Critical Minerals Alliances

For a Reenergized North America


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DATA MINE NORTH
Good Stories

Critical Minerals Alliances
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REBECCA LASLEY
EXECUTIVE DIRECTOR

SHANE LASLEY
PUBLISHER & CHIEF EDITOR

A.J. ROAN
STAFF WRITER & EDITOR

STEVEN MERRITT
PRODUCTION DIRECTOR

CHRIS DAY
GRAPHIC DESIGN

MAILING ADDRESS:
PO Box 773026
Eagle River, AK 99577-3026
Phone: (907) 726-1095
www.miningnewsnorth.com
www.metaltechnews.com

NEWS: 907-229-6289
publisher@miningnewsnorth.com
publisher@metaltechnews.com

ADVERTISING: 907-242-6084
RebeccaL@miningnewsnorth.com
discover@metaltechnews.com

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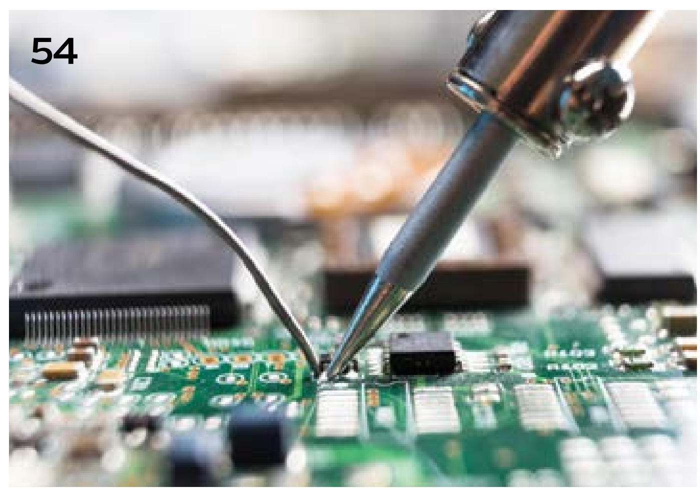
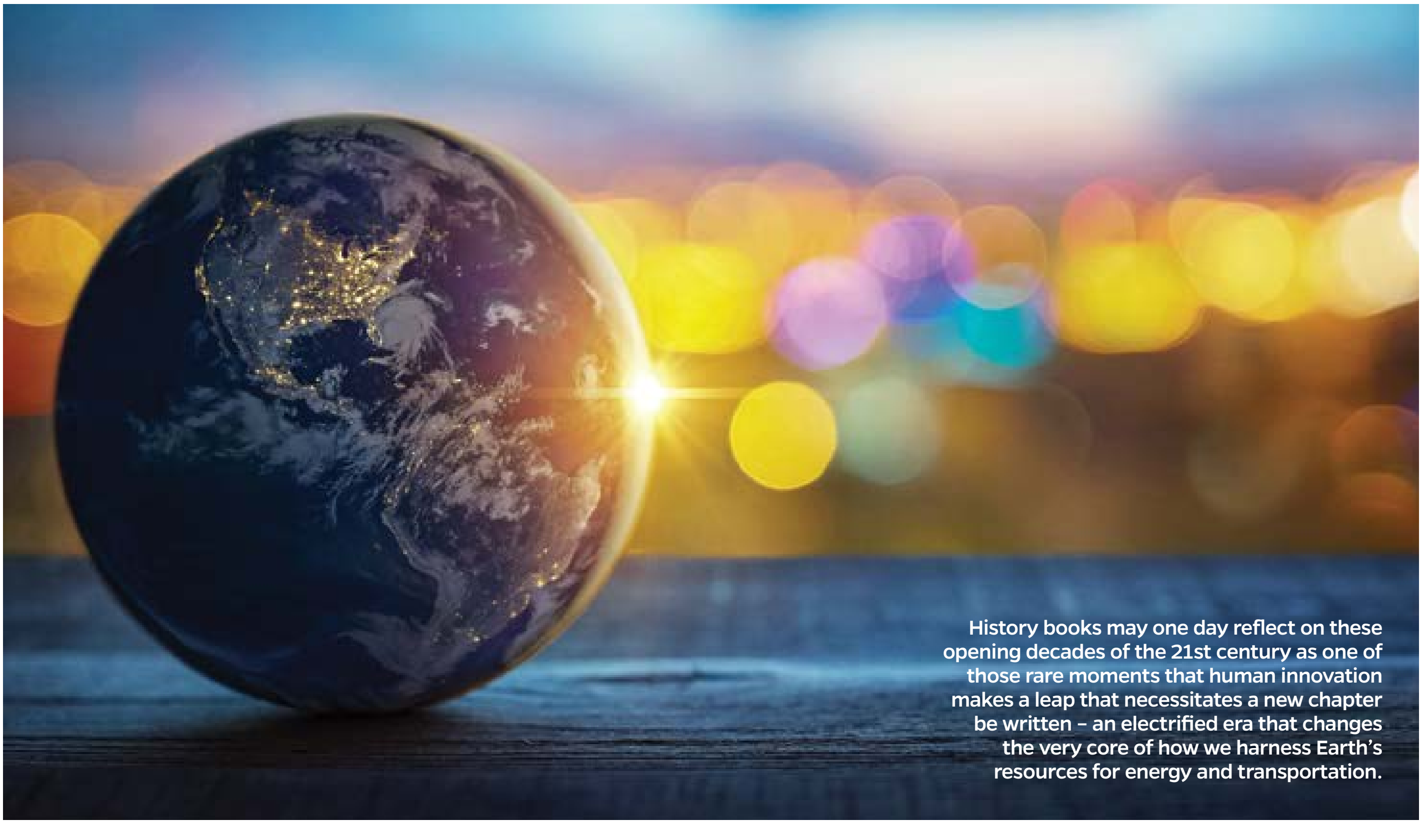




ADOBE STOCK

History books may one day reflect on these opening decades of the 21st century as one of those rare moments that human innovation makes a leap that necessitates a new chapter be written – an electrified era that changes the very core of how we harness Earth's resources for energy and transportation.

Forging Critical Minerals Alliances

For a healthy, prosperous, and exciting future for humankind

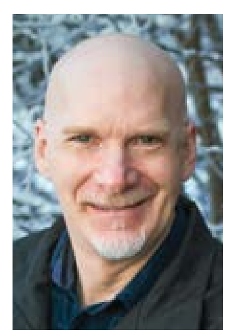
By SHANE LASLEY
DATA MINE NORTH

WHILE THE HISTORY OF HUMAN INNOVATION is a series of discoveries, each building on the last, there are certain "eureka moments" that mark a shift in the trajectory of mankind – taming fire, stone toolmaking, Bronze Age metalworking, the printing press, and harnessing electricity to name a few.

The history books may one day reflect on these opening decades of the 21st century as one of those rare occasions that human innovation makes a leap that necessitates a new chapter be written – an electrified era that changes the very core of how we harness Earth's resources for energy and transportation.

"There are moments in history when everything changes. Inflection points. We believe such a point is upon us for the mass adoption of electric vehicles," GM Global Chief Marketing Officer Deborah Wahl declared on Jan. 8. "Unlike ever before, we have the solutions, capability, technology and scale to put everyone in an EV."

Reminiscent of mankind's harnessing of electricity at the close of the 19th century, the world may not have reached this tipping point so soon if it were not for Tesla – Nikola Tesla in the 1880s and Tesla Motors in our modern era.



SHANE LASLEY

At the same time GM was making its electric ambitions known to the world, Tesla was celebrating the delivery of nearly half a million EVs to customers around the globe during 2020. As the largest single EV manufacturer, this trendsetting automaker accounted for roughly 17% of the nearly 3 million fully electric and hybrid vehicles sold during 2020.

Now, with every major automaker on Earth forging ahead on the e-mobility path blazed by Tesla, it is expected that in just 15 years EVs will overtake internal combustion vehicles in terms of sales.

This almost unfathomably rapid EV revolution is being spurred by a growing number of governments, companies, and individuals concerned that the carbon dioxide released by the continued burning of fossil fuels is creating an irreversible overheating of Earth.

The climate benefits of electrifying transportation, however, will not be fully realized if those EVs are plugged into fossil-fuel-burning power sources. So, global governments and industries are also making a massive push to harness the low-carbon energies offered by sun, wind, and water.

Whether it be EVs with lithium-ion batteries electrifying motors enhanced with rare earths, locomotives powered with hydrogen fuel cells that exhale water instead of CO2, solar panels converting the sun's rays into inexpensive and carbon-free electricity, or wind turbines creating power out of thin air, all paths to low-carbon energy and transportation will require enormous new supplies of metals.

No matter what mix of clean energy technologies emerge, the World Bank forecasts that a low-carbon energy future will require some combination of more than 3 billion tons of new minerals and metals to achieve global climate goals by 2050.

This transition will even necessitate enormous new supplies of already abundantly mined metals such as copper.

The World Bank estimates that 550 million tons of copper will be needed to generate and transmit electricity over the next 25 years, which is roughly equivalent to all the copper mined by humans over the past 5,000 years.

When it comes to lesser mined critical minerals and metals such as cobalt, chromium, gallium, germanium, graphite, indium, lithium, manganese, molybdenum, nickel, rare earths, and tellurium, the enormous gap between forecasted demand versus current supplies is staggering.

"Today, the data shows a looming mismatch between the world's strengthened climate ambitions and the availability of critical minerals that are essential to realizing those ambitions," said International Energy Agency Executive Director Fatih Birol. "The challenges are not insurmountable, but governments must give clear signals about how they plan to turn their climate pledges into action. By acting now and acting together, they can significantly reduce the risks of price volatility and supply disruptions."

> *>> This inflection point in human history also offers a rare opportunity for organizations and individuals that do not always see eye-to-eye to get together behind a common cause.*
>
> *–Shane Lasley*

This inflection point in human history also offers a rare opportunity for organizations and individuals that do not always see eye-to-eye to get together behind a common cause. An alliance of academia, conservationists, consumers, governments, investors, local stakeholders, manufacturers, and miners all working toward a brighter tomorrow.

A future in which humankind makes the most of the renewable resources offered, while also forging a cohesive strategy to sustainably extract, reuse, and recycle the elements of 21st-century innovation.

It is my hope that Critical Minerals Alliances' in-depth insights into these elements of innovation helps to forge partnerships that are not crippled by irreconcilable differences but strengthened by a spectrum of ideologies with a common goal – a healthy, prosperous, and exciting future for humankind. DMN

ADOBE STOCK

The American transition to electric mobility powered by renewable energy envisioned by the White House will require enormous supplies of cobalt, graphite, lithium, nickel, rare earths, and other critical minerals.

Building a US critical minerals strategy

Securing domestic and allied supplies part of Biden's plan

By SHANE LASLEY

DATA MINE NORTH

A HEAVY RELIANCE ON IMPORTS for a long list of minerals and metals critical to American supply chains could be a stumbling block for the Biden administration's ambitious "Build Back Better" agenda.

"From the largest infrastructure plan since the Eisenhower interstate highway system, to an aggressive plan for a national energy transition, the Biden administration's agenda will require an immense amount of minerals," National Mining Association President and CEO Rich Nolan inked in a June letter.

The United States, however, depends on foreign countries for more than 50% of its supply of 46 out of 63 minerals, metals, and groups of elements tracked by the U.S. Geological Survey, including 100% import-reliant for 17 of them.

The list of mined commodities for which the U.S. is reliant on foreign nations for most of its supply is littered with high-tech minerals and metals needed for renewable energy, electric vehicles, consumer electronics and military hardware – cobalt, gallium, graphite, indium, manganese, niobium, rare earths, tellurium, and vanadium are among the high-tech and energy elements at the top of this list.

In addition to the inherent risks to American supply chains, social and environmental baggage often accompanies critical minerals and metals imported from countries with lessor regard for human rights and the environment.

"American manufacturing and technological development can't be beholden to the whims of foreign nations, especially when we have these resources in our own back yard," said Sen. Kevin Cramer, R-North Dakota. "If we don't develop critical minerals in the United States, we force ourselves to rely on adversarial countries like China who have little-to-no labor or environmental protections."

This dependence on imports into American supply chains is further compounded by a global competition for the minerals and metals needed for the low-carbon transportation and energy transition to meet the goals of the 2015 Paris Agreement.

A typical EV requires six times the mineral inputs of a conventional internal combustion engine car and an onshore wind plant requires nine times more mineral resources than a gas-fired plant, according to "The Role of Critical Minerals in Clean Energy Transitions" report published by the International Energy Agency earlier this year.

With global EV sales expected to top 80 million per year by 2040 and international governments transitioning their power grids to low-carbon power, this amounts to a massive growth in demand for battery metals, other critical minerals, and even base and precious metals.

"Demand for minerals will soon exceed the global supply, creating a serious challenge for achieving a thoughtful future energy transition," Nolan wrote.

■ *Further details on the forecasted demand for the minerals required for EVs and renewable energy can be read at **Soaring critical energy minerals demand** on page 17.*

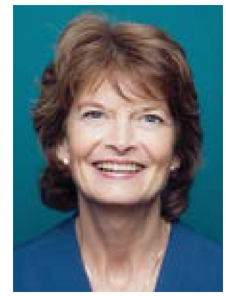
This challenge is not lost on the Biden administration, which addressed the massive quantities of cobalt, graphite, lithium, manganese, and nickel that will be needed for the batteries that will power America's transition to EVs and renewable energy.

"With the global lithium battery market expected to grow by a factor of five to ten by 2030, it is imperative that the United States invests immediately in scaling up a secure, diversified supply chain for high-capacity batteries here at home," the White House penned in a June 8 statement on battery supply chains. "That means seizing a critical opportunity to increase domestic battery manufacturing while investing to scale the full lithium battery supply chain, including the sustainable sourcing and processing of the critical minerals used in battery production all the way through to end-of-life battery collection and recycling."

To seize this opportunity, the Biden administration plans to invest heavily in both domestic and international production and processing of critical minerals.

New American mining, laws

In preparation for the "sustainable sourcing and processing of the critical minerals used in battery production all the way through to end-of-life battery collection and recycling," the White House has put together a working group of federal agencies led by the U.S. Department of Interior and supported by the White House Office of Science and Technology Policy to identify sites where critical minerals can be responsibly produced and processed in the U.S.



LISA MURKOWSKI

"This working group will collaborate with the private sector, states, Tribal Nations, and stakeholders – including representatives of labor, impacted communities, and environmental justice leaders – to expand sustainable, responsible critical minerals production and processing in the United States," the Biden administration penned in a June report outlining plans to strengthen American supply chains.

To ensure that domestic critical minerals fed into American supply chains meet the sustainability criteria, the White House is asking Washington D.C. lawmakers to establish a new mining regulatory framework with strong environmental standards throughout the entire mine life, from development to reclamation.

"We recommend Congress develop legislation to replace outdated mining laws including the General Mining Law (GML) of 1872

Ford Motor Company Executive Chair Bill Ford looks on as President Biden talks with Linda Zhang, chief engineer for the all-electric F-150 Lightning, during a May tour of Ford's Rouge Electric Vehicle Center.

SAM VARNHAGEN FOR FORD MOTOR COMPANY

governing locatable minerals (including nickel) on federal lands, the Materials Disposal Act of 1947 to dispose of minerals found on federal lands, and the Mineral Land Leasing Act of 1920 among others," the Biden administration wrote. "These should be updated to have stronger environmental standards, up-to-date fiscal reforms, better enforcement, inspection and bonding requirements, and clear reclamation planning requirements."

The three laws cited by the White House, however, are not related to the environmental regulations governing mining in the U.S. Instead, they detail how federal lands are prospected and staked (Mining Law of 1872); how minerals on federal lands are sold or leased (Materials Disposal Act of 1947); and royalties on mineral products on federal lands (Mineral Land Leasing Act of 1920).

Much of the federal regulations relating to environmental standards and permitting processes for mining projects in the U.S. are found within the Clean Water Act and National Environmental Policy Act.

The NEPA process is both renowned for its strong environmental protections and infamous for the near-decade it takes for a large domestic mine in the U.S. to gain permits under its process.

"It takes an average of seven to 10 years to secure a U.S. mine permit. This, compared to the two years it takes in countries with similar regulations like Canada or Australia, makes investing in American mining projects a challenge," according to Nolan.

The White House sees these allied countries with more efficient mine permitting processes as increasingly important and secure suppliers of minerals and metals into American supply chains.

While the NMA president agrees that importing minerals from Canada, Australia, and other allies is necessary, the U.S. also needs to emulate the effective and efficient permitting systems of the global mining powerhouses.

"By simply increasing coordination and reducing duplication between federal and state agencies, setting, and adhering to schedules for permit reviews, and transparently tracking progress to provide accountability, the U.S. can become competitive again," Nolan wrote.

President Biden has signaled that he too would like to see the process for permitting domestic mines feeding minerals and metals into U.S. supply chains streamlined.

TEXAS MINERAL RESOURCES CORP.

Rising 1,250 feet out of the Texas desert about 85 miles southeast of El Paso, USA Rare Earth and Texas Mineral Resources' Round Top hosts large quantities of rare earths, lithium, and other critical minerals to feed into American supply chains.

As such, the White House has directed a second federal interagency working group that includes experts in mine permitting and environmental law to fully explore "opportunities to reduce time, cost, and risk of permitting without compromising strong environmental and consultation benchmarks."

Critical minerals bills

The mine permit streamlining opportunities being investigated by the Biden administration echo the objects of legislation recently introduced by Sen. Lisa Murkowski, R-Alaska – S.1352: "A bill to improve the quality and timeliness of federal permitting and review processes with respect to critical mineral production on federal land, and for other purposes."

"America's reliance on foreign countries for the production and recycling of our critical minerals is a vulnerability to our national security, a disadvantage to our economy, and a hindrance to our global competitiveness," Alaska's senior senator said in April, when the bill was introduced. "By improving the permitting processes we have in place, we are creating greater opportunity for America to rebuild a robust domestic critical minerals supply chain."

To improve the efficiency and effectiveness of the U.S. mine permitting process, Murkowski's bill would require federal agencies to:

- Establish clear timelines for decisions regarding applications, operating plans, leases, licenses, permits, and other use authorizations for critical mineral-related activities on federal land.
- Create clear, quantifiable permitting performance goals and to track progress toward those goals.
- Engage in early collaboration with agencies, stakeholders, project sponsors, and consult with state, local, and tribal governments to resolve concerns.
- Provide clear and logical ways to make the process cost-effective and timely.

"It's imperative to our national security and economic growth that the United States have a robust domestic critical mineral supply chain," said Senator Thom Tillis, R-North Carolina, one of the 11 cosponsors of the mine permitting bill introduced by Murkowski. "This commonsense legislation is key to achieving that goal."

Ensuring America has a robust domestic supply of critical minerals has also become a priority for lawmakers out of Texas, a state that is emerging as a hub for renewable energy, battery manufacturing, and critical minerals.

A pair of Texas congressmen, Republican Lance Gooden and Democrat Vicente Gonzalez, introduced the Reclaiming American Rare Earths Act, bipartisan legislation aimed at reducing America's dependence on China for rare earth elements and other minerals critical to the United States.

"Our capacity to manufacture essential technology for our national defense and economic prosperity will remain in danger as long as we remain dependent on China," Gooden said upon reintroducing the RARE act in April. "We must start producing these critical minerals here at home and producing in America first."

Modeled after the Onshoring Rare Earths Act of 2020, or ORE Act, introduced by Sen. Ted Cruz, R-Texas, the RARE Act would establish tax incentives for the domestic production of rare earths and battery metals essential to U.S. technology, energy, transportation, infrastructure, healthcare, and defense sectors.

Under the legislation, companies that are mining, reclaiming, or recycling the 17 rare earth elements or five battery minerals and metals – cobalt, graphite, lithium, manganese, and vanadium – in the U.S. would be able to treat expenditures as operating costs that are fully deductible from their taxes.

The bill also offers a 200% tax deduction to U.S. buyers of these critical minerals and metals extracted from deposits in the U.S.

In addition to tax incentives, the RARE Act would require the Department of the Interior to establish a pilot grant program for the domestic development of critical minerals and metals.

Capped at $10 million for any grant award, the legislation instructs the Interior to prioritize projects determined to be economically viable over the long term. In addition, at least 30% of the grant funds must be allotted to projects focused on recovering critical minerals and metals from secondary sources such as mine tailings or recycling products with rare earths or battery metals.

OFFICIAL WHITE HOUSE PHOTO BY ADAM SCHULTZ

President Biden talks on the phone with Canada Prime Minister Trudeau in April. The White House is working closely with both Canada and Australia to secure minerals critical to U.S. supply chains.

The Texas congressmen, which come from opposite sides of the aisle, said reshoring America's critical minerals supply should not be a partisan issue – both former President Donald Trump and President Biden have recognized the need for our government to encourage domestic production of these basic building blocks of modern technologies.

"I am proud to support the RARE Act, critical bipartisan legislation that will jump-start domestic critical mineral and rare earth element production," said Gonzalez. DMN

While developed for underground mining, the Cat R1700 XE LHD unveiled at MINExpo International 2021 offers a glimpse of Caterpillar's development of battery-electric surface mining equipment.

CATERPILLAR INC.

Canada set to be critical minerals store

Ottawa, mining sector work together to deliver vital minerals

By SHANE LASLEY
DATA MINE NORTH

CANADA IS POSITIONING ITSELF as the "global supplier of choice" for the critical minerals and metals essential to tomorrow's technologies, especially the almost unfathomable quantities of raw materials that will be required by a world transitioning to low-carbon energy and electric vehicles.

"Demand for minerals and metals continues to grow with an increasing focus on critical minerals – vital in aerospace, healthcare, telecommunications and an array of clean technologies such as solar panels and electric car batteries," said Mining Association of Canada President and CEO Pierre Gratton. "We're confident that, with Canada's leadership in sustainable mining standards and the government's commitment to critical minerals development, the mining sector has the tools, skills and support to provide the responsibly sourced minerals vital to industries in Canada and around the world."

In March, government officials unveiled a list of 31 minerals and metals critical to Canada. Unlike similar lists previously assembled by the United States and European Union – which are focused on critical raw materials that are in high demand by technologies important to the national interests of these economic powerhouses but for which reliable supplies may not be readily available – Canada's list is more akin to a catalog of 31 critical minerals and metals it has in stock to meet the global needs.

While Canada's critical minerals catalog hosts many of the usual suspects – cobalt, graphite, lithium, rare earth elements, and a majority of the other minerals and metals considered critical to both the U.S. and EU – it also includes copper, nickel, and zinc – base metals that are fundamental to building the green energy future but are more readily available than traditional critical minerals.

"These minerals and metals are essential to lowering emissions, they are essential to net-zero by 2050; they are essential to our economic competitiveness and our energy security; they meet the needs of our partners and the demands of emerging global trends," said Canada Minister of Natural Resources Seamus O'Regan.

And Canada's federal and provincial governments are standing shoulder-to-shoulder with the mining industry to ensure the Great White North is the global stockhouse of the minerals and metals needed to feed into 21st century supply chains.

"Importantly, industry and government are pulling in the same


TOMRA

Left: The First Cobalt refinery in Quebec. Below: European Commission President Ursula von der Leyen, Canada Prime Minister Justin Trudeau, and European Council President Charles Michel discussed critical mineral supply chains during a June 14 summit in Brussels.

FIRST COBALT CORP.

direction," O'Regan and Gratton penned in a May column published in The Province. "We are building on our strengths, recognizing that the road to a low-emissions future is paved with clean technologies, and that minerals and metals will provide the materials we need."

Critical EU partnership

While the U.S. list of 35 critical minerals and EU list of 30 critical raw materials vary slightly due to the particular needs of these global economic powerhouses, the criteria for determining criticality are nearly identical – raw materials that are crucial to their economies but are at risk for disruptions due primarily to overreliance on limited and sometimes unreliable supplies.

"We import lithium for electric cars, platinum to produce clean hydrogen, silicon metal for solar panels. 98% of the rare earth elements we need come from a single supplier – China. This is not sustainable," European Commission President Ursula von der Leyen said during the opening speech at EU Industry Days 2021 in February. "So, we must diversify our supply chains."

Canada, which has plentiful supplies of all the energy materials named by von der Leyen and 18 others on the EU critical raw materials shopping list, is working closely with European leaders.

"We are moving forward with our allies and like-minded countries, including the European Union," said O'Regan.

This includes forging a new strategic partnership to help provide the EU with a secure and sustainable supply of minerals and metals critical to the global transition.

Following the 2021 G7 summit, held in Cornwall, United Kingdom in June, Canada Prime Minister Justin Trudeau made a stop in Brussels for an EU-Canada summit to further conversations with European Commission President von der Leyen and European Council President Charles Michel.

As part of a broader conversation, the leaders from opposite sides of the Atlantic committed to stronger collaboration on mining and mineral processing research and innovation, as well as creating new trade opportunities and private and public investment for critical mineral related businesses in Canada and the EU.

"We agreed on building a strategic partnership on raw materials," von der Leyen said during a joint conference with Trudeau following their meeting. "We, as Europeans, want to diversify our imports away from producers like China – because we want more sustainability, we want less

DATI BENDO; COURTESY OF THE EUROPEAN COMMISSION environmental damage, and we want transparency on labor conditions."

Trudeau agrees that EU- and Canada-centric supply chains would be more sustainable and offer job opportunities.

"In order to continue creating good, green jobs for the middle class, we must secure supply chains for critical minerals and metals that are essential for things like electric car batteries," the Canada prime minister said, following his meeting with von der Leyen.

To expedite trade cooperation between these cross-Atlantic economies, the leaders also reaffirmed the strong ties under the Canada-European Union Comprehensive Economic and Trade Agreement. And, to build on this relationship, advanced an Authorized Economic Operator Mutual Recognition Agreement to simplify border procedures and speed up the flow of trade between Canada and the EU. This is expected to increase predictability at the border and decrease fees and delays for Canadian businesses shipping goods to the EU.

President von der Leyen says this strengthening of CETA is "good for jobs, it is good for growth on both sides of the Atlantic."

US-Canada alliances

While forging stronger ties with the EU is good for Canada's mining sector, the U.S. is the northern nation's largest trading partner and is expected to be its biggest critical minerals customer moving forward.

"We already supply 13 of the 35 minerals on the U.S. list and we have the potential to supply more," said O'Regan.

While the Trump administration was still in the White House, Canada and the U.S. finalized a joint action plan to collaborate on securing supply chains for the critical minerals needed for EVs, renewable energy, high-tech, aerospace, defense, and other important sectors of the neighboring countries' economies.

Despite a major shift in the political views of the presidential office in Washington D.C. since this critical minerals action plan was initiated, O'Regan says the new occupants of the White House are eager to continue to work with Canada to diversify supplies of mined materials, especially those needed to meet the green energy goals of the Biden administration.

The Canadian natural resources commissioner says critical minerals was a major topic of his first in-depth meeting with U.S.

NATURAL RESOURCES CANADA

Canada has assembled a list of 31 critical minerals and metals that it has in stock to meet the growing needs of a world transitioning to low-carbon energy and electric vehicles.

Secretary of Energy Jennifer Granholm.

"There is definitely a very clear enthusiasm on securing critical mineral supply chains between our two countries," O'Regan said during the March unveiling of Canada's critical minerals list.

The Biden administration has several reasons to be enthusiastic about Canadian critical minerals – being environmentally sound, socially responsible, and right next door are at the top of this list.

"Canada has one of the cleanest electricity grids on the planet, with 82% of generation coming from non-GHG [greenhouse gas] emitting sources, meaning we produce some of the lowest carbon intensity mineral and metal products anywhere in the world, O'Regan and Gratton penned in their joint column. "Nickel mined in Canada, for example, produces lower emissions than nickel mined in 90% of the world."

They also said the northern nation's mining sector is years ahead of other industries when it comes to partnering with and providing economic opportunities to Canada's First People.

"Simply put, we are a responsible, reliable supplier of many of the world's mined resources, and we have room to grow," the Canadian government and mining sector leaders penned in their joint column.

Critical Ontario strategy

Many of Canada's provincial governments are also investing in and encouraging the sustainable development of critical mineral projects, often in partnership with Ottawa.

In March, Ontario has unveiled plans to develop a strategy to position the province as a global supplier, producer, and manufacturer of choice for critical minerals such as cobalt, copper, lithium, nickel, rare earths, and platinum group elements.

"Industries across Ontario and around the world need a steady supply of critical minerals to support new technologies and emerging industries, including electric vehicles," said Ontario Minister of Energy, Mines and Northern Development Greg Rickford. "With the development of a critical minerals strategy, the province can showcase Ontario's competitive advantage, high mineral development potential and world-class mining sector."

This strategy is expected to "generate investment, reduce red tape, create jobs, and advance Indigenous participation in the sector," according to Rickford.

Before the unveiling plans for this strategy, the province was already working to bolster its critical minerals sector.

Late in 2020, Ontario provided a C$5 million non-repayable grant to help accelerate the commissioning and expansion of First Cobalt's refinery in the province.

Located less than 500 miles north of Great Lakes manufacturing towns such as Detroit and Buffalo, the rail-accessible First Cobalt refinery will be capable of producing 25,000 metric tons of battery-grade cobalt sulfate per year, which will go a long way toward filling North American requirements.

In conjunction with the provincial grant, Ottawa provided First Cobalt with a C$5 million interest-free loan.

"Global demand for cobalt is increasing as electric vehicles become more widely adopted. Our refinery will be the only source of domestic cobalt for the North American electric vehicle industry and it will also be well positioned to support the European market," said First Cobalt President and CEO Trent Mell.

■ *Further information on cobalt, including First Cobalt projects in Ontario and Idaho can be found at **Solving the critical cobalt conundrum** on page 27.*

Sustainable Quebec investments

Not to be outdone, Quebec is also supporting the sustainable production of critical mineral projects in the province.

Nouveau Monde Graphite Inc.'s Matawinie project has emerged as the flagship for sustainable critical minerals development in Quebec.

A feasibility study completed in 2018 details plans for a mine at Matawinie that would produce 100,000 metric tons of graphite concentrate per year.

Flake graphite produced at Nouveau Monde's processing facility in the nearby town of Saint-Michel-des-Saints is to be trucked roughly 100 miles (165 kilometers) to its advanced material plant at Bécancour, where it will be upgraded to the coated spherical graphite that serves as the anode material in most lithium-ion batteries.

■ *Read more about graphite markets and companies advancing North American projects at **EV revolution drives graphite demand** on page 41.*

As a forward-looking company feeding a vital ingredient into renewable energy EV supply chains, Nouveau Monde intends to shrink the carbon footprint of all its Quebec operations to net-zero.

Ottawa and the Quebec provincial government supported this endeavor with a C$3.6-million contribution toward developing electric haul trucks, battery technology, and fast charging infrastructure for Canada's mining sector.

Being led by Propulsion Québec, a group aimed at positioning Quebec as a leader in developing and implementing smart and electric transportation, this project involves the development of an electric propulsion system for a 40-ton Western Star mining truck to be tested at Matawinie.

"We're helping mining companies lower their emissions by investing in onsite emissions reduction technologies, and they're helping us by powering the clean technologies we'll need to reach net-zero by 2050," said O'Regan.

Taking a major step toward this goal for its own mine and the mining sector at large, Nouveau Monde is collaborating with Caterpillar Inc. to develop, test, and produce a fleet of all-electric Cat mining equipment for Matawinie.

"The collaboration between Caterpillar and Nouveau Monde marks an important milestone in the mining industry," said Caterpillar Group President Denise Johnson. "Through integrated technology, machines and services, the entire Caterpillar team is proud to support Nouveau Monde as they work towards constructing and establishing their first zero-emission mine."

A coming mine that is serving as a shining example of what Canada's mining sector has to offer the U.S., EU, and the rest of the world.

"With companies like Nouveau Monde working toward all-electric mines and producing the critical minerals we need for advanced batteries, we are positioning Canada's mining industry as a progressive, sustainable global producer of critical minerals needed for the transition to a clean energy future," said Paul Lefebvre, parliamentary secretary to the Canadian minister of natural resources.

Or, as O'Regan and Gratton put it, "This is mining's moment. Canada will lead." DMN

Many global governments and automakers plan to completely transition to fully electric or other zero-emission automobile sales by 2035.

ADOBE STOCK

Soaring critical energy minerals demand

Grand climate goals require bold critical minerals strategy

By SHANE LASLEY
DATA MINE NORTH

GLOBAL GOVERNMENTS AND INDUSTRIES are setting increasingly ambitious targets for the phasing out of fossil fuel-burning automobiles in favor of electric vehicles charged with green energy. Achieving these grand climate objectives, however, is going to require an equally bold strategy to ensure there are plentiful supplies of the new generation of energy minerals and metals critical to building this revolution in the way the world generates and uses energy.

The World Bank Group estimates that more than 3 billion tons of minerals and metals will be required to achieve the 2-degree Celsius temperature increase limit outlined in the 2015 Paris Agreement.

That is due to every facet of a world transported with emissions-free electric vehicles charged with low-carbon energy being much more mineral-intensive than the legacy technologies they are replacing.

According to "The Role of Critical Minerals in Clean Energy Transitions" report published by the International Energy Agency earlier this year, the annual supplies of minerals and metals being fed into the burgeoning EV and battery storage sectors are expected to expand by 30 times by 2040. In such a scenario where global governments and industries achieve the targets of the Paris Agreement, the low-carbon demand for lithium is expected to rocket 40-fold; and the clean energy demands for graphite, cobalt, and nickel are expected to surge by upwards of 25 times.

The development of mining projects needed to meet this demand, however, is measured in geological time scales when compared to the relative lightspeed adoption of EVs and low-carbon electrical grids envisioned to meet 2050 climate targets.

"Today, the data shows a looming mismatch between the world's strengthened climate ambitions and the availability of critical minerals that are essential to realizing those ambitions," said IEA Executive Director Fatih Birol.

This imbalance could make full attainment of global climate goals out of reach.

"In the context of clean energy transitions, inadequate mineral supply could result in more expensive, delayed or less efficient transitions. Given the urgency of reducing emissions, this is a

A Zinc8 technician working on a zinc-air energy storage system.

ZINC8 ENERGY SOLUTIONS INC.

possibility that the world can ill afford," the authors penned in the IEA clean energy transition report.

EVs to be biggest driver

Given the colossal size of the automotive market and the aggressive industry and government push to transition as many drivers to EVs as soon as possible, electric mobility is expected to be the biggest driver of new demand for critical minerals in the coming two decades.

With the 2050 climate goals of the Paris Agreement serving as a waypoint, a growing number of automotive companies and governments have set 2035 as the target for a complete transition to electric vehicle sales. This date is based on the average 15-year lifespan of passenger vehicles – meaning that most everyday internal combustion engine vehicles would be cycled off global highways by mid-century.

General Motors, among the global automotive powerhouses declaring to sell only zero-emissions vehicles by 2035, recently announced that it is investing $35 billion toward this goal over the next five years.

"We are investing aggressively in a comprehensive and highly integrated plan to make sure that GM leads in all aspects of the transformation to a more sustainable future," said GM Chair and CEO Mary Barra. "GM is targeting annual global EV sales of more than 1 million by 2025, and we are increasing our investment to scale faster because we see momentum building in the United States for electrification, along with customer demand for our product portfolio."

This includes heavy investments into at least four lithium-ion megafactories and securing new sources of the battery metals that are going to be highly demanded as the e-mobility momentum continues to grow.

■ *Find out more about a GM partnership to secure sustainably produced lithium from geothermal waters in California at **Titans forge critical lithium alliances** on page 33.*

With both the global automotive industry and governments behind the transition to e-mobility, EV sales are forecast to hit 30 million per year by 2030 and 82 million by 2040. At this projected growth rate, battery-powered cars and trucks would overtake ICE vehicles in terms of sales volume by 2035.

This is going to drive enormous demand for lithium-ion batteries, a burgeoning sector that has already quadrupled in size over just the last five years and is expected to grow 20 times larger over the next two decades.

"The supply chain is geared for making batteries for laptops and mobile phones, it is not geared for making batteries for the size of a car," said Simon Moores, founder of Benchmark Mineral Intelligence, a global leader in lithium battery supply chain analysis.

With Benchmark tracking more than 200 lithium-ion battery gigafactories being built or planning to be built to meet EV demand, the companies that feed new supplies of minerals and metals into this supply chain must hit a higher gear.

The IEA estimates that approximately 117 pounds of copper and 54 lb of manganese goes into the average EV, which is more than double the 49 lb of copper and 25 lb of manganese that goes into a typical internal combustion engine vehicle. On top of that, standard lithium-ion EV batteries need around 146 lb of graphite, 88 lb of nickel, 29 lb of cobalt, and 20 lb of lithium.

At these quantity and production estimates, EVs alone will require roughly 12 billion lb of graphite, 9.6 billion lb of copper, 7.2 billion lb of nickel, 4.4 billion lb of manganese, 2.4 billion lb cobalt, and 1.6 billion lb of lithium.

While this will power significant new demands for copper and nickel, the growth rate for this already widely mined metal pales in comparison to the explosive need for new supplies of the lesser mined battery minerals and metals.

For example, the lithium-ion batteries powering EVs alone will soon require five times more graphite than is currently produced at all the mines on Earth. This is on top of the graphite needed for traditional uses like lubricants and steelmaking, and the rising demand for this carbon mineral in batteries storing renewable energy and powering the innumerable mobile electronic devices and tools.

The story is similar for cobalt, lithium, and nickel.

Caspar Rawles, the head of price assessment at Benchmark Mineral Intelligence, told Data Mine North that low minerals and metals prices have stifled investments into the mines that will supply these raw materials needed for lithium-ion batteries.

"We see key battery raw material markets falling into deficit, most imminently cobalt, but (also) lithium, graphite, and nickel over the coming years," he penned in a January email.

Mineral-intensive clean energy

The full climate benefits of transitioning to e-mobility will not be fully realized unless the millions of EVs traveling global highways and byways are being charged from zero-carbon electricity sources, which also happen to be much more mineral-intensive than their fossil fuel burning forebearers.

Offshore wind, for example, needs nearly 14 times the metals per megawatt of power produced than natural gas and roughly six times more than coal. While less intensive, largely due to the lesser amounts of copper needed to deliver the power, onshore wind needs approximately nine times more metals per MW produced than natural gas, and four times more than coal.

Copper, chromium, manganese, molybdenum, nickel, rare earths, and zinc all go into building wind turbines and connecting them to the grid.

While not quite as mineral-intensive as wind, photovoltaic solar requires more than six times the metals per MW of electricity generated than natural gas and nearly three times as much as coal.

What sets PV solar apart is the many rare elements such as cadmium, gallium, germanium, indium, selenium, and tellurium used to turn sunlight into electricity – all are scarce and seldom mined as a standalone commodity.

Three of these metals often used in PV cells – germanium, indium, and cadmium – are typically associated with zinc in nature and are primarily recovered as a byproduct of mining this galvanizing metal.

ZINC8 ENERGY SOLUTIONS INC.

The Zinc8 energy storage system uses zinc and oxygen to store electricity and deliver the energy back into the grid as needed.

Gallium is currently generally recovered as a byproduct of aluminum but is almost as common in zinc deposits and has recently been found alongside rare earths at the Alces Lake project in Canada.

Tellurium and selenium are oft associated with copper.

Currently, however, we only capture a small amount of these solar byproduct metals – the rest gets tossed with the other waste at refineries. With the renewable energy sector requiring more of these materials, mining companies and refinery operators are increasingly investing in the technologies to recover these critical byproduct metals.

One such example is the construction of a new plant to recover tellurium from copper refining at Rio Tinto's Kennecott mine in Utah.

"The minerals and metals we produce are essential to accelerate the transition to renewable energy," said Rio Tinto Kennecott Managing Director Gaby Poirier. "Rio Tinto is committed to using innovation to reduce waste in our production process and extract as much value as possible from the material that we mine and process."

■ *Read more about tellurium and Rio Tinto's investment to recover this solar energy metal at* ***Solar powers demand for rare tellurium*** *on page 24.*

More storage, more minerals

Storing the intermittent electricity generated by wind and solar for delivery to customers when the wind is not blowing or the sun is not shining adds another layer of demand for critical minerals.

Currently, lithium-ion batteries are providing the largest storage buffer between the ebbs and flows of variable renewable electricity and completely different undulations in the demands of people and businesses plugging into those sources of clean power.

Moving away from the same storage technology used in EVs, and alleviating additional market demands for lithium-ion battery metals, will make global climate goals more achievable and less costly.

