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WESTERN USA MINING 2025

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Dear Readers,

The priority of the Western USA mining industry can be summarized in one word: reshoring. The recent shift in government will only reinforce this focus. While Democrats emphasized 'friend-shoring' and 'near-shoring' in their minerals agenda, President Donald Trump has pledged to bring domestic mineral production home.

However, achieving this goal is far from simple. The US mineral supply chain remains fragile, with critical mineral imports hitting record highs. The nation relies entirely on foreign sources for 15 critical minerals and has the second longest mine development timeline in the world—averaging 29 years. Government pledges for net-zero emissions by 2050 and 50% electric vehicles by 2030 remain aspirational at best. And China, which controls global metals production, holds aces in its pocket and will play its hand at a time of its choosing.

Despite these challenges, industry momentum is accelerating. September 2024 saw Las Vegas host the quadrennial MINExpo, the world's largest mining event, with record-breaking attendance. The Western US remains a hotbed for mineral discoveries, from copper to lithium to rare earths. Companies are leveraging cutting-edge technologies—including AI-driven resource exploration and advanced recycling techniques—to foster a more self-reliant future.

The road ahead is complex, requiring innovation, technology, policy support, and collaboration between industry, government and academia. Over 100 executives across the mining value chain shared their perspectives with GBR, underscoring that while the stakes are high, so is the potential for the Western US to reclaim its former production strength and reignite a new era of manifest destiny.

We extend our gratitude to the National Mining Association, the American Exploration and Mining Association, and the state-level mining associations, as well as the many executives who generously shared their insights with us. We hope this report aids all stakeholders in navigating the evolving landscape of the Western US mining sector.

Alfonso Tejerina
Director and General Manager
Global Business Reports (GBR)

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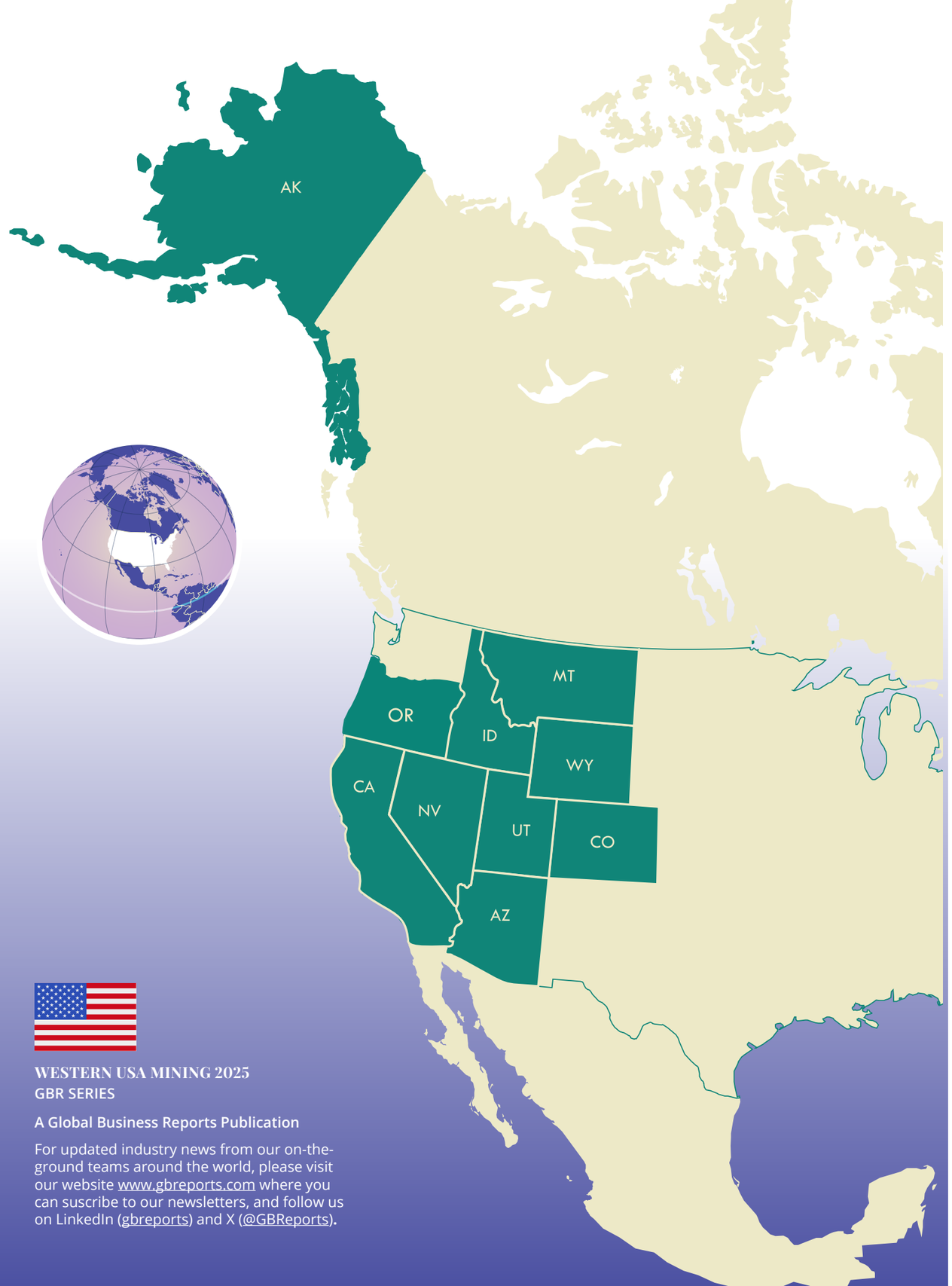

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INTRODUCTION TO WESTERN USA

> We believe ‘Made in America’ should be ‘Mined in America’, and to make that a reality we must reshore our minerals supply chains, even if that cannot happen overnight.

Rich Nolan
President and CEO
NATIONAL MINING ASSOCIATION

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Changing Tides

From offshoring to reshoring domestic mineral production

Donald J. Trump assumed office on January 20th, 2025, as the 47th president of the United States. Speculation abounds about the policies he will implement or undo, but one outcome seems certain: the mining industry stands to benefit. While the presidenthas made few direct statements on the sector, his 2020 pledge to "put our miners back to work" still resonates.

Trump's election victory has already garnered enthusiastic support from the mining industry: "Together with the next Trump administration and Congress, we can increase America's competitive standing on the global stage, ensuring that made in America also means mined in America," Rich Nolan, president and CEO of the National Mining Association issued in a statement following the election.

It remains to be seen how Trump will navigate the backdrop he inherited. In 2023, the United States achieved a record high for mineral imports, marking an all-time low for supply chain stability. According to the US Geological Survey's (USGS) 2023 Minerals Commodity Summaries report, the US was more than 50% reliant on 51 minerals, and 100% net import reliant for 15 of those 51 minerals, 12 of which are deemed "critical". In 2024, not much changed. The US is more than 50% reliant on 49 minerals, and 100% reliant on the same 15.

This reliance will likely be reduced under Trump if his previous presidency is any indication. In 2017, President Donald Trump issued Executive order 13817, to facilitate better management of critical minerals to strengthen energy security. Under the order, "it shall be the policy of the Federal Government to reduce the Nation's vulnerability to disruptions in the supply of critical minerals" by "streamlining leasing and permitting processes to expedite exploration, production, processing, reprocessing, recycling, and domestic refining of critical minerals."

While the Democrats' approach positioned "friend-shoring" and "near-shoring" at the center of the agenda, Trump claims he will prioritize "reshoring" domestic minerals production.

While federal policy plays a significant role, the local dynamics in key mining states illustrate the country's abilities to fulfill executive orders.

Nevada: a lithium island

Capital markets have been hesitant to invest in lithium, given the commodity's poor performance over the past 12 months. Under Biden, the government became especially involved in the space. While capital markets require quick returns, the Biden administration looked longer term, seeing lithium through the lens of energy transition demand. Nevada received four federal investments as the US worked to increase market share in the battery space. Under the Bipartisan Infrastructure Law, the DOE awarded a sum of US$4.62 billion to 35 projects in 2022 and 2023. Three are in Nevada.

Nevada, historically known as the 'Silver State' since the 1859 discovery of the Comstock Lode, evolved into a leading gold producer. "If considered a country, Nevada would rank as the sixth-largest gold producer globally. The state is responsible for approximately 73% of the gold mined in the US," said Amanda Hilton, president of the Nevada Mining Association.

However, Nevada is well on its way to becoming the White Gold State, hosting the only active lithium mine in the US, with two additional mines, Lithium Americas' Thacker Pass and Ioneer's Rhyolite Ridge, both expecting production by, or in, 2027.

Nevada houses the country's largest lithium deposits. Processing capabilities, however, are lagging. "Nevada is one of the few places on the planet with large enough critical element deposits to support multigenerational activity in mining, extraction, and advanced manufacturing. However, there is a large gap in processing abilities. Nevada is currently a net exporter of raw critical element ore to China," explained Frederick Steinmann, director, University Center for Economic Development (UCED), at the University of Nevada, Reno (UNR).

In 2023, the UNR received US$1 million in financing from the NSF's Regional Innovation Engines program to begin to address the challenge. "We recognize the processing and refining gaps and are attempting to bring in new technologies and improve old ones. We are working with consultancies and venture capital firms to provide information, knowledge, sophistication, and support to move towards commercialization," highlighted Erica Hall, senior project manager at UNR.

Trump vowed to eliminate incentives to promote EV production and adoption, which could curtail the entire multibillion dollar EV industry, which has Nevada at its heart. EV demand could fall 20% by 2030 if Trump follows through on campaign promises, according to Benchmark Intelligence.

Arizona: A US treasure chest

Under the red sands of Arizona lies a 21st century treasure chest. However, lifting the lid reveals something even more industrially valuable than gold. Copper, one of the leading metals for the energy transition, may not shine a bright as gold, but is equally the United States' plunder. Lately, the metal has been treated as fool's gold. Import reliance for copper grew 5% from 2023 to 2024. This reliance will only increase as American demand for copper will far outstrip supply in the coming years. The US lacks both raw and refined supply, housing only two functional smelters. Despite its critical role in the green energy transition and the country being 46% import reliant on the metal, copper is not defined as a critical mineral by the US government. The USGS even denied a bipartisan request to add copper to the list.

Arizona has been the leading copper-producing state in the US for over a century. Mining contributes approximately US$6.7 billion annually to the state's economy and supports around 38,000 jobs directly and indirectly. Several companies—including Resolution Copper, Florence Copper, Gunnison Copper, Arizona Sonoran—will likely bring mines online in the coming months to years to reduce foreign reliance on the metal amid rising demand. Demand is steep, increasing to 56 million t/y by 2050, a sizable increase over today's 21-million-t market.

Mines like Resolution Copper that have been stalled in litigation for decades may advance towards production under Trump rule. Rio Tinto executive Bold Baatar called on the administration to focus on speeding up permitting in the US. No matter the stance, one thing remains clear: "Copper is a critical mineral for decarbonization and securing the US supply chain. Arizona produces 74% of the nation's copper supply. The energy transition, innovation, our quality of life, and our ability to mine are all contingent on this mineral," said Steve Trussell, executive director of the Arizona Mining Association.

Utah, Wyoming, New Mexico: Riding the nuclear currents

The up-and-coming star in the US is Utah, having placed first in the Fraser Institute's Investment Attractiveness Index, after finishing 17th in 2022. Utah has long supported the growth of the nation, said Nathan Foster, managing director Kennecott at Rio Tinto: "About 25% of the metal supplied to the Allies during World War II came from Utah, underscoring Kennecott's role in North America's growth."

80 years after the end of WWII, Utah continues to play a pivotal role in the nation's development. The state houses one of the two operational copper smelters and Kennecott produces 15-20% of the domestic refined copper supply.

Utah is also the third-largest uranium-producing state in the US. The state's first uranium boom arrived in 1948 when the US Atomic Energy Commission provided benefits to domestically mined uranium for nuclear weapons. A second uranium boom followed in the early 1970s with the development of the nuclear power industry. With nuclear energy once again in the spotlight, the boom is returning to Utah, bringing mines online, like IsoEnergy's Tony M mine.

The Trump energy plan aims to boost to nuclear energy, which currently makes up only 18.6% of US electricity production, according to the US Energy Information Administration. "Trump will support nuclear energy production by modernizing the Nuclear Regulatory Commission, working to keep existing power plants open and investing in innovative small modular reactors," said David Bernhardt, former Interior Secretary, on a press call.

These plans will bode well for New Mexico and Wyoming, as the top producers of uranium. They produced 347 and 250 million pounds respectively during 2024.

Image by BrilliantPixels at Adobe Stock

Idaho: Anchored in opportunity

The mountains and valleys of Idaho cannot be overlooked when it comes to supplying the nation. "The northern part of the state features the Idaho Silver Valley, which has been producing silver for over 100 years. Central and southern Idaho has considerable gold deposits, along with molybdenum and copper. On the eastern side, we have the Idaho Cobalt Belt, which also includes rare earth elements," detailed Benjamin Davenport, executive director at the Idaho Mining Association.

Idaho's mining history dates to the 1860s, providing the foundation for the state's current mining-friendly status, said Jon Cherry, president and CEO of Perpetua Resources: "Idaho has a long history of mining, which is deeply embedded in the state's culture. The presence of significant mineral resources and a multi-generational mining workforce makes Idaho a unique and advantageous location for mining activities."

Under the Trump administration, Perpetua will likely come into the spotlight as its Stibnite gold project contains approximately 90,000 t of antimony. The US is 100% import reliant for antimony, but American manufacturers require more than 50 million lb/y for fireproofing compounds, batteries, ammunition, electronics, specialty glass, and other products, according to MetalTech. Antimony production is dominated by China, Tajikistan and Russia. China accounted for 48% global antimony production in 2023, according to the USGS, but restricted exports in September 2024.

The US government will provide a US$1.86 billion loan to bring Stibnite into production by 2029.

Colorado and Alaska: Tides of legacy

The snowcapped peaks of Colorado and Alaska are characterized by an enduring legacy of manifest destiny. The Pikes Peak Gold Rush in Colorado and discoveries like Fortymile River in Alaska brought settlers West. Though golden streams of opportunity once flowed more readily through their mountain valleys, these states still host much mining activity. Alaska is home to Kinross's Fort Knox gold mine and Hecla's Greens Creek mine. Colorado houses Freeport-McMoRan's Climax molybdenum mine and Newmont's Cripple Creek & Victor gold mine. Mining contributes US$7 billion annually to Colorado's economy and employs 58,000 people directly or indirectly.

Alaska ranked 11th on the Fraser Institute Attractiveness Index. The state contains significant antimony reserves, like Nova Minerals' Estelle gold project, which will likely receive attention under the current administration.

Colorado ranked lower in the Fraser ratings but has a unique proposition. "The state's diverse mineral endowment, combined with our broad range of mineral reliant industries including clean energy development, aerospace and national security applications, provides a broad range of investment opportunities for commodities needed in these sectors, and makes Colorado a unique and attractive place for mining investment," said Adam Eckman, president and CEO of the Colorado Mining Association.

Founded in 1876, Colorado has the oldest mining trade association in the US. As the legacy continues, so will miners across the entire Rocky Mountain Range.

Charting a new course

In his memoir One Man's West, author David Lavender details a mining operation in the mountains of Southwest Colorado: "Only the coarser particles of free gold could be extracted from the ore by the lease company's mill. The finest stuff and the various gold, silver, lead and zinc compounds were sent through a complicated 'floatation' process... The richly laden sand which remained was then sacked and sent to a smelter of final reduction."

The description is of Camp Bird—a mine operated over a century ago—when US$20/ oz gold brought profits and horse-drawn wagons transported extracted riches. Today, gold is over 100 times more valuable and trucks without drivers transport mined material. Lavender's description is perennial, but it should not be. "Mining has not changed over time; we still break, crush and heat rock to make metal, but now with bigger, more advanced equipment. The US mining industry must innovate, adopting new technologies and methodologies to stay competitive while meeting environmental and cost demands," said Travis McLing, directorate fellow and critical minerals research Co-lead at the Idaho National Laboratory.

For the US, competing on a global scale will be difficult. "China holds the equivalent of pocket aces at the poker table, and they will play that hand when they choose," warned John Swallow, president and CEO of Idaho Strategic Resources.

From what industry executives told GBR, the appeal of Trump is that he will play a seven deuce offsuit like he has pocket aces; those players are usually the most lethal. ■

Rich Nolan

President and CEO

NATIONAL MINING ASSOCIATION (NMA)

> "The pressure is immense to meet the demands driven by electrification, artificial intelligence, energy needs, and renewable energy projects."

How does the National Mining Association (NMA) help address the industry's challenges?

The United States is in the most intensive minerals and metals era since World War II. Demand is soaring, exploration continues to grow, but far too few projects are coming online as quickly as they are needed. The pressure is immense to meet the demands driven by electrification, artificial intelligence, energy needs, and renewable energy projects. These sectors depend on mined materials and the status quo is insufficient. Third-party forecasts indicate a looming deficit without more investment in the mining sector.

This creates significant opportunities for current operators, juniors and exploration companies, with industry looking to the government for support in permitting projects in a responsible yet streamlined way. That is where the NMA steps in. We are actively working with the federal government on the permitting reform that is sorely needed in the US. Our goal is to maintain the highest environmental, safety and labor standards in the world, while addressing the challenge highlighted by the S&P report that in the US it takes an average of 29 years to bring a new mine online. This timeline must be reduced to meet the growing demands of modern life.

How will the proposed legislative reforms impact mining projects in the US?

