory minerals in Europe. About 7 kt of sillimanite minerals were imported into the United States in 2019, about the same as in recent years. Most of this material is andalusite that originated from South Africa with lesser amounts imported from France and Peru.

Producers of kyanite, andalusite and sillimanite benefited from the strong economic conditions that characterized most of 2019. The COVID-19 outbreak that began spreading globally in early 2020 has the potential to negatively affect industrial output, including the manufacturing and construction sectors that rely upon refractory products. The outlook for the steel industry is cautiously positive, with pre-coronavirus forecasts estimating global steel output to increase by about 1.7 percent in 2020. This outcome clearly depends on the duration and extent of the imposed lockdown restrictions to prevent the spread of the coronavirus. The longer the restrictions remain in place, the deeper the disruptions will be to industrial operations, suspended construction activities, investor and consumer confidence. As part of the critical supply chain, the production of sillimanite minerals is closely balanced with demand to maintain low price volatility and minimize conditions of oversupply. As the health emergency begins to subside and economic conditions improve, there will likely be market growth opportunities in the emerging and developing economies in Brazil, India and Russia in particular. ■

(References available from the author.)

LIME

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

At present, all commercially produced lime in the United States is 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 report refers to high-calcium and dolomitic quicklime, their hydroxide (hydrated) forms and dead-burned dolomite.

In the United States, most lime (about 84 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 2019, an estimated 18 Mt of quicklime and hydrate were produced (excluding independent commercial hydrators), which was essentially unchanged from that of 2018. At year end, 28 companies were producing lime, which included 18 companies with commercial sales and 10 companies that produced lime strictly for internal use (for example, sugar companies). These companies had 74 primary lime plants (plants operating quicklime kilns) in 28 states and Puerto Rico. Six of these 28 companies operated only hydrating plants in 11 states. In 2019, five leading U.S. lime companies produced quicklime or hydrate in 21 states and accounted for about 80 percent of U.S. lime production. Principal producing states were, in alphabetical order, Alabama, Kentucky, Missouri, Ohio and Texas. The United States was the world's second-ranked lime producer in the world after China.

Apparent consumption at 18 Mt was estimated to have remained the same as that of 2018. 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 mining.

Foreign trade

Imports of lime decreased by 8 percent to 342 kt in 2019 from 370 kt in 2018. Canada (89 percent) and Mexico (8 percent) were the leading sources

of United States lime imports. U.S. lime exports decreased by 18 percent to 346 kt in 2019 from 422 kt in 2018. Lime exports were primarily shipped to Canada (97 percent).

Prices

The USGS calculates unit values of lime products from the quantity and value data reported for lime sold or used by the lime producers on a f.o.b. 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. There are no published lime prices 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 \$124/t and hydrate sold or used was \$151/t in 2019, which were about the same as those of 2018.

Outlook

The outlook for flue gas systems (lime's second leading market) serving coal-fired power plant, incinerators and other industries is more difficult 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 levels of emissions than coal and, as a result, does not usually require SO₂ scrubbing, which could lead to decreased use of lime in flue gas scrubbing systems. In 2019, 25 percent of domestic utility-scale electricity generation was from coal.

In December 2019, an outbreak of a novel coronavirus (COVID-19) was first identified in China. The World Health Organization declared that COVID-19 was a global pandemic on March 11, 2020. Measures instituted to mitigate the spread of the COVID-19 pandemic, such as closures of nonessential businesses, are likely to cause disruptions in the mining industry across the United States and around the world. The duration and the outcome of the COVID-19 pandemic remains uncertain, but it is expected that the economies of the United States and the world as a whole will likely be negatively affected, which could influence the performance of the lime industry. ■

LITHIUM

by Pablo Cortegoso, SRK Consulting

Lithium is mainly extracted from minerals in igneous rocks such as pegmatites (mainly spodumene), clay minerals (mainly hectorite) and from naturally enriched brines hosted within salars (salt lakes) in hyper-arid regions. Lithium produced from brine sources during 2019 accounted for about 50 percent of global lithium production — the remaining half being produced from hard-rock sources, mostly spodumene. 2019 saw several junior developments halted as well as established miners' expansion plans postponed, mostly due to lower lithium prices and an oversupply scenario.

Production and consumption

Global lithium production in 2019 decreased by 17 percent to 410 kt lithium carbonate equivalent (LCE) (77 kt of lithium metal) from 492 kt LCE (92.5 kt of lithium metal) in 2018 in response to lithium production exceeding consumption and decreasing lithium prices.

Silver Peak in Nevada remains the only producing lithium mine (brine) in the United States. Two companies produced a range of downstream lithium compounds in the United States from domestic or imported lithium carbonate, lithium chloride and lithium hydroxide.

Global consumption of lithium in 2019 was estimated to be about 57.7 kt of lithium metal, an increase of 18 percent from 49.1 kt of lithium metal in 2018. Consumption was lower than anticipated by the lithium industry owing to significant cuts in the value of subsidies in China in 2019 that halted Chinese growth, consumers reducing lithium inventories, and lower electric vehicle sales volumes. Lithium consumption for batteries has increased significantly in recent

years, because rechargeable lithium batteries are used extensively in the growing market for portable electronic devices and increasingly are used in electric tools, electric vehicles and grid storage applications. Lithium minerals were used directly as ore concentrates in ceramics and glass applications.

Pricing

Lithium prices declined during 2019 due to mostly oversupply and reduced electric-vehicle growth. Lithium prices saw a general decrease of 35 percent compared to the end of 2018.

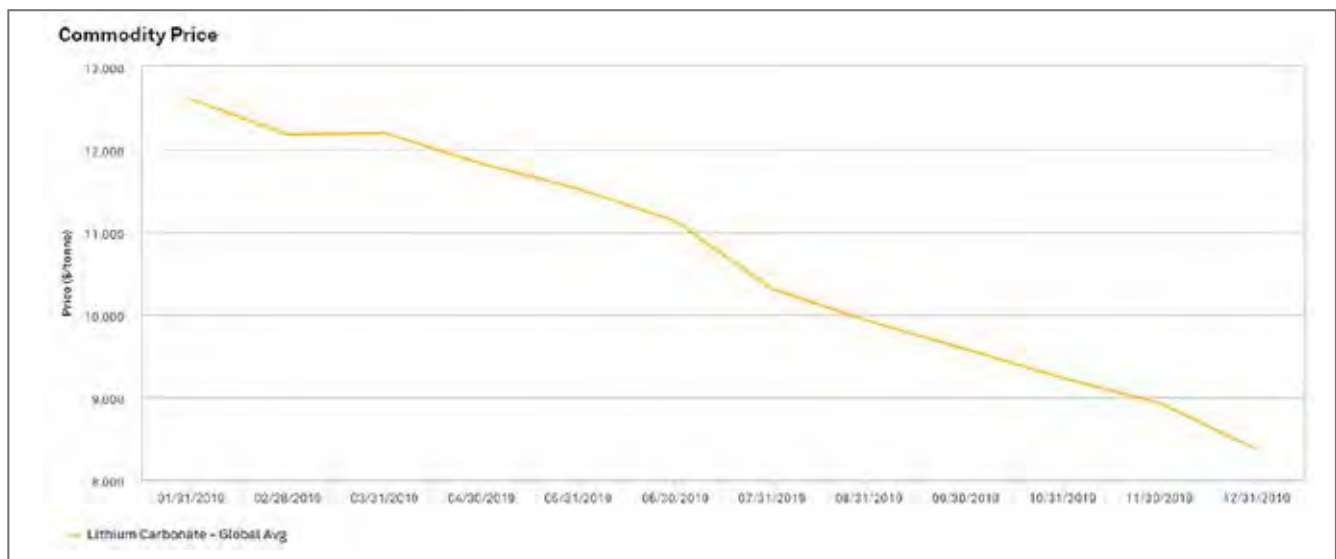
Trends and outlook

During 2019, several brine- and mineral-based operations were under development around the world. Production start for these developments has been further delayed due to the impacts of low prices, lower demand and, more recently, COVID-19-related delays. The downturn in the lithium market during the last 12 months has stimulated a range of supply cutback measures, with most of these being in Australia. A sustained shutdown in Europe, or a second wave of COVID-19 infections later on in 2020, could cause global industry to slow down significantly more than expected.

There are no signs of new domestic mine developments in the United States for 2020. Production is expected to remain unchanged from 2019 numbers. COVID-19-related impacts could result in a reduction of up to 10-15 percent of global lithium production compared to 2019 production levels. ■

Figure 1

Lithium prices declined in 2019 due mostly to oversupply and reduced electric-vehicle demand. Source: S&P Global, Market Intelligence, May 2020.



MAGNESIUM COMPOUNDS

by E. Lee Bray and Adam Merrill, National Minerals Information Center, U.S. Geological Survey

Seawater and natural brines accounted for about 73 percent of U.S. magnesium compound production in 2019. The value of production of all types of magnesium compounds was estimated to be \$276 million. Magnesium oxide and other compounds were recovered from seawater by one company in California and another company in Delaware, from well brines by one company in Michigan and from lake brines by two companies in Utah. Magnesite was mined by one company in Nevada. One company in Washington processed olivine that was mined previously for use as foundry sand. About 72 percent of the magnesium compounds consumed in the United States were used in agricultural, chemical, construction, environmental and industrial applications in the form of caustic-calcined magnesia, magnesium chloride, magnesium hydroxide and magnesium sulfates. The remaining 28 percent was used for refractories in the form of dead-burned magnesia, fused magnesia and olivine.

Dead-burned magnesia and fused magnesia

Dead-burned magnesia was produced by Martin Marietta Specialties LLC from well brine and dolomitic lime at a plant in Manistee, MI. Fused magnesia has not been produced in the United States since 2013. Refractory products were the main use of dead-burned magnesia and fused magnesia, with the steel industry as the leading consumer. Lesser amounts were consumed by the cement, glass and nonferrous metals industries. Dead-burned magnesia and fused magnesia have the same harmonized tariff system code so distinguishing trade trends for both materials by analyzing trade data is difficult. Imports of dead-burned and fused magnesia in 2019 were 242 kt, 7 percent more than imports in 2018. The leading sources were China (63 percent), Brazil (12 percent), and Hong Kong (6 percent). The annual average import unit value on a cost basis, insurance and freight (c.i.f.) for dead-burned and fused magnesia was \$751/t in 2019, 34 percent less than the unit value in 2018. The average annual unit value c.i.f. for dead-burned and fused magnesia imported from China was \$738/t in 2019, 39 percent less than that in 2018. Exports of dead-burned and fused magnesia in 2019 were 49.4 kt, 28 percent less than those in 2018. South Africa was the leading destination, receiving 74 percent of exports, followed by Canada (7 percent). The annual average export unit value free alongside ship (f.a.s.) for dead-burned and fused magnesia in 2019 was \$757/t, 9 percent more than that in 2018.

Even though it is more expensive than dead-burned magnesia, many consumers have switched to using fused magnesia because it has a more prolonged

use period and needs to be replaced less often as compared with dead-burned magnesia, reducing downtime for maintenance. This trend is expected to continue, which may result in reduced imports of dead-burned magnesia in favor of fused magnesia over the long term.

Caustic-calcined magnesia

Caustic-calcined magnesia was produced by Premier Magnesia LLC from magnesite mined at Gabbs, NV. Martin Marietta Magnesia Specialties produced caustic-calcined magnesia from well brine and dolomitic lime in Manistee, MI. Agricultural uses such as in feed supplements and for fertilizer, and environmental applications, mainly for wastewater treatment, were the leading end markets for caustic-calcined magnesia. Other uses included specialty cements, magnesium-based chemicals, and as fillers in plastics and rubber. Imports of caustic-calcined magnesia in 2019 were 188 kt, 5 percent more than imports in 2018. China (73 percent) and Canada (22 percent) were the leading sources. The annual average import unit value (c.i.f.) for caustic-calcined magnesia in 2019 was \$338/t, 18 percent more than that in 2018. The average annual unit value (c.i.f.) for caustic-calcined magnesia imported from China was \$261/t, 21 percent more than that in 2018. Exports of caustic-calcined magnesia in 2019 were 4,810 t, 55 percent less than 2018. Germany was the leading destination, receiving 26 percent of exports, followed by Saudi Arabia (17 percent) and Russia (12 percent). Exports to China decreased by 96 percent in 2019 from 2018. The annual average export unit value (f.a.s.) for caustic-calcined magnesia in 2019 was \$761/t, 6 percent more than that in 2018. Consumption of caustic-calcined magnesia was expected to continue to increase as its use in agricultural markets increases.

Magnesium hydroxide

Magnesium hydroxide was produced by several companies. Water treatment was the leading use of magnesium hydroxide. Other uses included magnesium-based chemicals, flame retardants, flue gas treatment, paper production and pharmaceuticals. Imports of magnesium hydroxide in 2019 were 11.6 kt, 4 percent more than those in 2018. Mexico (57 percent), the Netherlands (13 percent), and Austria (10 percent) were the leading sources. The annual average import unit value (c.i.f.) for magnesium hydroxide increased by 3 percent in 2019 as compared with the average annual unit value in 2018 to \$1,572/t. Exports of magnesium hydroxide in 2019 were 18.7 kt, 18 percent less than exports in 2018. Canada was the leading destination, receiving 58 percent

of exports, followed by Sweden (15 percent) and Mexico (7 percent). The annual average export unit value (f.a.s.) for magnesium hydroxide in 2018 was \$887/t, 8 percent more than that in 2018. Consumption of magnesium hydroxide was expected to continue to increase, mainly as its use increases in flame retardants, where it substitutes for bromine compounds.

International

Because China was the leading producing country for magnesite and magnesite, policy changes in China affected prices and availability of all grades of magnesite in the world market. Stricter enforcement of environmental regulations in Henan and Shandong Provinces that forced some refractory producers to decrease production was cited for decreased consumption of fused magnesite. Decreased demand in China resulted in lower prices as producers in China increased exports. Lower prices for fused magnesite caused prices for dead-burned magnesite also to decrease; the price range for dead-burned magnesite from China decreased by about 33 percent from the start of the year to the end of June in 2019.

Magnesite mines in Liaoning Province were shut down from Aug. 1 to Oct. 31, 2019, due to high

stocks of magnesite and stricter enforcement of environmental regulations. The temporary closure of these mines in China did not cause dead-burned and fused magnesite prices to increase significantly, as stocks of these products were at a high level before the announcement. The government of China announced mandatory shutdowns of capacity in several industries, including steelmaking, in certain areas during the winter months, which would likely decrease demand for fused and dead-burned magnesite.

Outlook

In December 2019, an outbreak of a novel coronavirus (COVID-19) was first identified in China. The World Health Organization declared that COVID-19 was a global pandemic on March 11, 2020. Measures instituted to mitigate the spread of the COVID-19 pandemic, such as closures of nonessential businesses, are likely to cause disruptions in the mining industry across the United States and around the world. The duration and the outcome of the COVID-19 pandemic remains uncertain, but it is expected that the economies of the United States and the world as a whole will likely be negatively affected, which could influence the performance of the magnesium compounds industry. ■

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 2019, U.S. mine production of scrap and flake mica was estimated to have been 38 kt, which was down from 44 kt in 2018. Production of ground mica also was estimated to have been lower at 63 kt as compared with 65.3 kt in 2018. Mica was mined

in Georgia, North Carolina and South Dakota. Scrap mica was recovered primarily from mica and sericite schist and as a byproduct of feldspar mining, industrial sand beneficiation and kaolin mining. Ground mica was produced from domestic and imported scrap and flake mica. A small amount of sheet mica was produced as a byproduct of feldspar mining in North Carolina. In 2019, world production of scrap and flake mica was estimated to have increased to 380 kt from 375 kt in 2018. China (100 kt), the United States (38 kt) and Madagascar (36 kt) were the leading producers, by quantity. World production of sheet mica was unavailable in 2019, but India (1 kt) was the leading producer.

Consumption

Domestic consumption of all forms of scrap and flake mica was 59.9 kt, down from 66.1 kt in 2018. Imports, exports and production were all lower in 2019. Consumption of sheet mica was estimated to have increased by 50 percent to 2,360 t in 2019 from 1,170 t in 2018, owing to a 41 percent increase in imports, primarily from China.

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

The plastics industry used ground mica as an extender and filler, especially in parts for automobiles as lightweight insulation to suppress sound and vibration. Other significant uses for ground mica are in the rubber industry as an inert filler and mold release compound. As a surface coating in the production of rolled roofing and asphalt shingles, mica prevents the sticking of adjacent surfaces. Mica 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, is used primarily in pearlescent paints by the automotive industry. In the cosmetics industry, its reflective and refractive properties make mica an important ingredient in blushes, eyeliner, eyeshadow, foundation, hair and body glitter, lipstick, lip gloss, mascara, moisturizing lotions and nail polish. Mica is 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 2019, the average unit value of scrap and flake mica produced in the United States, which included high-quality sericite, was estimated to be \$120/t. The average value of dry-ground mica was estimated to be \$310/t, and the average value of wet-ground mica was estimated to be \$480/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 values of mica splittings consumed in the United States in 2019 were muscovite splittings at \$1.61/kg and phlogopite splittings at \$7.68/kg.

Foreign trade

In 2019, U.S. imports and exports of scrap and flake mica were estimated to be 27.3 kt and 5.5

kt, respectively. Imports of scrap and flake mica decreased slightly, and exports decreased by 7 percent, compared with those in 2018. In 2019, Canada (39 percent), China (37 percent) and India (10 percent) supplied the majority of U.S. imports of scrap and flake mica, with the remainder from several other countries. Most U.S. exports of scrap and flake mica went to Brazil, Canada, Germany and Mexico.

In 2019, U.S. imports and exports of sheet mica were estimated to be 3,140 t and 797 kt, respectively. Imports of sheet mica increased by 69 percent, compared with those in 2018, owing to higher imports from China, and exports decreased by 19 percent. In 2019, China (72 percent), Brazil (8 percent) and Belgium (4 percent) supplied the majority of U.S. imports of sheet mica, with the remainder from several other countries. Most U.S. exports of sheet mica went to Canada, Germany and Mexico.

Outlook

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

Demand for ground mica in smaller specialty markets such as coated micas, cosmetics, nylon and polyester resins, and polypropylene composites, was expected to have an annual growth rate slightly higher than that of the entire ground mica industry.

Consumption of block mica was expected to increase slowly at about 1 percent per year as demand increases in a few specialty markets, such as electronics. A shortage of domestic high-quality block mica was expected to continue because of the generally low percentage of high-quality mica in deposits currently being mined, mostly from pegmatites. Future supplies of mica were expected to come increasingly from imports, primarily from Brazil, Canada, China and India.

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NITROGEN

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

Ammonia was produced domestically by 16 companies at 35 plants in 16 states during 2019. About 60 percent of total U.S. ammonia production capacity was based in Louisiana, Oklahoma and Texas because of those states' large reserves of natural gas, the dominant domestic feedstock for ammonia production. Four companies — CF Industries Holdings Inc.; Nutrien Ltd.; Koch Nitrogen Co.; and Dyno Nobel ASA, in descending order — accounted for about 70 percent of the total U.S. ammonia production capacity.

Production and consumption

U.S. production was estimated to be 14.0 Mt of nitrogen (N) content in 2019, a 7 percent increase from that in 2018. In 2019, U.S. producers operated at about 90 percent of their rated capacity (excluding plants that were idle for the entire year). Apparent consumption was estimated to have increased by 5 percent to 16 Mt of N content in 2019 from 15.2 Mt of N content in 2018. The United States was the world's third-ranked ammonia producer, after China and Russia, and the world's second-ranked consumer after China. Urea, ammonium nitrate, nitric acid, ammonium phosphates and ammonium sulfate were the major derivatives of ammonia produced in the United States, in descending order of tonnage.

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 plastics, synthetic fibers and resins, explosives and numerous other chemical compounds.

Foreign trade

Imports of ammonia (N content) decreased by 20 percent to 2.02 Mt in 2019 from 2.53 Mt in 2018. Trinidad and Tobago (61 percent) and Canada (38 percent) were the leading sources of U.S. ammonia imports. U.S. ammonia exports increased by 20 percent to 338 kt of N content in 2019 from 282 kt of N content in 2018. Ammonia exports were primarily shipped to Chile (37 percent) and Mexico (36 percent).

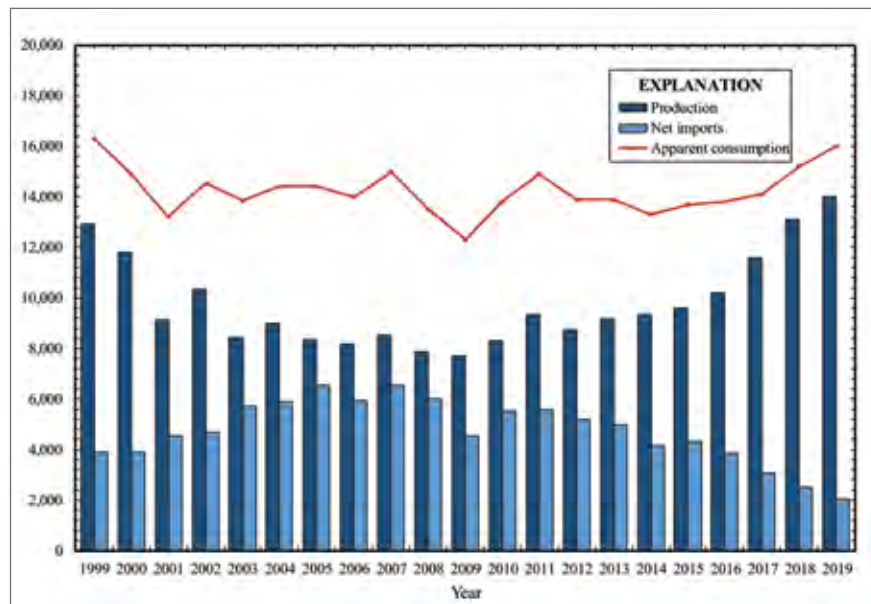
Prices

U.S. Gulf Coast ammonia prices in 2019 averaged \$255/t, 17 percent lower than the average in 2018. The Gulf Coast ammonia price was \$285/t at the beginning of 2019, decreased to a low of \$220/t in mid-April, and by year-end it was \$242/t.

Natural gas is often used as the feedstock to produce ammonia fertilizers, and the cost of natural gas can account for 70 to 90 percent of the production costs. The Henry Hub spot natural gas price ranged between \$1.82 and \$4.12/million Btu for most of the year, with an average of \$2.52/million Btu. The U.S. Department of Energy, Energy Information Administration projected that Henry Hub natural gas spot prices would average \$2.33/million Btu in 2020.

Figure 1

U.S. supply and apparent consumption of ammonia, 1999-2019.



Outlook

A long period of stable and low natural gas prices in the United States has made it economical for companies to upgrade existing ammonia plants and plan for the construction of new nitrogen projects. The additional capacity has reduced ammonia imports but likely will not eliminate nitrogen imports (Fig. 1). Expansion in the ammonia industry took place throughout the past five years; however, no additional ammonia plants are expected to be commissioned before 2022. The newest U.S. ammonia plant located in Freeport, TX, became operational in 2018. In addition to North America, capacity additions are expected in Africa, Eastern Europe and South Asia; however, ongoing plant closures will decrease capacity in East Asia. Demand for ammonia is expected to increase in all

regions with the largest increase expected in Africa and Eastern Europe.

According to 10-year projections (2019-2029) by the U.S. Department of Agriculture (USDA), projected plantings for the eight major field crops (barley, corn, oats, rice, sorghum, soybeans, upland cotton and wheat) in the United States were expected to remain about the same through 2029. Corn production accounts for about one-half of U.S. fertilizer use and planting fewer crops affects the demand for nitrogen fertilizers. During the last eight years of the 10-year projection period, plantings were expected to remain near 100 Mha compared with the recent high of 104 Mha in 2014. Corn, soybeans and wheat were expected to account for about 90 percent of acreage utilization for the eight major field crops. Overall corn acreage in the United States

was expected to remain about the same through the projected period. Corn yields are expected to remain high, with corn being used more for feed and residual use than for ethanol.

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PEAT

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

Peat is a natural organic material of botanical origin. Peatlands are situated predominately in shallow wetland areas of the Northern Hemisphere. Commercial deposits are formed from the incomplete decomposition of plant matter under anaerobic conditions and a gradual accumulation of peat over about a 5,000-year period. In 2019, peat was known to be harvested in 12 conterminous states, with Florida, Michigan and Minnesota being the leading producing states. Although peat has been produced in Alaska, the current status of operations in Alaska is not known because the Alaska Department of Natural Resources, Division of Geological & Geophysical Surveys discontinued its survey of peat producers. Reed-sedge comprised approximately 87 percent of the reported peat production in the United States, followed by sphagnum peat with 10 percent.

Production and foreign trade

In 2019, domestic production of peat, excluding Alaska, was estimated to be 470 kt, compared with 479 kt in 2018 (Fig. 1). In 2019, imports decreased by 3 percent to 1,160 kt compared with 1,200 kt in 2018 (Fig. 1), and exports increased to 46 kt compared with 37 kt in 2018. U.S. apparent consumption for 2019 decreased by 4 percent compared with that of 2018. World production was estimated to be about 30 Mt in 2019, which was slightly less than that of 2018.

At least 70 percent of all peat used in the United States was imported from Canada, which has extensive deposits of high-quality sphagnum peat. Deposits of sphagnum peat in the United States occur primarily in the northern states, with active operations in Maine, Michigan, Minnesota, Montana, Pennsylvania and Washington. The permitting

procedures for new peat operations have become increasingly time-consuming and expensive, causing some companies to abandon harvesting and reducing the number of new fens and bogs brought into production. In addition, extensive areas of peatlands are in protected wetlands, parks or other natural areas that restrict commercial development.

Consumption

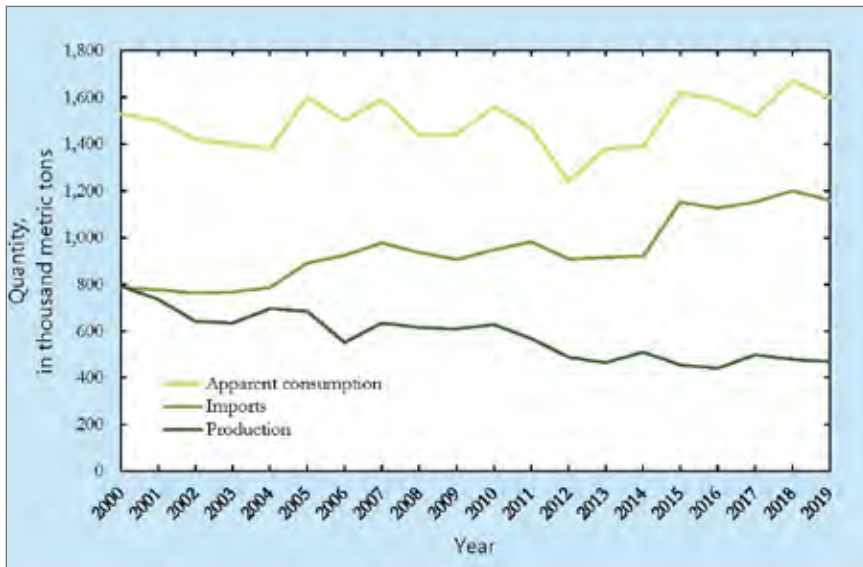
Demand for peat generally follows that of horticultural applications. Potting soil mixes and general soil improvement were the leading domestic end-use categories, accounting for about 90 percent of domestic peat sales. Sphagnum peat is preferred for custom soil mixes and for sale to retail consumers because of its more fibrous composition. More decomposed types of peat, such as reed-sedge or humus, are used primarily in bulk by commercial landscapers and on golf courses. In the industrial sector, peat was used as an oil absorbent and as an efficient filtration medium for the removal of waterborne contaminants in mine waste streams, municipal storm drainage and septic systems. Data for the end-use distribution of peat imported from Canada were unavailable, but the imported peat was sold both in bulk for soil blending and packaged for direct horticultural use. Packaged peat, regardless of origin, commanded a higher price than bulk sales.

International

Finland, Germany, Ireland, Belarus and Sweden were the world's top five peat producers, in descending order of production, based on estimated 2019 world production. Climate change concerns have prompted several countries to plan to decrease or eliminate the use of peat, owing to peatland's

Figure 1

U.S. production, imports and apparent consumption of peat, 2000-2019.



current levels for the next several years. However, U.S. producers face increasing competition from imports of peat from Canada and alternative soil amendments, such as composted organic waste, coir (coconut fiber), and wood byproducts (such as wood fiber and composted bark). The availability of alternative soil amendments as substitutes for peat will determine the future use of peat in different parts of the world.

Peatlands have been identified as carbon sinks, storing more carbon per hectare than any other ecosystem. Preservation and restoration of peatlands may become a high priority in the efforts to reduce greenhouse-gas emissions, further restricting its availability for commercial use in future years. Peat production is

expected to decrease across Europe during the coming years as peatland restoration efforts and use of alternative fuel sources increase.

In December 2019, an outbreak of a novel coronavirus (COVID-19) was first identified in China. The World Health Organization declared that COVID-19 was a global pandemic on March 11, 2020. Measures instituted to mitigate the spread of the COVID-19 pandemic, such as closures of nonessential businesses, are likely to cause disruptions in the mining industry across the United States and around the world. The duration and the outcome of the COVID-19 pandemic remains uncertain, but it is expected that the economies of the United States and the world as a whole will likely be negatively affected, which could influence the performance of the peat industry. ■

ability to act as a carbon sink. Ireland announced in 2019 that it planned to stop all peat harvesting by 2028. In the same year, Finland also announced its goal of becoming carbon-neutral by 2035. To achieve this, peat production will be phased out in favor of other forms of noncarbon energy. Restoration of peatlands in several European countries, including Belarus, Ireland, and Sweden, were being planned or implemented to help combat greenhouse-gas emissions and restore wildlife habitats.

Outlook

Peatlands also are used for agriculture, forestry, recreation and wildlife management. Factors such as the growing interest in gardening, golf course development and landscaping related to residential use indicate that peat usage is likely to remain near

PERLITE

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

Perlite is an amorphous siliceous volcanic glass with a relatively high content of water. When perlite ore is rapidly heated to about 900 °C (expansion temperatures vary depending on the chemical composition and water content of the ore), the contained water converts to steam, and the ore expands or pops like popcorn. Expanded perlite appears lighter in color (white) than the crude ore (gray to black) and can expand up to 20 times its original volume. The resulting ultralightweight material has many desirable attributes for myriad industrial applications.