While not as well-established as lithium-ion, there are several battery storage technologies being implemented that would diversify mineral demand and happen to be better suited for stabilizing grid power.

One such technology, redox flow batteries, is forecast to overtake lithium-ion in terms of total storage capacity by 2031, and investments by the Biden administration could help make these projections a reality.

In addition to diversifying the demand for metals needed for the clean energy revolution, flow batteries offer several advantages over their lithium-ion counterparts in terms of response time, reliability, and safety for keeping energy grids energized and stable.

The U.S. Department of Energy is investing up to $20 million for research and development to advance the manufacturability of mid-sized flow battery systems.

Vanadium redox is the most advanced flow battery technology and is currently considered the frontrunner for these battery systems.

■ *More information on vanadium and its uses can be read at **Battery valences power vanadium demand** on page 45.*

As the debate over whether lithium-ion, vanadium redox, or some other flow battery technology will dominate grid-scale energy storage, an intriguing new system that stores the energy in zinc particles is making inroads into the market.

Zinc-air battery systems, especially the technology developed by Zinc8 Energy Solutions, has attracted considerable attention as a lower-cost energy storage option for utilities and others with large power needs.

Electricity flowing into a Zinc8 battery splits the oxygen off zinc oxide and is stored in the resultant charged zinc particles. This stored electricity is released back to the grid by reuniting the charged zinc particles with oxygen, regenerating the zinc oxide for reuse.

These batteries are capable of storing multiple days' worth of energy and are up to five times cheaper than lithium-ion batteries.

Zinc8 says this system empowers the lowest cost of storage in the market for long-duration applications, resolving the intermittent and unpredictable nature of other renewable energy sources.

This groundbreaking energy storage solution won the New York Power Authority (NYPA) Innovation Challenge, which has resulted in a contract for a large installation of this system in New York State.

"This is the thing that's changed our company – going from having some interest, but nobody thinking that zinc-air was ready – to our phones ringing nonstop from big utilities and globally connected companies around the world," said Zinc8 Energy Solutions President and CEO Ron MacDonald.

This includes a call from SmartConsult, an Australia-based engineering firm with an extensive network of Aussie contacts and clients across the entire energy supply chain, to install Zinc8's zinc-air energy storage system at aquatic centers, remote mines, microgrids, and other Down Under applications.

"We have been looking for a battery solution that does not have the inherent issues that surround existing battery types with uncertain cycle life and limited longevity," said SmartConsult CEO Luke Hardy. "The Zinc8 solution will be ideal for our large-scale industrial customers."

And, with zinc being one of the most common metals on Earth, it offers an ideal solution for diversifying grid-scale energy storage and the mined materials needed to achieve the increasingly ambitious targets for phasing out ICE automobiles in favor of EVs charged with green energy. DMN

The World Bank estimates that the green energy transition alone will require roughly 1.1 trillion pounds of copper over the coming 25 years.
DANIELA MACKOVA VIA PIXABAY

Renewable revolution powers copper demand

Low-carbon trifecta elevates criticality of electric metal

By SHANE LASLEY
DATA MINE NORTH

CONSIDERING THE ALMOST UNFATHOMABLE quantities that will be needed to power the global shift to low-carbon energy and electric mobility, copper is the most critical of the minerals and metals that have not been deemed critical by the United States or the European Union.

How much demand will it take to push an abundant and widely produced metal like copper to the level of criticality? A doubling of current demand would likely be sufficient, and many analysts are forecasting that such a rise is on the horizon.

The World Bank estimates that roughly 550 million tons of copper will be needed for low-carbon technologies such as wind turbines, solar panels, electric vehicles over the next 25 years, which is roughly equivalent to the total copper mined by humankind since the dawn of the Bronze Age some 5,000 years ago.

The reason for this is no matter which battery chemistries power tomorrow's electric vehicles, what renewable energy solutions recharge those EVs, or if rare earth magnets are used to generate that electricity and propel those automobiles more efficiently, any path to a decarbonized electrified future is wired with copper.

"If you want to electrify the world economy, the electrically conductive elements are going to become much more valuable in real terms, compared to things that don't conduct electrical energy," Ivanhoe Mines Ltd. founder and co-chairman Robert Friedland said during a keynote address at the AME Remote Roundup held in Vancouver, British Columbia at the onset of 2021.

And mining more copper could help provide new supplies of the cobalt needed for lithium-ion batteries, tellurium used in thin-film solar panels, and rhenium that goes into the high-temperature superalloys used for aircraft turbines.

While generating and delivering renewable energy is creating enormous new copper demand, it is the EVs that "fuel up" their batteries with electricity that elevates the metal to the status of new oil.

ADOBE STOCK

This is because these critical metals are often found in the same deposits as copper, and mining companies such as Rio Tinto are increasingly looking at producing them as a byproduct of the conductive base metal that is seeing a once-in-a-century swell in demand.

The new oil

Copper is so vital to the renewable energy and electric transportation revolution that international investment bank Goldman Sachs has declared this conductor metal to be the new oil of the low-carbon electric future this base metal is helping to empower.

Jeff Currie, head of Goldman Sachs Commodities Research and lead analyst of the financial firm's "Copper is the new oil" report, points out that the transition to renewable energy such as wind and solar will not be possible without a surge in the use of copper and other key metals.

"If we are going to electrify the world and decarbonize that way, we absolutely need copper to do it," Currie said during an April appearance on CNBC's The Exchange. "Copper becomes the strategically most important commodity, taking over that role from oil."

The price for a pound of copper rocketed to an all-time record of $4.76 in May, double the $2.38/lb price a year earlier, before settling in at around $4.25 at mid-year.

This, however, is considered by many as just the start, as a "supercharged" surge in demand is forecast to continue elevating the price for this most critical noncritical energy metal.

"In the short term, we've had a big rise in the price of copper," Friedland said during a keynote address at the CRU World Copper Virtual Conference 2021. "But for the medium term, copper has really become a national security issue. It's central for what we want to do with our economy."

Goldman Sachs analysts foresee copper prices continuing to climb to between $5.00 and $5.45 per lb over the next year and upwards of $6.80/lb by around 2025.

Other analysts have predicted that copper could go as high as $10.00/lb before enough mine supply comes online to meet the demands of the global green energy and transportation revolution.

Copper demand trifecta

Copper's rise as an energy commodity with the power to dethrone oil is energized by three fundamentals – low-carbon electricity, low-carbon e-mobility, and more low-carbon electricity.

Or, as Friedland put it, "It's all copper, copper, copper, copper, copper, copper."

The low-carbon copper trifecta begins with the fact that generating electricity from renewable sources such as wind and solar needs a lot more copper than the fossil-fuel-burning counterparts they are replacing.

It is estimated that on average, low-carbon sources of electricity require roughly five times more copper per megawatt of generating capacity than carbon burning counterparts such as coal- and gas-fired plants.

For example, a natural gas-fueled power requires roughly 2,425 lb of copper for every megawatt of electrical generation capacity, but it takes about 6,400 lb of copper per megawatt of onshore wind generating capacity or 17,600 lb for offshore.

Even photovoltaic solar is estimated to need more than double the copper-per-megawatt than gas or coal.

Much of this increased copper demand is due to the powerlines needed to connect these more decentralized power sources to customers.

While generating and delivering renewable energy is creating enormous new copper demand, it is the EVs that "fuel up" their batteries with electricity that elevates the red metal to the status of new oil.

Benchmark Mineral Intelligence forecasts annual EV sales to hit 12 million units per year by 2025, a more than 500% increase from 2020 levels, before rocketing to 30 million by 2030 and 82 million by 2040.

The International Energy Agency estimates that roughly 117 lb of copper goes into the average EV, which is nearly 2.5 times the 49 lb of conductive metal needed for a typical internal combustion engine vehicle.

This means that by 2030 about 3.5 billion lb of copper per year will be going into EVs by 2030 and approximately 9.5 billion lb by 2040.

And, if you are going to have hundreds of millions of cars, trucks, busses, trains, heavy equipment, and other vehicles fueling up with electricity, much more copper-intensive renewable energy capacity will need to be added globally.

Goldman forecasts wind, solar, EVs, and charging stations will need a combined 11.9 billion lb of copper per year by 2030, with nearly half of the green metal going into EVs and the balance into power generation and charging stations.

The financial firm's copper forecast, however, only extends until the end of the decade and does not consider the continued transition to renewable energy and e-mobility.

Supply shortage coming

The World Bank estimates that the green energy transition alone will require roughly 1.1 trillion lb of copper over the coming 25 years, or an average of about 44 billion lb per year, which is roughly equivalent to all the copper mined around the world during 2020.

Nicholas Snowdon, a metals strategist for Goldman Sachs and contributor to the financial firm's "Copper is the New Oil" report, told attendees of the 2021 CRU World Copper Virtual Conference that there are not enough copper mining projects in the global pipeline to meet the green energy demands for the metal, creating "a record long-term supply gap by the end of the decade."

This lack of copper mines in the pipeline is largely due to weak prices and a reluctance to invest in new projects following the "Black Monday" stock market crash in 2011. As a result, copper prices dropped from above $4.00/lb before the Aug. 8, 2011 event to a low of $2.00/lb in 2016. As recently as March of 2020, following a drop related to the COVID-19 outbreak, the price for a pound of copper was only $2.17.

Ivanhoe Mines founder Robert Friedland

>> Copper is so vital to the renewable energy and electric transportation revolution that international investment bank Goldman Sachs has declared this conductor metal to be the new oil of the low-carbon electric future this base metal is helping to empower.

Snowdon says the copper imbalance being created by runaway renewable energy and e-mobility demand "can only be resolved by higher prices stimulating investment in new supply."

In a world with millions of EVs plugged into renewable energy-charged electrical grids, this will likely keep copper prices at levels that spur mining companies to invest in copper projects that have been sitting on the shelf for the better part of a decade.

Considering that it takes roughly a decade to get a large and already advance staged mining project through the permitting process, the mining industry is going to have a hard time feeding enough copper into global supply chains to meet the demand trifecta spurred by the envisioned transition to e-mobility plugged into renewable electricity.

With lofty climate goals at stake, the lack of copper needed to wire the renewable energy revolution raises the criticality level of this base metal.

"As we have long argued, moving the global economy toward net-zero emissions remains a core driver of the structural bull market in commodities demand, in which green metals – copper in particular – are critical," the Goldman Sachs analysts penned in the "Copper is the New Oil" report. DMN

Workers install cadmium-tellurium photovoltaic cells produced by First Solar.

FIRST SOLAR INC.

Solar powers demand for rare tellurium

Rio Tinto recovering metalloid as Kennecott copper byproduct

By **SHANE LASLEY**

DATA MINE NORTH

AMONGST THE RAREST OF THE STABLE ELEMENTS on the periodic table and an important ingredient in the emerging thin-film solar panel sector, tellurium embodies what it means to be a critical metalloid – an element that possesses the properties of both a metal and non-metal.

"Most rocks contain an average of about 3 parts per billion tellurium, making it rarer than the rare earth elements and eight times less abundant than gold," the United States Geological Survey wrote in a 2015 report on tellurium. "Grains of native tellurium appear in rocks as a brittle, silvery-white material, but tellurium more commonly occurs in telluride minerals that include varied quantities of gold, silver, or platinum."

Because it is so uncommon and typically recovered as a byproduct of its more abundant neighbors on the periodic table, very little of this element that possesses the properties of both a metal and non-metal is produced. During 2020, only about 490 metric tons of tellurium was recovered as a byproduct of refining copper concentrates, with roughly 60% being produced in China.

It is hard to pinpoint how much tellurium is produced in the U.S. due to the proprietary nature of the recovery of byproduct metals at refineries. One copper refinery in Texas ships tellurium-containing anode slimes to Mexico for further refining.

It is expected that other copper refiners will need to begin recovering tellurium considering the growing demand for the metalloid for photovoltaic solar energy generation.

"The main concern surrounding tellurium supply is the question of whether or not global copper production can meet the growth in tellurium demand," USGS penned in a 2014 tellurium brochure.

Fortunately, the same low-carbon energy push that is increasing the demand for more solar panels and the tellurium that goes into them is also creating massive demand for copper, which should create new sources of tellurium, if refiners are willing to invest in the equipment to recover it.

■ *More information on the copper needed for electric vehicles and renewable energy can be read at* ***Renewable revolution powers copper demand*** *on page 21.*

Solar powers new demand

Traditionally, the small amounts of tellurium produced globally was used as an additive to improve the strength and pliability of steel, copper, and lead alloys. This has changed with the advent of cadmium telluride (CdTe) thin-film solar panels.

While the solar market continues to be dominated by traditional silicon solar panels, CdTe panels are becoming increasingly popular. This is due to these thin-film panels' ability to absorb sunlight close to the optimal wavelength for converting to electricity, and they are relatively inexpensive to make.

Despite their sunlight absorption capacity, CdTe thin-film cells are less efficient than their silicon counterparts. The low production costs, however, often overcome this disadvantage and CdTe have been the panel of choice in some of the largest solar farms in the U.S.

USGS estimates about 40% of the tellurium consumed in the U.S. during 2020 went into CdTe photovoltaic cells, the balance was primarily used to produce bismuth telluride thermoelectric devices for cooling and energy generation; as an alloying additive to improve the machining characteristics of steel; and as a vulcanizing agent and accelerator in the processing of rubber.

"CdTe solar cells are the second most common photovoltaic technology in the world marketplace after crystalline silicon, currently representing 5% of the world market," according to the U.S. Department of Energy. "CdTe thin-film solar cells can be manufactured quickly and inexpensively, providing a lower-cost alternative to conventional silicon-based technologies."

Due to the low cost of CdTe solar cells, coupled with being less affected by dust, shading, and high temperatures, this emerging technology is expected to continue to nab larger shares of the solar market.

Earlier this year, First Solar, a world-leading manufacturer of CdTe solar systems, announced that it is investing $680 million to expand its U.S. photovoltaic solar manufacturing capacity by 3.3 gigawatts.

This new facility will be one of the most advanced of its kind in the solar industry, allowing First Solar to produce an anticipated average of one CdTe module roughly every 2.75 seconds across its three-factory Ohio footprint once full production capacity is reached.

"These investments in American-made solar technologies are the perfect embodiment of President Biden's strategy to build out domestic manufacturing and supply chains for critical industries," said U.S. Secretary of Energy Jennifer Granholm.

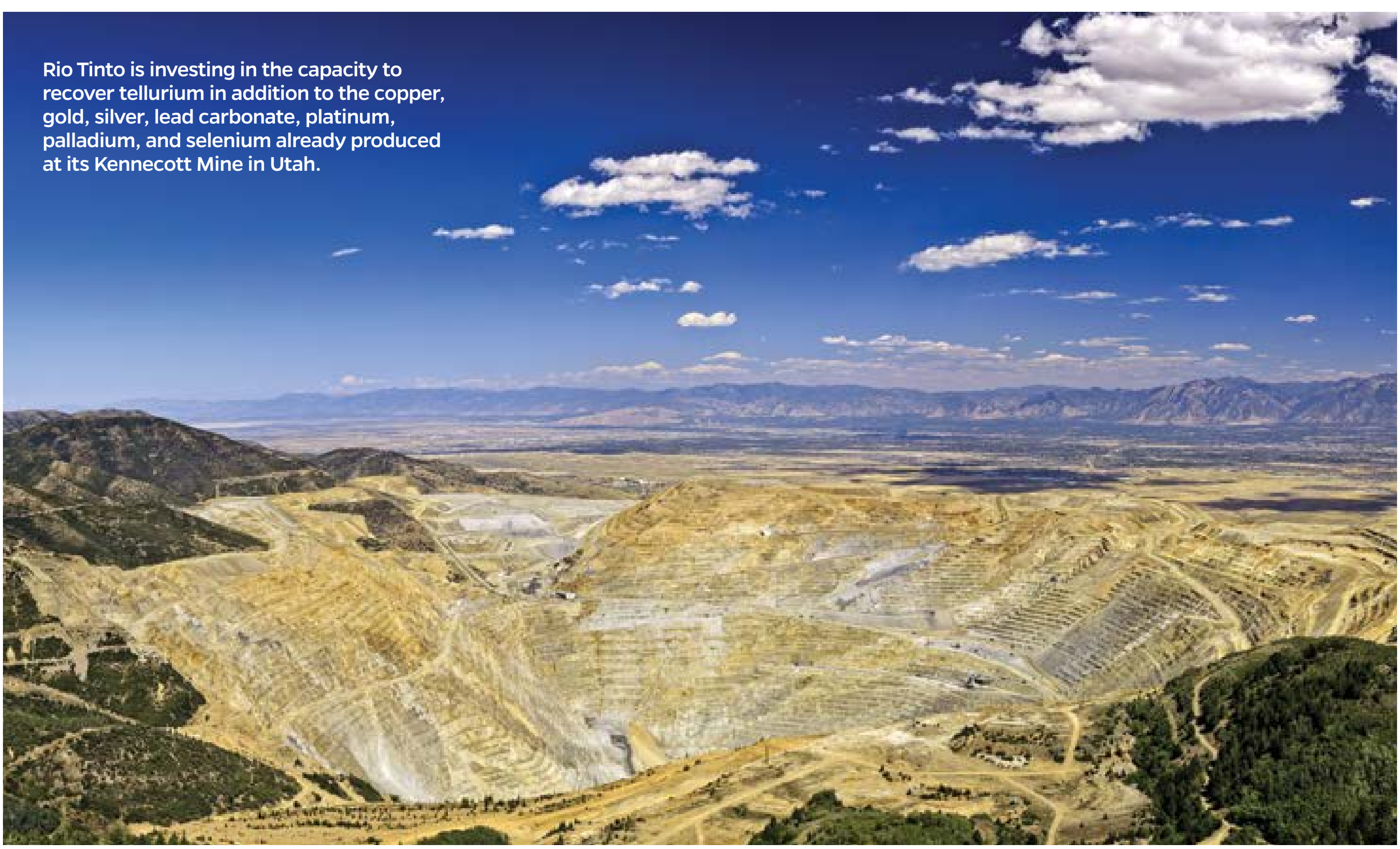
Kennecott tellurium

Thanks to a $2.9 million investment by global miner Rio Tinto, new supplies of American mined tellurium will be available to First Solar.

Announced earlier this year, Rio Tinto's investment is in a new plant that will recover about 20 metric tons of tellurium per year as a byproduct of smelting copper at its Kennecott Mine in Utah.

"With abundant natural resources, Utah is ideally positioned to help supply the critical minerals essential to maintain American manufacturing competitiveness," said Utah Gov. Spencer Cox. "Rio Tinto's smelter at Kennecott is one of only two that is capable of producing copper and other critical minerals. The new tellurium plant is another valuable contribution to critical mineral independence and energy security in the U.S."

In addition to accounting for nearly 20% of U.S. copper production,



Rio Tinto is investing in the capacity to recover tellurium in addition to the copper, gold, silver, lead carbonate, platinum, palladium, and selenium already produced at its Kennecott Mine in Utah.

ADOBE STOCK

COEUR MINING INC.

Coeur Mining's Kensington gold mine in Alaska hosts abundant telluride, but this mineral is tough to recover.

Kennecott's smelting process also recovers gold, silver, lead carbonate, platinum, palladium, and selenium. With the addition of the molybdenum recovered from Rio Tinto's Copperton concentrator, nine products are currently recovered from Kennecott ore.

"The minerals and metals we produce are essential to accelerate the transition to renewable energy," said Rio Tinto Kennecott Managing Director Gaby Poirier. "Adding tellurium to our product portfolio provides customers in North America with a secure and reliable source of tellurium produced at the highest environmental and labor standards with renewable energy."

First Solar said tellurium from the Utah mine could supplement its current supplies coming from the U.S., Canada, and Europe.

Telluride-rich gold mines

CdTe cells also happen to be long-lasting – First Solar says its newest series of cells will retain at least 92% of its original performance at the end of their 30-year warranty – so recycling from these panels may not be a significant source of tellurium in the near-term. If solar demand for tellurium does happen to outpace byproduct copper production, however, there is another option – gold mines.

"Recycling solar cells may help, but tellurium-rich films have long lifespans and to date have not been extensively reused. It might become an economic necessity to extract tellurium directly from telluride minerals during gold mining in locations such as Cripple Creek, Colorado; the Sierra Foothills of California; and southeastern Alaska," USGS wrote.

The world-class Archean gold deposits of the Abitibi and Yellowknife greenstone belts in Canada also have elevated concentrations of tellurium.

Telluride minerals are common in deposits in the Kirkland Lake and Red Lake districts of Ontario, as well as the Yellowknife mining district in Northwest Territories.

>> *"The new tellurium plant is another valuable contribution to critical mineral independence and energy security in the U.S."*

–Utah Gov. Spencer Cox

While much of the gold recovered from mines like Coeur Mining's Kensington operation in the Juneau Gold Belt of Southeast Alaska is hosted in telluride minerals, recovering the tellurium is not easy.

"Tellurium concentrations are highest in precious-metal-bearing deposits that contain abundant telluride minerals; these deposits, however, currently are not significant sources of tellurium because the ore-processing method to extract gold and silver is not amenable to tellurium recovery," the USGS reported in a 2018 report.

Tellurium, though, is seldom considered an economic byproduct from this type of mine globally, and only two mines on the planet produce this critical metalloid as a primary commodity.

So, the world will likely need to lean on porphyry copper mines for supplies of the tellurium that is expected to be needed to produce solar electricity in the coming years.

Considering that the World Bank estimates that the green energy transition alone will require roughly 1.1 trillion lb of copper over 25 years or an average of about 44 billion pounds per year, roughly equivalent to the total global copper consumption in 2020, there should be a lot more byproduct tellurium available. DMN

Cobalt sulfate is unmatched when it comes to delivering high-voltage, energy density, and allowing for the movement of lithium ions in batteries.

ADOBE STOCK

Solving the critical cobalt conundrum

A battery metal the EV sector cannot live with, or without

By SHANE LASLEY

DATA MINE NORTH

THE ENVISIONED GREEN FUTURE where every North American is driving a battery-powered electric vehicle charged with renewable energy could be undermined by cobalt, a somewhat scarce and controversial metal that makes lithium-ion batteries better.

"Cobalt is considered the highest material supply chain risk for electric vehicles in the short and medium term," the U.S. Department of Energy penned in an April report.

This risk has automakers, lithium-ion battery manufacturers, and government agencies investigating battery chemistries that reduce the amount of cobalt needed – a task that is not easy without sacrificing the safety and performance provided by this critical transition metal.

While the sector has made headway in reducing the amount of cobalt needed, the average 100-kilowatt-hour lithium-ion battery pack, the size used to power a Tesla Model S or Model X, currently has roughly 20 kilograms (44 pounds) of cobalt, according to DOE.

Benchmark Mineral Intelligence, a world-leading battery supply chain analyst, estimates that a 35 gigawatt-hour lithium-ion battery megafactory requires roughly 6,000 metric tons, or 6 million kg, of cobalt per year.

According to the United Kingdom-based firm's June data, more than 200 megafactories are being built, or are in the pipeline to be built in the coming years.

With existing battery chemistries, these currently planned lithium-ion battery factories alone would need a staggering 651,000 metric tons of cobalt, which is 465% more than the 140,000 metric tons that the United States Geological Survey calculates was mined globally during 2020.

This projected massive growth in cobalt demand is further complicated by the fact that this battery ingredient is seldom mined as a standalone metal. Instead, it is typically produced as a byproduct at copper and nickel mines.

"This situation limits producers' flexibility in adjusting the amount of cobalt mined in response to changes in demand and can result in periods of oversupply or shortage," according to the USGS.

With rocketing demand driving the price of cobalt up to above US$24 per pound by late July, a nearly 40% increase over the $33,000/t at the onset of the year, the economics of recovering cobalt as a byproduct is becoming more intriguing for North American copper and nickel producers.

The climbing demand and price has also spurred the revival of a cobalt factory in Ontario, a Canadian province known for hosting deposits rich in silver and cobalt.

SHANE LASLEY

A sample of copper- and cobalt-rich mineralization from Ambler Metals' Bornite project in Alaska.

The cobalt conundrum

Beyond the expectation that the global mining sector will be challenged to keep pace with skyrocketing demand, another impetus to establish North American sources of cobalt is most of this increasingly important battery metal is currently mined in the Democratic Republic of Congo (DRC), a country plagued with political and social issues.

Artisanal mining in DRC has captured headlines around the world due to the unsafe working conditions and human rights violations as men, women, and children hand-dig down into some of the richest sources of cobalt on Earth.

It is estimated that artisanal mines are the source of 10 to 20% of the cobalt coming out of DRC, a country that accounts for nearly 70% of the world's supply of this controversial battery metal.

This creates a conundrum for EV and green energy companies that need cobalt for their batteries but do not want to be seen as contributing to the endangerment of children to lessen mankind's carbon footprint.

Bending to pressure from human rights groups and socially conscious EV drivers, many electric automakers and lithium-ion battery manufacturers have sworn against sourcing their cobalt from DRC – especially artisanal mines.

TDI Sustainability, a global advisory firm, argues that turning a blind eye to DRC artisanal cobalt mining will only make matters worse for the people willing to put themselves and their families at risk to dig up enough of this important metal to survive.

"Presented with the option to not source from places considered high risk, most manufacturing companies would willingly opt out. But by doing so, the very people whose lives are most affected – for whom the risk is the greatest – can be left bereft of a livelihood: the very thing that sustains their families and communities," wrote TDI team members Assheton Carter and David Sturmes.

To help support safe small-scale cobalt mining, TDI has teamed up with like-minded businesses and social impact awareness groups to form the Fair Cobalt Alliance, a group focused on making artisanal mining of cobalt and other minerals, safer and more productive.

This alliance boasts Glencore plc, the largest cobalt mining company in the world, Swedish luxury automaker Volvo, and Tesla amongst its members.

Transforming DRC's artisanal mining to a force for good, however, would not completely resolve the cobalt stigma.

This is because roughly 80% of the global production of cobalt sulfate, the upgraded form of cobalt used in lithium-ion batteries, is produced in China.

Cobalt-free recipe

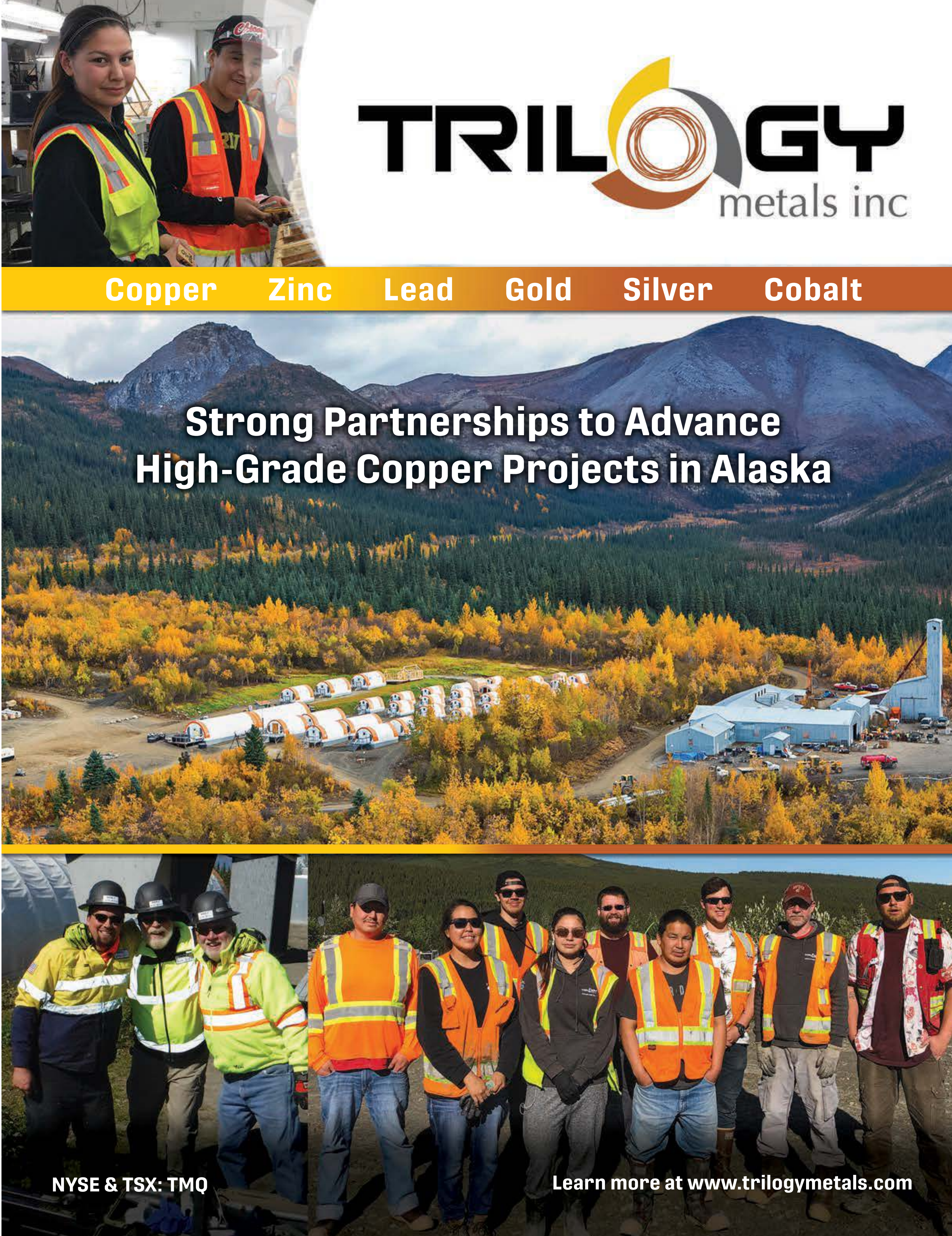
The perception that cobalt could be tainted by DRC human rights abuses and lax environmental standards in China has automobile and battery manufacturers looking for solutions, including less cobalt-intensive recipes for cathodes.

Tesla, which delivered 499,550 EVs to customers and continued to dominate the field during 2020, is among the companies seeking lithium-ion battery chemistries that require less cobalt.

Eliminating cobalt from the lithium-ion battery recipe is akin to developing a gluten-free pizza crust – alternatives are available for those who absolutely cannot have gluten, but it is tough to develop a flourless recipe that has all the attributes that would make all pizza lovers want to eat the pie.

While other transition metals such as manganese, nickel, iron, and titanium are potential substitutes in a lithium-ion battery recipe, none can match cobalt when it comes to delivering high-voltage, energy density, and the movement of lithium ions.

"Moving away from high cobalt content means the new cathode materials must be optimized for all of these performance characteristics via subtle changes in the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FIRST COBALT CORP.

Miners working underground at First Cobalt's Iron Creek cobalt-copper project in Idaho.

arrangement of the transition metals and their relative compositions," DOE explained.

While government and industry efforts are expected to lower the percentage of cobalt going into each battery, this will not offset the massive volume of batteries to be produced over the coming years and decades. This has battery manufacturers, even those looking to eliminate cobalt from the battery mix, racing to the mines to ensure they have the socially and environmentally responsible supplies of this battery metal.

Early in 2019, Tesla cut a deal to buy cobalt from Glencore Plc, the world's largest producer of this battery metal.

Samsung SDI, a South Korean lithium-ion battery manufacturer, also cut a deal for Glencore cobalt. Under the terms of this supply contract, Glencore will provide up to 21,000 metric tons of cobalt contained in cobalt hydroxide between 2020 and 2024.

In Europe, BMW Group secured a deal for 100 million euros ($119 million) worth of cobalt from Managem Group, a Moroccan mining company the German automaker selected for its sustainable and ethical mining practices.

Tesla CEO Elon Musk hinted that his EV company may form closer bonds with mining companies as it seeks to secure cobalt and other battery materials.

"We might get into the mining business. I don't know," Musk said. "We'll do whatever we have to ensure that we can scale at the fastest rate possible."

First Canadian cobalt

While not as rich as DRC, North America does have its own cobalt-enriched areas. This includes Ontario, which will soon be delivering the cobalt sulfate needed for the lithium-ion batteries being produced for EV manufacturers in the U.S. and Canada.

Looking to position itself at the front end of North American supply chains, the eastern Canada province recently unveiled plans to develop a critical minerals strategy to "generate investment, reduce red tape, create jobs, and advance Indigenous participation in the sector," according to Ontario Minister of Energy, Mines and Northern Development Greg Rickford.

The metals-rich province has already made several key moves toward this strategy to feed critical minerals into low-carbon supply chains, including the establishment of the first and, as-of-now, sole primary cobalt refinery in North America.

Being developed by First Cobalt Corp., this rail-accessible refinery less than 400 miles away from Great Lakes manufacturing towns such as Detroit and Buffalo will be capable of producing 25,000 metric tons of battery-grade cobalt sulfate per year, which will go a long way toward filling North American requirements.

In January, First Cobalt inked an agreement with Glencore to supply enough cobalt hydroxide feed material for the refinery to produce 22,250 metric tons of the cobalt sulfate used in the cathodes of lithium-ion batteries, which represents about 90% of plant capacity.

Commissioning of the First Cobalt refinery is slated to begin late in 2022 and by 2023 is expected to account for 25% of the cobalt sulfate produced outside of China.

The First Cobalt refinery happens to lie in a region of Ontario renowned for its cobalt-enriched silver deposits.

First Cobalt, the company, owns more than 10,000 hectares (24,700 acres) of silver-cobalt exploration properties along the Ontario Cobalt Belt near its refinery, which could offer new sources of cobalt coming out of the critical minerals-enriched province.

"Industries across Ontario and around the world need a steady supply of critical minerals to support new technologies and emerging industries, including electric vehicles," said Rickford.

First Cobalt project in Idaho

Despite its cobalt prospective lands in Ontario, First Cobalt is currently focusing its exploration efforts on the Iron Creek cobalt-copper project in Idaho, which hosts one of the few primary cobalt deposits in the world.

According to a 2019 calculation, Iron Creek hosts 2.2 million metric tons of indicated resource averaging 0.26% (12.3 million pounds) cobalt and 0.61% (29 million lb) copper; plus 2.7 million metric tons of inferred resource averaging 0.22% (12.7 million lb) cobalt and 0.68% (40 million lb) copper.

With the goal of doubling the size of the resource, First Cobalt launched a C$2.5 million exploration program at Iron Creek in June.

"With our Canadian refinery expansion underway, we are turning our attention to our flagship mineral project in Idaho," said First Cobalt President and CEO Trent Mell. "Drilling aims to extend the cobalt and copper mineralization at Iron Creek and test for new mineralization at nearby targets that could result in additional resources on the property."

"Our vision in Idaho is to build a modern underground mine operation and mineral processing facility centered on the Iron Creek cobalt-copper deposit," he added

To realize this vision, the company is working with experts at the Colorado School of Mines to develop innovative techniques for recovering the cobalt and copper from its Iron Creek.

This US$1.2 million research project is being equally co-funded by First Cobalt and DOE's Critical Materials Institute.

"To have the support of the United States government to further a national strategy of developing a domestic supply of cobalt further reinforces the First Cobalt value proposition as North America's only integrated supplier of battery materials for the electric vehicle industry," said Mell.

FIRST COBALT ALLIANCE

Many artisanal cobalt miners in the Democratic Republic of Congo take great pride in their work and see mining as an opportunity to build a future for themselves and their families.

On the northern horizon

In addition to Ontario and Idaho, several exploration projects in Canada and Alaska have the potential to offer cobalt as a coproduct of other metals that would be produced if a mine were to be developed.

One of the most intriguing of these deposits is at Fortune Minerals Ltd.'s Nico cobalt-gold-bismuth-copper project in Northwest Territories.

FIRST COBALT CORP.

The First Cobalt refinery in Ontario will be capable of producing 25,000 metric tons of battery-grade cobalt sulfate per year.

TESLA INC.

The average 100 KWh lithium-ion battery pack, the size used to power a Tesla Model X, currently has roughly 44 lb of cobalt.

According to a 2020 plan, a mine at Nico and an associated refinery in a Canadian province such as Saskatchewan would produce an average of 1,800 metric tons of battery-grade cobalt sulfate; 1,700 metric tons of bismuth; 300 metric tons of copper; and 47,000 oz of gold annually over the first 14 years of mining.

This mix of critical, precious, and base metals may be an intriguing prospect for those wanting to see more cobalt mined and refined in North America.

Giga Metals Corp.'s Turnagain project in Northern British Columbia is another potential Canadian source of cobalt, along with the nickel also needed in lithium-ion batteries.

A preliminary economic assessment completed last October outlined plans for a mine at Turnagain that would produce an average of 33,215 metric tons of nickel and 1,962 metric tons of cobalt annually over a 37-year mine life.

One of the things that could make this project attractive to automotive and battery manufacturers is a unique characteristic of the ore that could result in a truly carbon-neutral source of the battery metals.

This is due to the fact that the tailings left behind after the nickel and cobalt are extracted are really good at absorbing carbon dioxide out of the atmosphere.

"We now have empirical data that supports our ambition to build the world's first true carbon-neutral nickel mine, meaning a project that achieves carbon neutrality without purchasing carbon credits," said Giga Metals President Martin Vydra.

■ *More information on Turnagain can be read at* ***Miners answer Musk call for more nickel*** *on page 37.*

In Alaska, a world-class copper deposit being advanced toward development by Ambler Metals, a joint venture owned equally by Trilogy Metals Inc. and South32 Ltd., has the potential to produce cobalt alongside the copper needed in vast quantities for EVs and renewable energy.

According to a calculation completed in 2018, Bornite hosts 6.4 billion lb of copper and 77 million lb of cobalt.

Metallurgical work shows promise that a cobalt concentrate could be produced at this world-class deposit in Northwest Alaska, which is a good indication that a future mine there could produce the battery metal as a byproduct.

While currently off-limits due to being locked up in a park, the Windy Craggy deposit in northwestern BC is considered among the richest stores of cobalt in North America.

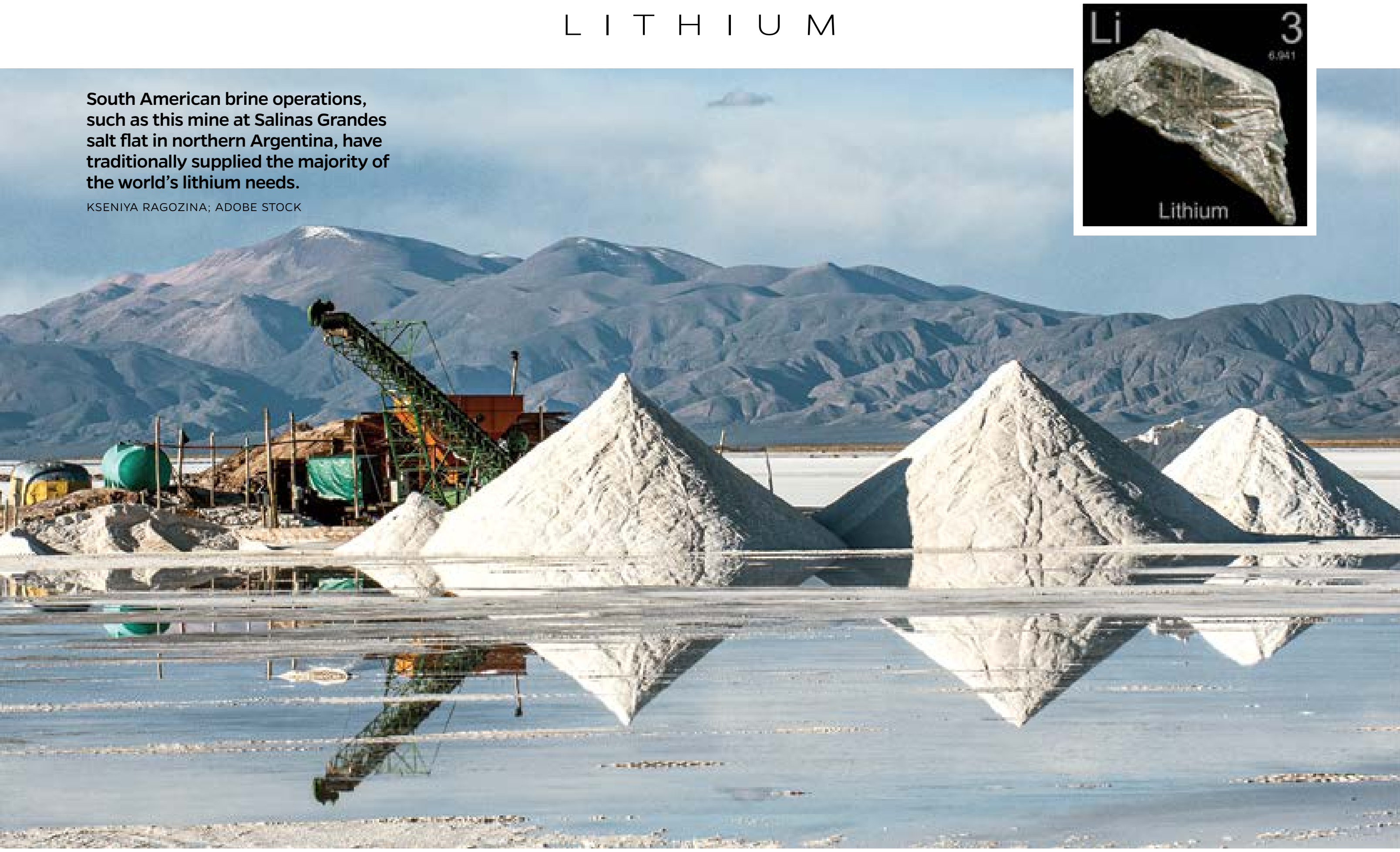
Situated about 30 miles east of the Alaska border, Windy Craggy hosts an estimated 297.4 million metric tons of historical resource averaging 1.38% (9 billion lb) copper, 0.069% (452.5 million lb) cobalt, 0.2 g/t (1.9 million oz) gold, and 3.83 g/t (35.3 million oz) silver.