A broad group of bipartisan congressional allies is growing, aligned behind the need for permitting reform, and we have seen an important bill move forward in the Senate. The legislation includes key judicial reforms aimed at addressing lengthy legal challenges to mining projects. It also brings much-needed clarifications on ancillary use, specifically regarding the ability to use public lands for essential activities like setting up mining infrastructure and depositing waste rock near mine sites. Proposed changes to the National Environmental Policy Act (NEPA) are pivotal. NEPA governs the timelines and deadlines by which the federal government must make environmental decisions on projects. These reforms are essential to ensuring that decisions are made transparently and within a reasonable timeframe, which is currently one of the biggest obstacles to advancing new mining projects. If passed, it would be a major win for the mining industry.

How can the US remain competitive on the global market while maintaining high standards?

The United States lags 20 years behind China in developing and advancing its minerals strategy. We believe "Made in America" should be "Mined in America," and to make that a reality, we must reshore our minerals supply chains, even if it can't happen overnight. There is strong bipartisan concern over China's dominance in locking up global supply chains. Recently, we have seen China weaponize materials like antimony and gallium by manipulating supply and restricting exports. China has been dumping materials, like lithium, to crush prices in the market. Russia has dealt a blow by wiping out the only US palladium and platinum-producing mine in Montana. These actions highlight the urgent need for the United States to strengthen its position in critical mineral supply chains.

What progress has been made in reducing the environmental impacts of mining operations?

About five years ago, the NMA launched a sustainability task force to share ideas and promote best practices across the industry. Many of our members publish annual sustainability reports, providing transparency on their progress in community engagement, and environmental and labor standards. Companies are focused on lowering electricity and diesel consumption and aiming to recycle 100% of the water used on-site. They are making great strides in minimizing energy use and improving sustainability across their operations. We are proud to see Arch Resources become the first US mining company to adopt the Towards Sustainable Mining (TSM) standard, and we expect others to follow.

Do you have a final message?

Through efforts like NMA TV, campaigns such as "Minerals Make Life", and other efforts, we are working to educate the public about the critical role minerals play in everyday life. Communicating with policymakers and the public is key to what associations like ours do, and we are fully committed to bridging this knowledge gap. ■

Steve Trussell

Executive Director

ARIZONA MINING ASSOCIATION (AMA)

What is the role of the Arizona Mining Association and how has membership evolved recently?
At the AMA, we focus on federal, state and local policy, regulatory work, and community relations. Our primary concern has been understanding how political shifts will impact mining and ensuring our 13 committees, composed of various mining companies, address key issues effectively. Additionally, we emphasize community relations, striving to unite mining communities and engage in meaningful projects that enhance these areas.

We have seen a significant increase in membership in exploration and development companies. Arizona boasts an incredible geological and mineral endowment, with much still to be developed.

What are recent advances in the Arizona mining sector?
The supreme court's decision for Resolution was huge. The Cactus mine of Arizona Sonoran recently achieved a significant milestone by being included in the city's general planning amendment. If they can get the mine operational, it would become the eighth largest copper producer in the US. Florence Copper, which is currently under construction, will have a mine life of ~22 years, mineral reserves of 320 million t grading 0.36% copper, and an annual production capacity of 85 million lb of LME Grade A copper cathode produced onsite. As one of the lowest-GHG sources of new US copper production, Florence Copper is expected to herald a new era of American mining in support of net-zero.

How is the AMA addressing challenges to advance the industry?
We are working to address the skilled labor shortage through career technical education (CTE) programs. We want people to understand how sophisticated the mining industry is. People's perception of mining of the past is not accurate today. Mining is a significant contributor to Arizona's economy. We are working to keep mining viable, responsible, and sustainable so we can continue to enhance the quality of people's lives. ■

Amanda Hilton

President

NEVADA MINING ASSOCIATION (NVMA)

What are recent milestones reached by the Nevada mining industry and the association?
Nevada has solidified its position as a national leader in lithium development, thanks to a collaborative effort between public and private entities. In 2023, the University of Nevada, Reno was designated a US technology hub, attracting federal funding that supports workforce development and Native American affairs. Nevada's 'lithium loop' now encompasses the full lithium value chain—from mining to battery production and recycling. With the only operational lithium mine in the US and two additional mines set to launch soon, Nevada is strengthening its role in supplying critical minerals essential for the nation's energy future. The state also produces key minerals like barium, magnesium and copper, further contributing to diverse industries.

What is the state's production and socioeconomic profile?
Nevada's mineral production is extensive, covering 20 minerals with gold as the largest output. If Nevada were a country, it would rank as the sixth-largest gold producer globally, accounting for approximately 73% of the gold mined in the US. In 2023, mining contributed over US$12 billion to Nevada's economic output. The industry supports more than 30,000 jobs.

How does the NVMA engage with schools to educate the younger generation?
With a significant portion of our skilled workforce nearing retirement, we're intensifying outreach to younger students to introduce them to mining careers before high school. Our education committee is expanding efforts across Nevada, utilizing digital and social media to connect with today's youth where they consume information and showcase modern mining opportunities.

How is Nevada's mining industry responding to the climate crisis?
Nevada's mining industry contributes to combating climate change both through the essential minerals it produces for renewable technologies and its own sustainability initiatives. For instance, Nevada Gold Mines recently installed a 200-megawatt solar facility and secured a federal grant for additional solar installations, significantly reducing its carbon footprint. ■

Adam Eckman

President and CEO

COLORADO MINING ASSOCIATION (CMA)

What were the major issues faced by members in the past year?
In the 2024 legislative session, the largest single issue was new water regulation in the aftermath of the US Supreme Court's Sackett v. EPA decision. The decision significantly impacted federal oversight of certain wetlands and streams, leading Colorado to establish state-level protections. This became a major legislative issue as the state needed to regulate waters no longer covered by the federal Clean Water Act. Colorado implemented a robust regulatory regime aimed at all state waters, which posed a significant challenge for mining operations due to their water intensity. CMA engaged with state legislators to amend the introduced legislation successfully, making it more workable for member companies as the state established its first dredge and fill regulatory permit process.

What notable milestones have been achieved by members in the past year?
There is significant excitement in mining focused on uranium and critical minerals. With the clean energy transition underway, interest in nuclear development has surged, and the price of uranium is currently the highest it has been in many years.

What makes Colorado an attractive place for mining development?
Colorado was recently ranked as the fifth most favorable jurisdiction in the world for mining investment by the Frasier Institute. Colorado boasts some of the most environmentally sound and safety-conscious operations globally. The state's diverse mineral endowment, including some of the most abundant molybdenum reserves in the world, one of the nation's leading gold mines, as well as copper, silver, uranium, and critical minerals reserves, combined with our broad range of mineral reliant industries, including clean energy development, aerospace, and national security applications, Colorado is a unique and attractive place for mining investment. Colorado is poised to play a leading role in raw materials production for the clean energy transition, advanced technology, and national security minerals applications, among others. ■

Benjamin Davenport

Executive Director

IDAHO MINING ASSOCIATION (IMA)

Can you introduce the Idaho Mining Association and how it supports Idaho's mining industry?
The Idaho Mining Association (IMA) acts as a crucial advocate for the mining industry in Idaho. Our primary function is to influence and shape policy to create a favorable operating environment for the industry. Beyond advocacy, we also spend time in the field networking and educating the public and policymakers.

Can you describe the geological makeup of the state?
In the southeast corner, we have the Idaho phosphate patch. The northern part of the state features the Idaho Silver Valley. Central and southern Idaho has considerable gold deposits, along with molybdenum and copper. On the eastern side, we have the Idaho Cobalt Belt, which also includes rare earth elements.

What are the benefits of Idaho in the mining space?
Our policymakers do a commendable job of facilitating natural resource development and mixed land use opportunities. The challenge, however, is that over 60% of Idaho's land is federally owned, making it difficult to assemble land packages for mining without federal permits. Despite this, local and state policymakers generally have an open-door policy for permitting and approvals.

How does the association support environmental stewardship?
The Idaho Mining Association has updated the Financial Assurance and Surface Mining Act for the first time in over 50 years to meet current standards. These updates ensure that adequate funds are set aside for land reclamation. We have also introduced new water quality and rock impoundment standards.

What are some of the challenges that miners face in Idaho today?
Federal delays are costly and time-consuming. Social acceptance and community perceptions can impede progress, with misunderstandings between industry and locals often a barrier. The well-funded conservation community and complex litigation, particularly during permitting, add to the difficulties. A major issue is the workforce shortage, with many experienced workers retiring and a struggle to attract young professionals. ■

Net Zero 2050 – A Note to Politicians

Sincerely, the Mining Industry

Humanity has been a fossil-fueled civilization for 125 years, when coal and oil surpassed wood as the leading energy source in the late 1800s. Net zero would mean a paradigm shift in the energy we have relied on since that time. As of 2022, fossil fuels accounted for 82% of the world's primary energy supply. Hydro, nuclear, wind, solar and geothermal plants provided only 18% of world energy supply. The share of fossil fuels in global energy use decreased only 4% from 1997 to 2022, according to Vaclav Smil's 'Halfway Between Kyoto and 2050' report.

Net zero means that in the 28-year span from 2022 to 2050, clean energies must not only displace fossil fuel's current place in electricity generation, but also account for the forecasted 3.3% annual growth in electricity demand. Clean energy technology must also replace all other sources of emissions, including transportation. These demands put unprecedented pressure on the mining and metals industry. It is estimated that 384 mines must be built by 2035 to meet EV and energy storage battery demand alone, according to Benchmark Intelligence. "Electric vehicles, batteries and renewable energy systems all require metals like lithium, cobalt, nickel and magnets," emphasized Robert Fox, materials separations and analysis department manager at the Idaho National Laboratory.

Achieving net zero would mean 3,500 GW of new renewable resources operating by 2050. Each megawatt of wind power demands 500 t of materials, including copper, neodymium and praseodymium, as highlighted by European Union research. Solar power, too, is straining the supply of precious metals, with silver demand projected to rise by 170% by 2030 due to solar panel production. "Demand from new photovoltaic installations globally could result in more demand for silver than total global annual supply," said Mitchell Krebs, president and CEO of Coeur Mining.

Net zero means electrifying the fleet of consumer vehicles. Replacing the 1.35 billion gasoline and diesel cars on the road today—and accommodating an expanded fleet projected to reach 2.2 billion vehicles by 2050—will demand an additional 150 million t/y of copper. The Energy Transition Commission estimates that cumulative copper demand for net zero will total 600 million t/y. For perspective, global copper production in 2023 was just 22 million t/y, according to the USGS 2024 Mineral Commodity Summary. With copper grades averaging 0.6%, meeting this demand would generate 100 billion t/y of waste rock.

While lithium scarcity concerns fueled the 2021 price rally, the mineral remains crucial for EV production, emphasized Bernard Rowe, managing director of Ioneer: "The US is the second-largest car market in the world. Today the production of lithium in the country is between 5,000-7,000 t/y. By the early 2030s, the US alone will require around 1 million t/y of lithium carbonate equivalent."

Recycling: A part of the minerals supply solution

At 29 years, the lead time to bring a mine into production in the US means a deposit discovered today misses contributing to the country's 2050 net zero target by four years, immediately extinguishing hopes of a cleaner future. However, metals supply can come in different forms: "There is no scenario in which the world could come close to Paris agreement targets without recycling all the needed materials in the world's supply chains," said Corrado De Gasperis, executive chairman and CEO, Comstock Inc.

There is an estimated 280 billion t of inactive tailings deposits worldwide, estimated to contain trillions in estimated value of critical, precious and strategic metals. Reprocessing this material is a no-brainer according to Tawana Bain, CEO of American Clean Resources Group: "The reintroduction of minerals and metals that were once considered waste into the supply chain not only diversifies our sources of supply but also advances America's goal of self-reliance. This shift has the potential to transform the mining industry in the US, creating safer job opportunities and redefining the sector's future."

The firm is starting with the tailings in the 1,183 acres of their Tonopah property in Nevada.

The US Forest Service identified 38,991 abandoned mine sites on National Forest Lands. Many of such mines operated under environmental regulations inadmissible today. Recycling the material is a win-win, according to Dustin Wasley market leader mining at Haley & Aldrich: "Legacy mine sites, although inactive, still hold valuable mineral resources. Revitalizing these areas not only limits the impact of reintroducing critical minerals into the supply chain but also facilitates needed environmental restoration."

In 2022, the Department of Energy awarded US$74 million under the Bipartisan Infrastructure Law to 10 projects focused on battery recycling and reuse. Two of the awarded companies, American Battery Technology Company (ABTC) and Redwood Materials, are recycling lithium-ion batteries in Nevada. ABTC's parallel lithium extraction and battery recycling businesses exemplify the importance of recycling when moving away from fossil fuels: "Building partnerships is crucial for creating a closed-loop supply chain, which differs significantly from the traditional hydrocarbon economy, where resources are used once and then depleted. With elements like lithium, having strong partnerships allows us to maintain control over these materials indefinitely." said Ryan Melsert, CEO and CTO, ABTC.

Solar panels provide another type of recycling feedstock. "More than 100,000 t/y of waste solar panels are generated, mostly from California, Arizona and Nevada. By 2030, this is expected to rise to 1 million t/y, and, by 2050, 8-10 million t/y," said Corrado De Gasperis.

In 2023, Comstock Metals, a subsidiary of Comstock Inc., established a commercial demonstration facility to recycle 100% of end-of-life solar panels, yielding glass, silica, aluminum copper and a high-silver-content metallurgical ore.

Without the uptake of recycling and reuse to meet 2050 targets, mining capital requirements would increase by a third, according to the International Energy Agency (IEA). The current recycling rate for copper is around 29%; increasing this to 100% by 2050 would reduce primary copper demand by 26%, according to the World Bank Group.

Even with significant improvements in recycling rates, secondary supply from recycling cannot fully meet the rapid growth in demand for critical minerals. "Most countries, including the US, Europe, China and Australia, are increasing their need for raw materials like copper. While recycling helps address this gap in supply, it is just one part of the solution. We need new mines to keep up with demand, but can we build these fast enough?" implored Nathan Foster, managing director Kennecott at Rio Tinto.

Climate goals and permitting reform: A policy balancing act

Many praise the Biden Administration as the administration that took more climate action than any other in history. The three legislative measures comprising Biden's Investing in America agenda include the Bipartisan Infrastructure Law (BIL), CHIPS and Science Act, and Inflation Reduction Act (IRA), which will have the biggest impact on the domestic mining industry.

Under the BIL, the US will invest more than US$7 billion in the supply chain for batteries, which includes production, sourcing and recycling. This amount is part of the US$62 billion allocated to the US Department of Energy to fund and expand clean energy initiatives and technologies. The CHIPS and Science Act, while primarily aimed at semiconductor supply chain resilience, seeks to jumpstart R&D and commercialization of leading-edge technologies, including clean energy and the creation new regional high-tech hubs. A portion of the IRA's US$370 billion in investments will accelerate private investment in clean energy solutions and strengthen critical mineral supply chains.

From a policy standpoint, the Biden administration made significant progress. However, many mining executives feel that critical issues remain unaddressed. According to Mark Compton, executive director American Exploration & Mining Association (AEMA): "The Biden administration recognized the need for mining to meet clean energy goals, but this has not yet translated into concrete actions to support domestic mining. While some projects, particularly in the lithium space, received federal support, widespread support remains lacking."

The US permitting landscape has resulted in some of the longest lead times globally to bring a resource from discovery to production, second only to Zambia. The National Environmental Policy Act (NEPA) sets the timelines and deadlines for federal environmental decisions on projects, but it also contributes to significant delays. In May 2024, the White House Council on Environmental Quality (CEQ) published its final Phase 2 rule, revising the agency's regulations for implementing the NEPA and expanding environmental reviews for projects, including mining, which will require more detailed assessments of climate impacts, community effects and cumulative impacts while adding enforceable mitigation requirements. The new guidelines raise concerns

Image by Lucrezia Falcidia

within the mining industry. The National Mining Association (NMA) argues that the administration's approach complicates the permitting process, disregarding Congressional intent to streamline it. This creates uncertainty for mining projects that are critical for the clean energy transition, potentially resulting in longer review times and increased costs. "[NEPA] reforms are essential to ensuring that decisions are made transparently and within a reasonable timeframe, which is currently one of the biggest obstacles to advancing new mining projects," said Rich Nolan, president and CEO of the NMA.

Under the new administration, this will likely change, as President Trump supports reshoring domestic production in the quickest manner possible.

No China, no transition

Mining, however, is not the main problem. Metals and minerals must be refined and processed to be used in clean energy technologies, and China alone refines 40% of the world's nickel supply, 50-70% of its lithium, 65% of its cobalt, and nearly 90% of its rare earths, according to the IEA.

Downstream, China dominates manufacturing energy technology capacity and capability, with a 60% share in wind foundations and a 97% share in solar PV wafers, according to Wood Mackenzie. When it comes to lithium battery manufacturing: "Less than 1% of global cathode production capacity is currently in North America. The four planned cathode plants will consume more lithium than all the proposed lithium refineries in the USA," added Melsert of ABTC.

For copper, the 2024 Mineral Commodity Summary shows Chinese copper mines produced 1.7 million t in 2023, an amount not significantly greater than the US's 1.1 million tons. However, China produced 12 million t of refined copper, while the US produced a balmy 0.89 million t. US$85 billion in new smelting and refining capability is needed to displace Chinese supply, according to Wood Mackenzie.

"China controls over 60% of global production of critical metals like copper, steel, aluminum and rare earths. China's dominance in metal smelting and refining is due not only to its investment in mines worldwide but also to its ability to overcome environmental and economic hurdles," highlighted Daniel Kappes, president and CEO of Kappes, Cassiday & Associates.