Production

In 2019, U.S. domestic production of processed crude perlite (the quantity sold or used by producers) increased to an estimated 480 kt valued at \$35 million from an estimated 460 kt in 2018. Crude perlite was

mined by six companies operating eight mines in five western states, owing to the ore's occurrence within areas of geologically recent volcanic activity. Processed crude perlite was expanded at locations closer to the point of use at 56 expanding plants in 27 states. World production of perlite was an estimated 4.1 Mt in 2019, a slight increase from 4.02 Mt in 2018. The world's leading producer was China, followed by Greece, Turkey and the United States.

Consumption

Expanded perlite's low density and porous structure, as well as its durability, fire resistance, inertness, low acoustical and thermal conductivity, and water-retention capacity make it well suited for a range of applications. In 2019, the major domestic markets for perlite were, in descending order of tonnage, construction products (58 percent); fillers

(18 percent); horticultural aggregate (16 percent); filter aid (4 percent) and other (4 percent), such as specialty insulation and miscellaneous uses. Domestic apparent consumption, defined as processed perlite sold or used by producers plus imports minus exports, increased to an estimated 645 kt from an estimated 620 kt in 2018.

As a relatively new product (commercial production of perlite began in the United States in the 1940s), innovative uses for perlite are still being developed. Alternate materials for construction applications include diatomite (also used in filtration), expanded clay and shale, pumice and slag. In horticulture, coco coir, exfoliated vermiculite, pumice and wood pulp may be used. Perlite is preferred over some substitutes for its unique physical properties and may sometimes be used in conjunction with other soil additives.

Prices

The average unit value of processed crude perlite sold to expanders in 2019 was estimated to be \$72/t, unchanged from the price in 2018. Expanded perlite unit values range widely depending on the grade of the perlite required for various end products.

Foreign trade. U.S. export and import data for perlite are not collected using a unique Harmonized

Tariff Schedule (HTS) subheading, but instead are included within the group “vermiculite, perlite and chlorites, unexpanded” (HTS of the United States code 2530.10.0000). Based on information published by the U.S. Census Bureau, domestic exports of perlite were estimated to have increased by 13 percent to 18 kt in 2019 from 16 kt in 2018, with Canada receiving nearly all exports (99 percent). Total United States imports for consumption of perlite were estimated to be 183 kt, a decrease of 10 percent from 204 kt in 2018, with most imports in 2019 coming from Greece (93 percent), China (3 percent), Mexico (2 percent) and Turkey (1 percent).

Outlook

The World Health Organization declared the novel coronavirus (COVID-19) a global pandemic on March 11, 2020, after COVID-19 was first reported in China in December 2019. Restrictions implemented by governments to mitigate the spread of the virus are likely to disrupt the global mining industry, and the outlook for 2020 remains uncertain. Demand for horticultural-grade perlite may increase owing to increased interest in home gardening, but construction products remain the largest domestic market for perlite. Economic recovery, including construction activity, is expected to influence the forecast for the perlite industry. ■

PHOSPHATE

by T.M. “Mike” Gurr and David M. Gurr, Gurr Professional Services Inc.

2019 crop year. U.S. marketable phosphate rock production for the 2019 crop year (July 1, 2018 to June 30, 2019) showed a decrease to 23.9 Mt from the 2018 crop year production of 25.8 Mt, as reported to the U.S. Department of the Interior by the mining companies operating in the United States during crop year 2019. Domestic consumption decreased in the 2019 crop year to 26.4 Mt, as compared to the 28.3 Mt consumed in crop year 2018. U.S. imports of phosphate rock decreased to 2.53 Mt for the 2019 crop year, a decrease from the 2.98 Mt for crop year 2018. Imports of phosphate rock were from Peru and Morocco. There was a decrease of 0.67 Mt in producers’ stocks from 10.3 Mt in crop year 2018 to 9.63 Mt in crop year 2019 (Table 1).

2019 calendar year. For calendar year 2019, Florida and North Carolina phosphate rock production accounted for 75 percent of the total U.S. production, with the balance being produced in the western states of Idaho and Utah. The Florida and North Carolina percentage of of U.S. production is declining.

Figure 1

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



Table 1

Phosphate rock production.

Crop year (July 1-June 30)						
Production (marketable, beneficiated)					Consumption	
Crop year	Phosphate rock tons ²	% BPL	Value (f.o.b. mine) ¹	Ending stocks tons ²	Tons ²	Value ¹
2009	27.8	62.6	\$111.09	8.89	26.8	\$116.75
2010	26.7	62.5	\$64.53	7.57	30.1	\$64.78
2011	26.5	63.4	\$93.72	5.37	30.6	\$92.31
2012	28.8	63.1	\$98.36	5.60	31.3	\$100.51
2013	31.9	62.6	\$99.58	7.14	30.9	\$95.51
2014	28.0	62.0	\$80.97	7.94	30.4	\$80.97
2015	26.1	61.3	\$70.09	6.87	28.4	\$72.94
2016	26.2	61.3	\$81.71	9.34	27.7	\$83.78
2017	27.1	61.1	\$75.45 ^e	7.45	27.2	\$77.55
2018	25.8	60.8	\$74.61	10.30	28.3	\$74.30
2019	23.9	61.1	\$69.00 ^e	9.63	26.4	\$69.00

¹ Price (U.S. dollars per metric ton), ² million metric tons, ^e estimated. Source: Stephen M. Jasinski
USGS Minerals Industry Surveys, draft crop year.

of the world production of 240 Mt for calendar year 2019 (Table 2). This was a decline from the production of 27.7 Mt. from calendar year 2018.

In calendar year 2019, U.S. phosphate production decreased by 2.5 Mt; in addition, companies decreased stocks of phosphate rock by 1.2 Mt. The domestic production for calendar year 2019 of 23.3 Mt represents 75 percent of the domestic production capacity of 31.1 Mt.

At present, China reportedly produces more than 45.8 percent of the world's total production of phosphate rock. As a result of planned expansions, Morocco production has increased from 33 Mt in 2018 to 36 Mt in calendar year 2019, which is approximately 15 percent of the world's production, moving ahead of the U.S. production. In calendar year 2019, the U.S. phosphate rock production was 23.3 Mt, which was less than 10 percent of the world's production of phosphate rock (Fig. 1).

Table 2

Phosphate production, U.S. position.

World production ¹						
Calendar year	Tons ^{1, 2}				U.S. percent	Morocco ³ percent
	World	China	Morocco ³	United States		
2009	166.0	60.2	23.0	26.4	15.90	13.86
2010	181.0	68.0	25.8	25.8	14.25	14.25
2011	198.0	81.0	28.0	28.1	14.19	14.14
2012	217.0	95.3	28.0	30.1	13.87	12.90
2013	225.0	108.0	26.4	31.2	13.87	11.73
2014	218.0	100.0	30.0	25.3	11.61	13.76
2015	241.0	120.0	29.0	27.4	11.37	12.03
2016	255.0	135.0	26.9	27.1	10.63	10.55
2017	263.0	144.0	27.0	27.9	10.61	10.27
2018	267.7	140.0	33.0	25.8	10.36	12.33
2019	240.0	110.0	36.0	23.3	9.70	15.00

¹ Estimate for 2019, ² million metric tons, ³ includes Western Sahara. Source: Stephen M. Jasinski, USGS Mineral Commodity Summaries, January 2020 pp 123-124, Phosphate Rock and Marketable Phosphate Rock in January 2020, April 2020.

U.S. production of 23.3 Mt in calendar year 2019 was produced by five companies at 10 mines in four states and accounted for approximately 9.7 percent

consumption. The remainder of the production is used to produce elemental phosphorus, defluorinated phosphate rock or was used for direct application to

Imports/exports

There were no reported U.S. exports of phosphate rock in crop year 2019 nor have there been any reported exports of phosphate rock since crop year 2004. U.S. producers continue to prefer to export the higher-value fertilizer products, such as monoammonium phosphate (MAP), diammonium phosphate (DAP) and triple super phosphate (TSP), in preference to phosphate rock. Approximately one-half of the MAP, DAP and TSP produced in calendar year 2019 were exported.

Importation of phosphate rock in calendar 2019 is estimated by the U.S. Geological Survey (USGS) at 2.53 Mt as compared to 2018 imports of 2.98 Mt. Imports were from Morocco (20 percent), Peru (79 percent) and others (1 percent).

Uses

The manufacturing of fertilizers and the production of animal feed supplements account for more than 95 percent of phosphate rock

Table 3**Phosphate rock prices¹.**

Phosphate use	Year				
	2015	2016	2017	2018	2019
Domestic production (f.o.b. mine)	\$72.41	\$76.90	\$73.67	\$70.77	\$70.00
Percent change from prior year	-7.24%	6.20%	-4.20%	-3.94%	-1.09%
Exports (FOB port)	N/A	N/A	N/A	N/A	N/A
Imports (CFI)	\$115.00	\$101.00	\$84.00	\$77.97	\$73.55

1 Price (U.S. dollars per metric ton). Source: USGS Mineral Industry Surveys, Stephen M. Jasinski, Mineral Industry Surveys Marketable Phosphate Rock in December 2019, Table 2, January 2020, Table 3, and 2019 Annual Phosphate Rock pp. 122 and 123.

the soil. 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.

Synthetic equivalents

There is no natural or synthetic substitute for phosphorus, which is essential for life in all growing things, plants and animals alike. There currently is no economical alternative to phosphate rock as the major source of phosphorus.

Prices

Calendar year. The 2019 calendar year average price at the mine was reported at \$70/Mt, which is slightly less than the calendar year 2018 average price of \$70.77/Mt (Table 3). The value of the imported phosphate in calendar year 2019 of \$73.55/Mt also declined from \$77.97/Mt in the prior calendar year (Table 3).

Morocco. In December 2019, Morocco phosphate rock prices had declined to \$72.50 from a high in January and February of 2019 of \$102.50/Mt.

Fertilizers: DAP and TSP spot prices, Tunisian granular, free on board (f.o.b.), peaked in September and October 2018 with DAP at \$421.63/Mt and TSP at \$385/Mt in October 2018, then prices began to fall; in December 2019 DAP fell to \$238.66/Mt and TSP fell to \$243/Mt.

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).

In the western states of Idaho and Utah there are currently three producers: Bayer (which acquired Monsanto), Itafos, a Brazilian operation (which acquired Nutrien) and Simplot. All producers are developing/permitting replacement mines for mines nearing exhaustion of reserves. The new mines will generally be located near existing facilities.

Due to decreased demand (resulting from adverse weather conditions in North America) and falling prices in the fourth quarter of 2018, many phosphate mining operations reduced production and idled mines. However, late in 2019, prices began to improve.

Despite the low prices in past few years, the

world capacity to produce phosphate rock is expected to continue to increase as a result of many other phosphate mine expansion projects. Although slowed by recent low prices, active exploration and feasibility studies of the potential for development of phosphate deposits worldwide are ongoing.

Most of the growth in phosphate production since 2000 has principally been in China (Fig. 1 and Table 2). China has transitioned from the largest importer of phosphate to the largest exporter of phosphate. At the present time, China is reported to be ahead of the United States in exports of all phosphate products, except MAP. In addition, China is the largest exporter of P_2O_5 products in the world.

Environmental, regulatory and reclamation issues

Because of the difficulties of permitting in Florida, there are numerous permitting activities ongoing in the western states.

Exploration activities on western phosphate lands have been extensive over the past few years. The permitting activities include extensions of existing phosphate mines, expansions of existing mines or new phosphate mines. Itafos is currently working with the U.S. Bureau of Land Management (BLM) on restarting the Environmental Impact Statement (EIS) process and the permitting for mining the Husky-North Dry Ridge phosphate leases.

BLM issued a Record of Decision for Bayer's Caldwell Canyon Mine in August 2019. Infrastructure and preliminary pit preparation were conducted in the fall of 2019 in preparation for mining to begin in 2020. The final EIS was released to the public in November 2019 with the Record of Decision anticipated to be issued in March 2020 for Simplot's Dairy Syncline in 2020. The final EIS for the Simplot East Smokey Canyon Panel is expected to be released in early 2020.

Trends and outlook

The worldwide demand for phosphate fertilizers is expected to increase gradually in proportion to the increase in the world population. The leading

plans for growth are reported to be in Africa and the Middle East. The USGS reports that industry analysts predict worldwide phosphate production will incrementally increase capacity to 171 Mt/a in 2023, excluding official reported capacity for China, which is considered to include phosphate ore in the reported production of marketable phosphate rock. Actual marketable phosphate production for China is believed by industry analysts to be 80 to 85 Mt/a year rather than the reported production.

A Russian company is reported by the USGS to have restarted an idled phosphate rock mine that is planned to produce 2.2 Mt/a. The contract with the Syrian government is for 50 years.

Continued depletion of high-yield deposits of phosphate ore in Florida and the environmental restrictions being placed on U.S. facilities will result in stable or declining production capacity from some of the existing and proposed U.S. facilities, which will limit the U.S. production. U.S. production is expected to gradually decline as a percentage of total

world production as U.S. reserves are depleted and as other countries continue to increase production as a result of the increased global competition in the fertilizer industry. As a result, domestic phosphoric acid production is also expected to slowly decline as a percentage of world production capacity.

Most of the near-term increases in world production is expected to occur in Africa and the Middle East, where expansion projects are ongoing in Jordan, Morocco, Saudi Arabia, Senegal and Togo. ■

¹Data compiled predominantly from personal knowledge, contacts in the industry, USGS Mineral Industry Surveys: USCOE and BLM EIS documents; personal communication with Stephen Jasinski, USGS and Jeffery Cundick U.S. BLM field office in Idaho; news and financial reports for, Mosaic, Ma'aden, Office Cherifien des Phosphates, Vale, Fosyieiki S.A.C, Itafos, and Simplot; indexmundi; World Bank, National Rural News, CRU; Reuters.com, Nutrien Ltd. and other various news and trade publications.

POTASH

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

In 2019, U.S. potash consumption was estimated to have declined by 18 percent to 5,000 kt of potassium oxide (K_2O) compared with 6,100 kt of K_2O in 2018, owing to wet weather conditions in the spring and fall, which reduced fertilizer application. U.S. production was 510 kt of K_2O , which was slightly lower than that in 2018. World production was estimated to be 41 Mt of K_2O , which was 5 percent lower than that of 2018. The major world producers closed mines and reduced output in the fourth quarter because of weak world demand caused by poor weather conditions in some regions and lower Chinese imports that resulted in higher stocks and falling prices. Canada (13.3 Mt), Belarus (7 Mt), Russia (6.8 Mt) and China (5 Mt) were the leading producers, accounting for 78 percent of total production.

Production

Potash encompasses a variety of mined and manufactured salts, all of which contain the element potassium in water-soluble form. The term potash, however, also can refer specifically to potassic fertilizers, which are potassium chloride [KCl] or the mineral sylvite, potassium sulfate [(K_2SO_4) or sulfate of potash (SOP), usually a manufactured product], and SOPM [$(K_2SO_4 \cdot 2MgSO_4)$ or langbeinite or double sulfate of potash magnesia]. Muriate of potash (MOP) for fertilizer use is an agriculturally acceptable mix of KCl (95 percent 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 K_2O content.

In 2019, about 20 percent of U.S. production was in the form of MOP, all of which 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.

Consumption

According to a February 2020 report from the International Fertilizer Association, world consumption of all forms of potash in 2019 was 42.9 Mt of K_2O , compared with 43.3 Mt in 2018.

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

U.S. imports of potash decreased 18 percent to 4.64 Mt of K_2O in 2019, compared with 5.71 Mt of K_2O in 2018, owing to reduced demand caused by wet weather during spring and autumn planting seasons. Canada (76 percent), Belarus (10 percent), and Russia (9 percent) were the leading suppliers. The United States is not a significant exporter of potash. SOP and SOPM accounted for 83 percent of U.S. potash exports. In 2019, exports increased to 145 kt of K_2O from 105 kt of K_2O in 2018.

Prices

The Vancouver, BC, Canada spot price for granular potash began the year averaging \$274/Mt and ended the year at \$248/Mt.

Industry developments

In the United States, development of the Crystal Peak Minerals Inc. Sevier Playa SOP project in Utah continued in 2019. The new facility, which is about 225 km southwest of Salt Lake City, would produce SOP from solar evaporation of surface brines. The company received final permits in 2019 and was expected to begin construction in 2020. Production was scheduled to begin in 2022 at 30 kt/a of SOP and ramp up to full capacity of 372 kt/a of SOP in 2025.

Canada is the leading potash-producing country in the world, with 38 percent of global capacity. All production in Canada was from Saskatchewan in 2019. Potash was produced by three companies: Nutrien Ltd., which controlled 24 percent of world MOP capacity at six mines; Mosaic, which operated three mines; and K+S Aktiengesellschaft, which operated one mine. In 2019, Nutrien temporarily closed its Allan, Lanigan and Vanscoy Mines for the final eight weeks of 2019 in response to high inventories and lower prices, reducing its production capacity by nearly 700 kt/a of MOP. The company reopened the Allan and Lanigan mines in January 2020. The Vanscoy Mine was scheduled to reopen in March 2020, but a fire at an above-ground storage facility in early March 2020 delayed the reopening indefinitely.

Mosaic closed its Colonsay Mine in August 2019 and the Esterhazy Mine in October 2019 in response to market conditions, reducing its production capacity by 600 kt/a of MOP. Belraskali JSC (Belarus), Israel Chemicals Ltd. (Israel), K+S Aktiengesellschaft (Canada and Germany), and Uralkali PJSC (Russia) all made significant

reductions in production during the fourth quarter of 2019. Worldwide reductions in potash production capacity were about 3 Mt/a.

In Russia, EuroChem MCC, OJSC began commercial production at the 2.3-Mt/a-MOP Usolskiy Mine in early 2019 and ramp up to full capacity was expected in 2021. Eurochem continued development of the VolgaKaliy Project, which began test production in 2019. The mine project was scheduled to be completed in two phases, each with a production capacity of 2.3 Mt/a of MOP. The first phase was projected to begin commercial production in 2021, and the second phase was expected to be completed after 2024.

Outlook

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

Between 2021 and 2023, other new mines were planned to start production in Belarus, Morocco, Russia and Spain, and expansion projects at existing facilities were ongoing in Canada, China, Israel and Russia. These new projects could increase world production capacity to 68 Mt/a of K_2O in 2023 from 60 Mt/a of K_2O in 2019. Other new potash mine projects in Australia, Canada, Congo (Brazzaville), Eritrea, Ethiopia and the United Kingdom were not expected to be completed until after 2024, owing to financing difficulties and low potash prices. Belarus, Canada, and Russia were expected to remain the leading world producers and exporters. World potash consumption for all uses was projected to increase to 44.4 Mt of K_2O in 2020 from 42.9 Mt of K_2O in 2019, with the largest consumption growth in Asia and South America.

All of these projections, however, may be slowed by recent global developments. In December 2019, an outbreak of a novel coronavirus (COVID-19) was first identified in China. The World Health Organization declared that COVID-19 was a global pandemic on March 11, 2020. Measures instituted to mitigate the spread of the COVID-19 pandemic, such as closures of nonessential businesses, are likely to cause disruptions in the mining industry across the United States and around the world. The duration and the outcome of the COVID-19 pandemic remains uncertain, but it is expected that the economies of the United States and the world as a whole will likely be negatively affected, which could influence the performance of the potash industry. ■

PUMICE

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

Mine production of pumice in the United States during 2019 was estimated to be 510 kt, which was 3 percent more than that of 2018. The unit value of pumice was estimated to be \$33/t in 2019, slightly more than that of 2018. Since 2015, the average unit value of pumice has ranged from \$33/t to \$39/t. Production occurred at 10 operations in California, Idaho, Kansas, New Mexico and Oregon. U.S. pumice exports totaled about 12.0 kt. Imports were higher at 136 kt.

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 2019. Pumice is used more extensively as a building material outside the United States, which explains the large global production of pumice relative to that of the United States. The top world producers in 2019 were, in descending order of production, Turkey (7.8 Mt), Greece (1.1 Mt), Algeria and Jordan (900 kt each), and Ethiopia and Uganda (800 kt each).

Pumice is an extrusive igneous 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.

Processing and uses

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. Although the generation and disposal of reject fines in mining and milling result in local dust issues at some operations, the

environmental impact is restricted to a relatively small geographic area.

Pumice blocks, the primary use for pumice, may be sawn into a variety of shapes and sizes. In 2019, 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, tooth-filing mechanisms for chinchillas, exfoliants in cosmetics, and a variety of heavy-duty hand cleaners. Imports were primarily used as raw material for building block (e.g., 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 is sensitive to mining and transportation costs. An increase in fuel prices would likely lead to increases in production expenditures; imports and competing materials could become attractive substitutes for domestic products.

In December 2019, an outbreak of a novel coronavirus (COVID-19) was first identified in China. The World Health Organization declared that COVID-19 was a global pandemic on March 11, 2020. Measures instituted to mitigate the spread of the COVID-19 pandemic, such as closures of nonessential businesses, are likely to cause disruptions in the mining industry across the United States and around the world. This likely includes the pumice producing community. The duration and the outcome of the COVID-19 pandemic remains uncertain, but it is expected that the economies of the United States and the world as a whole will likely be negatively affected, which could influence the performance of the pumice industry. ■

RARE EARTHS

by Weiping Liu, Technical Services, Freeport Minerals Corp.

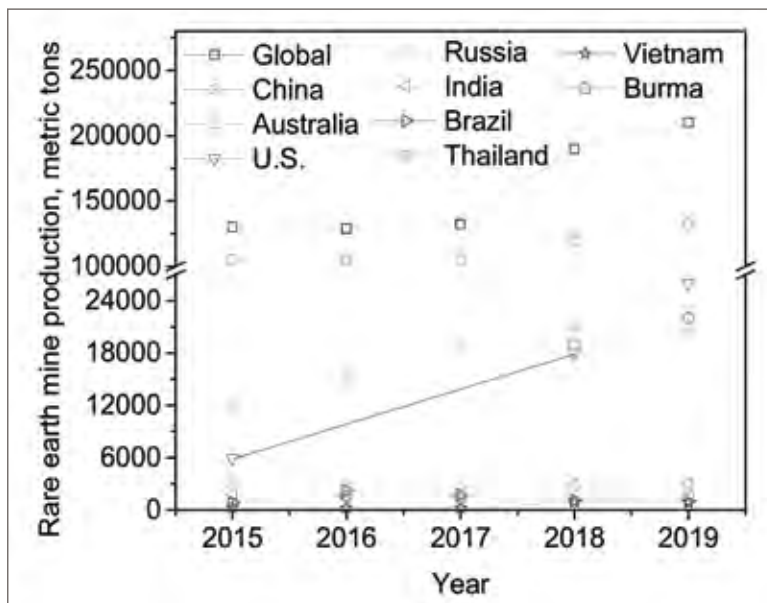
Rare earth oxides (REOs) are primarily concentrated from minerals such as bastnaesite, loparite, monazite, xenotime and lateritic ion-adsorption clays. REO mine production outside of China include primary production in the United States, Burma, Australia and byproduct production

from heavy-mineral, phosphate, uranium and other mining operations and from mine tailings in Russia, India, Brazil, Thailand, Vietnam, Malaysia and other countries.

The global mine production of rare earth elements (REE) in 2019, exclusive of undocumented

Figure 1

Global rare earth oxide mine production.



production in China and elsewhere, was estimated to be 210 kt of contained rare earth oxides, which increased 11 percent from 190 kt in 2018 as shown in Fig. 1. In the United States, domestic production of mineral concentrates, all of which were exported, increased to 26 kt, a 44 percent increase compared with that of 2018. China continued to dominate the global supply of rare earths and its mine and separation production quotas for 2019 were 132 kt and 127 kt, respectively.

In China, the government set the REO mine production quota at 132 kt in 2019, an increase of 10 percent from 120 kt in 2018. Australia kept the same rare earth production of 21 kt in 2019 when compared to 2018. In the United States, rare earths were mined in 2019. Bastnaesite (or bastnäsite), a rare earth fluorocarbonate mineral, was mined as a primary product at a mine in Mountain Pass, CA, which was restarted in the first quarter of 2018 after being put on care-and-maintenance status in the fourth quarter of 2015. Monazite, a phosphate mineral, was produced as a separated concentrate or included as an accessory mineral in heavy-mineral concentrates. The estimated value of rare-earth compounds and metals imported by the United States in 2019 was \$170 million, an increase from \$160 million in 2018. The estimated distribution of rare earths by end use was as follows: catalysts, 75 percent; metallurgical applications and alloys, 5 percent; ceramics and glass, 5 percent; polishing, 5 percent; and other, 10 percent.

Russia's mine production of REO was estimated to be 2.7 kt in 2019, which was the same when compared to the REO production in 2018. India, a significant producer of heavy-mineral sands, produced 3 kt REO in 2019, increased a little from 2.9 kt REO in 2018. Brazil produced 1 kt of REO equivalent in mineral concentrates in 2019, decreased 9 percent from 1.1 kt in 2018. REO concentrates in Brazil were

produced from a stockpile of previously mined heavy mineral concentrates. In recent years, monazite concentrates were shipped from Brazil to Chinese processors.

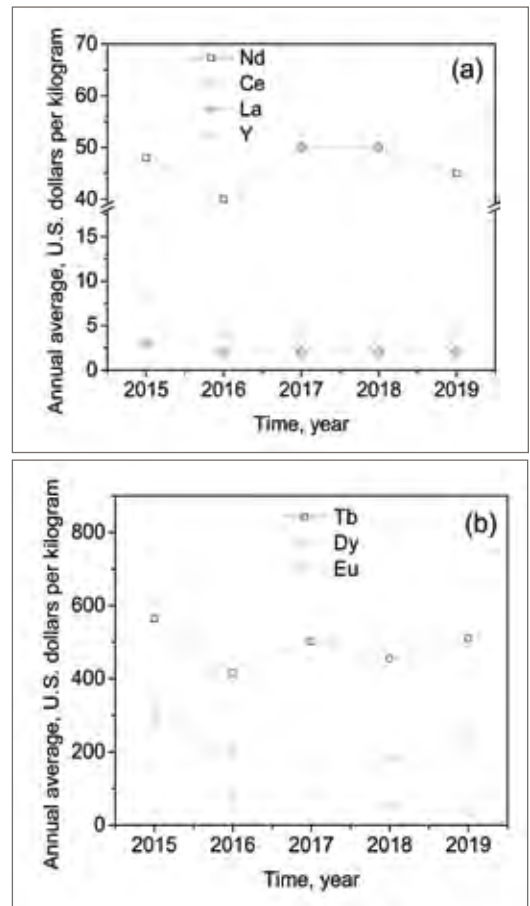
Thailand produced 1.8 kt of REO in 2019, an increase of 80 percent from 1 kt in 2017. Several countries produced and exported monazite and xenotime byproduct in the processing of heavy-mineral sands. Brazil, Thailand, Vietnam, Malaysia and Nigeria all exported mineral concentrates to China.

Consumption

The leading end uses for rare earth include, in descending order, catalysts, magnets, polishing, batteries and metallurgy. China emerged as the world's largest importer of rare earth compounds in 2019. Other leading importers of rare earth compounds were Japan, the United States, South Korea and India. The estimated global distribution of rare earth consumption by end use was as follows: magnets, 36 percent; catalysts, 15 percent; polishing materials, 12 percent; metallurgical applications, 9 percent; and other, 28 percent. The estimated distribution of rare earth consumption by countries was listed as China, 57 percent; Japan, 21 percent; the United States, 8 percent; Europe, 8 percent; and other 6 percent. The main application of rare earth by countries were as follows: China, 42 percent for magnets; Japan, 26 percent for polishing material; the United States, 60 percent for catalysts; Europe, 31 percent for catalysts.

Figure 2

(a) Neodymium, yttrium, cerium and lanthanum rare earth prices, (b) Terbium, dysprosium, and europium rare-earth oxide prices.



Prices

The USGS reported data indicated that the price of rare earth oxide slightly increased in 2019 as shown in Fig. 2. Cerium and lanthanum oxides are the largest REOs produced by volume and are mainly used in catalysts, metallurgy and polishing. Cerium, lanthanum and yttrium prices have followed a nearly identical pattern since 2016. Permanent magnets are a key end use for light REEs and heavy REEs. In addition to substitution and recycling efforts by phosphor consumers, prices for heavy REEs have been influenced by the rising popularity of less REE-intensive LED lighting.

Reserves and resources

Global reserves of REOs in 2019 were estimated to have been 120 Mt. Reserves of REOs in the United States included an estimated 1.4 Mt that were compliant with the international industry standards. On a global basis, compliant resources were estimated to be about 280 Mt.

Outlook

Mining of rare earth increased with renewed production in the United States supplemented with new and or increased production in China and Australia. It is expected that the rare earth production

will increase in the United States, Australia and Canada.

Global consumption of rare earths is expected to increase at a compound annual growth rate in excess of 5 percent through 2020. Rare earth use, particularly in catalysts, ceramics, magnets, hydrogen storage alloys and polishing compounds, is expected to continue to rise as future global demand for alternative energy sources, automobiles, consumer goods and industrial motors increases. Demand for cerium and lanthanum for use in automotive catalytic converters and catalysts for petroleum refining is expected to trend with the production of refining of heavy crude oil and automotive production; however, rare earth use in fluid catalytic cracking will be influenced by the cost competitiveness of reformulated catalysts that contain lower REOs. Similarly, demand for neodymium, praseodymium, and dysprosium are expected to trend with demand for neodymium-iron-boron permanent magnets used in industrial motors, consumer goods and conventional and electric vehicles. ■

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SODIUM CARBONATE

by Jonathan Kuhn, Genesis Alkali LP

Sodium carbonate, otherwise known as soda ash, is a basic alkali used in the manufacture of several industrial and consumer products. Roughly half of the world's production is consumed in the manufacturing of glass in various forms — architectural glazing, glass packaging, fiberglass and tableware. The other half of the world's production is consumed in a variety of industrial segments including the production of other inorganic chemicals, detergents, as well as water and air treatment applications.

Soda ash is primarily produced by either refining a naturally occurring ore (such as trona or nahcolite) or by reacting carbon dioxide with an ammoniated brine to form the alkali compound in what is referred to as the synthetic process. Naturally produced soda ash benefits from lower production costs, lower energy consumption and minimal environmental impact compared to synthetic production methods. Just under a third of the world's supply is produced from natural sources with two-thirds of this capacity concentrated in the United States due to the plentiful ore deposits in southwestern Wyoming. Due to the lack of ore reserves in other regions of the world, more than two-thirds of the global capacity was developed based on the synthetic process with the majority using a process

developed by Ernest Solvay that produces soda ash along with a calcium chloride byproduct. A modified process is used primarily in China, developed by Debang Hou, to produce soda ash and ammonium chloride as the byproduct to be marketed as a fertilizer.