This adds up to roughly US$59 billion based on mid-2021 prices.

Bruce Downing, a geologist who has been involved with Windy Craggy since 1975, and Contango ORE Inc. President and CEO Rick Van Nieuwenhuyse believe that this rich project is worth a second look.

"Cobalt in particular is a metal absolutely critical in battery storage for electric vehicles as well as other storage applications. It has been deemed a Critical Metal by the USA and Canada. When combined with the fact that 65% of the world cobalt metal is sourced in the Congo – not a country known for its stability or transparency, but rather known for its abuse of child labor and human rights violations – is it not our responsibility to ask ourselves if we made a mistake locking up a high quality, North American source of cobalt that could be mined and processed with strict environmental standards and appropriate human rights and labor controls so that cobalt is ethically sourced?" they queried in a 2020 article published in Resource World and North of 60 Mining News.

North American governments, carmakers, and battery manufacturers are pondering similar questions as they march ahead with plans to transition to an e-mobility future – a future that will likely have some cobalt in the recipe. DMN



South American brine operations, such as this mine at Salinas Grandes salt flat in northern Argentina, have traditionally supplied the majority of the world's lithium needs.

KSENIYA RAGOZINA; ADOBE STOCK

Titans forge critical lithium alliances

Tesla, GM, Schlumberger, and Panasonic focus on US supplies

By SHANE LASLEY
DATA MINE NORTH

THE LIGHTEST OF ALL THE METALS in the universe, lithium has emerged as the namesake for the batteries powering electric vehicles down global highways and storing renewable energy for those EVs to plug into. This is on top of the countless laptops, tablets, smartphones, wearable electronics, power tools, household appliances, electric bikes, scooters, toys, and the seemingly endless list of electric devices made possible by lithium-ion batteries.

"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," the United States Geological Survey penned in its 2021 mineral commodities report.

While a 10-fold rise in lithium-ion battery production has driven a roughly 325% increase in lithium usage over the past decade, this is only a start of the massive new demand being powered by a global push to transition to EVs plugged into power grids charged with renewable energy.

During Tesla Inc.'s 2020 Battery Day event, CEO Elon Musk elevated the electric automaker's already high battery production objectives from billions of watts of storage per year to trillions of watts.

"So tera is the new giga – and a terawatt is a thousand times more than a gigawatt," he said. "So, we used to talk in terms of gigawatts, in the future, we'll be talking in terms of terawatt-hours ... this is what's needed in order to transition the world to sustainability."

Tesla estimates that global battery factories will need to churn out 10 TWh of storage capacity per year to achieve the ultimate goal of trading in all the carbon fuel-burning vehicles traveling global highways with shiny new electric models.

For its part, Tesla plans to ramp up its in-house battery producing

Sitting atop one of the largest known geothermal resources in the world, Controlled Thermal Resources' Hell's Kitchen project in California has the potential to produce up to 1,100MW of renewable electricity and 300,000 metric tons of near-zero-carbon lithium per year.

CONTROLLED THERMAL RESOURCES LTD.

capacity to 3 TWh/year over the next decade.

"Long-term, we're expecting to make on the order of a 3,000 gigawatt-hours or 3 TWh per year," said Musk. "I think we've got a good chance of achieving this actually before 2030, but I'm highly confident that we could do it by 2030."

"It's a lot of batteries, basically," added Drew Baglino, Tesla's senior vice president of powertrain and energy engineering.

And a lot of EV batteries means a lot of lithium, which is why automotive, energy, and battery heavyweights have begun securing U.S. supplies of this lightest of metals.

Establishing local supply chains

With the rise of the electric vehicle revolution, automakers are becoming increasingly concerned about and vested in the battery metal supply chains. And these supply chains are expected to be shortened from global to continental and even regional as battery and vehicle manufacturers seek to hold down the costs and lower the carbon footprint of materials.

"If you put a GPS tracker on a molecule from when it got mined to when it was in a usable product, it would look insane," said Musk.

It has been estimated that the lithium that goes into its namesake batteries travels an average of 31,000 miles, or more than one trip around the world, before it reaches the customer. And this global excursion to be upgraded from a raw mined material to a battery-grade lithium product often makes a stop in China.

"Lithium's foundations for the 21st century are beginning to shift in what is a China-dominated part of the lithium-ion battery and electric vehicle supply chain," said Benchmark Mineral Intelligence Managing Director Simon Moores, a foremost expert on lithium-ion battery supply chains.

Any traffic jam along this global supply chain – whether it be at the mine, refinery, or battery facility – would likely slow EV adoption.

Another limiting factor is a mining sector that would be better likened to a cargo ship than a speedboat in terms of the maneuverability needed to meet rapidly changing market demands.

In the U.S., it typically takes a mining company at least a decade to deliver its first product from the time it applies for permits to build the mine. Even in countries such as Canada or Australia, where the permitting timelines are typically shorter, the time it takes to permit and build a large mining project creates a delay that does not reconcile well with the EV transition ambitions.

For these reasons, vertical integration – where one company becomes directly involved with two or more links along the supply chain – has become increasingly important to global automakers with world-changing EV ambitions.

"Tesla has clearly come to the realization that it cannot rely on the upstream of the supply chain or investors to expand quickly enough for its needs," said Moores.

Tesla heads upstream

The realization that it would need to become more vested in battery metals mining to achieve its EV goals led Tesla to cut a deal to buy future lithium from Piedmont Lithium Ltd.'s project in North Carolina, a U.S. state that once supplied most of the world's lithium and remains rich in the battery metal.

"As global automotive companies electrify their fleets, we expect them to increasingly seek ex-China sources of lithium supply, and North Carolina is ideally positioned to benefit given its proximity to major auto markets in the U.S. and Europe, and the deep lithium talent pool resident in the region," said Piedmont Lithium President and CEO Keith Phillips.

According to a 2021 calculation, Piedmont's North Carolina project hosts 39.2 million metric tons of indicated and inferred resources averaging 1.09% (422,000 metric tons) lithium oxide.

Piedmont envisions its coming North Carolina mine producing 248,000 metric tons per year of spodumene, a lithium mineral, concentrate per year, which the company will convert to 22,700 metric tons per year of battery-grade lithium hydroxide.

While the June scoping study shows robust economics for this operation, the company is particularly proud of North Carolina Lithium's sustainability profile.

"Customers, investors, and neighbors are increasingly focused on businesses that are 'doing things the right way.' It is critical that raw material supply chains do not detract from the overall sustainability of the transition to electric vehicles," said Phillips. "Our project will have a far lower environmental footprint than alternative suppliers, and we expect that to position Piedmont well with all stakeholders."

This sustainability will be of particular interest to Tesla, which has cut a deal to acquire 160,000 metric tons of spodumene annually. This is estimated to be enough to convert into 22,700 metric tons of the battery-grade lithium hydroxide needed to produce 25GWh of lithium-ion battery capacity, or around 400,000 Tesla vehicles per year.

Importantly, the lithium will be sold at a fixed price over the five-year term of the agreement. This will provide price stability for both companies in a market where oversupply followed by massive demand could cause major price fluctuations.

The North Carolina lithium produced by Piedmont will be delivered to Tesla's Texas Terafactory currently under construction near Austin. As its name implies, when built out to its full capacity, this facility is slated to produce 1,000 GWh (1 TWh) of batteries annually, which means this one megafactory alone will need nearly 1 million metric tons of battery-grade lithium per year.

More Nevada lithium

The Texas Terafactory and more than a dozen other lithium-ion battery gigafactories currently on the docket to be built in North America are going to need a lot more lithium than Piedmont will have the capacity to supply.

Currently, Albemarle's Silver Peak Mine in Nevada is the only large-scale lithium producer in the U.S.

Not a mine in the traditional sense, as Albemarle pumps brine from Nevada's Clayton Valley basin into ponds where the water is evaporated off to produce a lithium concentrate, Silver Peak is expected to produce 10,000 metric tons of lithium-carbonate-equivalent once an expansion to double capacity is complete.

"This investment in domestic capacity shows that we are committed to looking at the many ways in which Silver Peak can provide domestic support for the growing EV market," Eric Norris, Albemarle's president for lithium, said in reference to the nearly $50 million cost of the expansion.

The evaporation ponds such as those at Silver Peak cover thousands of acres, and it takes between 12 to 18 months of evaporation to produce concentrates that can be refined into battery-grade lithium.

There are others, however, that are developing innovative technologies capable of producing the enormous quantities of lithium needed from Nevada brines much faster and with a much smaller footprint.

This includes a partnership between energy powerhouses Schlumberger and Panasonic to validate and optimize differentiated direct lithium extraction technology.

Schlumberger, best known for delivering technological solutions to the oil and gas sector, recently formed Schlumberger New Energy, a division focused on low-carbon and carbon-neutral energy

SCHLUMBERGER NEW ENERGY

Schlumberger New Energy: NeoLith Energy's direct lithium brine extraction pilot plant is on Pure Energy Minerals' Clayton Valley project in Nevada.

technologies.

The lithium brine business, which involves drilling wells to extract the brine, is a perfect fit for leveraging Schlumberger's century of experience in oil and gas drilling and reservoir management.

One of Schlumberger New Energy's first projects in the United States is NeoLith Energy, a venture to utilize direct extraction to produce battery-grade lithium from brines in Nevada's Clayton Valley.

"We are committed to expanding the global supply chain for advanced lithium compounds to support the forecasted surge in demand and enable new opportunities for lithium production globally," said Schlumberger New Energy Executive Vice President Ashok Belani.

This project is benefitting from the lithium-ion battery experience brought by Panasonic, which joined the project earlier this year.

"Panasonic has a longstanding commitment to contributing to society and increasing sustainability in the supply chain as we work to produce the world's safest, highest quality and most affordable batteries is a critical priority," said Panasonic Energy of North America President Allan Swan. "We look forward to working with Schlumberger New Energy to help achieve our vision of advancing the lithium-ion battery space and accelerating to a clean energy society."

The plan for this facility first being developed as a pilot plant, is to pump brine from the subsurface, extract greater than 90% of the dissolved lithium, and pump more than 85% of the brine back to the subsurface in an environmentally safe manner.

This cutting-edge technology is expected to result in a sustainable process for producing battery-grade lithium material at a much faster rate than the months of waiting for the sun to evaporate the water off a lithium-rich brine.

With a much smaller groundwater and physical footprint than lithium brine extraction, this process has the potential to be a game-changer that creates new market opportunities for the lithium extraction and battery manufacturing sectors and maximizes the value of the lithium-rich resource base in Nevada.

The NeoLith Energy lithium pilot plant also happens to be only 200 miles from the Tesla Gigafactory 1 just outside of Reno, Nevada.

ADOBE STOCK

The global transition to electric vehicles plugged into low-carbon renewable energy is driving enormous new demand for sustainable sources of lithium in North America.

GM cooks up Hell's Kitchen deal

General Motors, which has declared plans to only manufacture zero-emission vehicles by 2035, has forged a strategic partnership with Controlled Thermal Resources Ltd. to source low-cost and environmentally responsible lithium from the Hell's Kitchen project at the Salton Sea Geothermal Field in Southern California.

"Lithium is critical to battery production today and will only become more important as consumer adoption of EVs increases, and we accelerate towards our all-electric future," said Doug Parks, executive vice president of global product development, purchasing and supply chain at GM. "By securing and localizing the lithium supply chain in the U.S., we're helping ensure our ability to make powerful, affordable, high mileage EVs while also helping to mitigate environmental impact and bring more low-cost lithium to the market as a whole. GM looks forward to working with CTR, in addition to state and local leaders, in achieving these goals."

Much like NeoLith Energy, Controlled Thermal Resources is establishing a direct extraction plant at Hell's Kitchen. This project, however, has the bonus of plentiful geothermal energy to power the lithium extraction process, as well as a plant that will upgrade it to the lithium hydroxide used in EV batteries. The lithium-less brine will then be pumped back down into the ground from which it was drawn, and the excess zero-carbon electricity will be delivered to the power grid.

This means that Hell's Kitchen can deliver a continuous baseload of renewable power to the Southern California electrical grid, as well as near-zero-carbon lithium that goes into the batteries that store intermittent solar and wind sources of renewable energy and EVs that plug into that green energy.

For an American automaker that aspires to lead "in all aspects of the transformation to a more sustainable future," lithium from a facility that also delivers near-zero carbon electricity will add several green energy stars to the 30 EV models it plans to have on global showroom floors by 2025.

"GM has shown great initiative and a real forward-thinking strategy by securing and localizing a lithium supply chain while also considering the most effective methods to minimize environmental impacts," said Controlled Thermal Resources CEO Rod Colwell.

Looking to ramp up operations in stages, CTR is planning to deliver the first 49.9MW of electricity by the end of 2023 and produce the first 20,000 metric tons of lithium hydroxide in 2024.

To keep up with the demand for domestic and environmentally responsible lithium to feed into a rapidly expanding American EV supply chain, CTR anticipates it will need to ramp up additional production capacity alongside this first stage of development at Hell's Kitchen.

"Worldwide growth in electric vehicle adoption has highlighted the critical need to develop a strong and secure battery supply chain in the United States," Colwell said. "CTR is fully committed to developing its significant lithium resource in response to this, and we look forward to collaborating with GM as we continue to accelerate these efforts."

Efforts that will help fill the demand for the millions of tons of lithium that will be needed each year to meet the skyrocketing demand powered by the rapid transition to EVs plugged into power grids charged with renewable energy. DMN

BHP's Nickel West operation in Western Australia includes nickel sulfide mines, a premium-grade nickel refinery, and a newly constructed plant to produce battery-grade nickel sulfate.
BHP GROUP

Miners answer Musk call for more nickel

Aussie mine to supply Tesla; much more battery metal needed

By SHANE LASLEY
DATA MINE NORTH

"PLEASE MINE MORE NICKEL," these four words from Tesla CEO Elon Musk reverberated across the global mining sector and raised awareness of how fundamental nickel is to the lithium-ion batteries powering hundreds of millions of electric vehicles to come off Tesla and traditional automaker assembly lines over the next two decades.

"Tesla will give you a giant contract for a long period of time if you mine nickel efficiently and in an environmentally sensitive way," Musk implored mining executives.

While there is no shortage of nickel in the world, the Tesla CEO is concerned that the global transition to EVs and the batteries that power them will outpace the mining sector's ability to deliver new supplies of this metal traditionally used for stainless steel and other alloys.

Benchmark Mineral Intelligence, a global leader in lithium-ion battery supply chain analysis, forecasts that roughly 1.7 million metric tons of nickel will be needed for batteries alone by 2030, a more than 900% increase over the 184,000 metric tons going into energy storage this year. As a result of this demand, the United Kingdom-based analytical firm anticipates that global needs for nickel will double over the next decade – from roughly 2.4 million metric tons this year to nearly 5 million metric tons in 2030.

This aligns with nickel forecasts put out in a 2021 International Energy Agency report that investigates "The Role of Critical Minerals in Clean Energy Transitions."

Under a scenario where low-carbon energy generation and EVs are adopted at a pace to meet the climate objectives of the Paris Agreement, IEA estimates that nickel demand will rocket to 4.6 million metric tons by 2030 and continue climbing to 6.3 million metric tons by 2040.

At this rate, EVs and low-carbon electricity generation would account for more nickel demand than all other uses for the metal combined.

The mining sector's inability to keep pace with this explosive new demand would drive up the costs of producing the batteries powering EVs and storing intermittent low-carbon energy, hampering global efforts to meet the climate goals of the Paris Agreement.

This is why Musk implored, "Any mining companies out there ... wherever you are in the world, please mine more nickel."

One global mining company has answered the Tesla CEO's call for nickel and many others, from junior explorers to global producers, are accelerating plans to bring more of this fundamental battery metal to markets as soon as possible.

Laterite versus sulfide

While nickel is found all over the world, the islands of the South Pacific are particularly enriched with this increasingly critical alloy and battery metal.

During 2020, three of these South Pacific Islands – Indonesia, Philippines, and New Caledonia – accounted for more than half of

GIGA METALS CORP.

Boxes of core from many years of exploration drilling at Giga Metals' Turnagain nickel-cobalt project in Northern British Columbia.

the nickel produced globally during 2020. Russia, Australia, Canada, and China accounted for much of the balance.

While the nickel mined from laterite ores found on South Pacific islands is great for stainless steel and other alloys, it is not ideal for transforming into the nickel sulfate needed that make up the bulk of cathodes in lithium-ion batteries.

The iron-nickel alloy produced from laterite ores can be upgraded to battery-grade nickel sulfate with a high-pressure acid leach (HPAL) process. The financial and environmental costs of HPAL, however, have many along the battery supply chains questioning whether laterite mines are viable sources of the nickel sulfate needed for lithium-ion batteries.

There were reports earlier this year, however, that Tesla was partnering as an industrial advisor to help ensure sustainable production at the Goro mine in New Caledonia. The government and other local interests own 51% of this potentially very large mine.

Brazil-based Vale SA, which recently sold its stake in Goro, and BHP Group are looking at increasing production of nickel from sulfide ore, which, as its name suggests, is more readily upgraded to battery-grade nickel sulfate.

Vale's Voisey's Bay operation in the eastern Canadian province of Newfoundland and Labrador is one such nickel sulfide mine.

Voisey's Bay is transitioning from an open pit mine to an underground operation capable of producing 40,000 metric tons of nickel-in-concentrate per year, which will be upgraded into finished nickel at Vale's Long Harbour facility in the province.

In addition to Voisey's Bay, Vale's Sudbury operation in Ontario, Canada, produces roughly another 65,000 metric tons of nickel and the Brazilian miner has been producing the highly demanded metal at its Thompson mine in the province of Manitoba since 1961.

According to a late-2020 Reuters report, Tesla and other lithium-ion battery manufacturers are negotiating deals to secure nickel from the Brazilian miner's Canada operations.

Mark Travers, executive director of base metals for Vale, confirmed that the miner is having conversations with Tesla and others about ensuring there is enough nickel available to meet battery demand in the coming years.

As a sign that the mining major is serious about ramping up Canadian nickel production to meet this demand, Vale announced that it is investing C$150 million to extend the life of its Thompson mine by 10 years and aggressively explore nearby orebodies that could extend the operation well past 2040.

"This is the largest single investment we have made in our Thompson operations in the past two decades," said Travers. "The global movement to electric vehicles, renewable energies, and carbon reduction has shone a welcome spotlight on nickel – positioning the metal we mine as a key contributor to a greener future and boosting world demand. We are proud that Thompson can be part of that future and part of the low-carbon solution."

Travers told Reuters that Vale is studying the potential to store carbon dioxide in tailings at the Thompson mine, which could lower the CO2 footprint of the nickel produced. This would make the nickel from this mine more attractive for Tesla and other global automakers looking for supplies of this battery metal that are mined "efficiently and in an environmentally sensitive way."

BHP secures Tesla contract

As attractive as Vale's Canadian nickel may be to the North American EV supply chain, BHP Group was the first to sign a giant nickel contract with Tesla.

"BHP produces some of the lowest carbon intensity nickel in the world, and we are on the pathway to net-zero at our operations," said BHP Minerals Australia President Edgar Basto. "Sustainable, reliable production of quality nickel will be essential to meeting demand from sustainable energy producers like Tesla Inc."

Under an agreement signed in July, the Anglo-Australian mining giant will supply the electric automaker with some of this quality battery metal from Nickel West, a Western Australia operation that includes nickel sulfide mines, a refinery that produces premium-grade nickel, and a battery-grade nickel sulfate plant.

While BHP and Tesla did not provide details on how much nickel this deal entails, Benchmark estimates that the contract is worth up to 18,000 metric tons of nickel per year starting in 2022.

In addition to the nickel supply pact, BHP and Tesla are working together to make the overall lithium-ion battery supply chain more sustainable.

This battery sustainability partnership is focusing on mine-to-EV raw material traceability using blockchain; technical exchange for battery raw materials production; and promoting the importance of sustainability in the resources sector, including identifying partners who are most aligned with BHP and Tesla's battery supply chain values.

"This is an alliance that will promote sustainability in the mining and resources sector," said Samantha Langley, principal of business development at BHP.

The global mining and EV companies are also working together to identify opportunities to lower carbon emissions in their respective operations through increased use of renewable energy paired with battery storage.

"We are at the beginning of a revolution that will transform our world," Langley said.

Carbon-neutral nickel mine?

While expanding current operations will help meet the needs of Tesla and other EV manufacturers in the near term, the rapid development of new nickel mines will be required to fill the doubling of demand forecast in the coming two decades.

A Canadian mine that produces both the nickel and cobalt needed for the lithium-ion batteries, while also locking up carbon dioxide in rocks for geological time periods, would check many of the environmental, social, and governance boxes of North American EV manufacturers seeking sustainable sources of battery metals.

Recent tests carried out at the University of British Columbia indicate the potential that Giga Metals Corp.'s Turnagain project in Northern BC could be one such greenhouse gas-absorbing mine.

A 2020 preliminary economic assessment outlined plans for a mine at Turnagain that would produce an average of 33,215 metric tons of nickel and 1,962 metric tons of cobalt annually for 37 years.

It just so happens that the tailings left behind after the nickel and cobalt extracted from the ore at Turnagain are really good at

Mining companies will need to nearly double nickel production over the next decade to keep pace with demand being set by the electric vehicle and renewable energy sectors.

TESLA INC.

absorbing CO2 out of the atmosphere. This process turns the tailings, which are typically crushed to a sand- or silt-like consistency, into carbonate rock.

A team led by UBC Professor Greg Dipple, who has been studying mineral sequestration of CO2 in mine tailings around the world for more than 15 years, shows the potential for this mineral carbonation process to permanently sequester vast amounts of CO2 at Turnagain.

An initial four-week test indicates that a mine at Turnagain could absorb at least 900,000 metric tons of CO2 over the life of the operation, or 0.72 metric tons of CO2 per metric ton of nickel produced.

Considering that this operation is only estimated to emit 0.75 metric tons of CO2 per metric ton of nickel if electric trucks are used for hauling, this baseline absorption would nearly make the mine carbon-neutral without any optimizations.

Dipple's tests, however, indicate that these CO2 absorption rates would increase by at least 25% under actual mining scenarios.

The testing also showed that only about 10% of the brucite – a magnesium hydroxide mineral at Turnagain responsible for sponging atmospheric CO2 – was consumed during the one-month sequestration test, indicating that Turnagain mine tailings would absorb more of the greenhouse gas with longer exposure to the air.

While much more detailed and longer-term testing will need to be done, a mine at Turnagain with an electrified mining fleet powered by the hydroelectric Northern BC is known for has the potential to be a CO2-negative producer of nickel and cobalt.

"We now have empirical data that supports our ambition to build the world's first true carbon-neutral nickel mine, meaning a project that achieves carbon neutrality without purchasing carbon credits," said Giga Metals President Martin Vydra.

Tesla CEO Elon Musk talks about the company's lithium-ion ambitions and the need for raw materials such as nickel to achieve those lofty goals during Tesla Battery Day 2020.

STEVE JURVETSON VIA FLICKER.COM; CREATIVE COMMONS 2.0

The ability to produce these lithium-ion battery metals with zero or less CO2 emissions would likely be attractive to EV and battery manufacturers looking to improve the ESG profiles of their supply chains.

"We recognize the growing importance of strong ESG performance from commodity producers," said Vydra. "We are proud that our project is at the forefront of being able to contribute to a carbon-free industry."

Much work, however, still needs to be done to demonstrate the economic viability of a carbon-neutral nickel mine at Turnagain and then advance that battery metals operation through permitting and development.

Getting projects like Turnagain across the finish line in time to supply the battery metals required to achieve the Paris Agreement vision of a carbon-neutral global economy by 2050 will require alliances between mining companies, conservation groups, local stakeholders, governments, academia, resource investors, and the low-carbon energy companies looking to transform critical minerals into EVs plugged into low-carbon energy.

Understanding that a shortage of battery metals, especially nickel, is the one thing that could hold back his vision of Tesla playing its role in e-mobility and renewable energy storage is why Musk sent out the message, "Any mining companies out there ... wherever you are in the world, please mine more nickel." DMN

Drills have outlined roughly 8.2 million metric tons of graphite in high-grade lenses at the Graphite Creek project in western Alaska.
GRAPHITE ONE INC.

EV revolution drives graphite demand

3 companies advance graphite anode projects in US, Canada

By SHANE LASLEY
DATA MINE NORTH

THE GLOBAL TRANSITION to electric vehicles plugged into renewable energy sources is powering enormous demand for graphite, the single largest ingredient in lithium-ion batteries.

"Graphite demand increases in both absolute and percentage terms since graphite is needed to build the anodes found in the most commonly deployed automotive, grid, and decentralized batteries," the World Bank penned in a 2020 report, "The Mineral Intensity of the Clean Energy Transition."

According to global lithium-ion battery experts at Benchmark Mineral Intelligence, a battery megafactory capable of producing 30 gigawatt-hours of annual capacity requires about 33,000 metric tons of graphite anode material per year.

When you extrapolate this out over the more than 200 battery megafactories that are being built or are in the pipeline, this equates to up to 5.4 million metric tons of battery-grade graphite anode material per year.

The International Energy Agency forecasts that the electric mobility and low-carbon energy sectors will demand 25 times more graphite per year by 2040 than today.

And this does not account for the traditional brake linings, lubricants, powdered metals, steelmaking, refractory, and other more traditional applications for this highly useful form of carbon.

According to "Mineral Commodity Summaries 2021," an annual report published by the United States Geological Survey, there are currently no graphite mines in the U.S., leaving American manufacturers reliant on imports for 41,000 metric tons of this industrial carbon allotrope.

China produced roughly 59% of the world's mined graphite during 2020. The next closest graphite producers were Mozambique (11%), Brazil (9%), and Madagascar (4%).

When it comes to battery-grade graphite anode material, which is

flake graphite that has been rolled into potato-shaped spheres and coated in a hard carbon shell that must be thermally treated, China was the only commercial-scale producer in 2020.

"North America produced only 2% of the world's graphite supply with production in Canada and Mexico," USGS inked in its 2021 mineral commodities report. "No production of natural graphite was reported in the United States, but two companies were developing graphite projects – one in Alabama and one in Alaska."

Both these companies – Westwater Resources Inc. in Alabama and Graphite One Inc. in Alaska – have plans to develop both graphite mines and the processing facilities to produce the spherical graphite that serves as the anode material in most lithium-ion batteries.

In Canada, Nouveau Monde Graphite Inc. is making progress on a similar strategy to supply battery manufactures with graphite anode material from the mine and processing facilities it is developing in Quebec.

Alabama graphite

Alabama is rapidly emerging as a center for producing the advanced anode material needed by North American automakers.

Westwater plans to have a graphite processing plant operating in Alabama by the end of 2022 and begin mining fresh supplies of the battery material from the Yellowhammer State's famed Alabama Graphite Belt by 2028.

In June, Alabama Gov. Kay Ivey signed an incentive package that will provide Alabama Graphite Products, a subsidiary of Westwater, with $29.9 million in jobs and tax credits over 15 years, and $925,000 in job training and employee recruitment incentives for a facility that will produce the battery-grade graphite anode material needed for lithium-ion batteries.

"This plant not only will make Alabama the U.S. leader in graphite production, the go-to place for this important resource in battery manufacturing, it also will elevate our standing even more as a major player in the fast-growing electric vehicle sector," Ivey said. "We're home to four major auto plants, and the ability to source precious materials in-state for the lithium-ion batteries used in electric and hybrid vehicles will be a big plus in attracting other manufacturing jobs to the state."

Alabama Graphite's processing plant will initially produce approximately 7,500 tons of battery-grade graphite per year, and the company has plans to double this output.

The initial investment for this facility is expected to be at least $80 million, with another $44 million for the second phase.

Construction is expected to begin later this year, with the plant upgrading third-party graphite concentrates into high-value anode


NOUVEAU MONDE GRAPHITE INC.

Nouveau Monde plans to produce 100,000 metric tons of graphite concentrate per year from a zero-carbon mine at its Matawinie project in Quebec.

material by the end of 2022.

"Even though the raw graphite we will process into battery-grade material will be imported initially, none of it will be from China. We have secured agreements from other providers," said Westwater Resources President and CEO Chris Jones.

While the company has not named its providers, Syrah Resources Ltd. and its Balama mine in Mozambique would be a good fit.

With roughly 16.9 million metric tons of graphite hosted in 107.54 million metric tons of proven and probable reserves averaging 15.7% graphitic carbon, Balama is one of the world's most significant sources of graphite.

Some of the raw graphite mined at Balama is being shipped to Syrah's plant in Vidalia, Louisiana, where it is being upgraded into lithium-ion battery anode material.

Syrah's Vidalia facility has the capacity to produce 5,000 metric tons of unpurified spherical graphite and, with the installation of the furnace, upgrade 200 metric tons to active anode material.

While 200 metric tons per year of active anode material only represents a fraction of the current and forecasted needs in the U.S., it takes Syrah a step in the right direction and provides battery manufacturers a sample of the product to be commercially produced in Louisiana.

Whether or not Syrah is a provider of material for Westwater's Alabama Graphite plant, the Colorado-based miner plans to have an in-state source when it develops a mine at its Coosa project in the Alabama Graphite Belt.

According to a 2015 calculation, Coosa hosts 78.5 million metric tons of indicated resource averaging 2.39% (1.9 million metric tons) graphitic carbon; plus 79.4 million metric tons of inferred resource averaging 2.56% (2 million metric tons) graphitic carbon.

Vanadium, a critical metal emerging as an important ingredient in large redox flow batteries for storing renewable energy, has also been identified at Coosa. Westwater is evaluating this vanadium potential at Coosa ahead of developing a graphite mine there, which is expected to go into production in 2028.

"Whether it's mining or processing graphite, our company is committed to doing it in an environmentally safe, sustainable manner," said Jones. "The biggest virtue of electric vehicles and other battery-powered products is they reduce carbon emissions and are better for the environment. Producing the key materials for those batteries, we believe, can and should be done in an environmentally responsible way as well."

Zero-carbon graphite

Environmentally responsible graphite lies at the very heart of the graphite supply strategy being implemented by Nouveau Monde Graphite in Quebec.

"Nouveau Monde has committed to a zero-harm approach to producing advanced battery materials for decades to come. Carbon neutrality is an important part of this commitment," said Nouveau Monde Graphite Chairman Arne Frandsen. "We know that for many of our potential global clients, being able to purchase North American produced, high-quality carbon-neutral battery anode material, is of great importance. Nouveau Monde is determined to establish itself as one of the world's largest and most important sources of anode material for lithium-ion batteries."

A feasibility study completed in 2018 detailed plans for a mine at its Matawinie project in Quebec that would produce 100,000 metric tons of graphite concentrate annually over an initial 26-year mine life, based on 59.8 million metric tons of reserves averaging 4.35% graphite.

Nouveau Monde has since expanded the measured and indicated resources used as a basis for this study by 25%, suggesting the potential to extend the mine life, increase annual production, or both.

Flake graphite produced at a facility in the nearby town of Saint-Michel-des-Saints will be trucked roughly 100 miles (165 kilometers) to its advanced material plant at Bécancour, where it will be upgraded to the coated spherical graphite that serves as the anode material in most lithium-ion batteries.

The plant will initially be built to produce 45,000 metric tons of graphite anode per year, but the site is large enough to easily accommodate a 100,000-metric-ton-per-year plant in the future.

As a forward-looking company that is supplying a vital ingredient to the lithium-ion batteries storing renewable energy and powering electric vehicles, Nouveau Monde intends to shrink the carbon dioxide footprint of all its Quebec operations to net-zero.

To accomplish this, the graphite producer will power its operations with hydroelectric and will have an all-electric fleet of mining equipment at Matawinie. When operational, the all-electric mining fleet will result in 82% less direct emissions from mining.

While great strides have been made in recent years to develop all-electric underground mining equipment, not as much progress has been made on the surface mining trucks, loaders, excavators, and other equipment that will be needed at Matawinie.

To overcome this hurdle, Nouveau Monde signed a deal with Caterpillar Inc. to develop, test, and produce a fleet of all-electric Cat mining equipment for its coming graphite mine in Quebec – a landmark collaboration that will allow Nouveau Monde to achieve its lofty goals and advance technology that will provide surface mines around the globe an electric equipment option for reducing their carbon footprints.

"We are proud to be a driving force for our peers as we strive to electrify our operations to meet our carbon neutrality commitments while maintaining the productivity and efficiency standards of our mining operations," said Nouveau Monde Graphite President and CEO Eric Desaulniers. "Even more gratifying and important to our corporate mission is that our project can serve as a springboard for the future of the mining industry by collaborating with Caterpillar on these cutting-edge technologies."

As an added bonus for Nouveau Monde, each of the battery-powered Cat mining machines will need about a ton of graphite.

Desaulniers told Data Mine North that battery manufacturers interested in securing Nouveau Monde graphite have expressed interest in supplying Caterpillar with the batteries to power its electric machinery at Matawinie and around the globe.

Earlier this year, the company received a Quebec government environmental decree to begin developing a mine at its Matawinie project, and the company plans to start delivering the first carbon-neutral graphite in 2023.

Alaska graphite supply

While not quite as advanced, Graphite One's Graphite Creek project in Alaska is another project poised to deliver battery-grade graphite into North America's emerging EV and lithium-ion battery supply chain.

"With the growing demand for graphite in electric vehicle batteries and other energy storage applications – and recent actions by the Biden administration to secure U.S. supply chains for critical minerals – we see Graphite One's aim to produce a U.S.-based supply chain solution becoming increasingly significant as a new potential source of advanced graphite products for decades to come," said Graphite One CEO Anthony Huston.

ADOBE STOCK

A lithium-ion battery manufacturing facility about the size of Tesla's Gigafactory 1 in Nevada requires roughly 33,000 metric tons of graphite anode material per year.

This supply chain solution would begin with a mine at the world-class Graphite Creek project about 35 miles north of Nome, the famed gold mining town in western Alaska.

According to the most recent calculation, the Graphite Creek deposit hosts 10.95 million metric tons of measured and indicated resources averaging 7.8% (850,534 metric tons) graphitic carbon; and 91.89 million metric tons of inferred resource averaging 8% (7.34 million metric tons) graphitic carbon.

A 2017 preliminary economic assessment offered a first glimpse of a mine at Graphite Creek that would produce roughly 60,000 metric tons of 95% graphite concentrate per year and a processing facility to upgrade these annual concentrates into 41,850 metric tons of the coated spherical graphite and 13,500 metric tons of purified graphite powders annually.

A PFS slated for completion by the end of 2021 will provide a more detailed and definitive look at this potential Alaska segment of North America's rapidly expanding lithium-ion battery and EV supply chains.

"While the 2017 preliminary economic analysis indicated excellent economics, we are very excited about the potential for the PFS to show a clear path for further development," said Huston.

In preparation for the PFS, Graphite One's 2021 summer program focused on collecting the data needed for designing and permitting a mine at Graphite Creek.

This included infill drilling in preparation of upgrading resources to reserves with the completion of the PFS, geotechnical drilling at the proposed open pit mine and supporting infrastructure sites, as well as engineering and environmental baseline studies.

Graphite One is working diligently to ready the large Alaska battery materials project for permitting.

"We're working simultaneously to complete our PFS, and to generate additional data for our FS to further demonstrate the strong value proposition of our Graphite Creek deposit," Huston said.

Earlier this year, the U.S. Federal Permitting Improvement Steering Council (FPISC) designated Graphite Creek as a high-priority infrastructure project.

This designation means the world-class graphite project qualifies for Fast-41 – short for Title 41 of the Fixing America's Surface Transportation Act – a program established by the Obama administration to improve the timeliness, predictability, and transparency of federal environmental review and authorization process for domestic infrastructure projects.

FPISC is an independent federal entity created to coordinate the permitting of eligible Fast-41 projects across different federal agencies, thereby streamlining and shortening the overall process for large infrastructure projects that are eligible for the program.

In January, FPISC informed Graphite One that its Alaska project "clearly qualifies" as a Fast-41 project.

"We see the fact that our project qualifies under the FPISC's Renewable Energy and Manufacturing sectors as recognition of graphite as essential to a sustainable U.S. infrastructure supply chain," said Huston. DMN

Thick zones of iron-titanium-vanadium mineralization tapped during the 2019 drill program at VanadiumCorp's Lac Doré project in Quebec, Canada.

VANADIUMCORP RESOURCE INC.

Battery valences power vanadium demand

White House eyes grid-scale potential of vanadium batteries

By SHANE LASLEY

DATA MINE NORTH

A HARDENER OF THE STEELS that have been helping to make Ford's tough for more than a century and an element with unique properties that make it the key ingredient in enormous batteries to store intermittent wind- and solar-generated electricity, vanadium is a critical metal with many valences.

It is vanadium's chemical valences that make this alloying metal an ideal ingredient in the redox flow batteries that scientists and governments see as the ideal large-scale storage solution for intermittent renewable energy.

Taking advantage of vanadium's ability to exist in a solution in four different oxidation states and using this property to make a battery that has just one element for both the positive and negative electrolyte solutions, vanadium redox flow batteries have shown the potential to be the superior choice for large-scale energy storage.

"The key to unlocking the full potential of solar and wind energy is to store it for use around the clock," Rep. Diana DeGette, D-Colorado, said during a March announcement the Biden administration is investing up to US$24.5 million to support next-generation batteries. "Flow battery technology can help us utilize the full potential of these clean-energy resources, and investing in this important new technology now is vital to our overall effort to combat the climate crisis."

Variably called vanadium flow or vanadium redox batteries, VRFBs have been touted for offering several advantages – ease of scalability, reliability, flexibility, quick response, and safety – over lithium-ion and other batteries for keeping energy grids energized and stable.

The amount of energy a VRFB can store is only limited by the size of the storage tanks built to hold the vanadium electrolytes, which

W. OELEN, COURTESY OF WIKIMEDIA

Above: Vanadium was named after the Scandinavian goddess of beauty and fertility, Vanadís (Freyja), due to the wide range of colors found in vanadium compounds. The vials show four oxidization states of vanadium in aqueous solution. Right: Vanadium is used to add strength and durability to tool steels.

are separated by a membrane that allows vanadium electrons to flow back and forth during charging and discharging.

"The emerging need for large-scale electricity storage makes vanadium redox flow batteries a major potential future use of vanadium," USGS wrote. "Because of their large-scale storage capacity, development of VRBs could prompt increases in the use of wind, solar, and other renewable, intermittent power sources."

Above the touted superiorities, using flow batteries for large-scale stationary energy storage would relieve some of the stress off lithium-ion battery supply chains that are already being scaled up at an enormous rate to keep pace with the manufacturing of hundreds of millions of electric vehicles expected to be traveling global highways within two decades.

Much like the minerals and metals needed for lithium-ion batteries, the growth of the renewable energy sector could drive unprecedented new demand for vanadium.

China, Russia, South Africa, and Brazil, however, accounted for roughly 99.8% of global vanadium production during 2020.

While only a trifle amount of vanadium was produced in North America last year, Canada and the United States each host rich deposits of this steel strengthening and emerging battery metal.