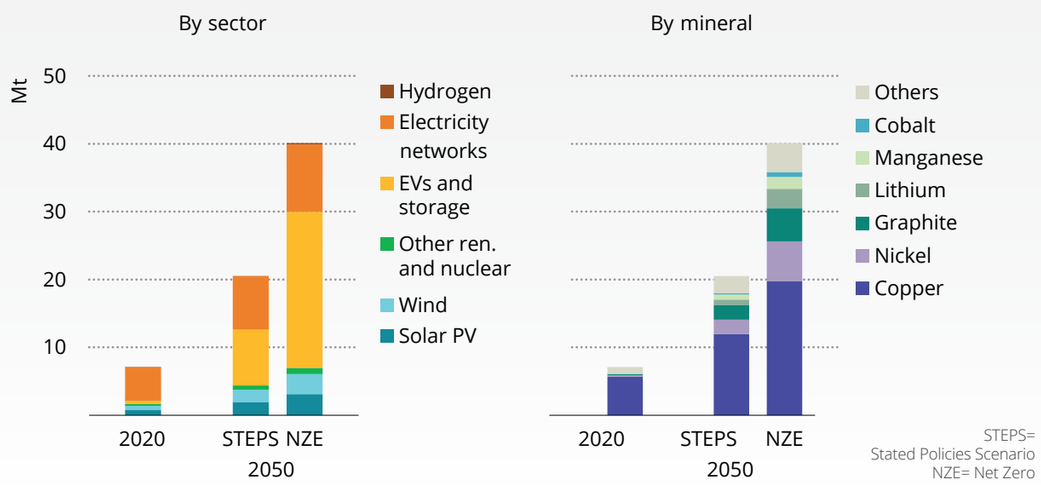
The capital expenditure required for the energy transition across power and renewables for Wood Mackenzie's net zero case is US$78 trillion between 2024 and 2050. Ridding the market of Chinese manufactured clean tech products would add an extra US$6 trillion.

The time is now

Critical mineral supply is concentrated in a smaller number of countries than for oil and natural gas. Supply chains for solar panels, wind turbines and batteries using imported materials could quickly be affected by regulatory changes, trade restrictions, or political instability. Decarbonizing the electricity and transport sectors will increase metal extraction over sevenfold by 2050 compared to 2015. Around 32-40% of this growth is expected in countries with weak resource governance. The impending mining boom may result in severe environmental degradation and unequal economic benefits. With the highest environmental regulations globally, the US has a distinct role to play in the world's decarbonization.

The US cannot do it alone. The path forward must be collaborative, and we cannot wait. Damages from 2023's 376 climate disasters totaled US$92.9 billion, according to the National Oceanic and Atmospheric Administration. From 2014 to 2023 that amount increases to US$1.2 trillion. This will only rise. While net zero may seem expensive, the price of not decarbonizing will be even greater. ■

Mineral Requirements for Clean Energy Technologies



Source: International Energy Agency's World Energy Outlook

Willem Van Twembeke

CEO

INKIA ENERGY

"Producing a ton of copper ore requires 30-100 kilowatt-hours of energy. By providing cleaner electricity, we help mining clients reduce emissions."

Can you introduce Inkia Energy and the firm's energy portfolio?

In 2018, I Squared Capital, a private equity fund that is the current controlling shareholder of the company, acquired Inkia Energy. By 2019, we merged Inkia with Orazul under the Inkia Energy name. Both Orazul and Inkia had substantial assets in Peru, which we combined to form Kallpa. Inkia Energy is now the largest power generation and commercialization company in Peru.

Inkia Energy is highly diversified, with a strong balance between thermal and hydroelectric capacity. The company operates 1,237 MW of thermal capacity in Peru, utilizing the most modern combined cycle plants that run on locally sourced natural gas. This gas is priced domestically so is very predictable, which makes electricity in Peru cheaper than other countries around. The plants are strategically located close to Lima. Inkia operates three hydroelectric plants, totaling around 1,000 MWs. This includes Cerro del Águila, Cañón del Pato and Carhuaquero. Inkia has expanded into battery energy storage systems (BESS).

What transformational change is the company undergoing?

Kallpa, which has 340 MWs under construction in its Sunny 1 and Sunny 2 projects, has signed power purchase agreements with Zelestra and Enhol. By early 2026, the company will have around 1,000 MWs of solar capacity, forming the largest solar hub in Peru, located in the resource-rich southern region with an excellent 33% plant factor. On top of this, Inkia is also targeting 600 MWs of eolic, and additional 300 MWs of solar capacity by 2030, bringing its total non-conventional renewable portfolio to around 2,000 MWs within the decade. This will bring specific emissions of the company well below 0.15 tons of CO_2 per MWh.

During construction, we hire many local workers. We also contribute to communities through taxes and cooperation programs. Kallpa`s ESG team is larger than our commercial team because building strong community ties is crucial for long-term success, especially in Peru.

How does the shift towards greener energy economy impact the mining industry?

There is a global shift toward greener industries, and mining is no exception. Energy costs comprise 15-30% of a mining company's expenses, with a significant portion of that being electricity. Producing a ton of copper ore requires 30-100 kilowatt-hours of energy, depending on the mine. By providing cleaner electricity, we help them reduce emissions.

How does legacy infrastructure affect countries' abilities to meet net-zero goals?

In Latin America, only Brazil surpasses Peru in terms of green energy production. While many countries struggle to reach their green energy goals, Peru is on track without needing new laws or drastic changes. Latin America leads globally in clean energy, outpacing continents like Europe and countries like the US or China, where legacy technologies hinder progress. Industrialized countries have more legacy systems, and a heavy industrial base compared to places like Peru and face by consequence greater challenges in going green.

Peru will naturally achieve net-zero emissions by 2050 due to its vast resources and existing policies.

What is the firm's approach to community relations?

At Inkia Energy, we do not believe in simply handing out money to local communities. Instead, we collaborate on infrastructure projects that benefit them directly. Working alongside the Peruvian state, we involve both the local communities and government in managing these projects. It is a true partnership. Education is another priority for us. We invest heavily in it because we believe it is key to Peru's future, both for the people and the economy. We also focus on entrepreneurship, helping local communities start their own businesses. Seeing them generate their own income provides true and solid long-term benefits. We prefer entrepreneurs to be proud of their own achievements.

What are Inkia's priorities moving forward?

The company's main priority is serving its clients professionally and helping them achieve their goals, whether they are large mining companies or small and medium enterprises. We focus on building long-term relationships, not short-term gains, because our sector, like mining, requires long-term planning. For example, we might work with a mining company for 10 years or engage with communities near our facilities for 30 years. It is essential to approach these partnerships with a serious, long-term mindset, ensuring that both sides benefit over time ■

The Role of Universities in the Industry's Future

Key enablers of the green energy transition

The mining industry will add between 11,000 and 13,000 jobs annually for the next 20 years. Many of these will likely remain unfilled; in April 2023, the US mining sector had 36,000 job vacancies, up from 27,000 in 2022.

International Council on Mining and Metals (ICMM) executives estimate more than half the mine workers in the US are aged 45 years or older. According to the Society for Mining, Metallurgy, and Exploration (SME), around 220,000 US mining workers are expected to retire by 2029, a mass exodus creating a substantial knowledge and skill gap and exacerbating the talent drought.

According to the ICMM, the global shift toward automation and digitalization is adding to this challenge by demanding more specialized skills. New roles, such as data scientists, geospatial analysts, and artificial intelligence (AI) specialists, are becoming increasingly vital. >>20

Image by jzehnder at Adobe Stock

Jodi Banta

Program Manager

THE UNIVERSITY OF ARIZONA SCHOOL OF MINING & MINERAL RESOURCES

> A major challenge in recruiting talent for the mining industry is its low visibility, making it less attractive compared to more well-known fields.

What initiatives has the University of Arizona implemented to tackle the talent crisis, and what recent milestones have been achieved?

The University of Arizona School of Mining & Mineral Resources (SMMR) is proactively addressing a significant talent crisis stemming from a global decline in mining-related education. US enrollment has dropped over 50% since 2015. And with digital transformation and increasing expectations around environmental and social performance, preparing talent has become more complex.

When it comes to attracting talent, a solution to the root of the problem must start early in the education system. Research revealed a critical lack of awareness about mining careers, highlighted by a survey showing that 60% of American science teachers felt unqualified to recommend mining. To combat this, SMMR launched a mining and minerals teachers' academy for high school and middle school science teachers. After a successful pilot program funded by the Freeport-McMoRan Foundation, SMMR aims to train 100 teachers each year, each with the potential to impact thousands of students over their career. The new teachers' academy is in addition to a well-established K-12 education outreach program funded by the Mining and Minerals Education Foundation, which reaches over 6,000 students and hundreds of teachers annually.

At the university level, making mining education widely available is a top priority. Two new general education courses on mining and minerals provide over 40,000 curious undergraduates the opportunity to fulfil their general education requirements by studying mining related topics, including the relationship between minerals and sustainability and the impact of choices we make as consumers every day. In 2022, SMMR launched an interdisciplinary minor in sustainable mineral resources, available to any major. The annual 'Mines for Limitless Minds' career expo, now entering its third year, attracted over 800 students last year, with a goal of over 1,000 attendees this year, helping students explore diverse career opportunities in mining. A new research innovation grants program encourages interdisciplinary collaboration, inviting faculty from various disciplines to apply for seed grants for mining-related research, further engaging graduate students in the field. All these efforts serve to put mining in front of more students, and a more diverse range of students.

How have enrollment figures fluctuated at the University of Arizona's mining engineering program?

The University of Arizona's mining engineering program represents approximately 10% of all mining engineering students in the US at the bachelor's level. Historically, the program maintained an enrollment of around 60. This, however, has become increasingly difficult. The latest data indicates that the university maintained steady enrollment in its mining engineering program at a time when enrollment figures nationally have declined 30%.

What challenges does mining face in attracting talent and how can they be addressed?

A major challenge in recruiting talent for the mining industry is its low visibility, making it less attractive compared to more well-known fields. It's impossible to attract talent to an invisible industry. Many students lack familiarity with mining and struggle to envision a career in it. To overcome this, industry and academia need to collaborate on raising the industry's profile, especially emphasizing its role in green energy and national security. Bringing mining education into communities and classrooms and providing real-world examples can help generate interest and curiosity among young people.

What were key findings from the SMMR's research on mining career perceptions?

The SMMR is currently conducting research to explore perceptions of mining education and careers among prospective students, parents, teachers and counselors. This study aims to understand attitudes toward mining, the influence of parental guidance on students' educational choices, and whether disinterest in mining careers arises from misconceptions or lack of exposure to the industry. Initial findings indicate that while students recognize that mining occurs in Arizona, they have limited knowledge about the industry and its career opportunities.

What are the SMMR's goals for 2025 and plans to enhance outreach?

Key objectives include adding mining content to a wide range of courses each year and significantly increasing enrollment in the Bachelor of Science in Mining Engineering program. The university will launch professional development courses focused on machine learning in mining. ■

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Unfortunately, the number of people entering the workforce will not be a rainstorm to fix the drought. US mining graduates declined by 39% between 2016 and 2022, according to the SME. There were only 600 mining engineering students enrolled across the US in 2022, a sharp decrease from 1,500 in 2015.

According to the Center for Strategic and International Studies, university programs dedicated to creating this workforce are shrinking, with mining and mineral engineering programs in the US dropping from 25 in 1982 to 15 in 2023. For comparison, China has over 38 mineral processing schools and 44 mining engineering programs. China's largest mineral processing program has 1,000 undergraduates and 500 graduate students alone to help accomplish China's mineral ambitions.

The shortage presents an imminent challenge, said Charles Kocsis, department chair at the department of mining engineering at the University of Utah: "With a labor shortage looming, particularly as many in the industry are set to retire, this decline in enrollment could have serious implications for the development of new mines and production output. An estimated 350 new mines will need to be developed over the next 20-30 years to meet the increasing global demand for critical minerals like copper, lithium, uranium, gold, silver, etc."

Metal ore output in the US has been declining at an average rate of 2.7% annually from 2019 to 2023. Labor shortages are a likely factor, reflected by the 7.3% annual growth in unit labor costs. To counter this, metal ore mining companies increased hourly compensation by 6.2% per year from 2019 to 2023. This effort did not result in significant increases in employment, which rose 0.6% over the same period.

These dynamics are concerning for the industry. 71% of mining leaders even say the talent shortage keeps them from delivering on production targets, according to McKinsey. Additionally, 86% report finding it increasingly challenging to recruit and retain talent, a significant issue as the green-energy transition drives up demand for mined metals. This pressure is exacerbated by the US goal to increase domestic production and reduce reliance on talent- and resource-rich China.

Universities step in

Institutions like the Colorado School of Mines are using this urgency as an opportunity to attract new talent. "We recognize the challenges facing the industry and appeal to our students' desire to solve global problems, particularly in areas like energy expansion, growing populations, and the need for more minerals. We highlight how important mining is to the world's future and present it as an opportunity for them to make a meaningful impact," said Bill Zisch, head of mining engineering at the school.

This approach has yielded promising results, said School of Mines president Paul Johnson: "We piloted a new "Futures" class where students tackle real-world issues like energy, water, and carbon. Through this, they discover the relevance of mining in the larger context of energy and sustainability. This approach helps increase awareness of mining as a career option, not just for mining engineers, but also for students in other fields."

The School of Mines is onto something; 86% of Gen Zs and 89% of millennials say having a sense of purpose is important to their overall job satisfaction and well-being and are increasingly willing to reject employers who do not align with their values, according to Deloitte's 2024 Gen Z and Millennial Survey.

Contributing to the world's electrification to prevent one of the greatest mass extinctions in the planet's history, and maybe even our own, should be reason enough. Even still, 70% of youth aged 15-30 say they "Definitely would not" (42%) or "Probably would not" (28%) work in mining, according to a survey cumulated by McKinsey.

Why?

A report published by the US Department of the Interior in 2023 cites the negative public perception of the industry as a major obstacle.

The invisibility cloak

But there is more to it. "It is impossible to attract talent to an invisible industry. Many students lack familiarity with mining and struggle to envision a career in it," revealed Jodi Banta, program manager at the University of Arizona School of Mining and Mineral Resources (SMMR).

"Although the relationship between mined materials and technology is evident for those in the industry, many people do not realize that the devices they rely on daily are made from materials that originate from mines," continued Kocsis.

"Surveys at the University of Arizona reveal that many students' 'top of mind' association with mining is still coal", added Banta, who also highlighted that "a recent study in Australia found that just under half of young people say they do not know there are career paths in the mining industry outside of doing the actual mining."

Changing the narrative

What is the solution? According to Johnson, early visibility, or making your company and employees known to students when they are freshmen, is one answer: "When students see someone just five or 10 years ahead in their career, someone they can relate to, it becomes easier for them to envision themselves in that career. The more visible companies are, the better chance they will attract talent."

Visibility efforts seem to be paying off, said Kocsis of the University of Utah: "In 2022, we had five, and last year we saw an increase to 15 incoming freshmen students. In 2024, we welcomed 20 freshmen into the mining engineering program. This increase can be attributed to a team effort that included open houses, outreach to parents and high school students, and engagement with professionals"

Starting even earlier is crucial to addressing the problem at its root. "Research revealed a critical lack of awareness about mining careers, highlighted by a survey showing that 60% of American science teachers felt unqualified to recommend mining. To combat this, SMMR launched a mining and minerals teachers' academy for high school and middle school science teachers. This is in addition to our well-established K-12 education outreach program, which reaches over 6,000 students and hundreds of teachers annually," shared Banta.

Fortunately, social media has made the world more connected and visible than ever before, presenting a powerful tool the industry must leverage to drive change. "This year, we are on track to receive over 20,000 employment applications, a significant increase from last year's 11,000," started Keaton Turner, founder, president and CEO at Turner Mining Group. "This surge reflects our robust social media efforts to not only promote our brand but also highlight opportunities within the mining sector, particularly in the US," he continued.

Action is needed

The Colorado School of Mines is the only US-based school in the 2024 QS World University Rankings of top 12 mineral and mineral engineering schools. Of the other 11, there are four in Australia and Canada and one in Russia, Chile and Saudi Arabia.

In September 2023, the Senate Committee on Energy and Natural Resources introduced the Mining Schools Act of 2023, a bipartisan legislation allocating US$10 million per year, from 2024 to 2031, to a grant program for mining schools to recruit more students. Moves like this are essential if the US is to meet the rising demand for talent in the mining sector.

The future of the mining industry—and its role in the green energy transition—hinges on attracting and developing skilled talent. Universities, industry leaders and policymakers must collaborate to reshape perceptions, increase visibility, and build purpose-driven pathways that appeal to the next generation. ■

PJ

BZ

Paul Johnson and Bill Zisch

PJ: President
BZ: Head of Mining Engineering
COLORADO SCHOOL OF MINES

> The mining industry needs all types of engineers, so we are reaching out to mechanical, electrical, environmental, and computer science students as well to introduce them to career opportunities in mining.

Can you introduce the university and its role in the national mining industry?
PJ: Colorado School of Mines was founded in 1874 to supply the region with mining engineers, metallurgists and mineral processing experts, which was vital for economic growth at the time. We evolved into a full-service engineering university, supplying talent not only to the mining industry but also to aerospace, IT, civil infrastructure and energy sectors, all critical for Colorado and the nation's economy.