Global demand and supply

Global soda ash demand in 2019 is estimated at more than 59 Mt, up about 1 percent from 2018 with 5 Mt being consumed in the United States. While China remains the largest consumer and producer of soda ash in the world, with 2019 demand and production estimated at 25 Mt and 26 Mt, respectively, both demand and capacity growth have slowed in China since 2013. Other regions of the world including Southeast Asia, the Indian subcontinent and Latin America have grown at a more rapid pace. Consistent with the last decade, the United States maintained full utilization, producing approximately 12 Mt of soda ash in 2019. Further development of natural ore deposits in Turkey added an additional 3 Mt of capacity, bringing Turkey's production in 2019 to just under 5 Mt. The increased production was supported by strong demand for natural soda ash in export markets driven

largely by the cost competitiveness, in addition to the lower environmental impact, of natural soda ash versus synthetic soda ash.

Pricing

Global prices of soda ash have generally been rebounding since the global financial crisis, as excess capacity has largely been rationalized, and global demand continues to grow at roughly 2 percent per year. From 2013 to 2016, roughly 2 Mt of capacity outside China was retired. Between 2016 and 2018, the Chinese government focused on eliminating overcapacity in several industrial markets and utilized increased environmental checks in an effort to reduce industrial pollution. Overcapacity was meaningfully curtailed in the Chinese coal industry in order to bring producer profitability to more sustainable levels. Increased energy costs, as well as energy's impact on other raw material costs, increased costs for synthetic soda ash in China. While the majority of global soda ash capacity is based on the Solvay process, the majority of the capacity in China is based on the Hou process. Due to a chronic oversupply in the fertilizer markets, the value of ammonium chloride has remained relatively low, resulting in higher costs for Hou based production and a higher floor for Chinese

market pricing. Natural soda ash production remains fully utilized with producers following regional market trends to stay competitive with the local synthetic production or other imports. Domestically, U.S. prices show much less volatility compared to most global regions due to a mature market demand, a more sustainable cost structure of supply and longer-term supply relationships.

Outlook

The coronavirus epidemic in early 2019 is leading to a near-term demand shock in most regions. Demand is expected to normalize in late 2019 to early 2020. Global production is being curtailed to match demand as the economics and product quality risks are not favorable for substantial long-term storage. Since the recession of 2008-2009, the global demand growth for soda ash has averaged roughly 2 percent per year with demand in developing economies growing at a faster rate than developed markets in the United States, Western Europe and China. These trends are expected to resume once the demand normalizes from the virus impact. Natural soda ash production will be able to meet expected future demand growth, as some capacity expansions have been announced for U.S. natural production. ■

SULFUR

by Gerard d'Aquin, CEO, Con-Sul Inc.

Elemental sulfur is essential to human existence. Without sulfur there would be no human life. Sulfur and its derivatives are intimately related to the formation of protein and amino acids in plants, animals and humans. In addition to allowing humans to thrive, sulfur is a cornerstone of agricultural, industrial, feedstuff, preservative processes and medicinal applications. Sulfur's pre-eminence commenced in antiquity as our predecessors recognized the element's myriad unique characteristics. Incipient chemistry in the Middle Ages brought further recognition, followed by a crucial role in industrial chemistry from the 18th century forward. Today, in addition to traditional uses, sulfur and its derivatives are being examined for applications in super-efficient electric storage batteries, as a superconductor and as a component for solar-based electrical generation. Searches through Wikipedia can be eye-opening on a rainy day.

Sulfur's millennia-old negative public perception is justifiably linked to odorous and deadly compounds from volcanoes: hydrogen sulfide (H_2S) along with sulfur dioxide (SO_2) and trioxide (SO_3), to name few. Being the alchemists' "stone that burns" (aka brimstone) to create the foregoing compounds, and more, added to its mystery. In

modern times, its negative persona is mostly linked to airborne pollution from power generation, fuels and industrial processes. The last 50 years' notoriety focused on the dramatic visual impact of acid rain and its resultant environmental degradation. Acid rain's link to deforestation, newfound understanding of respiratory illnesses tied to sulfur dioxide mist and legislated removal from fuels to de minimis levels are some of the negative headlines associated with sulfur and its compounds. The most recent restriction came in marine fuel where ships' bunkers must now reduce the sulfur content of ships' fuel oil from above 3.50 percent (mass by mass) to 0.5 percent on January 1, 2020. (<http://www.imo.org/en/MediaCentre/HotTopics/GHG/Documents/2020%20sulphur%20limit%20FAQ%202019.pdf>).

Unfortunately, many in society continue to view sulfur as a malignant substance rather than appreciating its essential role in human life: healthy food, medicine, green energy, construction materials, essential to innumerable chemical reactions and beneficial products, a natural fungicide and pest repellent, saving lives by providing the mercaptam-derived rotten egg odor in otherwise odorless natural gas, medicinal salve, and an organically certified material. Sulfur's role as an essential fourth plant nutrient is now recognized to be required in all

Industrial Minerals

Table 1

2020 edition — elemental sulfur production and demand (000,000 tons/year).

	2014	2019	2024
Total world production	56	61	68
World demand	57	63	66
Balance	2	(2)	2

2018 edition — elemental sulfur production and demand (000,000 tons/year).

	2014	2015	2017	2022
Total world production	59.3	62.0	66.9	75.0
World demand	61.4	61.8	63.0	66.0
Balance	-2.1	0.2	2.3	9.0
Sources: IFA, Integer Research, Acuity, Con-Sul Inc.				

Table 2

2020 edition—principal regions of elemental sulfur, production and forecast. (000,000 tons/year).

	2014	2024	Change: 10 years
Middle East	12	18	6
FSU	10	12	2
East Asia	10	13	3
North America	14	13	(1)
Western Europe	5	4	(1)
Other	5	8	3
Total	56	68	12

2018 edition—principal regions of elemental sulfur, production and forecast. (000,000 tons/year).

	2014	2018	2022	Change: 8 years
Middle East	13.4	21.7	25.0	11.6
FSU	10.3	12.6	14.0	3.7
East Asia	10.0	11.9	12.0	2.0
North America	14.1	13.6	14.0	(0.1)
Western Europe	3.8	3.9	3.0	(0.8)
Other	7.7	7.7	7.0	(0.7)
Total	59.3	71.4	75.0	15.7
Sources: IFA, Integer Research, Acuity, Con-Sul Inc.				

types of cultivation — conventional and organic. The Sulphur Institute (TSI) calls sulfur an advantaged element for its myriad uses. TSI represents an excellent resource for furthering readers' knowledge

of this element from uses, transportation and safety (sulphurinstitute.org).

Sulfur was historically obtained from volcanic deposits, which limited availability. *Fire and Brimstone: The History of Melting Louisiana's Sulphur* (D. Davis and R. Detro, Louisiana Geological Survey, 1992) may be consulted for further information. Its Latin name translates to "the stone that burns." In addition to the foregoing resource, the author recommends an excellent online resource for further information regarding this multifaceted element, *Materials Flow of Sulfur* (J. Ober, USGS 2002, <http://pubs.usgs.gov/of/2002/of02-298/>).

Sicily, a center of volcanic activity, was the focus of European sulfur availability from the pre-Christian era until the first decade of the 20th century. Sulfur's essential role in gunpowder manufacture made many Sicilians extremely wealthy. The early 20th century brought an indisputable paradigm shift to the industry. Herman Frasch developed a process to melt sulfur entrained in limestone deposits with superheated water, lifting molten sulfur to the surface with compressed air rather than pumps dependent on mechanical integrity and requiring periodic replacement. Frasch deposits are often associated with salt dome geologic structures prevalent in Gulf of Mexico oil fields. Almost overnight, this technology converted sulfur extraction from a labor-intensive gathering and purification process employing many persons to an industrial operation limited only by the size of equipment, deposits, the economics of heating makeup water due to geological losses and the price of sulfur. The Frasch method of hydraulic mining with superheated water upended the Sicilian sulfur monopoly at the dawn of the chemical century. From 1905, when the Italian island provided 95 percent of global supply, it fell to 50 percent by 1913 (Louisiana Geological Survey), as World War I's demand for gunpowder boomed. The advent of Frasch sulfur shifted production across the Atlantic, where deposits were ideally suited to the new technology. The U.S. Gulf Coast, eventually including output from coastal Mexico and Pecos County in West Texas, became the center of the Frasch sulfur industry until the late 1990s. Then, just as Frasch sulfur rapidly eliminated the Sicilian production monopoly, recovered sulfur from EPA-mandated hydrocarbon purification disrupted the Frasch monopoly. The price of U.S. natural gas, the Frasch method's essential raw material needed to heat injected process water, concurrently went from \$0.25/MMBTU in the mid-1970s to well over \$10/MMBTU by the early 1990. Excess U.S. sulfur output, no longer in the purview of three extracting companies (Freeport-McMoRan, Pennzoil and Texas Gulf) led to lower values and profitability, forcing all U.S. mines to close.

The U.S. Clean Air Act mandated removal of sulfur from motor fuels from the 1980s leading to a surge of sulfur supply as it was removed from refineries and gas plants. Refineries faced added investment, operating and disposal cost for what was viewed as a waste product. Faced with a disposal emergency, oil companies went to consumers of Frasch sulfur and offered recovered sulfur at “whatever price was needed to keep it moving from the refinery.” The magnitude of change and its continuing evolution can be appreciated by legally mandated change in the sulfur content of diesel fuel going from the range of 6 to 4 percent S to 0.15 percent from the 1980s through 1990s. This paradigm shift led to the demise of U.S. and Mexican Frasch output by 2001. Today, Frasch mining is limited to Poland. A 2015 attempt to reopen Iraq’s Mishraq Mine was stymied by armed conflict. Noted earlier, the latest legislated surge of sulfur from refineries commenced in 2020 as marine bunker fuels face reductions under International Maritime Organization (IMO) regulations from the same range of 6 to 4 percent S to 0.5 percent.

In summary, recovered sulfur is obtained from removing sulfur from natural gas and sulfur compounds present in crude oil. These are nondiscretionary waste processes required by regulations. Thus, sulfur extracted at refineries and gas processing plants must be disposed of continuously, regardless of demand; whenever output exceeds use, it must be disposed of, regardless of the cost to do so, often leading to erratic pricing. In contrast, Frasch mining operations closely balanced supply with demand using inventory infrastructure and production management to achieve commercially acceptable values. This fundamental economic change modified the supply of sulfur from on-demand mining to the required purification of hydrocarbons using either selective S-element-scavenging (elemental sulfur recovery from natural gas) or chemical processing (sulfur extraction from complex sulfur-containing oil compounds). The first process (gas-desulfurization) yields a sulfur which can be certified as “organic.”

Global sulfur producers and consumers face the monumental challenge of COVID-19. This will be addressed as our last point. Here we address issues that were raised in our last review.

IMO 2020’s mandated reduction in the sulfur content of marine (ship) fuels from more than 3 percent to 0.5 percent S, is now in its sixth month. As stated previously in prior *Mining Engineering* reviews, on the matter, the requirement was estimated by some to dramatically increase refinery sulfur output by more than 5 Mt (Ralph Grimmer; Stillwater Associates; TSI Annual Sulphur Symposium, April 2018). To date such volumes do not appear to have come to pass, leading to a very uncertain industry sourcing balance as COVID-19 rages.

The second is rapidly expanding sulfur recovery from gas processing activities in the Arab Gulf,

Kazakhstan and proximate country production.

As an example, Abu Dhabi has increased its sulfur output from under 2 Mt to 7 Mt (2013-2020).

Projects, plans and expectations are for another 4 Mt to be generated by 2022 and more growth thereafter. This rise is being supported by internal and external demand for gas as exports of LNG (liquefied natural gas), increasingly a global fuel of choice. At the time of this writing COVID-19 uncertainties are mandating reviews of all investment funds and timelines related to gas and oil expansion plans around the world.

As the world passes through the COVID-19-induced social, economic and (upcoming) political turmoil of the last 100-plus years, discussing sulfur demand and supply appears almost frivolous. Sulfur has been excess to world demand (primarily phosphate fertilizer manufacture for some time), leading to its being stockpiled in Northern Alberta (11 Mt currently). Sales by producers in the region have for some time been made at negative numbers \$50 to \$70/t. In other words, sulfur producers in the Alberta oil sands region pay buyers \$50 to \$70/t to ship (dispose of) sulfur from north of Fort McMurray, AB, to U.S. or international destinations. Despite this, about 300 kt were added to local plant inventories in 2019.

In 2020, it is not known what sulfur production and demand will bring. Con-Sul’s latest *North American Quarterly Sulfur Review* (copies of the NAQSR are available on request from Jerry@consulinc.com) opined from available data and discussions with industry sources that U.S. refinery operating rates would fall below 70 percent during more than half of the last three quarters of 2020. However, production of sulfur may only decline 20 percent as a consequence of higher sour crudes supplied from Arab Gulf and Canadian producers vs. lighter (less sulfur) crudes linked to shale oil. Only time will tell. But what of sulfur demand? That will likely fall by close to 30 percent as farmers’ interest in acquiring phosphate fertilizer between July and December 2020 will be minimal due to market uncertainty. This is underpinned by current high corn inventories, a very low price and lack of ethanol production for blending into motor fuels. Under normal circumstances, 40 percent of the U.S. corn crop is used to produce ethanol. Half the U.S. ethanol capacity is currently idle for lack of gasoline blending demand; making 20 percent of the presently planted corn crop excess.

Care should be taken when evaluating this potential excess supply balance. Such high indicated volumes have traditionally been unable to be consumed as sulfur is a very price-inelastic commodity. This means if it cannot be used (is not needed by fertilizer manufacturers), reducing price will not increase demand. This leads to stockpiling where feasible, putting supply and demand in balance. Should storage not be available, prices tend to collapse until elasticity is encountered or storage

options are discovered (as was the case with crude oil in early May 2020). Thus, the likely real surplus for 2024 should be 2-3 Mt.

Pre-COVID: The Middle East now leads all producing regions. Abu Dhabi's Habshan and Shah gas fields, and others, have propelled the region into first place. Greater sulfur output is expected in coming years as sour gas fields on the Arabian Peninsula, Kazakhstan, Kyrgyzstan, Turkmenistan, and others initiate startups, more sour crudes are refined and China continues aggressive oil and gas development. A note of caution regarding the forecasts, however — in this region, one almost always encounters delays. High temperature, pressure and hydrogen sulfide content create huge technical and operating challenges. Gas fields are deep and hot, with a very high content of hydrogen sulfide. For example, the Kashagan field in Kazakhstan, has now just re-started production and sales, compared to a 2002 forecasted startup

announced in 1990-1992. The third startup attempt, mentioned in the 2018 issue worked, possibly adding a million tons to the 2019 supply.

COVID-19: Conditions are less certain in that area than in North America due to the huge number of Asian expatriates used in all operations. Housing and health conditions are not the best and social distancing is an impossibility. The dilemma faced by Arab Gulf nations, in addition to the pandemic and mortalities, is that host governments would like to return guest workers to their home countries to avoid costs caring for incapacitated individuals. But the minuscule indigenous Arab-native population is unable to address the magnitude of civic or industrial tasks, without trained expatriate support. And limited personnel, with perhaps insufficient training, could lead to devastating accidents. Thus, we must withhold all forecasts at this time — hoping for the best and with very limited ability to prepare for worsening conditions. ■

TALC AND PYROPHYLLITE

by G.P. Tomaino, Minerals Technologies Inc.

Talc is a layered, hydrous magnesium silicate mineral. It has a soft, soapy feel and typically a smooth texture and is known for its insulation, heat resistance, chemical stability, oil absorption and strong covering quality. Talc, $\text{Mg}_3\text{Si}_4\text{O}_{10}(\text{OH})_2$, has a theoretical chemical composition of MgO at 31.7 percent, SiO_2 at 63.5 percent, and H_2O at 4.8 percent. However, talc's chemical and mineralogical compositions can vary depending on its geological history/parent rock association. These mineral associations are usually chlorite, quartz and carbonates (magnesite, calcite and dolomite)

in varying levels. Two key elemental substitutions can occur in the talc crystal structure — iron for magnesium and fluorine for hydroxyl. These compositional differences may limit or enhance the usage of talc in specific market niches. The United States remains self-sufficient in most grades of talc.

Talc deposits are categorized under four origin types occurring as secondary and/or tertiary alterations of pre-existing rocks: (1) ultramafic, (2) mafic, (3) metasedimentary and (4) metamorphic. Type 1 deposits, while the most abundant, are generally of lower grade and are second to Type 3

deposits based on utilization-commercialization. Type 4 deposits, while historically a dominant source, have diminished substantially in their usage over the years due to elevated amphibole content. Type 2 deposits are the least pure and utilized of all the origin-types. Another representation of the four talc origin categories noted above can be as ultramafic/mafic, metasedimentary-carbonate, metasedimentary-silicoaluminous and metamorphic.

Historically, product groupings such as industrial, cosmetic and pharmaceutical had

Figure 1

Twenty-one-year trend data for talc production (kt) and consumption (kt), 1999-2019e.

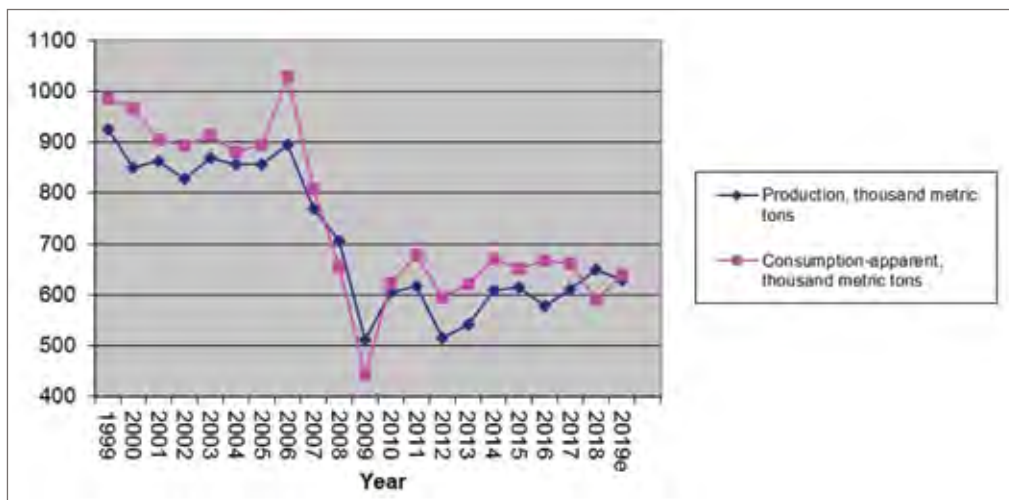
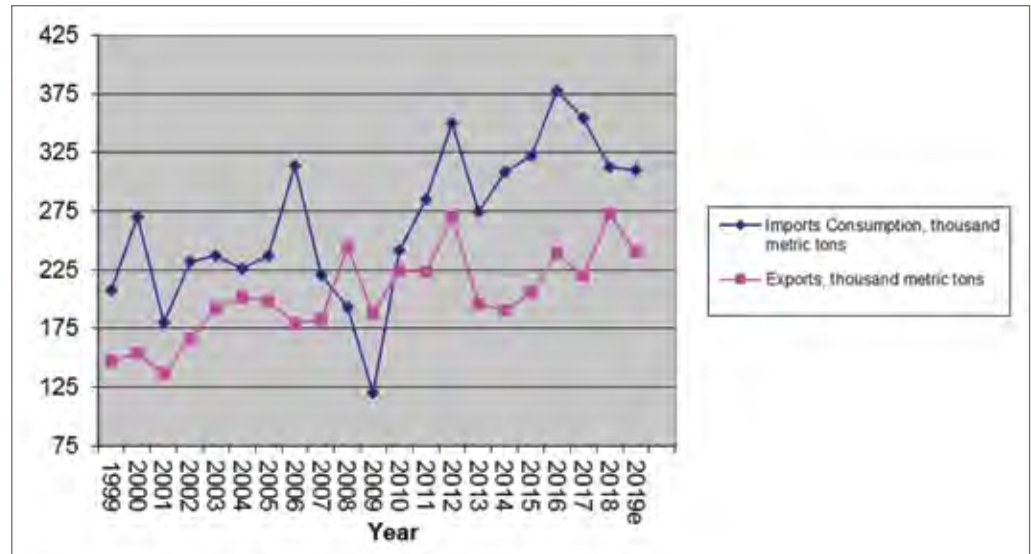


Figure 2

Twenty-one-year trend data for import consumption and exports (kt), 1999-2019e.



inferred or denoted purity. Presently, these groupings are no longer considered strict purity guidelines. Additional groupings of a talc product are categorized as chloritic-talc, carbonate-talc or tremolitic-talc with a hyphenated-statement denoting the second most dominant mineral phase (usually 20-50 percent) in addition to the predominant talc component (at 50 percent or greater).

Pyrophyllite is a layered, hydrous, aluminum silicate mineral. Pyrophyllite has similar physical properties as talc, while elemental substitutions are minimal compared to talc. Pyrophyllite, $\text{Al}_2\text{Si}_4\text{O}_{10}(\text{OH})_2$, has a theoretical chemical composition of Al_2O_3 at 28.3 percent, SiO_2 at 66.7 percent and H_2O at 5 percent. Typical accessory minerals are quartz, kaolin, diaspor, boehmite, sericite and chlorite, in addition to iron-containing impurities of hematite, limonite/goethite and pyrite. Grades are differentiated by particle size, moisture content, fired color and purity as measured by fineness and screen residue. Pyrophyllite deposits are generally classified under hydrothermal or metamorphic with more expanded types as: 1) hydrothermal in metasomatites continental and island-arc volcanic zones, platforms, folded systems 2) hydrothermal in metasomatites in wall rock quartz veins-granitoids and metamorphosed clastic suites 3) metamorphosed metasomatites in submarine volcanic zones enclosing sulfide ores 4) stratiform metamorphosed clastic clay suites with pyroclastic material and coal seams and 5) in clays formed by weathering. Pyrophyllite has a high dielectric strength, low electrical conductivity, reasonably high thermal stability and chemical inertness that allows for primary usages in refractory and ceramic applications. Critical attributes in refractory applications are iron and quartz content, while a critical attribute in ceramics is whiteness before and after firing. Additional industrial usages are in paint, chemical carriers in agricultural products and filler in industrial coatings, sealants and caulks.

Production and consumption

In 2019, the primary producer of pyrophyllite in the U.S. and with worldwide distribution was Vanderbilt Minerals, LLC — Standard Mineral Division (owned by R.T. Vanderbilt) in North Carolina. The parent company celebrated its 100-year anniversary in 2016. The division owns over 1,500 acres of land that have reserves in excess of 100

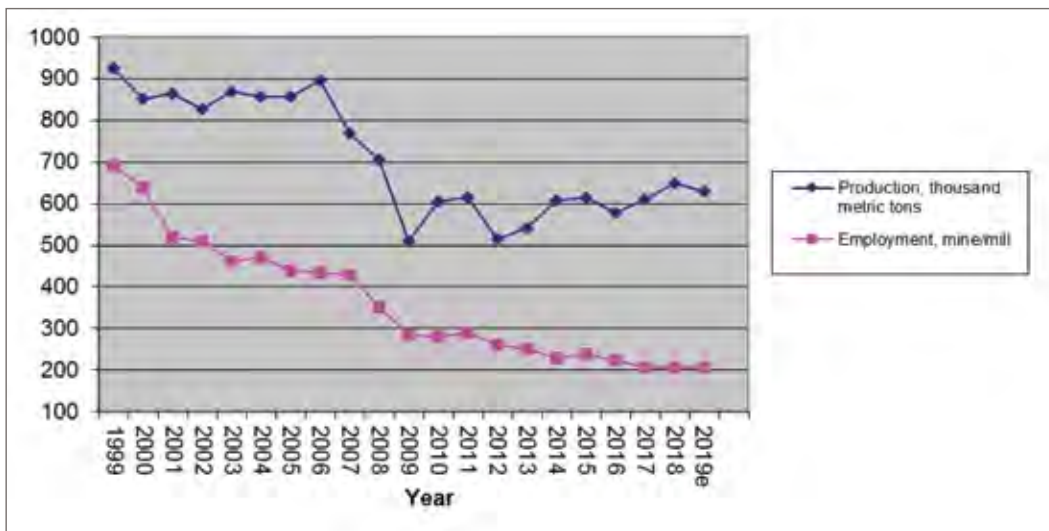
years. Pyrophyllite ore is mined in several openpit mines and is crushed, dry-ground and air-classified at the division's mill in Robbins, NC. The processed pyrophyllite ore is sold under the trade name PYRAX. Piedmont Minerals also in North Carolina supplies product but mainly for in-house usage with its parent company, RESCO. While the company's actual domestic production figures were not disclosed by USGS, domestic 2019 pyrophyllite production was estimated to have decreased from 2018 with consumption in refractory, ceramics and paint.

Employment: Pyrophyllite has remained stable over the last five years from 29 to 31 (2019e). For North America, Trinity Resources has mining, production and port facilities located in Newfoundland. Trinity Resources sells and distributes pyrophyllite products under the Altifil, Altiplus and Altiblock trade names with usage in refractory, automotive, plastics, paints, paper coatings and cosmetics.

In 2019, three talc companies operated five talc mines and production facilities located in three states accounting for 99 percent of domestic production. Domestic production is by openpit mining. Montana continues to be the leading state for production followed by Texas and Vermont. Imerys Talc America remains the top domestic and international talc producer with domestic mines and processing facilities in Montana and Vermont, processing in Texas, in addition to, operations in Canada, Australia, China, and Japan. Imerys Talc America has operated under Chapter 11 bankruptcy since February 2019. Minerals Technologies Inc. through its Barretts Minerals, a subsidiary of Specialty Minerals Inc. has mining and processing in Montana and processing in Texas. CIMBAR Performance Minerals has processing of imported talc in Indiana, Ohio and Texas in addition to facilities in China and

Figure 3

Twenty-one-year trend data for talc production (kt) and employment, 1999-2019e.



Pakistan, Canada and China at 41 percent, 27 percent and 21 percent, respectively. USGS also communicated that crude ore from Afghanistan was being milled and exported through Pakistan to other countries. Imported talc was used in various applications of cosmetics, paints and plastics with remaining usage for ceramics, paper, roofing and rubber. World mine talc production included dominant sources from the United States, Brazil,

Pakistan. Natural Minerals (formerly American Talc Co.) has mining and processing in Texas. IMI FABI has processing in West Virginia, in addition to mines and operations in Brazil, Italy, Australia, Pakistan and China. Alberene Soapstone Company operates in Virginia and Southern Oregon. Soapstone Co. LLC operates in Oregon.

Previously reported 2018 estimated production and consumption values have been corrected with 2018 actual data where applicable in the 21-year trend (Fig. 1). For 2019e, talc production is estimated at 630 kt, a decrease of about 3 percent from 2018. Talc sold by the producers that included domestic and exports was estimated at 540 kt, an increase of about 4 percent from 2018 levels and was valued at \$120 million.

For 2019e, apparent consumption of talc was at 640,000 t, an increase of 13 percent from 2018 levels. The 2019 average price for a processed ton of product with an averaged pricing at about \$230/t, an increase of about 2 percent from 2018 as shown in Fig. 1.

The distribution of talc produced and sold domestically was as follows: paint (23 percent), ceramics including catalytic converter (20 percent), paper (15 percent), plastics (12 percent), rubber (4 percent), roofing (3 percent), cosmetics (2 percent) and other (21 percent). The ceramic sector is dominated by catalytic converter usage a key component of the formulation. The other section includes a variety of applications for pharmaceuticals, refractories, agricultural products, animal feed, sealant, sculpturing, food and polishing.

Exports/imports

The 2019e talc exports were at 240 kt, a decrease of about 12 percent from 2018 actual at 273 kt. Canada and Mexico accounted for the majority of the export levels and usages. The 2019e talc imports were at 310 kt, a 1 percent decrease from 2018 at 313 kt, continuing a decreasing trend since 2016. From USGS reporting, imported talc was sourced from

Finland, Canada, China, France, India, Italy, Japan and Korea. The 21-year trend data of imports for consumption and exports taken from the USGS are provided in Fig. 2.

Over the last ten years (2009-2019e), talc sector employment continued to decline except in 2015, which had a very slight increase from 206 up to 208. An important note to the talc employment overview is that, historically, pyrophyllite mine employment was included under talc mine employment. Pyrophyllite mine employment ranged from 25 up to 31 from 2012-2019 and was adjusted in the 20-year trend data of production and employment from USGS in Fig. 3.

Prior to 2012, pyrophyllite mine employment was apparently included under talc mine employment. Pyrophyllite mine employment ranged from 25 up to 31 over 2012-2019e and have been adjusted to the talc mine employment data in the 21-year trend figure.

Uses, new applications, processing technology, future trends

Talc producers must continue to provide a functional and high-performance mineral additive that can increase the value of their products to the end use customer. In specific cases, unique properties can be achieved by employing proprietary coatings or processing products to increase aspect ratio by delaminating high aspect ratio (HAR) grades or to increase the overall talc purity by beneficiation. Silane or siloxane based and directed surface treatments are commonplace. Nano-talc products (10 to 100 nanometers in one dimension) continue to be researched and marketed for uses in various applications. Talc usage covers a multitude of product categories: plastics, cosmetics, flooring, healthcare, catalytic converters, animal feed, caulks, sealants, gaskets, belts, hoses, specialty anti-blocking/anti-hazing in plastic films, auto body putty, asphalt shingles, joint compounds, pharmaceuticals, ceramics and dimension stone.

In cosmetics, talc competes against cornstarched products and recently pyrophyllite. In ceramic applications of dinnerware, sanitaryware and hobby ceramics, talc provides low shrinkage as well as high brightness upon firing at various temperatures. In other applications, high-quality, calcined-talc blends can be tailored to each individual customer's specifications to impart a controlled shrinkage and reduce firing time. The reduced firing time aids in processing and energy costs for the customer. Another specialty usage for which talc demand remains high is combining talc with kaolinite and other proprietary additives to formulate fired-cordierite bodies used for catalytic converters for vehicles. The competitive products in this field are SiC or metal-based catalytic converters. In dimension stone applications, talc is used for countertops, sinks, mantels, fireplace surrounds, pavers and tile brick. In paints, talc is an economic extender and filler while providing brightness and durability to paint coatings. In rubber applications, talc provides reinforcement, UV radiation resistance, and it can be used as a processing aid for good extrusion rates, impermeability and improved surface finish. However, more and more paints are shifting to water-based matrices from oil-based matrices to reduce organic volatiles; talc being hydrophobic in nature loses opportunities in these market-product shifts.