Wherever strength is required

While grid-scale energy storage is poised to power future demand, vanadium's more traditional ability to enhance the strength and durability of steel and other alloys continues to be the dominant driver of demand for this critical metal.

The USGS estimates that 94% of the roughly 4,800 metric tons of vanadium consumed in the U.S. during 2020 was used in steel and other alloys.

Vanadium metal was first produced in 1869, and by the dawn of the 20th century, lighter, more durable, and flexible vanadium steels were being used in European racecars.

This inspired Henry Ford to use vanadium steel in the crankshafts, springs, wheel spindles, and other stressed parts in its famed Model T in 1908.

These characteristics were used to tout "Ford superiority" in car building at the time. More than a century later, the "Built Ford Tough" slogan for the legendary automaker's trucks is an echo of the strength vanadium imparted to the Model T.

The chrome-vanadium proudly stamped on tools found in nearly any hardware store is a more direct reference to the toughness vanadium imparts to steels used to make tools and a wide range of other products where strength is of utmost importance.

"The high-strength, low-alloy (HSLA) steels containing vanadium are widely used for the construction of auto parts, buildings, bridges, cranes, pipelines, rail cars, ships, and truck bodies, including armor plating for military vehicles," the USGS wrote.

While other metals could replace ferrovanadium steel alloys, it is typically not worth the costs and energy required to create steel that can compete with those imbued with vanadium's properties.

Steel, however, is not the only alloy enhanced by vanadium. When it comes to strength-to-weight ratio, titanium-vanadium alloys are among the best materials ever engineered. This is invaluable to an aerospace sector seeking to shave pounds of aircraft and space vehicles without sacrificing durability.

"Vanadium, when combined with titanium, produces a stronger and more stable alloy, and when combined with aluminum produces a material suitable for jet engines and high-speed airframes," USGS inked in the vanadium section of a 2018 report on critical minerals. "No acceptable substitutes exist for vanadium in aerospace titanium alloys."

Rise of the flow battery

While strong and stable alloys currently drive the market for vanadium, emerging vanadium redox flow battery technologies

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have the potential to be a market disruptor for this metal.

IDTechEx, a United Kingdom-based market and business research firm, predicts that flow batteries might overtake lithium-ion batteries in terms of total storage capacity by 2031.

"We are looking at the solution, but most of the time we forget the problem," IDTechEx penned in an introduction of its report, "Redox Flow Batteries 2021-2031."

When it comes to the global transition to low-carbon power sources, the problem is the increased use of intermittent renewable energy injects a higher degree of variability and uncertainty into the supply and demand balance of electrical grids.

The solution is a cost-effective and reliable large-scale storage technology that can serve as a buffer between the ebbs and flows of electricity supplied by these renewable sources and completely different undulations in the demands of people and businesses plugging into that power.

Based on scientific studies, IDTechEx believes redox flow batteries will likely be an increasingly important part of that solution.

"Driven by the adoption of an increasing amount of variable renewable energies, stationary storage devices – besides li-ion batteries – are approaching the market, and IDTechEx foresees a large adoption of redox flow batteries toward the end of the next decade," the research firm wrote.

The Biden administration agrees with this potential and is investing up to $20 million for research and development to advance the manufacturability of mid-sized flow battery systems.

Department of Energy, which is administering the program, will partner with industry to address technical and manufacturing challenges that have prevented flow battery systems from achieving cost targets and commercial viability.

"By investing in American-made, clean-energy technologies, the Department of Energy is harnessing our country's innovative spirit to build an equitable and sustainable energy system," said Secretary of Energy Jennifer Granholm. "These funding opportunities will help manufacture the next-generation energy storage systems and power lines that support President Biden's climate goals, create and sustain U.S. jobs, and build a strong, secure, and efficient electric grid."

VanadiumCorp supply chain

To help this maturation of flow batteries and to offer a North American source of the vanadium going into VRFBs, the most mature of the flow battery technologies, VanadiumCorp Resource Inc. has positioned itself along the entire vanadium-based energy storage supply chain.

"To facilitate the required transition from fossil fuels to green energy, VanadiumCorp has developed an integrated supply chain as a key solution," said VanadiumCorp Resource President and CEO Adriaan Bakker. "Our goal of cost-effective green energy is made possible by combining strategic vanadium battery supply and green process technology to enable the indefinite use of vanadium in energy storage."

The front end of VanadiumCorp's emergent supply chain lies in two promising vanadium exploration projects in Quebec – Lac Doré and Iron T.

Situated about 17 miles (27 kilometers) southeast of Chibougamau, a mining town in central Quebec, Lac Doré hosts 214.93 million metric tons of measured and indicated resources with the potential to produce 52.82 million metric tons of magnetite concentrate averaging 1.3% (676,000 metric tons) vanadium pentoxide, 62% (32.8 million metric tons) iron, and 8.7% (4.6 million metric tons) titanium dioxide.

"We can state Lac Doré is one of the largest undeveloped deposits of vanadiferous magnetite in the world, with an excess of 1.4 billion pounds of vanadium pentoxide contained in magnetite concentrate," said Bakker.

Iron-T, which is roughly 220 miles (350

kilometers) west of Lac Doré, hosts an additional 14.38 million metric tons of inferred resource averaging 0.42% vanadium, or about 0.77% vanadium-equivalent when you calculate the value of the iron and titanium also found there.

Working in partnership with Quebec-based Electrochem Technologies & Materials Inc., VandiumCorp has also developed a new process that uses less heat and more science to recover 95% of the vanadium, iron, and titanium from vanadiferous titanomagnetite deposits such as those at Lac Doré and Iron-T.

This is much cleaner than conventional roasting and smelting, which requires the burning of two tons of carbon to produce one ton of vanadium and leaves the iron and titanium as a waste material that must be disposed of.

In addition to significantly reducing the carbon and environmental footprint, this VanadiumCorp Electrochem Process Technology is expected to lower the cost of producing battery-grade vanadium due to the added revenue from selling the iron and titanium dioxide co-products.

Earlier this year, VanadiumCorp entered into an agreement to test its patented and proprietary green recovery process on titanomagnetite concentrates from Strategic Resource Inc.'s Mustavaara project in Finland.

Mustavaara hosts a historic mine that provided roughly 10% of the world's supply of vanadium over nearly a decade, ending in 1986. Strategic, which is working toward re-establishing vanadium production at this past-producing mine, believes the VanadiumCorp process could be a more environmentally sound means of extracting all the value Mustavaara has to offer.

"Our Mustavaara project could substantially benefit from the addition of a third revenue stream and potentially a lower capital, less carbon-intensive way of extracting vanadium and iron," said Strategic Resources CEO Scott Hicks. "Our team believes in redox flow batteries and would be excited to gear our project towards the growing market."

For VanadiumCorp, the implementation of its process technology offers a potential revenue stream through licensing and helps to advance its larger objective of establishing vanadium batteries as a major component of the green energy solution.

Toward this overarching goal, a Germany-based subsidiary of VanadiumCorp has developed a vanadium flow battery system that stores energy in liquid vanadium electrolyte that never degrades, another advantage VRFBs hold over lead-acid, lithium-ion, and other battery systems that experience cross-contamination due to the different anode and cathode materials.

VANADIUMCORP RESOURCE CORP.

VanadiumCorp has outlined 1.49 billion pounds of vanadium pentoxide in the measured and indicated resource categories at its Lac Doré project in Northern Quebec, Canada.

VanadiumCorp's flow batteries are modular and can be built with capacities as low as 20-kilowatt-hour for residential electrical storage and up to several megawatt-hours for grid-scale applications.

"VRFBs are uniquely suited to replace diesel for remote communities, build clean electric vehicle charging infrastructure, backup power to prevent blackouts and enabling microgrids crucial for national security and modernizing the entire power grid with renewable infrastructure," Bakker said.

Despite their advantages, vanadium redox batteries are lagging behind their lithium-ion counterparts when it comes to economics of scale.

A recent study funded by the U.S. Department of Defense, however, concluded that vanadium flow batteries may become the more attractive solution for microgrid electrical storage as the technology matures and the price comes down.

By tackling the entire supply chain, VanadiumCorp hopes to accelerate VRFB maturity, while also shrinking the carbon footprint of the entire process, from mines to batteries.

"With a substantial resource base in Canada and technology to unlock global supply, I believe VanadiumCorp may hold the key to our low-carbon future," said Bakker.

U.S. Vanadium

On the American side of the border, U.S. Vanadium Holding Company LLC produces small amounts of high-purity vanadium products used in a wide array of products – from dyes and vitamins to alloys and batteries – at its facility in Arkansas.

According to the USGS, roughly 470 metric tons of vanadium was produced in the U.S. in 2019 and about 170 metric tons in 2020. Most of this production likely came from the Arkansas facility, which was acquired by U.S. Vanadium in 2018.

Previously owned by a Russian steel conglomerate, production at the Hot Springs vanadium facility has been in decline since 2008.

Though the COVID pandemic has slowed its plans, U.S. Vanadium is working toward scaling production back up and plans to restore the operation's full 5,450-metric-ton-per-year capacity.

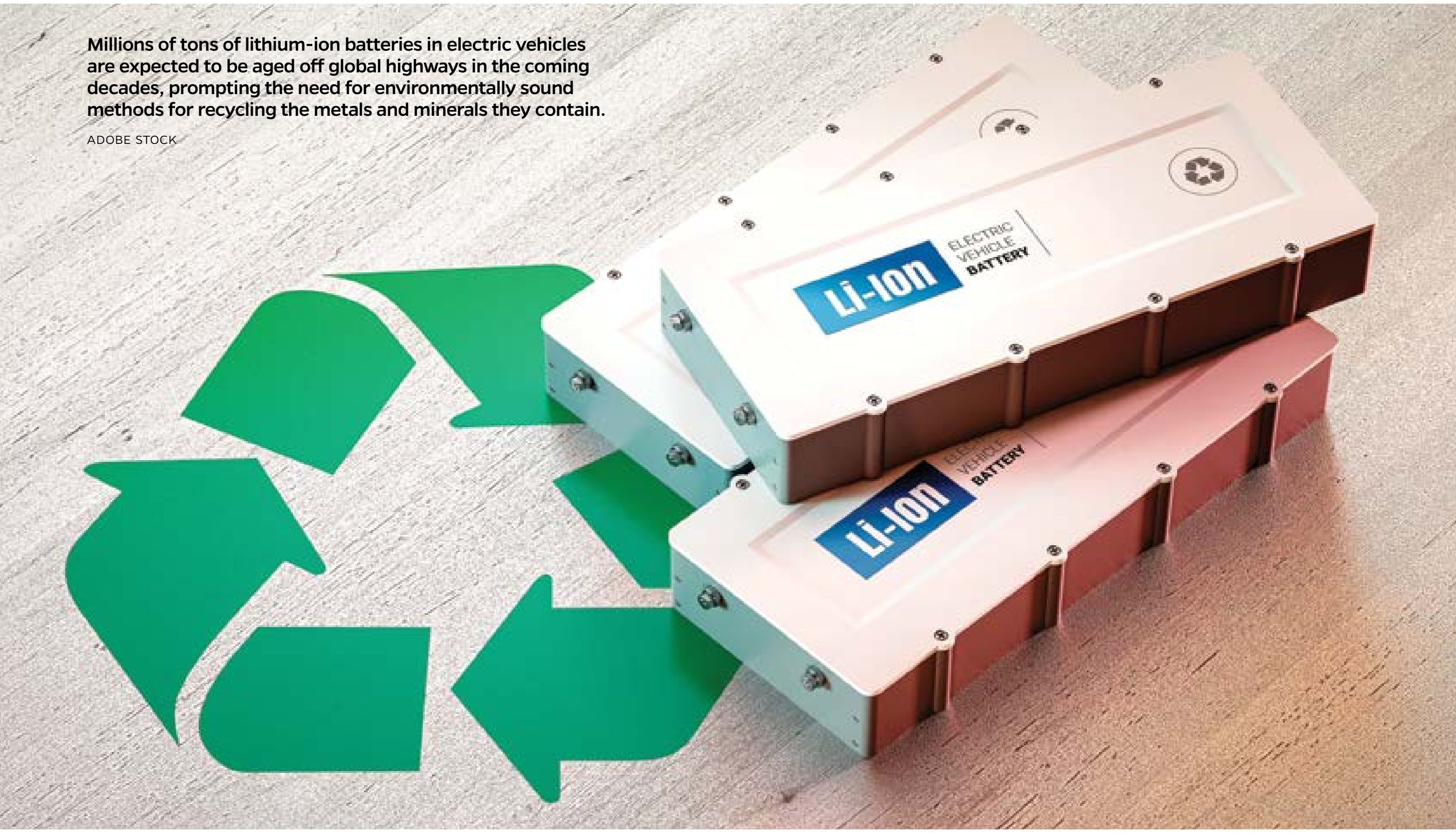
The company, however, says U.S. vanadium producers need federal support to help make domestic production competitive with China, Russia, South Africa, and Brazil.

U.S. Department of Commerce opened an investigation in 2020 into whether this import-dependence for the critical alloy and battery metal is a threat to national security.

In a joint letter to the Commerce Department, U.S. Vanadium and AMG Vanadium said tariffs on vanadium imports are needed to strengthen domestic production of this critical mineral.

"Supply lines from South Africa, Russia, Brazil, and China are obviously lengthy and subject to periodic and unpredictable disruption, particularly from government action," said U.S. Vanadium CEO Jody Orme. "Fortunately, the U.S. currently has the capability to meet total demand for high-purity vanadium, and more than half of the demand for steel-grade vanadium, if proper relief is provided and proper economic conditions are created."

The findings of the Department Commerce investigation into vanadium had not been released at the time of this report. DMN



Millions of tons of lithium-ion batteries in electric vehicles are expected to be aged off global highways in the coming decades, prompting the need for environmentally sound methods for recycling the metals and minerals they contain.

ADOBE STOCK

Recycling to complete a circular economy

Companies prepare for eventual battery material reclamation

By A.J. Roan

DATA MINE NORTH

REMINISCENT OF AMERICA'S GILDED AGE, the world is priming itself for a new era of technology and energy centered on the electricity that sparked the imaginations of visionaries such as Nikola Tesla and Thomas Edison. This new era, however, sets aside more than a century of burning fossil fuels in favor of new clean sources of the electricity that will power human innovation into the 21st century and beyond.

Solar, wind, hydro, and geothermal are but a few of the methods mankind has devised to generate 21st-century electricity without expending finite resources. With the early stirrings of this green transition, perhaps, for the first time in history, the global community has an opportunity to prepare for a full circular lifecycle of the world's energy and mobility technologies.

After the clean energy infrastructure is established and electric vehicles are built, what will people do with the spent batteries and worn-down amenities that provided clean energy and sustainability? The logical answer is to recycle them.

"Unlike fossil fuels, elemental battery metals are never consumed, and the development of economically competitive battery recycling systems can move industry to a closed-loop circular economy for these critical minerals," the Nevada-based American Battery Technology penned in response to a U.S. Department of Energy request for information on risks in American high-capacity battery supply chains.

In a report published by the World Bank in 2020, it estimated that the annual demand for battery materials alone – such as cobalt, graphite, lithium, manganese, and nickel – could increase by roughly 500% over the coming three decades. This projection is generalized and even considered vastly conservative by lithium-ion battery

In many lithium-ion battery recycling flowsheets, spent batteries are dismantled, and the parts containing the electrodes, such as battery cells, get crushed or shredded to produce powdery fraction referred to as "black mass."

DAVID BAILLOT/UC SAN DIEGO JACOBS SCHOOL OF ENGINEERING

insiders.

The International Energy Agency estimates that roughly 117 pounds of copper and 54 lb of manganese, double the amount in a conventional internal combustion engine, goes into the average electric vehicle. On top of that, standard lithium-ion EV batteries need around 146 lb of graphite, 88 lb of nickel, 29 lb of cobalt, and 20 lb of lithium.

In climate-driven scenarios, the IEA forecasts that the batteries used to power EVs and store electricity at grid-scale will demand at least thirty times more minerals in 2040 than they do today.

While recycling will eventually fill large portions of the world's EV and renewable energy mineral needs, it will initially take large-scale mining to feed EV markets with enough minerals and metals to prime this circular economy.

Nevertheless, that will not stop a handful of companies from preparing for that eventual outcome by developing technologies to reprocess, repurpose, and recycle the vital minerals and metals necessary to produce these technologies.

While a completed circle is decades off, there is no better time than now to prepare for when the life of today's EVs and renewable energy sources run their course, so future generations are not left with a bill they cannot pay.

General Motors

Perhaps, General Motors global chief marketing officer Deborah Wahl said it best regarding today's green transition.

"There are moments in history when everything changes. Inflection points. We believe such a point is upon us for the mass adoption of electric vehicles."

This was during the unveiling of the automaker's rebranding and launch of its "Everybody In" campaign earlier this year, setting an optimistic tone for its EV future.

Aligning with that optimism, the legacy carmaker has already begun taking steps to ensure the battery recycling capacity is in place well before large quantities of its early generation EVs reach the end of their lifecycle.

To prepare for a successful circulation of the materials put into its newest line of Ultium battery EVs, GM has entered into a multi-year contract with Canada-based Li-Cycle Corp. to recycle up to 100% of the scrap generated by its massive three million-square-foot battery cell manufacturing facility.

"GM's zero-waste initiative aims to divert more than 90 percent of its manufacturing waste from landfills and incineration globally by 2025," said Ken Morris, GM vice president of electric and autonomous vehicles. "Now, we're going to work closely with Ultium Cells and Li-Cycle to help the industry get even better use out of the materials."

By recycling Ultium scrap, Li-Cycle will help GM get the most out of its current battery materials. In addition, this recycling partnership is expected to be an essential piece in closing the circular battery supply chain as North America's EV production ramps up.

Li-Cycle

Its partnership with General Motors is the premise Li-Cycle was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founded on – provide an end-of-life lithium-ion battery solution that creates a secondary supply of critical battery metals to meet the increasing demand while also ensuring a sustainable future for our planet.

"Our combined efforts with Ultium and GM will be instrumental in redirecting battery manufacturing scrap from landfills and returning a substantial amount of valuable battery-grade materials back into the battery supply chain," said Li-Cycle President and CEO Ajay Kochhar.

Established in Ontario, Canada, Li-Cycle has developed a method to safely and sustainably process lithium-ion batteries by utilizing a unique proprietary solvent extraction process via its "spoke and hub model" to recycle spent batteries.

The spokes are the distributed network of how it takes in all types of lithium-ion batteries and transforms them into an inert product that is shredded and separated.

The remnants, colloquially known as "black mass," comprised of lithium, nickel, and cobalt on the cathode side and graphite on the anode side, is then taken to the hub.

The hub is a centralized operation. With 12 spokes to every hub, they convert the black mass directly to battery-grade chemicals and use a non-thermal process that purifies the materials to transform them back into ready battery-grade materials for future lithium-ion batteries.

Li-Cycle is not alone in its efforts, though, as another Canadian company has also taken steps to prepare for the eventual recirculation of end-of-life batteries.

American Manganese

As a pioneer in lithium-ion battery cathode recycling, British Columbia-based American Manganese Inc. has quickly grasped the dilemma of future battery materials scarcity and has come up with a solution that allows its patented RecycLiCo process to upcycle old cathodes to the new chemistries being used in the batteries powering EVs.

By dissolving cathode material from spent lithium-ion batteries or scrap from the manufacturing process, the company has shown that its approach can produce greater than 99.9% pure cathode material – with precisely the same nickel-manganese-cobalt ratio as the input material.

In response to the Biden Administration's Executive Order directing a 100-day battery supply chain review, American Manganese offered comments regarding the order while working closely with the U.S. Department of Energy and the Department of Defense – as members of a newly-designated U.S. Government "Battery Recovery and Recycling Task Force."

"American Manganese has been conducting recycling tests with battery cell manufacturing scrap since we commissioned our pilot plant in 2019 and are pleased to be recognized in the report as a North American recycler," said Larry Reaugh, President and CEO of American Manganese. "… we believe American Manganese can be a strong private-sector partner in the U.S. Government's new Battery Recovery and Recycling Task Force."

American Manganese says the ability to recovery nearly 100% of the material and then produce a high-quality cathode material that does not need further processing makes RecycLiCo a cost-effective and efficient solution for achieving the battery materials recycling required to tackle future demand.

American Battery Technology Company

While Canadian companies have taken the lead for North American battery metals recycling, the U.S. has quickly gained traction with the help of American Battery Technology Company. Previously called American Battery Metals, the Nevada-based exploration and mining company is focused on creating vertically integrated lithium that is environmentally sustainable in its mining and exploration, and green in its extraction processes, as well as its battery metal recycling.

High purity nickel-cobalt hydroxide produced from the cathodes of spent lithium-ion batteries using RecycLiCo, American Manganese's recycling process developed in partnership with Kemetco Research.

AMERICAN MANGANESE INC.

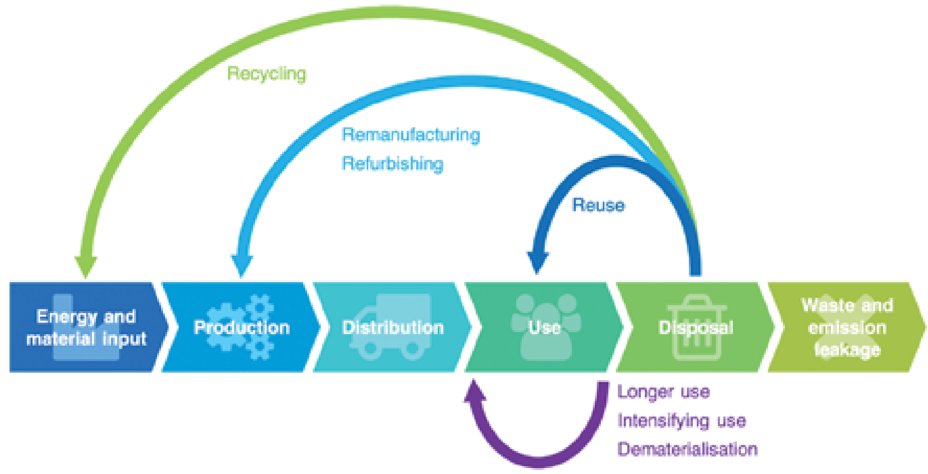
American Battery has built a clean technology platform designed to produce the primary materials used in batteries. As another closed-loop recycling system, similar to Li-Cycle and American Manganese, the idea is still toward recycling end-of-life lithium-ion batteries and putting them back into the market.

By disassembling the batteries in a three-hour automated process, removing unwanted content to minimize contamination and pollution, American Battery uses its own proprietary approach to reinvigorate used battery materials.

The materials are given a chemical bath, cleaned, filtered, and reused. High-grade metals include the much-needed lithium, cobalt, nickel, copper, and graphite, as well as the ever-present aluminum.

American Battery expects to process 20,000 metric tons per year of recycled material with its commercial pilot plant currently undergoing permitting.

"Our planned 20,000 metric ton per year lithium-ion battery recycling pilot plant has commenced permitting and design-build construction," said Doug Cole, CEO of American Battery Technology Company. "Its onsite global development center will support both recycling battery metal extraction technologies. … The pilot plant, located in an opportunity zone, is estimated to benefit the local economy by over $348 million in its first 10 years of operation, and will be scalable and repeatable for future plants around the United States."



MARTIN GEISSDOERFER/WIKIMEDIA COMMONS

A simplified representation of a circular economy. While recycling will eventually fill large portions of the world's EV and renewable energy mineral needs, a completed cyclical production system will take many years, if not decades, to come full circle.

Geomega Resources

Just as crucial to the future renewable transition are powerful rare earth element magnets in EV motors and wind turbines. It is estimated that upwards of US$13.8 billion worth of rare earth magnets are imported into the U.S. each year, which is creating a stockpile of the minerals and metals critical to the green transition.

Canada-based Geomega Resources has developed a process to recover the rare earths from those powerful magnets that are also used in medical resonance imaging (MRI), computer hard drives, and high-fidelity speakers to recycle them back into the North American manufacturing sector.

Focused on developing clean technologies for the mining, refining, and recycling of rare earths, Geomega has made strong headway demonstrating the viability of this technology at its pilot plant in Quebec.

Using a proprietary REE separation technology known as ISR, Geomega's pilot plant will have the capacity to process 4.5 metric tons of magnet waste per day. The company says ISR is inexpensive and is more environmentally sound than traditional solvent extraction rare earth recycling techniques.

Geomega has partnered with New York-based USA Rare Earth to recycle rare earth-containing waste from producing neodymium-iron-boron permanent magnets at a facility the latter company is planning to build in the U.S.

"We are very excited to be working in collaboration with USA Rare Earth. We both share the same vision to bring rare earth magnet production back to North America while securing the critical rare earth elements using Geomega's clean technology to process magnet waste," said Geomega Resources President and CEO Kiril Mugerman. "It is exciting to be part of USA Rare Earth mine-to-magnet strategy which we can participate in and support using our rare earth clean recycling technology."

■ *Further details on USA Rare Earths' mines-to-magnets strategy can be read at* ***Made in North America rare earths return*** *on page 58.*

Volkswagen

Not one to be outdone, the number one carmaker in the world, Volkswagen has shown its impressive foresight and, like GM, has also opted to begin preparing to recycle its EV lithium-ion batteries.

Unlike GM, however, Volkswagen has elected to build its own.

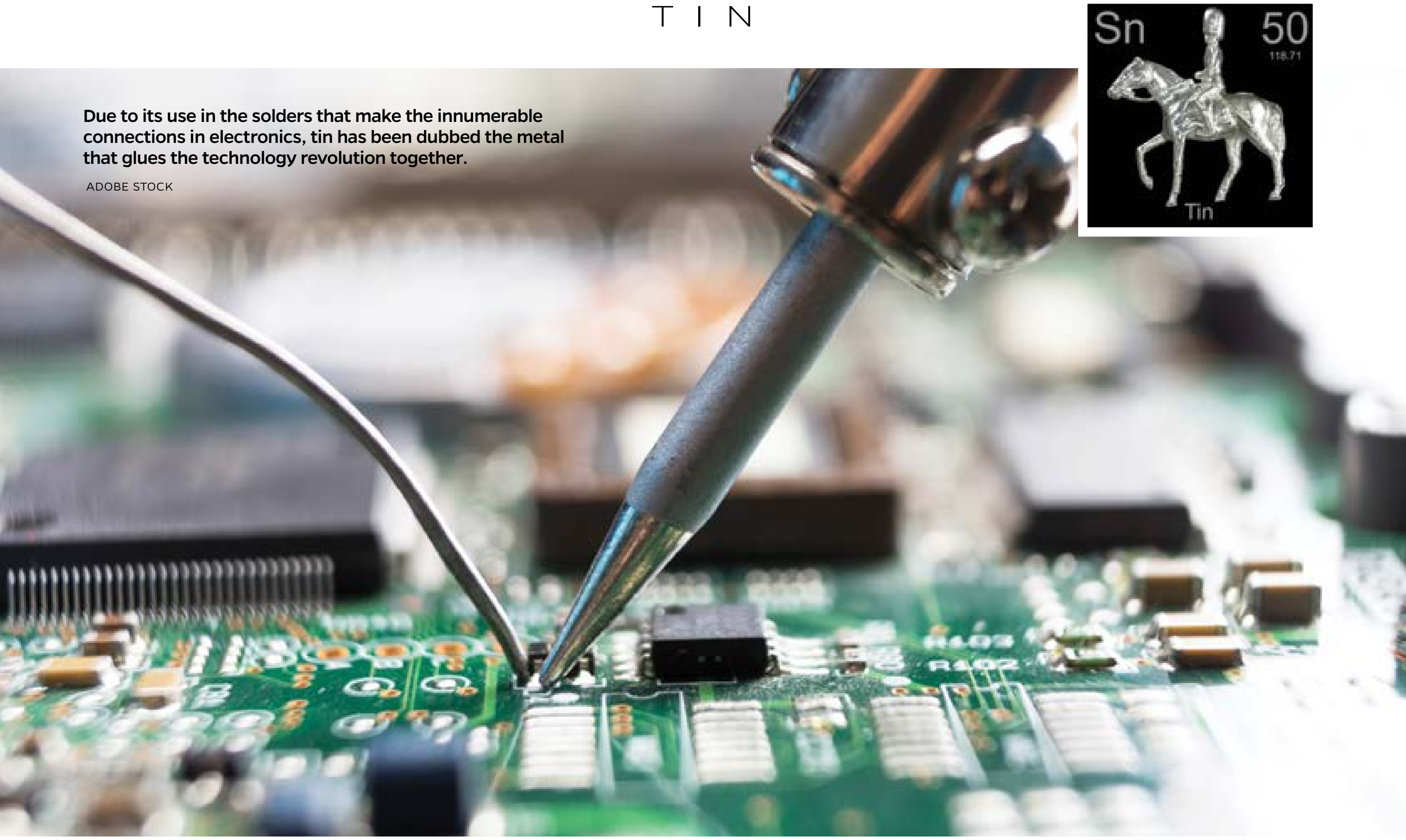
Though Volkswagen does not expect any appreciable quantities of spent batteries for at least another decade, the German automaker has already constructed its first plant to recover more than 90% of the raw materials from its cells.

"We are implementing the sustainable recyclable materials cycle – and play a pioneering role in the industry for a future-oriented issue with great potential for climate protection and raw material supply," said Volkswagen Group Components Chairman Thomas Schmall.

Its recycling process does not use an energy-intensive blast furnace to melt down the battery metals for recycling. Instead, the individual parts of dismantled batteries are ground into granules and dried. In addition to aluminum, copper, and plastics, this process yields "black mass," which also contains the lithium, nickel, cobalt, and graphite important for future batteries.

These valuable battery materials are then separated into individual metals and minerals with hydrometallurgical processes – using water and chemical agents – by Volkswagen partners specializing in metal separation.

As the world primes itself for a new era of electricity, Volkswagen, GM, and a growing list of innovative companies have seen a bigger picture and are looking beyond present supply chain concerns. While the going will be rough to meet the critical minerals demand projected by industry analysts, once the cycle is fully underway, these companies will be well established when the explosive growth in demand for the burgeoning battery recycling side of the circular EV and renewable energy economy fully emerges. DMN



Due to its use in the solders that make the innumerable connections in electronics, tin has been dubbed the metal that glues the technology revolution together.

ADOBE STOCK

Tin has been critical for 5,500 years

Alaska has more than 100 occurrences of this vital tech-metal

By SHANE LASLEY

DATA MINE NORTH

FROM THE ADVANCEMENTS OF TECHNOLOGY during the Bronze Age to the computers and telecommunication systems of today's Big Data Era, tin has been critical to human progress for at least 5,500 years.

Sometime around 3500 BC, Sumerians living in modern day Turkey and Iran discovered that mixing a little tin with copper created bronze, an alloy that produced much more durable weapons and tools than those cast from copper alone.

This cutting-edge discovery offered a strategic and economic advantage over those who did not possess the ingredients or skills to make this copper-tin alloy. The benefits offered by this metallurgical technology were so profound that we now consider the Bronze Age one of the most important epochs of human history, an era that spans more than 2,000 years.

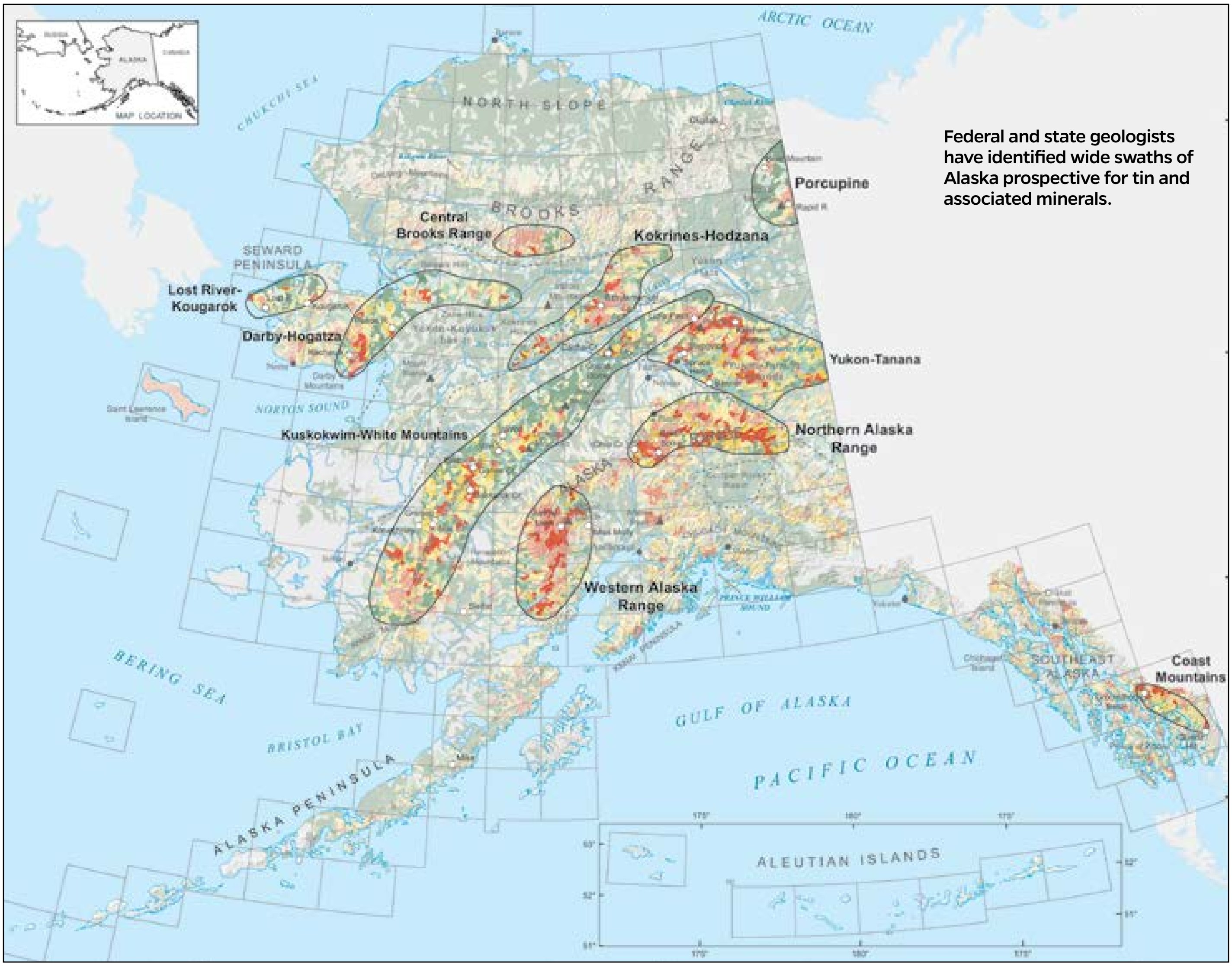
Not unlike our Bronze Age forebearers, modern civilization continues to almost exclusively use tin in alloys, mixtures that keep tin on the list of critical minerals.

"Almost without exception, tin is used as an alloy," the United States Geological Survey penned in the tin section of a comprehensive 2018 report on critical minerals. "The major uses of tin today are for cans and containers, construction materials, transportation materials, and solder."

Glue of modern tech

While tin cans, cups, roofs, and foil may not conjure up images of a metal that should be considered critical to the technological wellbeing of a country like the United States, researchers from the Massachusetts Institute of Technology rank it as the most critical tech metal on Earth.

A 2018 Rio Tinto-commissioned study carried out at MIT found that tin beat out more likely technology metal candidates like



Federal and state geologists have identified wide swaths of Alaska prospective for tin and associated minerals.

UNITED STATES GEOLOGICAL SURVEY

lithium, cobalt, and graphite it when comes to being impacted by new technologies such as autonomous and electric vehicles, advanced robotics, renewable energy, and computers.

"Rio Tinto's Ventures group is looking for new areas to invest and tin is at the top of their list of metals likely to be positively impacted by new technology," the global miner informed colleagues during a 2018 battery metals conference in Australia.

One of the main reasons these high-tech sectors are putting so much demand on tin is the metal's use in solders that make the innumerable connections in electronics and electrical products.

"Tin's extensive use in solders makes it the metal that glues the technology revolution together, and new applications, such as in emerging lithium-ion batteries, tend to grow as technology advances and diversifies," said Roskill, a world-leading metals consultant based in London.

Roskill expects emerging tech applications such as the rollout of a global 5G network, smart home devices, and advances in lithium-ion batteries to drive growing demand for tin.

New supply is not keeping pace with these growing demands for this, pushing the price of this underappreciated techno-glue to new record highs.

After plunging to a low of around US$13,680 per metric ton in March, tin prices rocketed to US$34,993/t in July, shattering the previous all-time high for the alloying metal set in 2011.

There are, however, no U.S. tin mines to reap the benefits from this unprecedented price rally.

Instead, roughly 77% of America's tin supply was imported from foreign countries – Indonesia (24%), Malaysia (21%), Peru (20%), and Bolivia (17%) were the top suppliers of tin to the U.S. during 2020. The balance of U.S. tin supply, roughly 18,000 metric tons, was the product of recycling.

"Tin has not been mined or smelted in the United States since 1993 and 1989, respectively," USGS inked in its Mineral Commodity Summaries 2021 publication.

This complete dependence on foreign sources for new supply, coupled with the alloying metal's importance to both manufacturing and defense, is the reason both the Pentagon and USGS consider tin critical to the United States.

The two best options for the U.S. to break its dependency on imports for this critical electronics metal is to develop some of the more than 100 tin occurrences identified across Alaska and recycle more tin from the thousands of metric tons of circuit boards discarded every month.

Alaska's gateway tech metal

Aside from the geopolitical factors that weigh on U.S. dependency on imports for other critical minerals and metals, the primary reason there are not any American tin mines is that deposits of this alloying metal are rare in the contiguous 48 states.

Alaska, on the other hand, hosts more than 100 known tin occurrences, making it the best place to establish a domestic source of this long-lived critical metal.

"Today, Alaskan tin deposits are known to be widespread, occurring from the central Alaska Range north to the Brooks Range and across Interior Alaska ... Southwest Alaska and the Seward Peninsula," according to Mineral Deposits of Alaska, a 1997 publication that compiles the work of nearly 50 geologists.

And when it comes to technology minerals exploration in Alaska, tin could be considered the gateway metal due to its direct affiliation with more than a dozen of the 35 metals deemed critical to the U.S.

Beryllium, bismuth, chromium, fluorspar, gallium, indium, manganese, niobium, platinum group metals, rare earth elements, scandium, strontium, tantalum, tungsten, and vanadium are among the critical metals and groups of elements associated with the placer and lode tin occurrences across the state.

Most of Alaska's tin occurrences are placer deposits of cassiterite, the primary tin mineral, found across the breadth of the Far North State. This follows a global trend – most of the world's production comes from alluvial deposits, rather than the hardrock sources that provide ore for large-scale production of most metals and minerals.

"Placer deposits have traditionally been an important source of tin; in 2012, they accounted for about 70% of the world output of cassiterite concentrates," USGS penned in its 2018 critical minerals report.

There are a couple of advantages that make placer deposits an intriguing source of tin – Mother Nature has completed the first

> *"Rio Tinto's Ventures group is looking for new areas to invest and tin is at the top of their list of metals likely to be positively impacted by new technology."*
>
> *–Rio Tinto*

stage of mineral processing – eroding cassiterite from the hard rock sources and concentrating the tin mineral in deposits that can be mined with simple gravity recovery systems – and these rich sources of Alaska tin are almost always associated with an array of other metals critical to the United States.

Interior Alaska placer tin

One of the most intriguing places in Alaska to explore for critical minerals-enriched placer tin deposits is a 200-mile-long area in the Interior region of the state just north of the Yukon River that also happens to be prime hunting ground for rare earths.

Ray Mountains, which is about 40 miles north of the community of Tanana, is an area rich in placer tin, rare earths, and other critical minerals.

Ucore Rare Metals, who staked claims over much of this placer potential about a decade ago, carried out preliminary work to test the viability of mining the critical minerals in the alluvial deposits at Ray Mountain.

Concentrates from gravity separation of placer samples collected in 2014 returned up to 50% tin; 10% rare earths; and 0.01 to 1% tungsten, tantalum, and niobium.

Ucore, which is focused on a mine at its Bokan Mountain rare earth deposit and associated REE separation plant in Southeast Alaska, has not carried out any recent work in the Ray Mountains.

Gold-rich Alaska mining districts on the south side of the Yukon River also happen to be enriched with tin and associated critical minerals.