BZ: We have maintained strong ties with the industry since our beginnings. I have personally been on the Industry Advisory Committee at Mines for over 20 years, and we get input from a broad range of industry participants. At a recent career fair, over 400 companies attended, including more than 40 companies looking to hire mining and other engineering disciplines. One of our key focuses is to ensure we produce mining engineers who are well-equipped not just for today's challenges but for future demands.

What enrollment figures has Mines experienced in recent years?
BZ: We have seen a significant increase in our department's numbers, up more than 25% in 2023, bringing us to around 120 students. The mining industry needs all types of engineers, so we are reaching out to mechanical, electrical, environmental, and computer science students as well to introduce them to career opportunities in mining. Addressing the industry's challenges requires a broad range of engineering talent.

What approach does Mines take to ensure the next generation of mining engineers?
PJ: Unlike other universities, we do not admit students into specific programs. Instead, we bring in students interested in being engineers, problem solvers, and innovators. From there, we help them find the best fit for their interests. We piloted a new 'Futures' class where students tackle real-world issues like energy, water, and carbon. Through this, they discover the relevance of mining in the larger context of energy and sustainability. This approach helps increase awareness of mining as a career option, not just for mining engineers, but also for students in other fields. We emphasize professional development. When you combine that with their love for challenges, it becomes easy to engage them in exploring mining as a career path.

What do you think the industry overlooks when it comes to attracting talent?
PJ: One thing that applies to any company is the importance of early visibility. We offer opportunities for companies to be visible on campus, like professional development workshops, classroom participation, and involvement in future-focused classes. When students see someone just five or 10 years ahead in their career, someone they can relate to, it becomes easier for them to envision themselves in that career. The more visible companies are, the better chance they will attract talent.

What are current research initiatives at Mines?
BZ: At our Edgar mine, we have seen increasing demand for its use as a subterranean laboratory. It offers unique opportunities for research that benefits from an underground environment.

PJ: Future advances in mining will focus on efficiency, with AI and automation playing key roles. This is critical for processes involving critical minerals, where ore concentrations are small. We are also working on extracting materials from recycled sources. Research in geophysics and underground construction will improve precision in mineral extraction.

What are some key goals for the Mining Engineering program to remain number one?
PJ: The aim is to grow the program while ensuring students are equipped for long-term success in the mining industry. We are integrating AI into the curriculum and emphasizing that future engineers need more than just technical skills. We are adding business acumen to the programs and giving entrepreneurial and innovation-minded students more opportunities, like industry innovation challenges. We have also doubled down on hands-on experiences.

BZ: Our initial focus is increasing enrollment, but we are also expanding research and the application of evolving technologies and strengthening industry relations. We are introducing new course requirements focused on waste, water and closure management and on community engagement and sustainability as we continue to prepare our graduates for some of the industry's challenges today and in the future. ■

Charles Kocsis

Professor & Department Chair -
Department of Mining Engineering
THE UNIVERSITY OF UTAH

> Our focus is on advancing innovations in mine automation, efficient ventilation, mine design, and cooling systems to boost productivity and prioritize worker safety.

Can you introduce the Mining Engineering Department of the University of Utah?
Presently, we have about 45 undergraduate students and eight graduate students. We observed a decline in enrollment in mining engineering programs across the country, not just here in Utah, and we have been trying to understand the reasons for this decline. In 2021, we had four incoming freshmen. In 2022, we had five, and last year we saw an increase to 15 incoming freshmen students. In 2024, we welcomed 20 freshmen into the mining engineering program. This increase can be attributed to a team effort that included open houses, outreach to parents and high school students, and engagement with professionals from companies like Rio Tinto, Newmont, Wolverine Fuels, who spoke directly to the students. We showcased emerging technologies, such as a health & safety training program using virtual reality (VR) and augmented reality (AR), which piqued the interest of high school students.

How have shifting demands changed the role of the university in the industry?
The Western US is home to some of the largest and most productive mining operations, with states like Utah, Nevada, Arizona, Wyoming and Montana making significant contributions to the extraction of precious metals and essential minerals. With a labor shortage looming, particularly as many in the industry are set to retire, this decline in enrollment could have serious implications for the development of new mines and production output. An estimated 350 new mines will need to be developed over the next 20-30 years to meet the increasing global demand for critical minerals like copper, lithium, uranium, gold, silver, etc. The permitting process in the US will make it nearly impossible to meet that demand. Fortunately, advances in mining technology such as automation, remote sensing, and digitization can help increase productivity, reduce environmental impact and alleviate the effects of labor shortage.

Can you discuss the immersive virtual reality training program for miners?
I noticed that students in traditional training programs often retain a portion of the information provided. To address this, we developed a new training program using virtual reality (VR) and augmented reality (AR) technologies that immerse miners in real-time in underground and surface operations. This immersive experience is designed to enhance information retention through interactive participation. We are collaborating with a Chilean virtual reality company Minverso, and our students are involved in developing these training modules. In addition, mining companies within the US have started to show interest in our VR initiatives.

How does the university maintain its relationship with the domestic mining industry?
We have a strong connection to the mining industry through our industry advisory board (IAB), which includes members from companies like Rio Tinto, Newmont, Wolverine Fuels, and Caterpillar. We meet each semester to discuss our curriculum and research, ensuring that we are addressing relevant topics and challenges within the industry. Our students benefit from this relationship through internships and job placements, with nearly all undergraduate students receiving full-time job offers upon graduation. Additionally, our faculty are engaged with industry projects, providing practical insights that enhance the educational experience.

Can you highlight specific research topics that demonstrate the department's focus?
We are looking into solutions to protect miners working in extreme conditions. For example, a Ph.D. student from my research team developed a device that is slightly larger than a cell phone, which can assess work comfort based on factors like body mass index, gender, age, clothing, and environmental conditions. This device warns miners when they are at risk of heat stress, helping them take necessary breaks before experiencing heat-related illnesses. The same Ph.D. student built a set of powered safety glasses designed for emergency situations, allowing miners to see through smoke and providing navigational assistance during an emergency underground. These research initiatives showcase our commitment to advancing safety technologies in the mining industry, reflecting the innovative spirit of our students.

What are the university's goals for the next 24 months?
Our focus is on advancing innovations in mine automation, efficient ventilation, mine design, and cooling systems to boost productivity and prioritize worker safety while instilling traditional mining engineering principles that minimize environmental impact. ■

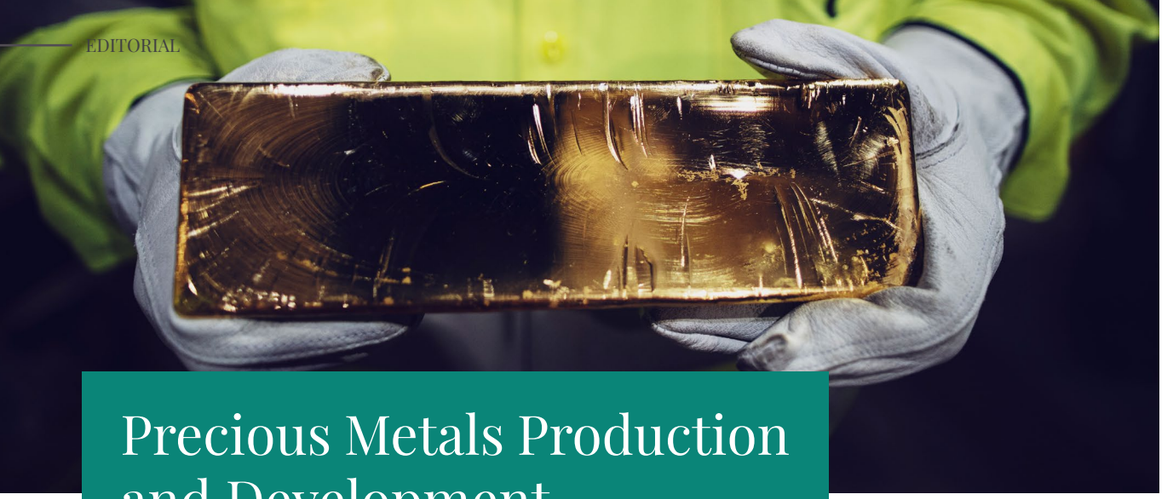
PRODUCTION AND DEVELOPMENT

“We must not only achieve the productivities and efficiencies we reached in the past but do even better. To do this, we must innovate and rethink our approach to mining.”

Joshua Olmsted
President and COO
FREEPORT-MCMORAN AMERICAS

GBR Series • WESTERN USA MINING 2025

Image courtesy of Rio Tinto Kennecott



Precious Metals Production and Development

Producers poised for growth amid market shifts

The United States' role in the precious metals space remains golden. The country houses the largest gold producing complex in the world at Nevada Gold Mines and ranks fifth in gold production volume. In 2023, the country produced 170 metric tons, according to the USGS. For silver, the country ranked ninth globally in 2023 and produced 1,000 t of the metal, according to the USGS. Silver was produced at only four primary silver mines, and as a byproduct of 31 others.

Gold production and development

Rare is the day over recent months when headlines do not read "gold price reaches record high." 2024 will be remembered as a golden year, as the yellow metal grew 35.1% in dollar value YTD, outperforming most asset classes. Gold has long been a haven asset, with 2024 feeding into this role, highlighted Jason Kosec, president and CEO of Integra Resources: "The ongoing bull run in gold prices, driven by factors such as massive Western debt and de-dollarization narratives, reflects its importance as a haven amid global uncertainties, including wars and climate crises."

The yellow metal bull run does not seem like it will back down. The Congressional Budget Office estimates US debt held by the public as a share of GDP will reach the highest level on record by 2029, increasing further to 180.6% as a share of GDP in 2053. High interest rates and inflation further support gold's rise. Central banks align with a global dedollarization trend; gold holdings are at 10%, up from 3% a decade ago. President Donald Trump and other advanced economies are prioritizing fiscal expansion, as spending commitments are forecasted to rise and as countries adapt to and tackle climate change along with other factors. This environment solidifies gold's position as a haven asset. Bank of America forecasted gold could reach levels of US$3,000/oz as early as 2025.

Although the high gold price presents opportunity, producers must continue to be disciplined, underscored Henri Gonin, managing director of Nevada Gold Mines (NGM), the joint venture between the world's top two gold producing companies, Barrick and Newmont: "The challenge is how we react to these increased prices. Operations that previously did not meet our financial thresholds now appear more attractive, but chasing every ounce can drive up costs. Sustainable growth requires balancing short-term gains with a focus on maintaining efficiency and profitability over time."

For NGM, sustainable growth comes in the form of ramped up production at Goldrush, which came online in April 2024, and exploration at the Greater Leeville and

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Image courtesy of Rio Tinto Kennecott

> While higher gold prices boost our revenues, we must remain disciplined in our response.

Henri Gonin

Managing Director

NEVADA GOLD MINES (NGM)

What milestones did Nevada Gold Mines (NGM) recently achieve?

At the Carlin complex, the Gold Quarry roaster underwent a significant expansion, increasing throughput by approximately 20%. This enhancement is expected to improve cost efficiency and boost gold production.

We commenced the deployment of 62 Komatsu 930E-5 haul trucks. These trucks are being integrated into our Cortez and Carlin operations, with 23 already operational at Cortez and 20 commissioned at Carlin.

Safety remains a core value, and we are advancing our "Journey to Zero" program, aiming to foster a culture of safety where everyone feels accountable. We saw continuous improvement in our safety performance metrics and introduced a fatal risk program to train employees to identify and manage critical risks.

In December 2023, we received the Record of Decision for the Goldrush project, enabling us to proceed with mine expansion and address ventilation bottlenecks. With over 75% of the first ventilation shaft work complete, we anticipate a significant production ramp-up as we approach full operations by 2025-2026.

How did NGM address recent operational challenges to meet future production goals?

In 2024, Turquoise Ridge faced infrastructure challenges that impacted aggregate movement, along with electrical and pumping failures that hindered dewatering efforts, affecting production. Recognizing that large-scale capital projects require time for effective execution, we are committed to refurbishment initiatives over the coming years to optimize operations.

Despite these hurdles, NGM maintained consistent performance in 2023. Notably, the Goldrush Underground project is projected to produce approximately 130,000 oz of gold in 2024, aiming for commercial production in 2026 and an increase to about 400,000 oz/y by 2028.

How will NGM ensure sustainable reserves and prevent depletion of existing resources?

Wholly owned by Barrick, the Fourmile project is situated north of the Goldrush development. Intensive drilling and testing identified four primary zones within the deposit, revealing high-grade mineralization that positions Fourmile is a potential Tier One mine, with production estimates exceeding 500,000 oz/y over more than two decades.

The Greater Leeville project demonstrated significant potential to expand mineralization. Ongoing exploration aims to convert these findings into reserves, extending the Carlin complex's life beyond 2045.

Located immediately north of Cortez, the Robertson project is undergoing evaluation, with a Record of Decision pending for its open-pit mine development. Full-scale pilot testing on three small pits is anticipated to commence around 2026. Its proximity to existing operations will allow for integrated planning and equipment sharing.

What is NGM's commitment to the environment?

We commissioned the first and second phases of our solar initiative, resulting in 200 MW of capacity. Solar power contributes approximately 17% of our total power requirement. This initiative allows us to eliminate about 235,000 tons of CO2. We are converting the TS power plant from coal-fired to gas-fired. We transitioned our fleet of light vehicles, including pickup trucks, from petrol to electric.

How does NGM balance opportunity and long-term profitability with elevated gold prices?

While higher gold prices boost our revenues, we must remain disciplined in our response. The challenge is how we react to these increased prices. Operations that previously did not meet our financial thresholds now appear more attractive, but chasing every ounce can drive up costs. There are valid reasons we avoided certain areas at lower prices, and we must be cautious not to pursue opportunities without weighing the long-term impact. Sustainable growth requires balancing short-term gains with a focus on maintaining efficiency and profitability over time.

What initiatives has NGM implemented to address workforce challenges?

We prioritize the development of our people. To elevate trade skills beyond traditional training, we launched our Training Mine program. We are introducing the Barrick Academy in the US, designed to enhance business acumen and financial management for engineers, geologists, supervisors, and other professionals. We are committed to offering diverse growth opportunities, including rotational assignments that provide exposure to different areas of our operations. We believe this holistic approach fosters job satisfaction and strengthens employee retention.

What is your outlook for coming years?

We are focused on maximizing our margins at the optimal production point. This effort includes reinvesting in our open pit fleets to maintain profitability and supplement our underground production, which has become the backbone of our life-of-mine production profile. We are positioning ourselves for success through critical investments. ■

Mitchell Krebs

President and CEO

COEUR MINING

> Rochester is now one of the world's largest open pit heap leach operations, and the largest source of domestically produced and refined silver in the USA.

What were recent operational milestones?
In 2023, we produced 317,000 oz of gold and 10.3 million oz of silver. For 2024, our gold production guidance range is 310,000-355,000 oz. We expect double digit increases for silver, primarily due to Rochester's expansion, projected to be between 10.7 million-13.3 million oz.

The key operational milestone was the completion of our Rochester expansion. We completed the construction of a new processing facility and a new heap leach pad. In March 2024, we completed the new crusher. We ramped up this crusher to its annual run rate of about 32 million t/y at the end of the second quarter of 2024.

Our unsung hero is our Wharf gold mine in South Dakota. We acquired this gold open-pit heap leach operation in 2015. Today, Wharf has generated US$400 million in free cash flow and has a seven-year mine life based on current gold reserves, with potential for further extension with incremental exploration investment. In 2023, it delivered record free cash flow, which helped to fund the Rochester expansion. In Mexico, our Palmarejo gold and silver mine in Chihuahua is expected to benefit from the recent consolidation of key land parcels located to the east of the operation, which were acquired from Fresnillo. This consolidation opens multiple new opportunities for Palmarejo. In Alaska, our Kensington gold mine faced a limited reserve mine life of less than two years about two years ago. We implemented a multi-year development and drilling program to extend its mine life. For the second consecutive year, we replaced more than what we mined in 2023.

What are the strategic and financial benefits of the Rochester expansion?
Rochester is now one of the world's largest open pit heap leach operations, and the largest source of domestically produced and refined silver in the USA. The expansion was a US$730 million investment. Rochester's silver production will increase from approximately 3 million oz/y to roughly 7-8 million oz/y and gold production from approximately 30-35,000 oz/y to 70-80,000 oz/y. With throughput 2.5 times larger than before, costs will decline significantly, and cash flow will increase. At current prices, Rochester should generate around US$100 million a year in free cash flow, pushing the company back into a positive cash flow position.

How has Coeur Mining's exploration investment strategy evolved?
Over the last five years, we invested around US$250 million in exploration, boosting our reserves by 35% and increasing resources by 45% on a gold equivalent basis. This investment has extended mine lives across our operations, except Kensington, where we expect to show a sizeable mine life increase by the end of this year. We expect Kensington to return to positive cash flow in the second half of 2025.

In 2024, we will allocate approximately US$55 million to exploration. Exploration will remain a key focus, funded by the positive cash flow generated from our recent investments.

What are the market dynamics supporting high silver and gold prices?
Demand for silver is growing driven particularly by photovoltaics. 2023 saw nearly 500 gigawatts of new photovoltaic installations globally, and experts predict this could exceed a billion gigawatts every year by 2030. Each gigawatt requires nearly 500,000 oz of silver, which could result in more demand for silver than total global annual supply. Silver is also essential in electric vehicles circuitry. This extends to charging stations and other infrastructure supporting EVs.

Gold benefits from the global de-dollarization trend. Central banks are diversifying away from the US dollar, boosting gold demand.