The plastics market continues to offer some potential growth opportunities especially in polypropylene. It is projected that increases in talc usage for lightweight and recyclable products are needed for the automotive market. Here, the desire for compacted and submicron talc products provide high-performance end use products.

Talc continues to be used in the papermaking process especially as a pitch control agent while it faces competition in the paper filler and niche paper coating sectors from precipitated and ground calcium carbonates. In ceramics, talc competes with clays and pyrophyllite; in paint, plastics and rubber with kaolin and mica.

Substitutes for talc in ceramics are bentonite, chlorite, kaolin and pyrophyllite; in paint are chlorite, kaolin and mica; in paper are calcium carbonate and kaolin; in plastics are bentonite, kaolin, mica and wollastonite; and in rubber are kaolin and mica, and

in cosmetics usage of corn-starch based products.

Environmental and regulatory

As reported in previous annual reviews, the talc industry had been working on responding to Canada's Health Canada and Environment Canada on the Domestic Substances List Inventory Update Phase 2 through its Chemicals Management Plan as to whether talc should be classified as an environmental toxin. In September 2015 and 2016, and most recently in 2018, industry representatives, consultants, and Industrial Minerals Association-North America (IMA-NA) staff finalized and presented a concise and informative presentation to Canadian authorities and continue to work on finalizing their work. While Canadian agencies categorized talc in a negative context IMA-NA and industry provided a quick and prompt additional response for review again by the Canadian agencies in 2019 for a favorable and final categorization.

Under United States Pharmacopeia (USP), a second USP Expert Panel-Talc 2015-2020 has been convened with representation from industry, contract testing laboratories, academia and USP. Work continued from 2017 into 2019 on improving the specificity of the talc monograph attribute for Absence of Asbestos testing using X-Ray Diffraction (XRD), Polarized Light Microscopy (PLM), and Transmission Electron Microscopy (TEM) for pharmaceutical-grade talcs (and indirectly for cosmetic grade talcs) with round robins planned and completed in 2019 for PLM and XRD. Similar and parallel work on testing of pharmaceutical and cosmetic grade talc is being done through the ASTM D22.07 subcommittee where many of the USP talc panel participants are also members of the ASTM subcommittee.

Talc continues to receive negative press coverage on two fronts through various articles and litigation notices of talcum powder usage and ovarian cancer linkage, and historical talcum powder body usage as purported to contain asbestos with linkage to mesothelioma cases after many years. High profile litigations for Johnson & Johnson continued for 2019. Additional U.S. congressional requests to specific suppliers of talc products and Johnson & Johnson for review transacted in early 2019. ■

TITANIUM

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

Titanium is the ninth most abundant element in the earth's crust and can be found in nearly all rocks and sediments. It has a strong affinity for oxygen and is not found as a pure metal in nature. Ilmenite (FeTiO_3) and rutile (TiO_2) are the two principal minerals used as the source for TiO_2

pigments and titanium metal. About 90 percent of global titanium mineral concentrate consumption is for production of TiO_2 pigments with the remainder used for abrasives, metal, metallurgical fluxes, welding-rod coatings and other titanium-based chemicals.

Industrial Minerals

Figure 1

Average annual prices for ilmenite, rutile and titanium dioxide (TiO₂) pigments from 2010 through 2019. Source: U.S. Census Bureau.

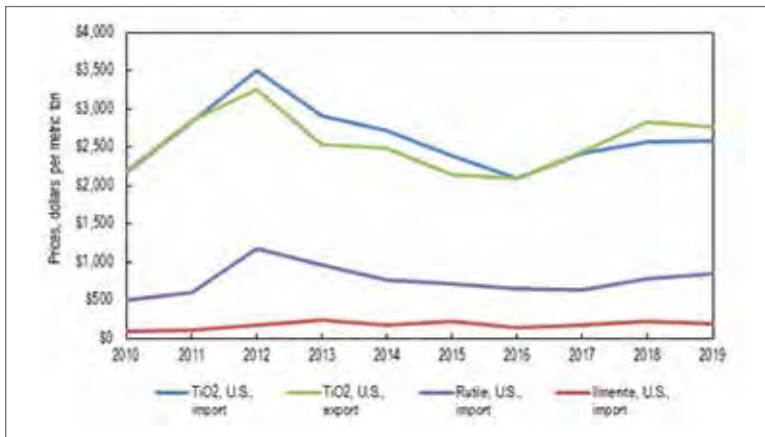


Table 1

Titanium, titanium dioxide and titanium mineral concentrates.

World: ilmenite and rutile production (kt of contained TiO ₂)		
Country	2018	2019e
Australia	861	800
Brazil	68	72
Canada	630	690
China	2,100	2,100
India	334	330
Kenya	362	270
Madagascar	235	310
Mozambique	583	600
Norway	236	260
Senegal	306	300
Sierra Leone	147	150
South Africa	868	930
Ukraine	467	470
United States ¹	100	100
Vietnam	105	150
Other countries	62	77
Total (rounded)	7,460	7,600

Source: U.S. Geological Survey.
e: estimated production
¹: rounded to one significant digit to avoid disclosing company proprietary data.

In 2019, global production of titanium mineral concentrates was estimated to be 7.6 Mt of contained TiO₂, slightly more than that of 2018 (Table 1). Rounded to one significant digit,

U.S. production of titanium concentrates was estimated to be 100 kt of contained TiO₂. In the United States, two companies, The Chemours Co. and Southern Ionics Minerals, LLC, produced titanium mineral concentrates at mining operations in Starke, FL, and Nahunta, GA, respectively. In August 2019, Chemours acquired Southern Ionics Minerals from its parent company Southern Ionics Inc.

TiO₂ pigment production in the United States in 2019 was estimated to be 1.1 Mt, a decrease of 4 percent from that of 2018, with domestic consumption estimated to have been 900 kt, nearly unchanged from that of 2018. U.S. producers of TiO₂ pigment using the chloride process were Cristal Global, Chemours, Louisiana Pigment Co. L.P., and Tronox Ltd. A buff TiO₂ pigment of finely ground synthetic rutile was produced by TOR Minerals International Inc. In May, INEOS Enterprises acquired Cristal Global's operations in the United States. Tronox planned to acquire Cristal Global's operations outside of the United States.

Global titanium metal sponge production in 2019, excluding the United States where production data were withheld to avoid disclosing company proprietary data, was estimated to have increased to 210 kt from 192 kt in 2018 (Table 2). In the United States, titanium sponge metal was produced by Titanium Metals Corp. in Nevada and Honeywell Electronic Materials Inc. in Utah.

Foreign trade

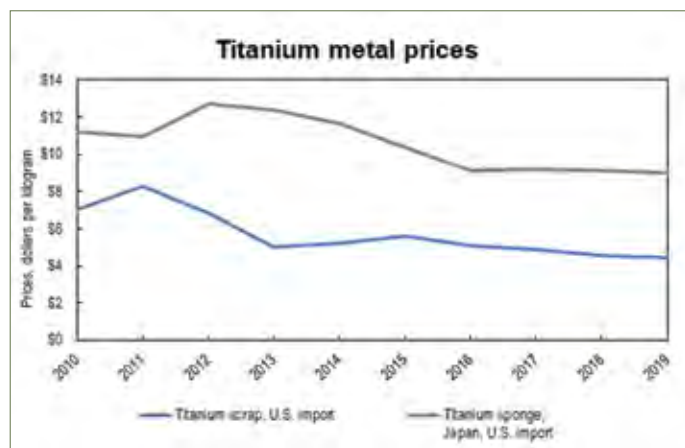
In 2019, the United States was more than 90 percent net import reliant for titanium mineral concentrates and imported about 1.3 Mt of contained TiO₂ in titanium concentrates. The leading import sources were, in the last five-year period, in decreasing order, South Africa, Australia, Canada and Mozambique. The United States was a net exporter of TiO₂ pigments with the majority of these exports, in descending order, going to Mexico (23 percent), Belgium (16 percent) and Canada (14 percent). The United States was net importer of titanium sponge metal and imported 30 kt of sponge in 2019. The leading import source was Japan, which accounted for 88 percent of imports.

Prices

Based on U.S. imports for consumption, the average annual prices (unit values) for ilmenite (\$186/t) decreased by 15 percent and rutile (\$846/t) increased by 8 percent, respectively, compared with those in 2018. U.S. import prices for TiO₂ pigments were nearly unchanged, and export prices decreased slightly (Fig. 1). The average annual price for titanium sponge metal imported from Japan (\$9.03/kg) was nearly unchanged, and the

Figure 2

Average annual prices for titanium metal sponge and titanium scrap from 2010 through 2019. Source: U.S. Census Bureau.



average annual titanium scrap price (\$4.46/kg) decreased slightly compared with 2018 (Fig. 2).

Outlook

In December 2019, an outbreak of a novel coronavirus (COVID-19) was first identified in China. The World Health Organization declared that COVID-19 was a global pandemic on March 11, 2020. Measures instituted to mitigate the spread of the COVID-19 pandemic, such as closures of nonessential businesses, are likely to

cause disruptions in the mining industry across the United States and around the world. The duration and the outcome of the COVID-19 pandemic remains uncertain, but it is expected that the economies of the United States and the world as a whole will likely be negatively affected, which could influence the performance of the titanium industry. ■

Table 2

Titanium sponge metal production (data in kt).

Country	2018	2019e
China	75	84
India	0.25	0.25
Japan	49	54
Kazakhstan	16	20
Russia	44	44
United States	W	W
Ukraine	8	9
Total (rounded)	192	210

Source: U.S. Geological Survey.
e: estimated production
W: withheld to avoid disclosing proprietary company data.

VANADIUM

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

In 2019, the United States continued to be a major producer of vanadium products from secondary sources. Secondary vanadium production continued primarily in Arkansas, Delaware, Ohio, Pennsylvania and Texas, where processed waste materials (petroleum residues, spent catalysts, utility ash and vanadium-bearing pig iron slag) were used to produce ferrovanadium, vanadium-bearing chemicals or specialty alloys, vanadium metal and vanadium pentoxide. In early 2019, byproduct vanadium production from the mining of uraniferous sandstones on the Colorado Plateau resumed. A total of 470 t vanadium content was produced in the United States in 2019.

Production

Vanadium is extracted from vanadiferous ores, slags and residues and converted into vanadium pentoxide or trioxide. Most vanadium pentoxide is converted into ferrovanadium. A majority of the world's supply of vanadium was derived either from vanadiferous titanomagnetite (VTM) mineral concentrates or from steelmaking slags, where the steel was produced from VTM. Japan and the United States were thought to be the only countries to recover significant quantities of vanadium from petroleum residues. In 2019, the vanadium-producing nations

(from ore, concentrate and slag) including China (54 percent), Russia (24 percent), South Africa (11 percent), Brazil (10 percent) and the United States (1 percent) produced a total of 73 kt vanadium content.

Energy Fuels Inc.'s White Mesa Mill, near Blanding, UT, had the only vanadium coproduct recovery circuit in the United States. The mill had produced approximately 20,400 t of vanadium pentoxide (11.4 kt vanadium content) during its 40-year operating history. In 2018, the company completed facility upgrades to the mill in order to begin vanadium recovery in January 2019. The company was expected to use new recovery techniques to recover vanadium from its existing tailings pond solutions. In early 2019, the mill produced the highest purity vanadium pentoxide in its history, averaging approximately 99.6 percent vanadium pentoxide. The company expected to produce approximately 70 to 90 t/month of vanadium pentoxide over a 16- to 20-month period. Energy Fuels announced that production could be turned on and off at minimal cost in response to any vanadium market changes. Energy Fuels had not produced vanadium since 2013 owing to low prices.

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. In 2019, production of carbon, full-alloy and HSLA steels accounted for 18 percent, 45 percent and 31 percent, respectively, of domestic reported consumption (4.6 kt vanadium content). Nonmetallurgical applications included catalysts, ceramics, electronics and vanadium chemicals. Catalysts were the leading nonmetallurgical use for vanadium.

Prices

In 2019, average Chinese vanadium pentoxide prices, as published by CRU Group, were \$12.17/lb of contained vanadium. In December 2019, Chinese vanadium pentoxide prices averaged \$10.20/lb of contained vanadium, compared with \$20.25/lb in December 2018. The annual average U.S. ferrovanadium price decreased to \$22.31/lb of contained vanadium in 2019 compared with \$39.13/lb in 2018. In December 2019, U.S. ferrovanadium prices averaged \$10.91/lb of contained vanadium compared with \$53.38 in December 2018.

Foreign trade

The United States continued to be a net importer of many vanadium materials in 2019. The United States imported (measured in vanadium content) 2,260 t of ferrovanadium, 3,700 t of vanadium pentoxide, 105 t of other oxides and hydroxides of vanadium, and 2,120 t of vanadium-bearing ash and residues. Total imports for consumption of all vanadium-bearing materials decreased by 26 percent from those of 2018. In 2019, the United States exported (measured in vanadium content) 295 t of ferrovanadium, 423 t of vanadium pentoxide, 750 t of other oxides and hydroxides of vanadium and 256 t of vanadium-bearing ash and residues. Total exports of all vanadium bearing materials increased by 14 percent from those of 2018.

Outlook

Owing to the fact that almost all vanadium is consumed in the production of steel, consumption trends are greatly influenced by trends in steel production; the range of steel grades that contain vanadium has continued to increase. The outlook for

demand in nonferrous alloys is largely dependent on trends in demand for titanium alloys in business, commercial and military aircrafts. The implementation of the new high-strength, reinforcing steel bar standards in China has been enforced more gradually than originally expected. Larger mills began implementation in 2018; however, smaller mills have been slower to implement the new standards. Enforcement of the new standards was also reportedly more difficult to monitor at smaller mills. The increase of vanadium in rebar was originally expected to increase overall consumption of vanadium in China by approximately 10 kt/a.

In addition to growth from the steel sector, one area of continued growth was in the energy storage market, specifically with vanadium redox batteries (VRFB). China, India and the United States are expected to account for two-thirds of the global renewable-energy expansion to 2022. All European Union countries have adopted national renewable-energy action plans showing what actions they intend to take to meet their renewable-energy targets. Many countries are seeking to meet renewable energy targets by 2022 or earlier, and VRFB storage is proving to be a potential solution, with many countries having numerous implementations already underway. However, the high cost of the electrolyte used in the VRFBs and the system complexity of the batteries may be difficult for widespread use. Companies are expected to continue to improve VRFB batteries to make them more competitive in the battery market.

In December 2019, an outbreak of a novel coronavirus (COVID-19) was first identified in China. The World Health Organization declared that COVID-19 was a global pandemic on March 11, 2020. Measures instituted to mitigate the spread of the COVID-19 pandemic, such as closures of nonessential businesses, are likely to cause disruptions in the mining industry across the United States and around the world. The duration and the outcome of the COVID-19 pandemic remains uncertain, but it is expected that the economies of the United States and the world as a whole will likely be negatively affected, which could influence the performance of the vanadium commodity industry. ■

WOLLASTONITE

by Kenneth C. Curry, National Minerals Information Center, U.S. Geological Survey.

Wollastonite, a calcium metasilicate (CaSiO_3), has a theoretical composition of 48.3 percent calcium oxide (CaO) and 51.7 percent silicon dioxide (SiO_2) but may contain trace to minor amounts of aluminum, iron, magnesium, manganese, potassium, sodium and/or strontium. Economic resources of wollastonite typically form as a result of thermal metamorphism of siliceous limestone during regional deformation or chemical alteration of limestone by siliceous hydrothermal fluids

along faults or contacts with magmatic intrusions. Deposits of wollastonite have been identified in Arizona, California, Idaho, Nevada, New Mexico, New York and Utah; however, New York is the only state where long-term continuous mining has taken place.

Production

In 2019, two companies mined wollastonite in the United States. NYCO Minerals Inc. (a subsidiary of

Imerys S.A., France) operated a mine and processing plant near Willsboro in Essex County, NY. The NYCO deposit contains diopside and garnet, which are removed using high-intensity magnetic separators, and up to 60 percent wollastonite. Vanderbilt Minerals, LLC (a division of R.T. Vanderbilt Holding Co. Inc.) operated a mine and processing plant near Balmat in Lewis County, NY. The Vanderbilt Minerals deposit is highly differentiated, with large regions of wollastonite separated from gangue zones, and consists primarily of wollastonite (up to 90 percent) and minor amounts of calcite, diopside and prehnite. Wollastonite production quantities for NYCO and Vanderbilt are withheld to avoid disclosing company proprietary data.

Consumption

Domestic wollastonite use in the United States includes construction-related markets, such as adhesives, caulks, cement board, ceramic tile, paints, stucco and wallboard, as well as friction product, metallurgical, plastic and rubber and miscellaneous applications. The U.S. Geological Survey does not collect consumption statistics for wollastonite, but consumption was estimated to be about the same in 2019 compared with that of 2018. In 2019, trends in domestic manufacturing sectors that use wollastonite were mixed; U.S. single-family housing starts increased by 3.3 percent and primary iron and steel products increased slightly, whereas output of plastics and rubber decreased by 2.4 percent and motor vehicle and motor vehicle parts production decreased slightly.

Plastics and rubber markets (thermoplastic and thermoset resins and elastomer compounds) were estimated to account for more than 25 percent of wollastonite sales in the United States, followed by ceramics (frits, sanitary-ware and tile), paint (architectural and industrial paints), metallurgical applications (flux and conditioner), friction products (primarily brake linings) and miscellaneous uses (including adhesives, concrete, glass and sealants). Globally, ceramics were estimated to represent more than 30 percent of wollastonite consumption,

followed by polymers (such as plastics and rubber) and paint. Other global uses for wollastonite included miscellaneous construction products, friction materials, metallurgical applications and paper.

Prices

At year-end 2019, prices for domestically produced wollastonite were estimated to be between \$305/t and \$325/t, slightly higher than those in 2018. Price data for wollastonite produced in other countries were unavailable.

Foreign trade

In 2019, wollastonite exports were estimated to be less than 10,000 t and imports were estimated to be about 1,000 t. Most of the trade was with Canada and Mexico by road or rail. Comprehensive trade data were not available for wollastonite because it is imported and exported under a generic U.S. Census Bureau Harmonized Tariff Schedule code that includes multiple mineral commodities.

Outlook

According to the International Monetary Fund's January 2020 World Economic Outlook Update, economic growth in the United States was 2.3 percent in 2019. Recent developments, however, may affect the short-term outlook for the wollastonite industry. In December 2019, an outbreak of a novel coronavirus (COVID-19) was first identified in China. The World Health Organization declared that COVID-19 was a global pandemic on March 11, 2020. Measures instituted to mitigate the spread of the COVID-19 pandemic, such as closures of nonessential businesses, are likely to cause disruptions in the mining industry across the United States and around the world. The duration and the outcome of the COVID-19 pandemic remains uncertain, but it is expected that the economies of the United States and the world as a whole will likely be negatively affected, which could influence the performance of the wollastonite industry. ■

ZEOLITES

by Daniel T. Eyde, St. Cloud Mining and Eleanor M. Olegario, University of the Philippines

The U.S. Geological Survey (USGS) estimates world production of natural zeolites at 1.2 Mt in 2019 up slightly from the previous year. This is less than half of its estimate for 2016, which was 2.8 Mt, but a significant portion of the change is a recalculation of the zeolite usage in China. Because much of the Chinese zeolite produced is ash fall tuffs with low to moderate amounts of zeolite they are now classified by their use as pozzolans rather than zeolites. This significantly changes the tonnages reported as zeolites and impacts the individual rankings as countries. China does remain

first with production estimated in the range of 320 kt, followed by the remaining significant producers including the Republic of Korea at 150 kt, Indonesia at 130 kt, Slovakia 120 kt, New Zealand at 100 kt, the United States at 98 kt, Turkey at 65 kt, Cuba at 55 kt, Jordan at 10 kt, and all other countries at 152 kt. Slovakia may be underreported, since the major producer Zeocem, alone, reports 200 kt of annual production (private communication).

In terms of production, the United States is up from 2018 levels, while the rest of the world is generally flat. In China and other countries, high-

Table 1

Salient statistics for zeolites — United States (source: USGS).

	2015	2016	2017	2018	2019
Production (t)	75,100	75,200	82,400	86,100	98,000
Sales	73,200	71,300	81,300	80,500	82,000
Imports	<1,000	<1,000	<1,000	<1,000	<1,000
Exports	<1,000	<1,000	<1,000	<1,000	<1,000
Consumption	73,200	71,300	81,300	80,500	92,000

volume, low-value construction applications (which include dimension stone, pozzolans and lightweight aggregate) have been removed from production figures. Thus, the production data more accurately reflect the quantities used in higher-added-value specialty applications like water treatment or consumer products. Italian zeolites, for example, are generally recorded in pozzolan applications even though the zeolite provides a critical component in the cementitious reaction.

Work continues commercializing the discovery of the mechanism that provided the durability in so-called Roman cements. The strength and longevity of Roman marine concrete is understood to benefit from a reaction of seawater with a mixture of volcanic ash and quicklime to create a rare crystal called tobermorite. As seawater percolated within the tiny cracks in the Roman concrete, it reacted with phillipsite naturally found in the volcanic rock and created aluminous tobermorite crystals. Gary Tomaino, at MTI Inc. is investigating this reaction more carefully, testing a variety of possible pozzolanic mineral materials. To date, only tuffaceous pozzolan materials with zeolites as a primary constituent, have been shown to reliably produce this mineralogy in cements.

The result is an extremely durable building material. Modern concrete exposed to saltwater deteriorates within decades in comparison. The formulery of Roman cement was considered a state secret by the Roman Empire. At the SME Annual meeting in Minneapolis, MN Tomaino on his research using different pozzolanic materials to develop the rapid growth of tobermorite crystals in a cementitious mix. Three materials were found to work, all commercial zeolite products.

Production in the United States grew again in 2018 from an estimated 86.1 kt to 98 kt according to preliminary USGS statistics. New Mexico was the leading producer of natural zeolites in 2019, followed by California, Idaho, Texas, Oregon and Arizona. The top three companies accounted for about 85 percent of U.S. production. Domestic uses for natural zeolites were (in decreasing order by tonnage) animal feed, odor control, unclassified other (soil amendment, traction control and synthetic turf), water purification/treatment, pet

litter, wastewater cleanup, fungicide or pesticide carrier, oil and grease absorbents, gas absorbent (air filtration and fertilizer carriers), desiccants and aquaculture. The three leading uses accounted for more than 70 percent of the domestic natural zeolite sales tonnage. Synthetic turf applications and green roofs as well as denitrification applications have a high potential for future growth.

Import/export

The United States is not a significant importer of natural zeolites. And, with the closure of trade between the United States and Cuba, this is unlikely to change. The United States does export high value-added, processed and activated chabazite products for gas adsorption and ion exchange applications. There is a growing market for specialty feed products as well. Interestingly there are some preliminary trial products from China being marketed in the United States. Initially the targeted markets are synthetic tuff applications, and low-cost zeolite deposits are being developed in Mexico as well. Whether they can economically be transported to U.S. markets is questionable, and the QA/QC controls on these deposits are not well established at this time.

Prices

Clinoptilolite remains the primary product at more than 90 percent of U.S. production. Chabazite remained at about 5-6 percent of production in 2019, with the remainder being principally mordenite. Both phillipsite and ferrierite are now available in limited quantities. However, if the products were examined based on the value of finished manufactured products, then the proportion of chabazite sales for specialty ion exchange and sorption products would be much higher than for its production volume.

Prices are based on the percentage of zeolite and accessory minerals in the product, chemical and physical properties and particle size. The price of zeolite products is reported fob mine in bulk at \$110-950/t 2019. Generally, granular products carry a premium, particularly for water treatment products that must carry an NSF certification. Products for pool filtration are significantly higher than fob mine costs due to distribution, packaging, marketing and certification expenses. 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 Corp. In 2019, Bear River's average sales price for clinoptilolite products was reported as \$192/t up about 2.7

percent from 2018.

Industry news

Six companies in the United States reported zeolite production in 2019 from nine mines unchanged from 2018. There were two major conferences for zeolites held in 2019. The 19th International Zeolite Conference in Perth, Australia with the theme “Zeolites Make Tomorrow Better” and the 4th Euro Asia Zeolite Conference held in Taormina, Italy. Both Conferences were geared primarily toward the development and use of synthetic zeolites.

Significant North American producers with their locations and their most important products are noted below.

St. Cloud Mining Co. Inc. (SCM) with operations, mines and deposits in Winston, NM, Ash Meadows, NV and CA, Bowie, AZ, and Rome, OR is the largest producer of natural zeolite products in North America. The company sells most of its products under private labeling agreements with brokers, distributors and manufacturers. SCM sells specialty clinoptilolite products for concentrated animal feeding operations (CAFO) that include feed amendments, odor-control products and turf and soil amendments. St. Cloud completed developmental drilling and expanded its proven mineral reserves by an additional 10 years of production. St. Cloud is one of the few zeolite operations with drill-proven reserves on all its zeolite properties. Presently, St. Cloud mines about half of the zeolite produced in the U.S. St. Cloud continues its push into nontraditional zeolite applications in CASE applications. The Ash Meadows clino and ash products have ASTM C618 certification as a natural pozzolan.

Zeotech in Tilden, TX is a privately held corporation with offices in Texas and New Mexico. Zeotech has a corporate emphasis on developing then producing new applications and products through research and development. They were also the first company in the United States to build a plant exclusively for mining, processing and packaging of natural zeolite products. Zeotech markets clinoptilolite filtration media for swimming pools and spas and has developed a new patented surfactant modified product for this application. Zeobrite Xtreme is already in the marketplace for filtration in pool and spa applications and is also certified NSF 61 for potable water systems. The company also sells adsorbents, modified zeolites for industrial and municipal water treatment and for solid waste and sludge decontamination.

Bear River Zeolite a subsidiary of the public company U.S. Antimony Corp. in Preston, ID is the only company that publishes its annual production and financial results. It has had occasional sales

of a clinoptilolite-based radioactive waste barrier product for the containment of high-level nuclear waste in addition to filtration media, coated clinoptilolite fertilizers, and pre-emergent seed products.

Teague Mineral Products (TMP) in Adrian, OR continues to be the largest supplier of clinoptilolite soil conditioners and amendments in Idaho, Oregon and Washington. TMP owns large deposits of clinoptilolite zeolite near the Sheaville and Castle Creek area of Idaho. Its zeolite is sold for animal feed additives, hazardous waste cleanup testing (West Valley Nuclear and Atomic Energy of Canada), soil amendments, seed coater, air filtration and odor control.

UOP LLC, a subsidiary of Honeywell, is the world's largest producer of molecular sieves and operates the EZ Chabazite Mine in Bowie, AZ. The company increased production to supply the rapidly growing market for chabazite molecular sieve products used in pressure swing adsorbent (PSA) plants that purify natural gas. Sales appeared to have slowed in 2017 and that trend appears to have continued in 2018, but picked up in 2019. The company also supplies some nuclear waste treatment products in partnership with Toshiba at the Fukushima facility for which work has also slowed significantly since 2017. UOP has teamed with Jacobs Engineering to look for treatment solutions at the Hanford, WA site treating high level Cesium wastes.

KMI Zeolite produces clinoptilolite from a deposit near Death Valley National Park, CA. Its processing plant is now the modernized Ash Meadows facility purchased from St. Cloud in Amargosa Valley, NV. This location allows the company to process product closer to its deposit as well as make equipment upgrades to the plant to increase overall production to keep pace with expanding sales. KMI Zeolite sales are mainly in the areas of synthetic turf products, odor elimination, water filtration, soil amendments, animal feed additives and industrial absorbents.

Steelhead Resources in Spokane, WA is a domestic zeolite producer and international provider of natural zeolites including clinoptilolite, ferrierite, phillipsite and mordenite. Steelhead has worked with a variety of industries to help it identify the appropriate zeolite for each application. Steelhead Specialty Minerals is the owner of several deposits and has strong relationships with other zeolite sources in the U.S. Steelhead sells clinoptilolite products from deposits in Oregon, California and New Mexico for industrial, agricultural, aquaculture, wastewater treatment, odor control and nuclear applications.

Kirkland Mining Co. a newcomer to the companies covered, is a family-owned enterprise

that has owned the Kirkland claims in Yavapai County, AZ and an adjacent property for many years and has spent the last five years investing in and planning to mine the high-quality pozzolan (HQP) deposit known as the Kirkland Mine. Mining has occurred at this location off and on since 1958 when the quarry was leased to Capital Quarries to provide dimensioned stone for construction of the Arizona State Capitol Building. This is an ash, low-grade zeolite deposit which would be like the deposits in China. In 2018, the plan of operation for the property was approved by the BLM and the operation is ready to start commercial operations. A resource of 21 Mt of pozzolan on the 88-acre claim block with an estimated mine life of 40 years has been developed. The development and permitting process lasted six years.

Outside the United States there is a robust natural zeolite industry with a range of companies from small regional producers, Canadian juniors and increasing sophisticated processors with a range of product offerings but typically still concentrated around a single deposit.

Canadian Zeolite Corp. has two deposits, including the Sun Group, a zeolite deposit held since 2004, which has a drilling-demonstrated potentially large resource near transportation infrastructure. The deposit is being held for future development. The company also has Bromley Creek zeolite deposit about 9 km from Princeton, BC, Canada with a small drilled-out reserve.

Progressive Planet Solutions (previously Ashburton Ventures Inc.) holds a 100 percent interest in the Z-1 Zeolite Quarry/Mine located about 3 km northeast of Cache Creek, BC. All mining and environmental permits are in place at this mine. The Z-1 deposit is located on a main east-west transportation corridor (Trans-Canada Highway and CN and CP rail).

Rota Mining was founded in 1995 in Turkey and started its minerals operations in 1998. It produces a range of natural zeolite products at the mining and processing plant in Manisa, Turkey. Rota Mining exports its products to more than 55 countries. The development of partnerships with customers is essential within the value-added markets of natural zeolite mineral.

Zeocem is one of the more interesting European producers of high purity clinoptilolite currently producing about 195 kt/a. Zeocem is maintaining its strong position in building industry and moving rapidly into the development of sales into more traditional markets of zeolitic products in Europe, mainly into feed applications. High content pozzolan cement production capacities, with original installed output up to 500 kt/a, were reconfigured and adjusted for production of fine

and coarse powders and granular zeolite products. New energy-efficient machinery and technology facilities for key stages of production (drying, milling, sorting and delivery) were installed and the gaps in follow-up phases of production were filled to match the installed factory production output and increase the economic efficiency of the production. Reconstruction of siding and renewal of rail loading places re-started high quantity rail-road deliveries of their products.