The best known of these tin- and gold-rich regions of Interior Alaska is the 12-mile-long Tofty tin belt in the Manley Hot Springs district about 90 miles northwest of Fairbanks.

"Gold mining in the district developed rapidly, and as the productive area in the vicinity of Tofty increased it was found that tin and gold were generally associated and that the richer concentrations of the two minerals were generally coincident," Henry Eakin wrote in a 1914 report, Tin Mining in Alaska.

This coincidence was oft a burden for early placer gold miners due the cassiterite, a relatively heavy mineral, plugging up sluice boxes and rendering them ineffective in recovering gold.

These miners, however, soon decided to try to cash in on the tin mineral piling up on their claims.

In 1911, about 1,200 lb of tin concentrates accumulated from cleaning out the sluice boxes were shipped to Singapore for processing.

"The ore was found to be of high quality, and the returns from the small shipment directed attention for the first time to the possible value of tin as a by-product," Eakin penned.

And in 1914, roughly 48 tons of cassiterite were shipped from the gold mines in the Hot Springs district.

Over the years since, various miners have recovered cassiterite as a by-product of gold mining.

While a search for the lode source of the Tofty Tin Belt placers did not turn up appreciable amounts of cassiterite, samples collected by the Alaska Division of Geological and Geophysical Surveys did find intriguing quantities of many other minerals deemed critical to the U.S.

Bismuth, chromium, gallium, manganese, niobium, rare earth elements, scandium, strontium, tantalum, and vanadium have been identified in samples collected from the Manley Hot Springs district.

About 200 miles east of Tofty and near another Interior Alaska hot springs, placer gold miners ran into similar problems of abundant tin plugging their sluice boxes while trying to recovery gold from Boulder Creek in the Circle Mining District.

While there has been no systematic testing of the placer tin content, a miner attempting to recover the gold in a particularly tin-enriched portion of Boulder Creek estimated the gravel contained more than 2 lb of cassiterite per yard.

An investigation by James Barker, a geologist that carried out extensive exploration of Alaska's critical minerals potential for the U.S. Bureau of Mines, indicates that the lode source of this tin mineralization is close."Cassiterite occurs as fresh unweathered crystals up to 3/8 of an inch long, some of which are attached to gangue rock," he wrote in a 1979 report. "Tin is particularly concentrated in the coarser size fractions. The gold is also quite fresh, occurring primarily as thin irregular flakes. The balance of the concentrate consists of rounded nuggets of hematite, magnetite, and scheelite."

Scheelite is a mineral of tungsten, which the USGS also considers critical.

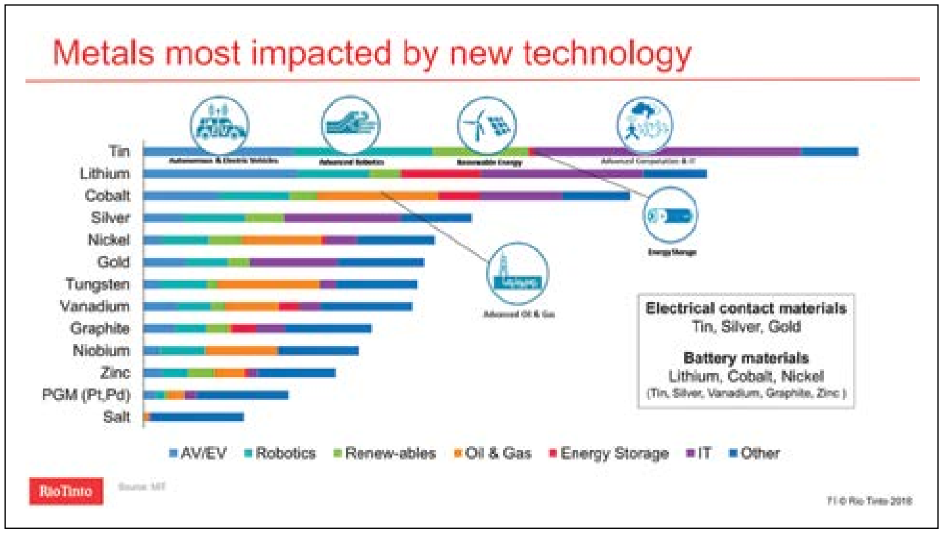
One sample of fresh granite collected by Barker near Boulder Creek returned 20 parts per million tin and 22 ppm tungsten. The sample also contained gold and molybdenum.

Tin and tungsten have been found in many of the other creeks in the Circle Mining District – Bedrock, Deadwood, Independence and Half Dollar, to name a few.

The Lime Peak and Mount Prindle areas to the west of the Circle Hot Springs granitic intrusive feeding these creeks also has tin, tungsten, and rare earth mineralization.

Tin City and beyond

Any mining company looking for rich sources of tin in Alaska would be remiss if it overlooked a place called Tin City.



Located on the western tip of the Seward Peninsula, Tin City was established in 1904 by Nome Gold Rush miners who found rich deposits of cassiterite in Cape Creek about 90 miles northwest of Nome.

Placer mining of Cape Creek, which drains the mountain rising to the northwest of Tin City, produced an estimated 3.3 million pounds of tin, according to the USGS. The largest known chunk of cassiterite recovered during placer mining of Cape Creek weighed 142 lb.

While Tin City is more of a forgotten outpost than the metropolitan that its name suggests, the streams in the area and the highlands feeding those streams still hold rich stores of the critical metal for which the ghost town derived its name.

"One of the few primary hard-rock tin deposits in the United States is the Lost River tin-tungsten-fluorine deposit in the Seward Peninsula, Alaska," the USGS wrote in its 2018 critical minerals report.

Kougarok, located about 90 miles east of Tin City, is another promising lode tin deposit on the Seward Peninsula.

Work in the 1980s estimated a portion of the tin-bearing granites there hosts some 6 million lb of tin in 240,000 tons of historical resource averaging 1.3% tin. Some of the cassiterite deposits at Kougarok also host considerable amounts of critical metals beryllium, tungsten, fluorspar, niobium, and tantalum.

When it comes to hardrock sources of tin in Alaska, one of the more promising areas lies alongside the Parks Highway about midway between Fairbanks and Anchorage.

One such prospect, Coal Creek, was discovered by Charles Hawley in 1972 and explored by Houston Oil and Minerals in the 1980s.

After drilling 42 holes, Houston Oil estimated the Coal Creek deposit contained roughly 4.8 million metric tons averaging 0.27% tin.

While the resource does not meet the rigor of current reporting standards, sampling of core stored at the Alaska Geologic Materials Center in Anchorage and four holes drilled in 2006 confirms the tin-silver potential of this easily accessible property.

Highlights from the drilling include: 9.4 meters averaging 0.41% tin, 18.21 grams per metric ton silver and 0.81% zinc; and 9.3 meters averaging 0.45% tin, 11.95 g/t silver, and 0.29% zinc.

Australia-based Discovery Africa Ltd. announced early in 2021 that it had staked claims over the Coal Creek discovery and other tin, silver, copper, and gold occurrences in the area.

The Aussie exploration company said it will prioritize its on-going exploration at Chulitna and is working toward identifying and reviewing other new projects, with a focus on Alaska.

At least four other hardrock tin prospects associated with other critical minerals – Sleitat, Bismarck Creek, Win, and Won – have been discovered in the Kuskokwim Mountains of Southwest Alaska.

So, while the Lower 48 states may not hold much promise for the tin needed for cans and robots alike, Alaska is heavily enriched with this alloying metal that has been critical to human progress for more than 5,500 years.

And, where you find tin in Alaska, a suite of other critical minerals is close by. DMN

Made in North America rare earths return

From Texas to the Canadian Arctic, new REE projects emerge

By SHANE LASLEY
DATA MINE NORTH

ROUGHLY 38,000 METRIC TONS of rare earth concentrates were produced from American soil during 2020, yet the United States remains 100% reliant on foreign countries for its supply of these 17 elements critical to our modern high-tech society – an apparent paradox that speaks to the complexities of these enigmatic metals.

The irony of rare earth elements (REEs) begins with their name, which is at the same time a misnomer and accurate descriptor.

"All the REEs except promethium are more abundant than silver, gold, or platinum in Earth's crust, on average. Thus, REEs are not rare in terms of average crustal abundance, but concentrated and economic deposits of REEs are unusual," the U.S. Geological Survey penned in a 2018 report on critical minerals.

When an economic rare earth deposit is discovered, it will typically have some combination of the 16 stable rare earths.

The Mountain Pass Mine in California's Mojave Desert, the only operation in the U.S., and the newly opened Nechalacho Mine in Canada's Northwest Territories are the only North American operations to produce these elements

Well, almost produce these elements.

While finding economically viable deposits of rare earths is not easy, the real complexity comes with separating these notoriously tightly interlocked elements into usable rare earth metals.

This gets to the heart of why rare earths are mined in the U.S., yet the country is 100% reliant on imports for the metals.

Once mined, the rare earth concentrates produced at Mountain Pass are shipped to China to be separated into the individual elements. American manufacturers then buy rare earth metals and upgraded products imbued with these elements from the Middle Kingdom and other overseas suppliers.

BILL BRADEN PHOTO COURTESY OF CHEETAH RESOURCES CORP.

Left: A bag of rare earths concentrates produced with the TOMRA ore sorter at Vital Metals' Nechalacho Mine in Canada's Northwest Territories. Below: The final step of Vital Metals' partnership strategy for Nechalacho is to have mixed rare earth carbonates separated into individual rare earths at REEtec's facility in Norway.

From 2016 through 2019, roughly 80% of the rare earth compounds and metals imported into the U.S. came from China, 5% from Estonia, 4% from Japan, and 4% from Malaysia.

Several companies in the U.S. and Canada are in various stages of developing new technologies for separating rare earths and establishing facilities to enable rare earth oxides production in North America.

Separating the rare earths

Though often referred to as a single entity, rare earths are a group of 17 elements – the 15 lanthanides that make up the second row from the bottom on the periodic table plus yttrium and scandium, a pair of elements almost always found in REE deposits and have similar characteristics – each with its own distinct traits.

The lanthanides are divided into two categories, heavy and light rare earth elements.

Light REEs make up the first seven elements of the lanthanide series and include lanthanum, for which the series gets its name; cerium, used for polishing high-quality optical surfaces; praseodymium, valued for its magnetic and optical properties; and neodymium, an extremely magnetic element.

"The most powerful magnet known to man is a neodymium magnet, one of the rare earths, so all electric cars have neodymium magnets in the electric motors," said Michael Silver, CEO of American Elements, a Los Angeles-based distributor of rare earths and other advanced materials.

The remaining eight lanthanides are considered heavy REEs, which are less abundant in most deposits and tend to be more valuable.

Some of the most commonly used of these heavy rare earths are europium, used primarily in red and blue phosphors in televisions and computer monitors; terbium, used in high-temperature magnets and to create a green phosphor; and dysprosium, which improves the durability of magnets in electric vehicle motors and wind turbine generators.

Then you have scandium, which when combined with aluminum becomes an extremely strong yet lightweight alloy used to make everything from Mars orbiters to baseball bats.

Finally, there is yttrium, an element that has numerous rare earth-esque attributes such as creating a red phosphor for televisions and other displays, as well as garnets used in lasers.

Rare earths are also vital ingredients to a wide array of U.S. military hardware, from helmet-mounted radios to laser-guided missiles.

A recent Pentagon report estimates that roughly 920 pounds of rare earths go into each F-35 fighter; 5,200 lb go into every Arleigh Burke DDG-51 destroyer; and a single SSN-774 Virginia-class submarine requires 9,200 lb of these strategic metals.

This puts the U.S. Department of Defense in the uncomfortable position of depending on a strategic rival for key ingredients of its military hardware.

Former Undersecretary of Defense for Acquisition and Sustainment Ellen Lord said domestic mines are not the primary hurdle for securing reliable supplies of rare earths for the wide array of military hardware and equipment that rely on the unique properties these enigmatic elements offer.

"The challenge is really the processing of them and having facilities to do that because quite often China mines them elsewhere and brings them back to China to process them," Lord said in August. "So, we are looking at a variety of mechanisms to stand up processing facilities."

While Lord has been replaced under the Biden administration, the Pentagon's position on establishing domestic rare earths processing has not.

In February, the Department of Defense announced that it is contributing $30.4 million to Lynas Rare Earths Ltd.'s efforts to establish a separation facility in Texas capable of producing the light rare earths used for petroleum refining, glass additives, and magnets used in electric vehicle drivetrain motors and precision-guided munitions.

Lynas already operates a rare earths processing plant in Malaysia, which up until this year was the only such facility outside of China.

"Upon completion of this project, if successful, Lynas will produce approximately 25% of the worlds' supply of rare earth element oxides," the Pentagon penned in a February statement announcing its funding contribution for the Texas plant.

The rare earths state

Texas, a state synonymous with the crude that lubricated the industrial revolution and fueled U.S. transportation throughout the 20th century, is emerging as an American source of the rare earths helping to generate renewable electricity and propel EVs into the 21st.

In addition to the REE separation facility being co-funded by the Pentagon, the Lone Star State is also home to Round Top, an enormous rare earths project that is also enriched in lithium and 10 other minerals considered critical to the U.S.

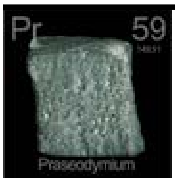
A preliminary economic assessment completed in 2019 outlines plans for a mine at Round Top would produce 2,212 metric tons of

REETEC

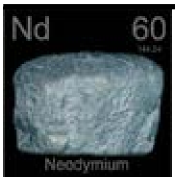
15 rare earth elements, scandium and yttrium

Lanthanum - High quality camera and telescope lenses; and as a cathode in nickel metal hydride rechargeable batteries. The nickel metal hydride batteries in each Toyota Prius hybrid car contains around 4.5 kilograms of lanthanum.

Cerium - Cerium oxide powders are used for polishing high quality optical surfaces; and as a catalytic converter to reduce carbon monoxide emissions. Cerium is also used in phosphors for color televisions and fluorescent lighting.

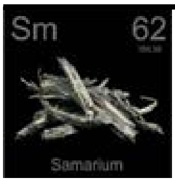


Praseodymium - As an ingredient in high-power magnets; an alloy in high-strength metals used in aircraft engines; carbon-arc lighting use by the motion picture industry; and to yellow coloring for glass, enamels and ceramics.



Neodymium - High-power permanent magnets in computers, cell phones, medical imaging equipment, electric car and other motors, wind turbines and audio systems; crystal in lasers used to treat skin cancer and for hair removal.

Promethium - Extremely rare and instable in nature. Atomic promethium batteries are used in pacemakers, guided missiles and radios. Due to this element's radioactive decay, electricity can be produced from the light given off by a promethium phosphor.

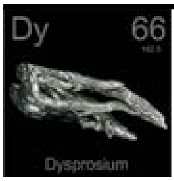


Samarium - Highly resistant to demagnetization, even at high temperatures, samarium-cobalt magnets are used in precision-guided weapons. These magnets are also used in headphones, quartz watches, camera shutters and electric guitar pickups.

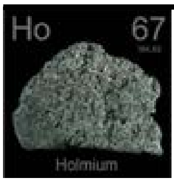
Europium - Widely used to create blue and red phosphors in televisions and computer monitors; white light in fluorescent bulbs; and anti-forgery marks on Euros. Quantum memory chips made with europium can store data for days.

Gadolinium - Small amounts of gadolinium are used to improve heat and oxidation resistance in iron and chromium alloys. This REE is also used as green phosphor in color televisions. Gadolinium yttrium garnets are used in microwaves and lasers.

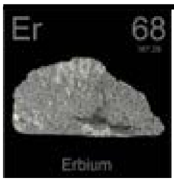
Terbium - Magnets for high-temperature applications such as electric vehicles and wind turbines; and a green phosphor used in televisions and other devices. Terbium green is among three colors used for trichromatic lighting technology.



Dysprosium - Improves durability and reduces weight of magnets in electric vehicle motors and wind turbine generators. It is estimated that each EV has roughly 100 grams of dysprosium, or about one metric ton per 10,000 cars.

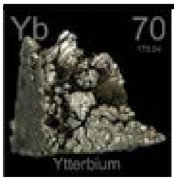


Holmium - Has the highest magnetic strength of any element, which is used to create the strongest artificial magnetic fields; holmium-doped garnets are used in lasers used for medical, dental, and fiber-optic applications.



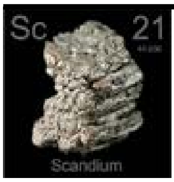
Erbium - Used with vanadium to increase the pliability of metals; medical lasers for tattoo removal and other skin resurfacing; nuclear reactor control rods; and pink coloring agent in glazes and glasses.

Thulium - High precision lasers used for surgery. Thulium that has been bombarded in a nuclear reactor is used as a radiation source for portable X-ray diagnostics. Euro banknotes also take advantage of thulium's blue fluorescence under ultraviolet light as counterfeit prevention.



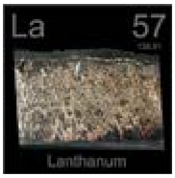
Ytterbium - Being studied as an alloy to improve the strength and other mechanical properties of stainless steel. Used in stress gauges to monitor ground deformations caused by earthquakes or underground explosions; and as a radiation source for a portable X-ray machine where electricity is unavailable.

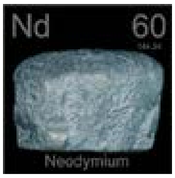
Lutetium - Has few commercial applications, due to being expensive and rarer than most REEs. It is, however, used as catalysts in petroleum cracking in refineries. Research indicates that lutetium-ion atomic clocks could provide greater accuracy than any existing atomic clock.

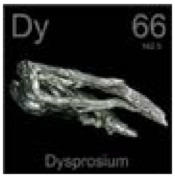


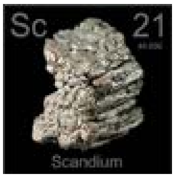
Scandium - Certain aluminum-scandium alloys are strong as titanium, light as aluminum, and hard as ceramic. These alloys are used in aerospace components and high-end sports equipment such as bicycle frames and baseball bats. Metal-halide lamps and lasers are other uses.

Yttrium - Yttria, an oxide used to create the red component of color in television picture tubes, is the largest use of yttrium. This element is also the ingredient of a large variety of synthetic garnets used as microwave filters, lasers, jewelry and white LEDs. An isotope of yttrium is used to treat cancer.










U.S. AIR FORCE; AIRMAN 1ST CLASS ISAAC JOHNSON

rare earths per year, including healthy supplies of all six permanent magnet rare earth oxides – 200 metric tons of dysprosium, 180 metric tons of neodymium, 67 metric tons of praseodymium, 65 metric tons of gadolinium, 65 metric tons of samarium, and 23 metric tons of terbium – once the mine reaches full production.

In addition, the mine summarized in the PEA would produce about 10,000 metric tons of lithium per year, which would help fill the expanding electric vehicle battery market.

According to current calculations, the Round Top deposit is large enough to supply the REEs, lithium, and other critical minerals at this rate for more than a century.

USA Rare Earth LLC, which owns an 80% interest in Round Top, raised US$50 million earlier this year to complete a prefeasibility study that will further refine the economic and design parameters outlined in the PEA, finish testing at the company's pilot rare earths separation plant in Colorado, and build a demonstration scale plant at Round Top this year.

The demonstration plant, which includes test heap leach pads and an upscaled version of the continuous ion exchange processing being piloted in Colorado, is expected to support a definitive feasibility study and permitting, as well as produce representative materials for evaluation by prospective customers.

"This will enable us to expedite bringing Round Top into production and provide the necessary materials for EVs and advanced manufacturing, including the essential materials for chipsets, semiconductors and 5G, all of which are hosted at Round Top and are the focus of President Biden's recent executive order," USA Rare Earth CEO Pini Althaus said in June.

While the separation of rare earths in Texas will be a major step for an all-American REE supply chain, USA Rare Earth is already working on adding another link to connect Round Top to the electric vehicle and other high-technology manufacturers that utilize the powerful magnets made from rare earths.

Last year, USA Rare Earth purchased neodymium-iron-boron permanent magnet manufacturing equipment that Hitachi Metals America briefly used at a facility in North Carolina that has the capacity to supply roughly 17% of the U.S. rare earth permanent magnet market and generate nearly $145 million in annual sales at 2019 prices.

This magnet making equipment is in storage and USA Rare Earth is narrowing down locations to set it back up. USA Rare Earth expects to make a final decision on the magnet plant's locale soon and the first REE magnets to be manufactured there by the end of 2021.

Coupled with the prospect of Round Top lithium going into batteries, the Texas project is rapidly establishing itself as a key first link in two supply chains vital to the envisioned transition to renewable energy and electric mobility in the U.S.

"We are well positioned to reestablish a fully-integrated, environmentally-friendly and U.S.-based mine-to-magnet and mine-to-bat-

A recent Pentagon report estimates that roughly 920 pounds of rare earths go into each F-35 fighter.

tery supply chain," said Althaus.

Vital Canada REE mine

Defying the common idea that bigger is better when it comes to mining, Australia-based Vital Metals Ltd. became the first company to produce rare earths from a deposit in Canada by leveraging a small but very high-grade rare earths deposit coming to the surface at its Nechalacho project in Northwest Territories.

A scoop of ore dug from the North T open pit at Nechalacho on June 28 marked a historic milestone for Vital, Canada, and its First People – Canada became a rare earth producing nation.

This first REE ore mined at Nechalacho comes just two years after Vital initiated a unique strategy to establish a mine at North T, a deposit with 101,000 metric tons of resources averaging 9.01% total rare earth oxide. This is nearly an order of magnitude higher grade than most REE deposits, which tend to average around 1% TREO or less.

Vital contracted Nahanni Construction, a Northwest Territories-based contractor majority owned by the Yellowknives Dene First Nation, to mine the high-grade rare earth ore at Nechalacho.

"The Yellowknives Dene First Nation is pleased to be the first indigenous group in Canada to be responsible for mineral extraction on their traditional territory," Yellowknives Dene First Nations Chief Ernest Betsina said earlier this year. "When indigenous people conduct the mining operations, they are better able to control the process, resulting in better safeguarding of the environment."

Cheetah Resources Ltd., Vital's Canadian subsidiary, is utilizing a TOMRA x-ray transmission (XRT) ore sorter to upgrade the ore to a concentrate that is expected to contain greater than 30% rare earth oxides.

Without the need for a complex ore processing facility, the Nechalacho Mine is something akin to a gravel quarry – simply mine and crush near surface rock and sort out the best material with little or no water and zero chemicals.

"Mining is changing. While sorter technology is widely used in diamond mining, this is the first time that sensor-based sorting has been used as a single step to produce a metal ore concentrate. It is much more environmentally friendly," said TOMRA engineer Russell Tjossem, who trained members of the Yellowknives First Nation to operate the sorter.

"We are developing Nechalacho using the most sustainable methods possible, which includes the use of local labor so that we can support the communities surrounding our project," said Vital Metals Managing Director Geoff Atkins.

The REE concentrates coming out of the sorter at Nechalacho are being shipped to Vital's rare earth carbonate production plant adjacent to Saskatchewan Research Council's REE facility in Saskatoon, Saskatchewan.

The final step of Vital's power-of-partnerships strategy is being carried out by Norway-based REEtec, which is using a unique and environmentally friendly process to separate the mixed rare earth carbonate product produced in Saskatchewan into the individual rare earth oxides needed by the high-tech, defense, and other industrial sectors.

Under an offtake agreement with REEtec, Vital will provide the Norwegian company with mixed rare earth carbonate product containing 1,000 metric tons of rare earth oxides, not counting the cerium, over the first five years.

The magnet rare earths praseodymium and neodymium are expected to account for about 447 metric tons, or roughly 45% of the annual rare earth oxides covered under the preliminary offtake agreement.

Vital intends to scale up Nechalacho output and the agreement with REEtec provides the companies with the option to increase this offtake volume up to 5,000 metric tons of rare earth oxides per year.

More Canadian high-grade REEs

The smaller is better when it comes to rapidly scaling up rare earth production strategy may also work well at Alces Lake, a project in northern Saskatchewan that hosts some of the highest REE grades ever discovered.

While a resource has yet to be calculated for the high-grade zones discovered at Alces Lake, grades as high as 16.1% total rare earth oxides over 15.6 meters and 31% TREO over 2.7 meters encountered during drilling completed by Appia Energy Corp. indicate the project could host a resource with grades multiples above the global average.

Located in northern Saskatchewan, Alces Lake is a 35,400-acre (14,300 hectares) property that has been explored for its uranium and rare earths potential since the 1950s.

The true potential of this property, however, was not revealed until Appia geologists collected samples with grades as high as 35.7% TREOS. Follow-up surface sampling in 2017 turned up even higher grades – 49.6% TREO over 0.95 meters and 45.9% TREO over 1.85 meters. A boulder at Wilson, a zone about 100 meters southeast of Ivan, contained 30.8% TREO.

Being located in Saskatchewan, a central Canadian province that is investing in becoming a North American rare earths leader, is also advantageous.

In August, the Saskatchewan government announced it is investing C$31 million in a facility with the ability to both concentrate ore and separate the concentrates into individual rare earth elements. This is the same facility where Vital has located its own REE carbonate facility.

"Appia is very pleased and excited to learn that the Saskatoon rare earth processing plant will be up and running by the end of 2022, especially since it is in such close proximity to Appia's high-grade critical rare


A float plane touches down on the bay next to Ucore's Bokan Mountain rare earths project in Southeast Alaska.

UCORE RARE METALS INC.

earth Alces Lake project," said Appia Energy President and CEO Tom Drivas.

The same mineralization that hosts world-class rare earth grades also happens to host very high concentrations of gallium, another mineral critical to the U.S. and Canada.

■ *More information on the Alces Lake gallium can be read at* ***Techy gallium overshadowed by rare earths*** *on page 67.*

Alaska 2023 plan

Ucore Rare Metals Inc. has a strategy to establish Alaska as another North American rare earth oxides hub.

Dubbed Alaska2023, this business is centered on building a commercial-scale RapidSX rare earths separation and purification plant in Southeast Alaska by 2023.

A search for an economically viable and environmentally sound method of separating rare earths led Ucore to Innovation Metals Inc., a private Canada-based company led by Gareth Hatch, an expert in both rare earths and metallurgy.

Solvent extraction, which involves the use of various chemicals to first break apart the rare earths into groups and then into individual elements, has long been the preferred method of REE separation. With its inexpensive labor and lax environmental standards, China has utilized this technique to dominate the business of rare earth processing for four decades.

Innovation's RapidSX takes the time-tested solvent extraction technique to a new level by utilizing an innovative column-based platform that is much faster and environmentally sustainable than its predecessor.

With the goal of incorporating this proprietary technology into the Alaska Strategic Metals Complex, the name of its planned Southeast Alaska processing facility, Ucore acquired Innovation in 2020.

Ucore also plans to eventually establish a mine at Bokan Mountain, a rare earths and critical minerals project about 35 miles away from where the company plans to build the SMC.

According to a calculation completed in 2019, the Dotson Ridge deposit at Bokan hosts 4.79 million metric tons of indicated resource averaging 0.6% (31,722 metric tons) rare earth oxides, 460 parts per million (2,205 metric tons) niobium; 1,880 ppm (9,001 metric tons) zirconium; 48 ppm (231 metric tons) beryllium; 37 ppm (178 metric tons) hafnium; 0.37% (17,715 metric tons) titanium dioxide; and 97 ppm (464 metric tons) vanadium.

While Bokan could be a future source of REEs and other critical metals, Ucore's immediate priority is to begin producing rare earths at the planned Alaska SMC.

"The ALASKA2023 timelines are aggressive and necessary to ensure US participation in a variety of emerging high-tech industries such as information technology, communication and electric vehicles," said Ucore Rare Metals CEO Pat Ryan. "Is Ucore up for the challenge? Just watch us." DMN

Worker at Rio Tinto's Saguenay-Grande-Baie aluminum plant in Quebec.
RIO TINTO

Scandium finds its own way in NA markets

Rio Tinto produces critical alloying metal at Quebec refinery

By SHANE LASLEY
DATA MINE NORTH

SCANDIUM IS AN ADOPTED BROTHER to the family of 15 lanthanides that make up the suite of elements known as rare earths.

While it may not have quite as strong a chemical bond to its adopted lanthanide siblings as they do to each other, scandium does possess similar characteristics and is almost always found at the same geological gatherings (deposits) as the rest of its rare earth family.

Beyond its close chemical and geological ties to rare earths, scandium is considered a critical mineral in its own right due to its traditional alloying qualities and emerging high-tech properties.

The traditional use for this critical metal is as an ingredient in lightweight and strong aluminum-scandium alloys for aerospace components and sports equipment. In recent years, however, solid oxide fuel cells have supplanted alloys as the primary use for this metal. Ceramics, electronics, lasers, lighting, and 3D metals printing are emerging areas of demand for scandium.

The United States is currently 100% dependent on imports for this alloying and technology metal that sits on the U.S., Canada, and European Union's critical mineral lists.

Though scandium is often associated with rare earths, most of the global supply of this alloying metal is recovered as a byproduct of titanium, zirconium, cobalt, and nickel production.

With the installation of a scandium recovery facility at a titanium and iron facility in Canada, Rio Tinto is the first commercial-scale producer of high-quality scandium oxide in North America.

Looking to produce roughly three metric tons of scandium per year, which is about 20% of the current global market, Rio Tinto is

AIRBUS APWORKS

Metal 3D printing is among the emerging uses for scandium. Weighing in at just 77 pounds, this motorcycle was printed from a scandium-aluminum-magnesium alloy known as Scalmalloy.

investing US$6 million for the construction of the first module of a commercial-scale demonstration plant at its Rio Tinto Fer et Titane (iron and titanium) metallurgical complex in Sorel-Tracy, Quebec.

Already proven at the pilot scale, this plant will extract high-purity scandium oxide from the waste streams of titanium dioxide production at its Lac Tio mine near Havre-Saint-Pierre, Quebec.

"We are proud to offer North America's first reliable supply of scandium oxide using an innovative and sustainable process, with the construction of this new plant," said Rio Tinto Iron and Titanium Managing Director Stéphane Leblanc.

The provincial government is contributing approximately US$650,000 to the scandium recovery project through the Quebec Plan for the Development of Critical and Strategic Minerals.

"The step just taken today by Rio Tinto Fer et Titane has the potential to position Quebec as a world leader in the extraction and commercialization of scandium," said Quebec Minister of Economy and Innovation Pierre Fitzgibbon said in January. "With this project, Quebec will become the largest producer of this rare metal, which will have a major impact on our exports and Quebec's supply chains, particularly in key sectors such as the electrification of transportation and aerospace."

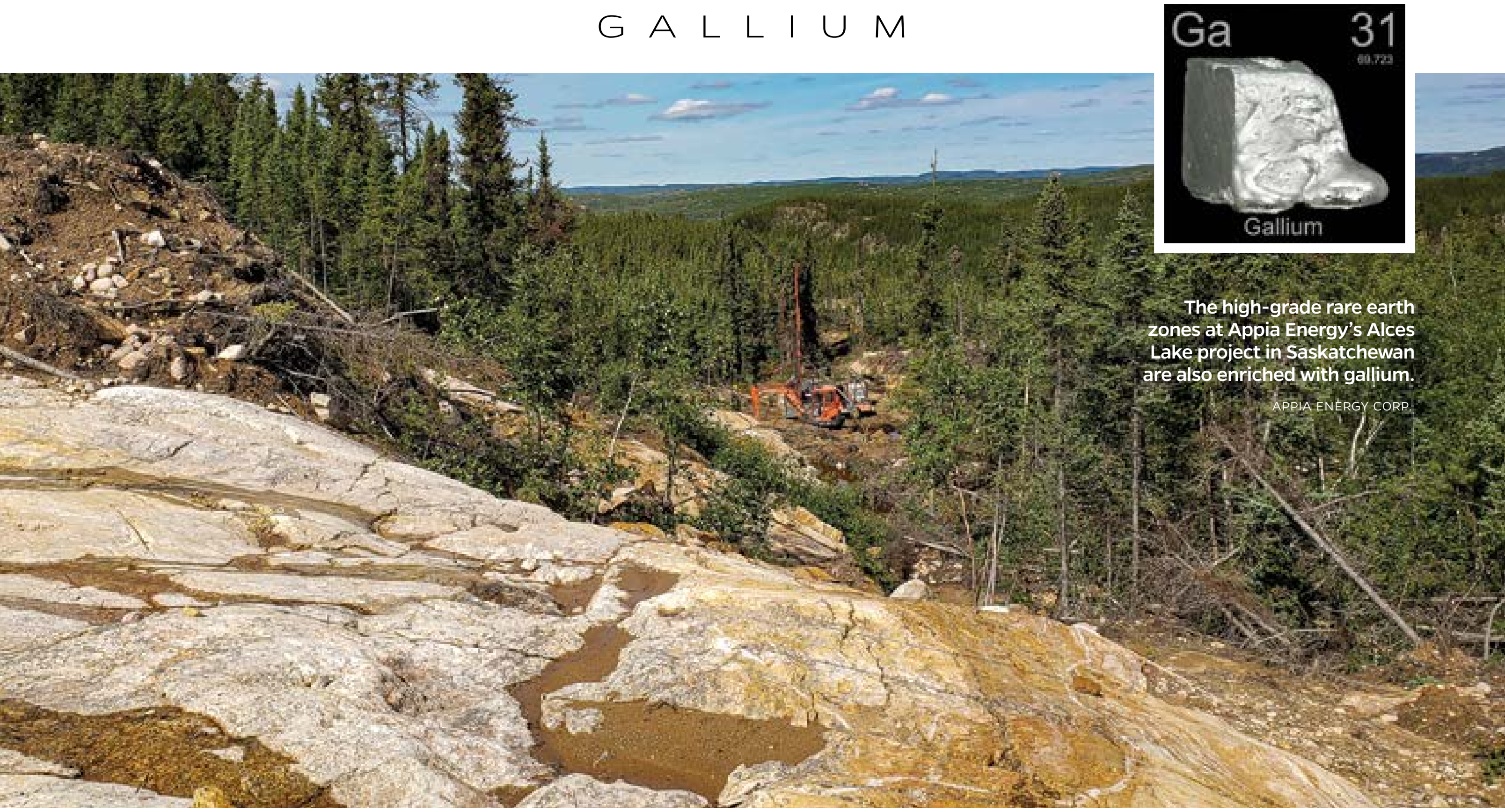
Rio Tinto said the scandium recovered from the new plant will also dovetail with its aluminum operations in the Saguenay–Lac-Saint-Jean region of Quebec.

"With the support of Rio Tinto's aluminium business, we are uniquely positioned to deliver aluminium-scandium master alloys and develop synergies with North America's manufacturing supply chain," said Leblanc.

To fully realize this potential, Rio Tinto has formed Element North 21, a business to commercialize its scandium products.

Deriving its name from scandium's number on the periodic table and the business' Canadian headquarters, Element North 21 will initially offer three scandium products – 99.9% pure scandium oxide, a standard aluminum-scandium alloy, and specialized aluminum-scandium alloys for aerospace and 3D printing applications.

Rio Tinto said it will be able to scale up scandium production to meet market demands by adding additional modules to its scandium recovery plant in Quebec. DMN



The high-grade rare earth zones at Appia Energy's Alces Lake project in Saskatchewan are also enriched with gallium.

APPIA ENERGY CORP.

Techy gallium overshadowed by REEs

Ironically, mining rare earths may offer new critical gallium supply

By SHANE LASLEY

DATA MINE NORTH

OVERSHADOWED BY HEADLINE-GRABBING rare earth elements, gallium is an underappreciated critical metal that is a vital ingredient in next-generation smartphones and communication networks, light-emitting diodes (LEDs), thin-film solar cells, and medical devices.

"The development of gallium arsenide as a direct band-gap semiconductor in the 1960s led to what are now some of the most well-known uses of gallium – in feature-rich, application-intensive, third- and fourth-generation smartphones and in data-centric networks," the U.S. Geological Survey penned in a 2018 report on the 35 minerals and metals considered critical to the United States.

The advent of 5G-capable telecommunication networks is pushing demand for this tech metal even higher.

"Owing to their large power-handling capabilities, high-switching frequencies, and higher voltage capabilities, GaN- (gallium nitride) based products, which historically have been used in defense applications, are used in fifth-generation (5G) networks, cable television transmission, commercial wireless infrastructure, power electronics, and satellite markets," the U.S. Geological Survey inked in its Mineral Commodities Summary 2021 report.

And this new demand is driving up the price for the semiconductor metal with a melting point so low that it will turn into a liquid in the palm of your hand.

Gallium prices have nearly doubled over the past year, from US$281.70 per kilogram of 99.995% gallium metal in August of 2020, to US$528.80/kg in May of this year.

The USGS estimates that American manufacturers used roughly 15,000 kilograms of gallium for the circuitry of smartphones and other computers; optoelectronic devices such as LEDs, laser diodes, photodetectors; and solar cells during 2020.

While integrated circuits in next-generation computers are anticipated to need increasing amounts of gallium, thin-film photovoltaic panels delivering electricity to homes and businesses is an emerging driver of demand for this critical metal.

Copper-indium-gallium-selenide (CIGS) solar cells can absorb much more sunlight than traditional cells, which means that a much thinner film is needed. These photovoltaic films can be applied on flexible materials and are less expensive to produce.

Despite these advantages, CIGS solar panels are much less

FOOBAR PHOTOGRAPHY

Gallium crystals.

efficient at converting electricity than their more rigid silicon-based counterparts. As such, CIGS only make up about 2% of the solar panel market. This is expected to climb with improved solar efficiency.

Now, scientists are looking at also using gallium as means of slowing the degradation of silicon-based solar panels.

Boron, a material traditionally added to silicon to convert sunlight into energy, has one big drawback – it also causes the panel to collect impurities that degrade performance over time. Replacing boron with gallium, however, substantially reduces this degradation.

While this fact has been known for two decades, a patent prevented scientists from pursuing gallium-doped silicon solar panels. With the patent expired, researchers at the University of New South Wales in Australia are now continuing the research into longer-lasting gallium-doped silicon solar panels, which could add new market demands for the tech metal.

"Because of the likelihood of rapid growth in the areas of photovoltaics and clean energy technologies, a potential exists for bottlenecks in the gallium supply pipeline," USGS inked in its critical minerals report.

And much like the rare earths that have captured global attention in recent years, China dominates the gallium mining sector, and the U.S. is 100% dependent on imports for the semiconductor metal.

According to the USGS, China produced 290,000 kilograms of gallium during 2020, or roughly 97% of the gallium mined globally last year.

Ironically, breaking America's dependence on China for rare earths through the development of deposits in the U.S. and Canada could also provide a steady and secure supply of gallium.

A critical REE byproduct

Like many other critical minerals and metals, gallium is typically recovered as a byproduct of mining more common metals – primarily aluminum, zinc, and sometimes copper.

While there are deposits of these base metals in both the U.S. and Canada enriched with gallium, two North American rare earths deposits – Round Top in Texas and Alces Lake in Saskatchewan – host richer stores of this critical metal.

Being advanced under a joint venture between USA Rare Earth LLC (80%) and Texas Mineral Resources Corp. (20%), the Round Top rare earths project in Texas is rich in a suite of critical minerals, including gallium.

According to a 2020 assessment by USGS, the Round Top deposit hosts a staggering 36,500 metric tons (36.5 million kg) of gallium, or enough to meet U.S. needs for roughly 2,281 years at the consumption rate in recent years.

This enormous lode of gallium, however, is in low concentrations in a very large deposit.

The continuous ion exchange and continuous ion chromatography (CIX-CIC) technology used to recover the rare earths mined from Round Top has also been designed to extract and purify the lithium, hafnium, zirconium, gallium, and beryllium also found in the critical Texas deposit.

Earlier this year, the Round Top joint venture began mining of a 20,000-metric-ton bulk sample to provide material for a feasibility study, as well as a demonstration plant that scales up a Colorado CIX-CIC pilot plant used to prove and refine the critical metals extraction and purification technology.

"This new plant will process leach solutions from the Round Top ore using continuous ion exchange and continuous ion chromatography (CIX-CIC) to separate and purify up to a total of 26 different recoverable elements," according to USA Rare Earth.

While not as large or advanced as Round Top, Appia Energy Corp.'s Alces Lake rare earths project in northern Saskatchewan may host the highest-grade gallium deposit in North America.

An electron microprobe study conducted by the Saskatchewan Research Council successfully demonstrated that the rare earths-enriched monazite mineral from two separate zones and trends at Alces Lake was also enriched with gallium.