How does Coeur view ESG?
We focus on emissions, water, tailings impoundments, increasing our use of renewable power sources, safety, and long-standing community relationships. Our governance is top-rated, reflecting our commitment as a company listed on the NYSE. In 2023, we were the safest metals mining company in America. We are implementing the global tailings standard and tied a significant portion of our executive incentive compensation to a three-year emissions reduction target, aiming for a 35% reduction in carbon intensity by the end of 2024. We are on track to achieve this goal. We introduced a biodiversity standard last year and have also implemented innovative sage grouse conservation programs in Nevada. ■

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Robertson areas. The Fourmile project, wholly owned by Barrick, will add to NGM's Cortez complex's growth. "Intensive drilling and testing identified four primary zones within the deposit, revealing high-grade mineralization that positions Fourmile as a potential Tier One mine, with production estimates exceeding 500,000 oz/y over more than two decades," continued Gonin.

The path to successful production in the gold sector requires navigating high barriers to entry, adapting to shifting economic trends, and anticipating the evolving pricing dynamics that increasingly reflect global, rather than Western, market forces. Benefitting from the current cost environment required a long-term view, reflected John Swallow, president and CEO of Idaho Strategic Resources: "We considered global trends like deglobalization, de-dollarization and interest rate cycles when building our company with the idea that good companies are built during tough times. With our workforce in place, land secured, and exploration and production ramping up, we are in a strong position."

Gold dynamics create an environment ripe for M&A, enabling Toronto-based firms Andean Precious Metals and Minera Alamos to diversify into the US, acquiring Golden Queen Mining and Sabre Gold respectively. Alberto Morales, founder, executive chairman and CEO of Andean Precious Metals, explained: "As interest rates decline, interest in riskier assets, including precious metals, is likely to increase. A disconnect exists between the value of mining companies' equities and the rising spot prices of commodities, creating opportunities for companies like Andean to acquire undervalued producing assets."

For junior companies, on the other hand, mergers can be used as a hedge against difficult capital markets, said Kosec of Integra, that merged with Florida Canyon Gold in July: "The merger will reduce our reliance on frequent capital raises, as the cash flow from Florida Canyon is expected to support costs for our key development stage projects DeLamar and Nevada North."

However, the industry continues to extract without replacing reserves. In an interview with the Northern Miner, Mark Bristow, CEO of Barrick gold, emphasized how the industry must "reinvest in its own future, not just rely on M&A."

One such investment includes U.S. Gold Corp's CK gold project in Wyoming, where construction is set to begin in 2025. The firm's CEO George Bee said: "Our permitted status positions us favorably to capitalize on these market conditions, particularly as gold producers struggle to main- tain production levels amidst increasing all-in sustaining costs from older producing assets." As gold continues its strong performance amid global economic shifts, silver also finds itself in a unique position. While gold is traditionally viewed as a haven asset, silver's dual role as both a precious metal and a key industrial component is driving new opportunities in production.

Silver production

The silver market, like gold, is poised for a sustained bull run. Silver is uniquely positioned as both a precious metal and an industrial component, making it an attractive asset in today's economic environment, especially given its critical role in green technologies.

The Silver Institute estimates that silver demand in the photovoltaic industry alone will exceed 140 million oz/y by 2030. "2023 saw nearly 500 gigawatts (GW) of new photovoltaic installations globally, and experts predict this will increase. Each GW requires nearly 500,000 oz of silver, which could result in more demand for silver than total global annual supply," said Mitchell Krebs, president and CEO of Coeur Mining.

2024's US$1.7 billion acquisition of SilverCrest Metals will help Coeur Mining fill the world's supply gap. "The addition of SilverCrest's high-grade Las Chispas silver operation positions Coeur as a global leader in the silver industry, with peer leading expected production of over 21 million ounces of silver", highlighted Krebs.

This production will complement production from Coeur's expanded Rochester operation. "We expect double digit increases for silver, primarily due to Rochester's expansion. For 2024, silver production is projected to be between 10.7 million and 13.3 million oz," Krebs added.

Polymetallic ore deposits account for more than two-thirds of US and world resources of silver, according to the USGS. As such, the importance of verified sources of silver increases. "It is not easy to find—often only as a byproduct in certain locations—and its rarity is becoming more apparent. Now is the time to recognize the importance of silver and prioritize its discovery and development," said Catherine Boggs, Chairperson of Hecla Mining Company. Hecla Mining named Rob Krcmarov as CEO, effective November 2024.

The firm's flagship asset, Greens Creek in Alaska, produced between 8.8-9.2 million oz in 2024. "The firm is focused on expanding and converting resources to upgrade multiple ore zones. When Greens Creek began operations in 1989, it had a seven-year reserve life. Now, the mine boasts a 13-year reserve life. This achievement is a testament to the success of our exploration teams in continuously converting resources into reserves," said Boggs.

As high gold prices present opportunities, American producers are careful to maintain sustainable growth, prioritizing operational efficiency over short-term gains. Silver's dual demand in both industry and investment strengthens its role as a critical asset in a world increasingly driven by clean energy needs. Whether through exploration, expansion or strategic acquisitions, the industry is preparing for a sustained bull market in precious metals. This disciplined approach, focused on both production and reserve sustainability, ensures the US remains resilient in the face of global market fluctuations, supporting its role in the future of precious metals production. ■

Catherine Boggs

Chairperson

HECLA MINING

How would you assess the performance of Hecla's key assets?

Our cornerstone assets, Greens Creek and Lucky Friday, continue to deliver. In 2023, Greens Creek produced 9.7 million oz of silver and generated US$122 million in free cash flow. In 2024, we project production between 8.8-9.2 million oz.

Lucky Friday, our second key mine, faced challenges in 2023 due to a fire that halted production for six months. Despite this setback, we resumed production in January, ramped up to full production in the first quarter of 2024, and by the end of the second quarter, we produced 2.4 million oz, positioning us to reach our 5-million-oz target for the year.

Our newest mine, Keno Hill in the Yukon, exceeded expectations, with a total of 1.5 million oz in the first half of 2024.

At Casa Berardi, our gold mine in Québec, we produced 45,191 oz in the first half of 2024. The mine is currently undergoing a transition to complete surface operations.

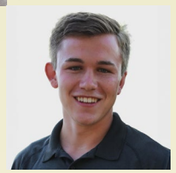
What is Hecla's exploration strategy?

At Greens Creek, we are focused on expanding and converting resources to upgrade multiple ore zones. Keno Hill has a reserve life of 11 years and, our exploration efforts are showing great promise, particularly in the Birmingham and Flame & Moth areas. The underground drilling continues to intersect high-grade silver mineralization, reinforcing our belief in the district's potential.

Lucky Friday has a reserve life of 19 years. We allocated fewer exploration dollars here but continue to evaluate the potential on the east side of the 30 Vein, where most of our resources are located.

We are currently awaiting approval for our plan of operations for our Montana assets. Once approved, we can begin dewatering the drift and proceed with the necessary exploration drilling. ■

JS



TS

John Swallow and Travis Swallow

JS: President and CEO

TS: Stakeholder & Corporate Development

IDAHO STRATEGIC RESOURCES

Can you provide recent production highlights?

TS: We remain Idaho's largest primary gold producer, with revenue up by about 50% in 2024. The gold head grade at our mill has improved by 40-50%, putting us on track to produce 10,000-15,000 oz of gold in 2024. We currently have three drills operating at the Golden Chest mine. Our entire land package spans over 7,000 acres, offering significant exploration potential. As a part of our plans to increase production, we are constructing a paste backfill plant at the Golden Chest mine, a key first step towards building a larger mill on-site.

JS: We have grown 30-50% annually, and see the potential to continue this growth ahead of us. We did the heavy lifting and are now a profitable gold producer.

How is Idaho Strategic advancing its rare earth element (REE) deposits?

TS: We are the largest REE landholder in the US, with three top-ranked projects in the Idaho Rare Earth Element Thorium Belt. We conducted extensive surface sampling and are collaborating with national labs to study mineralogy and develop processing methods to advance our REE ores into future metals and magnets. Samples from our Mineral Hill property contain up to 34% total rare earth oxides, among the highest in the world. ■

Jason Kosec

President and CEO

INTEGRA RESOURCES

How will the acquisition of the Florida Canyon mine impact Integra Resources?

The acquisition of the Florida Canyon mine transforms Integra Resources from developer to producer status. The cash flow from Florida Canyon is expected to support development costs for our key development stage projects DeLamar and Nevada North, and is expected to boost our valuation and reduce the company's cost of capital. Florida Canyon has a seven-year mine life with steady production of around 70,000 oz/y. With DeLamar and Nevada North coming online in later years, we anticipate steady state production exceeding 200,000 oz/y. This growth will move Integra from a junior to an intermediate producer.

Can you provide highlights from your completed drill program at DeLamar?

We inherited around 60 million t of stockpiled material from Kinross. Our team identified and drilled these areas, resulting in an updated resource of 42.5 million t of M&I material that will be incorporated into the updated mine plan in the FS. The PFS included 81 million t for heap leaching. ■

Alberto Morales

Founder, Executive Chairman and CEO

ANDEAN PRECIOUS METALS

How will the firm benefit from the Golden Queen mine acquisition?

With Golden Queen, we now have a presence in the US and diversified our jurisdiction and revenue streams—approximately 50/50 between Bolivia and the USA. This acquisition allowed us to more than double our revenues, while EBITDA grew from US$3.7 million to US$24.5 million during the same period. We are updating the geological model and investing in exploration and drilling to extend the mine's life. On the plant side, we are improving the crushing process, increasing cyanide use in leaching, and reducing water consumption among other measures.

What is driving acquisitions in the gold space?

A disconnect exists between the value of mining companies' equities and the rising spot prices of commodities, creating opportunities for companies like Andean to acquire undervalued producing assets. Focusing on these assets will enable us to evolve from a non-traditional mining company focused on processing to a more conventional mining company with our own resources and development assets. ■

George Bee

President and CEO

U.S. GOLD CORP

> We have a fully permitted project, significantly mitigating risk for potential investors. Our CK project will be the first gold mine in the state of Wyoming.

What were key milestones for the CK gold project in 2023 and 2024?

In 2012, previous owners completed a PEA revealing 1 million oz of gold and 250 million lb of copper in an open-pit scenario. We rebranded it to highlight its gold value, which represents 70-80% of the project's worth. Our first step involved hiring a local Wyoming environmental consulting firm to perform extensive baseline studies and prepare our permit application for submission to the Wyoming Department of Environmental Quality. We finalized two years of environmental baseline work by September 2022 and submitted our permit application. We received our conditional mine operating permit in May 2024. Conditions included requirements for obtaining a water discharge permit, posting a bond for initial disturbance, and applying for an air quality permit. All conditions have been met with the final air quality permit about to be announced in November.

What is the geological and economic viability of the CK gold project?

The CK gold project is situated in a granodiorite-hosted shear zone characterized by copper and gold mineralization, primarily in chalcopyrite, outcropping at surface. The site is within a mining area known as the Silver Crown Mining District which has a history of high-grade deposits exploited by miners as far back as the late 1800s and concluding in the 1920s. Our initial 10-year mine plan is designed to evolve as we explore and continue into known deeper mineralization. Economically, the project targets nearly 110,000 oz/y AuEq over an initial 10-year mine-life with a front-end loaded structure that promises a rapid payback period. We estimate our all-in sustaining costs will rise from US$900-US$1,000/oz, while the initial capital costs are expected at approximately US$300 million.

How are the dynamics of the gold and copper markets impacting junior mining companies?

The investment landscape for gold and copper mining has been challenged by competition for capital from sectors like cryptocurrencies and cannabis, leading to reduced funding for exploration. Major mining companies are currently focusing on shareholder returns rather than exploring new projects. Major and mid-tier companies often rely on juniors for discoveries and risk mitigation. We are observing a surge in exploration and M&A activity as companies seek to acquire promising projects to enhance their portfolios.

From U.S. Gold's perspective, our permitted status positions us favorably to capitalize on these market conditions, with the lower cost CK project production being attractive, particularly as established gold producers struggle to maintain production levels amidst increasing all-in sustaining costs from older producing assets.

How are the company's other projects progressing?

At Keystone, we hold 20 square miles of strategically significant land located approximately 11 miles south of Nevada Gold Mines' Cortez Complex, the second-largest gold producer in the state. Keystone has never been systematically explored using modern, model-driven techniques, presenting substantial exploration potential. We conducted remote sensing studies and identified promising targets, while also exploring AI technologies to analyze our vast data set to optimize future drilling efforts.

At the Challis gold project in Idaho, we are focused on advancing exploration in a historically rich mining area, located 20 km southwest of Revival Gold's Beartrack-Arnett gold project.

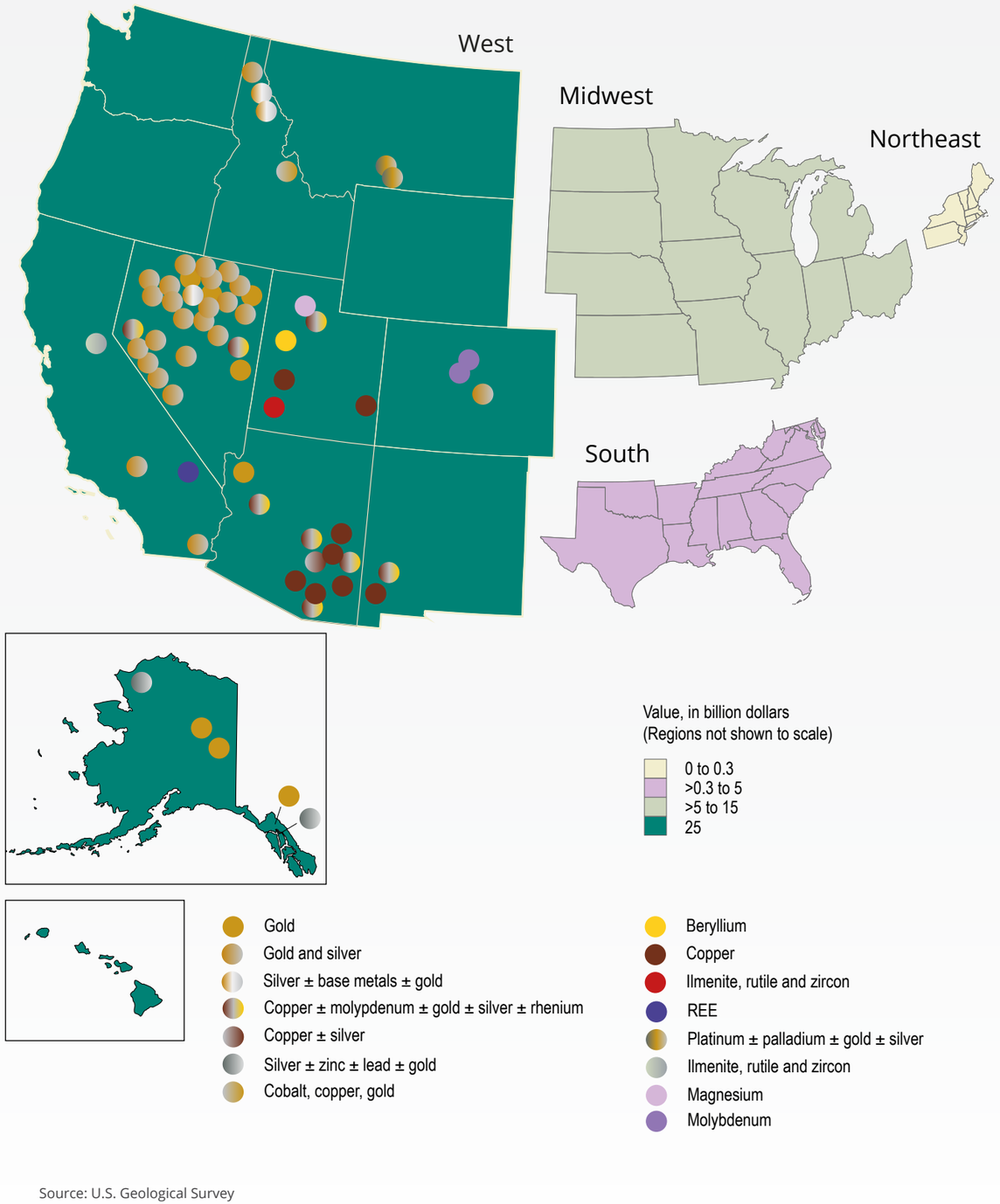
What makes U.S. Gold Corp a compelling investment story?

The Western US currently has a limited number of shovel-ready projects that have been de-risked for investment and development. We operate in Wyoming, a stable, resource-friendly jurisdiction. We have a fully permitted project, significantly mitigating risk for potential investors. Our CK project will be the first gold mine in the state. Our management team is deeply invested in securing optimal project financing while avoiding shareholder dilution. Being listed on NASDAQ enhances our access to capital in the United States compared to many junior resource companies.

Can you outline the key catalysts for U.S. Gold Corp over the next 24 months?

We will shortly announce the last step of our mine operating permit, the air quality, a final critical component for our mine operating permit approval. We plan to update the pre-feasibility study for the CK by Q4 2024 incorporating all permit requirements and optimization enhancements. We are engaging with the financing community to support project advancement and anticipate breaking ground as soon as late 2025, leading to production in 2027, subject to successful financing. ■

Value of Metals and Metallic Minerals Produced in 2023, by Region



Source: U.S. Geological Survey

Copper Production and Development

Humanity's second copper age

The primary demand story driving mineral and metal prices is the world's transition to the green energy economy. Electric vehicles (EVs), photovoltaic cells, wind turbines, energy infrastructure, etc. all require copper. Within this, EVs receive the most attention. In 2023, nearly one in every five cars sold was electric, and the number of EVs sold globally in the first three months of 2024 was roughly equivalent to the total number sold in 2020, according to the International Energy Agency.