Blue Pacific Minerals is New Zealand's largest processor and distributor of zeolite and perlite ore for domestic, commercial, agricultural and industrial applications throughout Australia, Asia and South Pacific regions. Blue Pacific Minerals is a privately held company located in the Waikato region of New Zealand. The company holds significant reserves both zeolite and perlite. One of its more interesting materials is a powdered product, Aqual P, that has proven to be a natural weapon in the battle against nutrient-based algal bloom. Aqual P has been used in New Zealand in the Central North Island lakes, including Rotorua's Lake Okaro.

SAILE Industries is the Philippines largest commercial mining and processor of zeolite and bentonite ore for domestic, commercial, agricultural and industrial applications. It is a private company located in Northern Luzon, Province of Pangasinan, Philippines. The main production scheme is the mining and processing of natural zeolite and bentonite products and the manufacture of products based on these minerals for the Philippine domestic market and Asia Pacific countries as well. The mineral ore processing facilities of SAILE Industries has the capacity to give a variety of coarse, granular and finely milled products specifically tailored to suit customer requirements and market applications, based on the selection of one of their mineral ore types they offer such as clinoptilolite-mordenite zeolite and montmorillonite bentonite.

Uses and applications

Worldwide, most natural zeolite mineral products are used in agricultural soil amendments, odor control, filtration applications and pozzolans that do not require ultra-high purity natural or synthetic zeolites. In general, most commercial deposits are comprised of a minimum 70-80 percent zeolite minerals. The exception is an Italian chabazite that at about 50 percent pure, is successfully used in several markets in compact septic systems, at a rate of about 4 kt annually, as well as other specialty applications. Chabazite from the Bowie, AZ deposit is high purity and is processed into beads and extrudates and used in specialty sorption applications. The properties of Chabazite from this deposit, primarily resistance

to harsh chemical environments and a cyclical adsorption rate that exceeds those of the competitive synthetic zeolite products, create a performance advantage. The largest application for chabazite is in PSA plants that treat natural gas from wells and landfills. This market has and will continue to expand over the long term as the worldwide production of natural gas increases.

Trends and outlook

Natural zeolite production should continue to grow at a rate between 3 and 4 percent per year. The markets that will grow most rapidly include the following:

Animal feeds. A substantial portion of clinoptilolite sold worldwide is used in animal feeds, primarily for cattle. Beef prices in the United States continue at record-high prices and it finally appears that the herd is beginning to be rebuilt. It will, however, take a while for this to occur. 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. Products for swine and poultry are available but have not yet taken off.

Cement, pozzolans and concrete additives. Zeolite pozzolan additives improve the physical properties of cement and reduce both the amount of limestone used and carbon dioxide emitted in manufacturing cement. If the EPA designates fly ash from coal-fired power plants as a hazardous waste, it may not be available for use as a pozzolan. In general, the availability of fly ash is decreasing as coal fired plants go offline. Several companies are considering volcanic ash and zeolite deposits as among the few cost-effective substitutes available. The major uses of natural zeolites outside the United States are in construction materials and pozzolans. There is also a significant interest in treating fly ash storage areas, which can contain metals and other deleterious contaminants. The Kirkland Mining Co. is the newest entrant into this market.

Water treatment. Zeolites are used in filtration pretreatment of reverse osmosis systems for potable water. Zeolite consumption will increase as wastewater recycling and conservation are mandated in the rapidly expanding urban areas of the desert southwest. Testing on mine waters in West Virginia showed that the clinoptilolite from the Winston, NM operation was effective in remediating Acid Mine Drainage as well as reducing aluminum, and manganese to acceptable levels both-pre and post-treatment. Several operations are testing the zeolite as a final polishing

filter in these applications. Encouragingly, testing at one facility showed a drop in COD and BOD of over 30 percent. Appalachian coal mining operations in the east and metal mining operations throughout North America have compliance issues with manganese and aluminum in mine water discharge. Additionally, ammonia has become a regulatory issue once again in many mining and industrial applications. Large scale water treatment projects using zeolites to remove uranium from groundwater at treatment rates of as much as 4.5 m³/min (1,200 gpm) began operations in 2015 and continued in 2018. Finally, the lead contamination of municipal water in Flint, MI brought national attention to significant issues in the water quality in the United States. Though zeolites were not a solution to water issues at Flint, there are applications for the filtration and treatment of municipal water supplies from both surface and well waters. There is also ongoing filtration testing of TOC at a municipal facility in an area prone to blue algae blooms and the results continue to be encouraging. Testing will continue in 2018.

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

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

Nuclear applications. Chabazite and clinoptilolite-based ion exchange products are used to remove radioactive isotopes in nuclear reactor effluents. Clinoptilolite, because of its lower cost, has been used in the construction of extensive impermeable waste barriers to prevent the incursion of radioactive contamination into ground and surface water. Water Remediation Technology LLC uses a modified clinoptilolite which is NSF 61 certified to remove radium, uranium and other contaminants from municipal water treatment systems and is examining the increasing problem of trace radioactive contaminants in frac and waste water from the production of natural gas and oil. WRT has more than 100 of these systems installed throughout the United States. One of the more interesting events that began in 2015 and

was completed in 2016 was the sale of Kurion, a primary user of natural zeolites at the Fukushima cleanup, to French based Veolia, which is one of the largest water treatment companies in the world. The purchase price was US\$350 million. Though work at Fukushima has slowed worldwide there will be a growing market for the treatment and storage of high and low level radioactive wastes.

COVID-19 opportunities

Most natural zeolite companies due to their position in animal feeds, water treatment, odor control and environmental remediation applications, were deemed critical industries and were able to remain open during the COVID-19 pandemic closures. From personal experience, both St. Cloud Mining in the United States and in the Philippines were able to continue deliveries to their feed industries, agriculture and aquaculture markets using special permits or letter from their customers identifying them as critical suppliers in the United States or on Food Lane Passes in the Philippines. Mining and milling productions are also in operations as IATF ID was secured from the Inter Agency Task Force of the Philippines. The IATF oversees the various operations in the Philippines especially tasked on COVID-19 operations for essential market operations which includes healthcare, agriculture, pharmaceutical, logistics and food businesses.

In the field of research in Asia and the Philippines, there is a call to submit proposals for COVID-19 related technologies from the Department of Science and Technology. SAILE as an industry partner in various academic institutions are preparing proposals that are zeolite-based to fight off COVID-19. These are the following:

1. Oxygen concentrators — Devices to produce pure oxygen for patients that have respiratory diseases. COVID-19 patients can use these mobile oxygen concentrators in hospitals. Persons under investigations having difficulty breathing sheltered at home and in isolation rooms can also use these concentrators. As this market grows natural zeolite-based concentrators containing modified natural zeolites that can adsorb nitrogen and produce pure oxygen from ambient air could replace synthetic zeolite products.
2. Zeolite masks — Besides filtering particulate matter, a zeolite-impregnated filter can use zeolite with copper nano particles can serve as an antibacterial mask.
3. Disinfecting zeolite — Pelletized zeolite with chlorine can serve as disinfecting crystals to fight bacteria and viruses. It can be packed in sachets or tubes near hospital entrances and emergency rooms. ■

ZIRCONIUM

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

Zirconium is most often in the form of zircon (ZrSiO_4) that is predominantly recovered as a coproduct of the mining and processing of placer deposits for heavy mineral sands including the titanium minerals ilmenite and rutile. The dominant end-use market for zircon was the ceramics industry, which accounted for about half of the total zircon market. Other markets, in decreasing order of zircon consumption, were zirconia [zirconium dioxide (ZrO_2)] and other zirconium chemicals, refractory and foundry applications, zirconium metal, and other uses. Milled zircon is used in ceramics as an opacifier in ceramic bodies and glazes. Zirconia and other zirconium chemicals are used in a variety of other uses. Yttria-stabilized zirconia (YSZ) is used in the manufacture of oxygen sensors that control combustion in automobile engines and furnaces and in the manufacture of diverse products including cubic zirconia, fiber optic connectors, refractory coatings, and structural ceramics. Zirconium metal is used in corrosive environments

and various specialty alloys. Because of its low thermal neutron absorption cross section, hafnium-free zirconium metal is used as cladding for nuclear fuel rod tubes. In refractory and foundry uses, zircon is used for facings on foundry molds, where it increases resistance to metal penetration and gives a uniform finish to specialty metal castings. Milled or ground zircon is used in refractory paints for coating the surfaces of molds, and refractory bricks containing zircon are used in furnaces and hearths for containing molten metals.

Production

Global production of zircon concentrates was estimated to be 1.4 Mt in 2019, a decrease from about 1.5 Mt in 2018. The leading producing countries, Australia and South Africa, accounted for 66 percent of global production (Table 1). In the United States production was about 100 kt (rounded to avoid disclosing company proprietary data). Two companies, The Chemours Co. and Southern Ionics Minerals, LLC, produced heavy

Table 1

World production of zirconium ores and concentrates, by country (kt, gross weight).

	2018	2019e
United States	1100	1100
Australia	560	550
China*	140	80
Kenya	45	50
Mozambique	48	50
Senegal	64	70
South Africa	350	370
Other countries	170	170
Total (rounded)	1,480	1,400

e: estimated production
 *: rounded to one significant digit to avoid disclosing proprietary company data. Source: U.S. Geological Survey

zircon mineral concentrates at mining operations in Starke, FL and Nahunta, GA, respectively. Twin Pines Minerals, LLC, processed existing Chemours mine tailings to produce zircon in Starke, FL. In August, Chemours acquired Southern Ionics Minerals from its parent company Southern Ionics Inc.

Trade

In 2019, the United States was a net exporter of zircon concentrates, with exports totaling 40 kt (ZrO_2 contained weight) with a value of \$55 million. Exports were about half the exports in the prior year but more than exports in 2017. China was the leading destination receiving 84 percent of U.S. exports of zircon concentrates. In 2019, the United States imported 23 kt (ZrO_2 contained weight) of zircon concentrates with a value of \$55 million. The leading import sources, in descending order of quantity, were South Africa (64 percent), Australia (17 percent) and Senegal (17 percent). China, the leading global consumer of zircon concentrates, imported 1.18 Mt (gross weight) of zircon concentrates in 2019, an increase of 13 percent from those of 2018 (Fig. 1).

Prices

On a gross weight basis, the average annual U.S. zircon export unit value in 2019 was \$875/t, an increase of 15 percent from that of the previous year. Average annual U.S. zircon import unit values increased by 14 percent in 2019 to \$1,570/t of gross weight (Fig. 2). For comparison to global markets, China's average annual zircon unit value of imports was \$907/t nearly unchanged compared with 2018, and Australia's leading zircon producer reported weighted average prices had increased 10 percent to \$1,487 in 2019.

Outlook

Global zircon production was forecast to decline owing to decreased demand in the short term. In December 2019, an outbreak of a novel coronavirus (COVID-19) was first identified in China. The World Health Organization declared that COVID-19 was a global pandemic on March 11, 2020. Measures instituted to mitigate the spread of the COVID-19 pandemic, such as closures of nonessential businesses, are likely to cause disruptions in the mining industry across the United States and around the world. The duration and the outcome of the COVID-19 pandemic remains uncertain, but it is expected that the economies of the United States and the world as a whole will likely be negatively affected, which could influence the performance of the zirconium industry. ■

Figure 1

U.S. salient statistics for zircon ores and concentrates from 2017 through 2019. Source: U.S. Census Bureau, U.S. Geological Survey.

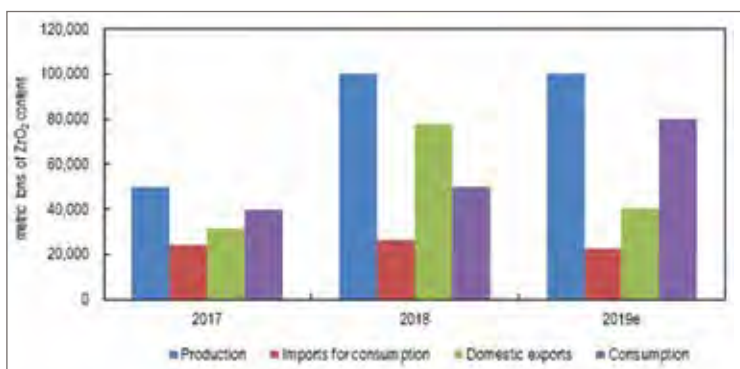
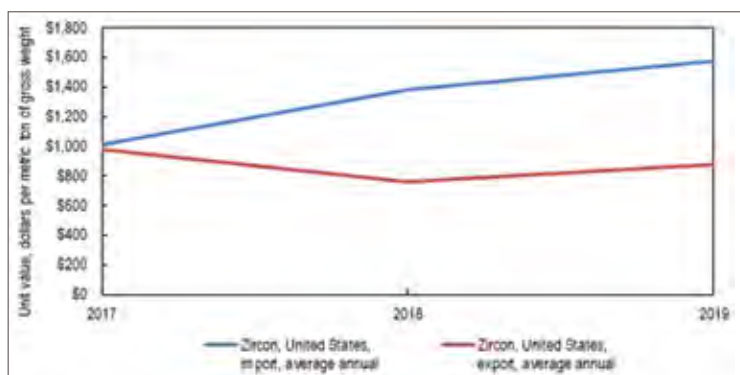


Figure 2

Average annual unit value of zircon ores and concentrates from 2017 through 2019. Source: U.S. Census Bureau.



Misconceptions, dreams and realities in the High-stakes game of rare earths

by Chee Theng, Managing Technical Editor

Following its funding opportunity announcement late last year for rare earth element (REE) separation and processing, the U.S. Department of Defense (DoD) granted initial funding to two projects to establish heavy-REE separation facilities in the country. Both awards, however, appear to have been put on hold after concerns were raised by U.S. senators.

MP Materials said on April 22 that the DoD's phase 1 funding would support detailed planning

Pentagon pushing it to only fund U.S. rare earth projects, and on April 29 the Pentagon informed the applicants that the decision had been "put on hold until further research can be conducted," *Reuters* reported.

National defense at stake

At stake are the raw materials needed for national defense, which are currently vulnerable to Chinese dominance over their supply and pricing. The stakes are unquestionably high.

"Making just one F-35 fighter plane requires 920 lb of rare earths," said David R. Hammond, principal mineral economist at Hammond International Group. "An Arleigh Burke DDG-51 destroyer ship requires 5,200 lb, and an SSN-774 Virginia-class submarine needs 9,200 lb."

Speaking on "U.S. Rare Earths in 2020: Misconceptions, Dreams and Realities" as the Mineral & Metallurgical Processing Division lunch speaker at the MineXchange

2020 SME Annual Conference & Expo held Feb. 23-26 in Phoenix, AZ, Hammond said his goal was to bring attention to, and help clarify, some of the core issues, problems and realities associated with DoD initiatives to address the supply of critical REEs.

"It is important to keep in mind that funding grants, financial underwriting, development cost sharing, etc., by governmental agencies all involve expenditures of taxpayer money. It is therefore crucial that such support goes to those projects and technologies that appear to hold the greatest promise for realization and potential for technologic and commercial success and, most importantly, can be potential material supplies of U.S. REE needs," he explained.



An F-35 fighter plane requires 920 lb of rare earths. An Arleigh Burke DDG-51 destroyer ship needs 5,200 lb, and an SSN-774 Virginia-class submarine 9,200 lb. (Image from Shutterstock.)

and design for a U.S.-based facility, with further awards for commercial-scale production possible based on the results. The company, which owns and operates Mountain Pass Mine in California, the only REE mining and processing facility in North America, is 9.9 percent owned by a Chinese company, Shenghe Resources Holding Co. Ltd.

Also selected for funding was a joint venture of Australia's Lynas Corp. and Texas-based Blue Line Corp., which plans to construct a facility in Texas that would process rare earths shipped from Lynas' mine in Western Australia.

The awards triggered consternation in several quarters, prompting U.S. Senator Ted Cruz and five other senators to send a letter to the

Realities

Starting with realities, the first reality he outlined was that the global REE industry is a monopoly with China controlling more than 90 percent of REE material sourcing and essentially 100 percent of metallurgical processing to metal. China also controls the majority of high-efficiency magnet manufacture.

The second reality was that REEs are not equal in importance and value. “A REE generation source has to have the right REEs in the right amount and right geographic location to be meaningful, to represent an economic value or to have a chance of ever being put into production. And this is before the question of having the right metallurgical processing technology to make REE oxides or extract metal,” he said.

The third reality was that the REE supply problem is one of processing, not sourcing, REE-containing material. The fourth was that commercial-level REE processing is extremely difficult, and the fifth was that no major mining-to-metal company will get involved with REEs unless there is significant byproduction from primary production.

Misconceptions

The realities tied in with five misconceptions: (1) “I can use market posted prices for my project economics.” (2) “I can use the REE ‘basket’ for projecting project revenues.” (3) “My REE resource can be processed by typical conventional metallurgical processes.” (4) “My process chemistry/metallurgy fits theory and works on the bench/pilot scale; it no doubt will work commercially.” (5) “I can cash out my project to some big mining company, or bring them in as a venture partner.” Hammond said an emphatic “No” to each of them. “There is no such thing as a price for rare earths; prices can suddenly be zero. Processing is extremely complex, with many different approaches and challenging problems.”

More realities

Because the majority of the world’s REE metals are produced by Chinese-controlled entities, China is the major customer for REE resource production, he continued.

“No matter how great your flowsheet is, you must have tons and grade to be an REE supplier that matters. Producing a small share of market demand won’t cut it,” he said. “REE sales will be to intermediate and end-use consumers through nontransparent, bilateral, long-term supply contracts. There won’t be a ‘spot’ market.”

The logical potential equity partners will be REE consumers, and the lowest possible production costs will be the determinant for consumer partner investment or supply contract decisions.

Producing, potential and dreams

Assessing the current U.S. REE supply possibilities (Fig. 1), Hammond said, “For me, the critical question for any REE supply source is, simply, can it be of material significance relative to U.S. needs. A project or research concept can have volume — tonnage or numerous individual source locations, such as acid mine drainage sites or fly-ash producing furnaces — or REE grade, but it must have both in a logistically concentrated location in order to represent materially significant production over an extended period of time. Many of the hypothetical U.S. supply sources do not meet this requirement.”

Looking at some projects in detail, he observed that Mountain Pass supplies more than 15 percent of U.S. neodymium (Nd) and praseodymium (Pr) oxide needs, making it a significant supply source for these metals, which currently represent the largest tonnages of specific REE metals going into magnet fabrication. Mountain Pass, however, had not been a provider of dysprosium (Dy) and terbium (Tb), which are needed in much smaller quantities as magnet components, and its Chinese ownership was noted as a negative aspect for U.S. national security.

The Bear Lodge prospect in Wyoming was considered to have real potential to be a material supplier of Nd and Pr, as well as Dy and Tb in smaller proportions. “A key aspect of this prospect is that it has both tons and grade, with the implication that it would be a long-term U.S. supplier if brought into production,” he said.

Conclusions

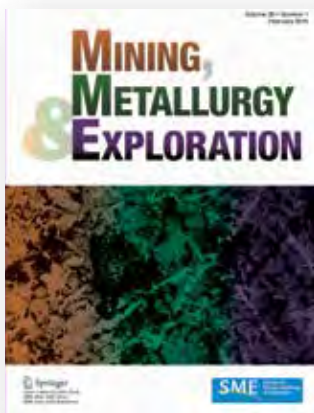
With the many challenges ahead, Hammond concluded that the DoD needs a fully independent advisory board of experienced resource, mining and processing experts for guidance on the optimal sourcing of critical REE supply, both in terms of cost and quantity. ■

Figure 1

U.S. REE resources at present (Hammond International Group).

• Coal	Dream (too low grade & too dispersed)
• Coal Waste	Dream (“ “ “ “ “)
• Coal Ash	Dream (“ “ “ “ “)
• Acid Mine Drainage	Dream (“ “ “ “ “)
• Round Top	Dream (extremely low grade)
• Bokan Mountain	Dream (very small resource; low-grade)
• Hicks Dome	Interesting, needs a lot of work
• Pea Ridge	Potential, REE as by-product
• Florida Phosphates	Potential, enormous resource
• Bear Lodge	Potential, large resource & high grade
• Mountain Pass	LREE Producer (but for China), small HREE output in the past
The Long-Term Winners:	
Phosphates, sea-bed nodules, and recovery from recycle	

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LED area lighting to reduce glare for roof-bolter operators

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To read the full text of this paper (free for SME members), see the beginning of this section for step-by-step instructions.

Special Extended Abstract

Researchers from the U.S. National Institute for Occupational Safety and Health (NIOSH) developed the Saturn light that significantly improves illumination for roof-bolting machine operators while reducing glare. The existing roof-bolter lighting was the baseline and was compared to the Saturn at 100, 75 and 50 percent intensities. Discomfort glare and disability glare were measured by the De Boer rating scale and the Mars Letter Contrast sensitivity test, respectively. Thirty study participants were tested. Discomfort glare was reduced at least three levels with the Saturn luminaire. Visibility levels were four to 6.5 times better with the Saturn than with the baseline. The Saturn design is freely available for commercialization.

Introduction

Accident data indicate that operating the roof bolter is a leading cause of machine-related injuries in mining [1]. The operational hazards of a roof-bolter machine include relatively poor visibility due to low ambient light levels and low contrast levels. Excessive glare is another visibility hazard and is a frequent complaint among roof-bolter operators. It is primarily due to the high luminance contrast between the background and high-intensity luminance of the luminaires mounted on the roof bolter. A high luminance contrast can result in discomfort glare, a loss or reduction in visibility, or both [2].

NIOSH researchers have developed the Saturn LED light to address these concerns, and the design documentation is freely available for downloading [3]. The Saturn was designed to improve floor illumination for detecting trip hazards and to reduce glare that has been historically problematic on roof bolters. The first objective was achieved with up to a 48 percent reduction in average trip detection time compared to the standard lighting on a roof bolter [4]. More importantly, the Saturn trip object miss rates were < 0.5 percent for all age groups in contrast to those of the standard lighting, which ranged from 32.5 percent for the youngest group to 50.4 percent for the oldest group [4]. Therefore, the present study's primary objective was to determine if the Saturn can reduce discomfort and disability glare. The second objective was to determine if varying the Saturn intensity results in differences in discomfort and disability glare.

Methods

The roof bolter's compact fluorescent lamp (CFL) luminaires with amber polycarbonate globes served as the baseline and were compared to the Saturn luminaire at 100, 75 and 50 percent intensities (Fig. 1). The study was conducted in two phases: phase 1 at the middle of the roof bolter, and phase 2 at the front. The De Boer scale was used to rate discomfort glare, and the Mars Letter Contrast Sensitivity test to rate disability glare. Of the 30 participants, 10 were in each of the three age groups: young, 18–25 years old; middle, 40–50 years old; oldest, older than 50 years old.

Results and discussion

For phase 1, no statistically significant differences existed among the luminaires for discomfort or disability glare; thus, the Saturn does not appear to reduce glare at this middle location. The median De Boer rating was 8 (better than satisfactory) for the CFL and the Saturn at 100 and 75 percent, and 7 (satisfactory) for the Saturn at 50 percent.

For the phase 2 location at the front, statistically significant differences existed among the luminaires for discomfort glare. The median De Boer rating was 5 (just acceptable) for the CFL, and ranged between 8 and 9 for all Saturn intensities with no significant differences among the Saturn intensities. For disability glare, age and luminaire were significant. Post hoc analysis on age showed that the results for both the younger and middle groups were significantly different from the older group, but the difference between the younger group and the middle group was not significant. Disability glare was the worst with the CFL for all age groups and decreased as the Saturn intensities decreased.

Additional analysis of the visibility level (VL) was conducted, given phase 2 data were significant. The worst VL was 2 for the CFL and 8, 12 and 13 (best) for the Saturn at 100, 75 and 50 percent, respectively, indicating the Saturn reduced glare without sacrificing visibility.

The phase 1 and 2 results differ because the luminaire mounting locations differed, resulting in varying levels of illuminance direct to the eyes. For phase 1, the CFL average eye illuminance was 5.3 lux and the Saturn luminaires ranged from 8.1 to 12.0 lux. For phase 2, the CFL average

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eye illuminance was 25.1 lux; the Saturn luminaires ranged from 0.6 to 1.2 lux, thus enabling significant glare reduction.

Conclusions and summary

Overall, the Saturn luminaires performed significantly better relative to discomfort and disability glare and visual performance than the CFL luminaires at the phase 2 location of the roof bolter; thus, the first study objective to determine if the Saturn luminaires could reduce discomfort and disability glare was achieved. The second objective to determine if there are differences among the Saturn luminaires was also achieved.

Among the Saturn luminaires, the Saturn at 50 percent enabled the least amount of disability glare and the highest visibility level at the phase 2 location, so it appears that the Saturn at 50 percent would be the most desirable luminaire in terms of reducing glare. Note that the phase 1 data analysis indicated no significant differences among the Saturn luminaires and the CFL lighting condition with respect to discomfort and disability glare because glare was not an issue at the phase 1 location. ■

Disclaimer

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References

1. MSHA. Accident, illness and injury and employment self-extracting files (part 50 data), 2004-2013. [cited 2019]

2. Lighting Research Center. Glossary. National Lighting Product Information Program 2018 10/24/18
3. Sammarco JJ (2018) NIOSH Saturn area light. 10/24/2017 8/28/18
4. Sammarco J et al. (2018) LED lighting for improving trip object detection for a walk-thru roof bolter. Light Res Technol 0(0):1-17

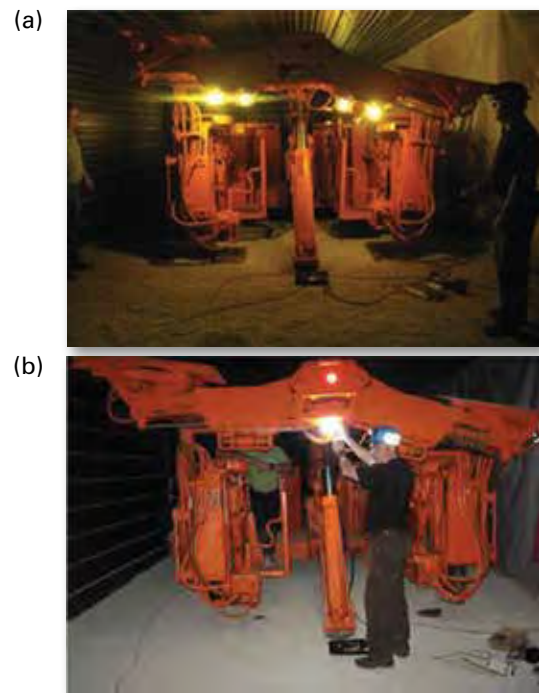


Fig. 1 Roof-bolter front illuminated with (a) CFL luminaires and (b) Saturn luminaire at 100 percent.

Numerical investigation of the effect of a novel wet scrubber on dust reduction in an underground coal mine

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Keywords: Dust control, Dust scrubber, Flooded-bed scrubber, Respirable dust, Room-and-pillar mine, Computational fluid dynamics (CFD)

To read the full text of this paper (free for SME members), see the beginning of this section for step-by-step instructions.

Special Extended Abstract

Controlling dust generation and keeping it below permissible limits to meet federal dust standards at the working face of a room-and-pillar coal mine is a challenge for a mine

operator. With the recent changes in federal dust regulations requiring lower worker exposure, maintaining compliance has become increasingly difficult. The current most effective

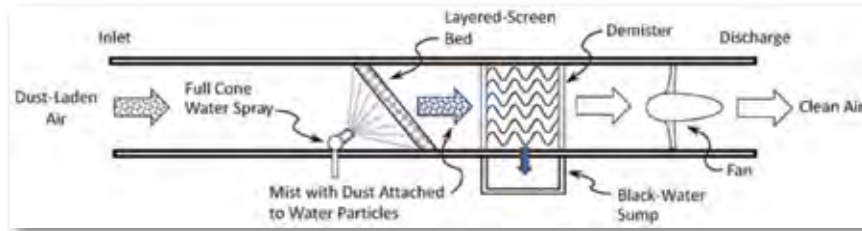


Fig. 1 Cross-sectional view of a flooded-bed dust scrubber.

practice of dust control at a continuous miner face in an underground mine is the use of a flooded-bed scrubber. A study carried out by the U.S National Institute for Occupational Safety and Health (NIOSH) indicated that a flooded-bed scrubber could achieve cleaning efficiencies between 58 and 90 percent. But the operation of such a system is maintenance intensive. The flooded-bed scrubber screen becomes clogged with dust particles and requires frequent cleaning to maintain performance. However, the dust-control issue is not solely a mining-industry problem. Other industries face similar issues. The University of Kentucky collaborated with Toyota Motor Manufacturing on the development of a novel wet scrubber, called the vortecone scrubber, for capturing over-sprayed paint particles in automotive paint booths. The vortecone scrubber achieved a cleaning efficiency of 99 percent and required minimal maintenance. This study aims to assess the ability of this vortecone scrubber to capture respirable dust in an underground coal mine. The paper presents the results of computational fluid dynamics (CFD) modeling of this vortecone scrubber. It discusses the effects of air quantity and dust particle size on the performance of the scrubber.

Background

The most popular dust-control techniques in an underground mine include dilution through ventilation air, suppression by water sprays, and dust capture through a machine-mounted wet scrubber [1]. In the United States, a flooded-bed scrubber is used as an integral part of a continuous miner unit to capture and remove the airborne dust generated at a room-and-pillar mine face (Fig. 1). Although the flooded-bed scrubber has been successful in removing dust from a room-and-pillar mine face, its cleaning efficiency and maintenance requirements are still in question. The wire-mesh screen becomes clogged with dust particles, re-

ducing airflow through the scrubber, and therefore requires frequent cleaning to maintain performance [2].

The research presented in this paper explores the possibility of replacing the maintenance-intensive flooded-bed scrubber with a maintenance-free vortecone scrubber. The vortecone scrubber has been tested in other industrial settings and is expected to have higher efficiency and lower maintenance requirements than flooded-bed scrubbers.

The novel vortecone scrubber

The vortecone scrubber works on the principle of vortex interaction of the particle-laden airflow with water for its particle-capturing mechanism [3]. Particle-laden air enters at the inlet and flows through the vortecone (Fig. 2a). Water is injected at the periphery of the inlet, creating a water film that circulates on the inner wall of the vortecone. When a particle encounters the water, it becomes entrained in the circulating water. As shown in Fig. 2b, the vortecone has four main components: a cone-shaped inlet, mixing chamber, vortex chamber and discharge. The cone-shaped inlet provides smooth acceleration of particle-laden air and the water film. This acceleration increases the momentum of the particles in the air, which hit a pool of water in the mixing chamber, where some particles are trapped. Particle-laden air then moves to the vortex chamber. The vortex chamber creates a swirling flow of air, imparting a centrifugal force to the particles, pushing them outward. This causes particle-water interaction at the wall of the vortecone. Finally, clean air and dirty water leave the vortecone through its discharge.