Following up on this initial study, Appia had select samples with high-grade rare earths from eight zones re-assayed to determine the extent of gallium mineralization across the property.

Analysis of 22 samples returned gallium grades ranging from 0.035 to 0.626% gallium trioxide. Values higher than 0.01% gallium trioxide are considered high-grade.

"The gallium concentrations on the property are remarkable. Gallium was found in naturally occurring high-concentrations on the property that far exceed current concentrations required for global production of gallium," said Appia Energy President Frederik Kozak.

By way of example, it is estimated that the ore intermittently mined over a century at Apex Mine in Utah, which was the only primary mined source of gallium and germanium in the U.S. before it was closed in 2011, averaged about 0.032% gallium, with locally occurring grades up to 0.148% gallium.

(USGS estimates that 79 metric tons of gallium remain at the shuttered Apex Mine.)

While a resource has yet to be calculated for the high-grade zones at Alces Lake, it is expected that the initial resource will confirm one of the world's highest-grade deposits of rare earths and gallium.

This expectation is based on drill intercepts of 15.6 meters averaging 16.1% total rare earth oxides and 2.7 meters of 31% TREO, which indicate the project could host a resource with grades multiples above the 1.89% average for REE deposits worldwide.

Appia says the latest testing indicates gallium concentrations in the rare earth zones at Alces Lake range from 0.01 to 0.104% gallium trioxide.

"The presence of gallium in the high-grade REO system on the Alces Lake property helps distinguish the property as a potential world-class asset for high-valued critical elements required for sustainable production of advanced technological applications," said Kozak. DMN

The U.S. Department of Energy is investing in projects to transform coal-producing communities from Appalachia to Alaska into suppliers of the critical minerals needed for the low-carbon energy transition.

ADOBE STOCK

Unconventional critical mineral solutions

Revisiting yesterday's waste for tomorrow's technology metals

By SHANE LASLEY

DATA MINE NORTH

FROM ELECTRIC VEHICLES PLUGGED into renewable energy to smartphones connected to 5G networks, new technologies take advantage of the special properties of a suite of critical minerals and metals that are often rare and in short supply.

In addition to the rare earths, cobalt, lithium, and other technology metals that capture headline attention, this list includes even more obscure mined materials such as gallium, germanium, scandium, and tellurium.

While scarce, these critical elements are often found alongside more common minerals and metals such as aluminum, coal, copper, and zinc.

Recent work by government, academia, and innovative companies has shown that sifting through the ash left behind from more than a century of powering America with coal and digging into the tailings of yesterday's mines could offer unconventional supplies of these equally unconventional metals needed to build tomorrow's technologies.

U.S. Secretary of Energy Jennifer Granholm understands the need for these critical metals, and her department is investing in companies and universities at the leading edge of recovering these technology metals from unconventional sources.

"America is in a race against economic competitors like China to own the EV market – and the supply chains for critical materials like lithium and cobalt will determine whether we win or lose," she said. "If we want to achieve a 100% carbon-free economy by 2050, we have to create our own supply of these materials, including alternatives here at home in America."

American coal ash resources

A compelling source for the rare earths needed for EV motors, wind turbines, and an array of high-tech digital devices is the ash left behind by more than a century of burning coal to generate electricity in the United States.

Not quite as uncommon as their name suggests, rare earths are often found in the coal that has been burned to generate electricity in America for decades. While the coal itself typically does not have high enough REE concentrations to recover economically, the burning of this fuel works like a concentrator that leaves behind higher grades of this suite of critical minerals in the ash.

"Coal ash is rich in rare earth elements, as rich as some of the ore deposits," said Linda Wang, a professor of chemical engineering at Purdue University. "The United States produces about 129 million tons of coal ash every year."

While this annual production of ash is expected to wane as America transitions to lower-carbon energy sources, more than a century of coal-fired electrical generation has created billions of tons of this REE-enriched waste product.

American Resources Corp. recently acquired exclusive rights to potentially game-changing rare earth and critical elements separation and purification technologies developed in Wang's lab at Purdue.

Joe Pekny, a professor of chemical engineering at Purdue, believes these processes developed by Wang offer a sustainable and economical path for the U.S. to become less dependent on imports for rare earths.

"Linda's method replaces a very inefficient process and replaces it with an earth-friendly, safe extraction process," he said.

Over the past five years, American Resources has accumulated more than $370 million worth of coal assets and related infrastructure, primarily in Kentucky, that could provide domestic sources of ash and other materials enriched with rare earths and other critical minerals that could be recovered with this process.

American Rare Earth LLC, a subsidiary of American Resources, plans to use the exclusive patents and technologies developed at Purdue to advance environmentally sound rare earths and critical minerals supply chains in the U.S.

"We're excited about partnering with American Rare Earth and American Resources on the implementation of our research," said Wang. "We look forward to working with their team on the design of a pilot production facility and an eventual full-scale production plant."

Critical coal clays

Ash left behind at power plants is not the only coal-related resource rich in rare earths.

Materia USA, a company formed for the very purpose of producing critical minerals from unconventional sources, has found that layers of clay underlying Pennsylvania coal seams are particularly enriched in rare earths and other critical minerals such as gallium and lithium.

With funding from DOE's National Energy Technology Laboratory, Materia has been advancing conceptual designs for a facility to recover critical minerals from these alternative sources uncovered by previous coal mining.

In addition to a potential new domestic source of the rare earths that America is almost completely dependent on China for, this project has the potential to provide work for Pennsylvania coal miners that are looking for new jobs as the U.S. transitions to lower carbon-emitting energy sources, as well as reclaim legacy coal mines.

"I was proud to support Materia-USA's application to recover rare earth elements and critical minerals from Pennsylvania's coal fields," said Rep. Guy Reschenthaler, R-Pennsylvania. "By working to establish a reliable domestic supply of these resources through projects like this, we can support good-paying jobs and economic opportunities in our communities, eliminate significant sources of pollution such as acid mine drainage, and end our nation's dependence on China and other foreign countries."

With conceptual studies showing promise, earlier this year Materia launched the second phase of the DOE-supported effort to recover critical minerals from coal under-clays.

In partnership with Penn State University, Materia is developing a feasibility study that details the economic benefits of its conceptual design. This study will also provide information on the environmental impact of the design through a life cycle analysis of greenhouse gas emissions.

"This feasibility study is another critical step in our work towards a sustainable future for the coal industry in a post-fossil fuel age," said Materia USA CEO Rabbi Yechezkel "Zeke" Moskowitz. "The fact that the Biden administration is taking an active role in our work means that the administration understands that rare earth and critical mineral extraction via reclamation work is not only an option but also economically viable – it's truly exciting."

The ash left behind by more than a century of burning coal to generate electricity in the U.S. offers a compelling source of the rare earths elements needed for electric vehicles, renewable energy, and high-tech devices.

Transforming coal country

The Biden administration's interest in transforming coal country into new energy regions is further evidenced by the $19 million DOE awarded earlier this year to 13 projects in traditionally fossil fuel-producing communities from Appalachia to Alaska.

"The very same fossil fuel communities that have powered our nation for decades can be at the forefront of the clean energy economy by producing the critical minerals needed to build electric vehicles, wind turbines, and so much more," said Secretary Gran-

ADOBE STOCK

holm. "By building clean energy products here at home, we're securing the supply chain for the innovative solutions needed to reach net-zero carbon emissions by 2050 – all while creating good-paying jobs in all parts of America."

Roughly $5.4 million of this funding went to universities researching techniques to extract and process the rare earth elements and critical minerals from coal, coal sediments, coal ash, coal mining waste, acid mine drainage, and other unconventional resources in the Appalachia coal mining region of eastern U.S.

Similar grants were awarded to universities in coal-producing regions across the U.S. – from Alabama to Montana, and even Alaska.

Sen. Joe Manchin, chairman of the Senate Energy and Natural Resources Committee, says these funds are helping to spur the economy of coal-producing areas like his home state of West Virginia while also creating innovative solutions for a cleaner energy future.

"The coal industry downturn has left many West Virginians without the good-paying jobs they once relied on, which has negatively impacted our state economy. I am pleased that DOE is investing in West Virginia University's Mid-Appalachian Carbon Ore, Rare Earth and Critical Minerals Initiative, which will work to expand and transition coal resources to other high-value products," said the Mountain State Democrat.

Liability to liquid asset

Penn State, which is among the universities to receive the coal country grants from DOE, has also developed a process that could transform acid mine drainage from an environmental liability that is costly to a liquid asset that produces rare earths and other valuable minerals.

"We are currently incurring costs just to treat the water, and in many cases, we are not even collecting all these minerals," said Sarma Pisupati, professor of energy and mineral engineering at Penn State. "Now we are able to turn what had been considered a waste product into a valuable resource."

Acid mine drainage occurs when mining exposes sulfide-containing minerals, which react to air and water to form sulfuric acid. While this process sometimes occurs naturally, it can be more pronounced after mining.

"Acid mine drainage has been a significant environmental concern for many decades," said Mohammad Rezaee, assistant professor of mining engineering in the College of Earth and Mineral Sciences at Penn State.

By their very nature, these acidic waters are laden with metals.

Rezaee and his colleagues have developed a two-stage treatment process that recovers more of the metals out of acid mine drainage, while using less chemicals than previous solutions to this environmental hazard.

"This research shows we can modify existing treatment processes in a way that not only addresses environmental concerns, but at the same time recovers valuable elements and actually decreases the cost of treatment," Rezaee added.

The traditional process Penn State is building on involves collecting acid mine drainage in ponds and using chemicals to neutralize the pH, which causes the dissolved metals to solidify and drop out of the water. The Penn State researchers said that about 70% of rare earths could be extracted as a sludge using this process.

By first injecting carbon dioxide into acid mine drainage, a process that produces a carbon mineral called carbonatites, the Penn State team found it could recover even more metals with less pH neutralizing. This is because rare earths and other metals latch onto the carbonatites and more readily settle out of the water.

With the CO2 technique, Penn State scientists were able to recover 90% of the contained aluminum at a pH of 5, which is still mildly acidic, and 85% of rare earths at pH 7, which is neutral.

To get the same recoveries with other methods would require raising the pH even higher, which translates to more chemicals and costs.

UNITED STATES GEOLOGICAL SURVEY

Penn State scientists have developed a process to efficiently recover metals such as rare earths from acid mine drainage, a win-win solution for the environment.

"With a simple modification of existing treatment processes, industry could use less chemicals and get more value out of AMD waste," Rezaee said. "This is the beauty of this research."

Phoenix arises from tailings

The tailings left behind from mining aluminum, copper, gold, silver, zinc, and other more common metals offer another potential unconventional source of critical minerals while also chalking up a win for the environment.

Mining is an energy-intensive industrial process that typically involves crushing massive quantities of rock dug from the earth into a sand- or silt-like consistency to extract the minerals and metals needed by society. The leftovers from this process, called tailings, are typically stored in a facility until the mine closes and then covered up and contoured during the mine reclamation process.

Critical minerals such as cobalt, germanium, rare earths, tellurium, and titanium are thrown out with the tailings. In the past, the market was not large enough to justify extracting most of these minor elements, or the cost of the extra steps was too great.

With modern solar panels, EVs, lithium-ion batteries, and other modern technologies creating new demand for these metals, companies are beginning to look at tailing storage facilities as critical mineral ore deposits – Phoenix Tailings is one such company.

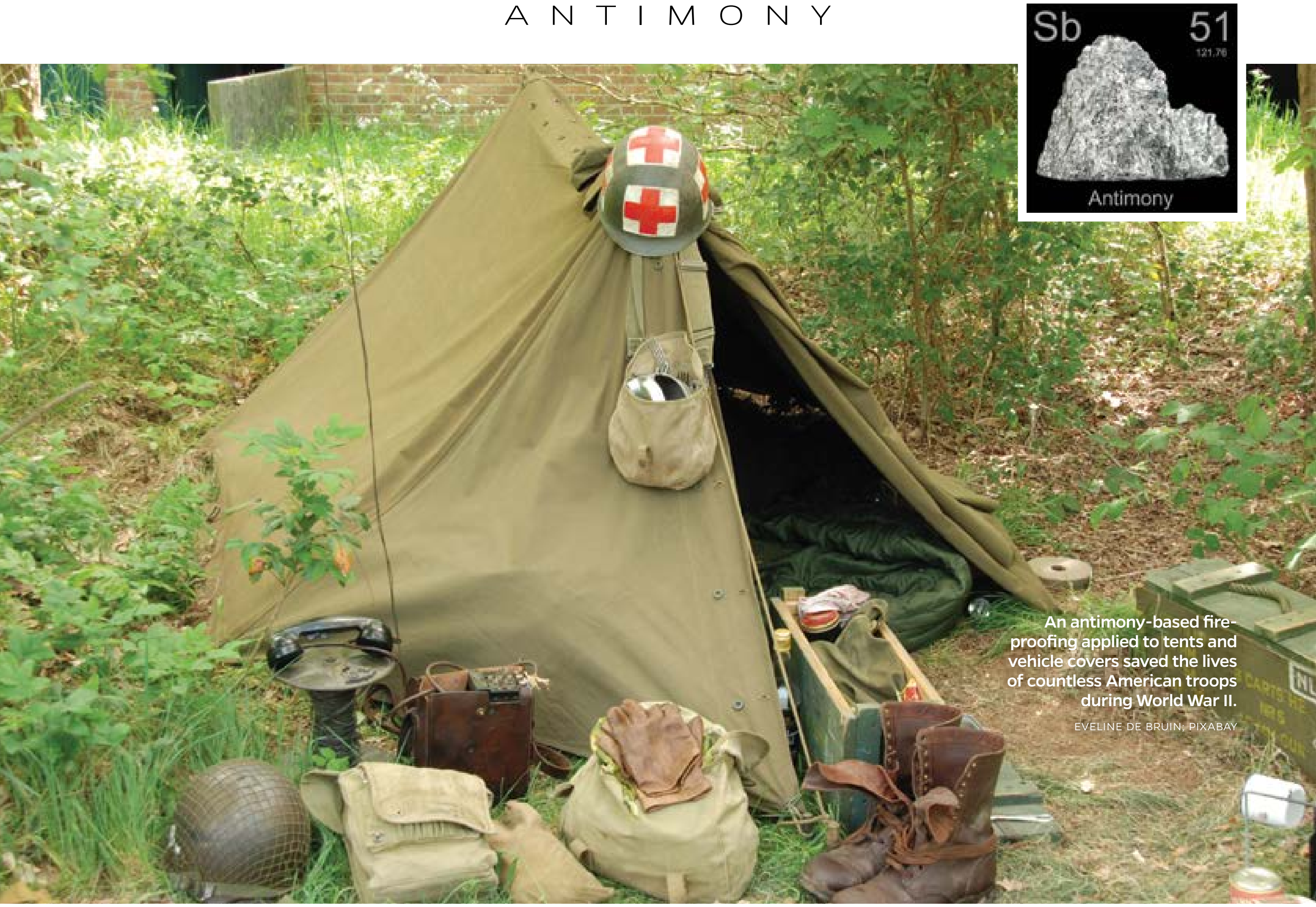
"We want to get to the point where there is no such thing as 'waste' and there is only material waiting to be processed into new products," Mike Martin, an engineer, material scientist, and co-founder of Phoenix Tailings, told Jaclyn Severance at the University of Connecticut. "To put it another way, we want to show people tailings ponds are a huge untapped opportunity."

One of the advantages of tapping this opportunity is most of the hard work has already been done – the rock has been mined and crushed.

With these energy-intensive and costly steps out of the way, a company like Phoenix only has to focus on the most efficient and sustainable methods for recovering whatever critical minerals might be in the cast-off material.

Using three separate processes – hydrometallurgy, solvometallurgy, and electrometallurgy – Phoenix has the ability to tailor its extraction systems to the tailings and minerals being targeted.

Much like extracting critical minerals from coal ash and acid mine drainage, the re-mining of tailings offers the added benefit of leveraging liabilities at already industrialized sites to produce the unconventional metals needed to build a cleaner and greener future. DMN



An antimony-based fire-proofing applied to tents and vehicle covers saved the lives of countless American troops during World War II.

EVELINE DE BRUIN, PIXABAY

Antimony may be a renewable energy hero

After saving millions of lives, stibnite poised for new heroics

By **SHANE LASLEY**

DATA MINE NORTH

AN UNSUNG WAR HERO that saved countless American troops during World War II, an overlooked battery material that has played a pivotal role in storing electricity for more than 100 years, and a major ingredient in futuristic grid-scale energy storage, antimony is among the most important critical metalloids that most people have never heard of.

While antimony may not be part of the common lexicon, humans have been using this semi-metal for more than 5,000 years.

"For example, the ancient Egyptians and early Hindus used stibnite, which is the major ore mineral for antimony, to produce black eye makeup as early as about 3100 B.C.," the United States Geological Survey penned in a 2018 report on critical minerals.

While antimony's cosmetic status has waned over the past five millennia, the metalloid's ability to resist heat and corrosion, make stronger lead alloys, produce clearer glass for high-tech devices, and store renewable energy has created new uses for the ancient metal.

A wide array of American industries, including the defense and energy sectors, are taking advantage of antimony's unique properties.

"Today, antimony is used in lead-acid storage batteries for backup power and transportation; in chemicals, ceramics, and glass; in flame-retardant materials; and in heat stabilizers and plastics," according to the USGS.

PIXABAY

PERPETUA RESOURCES CORP.

Left: The antimony mineral stibnite was used more than 5,000 years ago for the iconic black makeup worn by Ancient Egyptians and Hindus. Below: From 1941 to 1945, the Stibnite Mine in Idaho produced more antimony and tungsten than any other mine in the U.S.

Despite having significant reserves of stibnite, the U.S. depends on other countries, primarily China, for more than 80% of its supply of this critical mineral. The balance of American supply comes from recycling and refining concentrates imported from Italy, China, India, and Mexico.

"China continued to be the leading global antimony producer in 2020 and accounted for more than 52% of global mine production," USGS inked in its 2021 Mineral Commodity Summaries report.

Due to America's heavy reliance on imports, coupled with antimony's traditional and emerging applications, USGS recently ranked stibnite as the No. 10 most critical mineral to the U.S. when it comes to supply risk.

Idaho and Alaska have stepped up to meet America's strategic antimony needs in the past, and host rich deposits of the heat-resisting metal that could help fill current and future critical needs.

War hero

Antimony's flame and heat resistant properties elevated this metalloid to hero status during World War II.

This is largely due to the lives of countless American troops that were saved during the war by an antimony-based fireproofing compound that was applied to tents and vehicle covers.

When combined with a halogen – fluorine, chlorine, bromine, or iodine – antimony trioxide suppresses the spread of flames.

"Antimony is also vital to our military's effectiveness and has been since it was labeled as crucial to the war effort during World War II," U.S. Army Major General James (retired) "Spider" Marks penned in a 2020 column published in The Washington Times.

Over the eight decades since the end of World War II, antimony continues to save innumerable lives – from soldiers in the field to babies in the nursery – by lending its flame-resistant properties to mattresses, toys, electronic devices, aircraft, and automobile seat covers.

In addition to its widespread heat-resistance applications, antimony imparts increased hardness and mechanical strength into an alloy known as antimonial lead.

Bullets and shot, bearings, electrical cable sheathing, printing machines, solders, and pewter are among the products made of alloys that contain some amount of antimony.

The most common application for antimonial lead, however, is improving the plate strength and charging characteristics in the lead-acid batteries that have been used to start most internal-combustion-engine vehicles for more than a century.

Antimony is also used to make high-quality glass used by both civilians and soldiers. For example, a small amount of antimony oxide has the ability to remove bubbles and make super-clear glass used to make lenses for binoculars and similar optical equipment, as well as the glass screens of smartphones and other electronic devices.

"Antimony is a key ingredient in communication equipment, night vision goggles, explosives, ammunition, nuclear weapons, submarines, warships, optics, laser sighting, and much more," U.S. Army Major General Marks wrote.

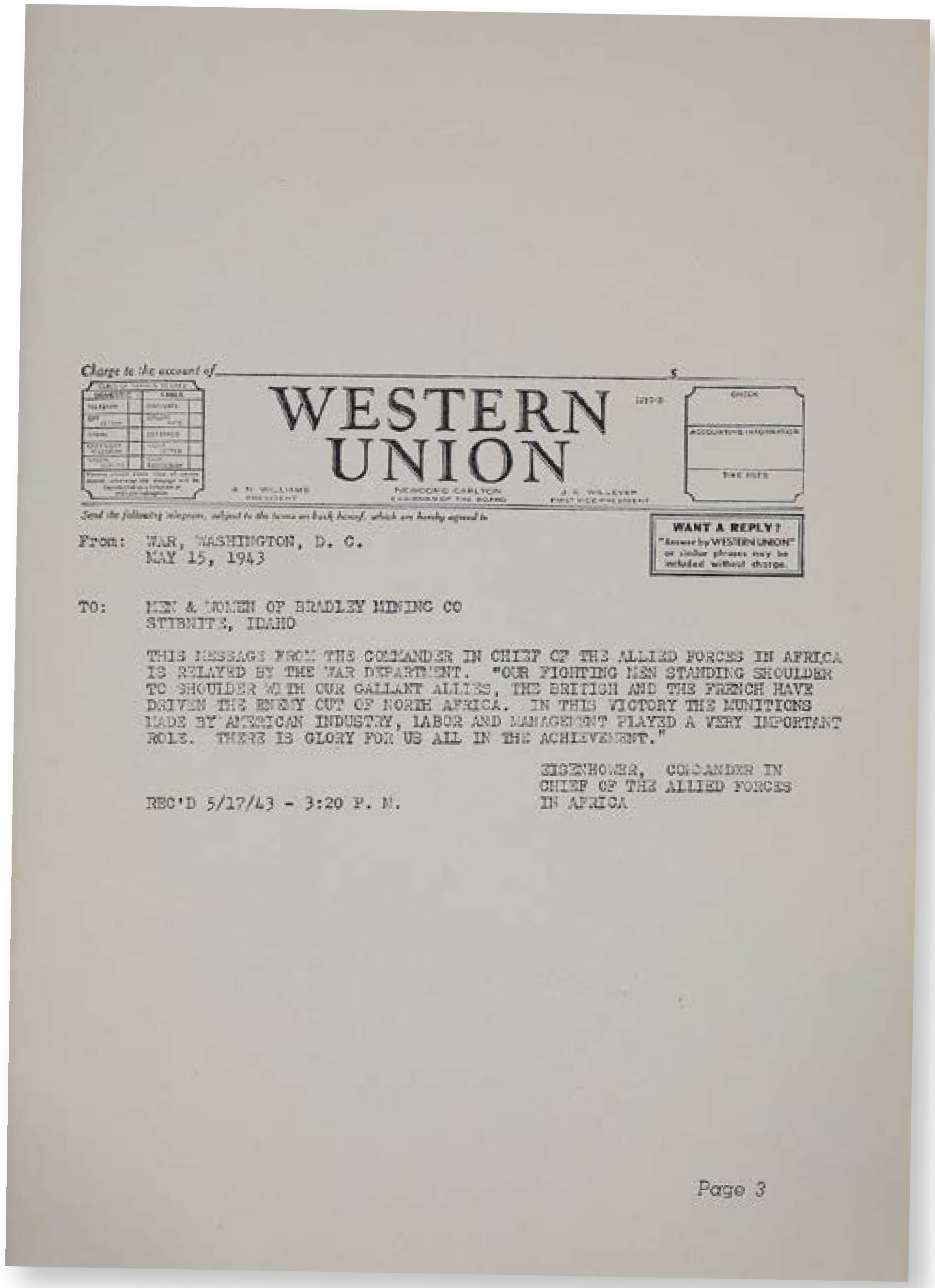
The majority of this antimony is recycled, which accounts for essentially all of America's supply of the metal that is not imported.

Molten antimony battery

While lead-acid battery usage is expected to decline as electric motors take the place of ICE engines in the vehicles traveling global highways, antimony is finding its way into new applications in next-generation batteries that can efficiently store electricity at the grid scale.

Known as liquid-metal batteries, this relatively new form of energy storage was developed at the Massachusetts Institute of Technology (MIT) in Cambridge.

Ambri, a battery research and development company born from the liquid metal battery research carried out at MIT, is advancing these large grid-scale batteries to commercial use.


Charge to the account of

WESTERN UNION

WANT A REPLY?
"Answer by WESTERN UNION" or similar phrases may be included without charge.

From: WAR, WASHINGTON, D. C.
MAY 15, 1943

TO: MEN & WOMEN OF BRADLEY MINING CO
STIBNITE, IDAHO

THIS MESSAGE FROM THE COMMANDER IN CHIEF OF THE ALLIED FORCES IN AFRICA IS RELAYED BY THE WAR DEPARTMENT. "OUR FIGHTING MEN STANDING SHOULDER TO SHOULDER WITH OUR GALLANT ALLIES, THE BRITISH AND THE FRENCH HAVE DRIVEN THE ENEMY OUT OF NORTH AFRICA. IN THIS VICTORY THE MUNITIONS MADE BY AMERICAN INDUSTRY, LABOR AND MANAGEMENT PLAYED A VERY IMPORTANT ROLE. THERE IS GLORY FOR US ALL IN THE ACHIEVEMENT."

EISENHOWER, COMMANDER IN CHIEF OF THE ALLIED FORCES IN AFRICA

REC'D 5/17/43 - 3:20 P. M.

Page 3

The Ambri battery has a calcium alloy anode, a molten salt electrolyte, and an antimony cathode.

At room temperature, Ambri's cell is non-conductive and its materials are solid. Once heated to 500 degrees Celsius (932 degrees Fahrenheit), however, the minerals and metals melt and become active. The passing of ions through the electrolyte as the battery charges and discharges keeps the metals molten, eliminating the need for auxiliary heating or cooling.

All these liquids are stored in a single stainless-steel tank without the need for dividers because, like oil and water, they have different densities and do not mix.

Ambri says these batteries are less expensive to manufacture, work in a wider range of climatic conditions, last longer, and are safer than their lithium-ion counterparts.

While such batteries won't likely be used in vehicles, they could solve the problem of creating durable batteries for storing power from renewable sources such as solar and wind power – electricity that can be delivered to the grid as needed.

"Our technology will fundamentally change the way power-grids operate, increasing the contribution from renewable resources and reducing the need to build traditional power plants," Ambri says. "Customers will see lower electricity bills and more reliable service."

TerraScale, a data center development firm that prioritizes sustainability and cybersecurity, is leveraging these advantages through the installation of 250 megawatt-hours of Ambri liquid-metal batteries to store solar energy at its Energos Reno project in Nevada.

"Our data center technology partners are looking forward to deploying Ambri's technology to enable high-volume, reliable, and resilient energy storage with potentially the lowest levelized cost of storage in the industry," said TerraScale CEO Danny Hayes.

This is a major step in commercializing Ambri's energy storage technology and bolstering demand for the antimony that goes into its liquid-metal batteries.

Idaho Stibnite Mine

Many of North America's richest gold districts also host healthy amounts of antimony, but the latter fire-resistant energy metal is often discarded in favor of the more valuable precious metal. This dynamic, however, reversed at gold mines in Idaho and Alaska when antimony's strategic value increased during the World Wars.

"During the Second World War, when the U.S. faced a crisis because it didn't have sufficient antimony of its own – let that be a lesson here – and so it launched the development of the Stibnite Mine in Idaho," Chris Ecclestone, a mining strategist with Hallgarten & Co. in London.

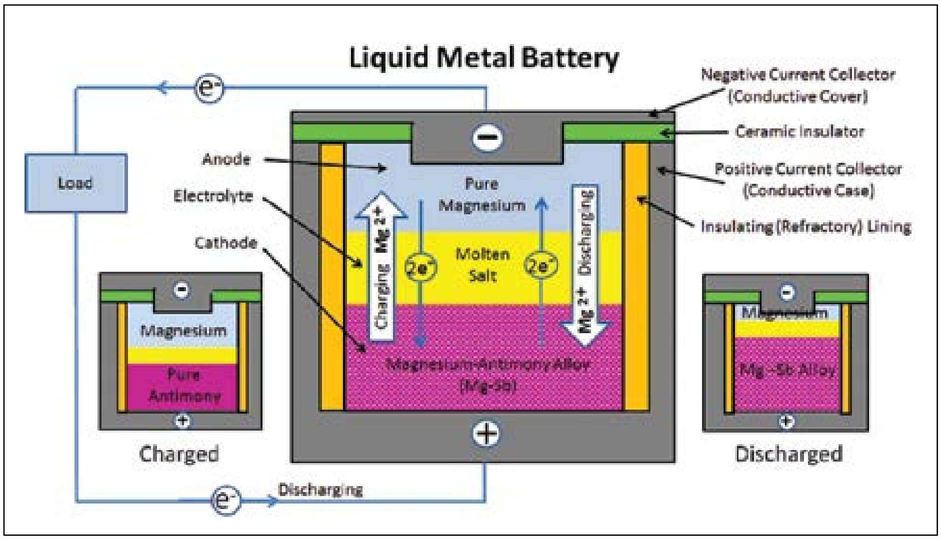
From 1941 to 1945, Stibnite Mine produced more antimony and tungsten than any other mine in the U.S. – accounting for 90% of the antimony and 40% of the tungsten produced during this wartime effort.

This Idaho mine has been credited for saving millions of lives and helping to bring World War II to an end.

"In the opinion of the munitions board, the discovery of that tungsten at stibnite, Idaho, in 1942 shortened World War II by at least 1 year and saved the lives of a million American soldiers," according to the March 7, 1956 U.S. Senate Congressional Record.

The lives saved came at an environmental cost to the Yellow Pine area of Idaho where the Stibnite Mine was located. Perpetua Resources Corp., however, plans to help clean up the environmental legacy of the mine while also producing the antimony critical to the U.S.

"America has the brainpower, spirit of innovation and work ethic to continue to solve some of the world's toughest problems. However, we lack the minerals and materials we need to bring those solutions to life,"



The Ambri liquid metal battery has a calcium alloy anode, a molten salt electrolyte, and an antimony cathode.

AMBRI

said Perpetua Resources CEO Laurel Sayer. "Perpetua Resources can play a key role in re-establishing domestic antimony production and protecting America's energy, technology and defense future."

According to a 2014 prefeasibility study, the Stibnite Mine being permitted by Perpetua would produce 99.85 million lb of antimony, 4.04 million ounces of gold, and 2.07 million oz of silver over a 12-year mine life. Perpetua hopes to finalize the federal permitting process by the end of this year and begin the work of restoring legacy environmental damage and building a modern era Stibnite Mine in 2022. Commercial production of antimony, gold, and silver from the Idaho mine is expected to begin in 2026.

"There is an exciting opportunity to rebalance antimony supplies away from China and break their stranglehold on the metal," Ecclestone said.

Century of Alaska antimony

For more than a century, Alaska's gold districts have been hailed for their potential to host economically viable deposits of antimony.

"It has long been known that stibnite, the sulfide of antimony and the principal source of that metal, is widely distributed in Alaska," Alfred Brooks penned in a 1917 report, Antimony deposits of Alaska.

Brooks' early 20th-century investigation identified 67 stibnite occurrences in Alaska, most of which are found in areas famed for their gold – Nome, Fairbanks, and Iditarod.

The first record of primary antimony mining in Alaska was the Sliscovich Mine about 30 miles northeast of the gold rush mining town of Nome.

First opened in 1906, Sliscovich was positioned to provide a domestic source of antimony at the onset of World War I, an event that sparked stibnite mining across much of Alaska.

"WWI created considerable demand for antimony," James Barker, who investigated much of Alaska's critical minerals potential while working as a geologist for the U.S. Bureau of Mines, told Data Mine North.

While roughly 100 tons of ore shipped from Sliscovich in 1914 and 1915 contained about 35% antimony, the value of the gold and silver in this ore outweighed the critical mineral.

While Sliscovich and other mines near Nome provided some antimony for America during World War I, larger loads of higher-grade concentrates were sent from mines around Fairbanks, in the state's Interior region.

"In 1915 antimony ore was mined on four properties in the Fairbanks district at the Scrafford, in Treasure Creek basin; the Stibnite, in Eva Creek basin; the Gilmer, in Vault Creek basin; and at Chatham Creek mine," Brooks wrote. "All the operations were on a small scale and consisted chiefly of open cuts. The total shipments of stibnite from the district during 1915 were 685 tons, which probably averaged 58% antimony."

Scrafford, the most prolific of these Fairbanks area stibnite mines, has been estimated to produce 2,700 tons of ore containing greater than 50% stibnite over the years.

Former U.S. Bureau of Mines geologist Barker said the lump antimony mined from this hand operation north of Fairbanks "was sacked and transported by cable tram up to the ridge top and then by horse-drawn wagons into Fairbanks to be shipped south by river steamer." Today, this property near Kinross Gold Corp.'s Fort Knox Mine is being explored primarily for its gold potential.

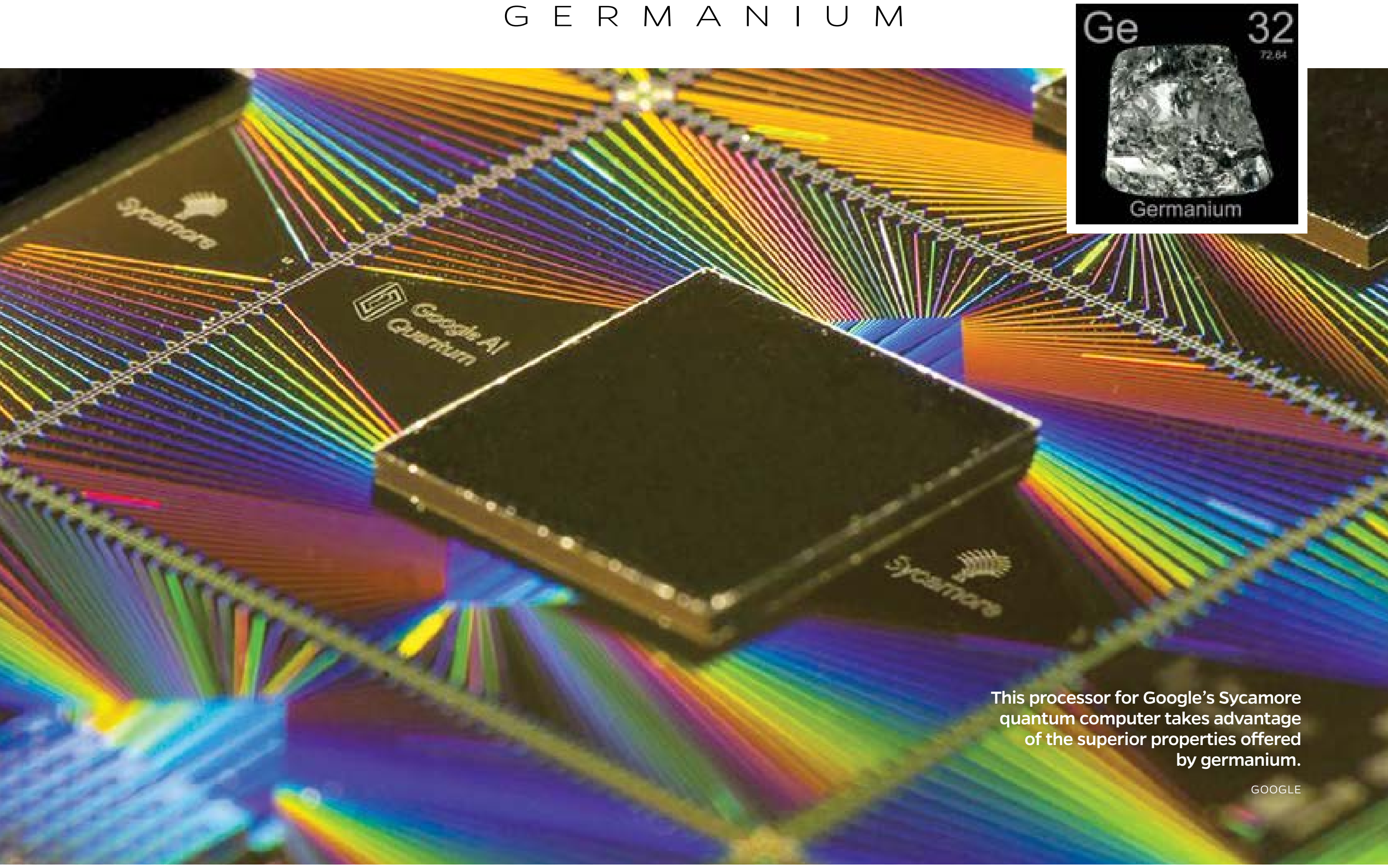
>> *The antimony potential found in Alaska trends eastward from Fairbanks and into Canada's Yukon, where one mine between Haines Junction and Whitehorse produced the critical mineral during the 1960s and veins containing an estimated 700 million lb of stibnite remain.*

The antimony potential found in Alaska trends eastward from Fairbanks and into Canada's Yukon, where one mine between Haines Junction and Whitehorse produced the critical mineral during the 1960s and veins containing an estimated 700 million lb of stibnite remain.

Much like what Perpetua proposes for the Stibnite Mine in Idaho, antimony recovered from deposits in Alaska or the Yukon will likely be a byproduct of mining the gold these northern mining jurisdictions are best known for.

"Enhanced recovery of antimony from precious metal deposits may represent the most readily available source of antimony if demand were to increase rapidly," USGS penned in its 2018 critical minerals report.

If molten-salt batteries gain traction for utility-scale storage of renewable energy, more gold miners will likely investigate the potential of producing the critical antimony that often accompanies the precious metal. DMN



This processor for Google's Sycamore quantum computer takes advantage of the superior properties offered by germanium.

GOOGLE

The quantum states of germanium demand

Critical metalloid for lightspeed communications, computations

By **SHANE LASLEY**

DATA MINE NORTH

FROM THE TRANSISTORS IN QUANTUM COMPUTERS that are millions of times faster than their classical counterparts to fiber optic cables that send data at the speed of light, germanium is a little-known semiconductor that is a small but extremely important ingredient in the technologies behind the future of ultrafast computing and communications.

Germanium traces its technological roots back to the 1950s, when scientists developed the transistor to replace vacuum tubes in the enormous mainframes of the day – a discovery that ushered in the era of personal computers.

These transistors utilized germanium's excellent semiconductor qualities to, in a sense, flick tiny on and off switches that create the streams of ones and zeros that represent the standard computer binary system.

While germanium is the original and more powerful transistor semiconductor, it was supplanted by silicon, a more abundant and less expensive material that has established such an important stake in the computing world that a valley named after the semiconductor is widely regarded as the global capital of computer technology and innovation.

Germanium's intrinsic semiconducting superiority has reemerged – this time in the realm of quantum computing and the most efficient solar panels ever created.

Despite its superlative-earning semiconductor achievements, germanium's superior optical qualities are what drive the highest demand for this metalloid.

"The major use of germanium worldwide is for fiber-optic systems, whereby germanium is added to the pure silica glass core of fiber-optic cables to increase their refractive index, minimizing signal loss over long distances," the United States Geological Survey inked in a germanium fact sheet.

These optical and other exceptional qualities are also important to making night-vision goggles and other infrared imaging devices that are used extensively by the military and law-enforcement agencies.

"Germanium is metallic in appearance and has unique properties that make it critical to the function of numerous commercial, industrial, and military applications," the USGS penned in the germanium chapter of a 2018 report on the 35 minerals and metals critical to the U.S.

Often found alongside zinc, germanium is almost always produced as a byproduct of the galvanizing metal.

"In 2020, zinc concentrates containing germanium were produced at mines in Alaska and Tennessee," according to the USGS.

The germanium-carrying zinc concentrates from the Alaska mine, Red Dog, were shipped to Teck Resources Ltd.'s Trail refinery in British Columbia, and the concentrates from the Middle Tennessee Mines were processed at a local refinery.

Quantum realm

Whether it be smartphones, laptops, or supercomputers, the central processing unit at the heart of these machines is built using semiconductor technology that is capable of holding billions of transistors onto a single chip. Now, researchers at QuTech, an advanced research center for quantum computing and quantum internet, are using germanium-based transistors in computers that are unfathomably faster and more powerful than the silicon-based computers we use today.

"We have been working with transistors as the building blocks for a quantum computer for some time now," says Nico Hendrickx, a Ph.D. student at QuTech. "Until now, however, it hasn't been possible to perform quantum calculations using only transistors. Other elements were needed as well, and this provided a limitation for upscaling. We now show that a single transistor can function as a quantum bit by using germanium."