"An EV contains five times more copper than an internal combustion engine vehicle. Charging an EV significantly increases a home's peak electricity consumption, comparable to adding 46 refrigerators. The federal goal of converting half of US households to EVs in the next decade will require substantial increases in electricity generation and infrastructure," said Nathan Foster, managing director Kennecott, Rio Tinto.

The green energy economy is not the only copper demand story. Artificial Intelligence (AI) took the world by storm over the past 24 months, a domino effect following the release of Chat GPT 3.5 in November 2022. Data centers provide the necessary infrastructure for storing, processing, and deploying large-scale AI models like ChatGPT. Data center power demand is predicted to grow 160% by 2030, estimated Goldman Sachs. In the US, centers will use 8% of US power by 2030, compared with 3% in 2022. Power translates into copper: "Each data center requires 27 tons (t) of copper per megawatt (MW) of power usage. The largest data center hub in the world draws 2,800 MW, translating to approximately 75,600 t of copper," emphasized Ronald Thiessen, president and CEO at Northern Dynasty Minerals.

A supply-side story

For typical commodities, high prices result in reduced demand and new supply. Copper is not typical; the exorbitant need for the metal makes it difficult to reduce demand sufficiently, and the supply side cannot keep up. While copper's last cycle was driven by demand from China, this cycle is primarily driven by lack of supply. Recent supply disruptions—Cobre Panama coming offline, lower than anticipated production output in Chile, and global reduction in ore grades to name a few—triggered the metal's bull run, leading to its record highs. The metal has backed off these highs as Chinese housing market demand remains soft. Ex China demand, driven by the US, has been strong, and the future of the metal remains bullish given electrification and decarbonization trends along with supply constraints. BHP and Lundin Mining's willingness to pay the 30% premium for the US$3 billion joint acquisition of Argentina-based Filo Mining highlighted the lack of good assets in the market.

Of the world's 20 largest copper producing mines, only two are in the Western US – Freeport-McMoRan's 72%-owned Morenci, responsible for 2.6% of world supply, and Rio Tinto's Bingham Canyon, responsible for 1.4% of world supply. However, global tensions have turned the spotlight back onto domestic assets. "As global competition for resources intensifies, prioritizing domestic production and reducing dependence on foreign trade will be increasingly important over the next few decades," emphasized Foster.

In 2023, domestic mined copper output in the US declined an estimated 11% from 2022. Output reached 1.1 million t/y, a five-year low. Of the 25 mines that produce copper in the US, 17 account for 99% of mine production. The drop in mined copper output can be attributed in part to disruptions at these mines. Copper production across Freeport McMoRan's North American assets dropped 74 million lb for the first six months of 2024, compared to the same period in 2023, due to lower ore grades and planned mill maintenance. Record-high snowfall and a conveyor belt failure affected production at the Bingham Canyon mine—commonly referred to as Kennecott— in Salt Lake City, Utah. Ramp-up at Nevada Copper's Pumpkin Hollow mine was delayed; operations started in October 2023. The company declared bankruptcy in June 2024, halting operations entirely, taking another domestic copper supplier off the table.

2024 started on the right foot. Domestic mines produced 209,000 t in January and February, an 8.29% increase over 2023's 193,000 t for that same period. Production at Kennecott for Q2 2024 was up 30% from the same period last year. First production from the Lower Commercial Skarn, a small underground ore body, was achieved in June 2024, marking the mine's return to underground production after four decades and paving the way for first ore from North Rim Skarn (NRS) by Q1 2025. "In 2023, Rio Tinto invested US$498 million to begin developing the NRS ore body. Initial probable ore reserve at NRS is 3-million t at 2.39% copper, 1.77 g/t gold, 18.59 g/t silver and 0.010% molybdenum," detailed Foster.

Image courtesy of Rio Tinto Kennecott

Copper Development

Gunnison Copper Corp, formerly Excelsior Mining, owner of the past producing Johnson Camp mine, received approval for its amended Mined Land Reclamation Plan in October, the final permit needed to restart production. First copper is anticipated in H1 2025. The deposit presents a unique opportunity, said Stephen Twyerould, president and CEO: "Our goal is to restart mining, creating two separate piles: a sulfide-rich pile for Nuton's technologies and an oxide-dominant pile for standard heap leaching. All material will go through our processing plant to produce copper."

In March 2024, Arizona Sonoran acquired the 523-acre MainSpring property immediately adjacent to its Cactus project. Comparing the February 2024 PFS with August's PEA shows that factoring in the MainSpring property, daily throughput for the mine increases 40%, while capital costs increase only 20%. George Ogilvie, president and CEO of Arizona Sonoran, explained: "Acquiring the MainSpring property changed the scope of the Parks/Salyer deposit to an open pit and therefore lowers mining costs, with the ability to access more tons. 94% of the approximately 900 million t of mineralized material now comes from open pit mining, which is less capital-intensive and has a lower execution risk than underground mining with sub-level caving as was previously planned."

Despite the government's outward commitment to the green energy transition, however, many fear its lack of clear direction when it comes to bringing new supply online. "Despite quotas on EV sales, the government lacks a clear policy for the clean energy transition. It fails to support mining permitting and infrastructure," emphasized Paul Harbidge, president and CEO of Faraday Copper.

In S&P Global's analysis of 239 copper deposits discovered between 1990 and 2023, the US and Canada combined account for only 10% of discovered copper. The lack of governmental support and ongoing litigation at Pebble and Resolution—respectively ranked fourth and seventh globally in terms of copper volume— will only the hinder the country's ambitions. However, these projects reached important milestones in 2024.

At Resolution Copper, the Rio Tinto- BHP joint venture, the Ninth Circuit Court of Appeals denied Apache Stronghold's request to further hear their case to stop the land exchange between Resolution Copper and the federal government. In 2024 the firm signed a Good Neighbor Agreement with surrounding towns, counties and groups. "Over the last decade, we have worked closely with local communities to co-design what this mine will look like. The project has evolved significantly due to the input from communities and Native American tribes, ensuring we can coexist with nature, riparian areas and ancestral sites," said Vicky Peacey, president and general manager.

In 2023, the Environmental Protection Agency (EPA) issued a final determination under Section 404(c) of the Clean Water Act, effectively vetoing any project in the Bristol Bay watershed. In 2024, Northern Dynasty Minerals, the State of Alaska and local native corporations filed lawsuits challenging the EPA's decision, alleging overreach and lack of scientific basis. "Legal proceedings are ongoing and Northern

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Joshua Olmsted

President and COO

FREEPORT-MCMORAN AMERICAS

> "Freeport supplies 60% of US copper consumption and 9% globally. Our priority is to focus on what we can control—maximizing production in the most efficient way possible."

How would you assess Freeport's recent performance in North America?

Overall performance improved significantly compared to 2023. Operational efficiencies and productivity remain a priority, as does the 'Leach the Last Drop' initiative, which supports incremental copper growth. Maintenance and reliability of equipment saw meaningful improvement. Freeport continues to face challenges with input costs and inflationary pressures, though these have softened slightly. The company made significant progress addressing labor challenges, having successfully onboarded, hired and integrated a substantial number of employees. We remain focused on strengthening the fundamentals of our business and continuing to build on these improvements.

Can you detail recent advancements at Bagdad?

Freeport made significant progress in 2023 and 2024 on the studies for the Bagdad expansion. We are conducting final engineering to refine costs and prepare for a decision to advance the project. We began work on a new tailings facility necessary for the expansion.

Another key development at Bagdad is the implementation of autonomous haulage. We expect the first autonomous trucks to begin operation in the first quarter of 2025, with the goal to achieve full autonomy by the end of 2025. This positions Bagdad to better support the expansion while addressing labor challenges tied to its remote location.

What is Freeport's approach to developing Lone Star?

While further drilling could reveal additional resources, we have identified enough to move forward with a pre-feasibility study. Rather than wait for full delineation, we decided to use the existing data to evaluate the potential for a milling operation and its integration with the current crush and leach operations. The pre-feasibility study is targeted for completion in 2025. Although Lone Star is a low-grade deposit, typical of many Freeport assets, we excel in operating in this space. Its location in the well-established Safford district, where we already have strong community and stakeholder relationships, provides a substantial advantage.

How has the 'Leach to the Last Drop' Initiative progressed?

We reached an annualized run rate of over 200 million lb of copper and have clear visibility to an additional 200 million lb. Our goal is 800 million lb/y. Initially, we focused on fundamental leaching improvements, targeting opportunities in both historic and current stockpiles. Key efforts included retaining heat within stockpiles, as increased heat directly boosts recovery rates. We leveraged data analytics and AI models to identify areas that were insufficiently leached, allowing us to apply targeted solutions for additional recovery. We are exploring new additives to enhance recoveries, drawing insights from AI, our technology center, and even pharmaceutical modeling techniques used to identify potential treatments. This work will ramp-up in 2025, complementing the practices that already deliver incremental copper.

What is the value add of innovation in the current capital environment?

Projects like Bagdad, Lone Star and El Abra involve substantial capital investments (US$3.5 to US$4 billion for Bagdad and up to US$8 billion for El Abra), while 'Leach to the Last Drop' could deliver 400 million lb of copper for under US$1 billion. This makes it the most economic growth project in our portfolio. It reduces greenhouse gas emissions and water consumption, making it a win on multiple fronts.

The entire industry faces declining grades and increasing haul distances, requiring more material movement to produce the same amount of copper. These challenges drive up costs, demanding greater productivity and efficiency. We must spend more to produce less. We must not only achieve the productivities and efficiencies we achieved in the past but do even better. To achieve this, we must innovate and rethink our approach to mining. Data analytics, AI, and other technologies play a critical role.

How is Freeport advancing the energy transition?

The best way for Freeport to support the green energy transition is by optimizing operations to produce as much copper as possible. Freeport supplies 60% of US copper consumption and 9% globally. Our priority is to focus on what we can control—maximizing production in the most efficient way possible. We are accelerating leaching initiatives to deliver incremental copper more quickly and advancing the Bagdad 2X concentrator project to enable a decision within the next 12 to 18 months. In addition, we are progressing the Lone Star pre-feasibility study toward feasibility. Achieving these goals over the next 12 to 24 months will position our North America operations for long-term success. ■

Nathan Foster

Managing Director Kennecott

RIO TINTO

> Over the next 24 months, we aim to make compelling investment decisions to extend mine life beyond 2032, particularly given the strong state of the copper market.

How has the Bingham Canyon mine evolved over its 121-year operational life?
Kennecott produces about 15-20% of the US domestic refined copper supply. In 2023, refined copper output was lower due to a 115-day planned smelter shut down. For 2024, we aim to produce around 200,000 t refined copper. We are progressing well, with the smelter fully operational and refined copper production on target.

How will the North Rim Skarn (NRS) expand Kennecott's underground operations?
Production from the NRS is expected to ramp up over two years, to deliver around 250,000 t of additional mined copper over the next 10 years alongside open cut operations. We are on track and excited about the higher-grade ore this underground project promises, which complements our open-pit operations, where ore grades have been declining after 120 years of mining.

What is the strategic advantage of operating a domestic copper smelter?
There were up to 15 operating copper smelters in the US throughout the 60's, 70's and 80's compared to today, with only two smelters in operation: Kennecott and Freeport's Miami smelter. The US imports approximately 50% of its refined copper, a figure expected to rise to 70% in the next 10-15 years. Rio Tinto views our smelter as a strategic asset, allowing the US to process copper domestically instead of exporting concentrate. This was a key reason for Rio Tinto's US$300 million investment for the rebuild, ensuring stable operations to meet market demand. A major challenge is the shortage of experienced copper smelting talent, both locally and globally. To address this, Rio Tinto and Kennecott are focused on developing internal talent through partnerships with universities, talent exchanges, and strategic recruitment. With limited copper smelting expertise available, building and retaining a skilled workforce is critical for our industry's future.

How will renewable diesel and BEVs help Kennecott progress towards carbon neutrality?
Following successful trials at Rio Tinto's Boron operation, we fully transitioned to renewable diesel in September 2024. This change, along with shutting down our coal-fired power plant, has reduced our operation's overall carbon footprint by more than 80% from 2019 levels (including Scope 1 and Scope 2 emissions).

In the underground space, our goal is to build a diesel-free operation, partnering with Sandvik. Our trial with Sandvik's electric equipment was a great success, offering benefits beyond decarbonization, including improved health and safety for miners by reducing diesel particulate matter, heat, and noise. Electric trucks are also more productive, with more speed on grade and power.

What is the Kennecott's Tellurium footprint?
Tellurium is a critical mineral, defined as such when a nation imports around 70% of its supply. It is essential in manufacturing solar panels. Kennecott began producing tellurium in 2021. We produce about 20 t/y, accounting for 3% of the global market. Tellurium production also supports circular economy principles. Our own tellurium is used to manufacture solar panels by First Solar, a US-based company supplying the solar panels for our planned 30-megawatt solar farm on our property. Our ability to extract tellurium from our waste stream is a significant achievement, helping maximize our ore body, with plans to explore 5-6 other critical minerals like germanium and gallium.

How does Kennecott promote responsible mining to benefit the Salt Lake City community?
Internally, we focus on decarbonization, water recycling, and early reclamation efforts. Given our location in the Salt Lake Valley, these efforts are closely linked to our community impact. Internal efforts, while important, cannot be done in solitude given our proximity to nearly 1.5 million Salt Lake Valley residents. We continually look for opportunities to improve the area. A notable project was the reclamation of the historic Barney's Canyon gold mine, where we achieved bond release. Our actions are not just about compliance, but about being a responsible neighbor and ensuring our ongoing partnership with the state and community.

What are the firm's goals for the next two years?
Our top priority is health and safety, ensuring our people have everything they need to succeed. Another key focus is successfully ramping up our underground operations, which are crucial for our future expansion plans. We are exploring ways to extend mine life beyond 2032. Our priorities are safety, people, and exploring growth opportunities for Kennecott's future. ■

Óscar González Rocha

President and CEO

ASARCO

> Once the smelter reopens, we would produce a more finished product, the anode, which would be sent to the Amarillo refinery in Texas to manufacture wire rods.

Can you provide an overview of Asarco's production profile in the US?
Asarco produces at our three mines in Arizona: Ray, Mission, and Silver Bell. The Hayden concentrator and the smelter in Arizona will remain inactive while we assess the situation to determine how to resume operations. Once the smelter is back online, the Amarillo refinery in Texas will also restart. This refinery supplies wire rod to the entire East Coast of the US.

Asarco's production in 2024 is seeing a small increase compared to 2023, thanks to an additional investment of around US$120 million. This boost is expected to benefit Asarco, despite challenges with staffing in the US mining sector. We have even brought in some personnel from Mexico to Arizona to support our operations.

What are Asarco's plans to restart operations at the Hayden complex and Amarillo refinery?
All of Asarco's facilities are operational, except for the smelter and the Hayden concentrator. We are currently evaluating these operations to see if they can be restarted to achieve additional production. The goal for the smelter is to produce copper anodes by processing concentrates from the Mission and Ray mines, as well as the Hayden concentrator.

As we await the decision on reopening the smelter, we continue selling copper concentrates. Once the smelter reopens, we would produce a more finished product, the anode, which would be sent to the Amarillo refinery in Texas to manufacture wire rods. Selling copper anodes and rod from the Amarillo refinery yields higher revenue than the concentrates we currently sell.

What investments is Asarco looking to make to improve operations?
The planned investment for this year across Mission, Ray, Hayden, and Silverbell is approximately US$120 million. Total investment in 2023, was around US$1 billion, and we see a similar budget for 2024, estimated at US$1.08 billion. In comparison, operations in Peru and Mexico also see substantial investments, with Peru receiving US$400 million and Mexico US$560 million.

How does Asarco use its proprietary Copper Basin Railway?
Currently, the Copper Basin Railway is being used to transport production concentrates. However, as the Hayden smelter is not operational, concentrates from Mission and Ray are being handled differently. Silverbell, with its leaching plant, produces copper cathodes. These concentrates are not being transported by rail due to the lack of a direct rail link from Arizona to the port of Guaymas. Instead, they are being trucked to Guaymas, where we take advantage of our storage facilities.

What is Asarco's relationship to the state of Arizona?
In Arizona, we face virtually no environmental issues, complying fully with all US mining regulations. We believe this will continue, and we aim to improve where possible. Hopefully, we can advance the restart of the smelter, refinery, and concentrator in Hayden, which would boost our concentrate production and increase Asarco's overall output for better revenue. We hope this will keep Asarco as one of the key operations in Arizona. However, there is another major company in the state, creating competition for skilled personnel, which makes it challenging to operate at maximum capacity.

How does Asarco plan to capitalize on copper's high trading levels?
Hopefully, the current copper prices above US$4/lb will continue, as this benefits the entire copper mining sector, particularly for us at America's Mining Corporation, including Asarco, Mexico, and Peru. These high prices are due to scarcity and production challenges, such as the slight decrease in Chile's output. Consequently, the demand from Chinese smelters remains high, and sometimes we can't meet the full volume. This has driven up copper prices, which benefits us and the regions where copper is produced worldwide.