One of the main reasons for the effectiveness of the vortecone scrubber is the extended resident time of particles in the capturing device. The resident time increases the opportunity for and frequency of collisions between particles and water, thereby improving performance.

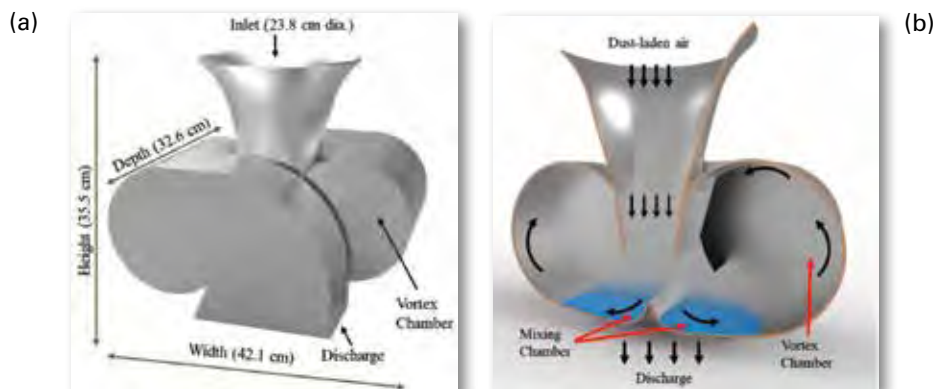


Fig. 2 (a) A 3-D model and (b) a cross-sectional view of the vortecone scrubber.

CFD modeling

A total of five cases for different vortecone inlet velocities were studied for this research: 6, 8, 10, 12 and 14 m/s. The five cases were selected considering the variation in inlet velocity with scrubber system resistance and scrubber fan speed. Each simulation was performed in two steps: (1) a single-phase, steady-state simulation was conducted to establish airflow in the computational domain, representing conditions before dust release, and (2) a multiphase, transient-state simulation that involved the transport and tracking of solid particles was performed for dust captured by the vortecone, representing the state after dust release.

Two dust particle size distribution with mass particles of density $1,200 \text{ kg/m}^3$ were used: (1) a hypothetical, uniform particle size distribution with particle size varying from 0.5 to $100 \mu\text{m}$ (0.5, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 15, 20, 25, 30, 40, 50, 60, 80 and $100 \mu\text{m}$) and (2) a measured particle size distribution of dust generated at a continuous miner face. Five simulations (for five vortecone inlet air velocity conditions) were performed for each dust particle size distribution.

Result

The results indicate that the vortecone scrubber system

has a higher cleaning efficiency than the flooded-bed scrubber system and that its cleaning efficiency positively correlated to airflow velocity. The vortecone scrubber can capture 90.1 and 93.4 percent of particles at 6 and 14 m/s inlet velocities, respectively. Furthermore, the research shows a higher capture rate for larger particles, with 100 percent of particles with diameters of $7 \mu\text{m}$ and larger being captured.

Conclusion

The CFD modeling of dust capture through the vortecone was performed for various scrubber inlet velocities ranging from 6 to 14 m/s. The results indicate that the vortecone scrubber can be a better alternative than the flooded-bed scrubber. Because of its reduced maintenance frequency, the vortecone scrubber offers greater system availability and, therefore, higher production rates. ■

References

1. Campbell JAL, Moynihan DJ, Roper WD, Willis C (1983) Dust control system and method of operation
2. Colinet JF, Reed WR, Potts JD (2014) Continuous mining dust levels in 20-foot cuts with and without a scrubber operating. In: Proceedings of Society for Mining, Metallurgy & Exploration. Salt Lake City, UT, Preprint 14-033
3. Salazar AJ, Saito K, Alloo RP, Tanaka N (2000) Wet scrubber and paint spray booth including the wet scrubber

Directional controlled blasting technique for excavation of unstable slopes along the Konkan Railway route

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To read the full text of this paper (free for SME members), see the beginning of this section for step-by-step instructions.

Special Extended Abstract

The paper presents an innovative directional controlled blasting (DCB) technique for excavating unstable slopes along the Konkan railway in India without disturbing the traffic. New empirical formulae for small geometry blasting to estimate burden and throw were developed. A unique sequence of firing and excavation with powder factor varying between 0.04 and 0.39 kg/m^3 , irrespective of the actual free face, was used for rock blasting. The process controlled the throw of blasted material over the track and resulted in a smooth and stable wall. The slope angle was changed from 80 – 82 to 45 – 47 degrees, and possible wedge, planar and toppling failures were eliminated. No incident of rockfall and slope failure

along these slopes has been observed after the stabilization.

Introduction

Konkan Railway Corp. (KRC) operates a 741-km railway transportation route between Mumbai and Mangalore through the Western Ghats hills. The tracks on the route were laid by excavating trenches that were 8 to 10 m wide, 50 to 1,000 m long and 10 to 50 m deep, with cuttings at 564 discrete locations, to maintain grade using a blasthole diameter of 115 mm. Six months after their inauguration in 1998, torrential rainfall triggered landslides and slope failures along the alignment, disrupting routine services. KRC

addressed the problems by adopting several geotechnical strengthening measures. Rockfall and slope failure kept on occurring frequently along the tracks, especially in the monsoon season. The Ministry of Railways of India's Research Design and Standards Organization (RDSO) then recommended a reprofiling of the vulnerable slopes. The present paper details a novel blast design technique executed on the accident-prone cuttings of KRC. The significant challenges were to design the blast geometry and firing pattern, and direct and control the throw in such a manner that existing rail tracks that are 2 to 3 m from the slope face as well as the train traffic remained undisturbed.

Method

No specific methodology to excavate and widen unstable slopes along a railway route without disrupting the traffic has been reported in the literature. Casale et al. [1] reported that before blasting an unstable slope, rails were to be removed and reinstalled after mucking.

KRC's existing slopes were to be stabilized by incorporating the suggestions of both RDSO and kinematic analyses. RDSO gave the permissible slope ratio of horizontal distance to vertical distance as 0.25:1 for hard rock and 1:1 for weathered rock, and suggested exposure of a berm, 4 to 5 m wide, at intervals of 6 to 8 m bench height. Kinematic analy-

sis called for safe slope angles of 45 to 47 degrees. The reprofiling proposal required systematic benching to remove fractured and weathered slope crest, and controlled blasting was found to be the only option for benching. Suitable excavation sequences were planned and developed to expose the berms.

For controlling the throw of blast, two new empirical equations for burden were developed to predict and control the throw within 2 m:

$$B = g / RQD \times d_b^{0.7} \times \sqrt{\rho_e / \gamma} \quad (1)$$

$$T_w = (RQD / g)^{0.35} \times P_F \times D_h / B \quad (2)$$

where B is burden in meters, RQD is rock quality designation, g is acceleration due to gravity, d_b is the hole diameter in meters, ρ_e and γ are the densities of explosive and rock, respectively, T_w is throw in meters, P_F is powder factor in kilograms per cubic meter and D_h is depth of hole in meters.

The excavation sequences were divided into two different stages in each slice. In stage I, excavations using the innovative DCB technique were done, leaving a 2 m-thick rock ledge all along the railway track (Fig. 1). In stage II, the left-out rock ledge was removed using either mechanical means or DCB (Fig. 2).

Discussion

The thickness of the rock ledge was kept at 2 m, which was 59 times the blasthole diameter, sufficient to withstand the dynamic impulse of the pit blast. The threshold value of peak particle velocity (PPV) was kept at 254 mm/s, which was effective in preventing crest failure or rockfall on the track during blasting. The measured value of PPV 0.5 m from the trial blast was 646 mm/s, which did not damage the rock mass. Burden estimated using Eq. (1) was effective in controlling the rock movement within a pit. The extent of throw before blasting estimated using Eq. (2) was within 2 m from the first row, as desired. The ledge blasting pattern using two opposite free faces and well-distributed critical charge resulted in satisfactory breakage of ledge without much displacement toward the track. The protection of track using scraped tyres in two to four layers provided enough cushioning during the dynamic collision of the fallen fragments on the track and prevented any damage.

Conclusion

Based on extensive work conducted during the study, stable rock slopes were created without disturbing train traffic. The empirical formulae developed for designing blasts with controlled throw were tested, validated and found to be useful in achieving stable slopes. The methodology developed using the DCB technique eliminated the failure of slopes and may be adopted for effectively solving such problems in hilly terrain. ■

Reference

1. Casale M, Oggeri C, Peila D (2008) Improvements of safety conditions of unstable rock slopes through the use of explosives. *Nat Hazard Earth Sys* 8:473–481. <https://doi.org/10.5194/nhess-8-473-2008>

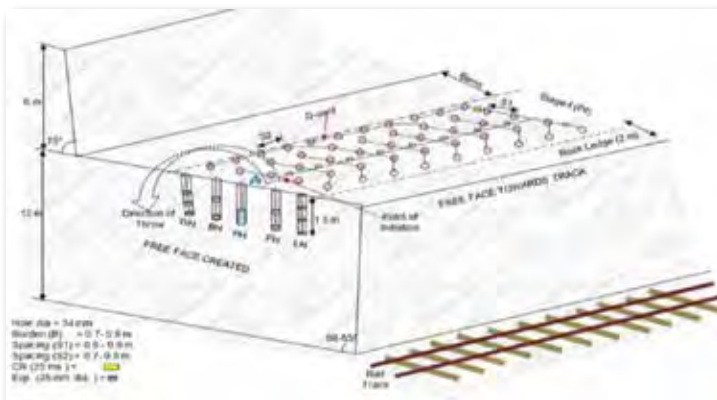


Fig. 1 Layout of DCB (stage I) at depth of 1.5 m showing desired directional throw parallel to track.

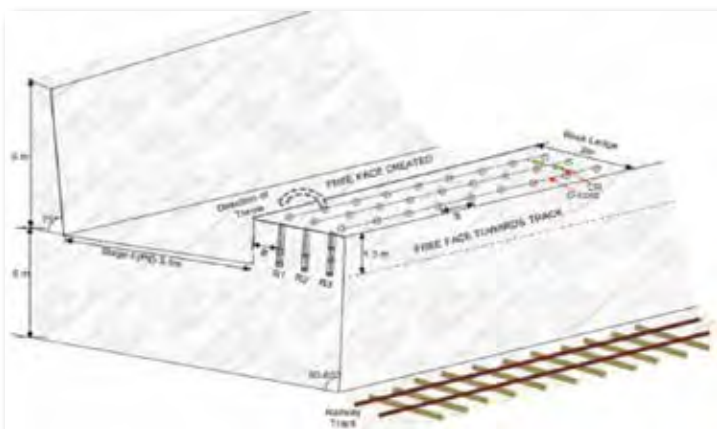


Fig. 2 Layout of rock-ledge blasting showing desired directional throw toward the pit.

Experimental evaluation of a two-entry gate-road yield pillar: Convergence monitoring and physical properties

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Keywords: Longwall mining, Coal, Ground control, Convergence

To read the full text of this paper (free for SME members), see the beginning of this section for step-by-step instructions.

Special Extended Abstract

Gate-road yield pillars are subject to increases in stress as the longwall face advances toward the pillars. Abutment loading conditions are important to gate-road layout and support design in longwall mining systems. Ground support systems are often designed based on mine experience [1,2]. Convergence monitoring is one method of ground support monitoring that can be used to infer increases in pillar stress. Convergence of a yield pillar was measured regularly over the course of six months as the longwall face approached and passed the pillar. Measurements were collected at eight locations surrounding the pillar. The convergence measurements contribute to the knowledge of when yield pillar abutment loading, caused by the encroaching longwall, is first detected. Knowing when abutment loading begins to yield the pillars can help define when standing secondary roof supports are required for head-gate entry access for specific geologic and mining conditions.

Background

At the mine, the depth of cover varies from about 150 to 610 m and the elevation of the terrain ranges from 2,286 to 3,048 m above sea level. The portal is developed in a canyon outcrop. At the location of the instrumented pillar, the average coal seam thickness is about 3 m. Parallel to the head gate outside the longwall panel, a vertical geologic feature cuts through the coal seam. Parallel to the tailgate outside the longwall panel, there is a major normal fault with displacement over 25 m. The coal seam contains a 0.3-m parting. The parting is located in the center of the seam, is parallel to bedding and appears to be a carbonaceous mudstone.

The pillar evaluated in this study is a head-gate yield pillar. The head gate uses a two-entry system with the travelway and beltway both supplying intake air to the working face. The tailgate uses a three-entry system with the bleeders containing three entries. The longwall panel is approximately 260 m wide and 1,800 m long. The longwall panel was de-

veloped between two existing mined-out longwall developments. The tailgate is a significant distance from the adjacent mined-out longwall development. The head gate is much closer to the adjacent mined-out longwall development.

Data collection and methodology

Convergence was monitored as the longwall approached the test pillar. Convergence data were collected over a six-month period. Measurements were collected at eight locations surrounding the pillar: four in the travelway and four in the beltway. Convergence was measured in the travelway until access to the head gate was no longer attainable. Convergence was measured in the beltway until the longwall face passed the test pillar and the beltway was no longer accessible due to the development of the longwall gob. The longwall face location was recorded throughout the experiment, and to plot the convergence data relative to the longwall face advance, the distance from the longwall face to the inby edge of the test pillar was measured. Convergence measurements began when the longwall was 1,407 m inby the edge of the test pillar, and although the pillar was already under some load, convergence was assumed to be zero at the beginning of the experiment.

Block samples of coal and parting were collected from the instrumented test pillar to determine the unconfined compressive strength (UCS), the tensile strength and the Young's modulus of the materials. Bit diameters of 53 mm (NX) and 32 mm were used to drill samples from the blocks to generate two independent sample populations.

Key results

Figure 1a shows the measured convergence versus longwall face distance from the pillar for the stations in the beltway (B01, B02, B03 and B04). The measurements for these stations stop before 0 m relative to the inby edge of the test pillar because convergence stations were damaged in the

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process of moving longwall equipment. Figure 1b shows the measured convergence for the stations in the travelway (T01, T02, T03 and T04). In the travelway, convergence was measured until the longwall had advanced 180 m past the inby edge of the test pillar.

For all of the stations except T04 and B04, the rate of convergence from the tributary area loading is fairly steady for distances between 1,407 and 262 m. At a distance between 408 and 262 m, the longwall abutment load begins to impinge on the pillar. At distances less than 100 m, the rate of convergence drastically increases. Overall, the convergence rates are highest at T04 and B04, the stations located near the corners of the pillar closest to the longwall face advance.

Table 1 summarizes the laboratory tests performed on core developed from the block samples of coal and parting collected from the instrumented test pillar, including number of samples, sample diameters and aspect ratios. Table 2 summarizes the UCS, Brazilian and Young's modulus laboratory test results for coal and parting sampled perpendicular to bedding. Densities were calculated for 117 samples of coal. The average density of the coal samples is 1.29 g/cm³. For coal, the laboratory-measured P and S wave velocities are 2,123 and 1,101 m/s, respectively. Densities were calculated for 10 samples of parting. The average density of the parting samples is 1.64 g/cm³. For parting, the laboratory-measured P and S wave velocities are 2,111 and 1,200 m/s, respectively.

Conclusions

Convergence measurements may be useful to identify ap-

propriate timing for installation of secondary support. In this mine, Burrell CANs are placed approximately 30 m ahead of the retreating longwall face; however, based on the pillar assessed in this study, it may be useful to place the CANs further ahead of the longwall face to maintain the entry for ventilation and greater assurance of operational safety.

For the UCS tests, although the differences in the means and standard deviations of the samples with diameters of 53 and 32 mm are not statistically significant, the mean of the 32 mm-diameter coal samples is slightly larger than the mean of the 53 mm-diameter coal samples. A higher mean for the smaller-diameter coal sample suggests that samples with larger physical size under unconfined compression are weaker than smaller-sized samples of the same material. This interpretation is consistent with the findings of other research [3]. In addition, the standard deviation of the 32 mm-diameter coal samples is larger than that of the 53 mm-diameter coal samples, which suggests that the smaller-diameter coal samples may detect a greater diversity in material conditions: that is, defects versus no defects. In the case of the Brazilian (tensile) strengths, the means are significantly different for the samples with diameters of 53 and 32 mm; the larger samples are weaker than the smaller samples. As demonstrated by the laboratory results (Table 2), using the Brazilian tensile strength test on small-diameter samples will tend to overestimate the tensile strength. ■

Funding information

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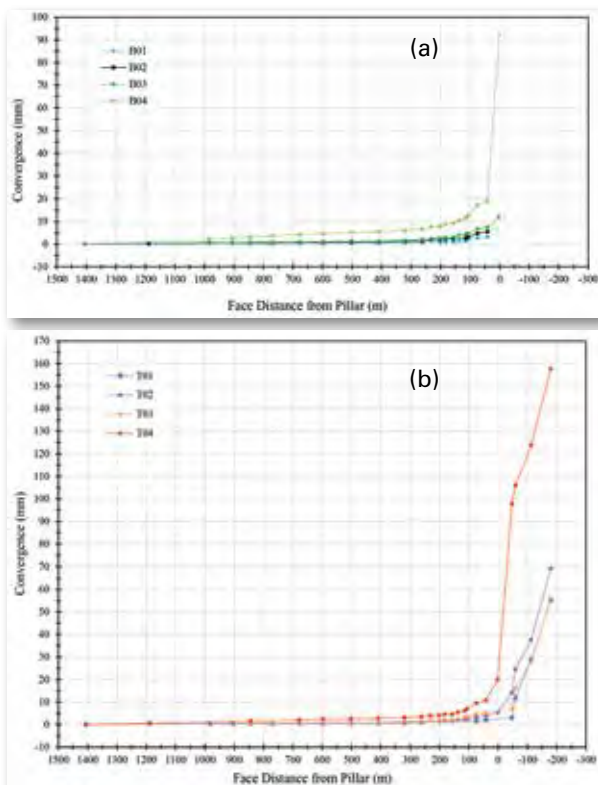


Fig. 1 Cumulative convergence measured in the (a) beltway and (b) travelway during longwall approach.

Table 1 — Samples prepared for testing.

Test	No. of samples	Diameter (mm)	Aspect ratio	
			Range	Average
UCS	72	53	0.63–2.00	1.84
	58	32	1.35–2.24	1.88
Brazilian	38	53	–	–
	77	32	–	–

Table 2 — Summary of laboratory test results for coal and parting.

		Coal		Parting	
		Diameter (mm)			
		53	32	53	32
UCS	No. of samples	42	45	4	6
	Mean (MPa)	24.20	25.19	32.48	33.07
	Std. dev. (MPa)	4.92	6.38	10.16	7.10
Brazilian	No. of samples	13	61	12	11
	Mean (MPa)	0.99	1.64	1.33	1.56
	Std. dev. (MPa)	0.29	0.57	0.49	0.45
Young's modulus	No. of samples	41	42	4	6
	Mean (GPa)	3.10	3.09	4.31	4.82
	Std. dev. (GPa)	0.45	0.44	1.01	0.67

tional Institute for Occupational Health and Safety. The conclusions of this work are those of the authors and do not necessarily represent the opinions or policies of the National Institute for Occupational Health and Safety.

References

1. Esterhuizen GS, Gearhart DF, Klemetti T, Dougherty H, van Dyke M (2018) Analysis of gateroad stability at two longwall mines based on field monitoring results and

numerical model analysis. *Int J Min Sci Technol* 29(1):35–43. <https://doi.org/10.1016/j.ijmst.2018.11.021>

2. Gearhart D, Esterhuizen G, Zhang P (2018) The effects of a passing longwall face on the roadway, pillar, and standing supports in northern West Virginia. In: Mishra B, Klemetti T, Lawson H, Murphy M, Perry K (eds) *Proceedings of the 37th International Conference on Ground Control in Mining*. Society for Mining, Metallurgy & Exploration, Englewood, CO, pp 359–365
3. Pariseau WG (2012) *Design analysis in rock mechanics*, 2nd edn. CRC Press, Taylor & Francis Group, London, pp 607–610

Optimization of tellurium and antimony extraction from residue generated in alkaline sulfide leaching of tellurium-bearing alkaline skimming slag using central composite design

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Keywords: Optimization, Tellurium and antimony extraction, Alkaline sulfide leaching, Central composite design

To read the full text of this paper (free for SME members), see the beginning of this section for step-by-step instructions.

Special Extended Abstract

Tellurium (Te) is an important scattered metal. Known as the vitamin of modern industry, national defense and cutting-edge technology, it is the supporting material for new high-technology materials. Currently, its separation and extraction from Te-bearing materials face problems such as long flowsheets and high reagent consumption, giving rise to an urgent need to develop new methods for its recovery.

Background

Tellurium is widely used in thermoelectric devices, phase change memory chips, gas sensors, photovoltaic modules, and piezoelectric energy harvesters [1] and, especially, as the fundamental materials of CdTe thin-film photovoltaic cells. Demand is expected to reach high levels. However, Te is a typical scattered element with relatively low abundance of 6×10^{-6} in the Earth's crust. An important raw material for its recovery is Te-bearing alkaline skimming slag [2]. As a rule, its recovery from Te-bearing alkaline skimming slag is a multistage process, including ball-mill alkali leaching, purification, neutralization, incineration, alkali-dissolving and electrowinning [3]. The main disadvantages of this process

are long flowsheets and high reagent consumption. In consequence, it is of great interest to develop a new method to improve Te extraction.

A possible process for extracting Te and antimony (Sb) from residue generated from the alkaline sulfide leaching of Te-bearing alkaline skimming slag is proposed. Central composite design (CCD) was used to define the optimal leaching conditions for Te and Sb extractions from the residue sample.

Methods

Originally developed by Box and Wilson [4] and improved upon by Box and Hunter, CCD is a popular technique to find optimal conditions by using a quadratic polynomial model and is applied following a screening or diagnostic experiment [5]. In this work, CCD was used to optimize the alkaline sulfide leaching parameters, including Na_2S concentration, leaching temperature and time. Te and Sb extractions were chosen as the response variable.

Results and discussion

The analysis of variance, or ANOVA, results (Table 1)

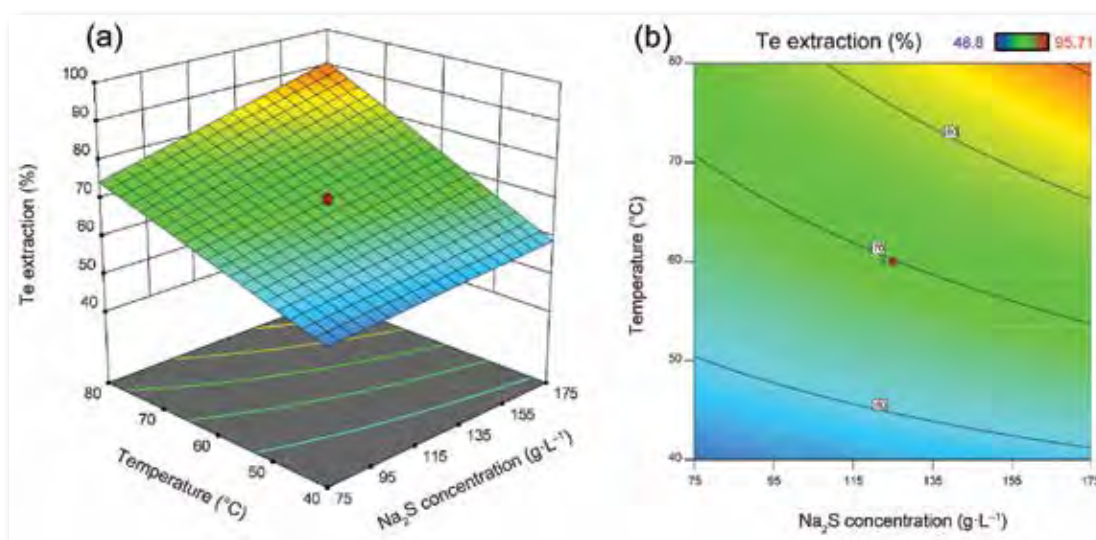


Fig. 1 Surface (3D) plots and contour (2D) plots for Te extraction (leaching time of 40 min).

indicate that the regression model is significant and suitable for use in the optimization of independent variables within the range. The mathematical equations, in terms of the coded factors, to predict the Te and Sb extractions are:

$$Y_{Te} = 69.68 + 5.14X_1 + 12.91X_2 + 4.75X_3 + 3.06X_1X_2 - 1.41X_3^2 \quad (1)$$

$$Y_{Sb} = 41.00 + 12.93X_1 + 33.67X_2 + 8.88X_3 \quad (2)$$

The statistical analysis suggests the predicted and actual val-

ues are close to linear regression, indicating good agreement between the experimental and predicted values for Te and Sb extractions.

The notable factors influencing Te and Sb extractions were leaching temperature, Na₂S concentration and leaching time (Fig. 1). The optimal leaching conditions for Te and Sb extractions were 175 g/L Na₂S concentration at 80 °C for 60 min. Under these conditions, 96.36 percent of Te and 99.64 percent of Sb were extracted. An additional experimen-

Table 1 – Results from ANOVA for response surface models established for the modeling of Te and Sb extractions (X_1 = Na₂S concentration, X_2 = leaching temperature, X_3 = leaching time).

Metal	Source	Analysis					
	Model	Sum of squares	Degree of freedom	Mean square	F value	P-value	Conclusion
Te	Model	3047.23	5	609.45	135.19	< 0.0001	Significant
	X_1	360.42	1	360.42	79.95	< 0.0001	Significant
	X_2	2274.47	1	2274.47	504.55	< 0.0001	Significant
	X_3	308.52	1	308.52	68.44	< 0.0001	Significant
	X_1X_2	74.73	1	74.73	16.58	0.0011	Significant
	X_3^2	29.10	1	29.10	6.45	0.0235	Significant
	Residual	63.11	14	4.51			
	Pure error	3.13	5	0.63			
Sb	Cor Total	3110.34					
	Model	18842.74	3	6280.91	58.11	< 0.0001	Significant
	X_1	2282.62	1	2282.62	21.12	0.0003	Significant
	X_2	15482.68	1	15482.68	143.25	< 0.0001	Significant
	X_3	1077.43	1	1077.43	9.97	0.0061	Significant
	Residual	1729.27	16	108.08			
	Pure error	1728.07	11	157.10	655.25	< 0.0001	
	Cor Total	1.20	5	0.2397			

tal trial validated the model predictions for the maximum Te and Sb extractions at the obtained optimum operating conditions. Sb and Te in the leach liquor were separated and recovered by H_2O_2 oxidation followed by Na_2S – Na_2SO_3 reduction. $\text{NaSb}(\text{OH})_6$ and elemental Te were obtained as the product. During H_2O_2 oxidation, 98.93 percent of Sb was precipitated selectively, and during Na_2S – Na_2SO_3 reduction, 95.06 percent of Te was precipitated. $\text{NaSb}(\text{OH})_6$ and elemental Te were obtained as the product.

Conclusions

A possible process for extraction of Te and Sb from residue generated from the alkaline sulfide leaching of Te-bearing alkaline skimming slag was developed. CCD was successfully applied to evaluate the interactive effects of

leaching variables and optimize the alkaline sulfide leaching process. Under the optimum conditions, Te and Sb were effectively extracted. ■

References

1. Woodhouse M, Goodrich A, Margolis R, James T, Dhare R, Gessert T, Barnes T, Eggert R, Albin D (2013) Perspectives on the pathways for cadmium telluride photovoltaic module manufacturers to address expected increases in the price for tellurium. *Sol Energy Mater Sol Cells* 115:199–212
2. Makuei FM, Senanayake G (2018) Extraction of tellurium from lead and copper bearing feed materials and interim metallurgical products—a short review. *Miner Eng* 115:79–87
3. Wang S (2011) Tellurium, its resourcefulness and recovery. *JOM* 63(6):90–93
4. Box GEP, Wilson KB (1951) On the experimental attainment of optimum conditions. *JR Stat Soc Ser B-Stat Methodol*, 13(1):1–45
5. Lambert A, Drogui P, Daghrir R, Zaviska F, Benzaazoua M (2014) Removal of copper in leachate from mining residues using electrochemical technology. *J Environ Manag* 133:78–85

Cold-model study on the maximum penetration distance of the injection lance in a Kaldofurnace

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Keywords: Kaldofurnace, Top-blown rotary reactor, Splashing, Doré, Hydrodynamics

To read the full text of this paper (free for SME members), see the beginning of this section for step-by-step instructions.

Special Extended Abstract

The Kaldofurnace is a type of top-blown, rotary reactor that is widely used for the production of precious metals. During the production of doré, a gas jet of compressed air is injected through a water-cooled lance to impinge upon the molten bath surface in the presence of molten metal and a slag phase. A common problem during operation is the difficulty in controlling the distance that the injection lance can penetrate through the reactor mouth without being splashed by the molten phases. Splashing may produce accretions on the lance surface as well as plugging of the nozzle at the lance tip. An additional problem may occur when the gas jet impinges upon the furnace wall and causes rapid wearing of the refractory linings. Because the conditions prevailing in the Kaldofurnace offers poor visibility to the human eye, its operation mostly relies on the empirical knowledge of plant operators and process engineers. A systematic study in a scale model of the Kaldofurnace under controlled laboratory conditions

may be valuable to estimate the maximum penetration distance of the injection lance, and thus help improve the operation of an industrial reactor. From a fundamental perspective, the observation of the basic features of the flow patterns in the scale model may help elucidate the relevant phenomena governing the hydrodynamics in this type of system.

Background

This work is related to the processing of anodic slimes in the Kaldofurnace to produce a doré with 98 percent by weight of silver [1]. The uncertainties surrounding the correct position of the injection lance during the conversion and refining steps are strongly related to the hydrodynamics in this type of reactor. However, this topic has received little attention in the literature [2,3]. The goal of this work was twofold: first, to determine the maximum penetration distance of the injection lance in a laboratory model of the Kaldofurnace

actor, and second, to identify the major macroscopic features of the motion of the liquid phases in the system.

Experimental work

A 1:7 scale model of the Kaldo furnace currently in operation at Metalúrgica de Cobre, México [1] was built using transparent acrylic plastic. Red mineral oil and yellow motor oil were used to represent the slag phase, and tap water was used to represent the doré. The input variables tested in the experiments included the vessel rotation speed, ω ; the fraction of the vessel volume occupied by the liquid phases, φ ; the inclination angle of the vessel with respect to the horizontal, θ ; the oil-to-water kinematic viscosity ratio, η ; and the Reynolds number at the lance tip, Re . The experimental program consisted of a full factorial $3 \times 3 \times 4 \times 2 \times 3$ matrix for the test variables (ω , φ , θ , η , Re) for a total of 216 runs. In a typical experiment, the lance was introduced into the model along the vessel centerline until it was contacted by any of the liquids. When this occurred, the distance measured from the vessel mouth to the lance tip was divided by the vessel length to obtain d^* , which represents the fraction of the vessel length that the lance penetrated into the vessel prior

to being contacted by any of the liquid phases. In selected experiments, digital images of the flow patterns in the vessel were captured.