The QuTech researchers have long considered germanium as a superb material for making quantum bits, or qubits, but manufacturing with this material has been challenging.

These hurdles have now been overcome and the team has now demonstrated they "can perform reliable and extremely fast quantum calculations with germanium."

How fast? In a mere 200 seconds, Google's quantum computer Sycamore solved a calculation so mathematically complex that it would take the world's most powerful supercomputer 10,000 years to figure out, or roughly 158 million times faster than the fastest classical computer on the planet.

The researchers at QuTech consider germanium as the ideal platform for several quantum technologies they are developing.

"Now that we know how to manufacture germanium and operate an array of qubits, the germanium quantum information route can truly begin," said Menno Veldhorst, a team leader at QuTech.

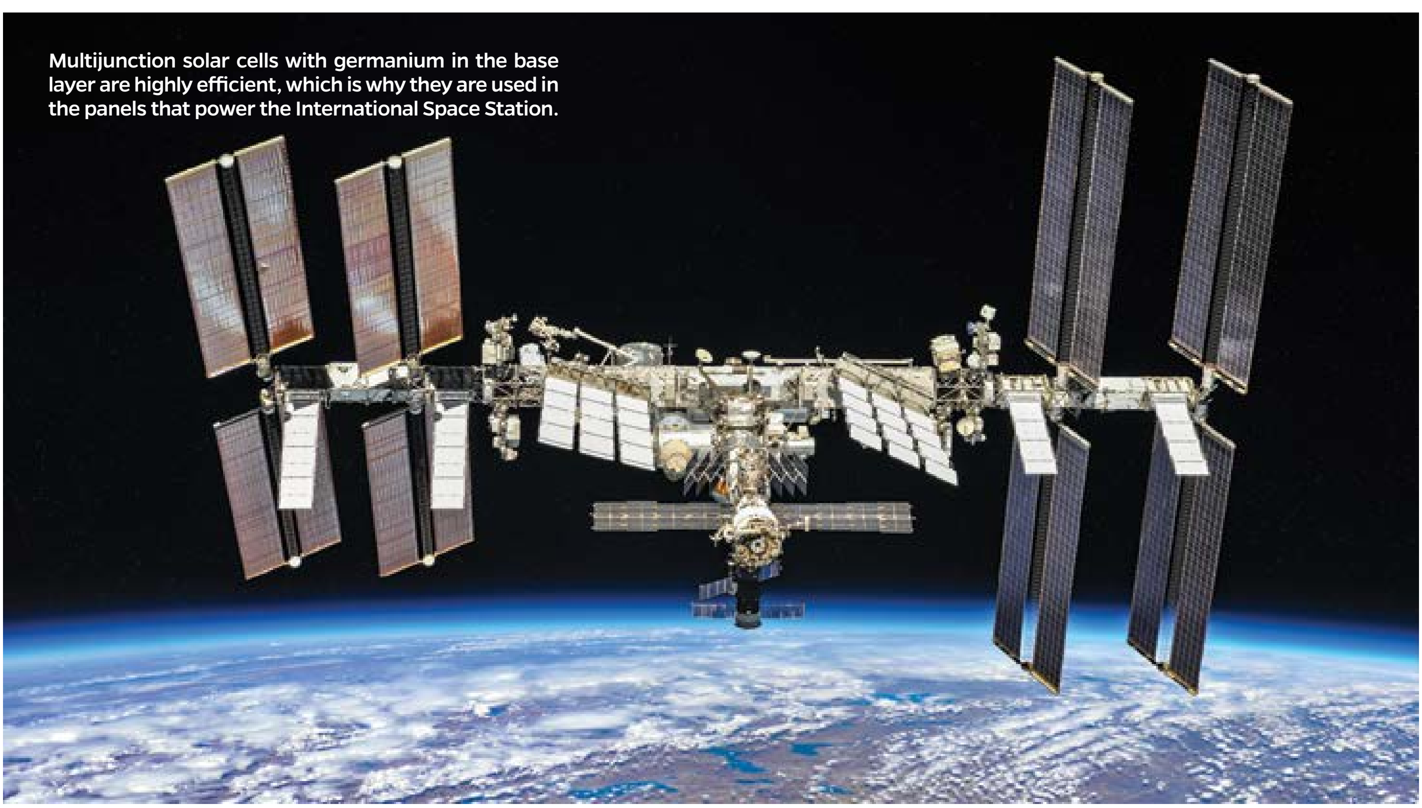
Best in the solar system

The same semiconducting properties that are taking computing into the quantum realm are also are being used in the most effective photovoltaic panels in the solar system.

"Germanium substrates are used to form the base layer in multijunction solar cells, which are the highest efficiency solar cells currently available," according to the USGS.

These solar arrays, which have three layers of cells that use germanium and other critical metals, are much more expensive to build than the typical photovoltaic cell that primarily uses silicon to convert light into electricity.

The high efficiency of the germanium germanium-infused solar cells, however, makes them preferred for space applications such as



Multijunction solar cells with germanium in the base layer are highly efficient, which is why they are used in the panels that power the International Space Station.

NASA

some of the Mars rovers.

"The solar cells are stacked in three layers on the rover's solar arrays and, because they absorb more sunlight, can supply more power to the rover's re-chargeable lithium batteries," NASA Jet Propulsion Laboratory explains on technologies to power space missions.

USGS said recent research could make similar high-efficiency solar arrays commercially viable on Earth, a potential driver for future germanium demand.

"Solar powerplants that use concentrator technology composed of lenses or mirrors that focus high concentrations of direct sunlight onto germanium-based multijunction solar cells have emerged as viable sources for large-scale renewable energy generation," according to USGS.


SILIXA LTD.

Adding a bit of germanium to fiber-optic cables minimizes signal loss over long distances.

Exceptional optics

While quantum computers and solar panels may be the future demand drivers for germanium, most of the metalloid's current applications are focused on its optical qualities – transparent to the infrared electromagnetic spectrum, can be formed into glass, exceptionally high refractive index, and low chromatic dispersion.

"Chromatic dispersion is a serious consideration in long-haul optical fibers. Its effect is essentially to stretch or flatten the initially sharply-defined binary pulses of information. This degradation makes the signals (ones and zeros) more difficult to distinguish from each other at the far end of the fiber," M2 Optics Inc. CEO Kevin Miller explains.

The growing need to send and receive enormous quantities of data at lightning-fast speeds continues to drive the demand for more fiber-optic cable and the germanium that goes in it.

U.S. demand for fiber-optic cable decreased during 2020 as a side effect of the COVID-19 pandemic. Federal funding to increase broadband infrastructure in rural communities and a nationwide increase in remote work, however, partially offset the lowered demand.

The demand for germanium is expected to continue trending higher with the global installation of 5G network technology that will require the speeds delivered by fiber optics.

Infrared imaging devices used by the military, law-enforcement agencies, and increasingly in the private sector are another major driver of demand for germanium.

"Infrared optical devices improve a soldier's ability to operate weapon systems in harsh conditions effectively, and they are increasingly used in remotely operated unmanned weapons and aircraft," the USGS inked in its germanium report. "Infrared optical devices are also used for border patrol and by emergency response teams for conducting search-and-rescue operations."

While military and law enforcement are the major buyers of night-vision technology, USGS said commercial applications for thermal imaging devices that use germanium lenses have increased during the past few years.

From concentrates to coal ash

While there is currently plenty of germanium mined to meet demands for this critical tech metalloid for the foreseeable future, only a fraction of this zinc-byproduct is recovered at the refineries.

Teck Resources' Trail Operations in southern British Columbia, which refines zinc and lead concentrates from the company's Red Dog Mine in Alaska, is considered one of the largest producers of germanium in the world.

The Trail refinery offers a wide variety of high-quality germanium products, including germanium dioxide and fiber optic grade germanium tetrachloride.

With the refinery processing concentrates from other mines, it is hard to track exactly how much, if any, of this germanium comes from Red Dog concentrates.

This situation has created a conundrum for agencies tracking critical minerals.

"Because zinc concentrates are shipped globally and blended at smelters … the recoverable germanium in zinc reserves cannot be determined," USGS penned in its 2021 mineral commodities report.

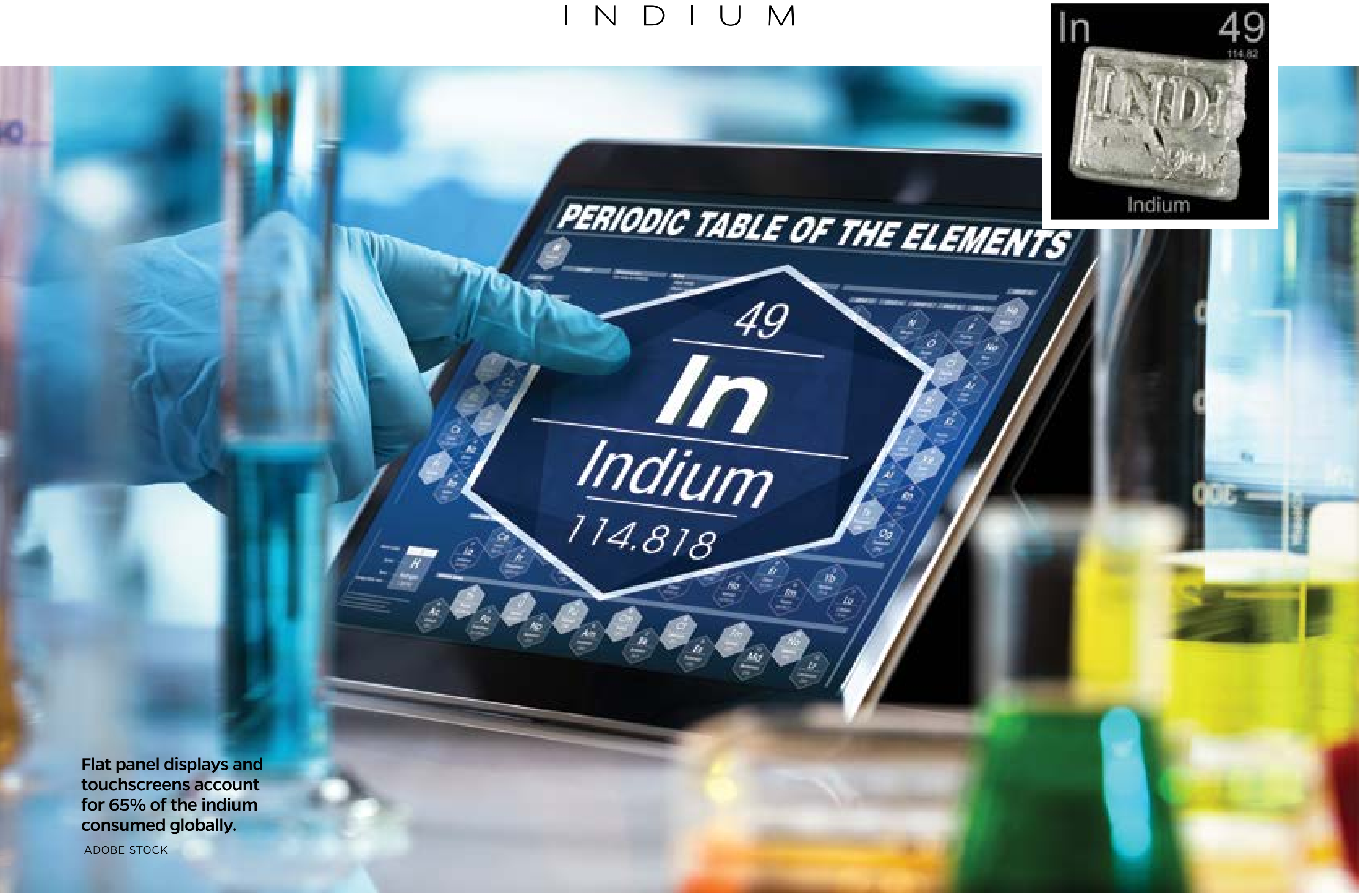
In addition to zinc concentrates, germanium, rare earths, and other critical minerals are often also found in coal deposits. While the concentrations of critical minerals in the deposits themselves are typically too low to be economical, this percentage becomes much higher in the ash left behind by more than a century of burning coal to generate electricity.

Looking to transform old coal mining regions into new domestic sources for critical minerals, the U.S. Department of Energy has awarded $19 million for 13 projects in traditionally fossil fuel-producing communities from Appalachia to Alaska.

While rare earths are the primary target of this DOE-funded project, the cash that has been stacking up at coal-fired power plants also often contains germanium, lithium, cobalt, titanium, vanadium, and a dozen other minerals and metals considered critical to the U.S.

This could provide a new source for germanium and other metals needed for the envisioned renewable energy and electric vehicle transition, while also providing new career opportunities that are being affected by this transition.

"The very same fossil fuel communities that have powered our nation for decades can be at the forefront of the clean energy economy by producing the critical minerals needed to build electric vehicles, wind turbines, and so much more," said Secretary of Energy Jennifer Granholm. DMN



Flat panel displays and touchscreens account for 65% of the indium consumed globally.
ADOBE STOCK

The invisible technology demand for indium

A critical zinc byproduct everybody touches, and nobody sees

By SHANE LASLEY
DATA MINE NORTH

THE ABILITY TO TYPE, TAP, swipe, and scroll your way through articles such as this one from a smartphone, tablet, computer, and now even refrigerators is made possible by indium-tin oxide, which is used as a transparent conducting film applied to virtually every flat-panel display and touchscreen on the market.

This thin and invisible layer lying just under the glass senses incoming electrical data triggered by the touch of your fingertip and transforms it into an optical form, a property that makes touchscreens touchable.

Flat-panel displays and touchscreens account for 65% of the indium consumed globally. While each of these devices only needs a small amount of indium-tin oxide, the massive and growing number of phones, computer monitors, televisions, household appliances, and other devices with displays adds up to a lot of this metal.

And indium-tin oxide currently has no equal when it comes to the combination of characteristics – transparency, electrical conductivity, strong adherence to glass, corrosion resistance, and stability – required to search for the latest critical mineral news on your smartphone or order groceries from your fridge.

"Indium can be considered a critical material for display technology because there are few substitutes," the United States Geological Survey penned in its 2018 report on the 35 minerals and metals deemed critical to the U.S.

The other factor that elevates indium to critical material status is the U.S. depended on imports for 100% of the approximately 100 million metric tons needed during 2020. Roughly 34% of this supply came from China, 22% from Canada, and about 15% from Korea.

Solar powers new demand

While flat-panel displays and touchscreens are by far the largest drivers of demand, indium is also used as a reflective yet transparent energy-saving coating, especially on architectural glass that clad high-rise buildings; low melting point alloys and solders often used in electronics; and in semiconductor materials for light emitting and laser diodes

The biggest new market driver for indium, however, may be the thin-film photovoltaic solar cells that are emerging as a popular choice for generating low-carbon residential and commercial electricity.

The most popular of these is copper-indium-gallium-selenide (CIGS) solar cells that can absorb much more sunlight than traditional cells, which means that a much thinner film is needed. These thinner cells can be applied on flexible materials and are less expensive to produce.

Despite these advantages, CIGS solar panels are less efficient at converting electricity than their more rigid silicon-based counterparts. As such, CIGS only make up about 2% of the solar panel market. This is expected to climb as researchers continue to improve the efficiency of solar cells with copper-indium-gallium-selenide semiconductor material.

CIGS cells have reached 22.9% efficiency in labs, and several technological advancements are underway to further increase their efficiency. A research team in Germany has identified areas where CIGS can be optimized and believe they can boost the efficiency rate to above 33%.

Analysts predict sharp sales growth for these cheaper to produce and more environmentally benign cells as efficiencies rise.

Indium is also used in powerful lasers and receivers used in 4G and 5G fiber-optic networks that have data transmission speeds of greater than 10 terabits (10 million bits) per second and transmission distances of more than 3,100 miles (5,000 kilometers).

So far, however, solar cells or 5G networks have yet to move the dial on indium demand or price. In mid-2021, a kilogram of indium was selling for around US$340, which is only about 11% higher than the US$300/kg price for the tech metal in 2016.

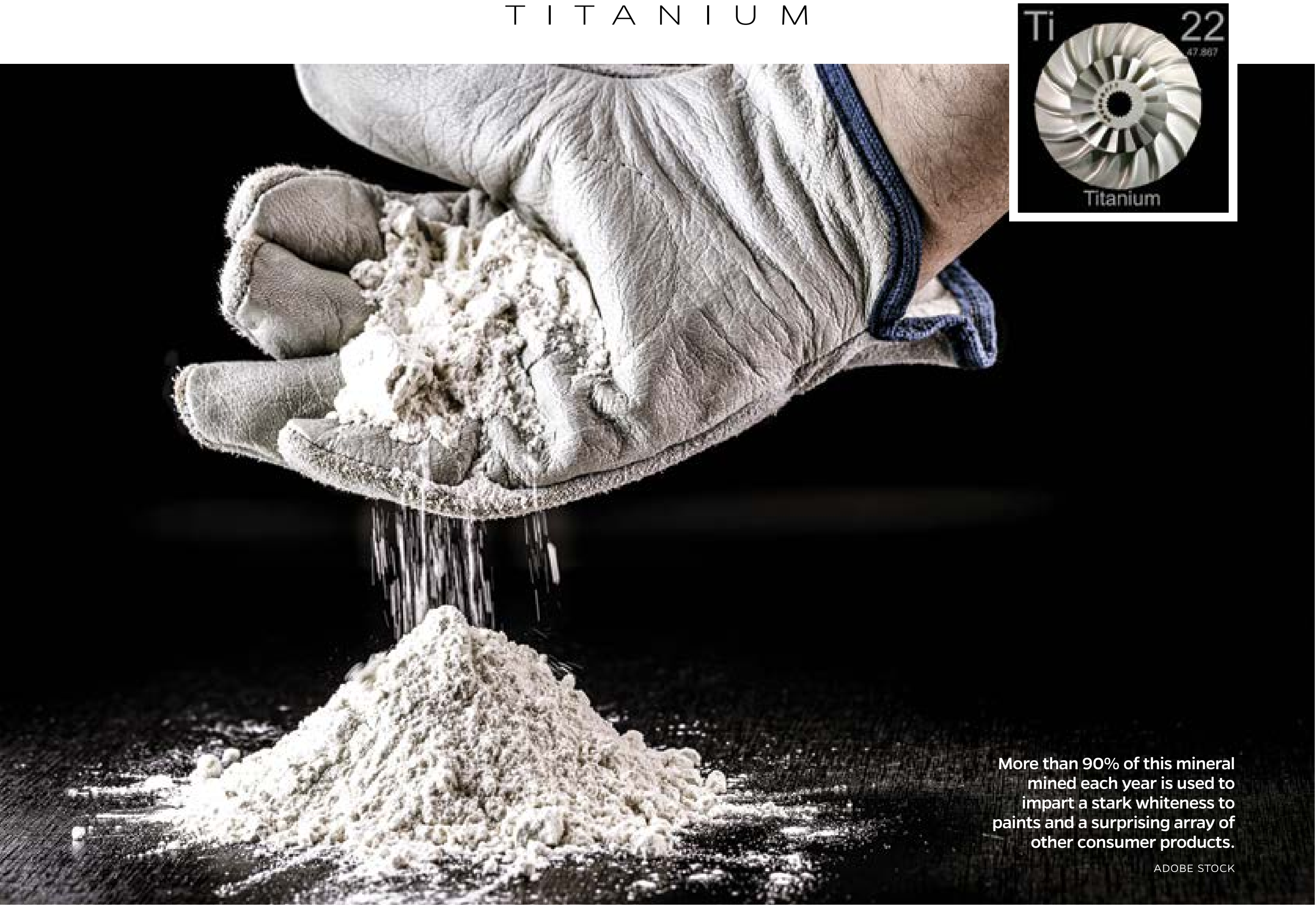
Most of the roughly 900 metric tons of annual indium produced globally during 2020 were recovered as a byproduct of refining zinc concentrates, including at Teck Resources Ltd.'s Trail refinery in British Columbia.

"Indium is produced as a co-product of the zinc smelting process at our integrated refinery in Trail," according to the Teck website. "We have expanded our production capability to meet the growing demands of indium-tin-oxide manufacturers."

Teck Resources CEO Don Lindsay has previously noted that Trail could easily deliver 75 metric tons of indium annually, which to approximately 75% of all the indium used in the U.S. last year. DMN

With a natural ability to adhere to glass and silvery appearance, indium is used in energy-saving coatings on architectural glass commonly seen on high-rise buildings.

ADOBE STOCK



More than 90% of this mineral mined each year is used to impart a stark whiteness to paints and a surprising array of other consumer products.

ADOBE STOCK

Titanium demand drivers are in whitening

Roughly 90% of lightweight mineral is used in paints, pigments

By **SHANE LASLEY**

DATA MINE NORTH

LIGHTWEIGHT, STRONG, AND RESISTANT to corrosion, titanium is best known for the properties it lends to rockets, aircraft, and high-performance sports equipment. Only about 3% of the more than 8 million metric tons of titanium minerals mined each year globally, however, go into high strength-to-weight ratio and corrosion-resistant alloys. What does drive the mass majority of the demand for this critical mineral is "enwhitening."

According to the United States Geological Survey, more than 90% of the titanium mined each year is used to impart a stark whiteness to a surprisingly wide variety of consumer goods we use every day.

"Titanium is different than most other metallic elements in that it is mined primarily to satisfy demands for a chemical product – titanium dioxide for pigment – rather than for the metal itself," the U.S. Geological Survey penned in a 2018 report on the durable mineral.

Because this titanium dioxide pigment is used to color paints, paper, plastic, cosmetics, and even dairy products, the demand for this whitening metal is tied closely to consumer buying.

"Demand in the first half of 2020 decreased sharply owing to restrictions implemented to limit the spread of the COVID-19 virus," the USGS penned in its 2021 annual mineral commodities report. "In the second half of 2020, titanium producers reported that demand was recovering, led by demand for TiO2 in paints and coatings."

Whiter whites

Titanium dioxide has three qualities that make it an ideal material for creating whiter whites – it is white, it is safe for human consumption, and it scatters light extremely well.

"Titanium dioxide has properties of whiteness, opacity, and chemical inertness that make it especially suitable for use as pigment to impart a durable white color to paints, paper, plastic, sunscreen, toothpaste, and wallboard," the USGS inked in its 2018 titanium report.

Most high-quality white paints you buy in the hardware store today contain "titanium white," a pigment made from this white material.

In addition to imparting a reflectiveness and whiteness that makes rooms appear brighter, titanium dioxide increases paint's opacity, which assists in the "one-coat cover" touted by many paint manufacturers.

And titanium dioxide is even used to make foods such as skim milk and cottage cheese whiter and creamier looking.

There are very few replacements for titanium dioxide when it comes to pigments. Lead, which was the ingredient of choice for white paint for nearly 2,000 years, has similar whitening qualities but is seldom used in paints today because of its toxicity.

According to the USGS, roughly 60% of the 900,000 metric tons of titanium dioxide used in the U.S. during 2021 went into paints; 20% into plastics; 5% into paper; and 15% into cosmetics, foods, and other products.

Because it is used in such a wide variety of products, most U.S. consumers use a product containing titanium dioxide every day.

Lighter, stronger metal

While we typically do not think about titanium dioxide in our toothpaste or milk, many of us are much more familiar with the exceptional weight-to-strength ratio that titanium metal lends to high-performance sporting gear such as bicycle frames, golf clubs, tennis rackets, and goalie masks.

Medical implants, such as hip and knee replacements, also take advantage of titanium metal's lightweight durability, along with an inertness that allows it to be added to milk.

The aerospace industry, however, is by far the largest consumer of titanium metal.

While aluminum is about 60% lighter than titanium, it is only about half as strong, corrodes much easier, and does not hold up to heat as well. Since it is important not to break or melt down at 20,000 feet, titanium is the metal of choice for many aircraft parts.

"Titanium metal's combination of corrosion resistance, excellent weight-to-strength ratio, and very high melting point is not found with other metals," the USGS penned in its titanium report.

And when it comes to aircraft performance, the lighter the better.

"In the 1950s, the titanium metal industry was established primarily in response to the emerging aerospace industry, which used it in the manufacture of airframe structural components and skin, aircraft hydraulic systems, air engine components, rockets, missiles, and spacecraft," according to ASM Aerospace Specification Metals Inc.

In addition to being lightweight and strong on its own, titanium alloys with aluminum, iron, nickel, molybdenum, vanadium, and other metals – which makes it ideal for a wide array of aircraft parts and military equipment.

The airframes, landing gear and fasteners used in many commercial and military aircraft today are made from titanium or a titanium alloy.

The ability to withstand temperatures from subzero to above 1,100 degrees Fahrenheit also makes titanium an increasingly useful metal for jet and rocket engine parts.

According to the USGS, an estimated 80% of titanium metal consumed in the U.S. during 2019 was used in aerospace applications; the balance was used in armor, chemical processing, marine hardware, medical implants, power generation, and other applications.

There are no completely satisfactory substitutes for titanium when it comes to many of its aerospace, marine, and military applications.

Widely dispersed

While titanium is the ninth most abundant element in the Earth's crust, for the most part, it is too widely dispersed to be economically mined. There are a few titanium minerals, however, that contain

Launch of a SpaceX Falcon Heavy rocket and Dragon spacecraft. The aerospace sector is by far the largest consumer of titanium metal.

SPACEX

ADOBE STOCK

The whitening of dairy products such as milk, mozzarella, and cottage cheese is among the surprising uses of titanium dioxide.

higher concentrations of this element. About 90% of the world's titanium is found in one such mineral, ilmenite, made up of iron and titanium oxide.

Roughly 100,000 metric tons of titanium mineral concentrates were produced in the U.S during 2020. This production came from mining and tailings in Florida, Georgia, and South Carolina.

The remaining 800,000 metric tons of titanium mineral concentrates used to make titanium dioxide pigment, welding rod coatings, and titanium metal in the U.S. last year were imported.

South Africa (39%), Australia (20%), Madagascar (10%), and Mozambique (9%) were America's principal suppliers of titanium concentrates.

This heavy reliance on imports, coupled with the broad applications – from skim milk to stealth fighters – are the reasons titanium is found on both the U.S. and Canada's critical mineral lists.

The sparse quantities of titanium mined in the U.S. and Canada, not being named as a top American supplier last year, belies the amount of titanium resources available in North America.

Titanium-rich Quebec

While Canada was not on the list of the top U.S. titanium suppliers during 2020, the mineral-rich neighbor did produce roughly 680,000 metric tons of titanium mineral concentrates last year.

Much of this production came from Rio Tinto's Lac Tio mine near Havre-Saint-Pierre, Quebec, which is home to the largest ilmenite deposit in the world. Ilmenite from this mine is processed into iron and titanium at its Rio Tinto Fer et Titane metallurgical complex in Sorel-Tracy, Quebec.

Rio Tinto recently invested US$6 million for the construction of the first module of a commercial-scale demonstration plant that will extract high-purity scandium oxide from the waste streams of titanium dioxide production at Rio Tinto Fer et Titane.

■ *Further details on scandium and the Rio Tinto's demonstration plant can be read at* ***Scandium finds its own way in NA markets*** *on page 65.*

Numerous other iron-titanium oxide deposits can be found in eastern Canada and extending into northeastern U.S. Most of these, however, have lower titanium grades.

Some of these deposits, however, also happen to be rich in vanadium, a metal that is gaining popularity as an ingredient in redox flow batteries for the grid-scale storage of electricity from intermittent sources such as wind and solar.

With flow batteries being viewed by many researchers and governments, including the Biden administration, as a solution to the need for large-scale storage of renewable energy, the growing demand for vanadium could bring more titanium into the markets as a byproduct of the emerging battery metal.

VanadiumCorp Resource Inc., which has positioned itself along the entire vanadium-based energy storage supply chain, is advancing titanium-enriched vanadium deposits in Quebec.

VanadiumCorp's Lac Doré project in the province hosts 214.93 million metric tons of measured and indicated resources averaging 0.4% (965,000 metric tons) vanadium pentoxide, 27.1% (58.3 million metric tons) iron, and 7.1% (15.2 million metric tons) titanium dioxide.

Though VanadiumCorp is most interested in the vanadium portion of this deposit, the mining of the battery metal is expected to offer a significant new supply of titanium.

■ *Further details of emerging vanadium markets and Vandium-Corp's mines-to-batteries supply chain strategy can be read at* ***Battery valences power vanadium demand*** *on page 45.*

Georgia critical mineral trio

In the U.S., coastal heavy mineral sand deposits in the southeastern states of Florida and Georgia are rich in titanium minerals.

Chemours Titanium Technologies, one of the world's largest producers of titanium dioxide, is investing roughly US$86 million into a heavy mineral sand project in Georgia that is producing three critical minerals – titanium, zircon, and rare earth elements.

"It's with great excitement that we expand our minerals operations into the state of Georgia following 71 years of successful mining in Florida," Chemours Titanium Technologies President Bryan Snell said during the September 2020 announcement of the new mine.

These heavy mineral sands being mined in Georgia also happen to be enriched in monazite, a mineral that is rich in the suite of 17 rare earth elements, especially the highly sought-after magnet REEs neodymium and praseodymium.

After extracting the titanium and zircon from these sands, Chemours is shipping the REE-enriched monazite to Energy Fuels Inc.'s White Mesa Mill in Utah to create rare earths carbonates that will be separated into individual rare earths at Neo Performance Materials Inc.'s Silmet plant in Estonia.

The first shipment of rare earths carbonate produced from Chemours-supplied monazite was shipped from White Mesa Mill to Neo's REE separation facility in July.

The success of this three-company collaboration to produce rare earths from monazite mined in America opens the door for a complete REE supply chain in the U.S. and Europe.

"Chemours is pleased to support the developing rare earth supply chain in the United States," said Snell. "Our partnership with Energy Fuels came from a deliberate process of customer selection and developing sustainable solutions for our critical minerals."

Producing titanium dioxide that imparts a whiteness and brightness to "brilliant paints, pristine plastic, gleaming laminates, and durable automotive and aerospace coatings," however, remains the main product of Chemours newly established mine in Georgia. DMN

Tungsten's ability to maintain its strength at extremely high temperatures makes it an ideal metal to use for the filament in incandescent light bulbs.

ADOBE STOCK

Tungsten vulnerable to China control

Middle Kingdom dominates supply, demand of critical metal

By SHANE LASLEY

DATA MINE NORTH

EXTREMELY HARD AND WITH THE HIGHEST melting point of all the metals, tungsten's toughness is legendary. Like many of the other metals that have found their way onto critical mineral lists in Canada, Europe, and the United States, this durable metal is vulnerable to Chinese control.

"World tungsten supply was dominated by production in China and exports from China," the U.S. Geological Survey inked in its 2021 mineral commodities report.

It is estimated that mines in China accounted for roughly 82% of the 84,000 metric tons of global tungsten production during 2020.

Vietnam, Russia, Mongolia, and North Korea round out the top five global producers of this tough metal.

China also happens to be the world's largest consumer of tungsten. By dominating both the supply and demand side of tungsten markets, the Middle Kingdom has a strong hand when it comes to controlling pricing and global supply, something the country has been known to use to maintain and strengthen its control over many of the minerals and metals now considered critical.

"China's government regulated its tungsten industry by limiting the number of mining and export licenses, imposing quotas on concentrate production, and placing constraints on mining and processing," according to the USGS.

Due to this Chinese control, USGS ranks tungsten among rare earths, cobalt, graphite, platinum group metals, and tantalum as the minerals and metals most at risk for disruptions of supply to the U.S.

Despite the U.S. dependence on China and other countries for much of its tungsten supply, North America has significant unmined tungsten resources.

Demanding durability

With no mines of its own to produce tungsten, the U.S. depends on recycling and imports to meet its needs for this metal with legendary strength and durability.

As a stopgap, the U.S. government has also been supplementing American tungsten supply out of its stockpiles. According to USGS data, roughly 4,100 metric tons of tungsten have been sold out of


TIG welding is among the many applications that take advantage of tungsten's properties.

PROWELDER87/CREATIVE COMMONS 4.0

government stockpiles since 2017.

Nearly 60% of the tungsten consumed in the U.S. during 2019 was used to make the cemented tungsten carbide, a compound of roughly equal parts tungsten and carbon.

Nearly twice as strong as steel, tungsten carbide is often found on the working end of drill bits, saw blades, wear plates, and other items that require this compound's toughness to meet some of the most demanding conditions in the mining, oil and gas, construction, and metal-working industries.

Tungsten carbide's hardness and density also make this metallic compound ideal for making armor-piercing ammunition for the military.

Of all metals in pure form, tungsten has the highest melting point (6,192 degrees Fahrenheit). Because it retains its strength at these high temperatures, elemental tungsten is used in many high-temperature applications.

Heating elements, lightbulb filaments, rocket engine nozzles, and TIG (tungsten inert gas) welding are among the many applications that take advantage of tungsten's ability to hold up to heat.

North American tungsten

Tungsten resources are plentiful in Canada and the U.S., especially the Rocky Mountain states and provinces, Alaska, Yukon, and Northwest Territories.

Mines along the Yukon-Northwest Territories border are past tungsten producers and are among the most promising projects for restoring a North American supply of this durable critical metal.

According to a 2014 technical report prepared for North American Tungsten, a company that fell on financial difficulties in its attempts to resume tungsten mining in this area, the Cantung project hosts 3.84 million metric tons of indicated resources averaging 0.97% tungsten trioxide, and 1.37 million metric tons of inferred resources grading 0.8% tungsten trioxide.

Mactung, which is about 100 miles northwest of Cantung, hosts 33 million metric tons indicated resource averaging 0.88% tungsten trioxide, making it one of the largest known undeveloped, high-grade tungsten-skarn deposits in the word.

Despite Mactung's world-class size and grade, along with being advanced well into permitting, North American Tungsten had to file for creditor protection before it could develop the mine that would have produced roughly 750,000 metric tons of tungsten per year, which would have been added to the 383,000 metric tons per year being produced at Cantung up until around 2015.

Following North American Tungsten's bankruptcy, a court-appointed monitor oversees site operations, which is funded by the federal government.

Under direction from the court-appointed monitor, North American Tungsten continues to undertake care and maintenance activities at Cantung in order to meet its regulatory requirements.

This work is being carried out in conjunction with federal officials and in consultation with Indigenous groups with asserted rights in the area.

Viable tungsten and copper reserves remain at the Cantung mine and the federal government is looking for a company to resume operations at the mine before the site is remediated and eventually closed.

At least six tungsten exploration projects are located just across the border in Canada's Yukon.

Interior Alaska tungsten

While there is not any tungsten produced in the U.S. today, this sturdy, industrial metal was historically mined in several Alaska locales to meet America's needs during both World Wars.

The gold-rich hills around Fairbanks, in the heart of Alaska's Interior, are one of the past-producing tungsten regions.

In 1915, Balkan immigrant "Wise" Mike Stepovich discovered hardrock tungsten mineralization on the eastern flank of Gilmore Dome about 15 miles northeast of Fairbanks and near Kinross Gold Corp.'s currently producing Fort Knox gold mine.

Over the ensuing three years, Stepovich and his crew dug more than 2,000 feet of underground workings and produced 300 tons of high-grade ore averaging 8% tungsten.

With a substantial drop in tungsten prices at the end of World War I, however, Stepovich put a halt to his hardrock tungsten operations to resume mining the rich deposits of placer gold near Fairbanks, which is what drew him to Interior Alaska in the first place.

World War II rekindled interest in the tungsten around Fairbanks. In 1942, Cleary Hill Mines Co. leased the properties covering the tungsten lode from Stepovich and produced another 43,920 pounds, or nearly 22 tons, of tungsten trioxide.

All of Cleary Hill Mines' World War II production was sold to the Metals Reserve Company, a subsidiary of the federal government-backed Reconstruction Finance Corp. in Washington D.C.

Several other tungsten deposits and prospects were identified near Stepovich's discovery, including the Colbert lode, as well as the Yellow Pup and Schubert prospects.

Most of Alaska's Interior region is considered highly prospective for tungsten. This includes the Circle Mining District northeast of Fairbanks, where potentially "minable deposits of placer tin-tungsten minerals" have been identified, and the Livengood Mining District north of Fairbanks, where Freegold Ventures Ltd. has discovered intriguing quantities of tungsten alongside the copper, gold, and silver on its Shorty Creek property.

Friendliest tungsten ghost town

The Interior is not the only region of Alaska to produce tungsten in times of American need. During World War II, this critical industrial metal was also extracted from the zinc-lead-copper concentrates produced from the Riverside Mine in the Hyder District on the Southeast Alaska panhandle.

Located just across the border from Stewart, a British Columbia mining town at the southern tip of the Canadian province's famed Golden Triangle, the Hyder District experienced a boom of mining activity in the 1920s. While most mining in this region faded in the 1930s, the Riverside Mine was revived in 1940.

Records show that 70,000 lb (35 tons) of tungsten, 3,000 oz of gold, 100,000 oz of silver, 100,000 lb of copper, 250,000 lb of lead, and 20,000 lb of zinc were recovered from 30,000 tons of ore mined at Riverside.

JAMES BARKER

Bear Mountain tungsten: Bear Mountain northeast Alaska may host one of the largest tungsten deposits in the United States.

At least six prospects – Last Shot, Mountain View, Fish Creek, Blue Bird, Monarch, and Last Chance – have been identified across a 1.5- by three-mile area near the Riverside Mine, about 5.5 miles north of the town of Hyder.

While mining and mineral exploration is prolific around Stewart, there has been virtually no mining in the Hyder District just across the Alaska-B.C. border since the closing of the Riverside Mine.

The less than 100 current residents of Hyder embrace this disparity with the motto "the friendliest ghost town in Alaska."

Massive, off-limits Bear Mountain

The largest deposit of tungsten in Alaska, however, may lie in the Bear Mountain occurrence along the southern slopes of the Brooks Range.

During visits to Bear Mountain in the 1980s, U.S. Bureau of Mines geologists James Barker and R.C. Swainbank identified a 100-acre area of surface mineralization indicative of a large porphyritic molybdenum-tungsten deposit.

Analysis of 20 soil and 36 rock samples collected during 1985 returned abundant tungsten and molybdenum along with lesser amounts of niobium.

Soil samples collected at the time returned tungsten values exceeding 500 parts per million wolframite, with the best samples containing 5,000 ppm of this tungsten mineral.

"I believe Bear Mountain to be likely the most important tungsten deposit in the U.S.," Barker, who spent much of his career doing critical mineral assessments for the former U.S. Bureau of Mines, told Data Mine North.

The potential of this intriguing tungsten-molybdenum discovery, however, may never be realized due to its location.

In addition to being in a remote corner of northeast Alaska, this potentially world-class tungsten-molybdenum deposit is situated within the Arctic National Wildlife Refuge, or ANWR, a 19.3-million-acre region set aside for wilderness and wildlife conservation.

"It's a shame that mineral evaluations aren't done before we place an area off limits," Barker reflected.

While Bear Mountain tungsten, molybdenum, and niobium may be stored in an off-limits reserve, past producing mines in Alaska and Northwest Territories have answered North America's urgent call for tungsten in the past and have the potential to answer a similar call should a pressing need for the durable industrial metal rise again in the future. DMN

Countless lives have been saved by diagnoses made with the assistance of magnetic resonance imaging (MRI) scanners, which use niobium superconducting magnets to provide detailed images of the inside of a human body.

ADOBE STOCK

Critical twin metals take differing paths

Niobium prefers blue-collar work; tantalum is more high-tech

By **SHANE LASLEY**
DATA MINE NORTH

THOUGH IT IS TOUGH TO DISTINGUISH the nearly identical properties of niobium and tantalum in nature, at the workplace, one of these critical twin metals typically dons a hardhat and boots to work in the construction and energy industries while you are more apt to find the other working in the high-tech sector. Their differences, however, are subtle, and their careers sometimes overlap.

"The leading use of niobium is in the production of high-strength steel alloys used in pipelines, transportation infrastructure, and structural applications," the United States Geological Survey penned in a 2018 report on the indispensable twins. "Electronic capacitors are the leading use of tantalum for high-end applications, including cell phones, computer hard drives, and such implantable medical devices as pacemakers."

While niobium and tantalum typically take differing career paths, they have a common origin story due to the shared traits of these nearly identical twin metals.

"Niobium and tantalum are transition metals that are almost always found together in nature because they have very similar physical and chemical properties," the U.S. Geological Survey wrote in a 2018 paper on the twin metals.