What are the firm's goals to increase revenue?
Asarco is set to improve its production. Investments in 2023 hovered around US$1 billion, and the 2024 budget is slightly higher, nearing US$1.1 billion, a roughly 10% increase. We hope that increased production at Ray and Mission, whether through better ore grades or higher volumes, will boost our revenue. This would help recoup part of the US$1 billion investment. We expect Ray's production to increase slightly, while Mission's may not see as much growth. Silverbell will also contribute modestly with finished copper cathodes. Overall, these improvements should help Asarco increase its current income. ■

Neil Jensen

General Manager, Robinson Mine

KGHM

> KGHM's copper production on a 9-month view is 89% higher in 2024 compared to 2023. This is largely due to higher copper production by Robinson Mine.

What are recent milestones and production guidance at Robinson Mine?
We commissioned 10 new haul trucks, two large shovels, and several wheel loaders, enhancing operational efficiency. These improvements enabled us to meet our waste-stripping and mining targets, with production in 2024 exceeding expectations. We celebrated 20 years of continuous operation in 2024.

KGHM International copper production on a 9-month view is 89% higher in 2024 (45,000 t) compared to 2023. This is largely due to higher copper production by Robinson Mine resulting from extraction from the main, copper-rich zone in the Ruth Pit. Actual production results at the end of Q3 2024 show that Robinson is on track to achieve production targets this year in excess of 118 million lb of copper. Spatial reconciliation of the development in Liberty Pit is on track to achieve 2024 targets and this supports future ore delivery in the life of mine plan.

How does Robinson Mine address workforce development?
We collaborate with Great Basin College in Elko and its Ely campus, offering dual-credit courses for high school students and re-training opportunities for current employees. We provide opportunities for employees to transition into maintenance roles by attending diesel mechanic training while continuing to work at the mine. This focus on both attracting new talent and upskilling our existing workforce ensures we can maintain a skilled labor force to support ongoing operations for years to come.

Operating in a rural area like White Pine County has allowed Robinson Mine to provide stable, high-paying jobs and significant economic contributions. With the mine life extending to 2036, we are committed to sustaining our impact and fostering social and economic growth in rural Nevada.

What are Robinson Mine's future operational plans?
Our focus is on the Ruth Pit, which will drive significant copper output well into 2025. We are advancing the Liberty Pit with an aggressive waste-stripping campaign to prepare it for production in 2025 through 2027. We are developing the Veteran Pit, which is our mine plan ore source through 2032. While our primary focus is on brownfield opportunities near existing pits, we are also exploring areas like Lane Valley, where we conducted drilling in 2023. KGHM's International exploration team continues to evaluate both near-site and broader opportunities in Nevada.

How is the firm adapting to meet domestic and global copper demand?
A significant hurdle in the US is the lack of smelting capacity, which limits domestic copper processing and forces firms to sell concentrates internationally. This poses challenges for meeting copper demand, particularly as new mines come online, or existing ones ramp up production.

What innovations is KGHM implementing at Robinson Mine?
Robinson Mine has seen success with its autonomous drill fleet. These drills enhance blasting precision, optimize drilling times, and increase footage rates while reducing operating hours. We are exploring technologies for the mill circuit, such as automation and artificial intelligence, to enhance efficiency and recoveries. By automating adjustments in the milling process, we can respond quickly and accurately to ore changes, improving asset utilization. We plan to integrate AI to analyze data and streamline operations and maximize productivity.

What opportunities do you see for KGHM following the US elections?
Election results bring stability, which is critical for economic planning. This stability is important for Nevada, especially with the outcome at the state level, where bipartisan representation was maintained. A balanced government supports a favorable economic environment for all industries, including mining. Nevada's operating environment remains strong, with its mineral-rich land, robust yet manageable permitting process, and a government that recognizes the importance of mining to the state's economy.

What are Robinson's priorities for the next 24 months?
Key priorities in the next 24 months include achieving operational efficiency targets in the mine, recovery optimization in processing, increasing capacity of the Tailings Storage Facility with lifts of the embankment, and identification of new concurrent reclamation activities extending the reputation of environmental stewardship.

We will achieve our waste-stripping targets to support future production. Innovation is key to driving improvement, and safety remains a top priority—not just as a goal, but as a clear indicator of the quality of our operations. We aim to stay innovative, transparent, and adaptable, continuously refining our practices to meet business demands and sustain our performance. ■

Lyndsay Potts

General Manager – Pinto Valley Mine

CAPSTONE COPPER

What were operational highlights from Pinto Valley for 2023 and H1 2024?
In 2023 Pinto Valley produced 55,100 t of copper and in 2024 we have guided for copper production of 58,000 to 64,000 t. Over the past two years, we have made significant strides to improve our maintenance practices to increase mill availabilities and plant runtime. We have also put a significant emphasis on our people, with changes to our shift schedules and more involvement in the community to attract young talent to mining.

How does Capstone Copper plan to grow and consolidate in the Globe-Miami district?
Pinto Valley is an operating mine located in the historic Globe-Miami mining district of Arizona, which is one of the oldest and most productive mining districts in the US. We have a mine plan that extends through 2039, but we are currently evaluating the potential for possible extensions and expansions. We also have an exploration access agreement with BHP's historic Copper Cities mine next door, where we are evaluating district consolidation opportunities.

Can you comment on global copper supply dynamics and how Pinto Valley plans to benefit from the high price environment?
On the supply side copper is constrained. There have been very limited new discoveries of copper over the past 20-30 years. Existing mines are seeing significant grade decline, and new deposits face increasing complexities, such as environmental, social, and infrastructural challenges. This results in high barriers to entry for new copper mines, which will likely continue to push copper prices higher.

What are Capstone's goals for Pinto Valley for the next 24 months?
First, we'd like to continue improving the reliability and efficiency of our operations to increase our production and lower our costs. From there, we will continue to evaluate the potential for further mine life extensions or expansions, including a potential district consolidation. ■

Javier Del Río

Sr. Vice President, US Business Unit

HUDBAY MINERALS

Can you introduce Hudbay's US-based assets?
Hudbay has two key assets: the Copper World Complex and the Mason project. Copper World is a proposed open-pit copper mine, projected to produce an average of 85,000 t/y of copper over its 20-year lifespan, positioning it among the largest copper producers in the US. The Mason project, located in Nevada's historic Yerington district, is one of North America's largest undeveloped copper deposits. Currently in the pre-development phase, Mason is expected to have a 27-year mine life, with average copper production of 140,000 t/y during its first 10 years.

What were highlights from Copper World's enhanced PFS?
The Copper World PFS outlines a two-phase approach to responsibly extract minerals and produce finished copper on-site. Phase one is a standalone operation, requiring only state and local permits, with a 20-year mine life. During this phase, Copper World is expected to produce an average of 85,000 t/y. Phase two aims to expand operations onto federal land, which would require federal permits, and could extend the mine life beyond 20 years.

The pre-feasibility study for phase one was completed in September 2023, demonstrating strong economic potential, with a projected IRR of 19% and a NPV of US$1.1 billion.

What is on the horizon for Hudbay?
With the receipt of the Aquifer Protection Permit, Hudbay is set to begin preparations for the Copper World feasibility study. The company plans to start the definitive feasibility study activities in 2025. Once the final air permit is secured, expected by the end of 2024 or early 2025, Hudbay will launch a search for a minority joint venture partner. Hudbay anticipates the project sanctioning to happen by early 2026, based on current timelines. The company is excited about the traction expected during the joint venture search and looks forward to turning Copper World into a reality. ■

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Dynasty expects a hearing in Alaska's federal court in 2025. This appeal could clear a path for permitting, overturning both the veto and previous denial based on what the company describes as unsupported claims," said Thiessen.

To account for the EPA process and streamline production timelines, Hudbay is using a two phased approach for their Copper World project explained Javier Del Rio, senior vice president, US business unit: "Phase one is a standalone operation, requiring only state and local permits, with a 20-year mine life. During this phase, Copper World is expected to produce an average of 85,000 t/y of copper. Phase two aims to expand operations onto federal land, which would require federal permits, and could extend the mine life beyond 20 years."

The narrative may shift, as the government becomes cognizant of the dire need to increase production. "Typically, a company like World Copper would focus on exploration and development to expand a deposit. However, given the current deficit and our asset's potential to quickly impact supply, we decided to move straight into production. The US Government is actively supporting us in this endeavor, and we are working closely with them to ensure it happens," said Gordon Neal, the firm's president and CEO.

Demand for copper is estimated to grow 75% to 56 million t/y by 2050 primarily due to the energy transition. The world's current production profile is 26 million t/y, of which 5 million t/y is recyclable. To put the needed amount into perspective, think about it this way: "To meet climate change goals, we need to produce as much copper in the next 50 years as we did in the entire existence of modern civilization", emphasized Tim Smith, president and CEO of U.S. GoldMining. Now is the time for the government to realize the critical nature of advancing copper projects to meet demand. If it does not, the country will face the devastation, loss of biodiversity and human lives, that will accompany the climate crisis. ■

Gordon Neal
President and CEO
WORLD COPPER

"With the projected surge in electric vehicles from 2030 to 2050, we simply will not produce enough copper to meet demand, which is already impacting copper prices."

Victoria Peacey

President and General Manager
RESOLUTION COPPER

"In 2024, we signed a groundbreaking Good Neighbor Agreement, formalizing our commitment to transparency and two-way dialogue throughout the mine's life."

Can you discuss milestones reached by Resolution Copper in 2024?
For the third year in a row, we were awarded the safety award for small underground mine by the Rocky Mountain Mining Institute, recognizing the employees and contractors who come to work on our site every day.

We are also very proud of our teams work on the reclamation of the old Magma site. In total, Resolution Copper spent US$75 million over a period of 15 years to reclaim hundreds of acres of land within the footprint of the historic Magma mine site.

What is the significance of the Good Neighbor Agreement?
Resolution Copper is in the Copper Corridor, a rural part of Eastern Arizona. Over the last decade, we worked closely with local communities to co-design what this mine will look like. The project has evolved significantly due to the input from communities and Native American tribes, ensuring we can coexist with nature, riparian areas, and ancestral sites. In 2024, we signed a groundbreaking Good Neighbor Agreement with the Town of Superior, Pinal County, Gila County, and other Copper Triangle towns, and over a dozen groups with interests in the area. This agreement formalizes our commitment to transparency and two-way dialogue throughout the mine's life. It emphasizes improving environmental stewardship, conserving nature, and fostering economic development in the region.

Can you discuss your firm's plans to minimize environmental impact?
We prioritize coexistence with nature through partnerships with local, state and national-level Civil Society Organizations and Native American tribes, and others. Together, we have conserved over 5,500 acres across Arizona, protecting habitats for endangered species and preserving cultural sites.

Regarding water management, our deep underground mine collects water at depths of up to 7,000 feet. We treat and donate this water to local farmers, totaling more than 7 billion gallons over a decade. This supports local agriculture while preserving groundwater reserves for future use. Our operations undergo independent monitoring by local communities and Native American Tribes. We implemented a Dark Skies program with the Town of Superior to reduce light pollution, preserving the area's natural night sky.

What is Resolution Copper's approach to workforce development?
Our approach to workforce development is deeply rooted in investing in the local communities of rural Arizona, spanning from the San Carlos Apache tribe to the town of Superior and beyond. Over two decades, we implemented a three-step strategy. First, we prioritize local hiring within a 40-mile radius through our local hire and procurement policies. Second, we have heavily invested in STEM education across K-12 schools in the Copper Triangle district, complemented by scholarships for graduating seniors. In 2023, our Resolution Copper Scholarship program awarded US$38,000 in financial assistance to 15 graduates as they begin their collegiate careers. We have also continued our extensive STEM partnership with the Superior Unified School District with funding of US$300,000 in 2023.

Third, we operate an apprentice program in collaboration with local technical colleges, providing training and employment opportunities to individuals without prior experience. We offer graduate programs in partnership with Arizona universities. Currently, over 350 people comprise our workforce, 90% of whom are local. Our initiatives have proven successful, which is evident in the high demand for positions like apprenticeships, which garnered over 600 applications within two weeks last year.

How could Resolution Copper help address supply imbalances in the US?
Resolution Copper stands out as one of the largest undeveloped copper deposits globally, strategically located in a copper-mining region. At full capacity, Resolution Copper has the potential to satisfy 25% of current US copper demand, significantly reducing our reliance on imports, which presently account for approximately 50% of our needs. Harnessing this resource effectively will improve our energy security, strengthen economic resilience, and support sustainable development, positioning the US as a leader in global copper supply.

The current tightness in the copper market underscores the critical need for projects like Resolution Copper. Permitting new mines is a lengthy process, emphasizing the urgency of advancing local projects like ours. Maintaining domestic supply through operational smelters like Kennecott in Utah is crucial for US resilience in copper production. Resolution Copper aims to strengthen these efforts by ensuring consistent supply to meet American demand. ■

George Ogilvie

President and CEO

ARIZONA SONORAN COPPER

> On average, we are showing 86,000 short t/y of cathode production, which is 172 million lb/y of copper, totaling 5.3 billion pounds of copper over the 31-year LOM.

What were main developments for Arizona Sonoran Copper (ASCU) over the past year?

2024 has been transformational for the company. ASCU announced an updated mineral resource estimate (MRE) for our Cactus project in July 2024, indicating a total resource of approximately 7.3 billion lb of contained copper in the measured and indicated category and 3.8 billion lb inferred. This is a significant increase from the 5.2 billion lb of copper in the measured and indicated category and 2.2 billion lb inferred we had roughly a year ago. We quickly followed the MRE update with an updated Preliminary Economic Assessment (PEA) in August, outlining an 86,000 short t/y mine plan over a 31-year LOM. The study details a heap leach and SXEW open pit operation with the intent to produce copper cathodes directly onsite for use within the US.

What is the financial outlook for the updated Cactus project?

We used a price of US$3.90/lb of copper and reported a post-tax NPV using an 8% discount factor of US$2.03 billion, and an IRR of 24% with a 4.9-year payback period. On average, we are showing 86,000 short t/y of cathode production, which is 172 million lb/y of copper, totaling 5.3 billion pounds of copper over the 31-year LOM.

We gained legal title to the MainSpring property in March 2024, allowing us to include the MainSpring resource in the latest numbers. MainSpring brings an additional 1.9 billion lb (all inferred) of copper to the project. A significant amount of mineralization is close to the surface which allows for open pit mining, and MainSpring advances to the north and connects into Parks/Salyer.

Acquiring the MainSpring property changed the scope of the Parks/Salyer deposit to an open pit and therefore lowers mining costs, with the ability to access more tons. 94% of the approximately 900 million t of mineralized material now comes from open pit mining. Drilling on the MainSpring property extended the Parks/Salyer mineralization 900 m south and from within 42 m of surface. Now, of Cactus' 889 million short tons processed in the mine plan, Parks/Salyer as an open pit contributes 69% of the oxides and enriched and 34% of the primary sulphides.

How has the community responded to the Cactus mine?

We have strong support from Casa Grande and Pinal County, who remember the economic benefits of the historic mine. Since acquiring the asset from the Arizona Department of Environmental Quality in 2020, we have maintained constant communication with the community and our regulators. Our entire land package is on private land, streamlining permitting efforts within the state. We are grateful to have a good relationship with state regulators who acknowledge that the Cactus project could generate in excess of US$10 billion in economic activity for Pinal County.

What are the catalysts ahead for ASCU?

Moving forward, capital will be delegated to infill drilling to move as much of the Inferred resource into the Measured and Indicated category ahead and continuing our metallurgical programs relevant to a PFS in the first half of 2025. Based on this, we will release a PFS, including the Nuton scenario, leading to Nuton's decision on investing as a JV partner. Regardless of Nuton's decision, we will initiate a definitive feasibility study (DFS), in the second half of 2025. Assuming a financial investment decision in early 2026, we anticipate first copper cathode production by late 2027 or early 2028.

What is ASCU's agreement with Nuton?

Arizona Sonoran's investment from Nuton is driving exploration, focused on expanding primary sulfides. Our partnership ties into the integrated PFS set for the first half of 2025, with Nuton aiming to discover additional primary material. If phase two column tests prove as successful as those in 2023 and meet key financial triggers, including boosting our NPV by 20% with MainSpring now included, Nuton can earn a 35% to 40% stake in the project. Should they exercise this option, it would inject substantial capital into Arizona Sonoran, with both parties sharing future costs. Traditionally, copper primary sulphide recovery would require a mill with a flotation circuit, leading to higher energy, water use and carbon emissions. Nuton technology, however, leverages a standard heap leaching pad and solvent extraction-electrowinning plant to efficiently recover copper from low-grade primary sulfide deposits. ■

Stephen Twyerould

President and CEO

GUNNISON COPPER CORP

> Gunnison presents a significant opportunity. We are currently permitted for hydraulic fracking at a commercial scale to improve production.

Can you provide updates from 2024?

Over the last six to 12 months, we have moved forward with our partnership with Nuton LLC (a Rio Tinto Venture). In May 2024, we progressed to Stage 2 of our option agreement, which means we are working with Nuton to restart the Johnson Camp mine (JCM) for sulfide leaching using their technologies. Construction has begun, and we expect it to be completed by the end of 2024. We aim to start producing copper cathode from the open pit mine in the first half of 2025.

Can you talk about the existing Burro pit at the JCM?

The Burro pit is a historic oxide copper open pit that operated as a heap leach operation. The previous owners mined until 2010, at which point they intersected the sulfide below the oxide. Mining operations halted then, but the advancements in sulfide leaching technology have been significant in the last few years. Nuton has over 20 years of research and development in this area. Our goal now is to restart mining, creating two separate piles: a sulfide-rich pile for Nuton's technologies and a more oxide-dominant pile for standard heap leaching. All material will go through our processing plant to produce copper.

How does the Nuton technology work within the deposit?