Discussion of results

Figure 1 shows a plot of the values of d^* against θ for the experiments conducted with red mineral oil at the highest gas flowrate tested ($Re = 6 \times 10^4$) and all combinations of φ and ω . The full paper shows similar plots under $Re = 0$ and $Re = 3.7 \times 10^4$ for both mineral and motor oil. Overall, the value of d^* decreased substantially as the Re number was increased, it decreased linearly with θ and was mostly independent on the rotation speed, ω . Under extreme conditions, the lance could not be introduced into the vessel as it was splashed by the liquids at the vessel mouth ($d^* = 0$). Also, d^* decreased as η was increased. By means of dimensional analysis, a mathematical correlation was developed to calculate d^* in terms of Re , φ , η and the Froude number of the liquid phases in the vessel, Fr . A reasonable agreement between the calculated and experimental values was obtained (Fig. 2). Visual observations showed that the red mineral oil tended to follow the behavior of the aqueous phase underneath, whereas the yellow motor oil showed little affinity to water and tended to form large clots on top of the aqueous phase. In the presence of gas injection, the flow field was clearly turbulent and showed a number of features, such as severe distortion of the free surface of the liquids, ejection of droplets to the gas phase, and complex three-dimensional trajectories of oil droplets suspended within the aqueous phase.

The basic features observed in this work proved to be useful to improve the operation of the industrial reactor at Metalúrgica de Cobre, Mexico. Prior to this work, process engineers assumed that vessel rotation produced the so-called cascade effect, and the gas jet was aimed at impinging upon such cascade. This work showed that the cascade effect was negligible even in the absence of gas injection. Other benefits described in the full paper include the establishment of the correct position of the lance during operation, longer campaigns and maintenance cost savings. With these improvements, the lance operating life is increased to more than twice its previous value.

Conclusions

The maximum penetration distance of the injection lance in the scale model varied in the range of 0 to 0.67 times the vessel length. A mathematical correlation was developed to calculate this quantity in terms of the input variables tested in the experiments. Digital images showed that the motion of the liquid phases was strongly dependent upon the gas flowrate, whereas the cascade effect was negligible. Despite the simplifications made in this study, the basic features observed in this work proved to be useful to improve the operation of an industrial reactor. ■

References

- Perez-Tello M, Prieto-Sánchez M, Rodríguez-Hoyos O, Sánchez-Corrales V (2004) A kinetic model for the oxidation of selenium and tellurium in an industrial Kaldo furnace. JOM 56(12):52-54
- Menshchikov VA, Ageev NG, Kolmachikhin, BV (2016) Study of the hydrodynamics of a TROF converter by numerical and cold modeling. Metallurgist, 60(1):212-216
- Menshchikov VA, Kolmachikhin BV, Ageev NG (2018) Physical simulation of melt lancing in a TROF converter. In: Brebbia C, Connor JJ (eds) Progress in Materials Science and Engineering, Springer, Cham, pp 65-71

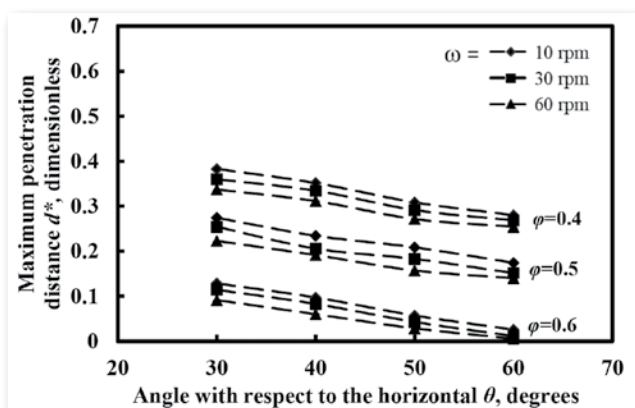


Fig. 1 Maximum penetration distance of the injection lance in the scale model. Experiments with red mineral oil ($\eta = 9.6$) and $Re = 6 \times 10^4$.

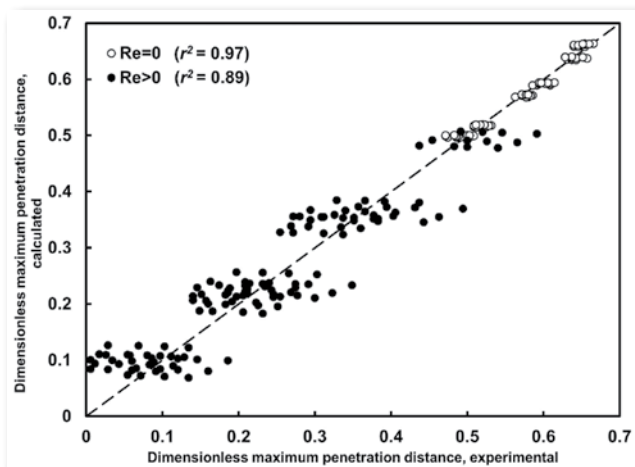


Fig. 2 Calculated and experimental values of d^* for all experimental conditions tested in this work.



New Products

Gradall Discovery Series excavators are more productive

Gradall Industries has introduced two new Discovery Series hydraulic excavator models — D172 and D174 — that are bigger and more productive than the previous D152 and D154 models. The new models benefit from a 36 percent increase in horsepower as well as greater torque to increase travel speed, hill-climbing capability and overall productivity.

Developed in collaboration with Freightliner, the excavators are designed to deliver budget-priced Gradall versatility. Both models have Freightliner undercarriages. Discovery D172 has two-wheel-drive while the D174 is a four-wheel-drive machine. Both feature a Gradall upper structure and versatile telescoping, full-tilting boom, able to

rotate attachments 220 degrees. The low-profile boom design allows Discovery Series models to work productively under bridges and in tunnels.

D172 and D174 models have 224-kW (300-hp) Cummins 6.7-L engines, enabling them to travel at speeds up to 60 mph. When operating the engine from the upper cab, a lower RPM reduces fuel consumption and noise. The advanced Bosch Rexroth-designed hydraulic system has pressure-compensated, load-sensing valves with reliefs on all circuits. This system supplies the right amount of hydraulic power for the job at hand while also conserving fuel.

www.gradall.com/discovery

Epiroc has introduced the fifth generation of its Rig Control System

Epiroc's new Rig Control System (RCS 5) makes full automation easier and more productive. RCS 5 provides a number of safety and interlock features, as well as a foundation to add new functionality/options later without a major rebuild of the machine. Drills can be run with an operator on board using options such as Autodrill and Autolevel — or they can be run with the operator off the drill with the optional BenchREMOTE package, allowing one operator to run one or multiple units.

The new drilling data screen in RCS 5 features real-time depth monitoring and creates a penetration rate histogram to monitor what's happening in the hole. The operator can now create and edit drill plans on-board the rig or from a remote location quickly and easily. All key parameters are tracked during the shift helping to make end-of-shift reports by the operator easier than ever.

Using the machine-to-machine communication add-on feature, machines operating on the same pattern can share real-time updates of the progress each drill is making against the drill plan.

www.epiroc.com



Inmarsat offers Tailings Insight for safer tailings management

Inmarsat has launched Tailings Insight, a new Internet of Things solution for monitoring mining tailings storage facilities (TSF). Tailings Insight upgrades the company's Tailings Dam Monitoring program and is available as Tailings Insight-Cloud and Tailings Insight-Plus. Tailings Dam Monitoring works by collecting data from a range of industry-established sensors via long-range, wide-area network edge connectivity, before transferring that data across Inmarsat's L-band network to a dashboard.

Tailings Insight-Cloud is a software-as-a-service application that easily integrates with existing on-site sensors and connectivity networks to enable real-time monitoring, as well as supporting historical data input for comparative analysis. It offers a fully customizable interface, multiple sensor map views, custom alarm monitoring, data logging, journaling functionality, sensor health reporting and easy data export. The application allows personnel across min-

ing companies and external bodies, such as regulators, auditors and insurers, complete visibility of TSF conditions on a site and global-level in one place.

Tailings Insight-Plus is a fully managed solution that incorporates Tailings Insight-Cloud plus sensor integration, edge connectivity, satellite connectivity and ongoing service monitoring and management. With Inmarsat controlling the entire, end-to-end process, it can offer service-level agreements ensuring the continuous gathering of data, which best supports real-time monitoring. The proposition can be installed at any mine and is ideal for TSFs without reliable connectivity, TSFs that require special attention due to their risk status and for mining companies that wish to demonstrate their commitment to safe tailings management.

www.inmarsat.com

A company and a nonprofit —

Sustainable investment in mining education

by Greg Hinshaw, chief executive officer, J.H. Fletcher & Co.

I have listened to several online commencement talks this year. The word of choice chosen by speakers and offered to these new graduates that I heard repeatedly is resilience. Another term we all have heard for many years now, which is the management term of favor, has been sustainability.

In the mining industries, how do we foster sustained business while remaining resilient? We know that embracing and utilizing new technology is key to long-term success in today's fast-paced world. To embrace and utilize new technology requires a continuous supply of professionals who are educated both in current mining practices and in the new technologies that will impact our mining methods and processes in the future. Tunneling has the same needs.

As a society organized around mining and tunneling, SME exists because it recognizes that the gain our entire industry enjoys from professionals must have investment to attract talented individuals and reward them to stay the course. This is a continuous long-term requirement. Without continuous investment, we cannot have a sustained creation of talented industry professionals. Continuous investment, even when revenue streams are reduced, requires resilience. Our market-based economic system does not openly reward this type of investment. It requires an understanding of these needs at the board and upper management level.

The SME Foundation plays a role within our society that conveys the need for continuous corporate investment in education specific to the mining industry. It also becomes a conduit by which a corporation can invest in long-term mining industry professional and technical development.

Specifically, in my case as CEO of J.H. Fletcher & Co.,

the SME Foundation manages mining engineering scholarship funds, the selection of scholarship recipients and award administration. What the Foundation does for us is a small portion of all that it offers and provides. The Foundation's work is on a national and increasingly worldwide scale. Like many companies, J.H. Fletcher supports both the local SME chapters and the local schools of higher education that provide engineering education. The SME Foundation allows us to increase that support for education to a broader group of schools, students and rising professors without sacrificing focus on the industry we serve.

Be resilient in contributing to education to help sustain our industry, which in turn sustains all of us involved with SME. Take advantage of what the SME Foundation offers when you contemplate how best to invest in the future of mining and tunneling. Know that we have a need for new professors to sustain the future of our mining schools and support the efforts of the SME Foundation to fill that need.

Note from Niki Humphreys, Manager, SME Foundation

J.H. Fletcher & Co. funds a college scholarship through the SME Foundation, sponsors annual gala dinner door prizes and an annual gala dinner table.

Greg Hinshaw is an SME Foundation trustee and donor. The Foundation is grateful for the generosity that J.H. Fletcher & Co. has continued to provide to the Foundation over the years and also for the generosity of Hinshaw, himself. As a Foundation trustee, his steadfast guidance stays focused with the future in mind to lead us toward a more sustainable future. ■

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Minerals Education
Coalition

CSM center to design rapid-tunneling technology

The Center for Underground at Colorado School of Mines (CSM) has received a major contract from the U.S. Defense Advanced Research Projects Agency to design and demonstrate rapid-tunneling technology.

According to Mike Mooney, Grewcock Distinguished Chair of Underground Construction and Tunneling and the project's director and lead investigator, "This project should dramatically improve tunneling efficiency. Our approach blends horizontal directional drilling's operational framework and oil and gas directional drilling's proven metric — exceeding speed and distance performance with additional advances in excavation mechanics, tunnel installation, ground imaging and artificial intelligence. This unique project provides an opportunity for step-change advances in tunneling technology that can improve tunnel construction for water, wastewater, transportation and utilities.

Alfred Eustes, associate professor of petroleum engineering, said, "Our proposed advances aim to drive down the cost of tunneling and dramatically increase the speed of tunneling over current practice. The project is highly interdisciplinary, blending the

(Continued on page 116)

The show must go on

by Jim Wickens, chairman, Nevada MPD meeting

At the time of this writing, the country is slowly emerging from COVID-19 restrictions, and we are eagerly looking forward to a return to some sort of normal. With that in mind, the Nevada MPD (Mineral & Metallurgical Processing Division) subsection is forging ahead with its second annual Nevada MPD meeting. Even though MIN-Expo 2020 has been postponed to 2021, and the venue for the SME midyear meeting has been changed, the 2020 Nevada MPD meeting is independent of those events and remains scheduled to take place Sept. 25-26, 2020, in Las Vegas, NV.

Before plugging this year's meeting, the Nevada MPD team would like to take this opportunity to thank all of last year's speakers, attendees and sponsors for making the 2019 inaugural meeting an overwhelming success. With more than 100 attendees, we far exceeded expectations.

Like last year, the 2020 meeting will feature high-quality technical presentations led by keynote speaker Tim Arnold and featuring operators representing Nevada Gold Mines, Kinross and Nevada Copper. The luncheon speaker will be Greg Crouch, author of *The Bonanza King: John Mackay and the Battle Over the Greatest Riches in the American West*. Our Lifetime Achievement Award recipient for 2020 is Dan Kappes, and we will honor him at the awards dinner Friday evening. The golf tournament Saturday afternoon will be held at Desert Pines Golf Club. This is a course designed by Pete Dye, and it features a Carolinas Sandhills layout. Because of COVID-19, our plans to have Bass Metals play at the awards dinner have changed. We look forward to having them back with us in 2021.

CSM tunneling

(Continued from page 115)

civil tunneling and horizontal directional drilling expertise at Mines with petroleum drilling engineering, chemical engineering, mechanical engineering and geophysics expertise. This project brings together all the right expertise to advance rapid tunnel construction."

The R&D effort is structured as a university-industry innovation incubator at Mines. The Center for Underground has brought in full-time engineering professionals with expertise in sensing, artificial intelligence, mechanical systems, smart fluids and instrumentation to work closely with Mines faculty experts.

The research team plans a field-site demonstration targeting sustained tunneling advance rates of 1,200 ft/hr next year. The project will be described during the Tunneling Fundamentals, Applications and Innovations industry short course held at CSM Oct. 19-22, 2020.

More information can be found at underground.mines.edu. ■



(l-r) Jim Wickens, chairman of the Nevada MPD meeting, and Andy Cole, 2019 luncheon speaker.

The success we had last year, and the support we are already getting for this year's meeting (despite COVID-19), have given us great confidence in our vision to provide our regional mineral processors with a technical meeting that shares knowledge and expands our professional family. Unlike other industries, mining (and especially mineral processing) is collaborative. We are a small group, and we almost certainly will cross paths with each other somewhere along the way. Forging and maintaining these relationships, and sharing our wins and losses, is fundamental to our collective success.

The Nevada MPD team is especially proud to have raised enough money at the 2019 meeting to support student speakers for 2020, provide the SME Foundation with a \$5,000 donation this year and to potentially support a scholarship for a deserving undergraduate in the 2020/2021 school year. We hope the 2020 meeting will be as fruitful and allow us to continue supporting worthwhile industry initiatives.

For 2020 meeting information, please visit our website at: <https://community.smenet.org/nevadampdsubsection/home>. Speaker, program and contact information can be found there, as well as links to our registration e-pay site and hotel booking site and, of course, sponsorship information.

We look forward to seeing everyone in Vegas. ■

Fine Grind serves as a forum for the presentation and discussion of facts, ideas and opinions pertaining to the interests and technology of the Mineral & Metallurgical Processing Division. Accordingly, all material published herein is signed and reflects the individual views of the authors. It is not an official position of SME or the division. Comments by readers will be referred to the division for response. The division chair in 2020 is Scott Shuey.

Ronald L. Parratt is the nominee for SME President in 2022

Ronald L. Parratt has more than 40 years of exploration experience for precious metals, including service with Santa Fe Pacific Gold, Homestake Mining Co., AuEx Ventures and Renaissance Gold Inc. During his years of precious metals experience, he had direct involvement in the discovery of the Rabbit Creek (now Twin Creeks), Lone Tree, Trenton Canyon, Gold Hill and Long Canyon gold deposits — all in Nevada.

Parratt is a graduate of Purdue University with degrees in geochemistry and economic geology. He is a certified professional geologist with the American Institute of Professional Geologists, a registered geologist in California and a professional geologist in Wyoming. He is a Fellow of the Society of Economic Geologists (SEG) and a past president of the SEG Foundation. He is also a past president of the American Exploration and Mining Association.

Parratt is an SME Fellow and was chair of the Mining & Exploration (M&E) Division. He has received the Robert M. Dreyer Award, the M&E Division Distinguished Service Award and has served on the SME Board of Directors.



PARRATT

Nominees for the 2021 SME Board of Directors

CATHERINE A. (CAT)

JOYNER is a professional mining engineer with more than 20 years of diverse mining experience in industry, government and consulting, both in the United States and internationally. In 2015, she and two business partners started Minetech USA, where she is currently principal and co-owner. She specializes in underground mine planning and NI 43-101 compliant studies. In 2016, she became a member of the inaugural class of inductees into the Maptek Hall of Fame for her significant contributions in developing and advancing Vulcan software.



JOYNER

In her more than 20 years as a member of SME, Joyner has served as Mining & Exploration (M&E) Division chair, GPAC chair, a member of the SME Nominating Committee, a charter member of GPAC and an associate editor of SME's Peer Review Editorial Board. She has also assisted programming efforts, implemented restructuring of the M&E Division award committees, reviewed and revised the M&E Division bylaws, and spearheaded

the writing of the *M&E Division Handbook*. In 2016, she received the Mining & Exploration Division Distinguished Service Award.

Joyner earned a B.S. degree in physics with a minor in German at the University of California, Davis. She received two M.S. degrees in mining engineering and environmental engineering from Montana Tech.

JERRY GAUNT is a mining professional with 40 years of industry experience. Trained as a mineral economist (Penn State), he has primarily worked for large mining firms as well as for several consulting organizations in numerous management roles. During his career, he has worked at Rio Tinto (Luzenac), Asarco, Imerys and Rocky Mountain Energy, primarily selling a variety of metals and industrial minerals. He was a consultant with Golder Associates for many years and also with Marston & Marston and Kline & Co. In addition to leading mining business development activities, he also assisted numerous clients with due-diligence reviews involving mineral investments.



GAUNT

Gaunt has been an active SME member since 1978. He has twice served as the chair of the Industrial Minerals & Aggregates Division (2016 and 2019). Currently, he is a member of SME's Structure & Governance Standing Committee. In addition to attending SME Annual Conferences, he frequently participates in regional events such as the conferences in Duluth, MN, New York, NY (Current Trends in Mining Finance) and Lakeland, FL.

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 of one hundred (100) members or more 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.

Coal & Energy Division officer nominees

CHAIR

RYAN MURRAY is the vice president of operations for Murray Energy Corp., the largest underground coal company in America. He has worked in surface and underground coal mines for his entire career. His duties have consisted of labor and operations management positions, ranging from laborer to vice president.



MURRAY

Murray earned his master's degree in business administration from Ohio State University and a B.S. in mining engineering from West Virginia University. He was a member of SME's Young Leaders Committee and has received the 2010 J.W. Woomer Award from the Coal & Energy Division and the 2019 SME Foundation Excellence in Prospecting Award. He is also a Pittsburgh Local Section Distinguished Member. Murray is currently a member of the SME Foundation Board of Trustees and the Corporate Giving Committee.

VICE CHAIR

SUSAN B. BEALKO is corporate safety director at GMS Mine Repair & Maintenance, the largest underground coal contractor in the nation, where she is responsible for compliance, safety and training.



BEALKO

Bealko has 28 years of experience in coal mining through her work in engineering, production and mine safety. She holds a mining engineering degree from The Pennsylvania State University, a masters degree in safety management from West Virginia University and a masters degree in public health from the University of Pittsburgh. She also holds mine foreman certification papers in Pennsylvania, West Virginia and Ohio.

Bealko began her mining career in 1991 working at Consol Energy's Bailey Mine as an industrial engineer. In 2002, she joined the NIOSH Pittsburgh Research Center as a mining engineer and gained international mining experience. Bealko received the 2015 Coal & Energy Division Distinguished Member Award, the 2010 SME Local Section Hero of the Month Award, the 2004 J.W. Woomer Young Engineer Award and served as chair of the SME Pittsburgh Section from 2009-2010. She is one of the frontrunners in the creation of eastern U.S. collegiate mine rescue teams and a mentor to young coal mining professionals.

PROGRAM CHAIR

PAUL W. CONRAD is professor of mining engineering at Montana Technological University. After graduating

from high school, he worked in an underground coal mine for two years with his father, making him the third generation in his family to work in that same mine. He has B.S. and M.S. degrees in mining engineering from The Pennsylvania State University and a Ph.D. degree in mining engineering from the University of Kentucky. He is a registered professional engineer in Pennsylvania.



CONRAD

Conrad has more than 38 years of work experience in the fields of mining, civil, hydraulic, environmental, construction, permitting and research engineering. This includes work at mining and construction operations, government agencies, consulting firms and in academia. He has conducted research in reforestation, mine optimization and mine reclamation and has many peer-reviewed publications with his graduate students and research collaborators.

This is Conrad's second time serving on the Coal & Energy Executive Committee, and he has chaired technical sessions at SME meetings for the division. He is currently a member of the Professional Engineers Exam Committee, an ABET program evaluator for mining engineering programs and is a former associate editor on the SME Peer Review Editorial Board.

PROGRAM VICE CHAIR

STEVEN J. SCHAFRIK is currently an associate professor at the University of Kentucky conducting research applying advanced computing technologies to mining problems, such as mine automation, mine ventilation, underground wireless communication, underground tracking and TTE communications. He is engaged in research on a



SCHAFRIK

variety of topics, including underground coal mining expert systems and simulators, the effectiveness of technology, such as virtual reality in safety training and learning and enhancements of location and tracking technologies for underground mining.

Schafrik has a Ph.D. in mining and mineral engineering, underground communications, an M.S. in mining and mineral engineering, system simulation and a B.S. in mining and mineral engineering, all from Virginia Tech. He has served SME on the Innovation Committee, the *Mining Engineering* Committee, the Research Committee, the Information Publishing Committee and on the Executive Committee of the Central Appalachian Local Section.

SECRETARY

TATHAGATA GHOSH is an associate professor of mining engineering at the University of Alaska-Fairbanks. He earned his undergraduate degree in mining engineering from the Indian Institute of Engineering, Science and Technology, Shibpur, India, and an M.S. in mechanical engineering from the University of Mining and Metallurgy, Krakow, Poland. He received his Ph.D. degree in mining engineering from the University of Kentucky (UK).



GHOSH

Ghosh worked for Tega Industries in Kolkata, India as a mining engineer consultant with International Mining Consultants and was involved in mine planning, pit expansion and exploration projects. At UK, he was involved in several projects funded by the U.S. Department of Energy, the U.S. State Department and industry.

Ghosh's areas of interest include computational fluid dynamics, numerical modeling, process optimization, rare earth elements from coal, fine-coal processing, clean coal and advanced beneficiation technologies. He has been involved in government and industry-sponsored projects worth more than \$10 million. He received the Invent Alaska Award in 2016, is an SME Young Leader and served as an adjunct lecturer at UK. He currently serves on the editorial board of the *International Journal of Coal Preparation and Utilization*, he is a technical peer reviewer for several journals and was a co-editor of the *Proceedings of the 37th APCOM*.

EXECUTIVE BOARD

MICHAEL A. TREVITS, PG, is the president of Xtraction Science and Technology, president of MB³ Innovations, LLC and president of the Rebuilding Their Future Foundation. During his 39-year government career, Trevits worked for the U.S. Bureau of Mines, the U.S. Department of Energy and National Institute for Occupational Safety and Health (NIOSH). His current research work is dedicated to post-event, safe, remote mine evaluation using unmanned aerial vehicles, refuge alternative communications, and the development of training videos for responsible persons and mine rescue teams.



TREVITS

Trevits has served as a member of the SME Board of Directors, as chair of the Coal & Energy Division, as president of OneMine.org and as a member of the SME Foundation Executive Committee. He also served as chair of the Pittsburgh Section. He currently serves on the board of the Pittsburgh Coal Mining Institute of America, as chair of the Pittsburgh Section,

as a trustee of the SME Foundation and on the board of OneMine.org.

Trevits is a Distinguished Member of the Pittsburgh Section and an SME Fellow. He holds an undergraduate degree in geology and an MBA from the University of Pittsburgh. He is a registered professional geologist in North Carolina. He has written 133 publications and received one patent.

RAY DONELICK is the senior geochronologist at Apatite.com Partners LLC, a rural Idaho-based company with a global reach specializing in rock-thermal-history reconstructions for the metals, oil and gas extraction industries.



DONELICK

His current interests include studying ways to store intermittent solar and wind energy using mines and mining byproducts, such as coal ash, at his start-up BiMBy Power Corp. He has received several patents in the fields of thermochronology and mine-based renewable energy storage and has a keen interest in natural and simulated geothermal systems.

Donelick holds a B.S. in geology from the University of Miami and M.S. and Ph.D. degrees in geology from Rensselaer Polytechnic Institute. He is a member of the American Geophysical Union and the Mineralogical Society of America. He is currently an adjunct faculty member in Washington State University's School of the Environment and an adjunct assistant professor in the University of Idaho's Geology and Geological Engineering Department. He previously held adjunct positions at the University of Nevada-Reno and Rice University. He is a Pittsburgh native, the grandson of steelworkers and coal miners, and the first in his family to complete university.

JAMES HAUGHEY, P.E., is currently the global product director for room-and-pillar products with the Komatsu Mining Corporation Group (KMC). He has been with KMC since 1993 following his graduation from Grove City College with a bachelor's degree in mechanical engineering.



HAUGHEY

Throughout his career, he has been involved in the design, application and product management of Joy continuous miners and haulage products for global coal and industrial minerals applications, including the introduction of mechanized mining to salt and gypsum mining. In addition, he spent several years leading the Joy longwall shearers from a design and product management aspect.

Environmental Division officer nominees

CHAIR

BRETT WATERMAN is manager of environmental projects with Freeport-McMoRan. He has extensive experience related to hydrometallurgy and mine water treatment. His role is to manage water treatment and residual resource technology, including development and operation of multiple new-technology pilot plants and full-scale plants to treat mine-impacted waters. Another important focus of his work is water management related to minimizing water treatment at Freeport sites.



WATERMAN

VICE CHAIR

ANDREA MARTIN is a chemical engineering graduate of Michigan Tech. She also has a master's degree in environmental science and policy from University of Wisconsin, Green Bay. She has led permitting efforts for air and water discharge permits for mining projects, working mostly in the Midwest region of the United States. She holds professional engineer licenses in Illinois, Wisconsin, Michigan and Minnesota. Martin is currently the chair of the Wisconsin SME Local Section and is a registered member of SME.



MARTIN

SECRETARY

LISA GONZALES is a principal engineer at Arcadis.

She is a licensed professional engineer and has more than 20 years of experience specializing in mine reclamation closure and multidisciplinary environmental and engineering projects for mining clients. Her technical background and project experience includes: CERCLA and RCRA sites, smelter facilities remediation, voluntary clean-up sites, site characterizations and radiologically impacted site closures.



GONZALES

Gonzales has been active in SME for several years. She recently co-chaired the 2019 Environment Division's student poster contest and serves on the SME Professional Engineers Exam Committee.

PROGRAM COMMITTEE CHAIR

JEN PEPE, a senior engineer with Golder Associates, has 29 years of experience in site characterization and



PEPE

remedial design, including 25 years specializing in characterization and closure issues for mines in the western United States and northern Mexico. Her technical background is in field investigations at sites involving soil and groundwater impacts, development and implementation of remediation and closure alternatives, water management, and water balance modeling.

Pepe has been active in SME for several years and has recently served on the SME Sustainability Committee as a representative of the Environmental Division.

Health & Safety Division officer nominees

CHAIR

ALI LASHGARI is a principal investigator for advanced monitoring solutions at Clean Air Engineering. There, he provides technical input on a variety of regulatory matters such as air-pollution monitoring, air-quality permitting and dispersion modeling, Next Generation Air Monitor networks and occupational exposure to dust and noise. Lashgari earned his Ph.D. in energy and mineral engineering, mining engineering option, from Penn



LASHGARI

State. He has experience in surface mining and occupational health, safety and environment. Before starting his Ph.D., he worked as a mining and earth-moving engineer, where he performed economic evaluation and feasibility studies for mining and earth-moving projects. Prior to joining Clean Air Engineering, he worked for Civil and Environmental Consultants Inc., where he was responsible for air permitting and compliance for mining, power, oil and gas and manufacturing projects. He has published and presented his research findings in leading peer-reviewed journals and international conferences.

CHAIR ELECT

EMILY HAAS is a senior research behavioral scientist with the National Institute for Occupational Safety and Health. Leading social science research in mineworker health and safety, she conducts research studies on organizational climate and risk management in areas specific to leadership and communication to discover ways to strengthen safety culture and worker performance in the mining industry. Her research solutions have achieved high impact with industry adopting best practices around safety climate and risk management initiatives. Haas has authored more than 60 publications, 48 of which she is the primary author. She has provided more than 75 technical presentations, including workshops and keynotes, at international mining conferences.



HAAS

SECRETARY

PALOMA LAZARO recently received her Ph.D. from the University of Arizona, Mining & Geological Engineering Department, in Tucson, AZ. Her research was focused on heat-stress and strain-assessment modeling in underground and surface mines. She has a master's degree in industrial risks and environmental management from the University of Poitiers, France. She has extensive experience as an industrial hygienist and an environ-



LAZARO

mental and health engineer in the United States and internationally at Rio Tinto's boron operations in California; Alcoa Aluminum in Peru and Brazil; and with Constellium, France and Assa Abloy, France.

COMMUNICATIONS CHAIR

PATRICK JAMES recently became the head of Health, Safety, Environment and Risk for Vale Base Metal. He will provide strategic direction and guidance to the company in the areas of health, safety, environment and risk. He will also focus on the continuous improvement of systems, processes and ongoing business transformation for world-class performance.



JAMES

James has more than 35 years of experience in mining, metals, aggregate/cement and the power generation industries. His previous career included leadership roles with Rio Tinto, Lehigh Hanson, PacifiCorp and Cementation Americas. These roles have included accountabilities throughout the United States and Canada as well as international experience in South America, Europe, Mongolia, Indonesia, South Africa and Australia.