These transition metals share two additional traits that place them high on the list of minerals and metals the USGS has deemed critical to America's security and economic wellbeing – the U.S. is 100% import reliant for both, and you cannot find a good substitute for either without sacrificing performance and increasing costs.

Blue-collar niobium

A tough metal that is resistant to corrosion and boasts an exceptionally high melting point, niobium tends to be the blue-collar working twin.

Roughly 81% of the 10,100 metric tons of niobium imported into the U.S. during 2020 was used as an alloy in high-strength steel.

"Niobium microalloyed high strength steel plates are used in a variety of applications, such as large diameter line pipe for the transmission of gas and oil, shipbuilding, offshore platforms, bridges, and energy generation structures such as wind turbines," according to Oakley Steel.

The Asian steel supplier says that less than 0.1% niobium is all that is needed to boost the strength, toughness, and weldability of steel.

Niobium's extreme resistance to heat and corrosion also makes this strong metal an important ingredient for iron-, nickel- and cobalt-based superalloys that need to stand up to high temperatures.

Roughly 18% of the niobium consumed in the U.S. last year was used to make high-temperature superalloys for parts that go into jet engines, rockets, gas turbines, and turbochargers.

Adding to its résumé of "super" properties, niobium is among the most powerful superconducting metals.

Superconducting magnets made from niobium-germanium, niobium-tin, and niobium-titanium alloys are used in a range of important devices, from imaging equipment to particle accelerators.

The magnetic resonance imaging (MRI) scanners, which use niobium superconducting magnets, along with radio waves and a computer to create detailed images of the inside of a human body – are among the applications of this critical metal's special characteristics.

Niobium superalloy magnets also play a crucial role in accelerating particles to near the speed of light in the Large Hadron Collider, a 17-mile circular tunnel deep under the border between Switzerland and France. The resulting high-energy collisions of protons help physicists investigate dark matter, antimatter, and other secrets of the universe.

Niobium-titanium magnets currently being used to produce these powerful fields are being replaced with even more powerful niobium-tin magnets used in the search for dark matter and other cutting-edge experiments at the Large Hadron Collider.

International scientists are now floating the idea for the Future Circular Collider, a 62-mile successor that would be 10 times more powerful than the Large Hadron Collider. This massive US$27.5 billion project would need a whole lot more niobium, along with other critical minerals.

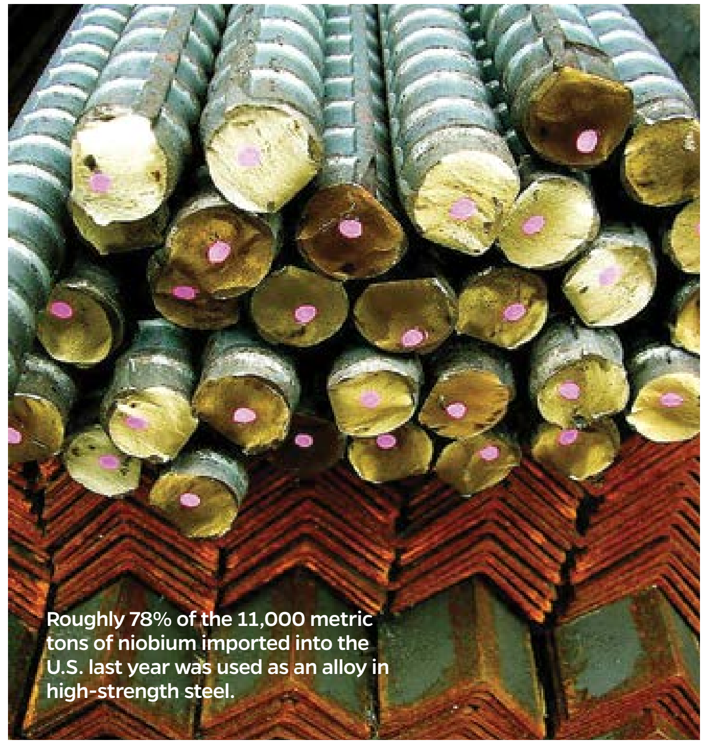
Beyond its super characteristics, niobium is hypoallergenic and inert, making it a good candidate for uses inside the human body, such as pacemakers and prosthetics.

Niobium is also one of the few metals that can be heated to produce a wide array of iridescent colors. The heat creates anodized oxide layers on the surface of niobium that make this color-changing effect by diffracting the light that bounces off it.

This ability, coupled with being hypoallergenic, makes it popular for creating colorful jewelry, especially for body piercing.

High-tech tantalum

Similar to its twin, tantalum can be implanted into the human body without any side effects. Because it is completely void of any immune response in humans, tantalum is used in critical bone replacements such as skull plates, tantalum-coated blood vessel stents, nerve connections, suture clips to close up wounds, and as a gauze to help bind abdominal muscles.



CREATIVE COMMONS

Roughly 78% of the 11,000 metric tons of niobium imported into the U.S. last year was used as an alloy in high-strength steel.

In addition to sharing many of niobium's traits, tantalum sets itself apart with an exceptional capacity to store and release energy that takes it down a high-tech career path.

While the use of tantalum is more opaque than its twin, the greatest benefit of this metal is in the powerful capacitors and resistors for modern electronics.

Because tantalum is so good at storing and releasing energy, capacitors and resistors made with this transition metal can be exceptionally small. This is crucial in the shrinking of modern electronics, such as smartphones, hearing aids, personal computers, and automobiles.

Tantalum oxides are also used to make lighter-weight glass camera lenses that produce a brighter image.

In addition to traits that set it apart from its twin, tantalum shares many of niobium's characteristics and is often used for similar applications. Being substantially more expensive, however, tantalum typically imbues its superlative properties as a coating on other metals.

In the chemical industry, tantalum's corrosion resistance makes it useful as a lining for pipes, tanks, and other vessels that store and transport corrosive materials.

Indispensable twins

While deposits of both niobium and tantalum are found in the U.S., it has been nearly six decades since either of these critical minerals have been produced domestically.

"Primary production of niobium or tantalum in the United States has not been reported since the late 1950s; therefore, the United States has to meet its current and expected future needs by importing primary mineral concentrates and alloys, and by recovering them from foreign and domestic alloy scrap," USGS inked in its 2018 report, "Niobium and Tantalum – Indispensable Twins."

As a result, the U.S. imported an estimated 22.2 million pounds of niobium, valued at US$280 million, to meet the needs of U.S. manufacturers during 2020.

Accounting for roughly 68%, Brazil was by far America's largest supplier of ferroniobium and niobium metal. Canada (25%), Germany (4%), and Russia (3%) accounted for most of the balance.

While tantalum consumption in the U.S. is less than 10% that of niobium, the higher price this energy storing metal fetches makes up much of the differential.

According to the USGS, roughly 2 million lb of tantalum, valued at US$210 million, was used in the U.S. during 2020.

When it comes to tantalum metal, China, at 38%, was America's largest supplier last year, followed by Germany (21%), Thailand (13%), and Kazakhstan (12%).

A small quantity of ores and concentrates containing both niobium and tantalum were also imported from Rwanda, Australia, Brazil, and the Democratic Republic of Congo.

Because the U.S. is wholly dependent on foreign sources for both niobium and tantalum, it is vulnerable to potential supply disruptions from swings in the metal markets, geopolitical unrest, and global economic instability.

"Niobium and tantalum are considered critical and strategic metals based on the potential risks to their supply (because current production is restricted to only a few countries) and the significant effects that a restriction in supply would have on the defense, energy, high-tech industrial, and medical sectors," according to the USGS.

While both the U.S. and Canada have potentially viable niobium resources, economically viable deposits of tantalum in North America are hard to come by.

Niobium in Nebraska

On the American side of the border, NioCorp Developments Ltd. plans to produce niobium, along with scandium and titanium, at its Elks Creek mine project in Nebraska.

A 2019 feasibility study details plans for a mine at Elk Creek that would produce 7,220 metric tons of ferroniobium, 95 metric tons of scandium trioxide, and 11,642 metric tons of titanium dioxide per year over a 36-year mine life.

This mine plan is based on 36.3 million metric tons of probable reserve averaging 0.81% niobium oxide, 2.86% titanium dioxide, and 65.7 g/t scandium.

Above: Eight niobium-rich superconducting magnets called toroids radiate out from the ATLAS detector in the Large Hadron Collider. This is currently the largest superconducting magnet on earth. CERN has plans to build a particle accelerator that is nearly four times larger than the LHC.

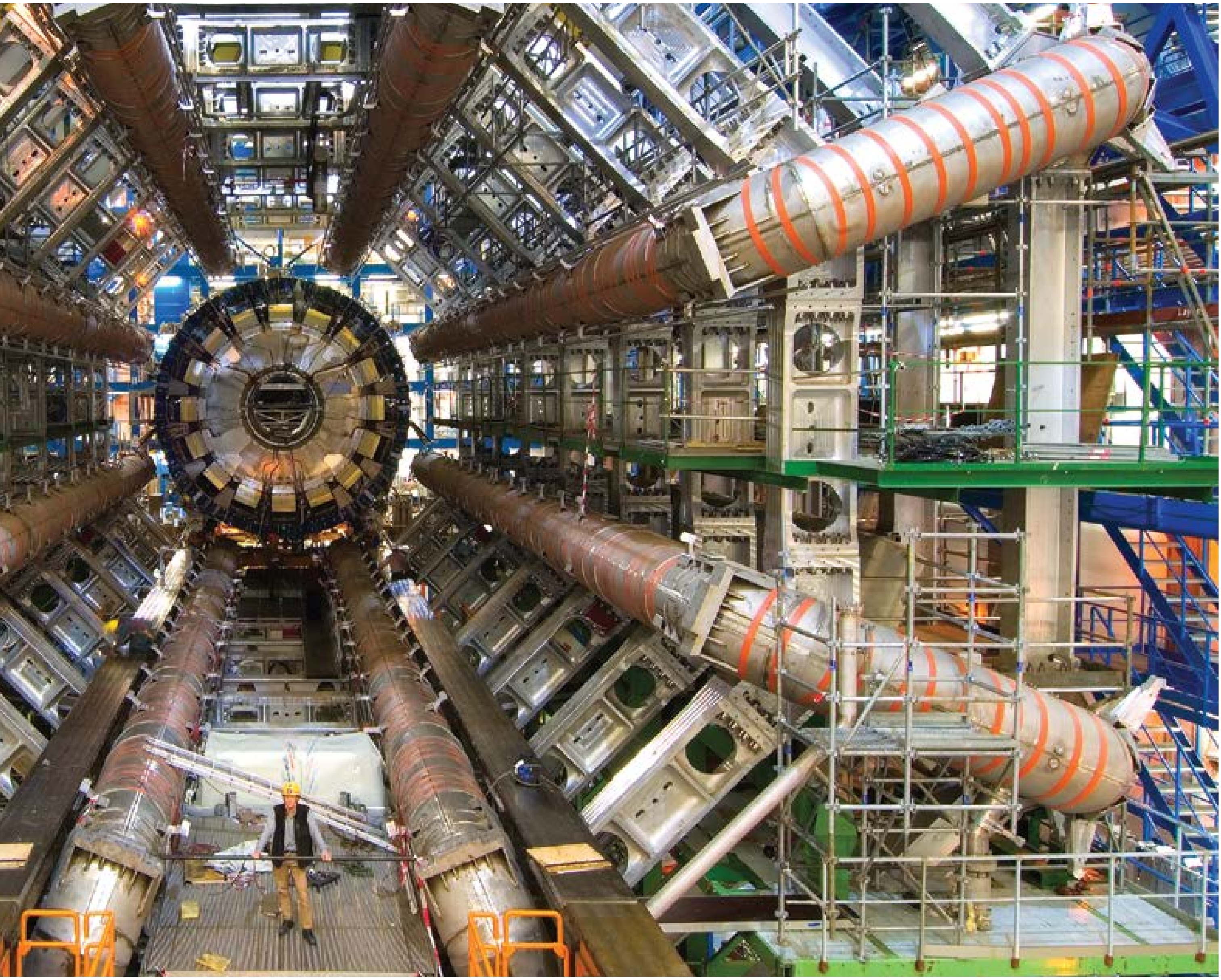
The Elk Creek deposit also hosts appreciable quantities of rare earths and NioCorp has recently embarked on testing to evaluate the viability of also recovering this suite of technology elements.

"We think this is logical, given that we are putting a significant quantity of rare earths into solution at zero additional cost to our current mining and processing plans," said NioCorp Developments Executive Chairman Mark Smith.

This work is being carried out alongside the company's investigation into carbonation as a potential alternative metallurgical process for the extraction of niobium from ore at Elk Creek.

Carbonation is a relatively clean, environmentally friendly, and sustainable hydrometallurgical process that can potentially be employed to use and recycle carbon dioxide to extract niobium and other elements in a manner similar to extractions with acids such as hydrochloric or sulfuric acid.

NioCorp Developments COO Scott Honan said, "The idea is that



EUROPEAN COUNCIL FOR NUCLEAR RESEARCH (CERN)

you can use carbon dioxide to leach things like niobium out of rock."

Initial tests of carbonization showed promise for recovering niobium and Honan said larger scale testing of this process will include the evaluation of extracting the rare earths that are present alongside the niobium, titanium, and scandium at Elk Creek.

Boosting Canadian production

While the U.S. is looking to re-establish a domestic supply of niobium, Canada has been producing significant quantities of this alloying metal for more than 30 years.

While well behind Brazil, which accounted for 91% of global niobium production during 2020, one Canadian mine produced most of the balance.

This operation, the Niobec mine in the Saguenay-Lac-Saint-Jean region of Quebec, is the only underground niobium mine in the world. As one of the three main global niobium producers, Niobec accounts for roughly 8 to 10% of the world's production of this critical metal.

Niobec Inc., which operates this Canadian niobium mine, also owns a 27.5% interest in Crevier, a niobium-tantalum project about 95 miles (152 kilometers) to the northwest. Niobay Metals Inc., a mineral exploration company working towards being a second Canadian miner, owns the remaining 72.5%.

Crevier hosts 25.4 million metric tons of measured and indicated resources averaging 0.2% niobium oxide and 234 parts per million tantalum oxide.

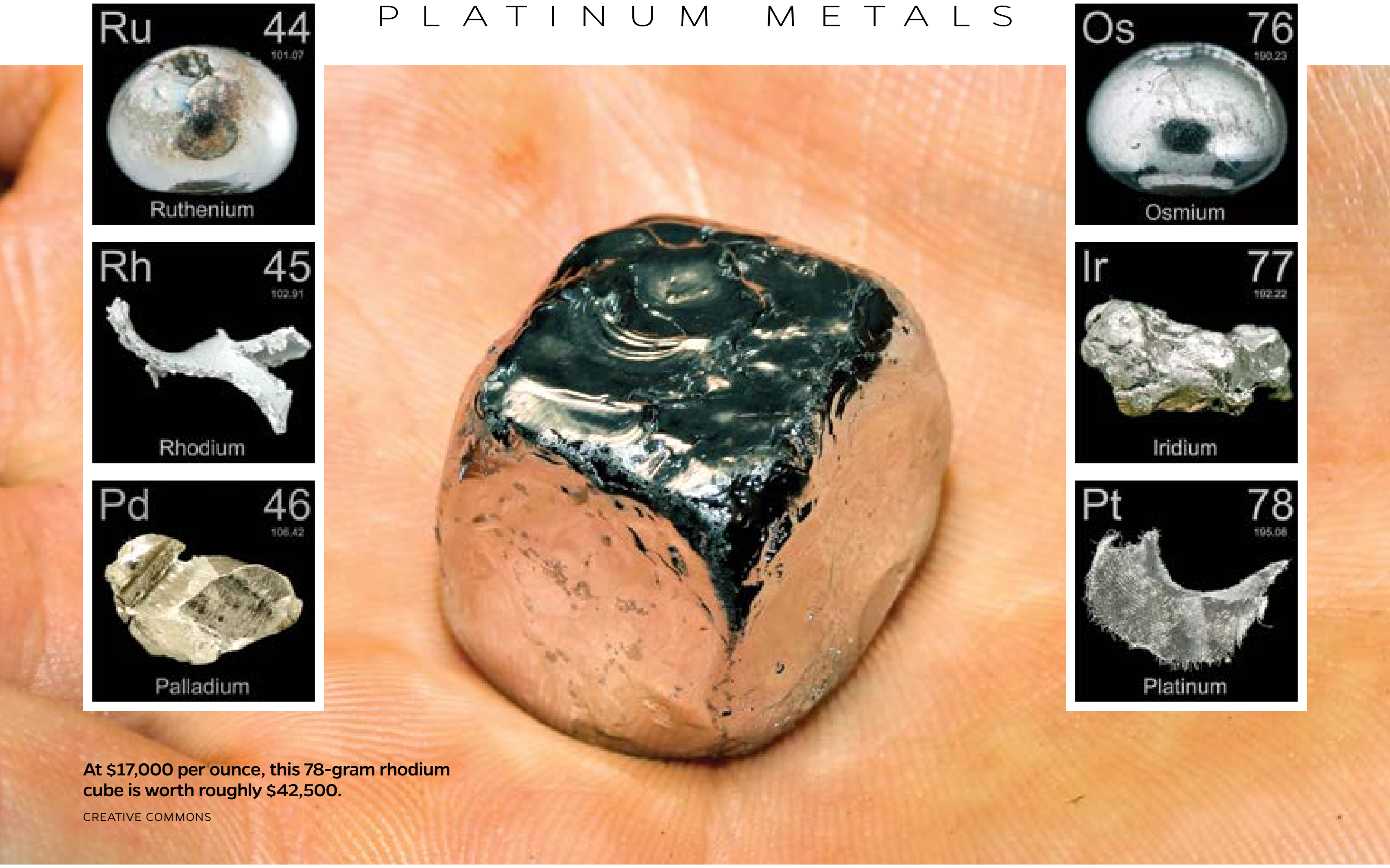
While a preliminary economic assessment indicated mining the niobium and tantalum at Crevier was economically viable, a subsequent pilot-scale test did not confirm these findings, and the project has largely sat idle for the better part of a decade.

Niobay, however, is advancing another niobium project in Ontario that shows more promise.

Located south of the southernmost tip of Hudson Bay, the James Bay project hosts 29.7 million metric tons of indicated resource averaging 0.53% (348 million lb) niobium.

A PEA completed at the end of 2020 outlines plans for a mine at James Bay that would produce an average of 5,470 metric tons of niobium annually over a mine life of 30 years.

If put into production, a mine of this size at James Bay would boost Canada's share of global niobium production by at least 5%. DMN



At $17,000 per ounce, this 78-gram rhodium cube is worth roughly $42,500.

CREATIVE COMMONS

Platinum metals are catalysts for change

Fuel cells offer future demand for precious, industrious PGMs

By **SHANE LASLEY**
DATA MINE NORTH

FROM JEWELRY AT A BLACK-TIE SOIREE to scrubbing harmful emissions from the exhaust system of a farm truck, the six platinum group metals – platinum, palladium, rhodium, ruthenium, iridium, and osmium – are metals that are both precious and critical to the United States and Canada.

Extremely rare, durable, and with a brilliance that does not tarnish, platinum and other metals in its group are a treasured choice for high-end jewelry that stands the test of time.

Three of the platinum group elements – platinum, palladium, and rhodium – are also minted into coins and bars for investment purposes, further solidifying the group's role as precious metals.

While scarcity and beauty already make PGEs highly valued, it is more its industrial applications in the automotive, petrochemical, and electronics industries that serve as the catalysts that drive the price of these precious metals to highs on the cusp of $30,000 per ounce, in the case of rhodium.

"PGEs are indispensable to many industrial applications but are mined in only a few places," the U.S. Geological Survey inked in the PGE section of a 2018 critical minerals report. "The availability and accessibility of PGE supply could be disrupted by social, environmental, political, and economic events."

It is this combination of rarity, industrial need, and potential supply disruptions that lands PGMs firmly on the USGS list of 35 minerals and metals critical to the U.S.

Catalysts for change

The list of properties that make PGMs indispensable to global industries is long – exceedingly resistant to wear, tarnishing, and chemical attack; able to endure high temperatures; and excellent

Right: Platinum ring featuring a 9.4-carat trillion cut tanzanite and one carat of white diamonds.


MARK SCHNEIDER

electrical stability are near the top of this list. It is this group of metals' catalytic properties, however, that are cherished above all the rest. "The leading domestic use for PGMs was in catalytic converters to decrease harmful emissions from automobiles," USGS wrote in its Mineral Commodity Summaries 2021. "Platinum group metals are also used in catalysts for bulk-chemical production and petroleum refining; dental and medical devices; electronic applications, such as in computer hard disks, hybridized integrated circuits, and multilayer ceramic capacitors; glass manufacturing; investment; jewelry; and laboratory equipment."

As fossil fuel-burning cars give way to electric mobility, so goes the need for catalytic convertors. E-mobility, however, is also making use of the catalytic properties PGMs have to offer.

Fuel cells being manufactured for large trucks, busses, trains, ships, and even airplanes take advantage of the PGMs catalytic properties to split hydrogen molecules into electrons that create a flow of electricity and protons that unite with oxygen to produce water vapor exhaust and heat.

Earlier this year, Wabtec Corp. signed an agreement to use General Motors' Hydrotec fuel cell and Ultium lithium-ion battery technologies to electrify locomotives.

"The rail industry is on the cusp of a sustainable transformation with the introduction of batteries and hydrogen to power locomotive fleets," said Wabtec President and CEO Rafael Santana. "Our FLXdrive locomotive, the world's first 100% battery-powered locomotive, has proven its potential to slash carbon emissions by up to 30% when operating at 6 MWh (megawatt-hours). But we can't stop there. By working with GM on Ultium battery and Hydrotec hydrogen fuel cell technologies, we can accelerate the rail industry's path to decarbonization and pathway to zero-emission locomotives by leveraging these two important propulsion technologies."

In addition to further commercializing both its hydrogen fuel cell and lithium battery technologies, the collaboration with Wabtec offers GM and other users of North American railroads the opportunity to lower the carbon footprint of receiving raw materials and parts, and then delivering finished products to customers.

"Rail networks are critical to transportation and to GM's ability to serve our customers across North America, and Wabtec's bold plan to de-carbonize heavy haul and other locomotive applications helps advance our vision of a world with zero crashes, zero emissions and zero congestion," said GM President Mark Reuss. "Wabtec's decision to deploy GM's Ultium battery and Hydrotec hydrogen fuel cell systems further validates our advanced technology and demonstrates its versatility."

GM also has deals to install its hydrogen fuel cells for powering electric 18-wheelers.

While GM and others have worked to minimize the amount of PGMs needed for hydrogen fuel cell technology, much like the catalytic convertor industry has found, the best replacement for a platinum group metal is one of the other platinum group metals.

As such, PGMs are expected to once again be catalysts for change as the world transitions from scrubbing harmful emissions from burning fossil fuels to generating electricity and water by splitting hydrogen molecules.

Rhodium rockets

The most valued of the PGMs is rhodium, a sliver-colored metal that is extremely resistant to corrosion and highly reflective – qualities used to add luster to jewelry, mirrors, and even searchlights.

As cherished as it is for aesthetics, the largest use for rhodium is as a catalyst to scrub carbon monoxide, hydrocarbons, and nitrous oxide from the exhaust of automobiles and petroleum refineries.

The combination of beauty and work ethic ranks rhodium among the most valued metals on the planet, rocketing to an astronomical high of US$27,000/oz in March 2021, a more than 500% climb in a year. By the end of July, the price for an ounce of rhodium had settled to around US$17,000.

It is platinum and palladium, however, that are most commonly used as catalysts to reduce harmful emissions from automobiles. As a result, the auto sector has shifted its preferred catalytic metal depending on price.

"Palladium has been substituted for platinum in most gasoline-engine catalytic converters because of the historically lower price for palladium relative to that of platinum," USGS penned in its annual Mineral Commodity Summaries.

This shift has driven the price of palladium to around US$2,700/oz at mid-2021, while platinum prices were hovering around US$1,100/oz.

Iridium sells for around US$5,500/oz and ruthenium is roughly US$750/oz. Reliable prices for osmium are unavailable due to its scarcity.

Stillwater platinum

Practically all of the 603,000 oz of palladium and platinum mined in the U.S. during 2020 was produced at the Stillwater and East Boulder operations about 85 miles southwest of Billings, Montana.

AVALON DEVELOPMENT CORP.

Bands of chromite with platinum and palladium stripe this outcrop on Bernard Mountain at New Age Metals' Genesis PGE-nickel-copper property in Alaska.

Going into 2021, Stillwater and East Boulder hosted 58.2 million metric tons of proven and probable reserves averaging 14.4 g/t (26.9 million oz) of palladium and platinum.

Sibanye-Stillwater, the South Africa-based miner that owns Stillwater, estimates that this is enough reserves to continue producing PGMs until 2059.

In addition to mining, Sibanye-Stillwater recycles large quantities of PGMs from spent automotive catalytic converters at its Columbus Metallurgical Complex, a smelting and base metal refinery between Stillwater mine and the town of Billings.

During 2020, the Columbus complex processed and recycled 840,170 oz of palladium, platinum, and rhodium from spent catalytic converters.

Overall, roughly 1.8 million oz of platinum and palladium was recycled in the U.S. last year.

Canadian PGMs

With only one PGM mining operation in Montana, the U.S. relies on other countries – primarily South Africa and Russia – for roughly 70% of its platinum and 40% of its palladium.

The third-largest producer of mined PGEs behind Russia and South Africa, Canada produces roughly 1 million oz of PGMs per year – 690,000 oz of palladium, 260,000 oz of platinum, 24,000 oz rhodium, 16,000 oz ruthenium, and 12,000 oz iridium.

Roughly 75% of Canada's platinum metals are mined in Ontario, which is home to the only primary PGM mine in the country. The rest are produced as a byproduct of nickel mining.

Impala Canada's Lac des Iles Mine, northwest of Thunder Bay, Ontario, is the only primary PGM producing operation in Canada. While very little public information on this mine is available since global PGM miner Implants Group acquired Lac des Iles Mine, during 2019 this operation produced roughly 230,000 oz of palladium, the primary metal at the mine.

At the end of 201,8 Lac des Iles hosted 40.9 million metric tons of proven and probable reserves averaging 2.31 grams per metric ton (3.04 million oz) palladium, 0.21 g/t (274,000 oz) platinum, 0.17 g/t (229,000 oz) gold, 0.07% (64 million pounds) nickel, and 0.06% (55.1 million lb) copper.

The Sudbury region of eastern Ontario – where global miner Vale has five mines, a mill, a smelter, a refinery, and nearly 4,000 employees – is also rich in PGMs associated with the nickel mines for which this area is renowned.

PGMs are also produced as byproducts of nickel mines in the Canadian provinces of Newfoundland-Labrador, Quebec, and Manitoba.

Total exports of PGMs and PGM-related products from Canada were valued at $1.65 billion in 2019, with the U.S. receiving more than 76% of those exports.

Alaska-type platinum

Besides the PGM-rich regions of Montana and Ontario, along with the platinum metals being produced as byproducts of nickel mining in Canada, there are some areas of North America prospective for future sources of this group of high-priced critical metals.

A special category of PGM-hosting deposits that partially derive their name from Alaska – Ural-Alaska-type ultramafic complexes – hint at the prospectivity for this group of industrious precious metals across the Last Frontier. The geological terrane that hosts these PGM prospective intrusive bodies, however, extends beyond Alaska and well into western Canada.

Known as the Wrangellia Composite Terrane, this microcontinent is considered to be a prime hunting ground for the suite of platinum metals that arcs more than 1,250 miles across the breadth of Alaska, through southern Yukon, and down the Southeast Alaska Panhandle and western side of British Columbia.

The most advanced PGM deposit along the Wrangellia Terrane is Nickel Shäw (formerly known as Wellgreen) in southeastern Yukon, about 60 miles east of the Alaska border.

According to a 2018 calculation, Nickel Shäw hosts 323.4 million metric tons of measured and indicated resources averaging 0.26 g/t (2.65 million oz) palladium, 0.2 g/t (2.63 million oz) platinum, 0.27% (1.88 billion lb) nickel, 0.16% (1.11 billion lb) copper, and 0.015% (107 million lb) cobalt.

Nickel Creek Platinum Corp. is exploring 11 high-priority targets that could add to this resource as it continues to optimize plans for developing a mine at Nickel Shäw.

PGM-rich Wrangellia

There are intriguing signs that similar PGM-nickel-copper-cobalt deposits may be found in the Alaska portion of Wrangellia, such as the Man property about 250 miles northwest of Nickel Shäw.

Grab samples with extremely high concentrations of PGMs and associated metals have historically been collected by Pure Nickel Inc., the former explorer of this property. One particularly high-grade rock collected at Man contained 13.6% nickel, 2.9% copper, and 26 g/t PGMs.

While these samples are abnormally high-grade due to the selectivity of geologists collecting the most metals-rich samples they come across, such samples show that there are highly enriched metal layers nearby.

The PGM and nickel potential of this section of the Wrangellia Terrane stretching across Southcentral Alaska has attracted the attention of global miners such as MMG Ltd.

In 2013 and 2014, MMG investigated three large blocks of state of Alaska mining claims that follow an arc south of the Alaska Range.

The Peninsular Terrane, a subsection of the Wrangellia Composite Terrane that stretches along the Chugiak Mountains in Southcentral Alaska, is also known for its platinum potential.

New Age Metals Inc. has advanced early staged exploration at Genesis, a 10,240-acre PGM-nickel-copper project that lies alongside a paved highway about 75 miles north of the deep-water port city of Valdez in the Peninsular Terrane.

Sampling of one drill-ready target at the Sheep Hill prospect on Genesis returned up to 2.4 g/t palladium, 2.4 g/t platinum, 0.96% nickel, and 0.58% copper.

Bernard Mountain, about 4.7 miles west of Sheep Hill, hosts a separate style of chromite mineralization where samples with up to 2.5 g/t palladium and 2.8 g/t platinum have been collected.

New Age is also advancing the multi-million-oz River Valley palladium project about 60 miles Northeast of Sudbury, Ontario.

Following the Wrangellia Terrane as it arcs south, the entire Southeast Alaska Panhandle is prospective for PGM deposits.

This includes the historic Salt Chuck Mine, which produced 300,000 metric tons of ore averaging 0.95% copper, 1.96 g/t palladium, 1.12 g/t gold, and 5.29 g/t silver during operations from 1915 to 1941, according to U.S. government summaries (1948).

Though Salt Chuck was never put back into production after its wartime shutdown, a 7,000-meter-by-1,600-meter mafic-ultramafic igneous complex is prospective for the metals recovered at the bygone mine.

Duke Island, about 70 miles southeast of Salt Chuck is another PGM-rich project on the panhandle.

Group Ten Metals, the company exploring the Duke Island project, said the abundance of copper-nickel-PGE sulfide mineralization found there is unlike any known Ural-Alaska complex.

Surface rock samples collected from Dukes Island have returned grades as high as 1.95% copper, 0.25% nickel, and more than 1 g/t PGM.

Group Ten Metals is also exploring PGM projects adjacent to Nickel Shäw in the Yukon, in the Stillwater area of Montana, and in southeastern British Columbia.

Goodnews in Alaska

Goodnews Bay is another area of Alaska that is a past producer of PGMs and has future potential that intrigues the USGS.

About 120 miles south of Bethel, the Goodnews Bay region of Southwest Alaska was the primary domestic source of platinum in the U.S. for roughly five decades. This platinum, however, was not mined directly from an ultramafic complex. Instead, it was recovered as placer nuggets and sands in streams that eroded one of these orebodies.

Yup'ik residents of the area, Walter Smith and Henry Wuya, first discovered platinum in these streams in 1926.

This discovery led to a claim-staking rush followed by several small-scale mining operations. Goodnews Bay Mining Co. consolidated the platinum producing claims and operated a bucket-line dredge from 1937 to 1978, accounting for most of the roughly 650,000 oz of platinum that has been mined from the streams in this area.

High PGM prices have sparked renewed interest in the Goodnews Bay placer deposits over the past decade. This interest has included using modern equipment and techniques to recover platinum left behind by the dredge.

In addition to additional PGMs remaining in the streams of this platinum-producing area of Southwest Alaska, USGS geologists believe there could be significant marine placer platinum deposits just offshore.

"Undiscovered marine placer deposits could be associated with paleochannels or beach deposits in the Goodnews Bay region in Alaska," USGS penned in the PGE chapter of its 2018 critical minerals report. "A geophysical survey indicates the presence of ultramafic rocks offshore, which could be a source of placer platinum."

In addition to what might be found in the ocean downstream from these historical placer deposits in Goodnews Bay, there has been interest in finding the lode source upland from Salmon River and its platinum-bearing tributaries.

A Ural-Alaska-type ultramafic body on Red Mountain, which is being drained by these PGM-rich streams, is believed to be the lode source of the historic placer production that provided the primary domestic source of platinum to the U.S. for nearly 50 years. DMN

Platinum, palladium, and rhodium have all been used as catalysts to scrub carbon monoxide and other harmful emissions from the exhaust of automobiles.

CREATIVE COMMONS

Until the advent of affordable cameras at the dawn of the 20th century, coins were the primary driver for silver demand for nearly 4,000 years.

CREATIVE COMMONS

Silver evolves from money to techno metal

From coins and jewelry to EVs and solar panels, silver adapts

By SHANE LASLEY

DATA MINE NORTH

TYPICALLY THOUGHT OF AS A PRECIOUS metal used to make coins, jewelry, tableware, and other glimmery objects, silver's true value lies in more industrious properties that make it invaluable to high-tech applications such as solar panels, electric vehicles, and 5G networks.

Roughly 28% of the 8,000 metric tons (257.2 million ounces) of silver used in the United States during 2020 went into electrical and electronics devices; 26% into jewelry and silverware; 19% for coins and medals; and 3% for photography. The remaining 24% was used in a wide variety of other applications such as antimicrobial bandages, clothing, and pharmaceuticals; batteries; brazing and soldering; automotive catalytic converters; mirrors; and photovoltaic solar cells.

"Silver demand has evolved from a monetary ornamental use, to photographic, to digital, and now to energy," Hecla Mining Company President and CEO Phillips Baker, Jr. said during a presentation earlier this year.

Hecla, which has been mining silver for 130 years, has witnessed first-hand silver's demand transition from coins and jewelry to solar panels and EVs.

In fact, the Idaho-based mining company traces its founding to a time when silver was losing its 4,000-year status as a choice metal for making coins and the rise of a revolutionary technology that would dictate silver demand for the entire 20th century – a camera for the masses.

Century of silver photography

In 1900, Eastman Kodak introduced the Brownie camera, an affordable camera that allowed everyday people to capture treasured moments and imagery for posterity.

"It was a very inexpensive camera when it first came out in 1900 – it sold for $1, which in today's dollars would be about $31," Baker said.

While the Brownie itself did not contain any silver, the film that images were captured on did. For the entirety of the 20th century, photography was a major consumer of silver. In 1999, roughly 250 million oz of silver was used each year for photography.

When Baker joined Hecla in 2001, most silver analysts believed photography would continue to drive the demand for silver. The advent of the digital camera and then the smartphone, however, nearly completely ended the century-long era of silver-infused film. By 2019, photographic demand for silver had plummeted to just 34 million oz/year.

Despite this 86% drop in photographic demand, total silver consumption over the same period rose from 875 million oz/year to 1.07 billion oz/year. This is because of silver's rise as an investment metal and steady growth in industrial uses outside of photography.

The techno metal era begins

The very technological advances that looked to tarnish silver demand have brightened the future for this glistening metal.

It is not silver's luster, however, that is driving the metal's technological demand. Instead, it is physical properties such as very high electrical conductivity, reflectivity, ductility (stretchability), and malleability that has transformed silver into a techno-metal.

In fact, silver is the best metallic conductor of electricity there is. Because of this exceptional quality, silver beats out lower cost copper when building a powerful computer that you can slip into your pocket.

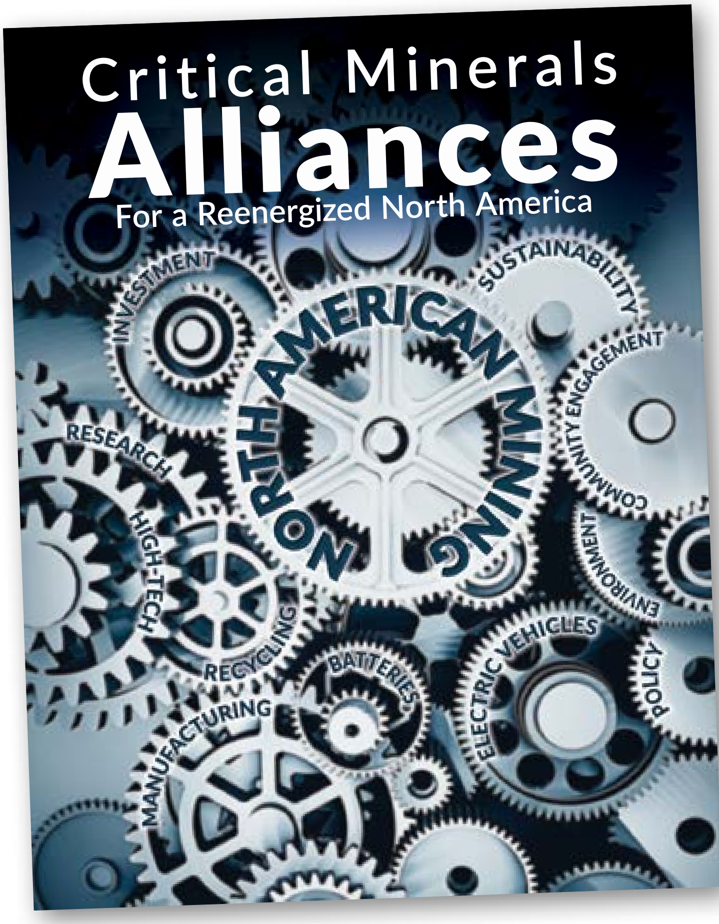
The same traits that make silver invaluable to your smartphone also make this precious tech metal a vital ingredient for renewable energy and EVs.

Photovoltaic solar cells take advantage of both the high electrical and thermal conductivity traits offered by silver.

Approximately 0.7 oz of silver goes into the making of each photovoltaic solar panel. This currently accounts for roughly 90 million oz of silver demand per year, and Goldman Sachs projects this demand to climb to 105 million to 150 million oz

JACQUELINE MACOU; PIXABAY

Developing film in silver salts suspended in gelatin creates an appealing clarity and sharpness to black-and-white photos.



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Going into the 21st century, silver has emerged as a techno metal vital to solar panels, electric vehicles, and 5G networks.

by 2023. "So, strong, strong demand growth for photovoltaics," said Baker.

The transition to electric mobility is pushing similar demand growth by the automotive sector.

This is because virtually every electrical connection in a modern car is activated with silver-coated contacts, and by their very nature, EVs contain many more electrical connections than a traditional car propelled with an internal combustion engine.

While approximately 0.64 oz of silver goes into the average ICE vehicle, an EV needs about 1.25 oz of the highly conductive precious metal.

As a result, Bank of America forecasts the automotive sector will need about 90 million oz/year by 2026, a 64% increase over the roughly 55 million oz/year currently needed. And this demand is expected to continue to grow as EVs overtake ICE vehicles for market domination.

Adding to the technological demands driven by solar and EVs, a recent report released by the silver institute forecasts that the global roll-out of 5G networks will require another 16 million oz/year by 2025 and as much as 23 million oz/year by 2030.

Seeking balance

Global silver production currently sits at about 840 million oz/year and consumption is roughly 1 billion oz/year. The roughly 170 million oz of silver recycled annually fills the difference between supply and demand. The emerging technological demands for silver, however, are expected to upset this balance.

Using very conservative estimates, the need for newly mined silver is forecast to increase by 95 million oz per year over the next decade.

This is nearly 10 times more than Hecla's Greens Creek Mine in Alaska, which singlehandedly accounted for roughly one-third of total U.S. silver production during 2020.

"Our largest mine, Greens Creek, produces 10 million oz of silver per year. By 2030 … you would need 10 more Greens Creeks," said Baker.

Though silver prices rose sharply, from around $16/oz to around $28/oz during 2020, the Hecla Mining CEO says it will likely take even higher silver prices to spur the investments to build the silver mines needed to meet the emerging demands for this metal that continues to evolve with the times.

Most analysts are forecasting that silver will break above $30/oz this year and some predict that between industrial demand and a hedge against inflation, the techno-precious metal will reach highs of $50/oz in the coming two years. DMN