James has undergraduate and graduate degrees from the University of Wyoming and his professional certifications include the Certified Safety Professional, Associate Safety Professional and Certified Mine Safety Professional.

Industrial Minerals & Aggregates Division officer nominees

Chair



KOSLOSKI

KATHRYN KOSLOSKI is a plant manager for Luck Stone, based in Atlanta, GA. After graduation from the Virginia Tech Mining and Minerals Engineering Department in 2012, she began her career with the Mining Engineering group at Luck Stone and has since moved into the Operations Division. She is currently helping lead the acquisition of Luck Stone's first quarry in Georgia.

Kosloski is an active member of SME and is currently a member of the Minerals Education Coalition Committee and the Student Design Team Committee. She serves the Industrial Minerals & Aggregates Division in several capacities.

Vice Chair



GUPTA

NIKHIL GUPTA has been actively involved with SME since he joined in 2011. He has chaired sessions at SME annual conferences and served on various committees including the Industrial Minerals & Aggregates Division (IMAD) Executive Committee, the 2019 SME Program Committee and as chair of the Technical and Program Committee. He received the 2017 IMAD Outstanding Young Scientist Award and 2016 J.W. Woomer Award for his professional contributions to the mining industry.

Gupta has successfully completed multiple, pilot-scale demonstrations in-field test programs with a focus on fine and ultrafine minerals recovery and dewatering, dry

separation methodologies, process design and optimization. He received Ph.D. (2014) and M.S. (2011) degrees in mining engineering from Virginia Tech and a B.S. degree (2008) in minerals engineering with first class honors from the Indian School of Mines.

Secretary/Treasurer

RAGHAV DUBE received an M.S. degree in mining and mineral engineering from the University of Kentucky in 2012 and a bachelor's degree in mineral engineering from the Indian School of Mines in 2009. He is currently working in Denver, CO as a senior process metallurgist on the Outotec Plant Solution team where he is responsible for mineral processing plant design, startup and commissioning. He started his career in 2009 at an iron-ore processing plant and joined Outotec in 2012 as an expert systems specialist. He has 10 years of experience in the mineral processing industry including laboratory test work, pilot-plant operations, modeling and simulating plant flowsheet, startup, and commissioning greenfield plant projects.



DUBE

Program Chair/Industrial Minerals

RIDDHIKA JAIN has more than 10 years of experience in the mining and aggregates industry. After graduating with a degree in fuel and mineral engineering from the Indian Institute of Technology, Dhanbad in 2010, she worked with Sandvik Asia Pvt. Ltd. Gurgaon as a technical sales engineer. She then obtained her master's degree in mining engineering from Virginia Tech in 2013, where she also worked as graduate research assistant. She, along with her advisor, developed the HHS process for concentrating ultrafine minerals. She received her M.S. degree in mining engineering from Virginia Tech in 2013. Since then she has been working with Outotec USA Inc., first as product development manager for flotation and now as product manager for the Outotec high-intensity grinding mill.



JAIN

Program Chair/Aggregates

PATRICK JACOMET has more than 30 years of experi-



JACOMET

ence in the aggregates, construction materials and testing industry. After graduating from Earlham College, he earned a master's degree from Ball State University. He then worked for Bowser-Morner for seven years as a supervisor of construction materials testing and for Martin Marietta for seven years as a technical engineer-project specialist in research and development and quality control. He joined the Ohio Aggregates & Industrial Minerals Association in 1999, where he currently serves as executive director. He works closely with the Ohio General Assembly, the Ohio Department of Transportation, the Ohio Environmental Protection Agency, the Mine Safety and Health Administration and the Ohio Department of Natural Resources to ensure that Ohio's mining industry remains a safe, environmentally conscious and community-friendly part of Ohio's economy.

Jacomet serves on the Board of Skills USA Ohio, he co-chairs ASTM Subcommittee D 04.51 on aggregate specifications and is chair of the Minerals Education Coalition. He was named NSSGA State Aggregate Association Director of the Year in 2014.

Technical Committee Chair



SONI

GAURAV SONI is a proposal manager with Outotec USA Inc. in Denver, CO. He received an M.S. degree in mining & mineral engineering from Virginia Tech and a B.Tech. degree in mineral engineering with first-class honors from IIT(ISM), Dhanbad. He is a certified project manager with the Project Management Institute.

Before joining Outotec, Soni worked as a process and engineering manager at Tata Steel, a senior process engineer at Metso Minerals and as a process engineer at Imerys. He has 11 years of work experience in the mining industry focusing on business development, supply-chain management, large Capex cost analysis, project execution, operation, simulation and optimization. He has been involved in grinding and flotation project activities in industrial minerals, coal, gold, copper and iron ore. He joined SME in 2011 and co-chaired the Digitalization, Automation & Control Strategies session at the MineXchange 2020 SME Annual Conference & Expo.

Mineral & Metallurgical Processing Division officer nominees

Chair

GARLAND DAVIS is sales manager, services, West Region for Outotec USA Inc. in Salt Lake City, UT. He has 30

years of mining industry experience beginning in engineering and operations and more recently in sales and supply



DAVIS

of process-related services and technical support. Work responsibilities have primarily focused on precious and base metals in the United States, but have also included global project work in engineering, exploration, development and startups.

Davis received a B.S. degree in geology from James Madison University and an M.S. degree in mining and minerals engineering from Virginia Tech. Prior to joining Outotec in late 2018, Davis worked for GE/ABB, FLSmidth, Freeport-McMoRan (Cyprus Amax and Phelps Dodge), Barrick Gold (LAC Minerals) and Pincock Allen and Holt.

Davis has been a member of SME for 28 years and has served the Mineral & Metallurgical Processing Division (MPD) on the Technical Programming Committee, as chair of the Comminution Unit Committee and as a member or chair of MPD awards and scholarship committees. He has also served as officer for SME's Tucson and Pinal Mountain local sections in Arizona.

Associate Chair

RONEL KAPPES is director, Processing with Newmont's Processing and Metallurgy Technical Services team located in Englewood, CO. She earned a



KAPPES

baccalaureate degree in chemical engineering from Potchefstroom University, South Africa, in 1998 and a Ph.D. in metallurgical engineering from the University of Utah in 2003. She is a qualified professional member of the Mining and Metallurgical Society of America and is a member of the board of AMIRA. She received the MPD's Outstanding Young Engineer award in 2009. She was an

editorial board member of the *Minerals & Metallurgical Processing* journal and is now section editor-in-chief for mineral and metallurgical processing for the SME journal, *Mining, Metallurgy & Exploration*.

Kappes has extensive flotation development experience in a variety of commodities, including copper, gold, platinum-group metals, molybdenum, lead and zinc. In her current role, she supports Newmont's global flotation portfolio.

First Vice Chair

DAVID MEADOWS graduated from the Camborne School of Mines, England, with a B.S. (Hons) in mineral processing technology. He has 34 years of diversified international experience in minerals processing. He started his career in operational roles in the gold and diamond mining industry in South Africa with Johannesburg Consolidated Investments and DeBeers Consolidated Mines. He worked for Bechtel Mining and Metals at its headquarters in San Francisco, CA with assignments in Brisbane, Santiago and



MEADOWS

Belo Horizonte. He spent four years with Phelps Dodge on new project development and worked on Cerro Verde I commissioning, El Abra Sulfolix, Climax Moly's new concentrator and Tenke Fungurume.

In 2008, Meadows joined FLSmidth, leading its process technology group globally and participating in the growth of its world-class mineralogical testing laboratory.

Meadows returned to Bechtel Mining and Metals and provides ongoing support to the optimization and growth of the Las Bambas concentrator in Peru. He is currently manager of technology and a Bechtel Fellow. He has published more than 33 technical papers and presentations. He is a chartered engineer, a chartered scientist in the UK, a Fellow and member of the board of directors of the Institute of Materials, Minerals and Mining. He has Qualified Person status in the United States.

Second Vice Chair

JAEHEON LEE is an associate professor in the Department of Mining and Geological Engineering at the University of Arizona in Tucson, AZ. He earned his B.S. and M.S. degrees with an emphasis on extractive metallurgy and chemical metallurgy from Korea University in Seoul, Korea. He received his Ph.D. from the University of Arizona in 2003.



LEE

Before he returned to Tucson as a faculty member, Lee worked as a metallurgical engineer at Newmont's Malozemoff Technical Facility in Denver, CO and at Barrick Gold's North America regional office in Salt Lake City, UT. He was involved in R&D projects for gold and copper deposits around the world. His technical expertise and research interests are in ore characterization and extractive metallurgy of precious and base metals, and he is an expert in biohydrometallurgical process for treatment of refractory sulfide minerals. Additionally, he is interested in metal recovery from electronic wastes, lithium-ion batteries and other recycled resources using environmentally friendly alternative chemicals.

Lee has chaired or served on several SME committees and is currently a member of the scientific committee for the International Biohydrometallurgy Symposium. He received an SME Career Development Grant in 2018 and Freeport McMoRan Copper & Gold's Academic-Industry Mining Fellowship in 2017 and 2018.

Secretary-Treasurer

TARUN BHAMBHANI is principal scientist at Solvay Mining Solutions. He has worked at the company for 14 years in the development of novel reagents to solve challenging separations and enable step-change in the flotation



BHAMBHANI

outcome. His contributions include the development of novel collectors for gold, platinum-group metals, oxide copper and modifiers for problematic gangue. His work has included collaborations between industry and academia to study pathways for deleterious effects and solutions for difficult-to-treat ores. He has lectured extensively on the role of chemistry in flotation at mining companies and plants. He has organized several SME flotation sessions and symposia, has served on research, membership and scholarship committees, and has written more than 40 papers. He is an associate editor for SME's *Mining, Metallurgy & Exploration* journal and received MPD's Outstanding Young Engineer Award in 2013. He was a co-organizer of the Sulfide Flotation Symposium at the Extraction 2018 conference. He has a bachelor's degree in mining and minerals engineering from Virginia Tech and a Ph.D. from Columbia University.

Technical Program Associate



NOBLE

AARON NOBLE is an associate professor in the Mining and Minerals Engineering Department at Virginia Tech and the associate director for the Center for Advance Separation Technologies. His instruction and research are in the general areas of mineral processing, process economics and mine pollution control. Since 2014, he has acquired a personal share of research funding totaling nearly \$3.4 million, with specific

topics in process simulation and optimization, critical material and rare-earth-element processing, and extraterrestrial mining operations.

Noble has B.S., M.S. and Ph.D. degrees from Virginia Tech, all in mining and minerals engineering. He is an inaugural recipient of the SME Academic Career Development Grant (2015). He has also received the J.W. Woomer Award (2019), the MPD Outstanding Young Engineer Award (2018), the Rossiter W. Raymond Award (2017) and the Stefanko Best Paper Award. He was a Henry Krumb Lecturer in 2016 and 2018.

Membership Associate

KIMBERLY MILLS is a process engineer with Samuel Engineering based in Greenwood Village, CO. She earned



MILLS

her B.S. and Ph.D. from the Colorado School of Mines (CSM) in metallurgical & materials engineering. She has significant experience in hydrometallurgy including pressure oxidation, in situ leaching, dump and heap leaching, bio-leaching, solvent extraction and electrowinning, as well as ion exchange. Her experience spans many commodities including base, precious metals and industrial minerals.

Mills received the MPD 2014 Outstanding Young Engineer award. She currently serves as chair of the Student Member Affairs Committee, the Ivan B. Rahn and Mineral Industry Education committees and has served on several MPD award committees. She also serves as a member of the CSM Mining Engineering Department Industry Advisory Council.

Mining & Exploration Division officer nominees

Chair

MATT BLATTMAN is a manager of engineering with Hecla Mining's corporate team, based in Coeur d'Alene, ID. Prior to joining Hecla in February 2018, he worked for Dassault Systèmes as the director of technical services in the Geovia Center of Excellence for the Americas. Before Dassault Systèmes, he worked for Blattman Brothers Consulting, Northland Resources, Cemex USA, Mine Development Associates and Hecla's Rosebud Mine.



BLATTMAN

Blattman has been an SME member for more than 20 years and has served the Mining & Exploration Division in many positions. He was the division's program area manager for the Management Program at the 2016 SME Annual Conference & Expo. He has served on the Education & Professional

Development strategic committee, the ad hoc Governance Committee, the Accreditation and Curricular Issues subcommittee and co-chaired the Young Leaders Committee. Blattman holds a B.S. in mining engineering from the University of Nevada, Reno and is a Registered Member of SME.

Chair Elect

GREGORY F. SUTTON is a project manager for Cementation USA. He oversees underground mine development and construction projects in the eastern United States. He has a broad range of experience in technical, operational and managerial roles. His underground hard rock experience includes mine planning and design, construction, mine operation, development and project management with extraction methods including cut and fill, vertical crater retreat, room and pillar, and pillar extraction.



SUTTON

In 1988, Sutton earned a B.S. degree in mining engineering from the University of Missouri-Rolla, now Missouri University of Science and Technology (M&ST). In 2018, he completed his MBA from M&ST. He started his career at the Homestake Mining Co.'s historic gold mine in Lead, SD as a mine planning engineer and supervisor. He later held various positions of responsibility with the Doe Run Co., including mine engineer, mine general supervisor, mine superintendent and general mine manager. He started his current role with Cementation in 2015.

Vice Chair Programs

BRAD M. DUNN is a senior mining geologist for Barr Engineering Co. where he specializes in mine grade control and mine operations consulting. Prior to consulting, he worked in hard rock and openpit operations, most recently for Oceana Gold Corp. in New Zealand. Dunn started his career as a gold fire assayer and has since held roles as grade-control technician, mining supervisor, grade-control geologist and senior mining geologist for operations in New Zealand, Australia, Indonesia, Canada and the United States.



DUNN

Dunn has served the M&E Division as program area manager for geosciences in 2017 and 2018. He has also served on the Research Committee. He holds a bachelor's degree in geology from the University of Otago, New Zealand and is a certified professional geologist with the American Institute of Professional Geologists.

Vice Chair Program Planning

DON DWYER, Elko, NV, earned a B.S. in mining engineering from the University of Missouri-Rolla in 2002. He is currently the mine manager at SSR Mining's Marigold Mine. Prior to this role, Dwyer worked for Barrick for approximately 11 years in underground and surface operations at the Goldstrike and Cortez properties. While at Barrick, he held the positions of mining engineer, front-line supervisor, general foreman, maintenance superintendent and openpit manager. He also worked abroad for a year with Barrick as an area manager on the construction of a mine in Chile and Argentina.



DWYER

Previous to Barrick, Dwyer worked for Teck Cominco American at its Pend Oreille underground operation in Washington, where he served as mining engineer and front-line supervisor. He is active in SME, through participation on committees and with the Mining & Exploration Division.

Assistant Vice Chair Program Planning

JENESSA HAARALA has 15 years of experience as an underground mine engineer. She has worked in gold, copper and contractor business development in Nevada, New Zealand and Utah. She has helped start up several new mines and specializes in leading and developing engineering teams responsible for design, scheduling, ventilation, reserves and budgets. She is passionate about promoting inclusion in the mining industry.



HAARALA

Haarala earned her bachelors degree in mining engineering from the University of Nevada, Reno.

Secretary

DANIEL ROSENBACH is an area manager for Epiroc USA and has been involved in the mining industry for 13 years. He graduated with a degree in mining engineering from the Colorado School of Mines in 2011. He began full-time employment with Atlas Copco upon graduation and served the company in Pikeville, KY, Carlin, NV, Denver, CO and Duluth, MN. He now resides in Eveleth, MN. His current position as area manager for Minnesota and the Upper Peninsula of Michigan primarily focuses on drilling consumables for the iron mines in those areas.



ROSENBACH

Rosenbach has remained active in SME since he joined during college in 2005. He has chaired three technical sessions at SME conferences and was a Mining & Exploration Division Program Area Manager for technology. One of his goals is to keep the next generations of miners involved in SME, and he makes an effort to mentor multiple students each year. ■

Personal News

ROBERT HALL, P.E., is the new head of the Department of Mining Engineering and Management (MEM) at South Dakota School of Mines & Technology. Most recently he served as a professor in the School of Mining and Petroleum Engineering at the University of Alberta. Prior to that, he spent 15 years at the University of British Columbia. His areas of research include mining equipment design, automation, equipment maintenance and reliability, comminution and energy reduction. His skillset will help MEM continue to meet the engineering needs of South Dakota and the United States by attracting the best and brightest students and faculty. Hall earned bachelor's and master's degrees in mechanical engineering and a Ph.D. in mining engineering from Queen's University in 2000. ■

The faces behind the outreach and education:

Meet the MEC Committee

by Tanya Kriss, MEC Outreach Coordinator

Each month the Minerals Education Coalition (MEC) highlights activities, projects and outreach events so that SME members can see the MEC mission in action: “to identify, produce and disseminate fact-based, K-12 mineral education lessons and activities and to inform and educate the general public about the importance of minerals and mining in their daily lives.” From scouting activities, curriculum for teachers, Move Mining and Move Mining Next Gen competitions and Earth Science Week materials, to teacher events and supporting outreach conducted by SME members, the MEC Committee focuses on this mission and goes above and beyond to ensure that it is achieved.

The people who make the work possible are part of a dedicated committee that meets monthly and at all SME meetings. They also form subcommittees with additional volunteer support from SME members, Young Leaders and students. Through these projects, MEC continues to be a true asset to SME and to each member, for it elevates the industry, helps to promote careers in the field, and informs an audience outside of the industry that mining is essential to daily life. Here are their comments.

Pat Jacomet, MEC Committee chair and executive director of the Ohio Aggregates & Industrial Minerals Association



JACOMET

I feel that my involvement in MEC has been one of the most rewarding undertakings of my career. The tools, information and activities developed by MEC and its very active members are invaluable in changing the perceptions of mining in society. The staff and members of the MEC Committee are some of the most passionate and energetic people in the business and share a common bond — to educate the general public about the importance of mining and the many ways it impacts our lives. This mission not only ensures the viability of mining in the future but helps promote the many career opportunities mining provides.

Dan O'Connor, MEC Committee vice chair and quality control/geologist for the Melvin Stone Co. of Jurgensen Companies



O'CONNOR

The MEC has the ability to seek out, educate and inform the future leaders of our industry. I feel honored to be part of a group that has such a strong desire to get this accomplished. There is nothing better than opening young minds to something they never knew they needed or wanted. With the help of the industry and team members, these efforts will not go unnoticed. Education with pas-

sion is almost impossible to resist. If we love mining and mineralogy, we can show them. This will hopefully create a motivating and clear path for future miners to find the information and resources that they need to be successful.

Katie Kosloski, MEC past chair and plant manager with Luck Stone



KOSLOSKI

Since entering the industry, I have had a passion for sharing with the public how important mining is to our culture. Participating in the Minerals Education Coalition has been such an amazing experience, because it has introduced me to folks from all walks of the extraction business who are similarly excited and interested in creating opportunities and content that helps to build a positive perception of mining. My favorite of these opportunities is our participation in the National Science Teaching Association Conferences, where we pass out more than 1,000 rock and mineral kits to teachers from across the United States. This is such a unique chance to interact and share with educators from across the nation on how they can teach the next generation about the Earth, the uses of the materials we mine from it and, most importantly, how we can do it sustainably.

These events are so much fun. They have allowed me to build strong relationships with my committee members and given me the opportunity to share why I love this industry with folks who may have never thought twice about the importance of mining.

C. Dale Elifrits, retired geological engineering professor, University of Missouri-Rolla



ELIFRITS

My involvement with MEC has been and is one of the most rewarding activities of my more than 50-year career. The projects and activities that MEC tackles and successfully delivers clearly make a difference in the public perception of the mining industry and the understanding of its importance to every person. Specifically, I greatly enjoy my annual engagement with the passionate MEC Committee members and the highly qualified and professional staff to produce the teaching activities and materials for AGI's Earth Science Week mailout and the AGI Earth Science calendar page. The preparation for and delivery of the MEC booth activities at the three area conventions of the National Science Teaching Association every fall is an exciting and rewarding annual experience. The interaction with K-12 science teachers at the MEC booth, as the teachers make their mineral and rock sample kits, is highly rewarding — “icing on the cake” com-

pared to the preparation. The valuable life-long friendships developed from creating these activities and the interaction with MEC Committee members and staff are priceless.

Wendi Cooksey, metallurgical lab manager, FL Smidth Minerals Testing Research Center



COOKSEY

I joined the MEC committee to help promote education on the importance of the minerals industry and the efforts the industry takes in sustainability and carbon footprint reduction. My favorite part about MEC is the mineral science and engineering education support to teachers with material that matches their standards and curriculum.

Kurt Doran, project manager, NTS



DORAN

I have been involved in mining my entire career and I have seen firsthand the benefits of having an engaged public whether during permitting, operating or going through closure. In Minnesota, we emphasize educating at a young age, so the curriculum and programs offered by the MEC are a natural fit to provide a positive exposure to kids and further serve as a framework for creatively designing new opportunities for minerals education advancement.

Having worked with the material for quite a few years, I am excited to help further develop the tools we use to educate the public on mining, and I look forward to bringing my experiences from Minnesota to the committee. Lastly, the MEC comprises some of the most passionate, honest and genuine mining and minerals industry advocates, and I am honored to be a part of the committee.



DIMMICK

Mike Dimmick, marketing consultant, Caterpillar Mining

I'm proud to be a part of the Caterpillar Mining team. We not only provide the majority of surface mining equipment in the world, we provide services and solutions to help our customers get the most out of our mines. I'm also proud to be a part of the MEC committee to help people learn how minerals

help them get the most out of their lives.

Emily Muteb, strategic community development manager, Freeport-McMoRan

Educating the public about our industry is critical to



MUTEB

achieving long-term acceptance of mining. And, it is not something that any company can do alone. The Minerals Education Coalition provides an opportunity for companies to collaborate around the mutual goal of changing the perception of the mining industry. The dedication of our staff and members as they make an impact through relevant and valuable resources and events is inspirational.

I have enjoyed leveraging my network to broaden the reach of the MEC. Building a strong network of champions for the industry will be vital to the organization and its members as we work together to power the future.

Karen Rose, senior project manager, SynTerra Corp.



ROSE

I've always enjoyed working with youth and teaching others about mining and the environment, so the MEC Committee has been a great fit for me. I have been an officer on the MEC Committee and contributed to many MEC projects, and MEC has also given me a great channel to work with Scouts. I've been working with Scouts for more than 12 years, and with SME and MEC I have had the opportunity to be staff for the Mining in Society merit badge for two national jamborees, as well as being lead counselor for the badge within my council.

I have also enjoyed more than 10 years assisting with after-school science events at local schools. MEC gives me a great platform to promote mining through outreach.



ZIMMERMAN

Charlie Zimmerman, independent communication specialist

Mining was never my calling, and I didn't even begin my Caterpillar career with mining in mind. However, I believed in the need to take care of our planet, while also valuing our modern life and technology. I knew coexistence between those two was vital. In the MEC, I found a group committed to showing how critical it is to mine sustainably and so well-aligned with the ideals of Scouting that it had developed a mining-focused merit badge.

Having retired from Caterpillar, the MEC is now my closest tie to the mining industry, and it allows me to contribute my energy to an incredibly worthwhile mission. It has also enabled me to reconnect with Scouting at both the national and local levels. I couldn't ask for more. ■



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Challenging times present opportunity



William Gleason
Editor

Supply chain could be changed

One could make the case that the mining industry is uniquely positioned for these difficult times. Booms and busts are nothing new for this industry. I have heard some SME members who are long in the tooth measure their careers not by years or positions they have held but by the number of boom-bust cycles they have been through.

This cycle, though, is different. This time the entire world is feeling the pain of the downturn, and there are many businesses, and probably some industries, that will not come out of this. However, there is also opportunity that presents itself in difficult times. Recently, I began to think back to an event hosted by Caterpillar in 2015. The world's largest mining equipment maker had seen better years than 2014-2015. Commodities prices were down 60 percent and the multibillion dollar investment Caterpillar made a few years earlier into mining was probably being questioned, but through the haze representatives of the company told media and customers that the down cycle presented the opportunity to slow down, reset and reposition for the future (**ME**, Aug. 2015, p. 68).

Caterpillar, and many other companies, emerged from that down cycle with incredible innovations that have since changed the industry. The onset of COVID-19 and the lockdown that followed has spurred similar innovations. As a society we have adapted to working from home, to having virtual meetings and happy hours and to staying connected in ways most of us had never considered before.

In this issue, we take a deep dive into 43 commodities that are classified as industrial minerals thanks to SME's Industrial Minerals & Aggregates Division. Generally, these are the commodities the general public does not know much about or even how to pronounce in many cases. Some of these are foundational commodities that are used in road and structure construction and others have more specialized uses, such as pumice's use as a

polishing agent for circuit boards and television monitors and as tooth-filing mechanisms for chinchillas. And some of the commodities that are covered in this issue have been deemed critical minerals. These are the minerals that power technology and the green environment. They are the minerals that are needed for military and defense applications and the minerals that keep iPhones and Teslas operating.

In the prologue of the Industrial Minerals Review, Mike O'Driscoll, the founder of Industrial Minerals Forums & Research Ltd (IMFORMED), points out that the importance of these minerals was put into a sharp focus by the spread of the COVID-19 virus and the lockdowns that followed.

"Perhaps the single most obvious factor that emerged from the start of the crisis was the world's (over-)reliance on sourcing minerals (and many other items) from China," O'Driscoll writes. "It had happened a few times before: during the SARS outbreak of 2003, the Beijing Olympics of 2008, and most recently the 2017-19 anti-pollution drive (continuing) within China, but this time the impact has been felt deeper and wider, and crucially, perhaps for a longer term."

According to the USGS, the United States is 100 percent reliant on bauxite, fluor spar, graphite, mica, rare earths, scandium and yttrium, which are all critical minerals. Additional minerals from China on which the United States is ≥ 50 percent import-reliant include barite, antimony, fused alumina, garnet, silicon carbide, diamond, iron oxide pigments and magnesite.

This is not new, or especially good news. However, O'Driscoll writes that the challenges being faced today could lead to needed changes, among them changes to the global supply chain and an eventual break from China.

"With this latest stimulus, the start of the 2020s may well herald a surge in global mineral project development, especially in critical minerals, in order to lessen markets' reliance on China's mineral resources. Along with this quest for alternative sources to China will be a boost for the already fast-evolving mineral recycling sector," writes O'Driscoll.

It has been a challenging time for everyone, but sometimes the best lessons are learned from the hardest times.

You can read the full prologue starting on page 30 and the 43 mineral reviews on page 31. ■

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On January 1, 2020, North America Keller companies Bencor, Case Foundation, Hayward Baker, HJ Foundation, Keller Canada, McKinney Drilling and Moretrench joined together and rebrand to Keller. As one company, we are the world's leader in geotechnical construction, providing solutions for the challenging subsurface conditions mining contractors and owners face. Our combination of detailed local knowledge and connected global resources ensures no question goes unanswered, no problem goes unsolved, and no job goes unfinished. Collectively we've been keeping mining operations moving along for almost 100 years. Keller's full range of geotechnical construction techniques has been applied to hundreds of mining projects to ensure the highest quality product and service. Our patented vertical drainage system for heap leach piles prevents slope failure. This system also allows subsequent percolation to reach deeper into the pile for an increased yield.

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Luvan was founded in 2007 and focuses on design, engineering, fabrication and supply of the following solutions for mining industry:

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- (2) Ventilation Doors for underground mines - Heavy duty units for all applications.
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- (4) Modular Belt Conveyors, for bulk material handling - modular and custom conveyors to meet industry needs.

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www.macleaneengineering.com

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Founded in 1944, Martin Engineering is a global leader in making bulk materials handling cleaner, safer and more productive. The company supplies flow aids, conveyor products and expert services for a wide variety of applications, including biomass, mining, aggregate, coal handling, cement and other materials. Product families include air cannons, conveyor belt cleaners, belt trackers, impact cradles, modular transfer points, dust suppression and industrial vibration. With nearly 400 active and pending patents globally, the firm has earned a reputation as an innovator of quality products and services, backed by unconditional guarantee. Headquartered in Neponset, IL, Martin offers manufacturing, sales and service from 19 factory-owned business units around the world. The company's series of Foundations books is an internationally-recognized resource for safety, maintenance and operations training, and the firm played a pivotal role in writing and producing the 7th edition of the CEMA reference book, Belt Conveyors for Bulk Materials.

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Working with clients in mining operations for over 80 years, Mineral Technologies delivers innovative and cost-effective process solutions for the treatment of Iron Ore, Mineral Sands, Silica Sands, Coal, Chromite, Gold, Tin, Tungsten, Tantalum and a wide range of other fine minerals globally. Recognized worldwide as the go-to partner for process solutions across the project lifecycle from prefeasibility to plant commissioning and ongoing process support, Mineral Technologies' offers a holistic approach to project execution that includes metallurgical testing, plant design, equipment supply, and technical services. Mineral Technologies line of wet and dry processing equipment maximizes grade and recovery whilst delivering low operational costs. With a product line including wet gravity separators, magnetic separators, and electrostatic separators, Mineral Technologies supplies fit-for-purpose and cost effective equipment to clients in a wide range of processing applications.

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Founded in 1992 Open Loop Energy has offices in Safford, Arizona, Winnemucca, Nevada, Cedar Fort, Utah and Farmington, New Mexico. Open Loop Energy is ISO 9001 certified at all locations to insure the focus on enhancing customer satisfaction. Each location has Six Sigma professionals on staff that enable projects and daily tasks to function in an efficient manner. Sixteen staff members hold certifications within the International Fluid Power Society, with this knowledge comes application expertise. Our innovative focus begins with Hydraulic Repairs. New manufacturing includes HydroStruts for Cat and Komatsu haul trucks, Bladder Accumulators, and HydroSNUBB Snubbers for Electric Shovels. One Key innovation is the “Patent” Digital Controlled Water Distribution System known as DCWD-G2. This is the only system that can track and report water usage of water trucks based on the ground speed of the water truck.

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www.townley.net

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West Virginia University Department of Mining Engineering

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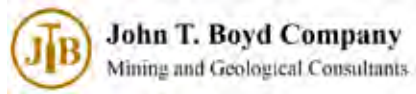


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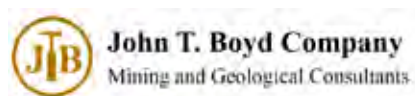
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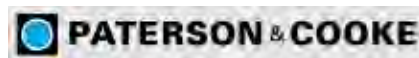
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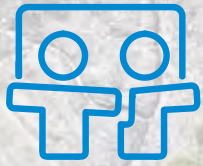
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