Traditionally, treating sulfide requires crushing, grinding, and producing a concentrate, which is energy-intensive and consumes a lot of water. Sulfide leaching uses around 60% less water per pound of copper, reduces greenhouse gas emissions, and lowers capital costs. The technology involves bio-oxidation and uses certain catalysts and additives that improve copper recovery from sulfide minerals. Moreover, it minimizes risks associated with tailings and acid mine drainage since we do not generate traditional tailings. This technology could also render currently uneconomic projects viable, especially in arid regions where water is limited.

At Johnson Camp we believe there are sulfide resources extending to the southeast and potentially deeper. Historical workings in the area produced around 3-4% copper. Stage 2 focuses on sulfide in and below the existing Burro pit over a five-year period. We conducted a preliminary economic assessment a few years back, which suggested a 20-year mine life, excluding additional sulfides if discovered through further exploration. The rising copper prices make this exploration worthwhile.

We expect to produce approximately 25 million lb/y of copper from the plant. Our aim is to keep the plant fully operational during the initial five-year period and maintain that production throughout the total 20-year mine life.

What change will the option agreement with Nuton catalyze?

The option agreement during stage two stipulates that Nuton will fund construction and development activities. This is not a loan or equity investment, meaning we do not incur debt or dilute the company's equity. The revenue from the copper production, including from oxides, will first cover Nuton's initial investment. Once that investment is recouped, we will receive 100% of the operating profits. Nuton has the right to form a joint venture to mine the remaining 18 years of mine life after the program, where we will maintain a 51% interest.

How do you plan to approach the sulfide resource beneath Gunnison?

While our immediate focus is on Johnson Camp, Gunnison presents a significant opportunity. Initially, we planned it as an in-situ leaching project but encountered technical challenges. We believe we found solutions to those challenges and are currently permitted for hydraulic fracking at a commercial scale to improve production. However, when we consider the sulfide resource beneath Gunnison, it makes sense to look at alternatives like open-pit mining that could access both sulfides and oxides.

What catalysts are on the horizon for Gunnison toward the end of 2024 and into 2025?

The primary catalysts for the remainder of the year will revolve around advancing construction at our Johnson Camp mine. The leach pad construction has begun, and we will be sharing updates as the project progresses. We anticipate mobilizing our mining fleet and starting mining later this year, followed by stacking on the leach pad. In H1 2025, we will focus on ramping up copper production. We are also considering further studies on the potential for a large open pit at Gunnison. ■

Ronald Thiessen

President and CEO

NORTHERN DYNASTY MINERALS

> Not bringing a large-scale mine like Pebble into production is a delay the US cannot afford.

Can you detail developments in the legal battle over Northern Dynasty's Pebble project?

We achieved a major victory through an administrative appeal that contested the US Army Corps of Engineers' permit denial for the Pebble project. The appeal led to a remand order, requiring the Corps to reconsider its decision, which lacked alignment with scientific findings in the Final Environmental Impact Statement (FEIS). The remand also challenges previous mitigation requirements imposed by the Corps, which were flagged as noncompliant with federal guidelines. The Environmental Protection Agency (EPA) invoked a rare preemptive veto to prevent mining activities in Alaska's Bristol Bay watershed. Northern Dynasty, the State of Alaska, and local Native Corporations filed lawsuits arguing that the EPA's veto overreaches legal authority, lacks a scientific basis, and contradicts the findings of the FEIS. Legal proceedings are ongoing, and Northern Dynasty expects a hearing in Alaska's federal court in 2025. This appeal could clear a path for permitting, overturning both the veto and previous denial based on what the company describes as unsupported claims.

How will the emergence of data centers further strain copper supply?

AI and data centers consume vast amounts of electricity and copper. Each one requires 27 t of copper per MW of power usage. The largest data center hub in the world draws 2,800 MW, translating to approximately 75,600 t of copper. Microsoft's new data center in Chicago faces a shortage of available power, leading to discussions with local utilities and the US government about potentially restarting the Three Mile Island nuclear plant. This data center will require at least 1,000 MW. Without a sustainable domestic supply of critical metals, we will increasingly rely on offshore sources to meet these demands.

In the Western world, capital for mine development is scarce, especially compared to China's substantial investment in mining. To keep pace, the Western world must advance mining technologies, secure capital and streamline permitting. Not bringing a large-scale mine like Pebble into production is a delay the US cannot afford. There is a growing realization that boosting critical metal production is essential to remain competitive in the global market.

What is the potential of the Pebble Creek resource?

The Pebble resource is vast and shallow, with the eastern end reaching 1,500 feet. Permitting efforts focus on the initial 1.3 billion t over a 20-year mining span at the west end, where the waste-to-ore ratio is just 0.1:1. This reduces mining costs to US$2/t—far below the industry average of US$6/t. Our ore is well-suited for flotation, with recovery rates around 88% for copper and 70% for gold. Our recent economic analysis, based on conservative prices (US$3.50 copper, US$1,600 gold), estimated an NSR over US$40/t against a US$14/t operating cost. After the initial 20 years, mining shifts eastward to higher-grade zones, with some areas holding copper grades nearly three times higher than our starting grades.

How will the approach to tailings ensure environmental sustainability?

Tailings start as a downstream embankment for the first decade, followed by a centerline design with additional downstream embankments. Unlike conventional tailings facilities, this design allows controlled weeping and seepage, with seepage captured in settlement ponds at the embankment's base. Pebble's tailings lack significant acid-generating (ARD) rock, allowing us to safely drain the tailings. Water treatment plants will process the captured water and release it seasonally into nearby creeks to create spawning habitats for salmon. In the summer, most streams around Pebble dry up, so this release will enhance an otherwise limited habitat. This approach to water management addresses concerns about tailings failures. With no standing water in the Tailings Storage Facility (TSF), catastrophic failures due to liquefaction are effectively eliminated, as confirmed in the project's FEIS.

What is the firm's value proposition and goals?

We are trading at 0.19 cents/lb of contained copper— most exploration-phase projects trade at 0.32 cents/lb. If we traded in line with peers, our stock would be closer to US$6. Established producers typically trade at 20.5 cents per pound, which would put us at about US$34 a share. The market discount largely stems from a perception that Pebble cannot secure a permit. Litigation has been necessary for the top US copper projects, including Resolution, Rosemont, NorthMet and Twin Metals. My goal is to secure a development partner to advance the project. ■

Critical Minerals Production and Development

Chinese withdrawal symptoms

In the US, critical mineral status is determined by the United States Geological Survey (USGS) whose methodology is a supply-side approach using historical data to determine criticality within the context of the economy and national security. Critical minerals are those essential to the US economy, technology, or national security with a high supply risk.

Critical minerals are challenging to source due to limited global availability, geographic concentration of supply, or reliance on a small number of supplying countries. The International Energy Agency (IEA) estimates the world's top-three producing nations control well over three-quarters of global output for lithium, cobalt and rare earth elements. The level of concentration is even higher for processing operations, with China dominating, processing nearly 60% of lithium, 65% of cobalt, and close to 90% of rare earths, according to Brookings.

Lithium production and development

Lithium took the spotlight in 2022 as the EV craze hypnotized Americans, but the mineral's price plummeted 80% over 2023. The lithium market is immature compared to established metals like copper and high prices lead to demand destruction and new supply. With confusing futures pricing, market leader China made the market opaque, leaving it unclear what a realistic global reference point should be. Despite this, demand grows. US demand alone is predicted to increase 29% year-on-year through 2030, according to Fastmarkets data. To reach net zero, lithium will see the fastest growth among the key minerals, with demand up over 100-times its 2021 level by 2050, according to the IEA.

Global lithium supply is predicted to more than double by 2026. However, if prices remain low, this supply is unlikely to become available. US-based Albemarle held numerous spodumene concentrate and lithium carbonate auctions in 2024 to boost market transparency. The firm reported US$1 billion in losses in Q3 due to price drops. Albemarle owns the longstanding sole producing lithium mine in North America— the Silver Peak mine in Nevada— where lithium is produced from brine. US consumption majorly outweighs its production. That will change soon, according to Jonathan Evans, president and CEO of Lithium Americas: "The US produces roughly only 0.5% of the lithium consumed globally and only 2% of it is processed in the US. Thacker Pass will dramatically change that by initially increasing US output of lithium by up to 8 times and scaling up from there with production expansion plans."

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Image courtesy of Lithium Americas

Bernard Rowe

Managing Director
IONEER

What were highlights from 2024?
On the funding side, we continue to work with the Department of Energy Loan Programs Office. We are also focusing on operational readiness, updating engineering studies, and have released a significant resource update.

The resource is approximately 350 million t of contained ore, which includes lithium and boron. The total resource contains over 3 million t of lithium carbonate equivalent, making it a very large and unique resource with a long mine life. Our initial Phase One project is expected to produce about 22,000 t/y of lithium. This deposit can potentially supply enough lithium to power more than 50 million electric vehicles, assuming current efficiency levels. This unique combination of lithium and boron in a sedimentary deposit, without clay, sets it apart from other lithium deposits worldwide, ensuring a multi-generational resource.

Can you describe off-take agreements and the recent partnership with EcoPro?
Our agreement with EcoPro involves supplying them with lithium carbonate for further refining. This approach avoids the industry's challenges of producing and transporting high-purity products. ■

Jonathan Evans

President and CEO
LITHIUM AMERICAS

Can you describe the geological uniqueness of Thacker Pass?
Lithium Americas' Thacker Pass project is the largest known Measured and Indicated (M&I) resource for lithium in North America and is the most significant opportunity to create a North American lithium battery supply chain for electric vehicles.

How will Thacker Pass improve the US's supply chain resilience in the lithium space?
Thacker Pass will dramatically change that by initially increasing US output of lithium by up to eight times. General Motors (GM) has the right to purchase 100% of the production volumes for 20 years from the first phase, which is enough to produce roughly 800,000 EV batteries per year. This arrangement with GM ensures that Thacker Pass material will be mined, processed and placed in EV batteries, all in the US.

What socioeconomic benefits will Thacker Pass contribute to Nevada?
Peak construction is anticipated to employ approximately 1,800 skilled workers. We expect to have more than 300 full-time employees once Thacker Pass is fully operational. ■

Ryan Melsert

President and CEO
AMERICAN BATTERY TECHNOLOGY COMPANY (ABTC)

What are recent highlights at American Battery Technology Company (ABTC)?
ABTC is in a unique position with two business units: battery recycling and lithium hydroxide extraction from clay. We completed our first commercial-scale recycling facility in 2023 and began operations in October.

Can you provide updates into ABTC's lithium extraction business?
We completed most exploration work and released an initial preliminary economic assessment in December 2023, updating it in April 2024. We have over 21 million t of lithium carbonate equivalent (LCE), making it one of the largest identified lithium resources in the country.

In 2021, we were awarded a US$2.27 million DoE grant to build an integrated pilot facility to process claystone from our property into battery-grade lithium hydroxide. We completed the pilot plant in 2024 and recently began producing battery-grade lithium hydroxide. The pilot plant is a precursor to a larger US$57.7 million DoE grant to build a commercial-scale refinery on our property with a capacity of approximately 30,000 t/y. ■

Pat Risner

President of Hermosa
SOUTH32

> "As the only advanced mine project in the US that could produce two federally designated critical minerals — manganese and zinc — Hermosa can help put Arizona in the driver's seat of the clean energy race."

Can you introduce South32's Hermosa project?
Located in an historic mining district in the Patagonia Mountains of Southern Arizona, South32 is designing the Hermosa project, a mine with state-of-the-art technology, so that it is safer, more sustainable, and more advanced. Reducing greenhouse gas emissions and competing in the global clean energy economy will require major investments in America's infrastructure and domestic supply chains. As the only advanced mine project in the US that could produce two federally designated critical minerals — manganese and zinc — Hermosa can help put Arizona in the driver's seat of the clean energy race.

What milestones were achieved over the past 24 months?
The Hermosa project was designated as the first mining project under the federal government's FAST-41 permitting program, meant to introduce more transparency and efficiency in the federal permitting process. South32's board approved a US$2.16 billion final investment decision to develop the Hermosa project's zinc deposit – the largest private investment in Southern Arizona's history. South32 announced the location of Centro, its remote operations center in Nogales, AZ.

The environmental review process for the NEPA process began in May 2024 with the U.S. Forest Service completing its initial public comment scoping period. The Department of Defense awarded the Hermosa project a US$20 million grant under its Defense Production Act (DPA) battery grant program to help accelerate the domestic production of battery-grade manganese. Construction onsite has been ongoing, including work on both shafts with the continued construction of the headframes and hoisting facilities. Shaft sinking equipment has been installed in the shafts and work is advancing to begin sinking later this year.

Can you describe the significance of FAST-41 and how it will help advance operations?
Permitting a mine in the US is no easy task. It takes years of development, study and analysis to navigate the complex permitting structure that can spread across multiple federal agencies and departments. The FAST-41 program is about streamlining that process for critical infrastructure projects that benefit the nation and making sure there are open lines of communication and transparency between all the stakeholders in the process.

It is still a full and rigorous review, and we expect federal authorization for full development will take a little over two years. So far, we have hit all the permitting milestones for the project, and we are hopeful we can stay on that path.

What socioeconomic impact will Hermosa have on the state of Arizona?
The Hermosa project is in one of the most economically disadvantaged counties in Arizona that has double the unemployment of the rest of the state and per capita incomes about 40% below the state average. So having this quite unique resource of manganese and zinc that can support efforts to address climate change and create jobs and economic opportunity in what has been a historically disadvantaged community in the process is what makes it such a great opportunity.

Not only will the project provide upwards of 900 jobs, we are also investing in the community, partnering with the community on workforce development initiatives, building strong relationships to ensure transparency and cultural preservation. Our goal is to develop a homegrown workforce with the skills needed to operate the Hermosa project and support our broader community for generations to come by prioritizing local hiring.

How will Hermosa create the foundation for a critical mineral domestic supply chain?
There has been no manganese ore mining in the US since the 1970s, and the US is now 100% reliant on foreign sources for manganese. The Hermosa project can help fill that void.

In recognition of its importance to national security, the US Department of Defense awarded a US$20 million grant in May under the Defense Production Act (DPA) battery grant program to help accelerate the domestic production of battery-grade manganese. In 2023, the Hermosa project earned the designation as the first critical mineral mining project under the federal government's FAST-41 permitting program, meant to introduce more transparency and efficiency in the federal permitting process.

It is an American resource that can create a short, local, domestic supply chain and in doing so create jobs in a community that has been historically economically disadvantaged. ■

Jon Cherry

President and CEO

PERPETUA RESOURCES

> Our site, once a major producer of antimony, presents a unique opportunity to reestablish domestic production.

What are recent milestones for Perpetua Resources in 2023 and 2024?

In September 2024, Perpetua Resources received its Final Environmental Impact Statement and the Draft Record of Decision authorizing the Stibnite gold project, and according to the US Forest Service schedule, Perpetua is on track to receive our Final Record of Decision by the end of 2024. The project is economically promising; the US military invested US$75 million. We also received a letter of interest from the US Export-Import Bank for up to US$1.8 billion to assist with capital costs. The US Export-Import Bank is now focusing on domestic investments through its new "Made in America" program, aiming to compete with international markets, particularly China.

We plan to produce approximately 148 million lb/y of antimony, which will supply about 35% of the US demand. My vision includes successfully and safely developing the project, fulfilling environmental commitments, and leveraging the economic benefits of gold production while contributing significantly to antimony supply.

Why is antimony considered critical?

Antimony is vital for various applications, including semiconductors, night vision goggles, fire retardants, military munitions, solar panels, and new battery technologies for grid storage. Currently, about 90% of global antimony supply comes from China, Russia, and Tajikistan—countries that are not necessarily allies of the US. Given that China controls about 50% of the global supply and recently announced global export restrictions, the US needs to increase domestic production. Our site, once a major producer of antimony, presents a unique opportunity to reestablish domestic production.

Can you discuss the socio-economic impacts the project will have on the state of Idaho?

During construction, we will peak at about 1,300 contractors working on the project, which will take around three years to complete. Once fully operational, the site will employ 500 to 600 full-time employees.

Idaho is rich in minerals and has a long history of mining, which is deeply embedded in the state's culture. The presence of significant mineral resources and a multi-generational mining workforce makes Idaho a unique and advantageous location for mining activities.

Can you provide an overview of the site restoration progress?

The site experienced mining activities on and off for over 100 years, impacting the natural habitat with waste rock and tailings. We have already invested US$17 million in cleanup efforts even before obtaining our permits. We plan to continue this restoration as part of our overall mine plan, including developing a fish tunnel to allow migrating fish access to 20 miles of habitat that has been inaccessible for decades.

Modern mining involves designing the mine with the end vision in mind, using advanced technology and detailed planning to ensure environmental and economic objectives are met.

Is there a specific technology utilized for the project?

The project will use advanced technologies and sophisticated modeling to measure and monitor various aspects of site during operations, as well as to design the post-mine landscape. We will employ cutting-edge monitoring technologies to measure ground movement and topographical changes, reflecting the rapid advancements in the mining industry.

How does Perpetua Resources approach community relations?

Our approach to community relations involves earning the trust of the local communities through ongoing outreach and engagement. We have established the Stibnite Advisory Council, consisting of representatives from surrounding communities who meet regularly to discuss the project and provide feedback. We set up a charitable foundation called the Stibnite Foundation with seed money to ensure a lasting positive impact on the community even after the mine's life ends. This foundation will grow over time and support long-term contributions to the area.

Can you outline the upcoming catalysts for the project?

Now with our Final Environmental Impact Statement and Draft Record of Decision in hand, we are looking forward to achieving our Final Record of Decision by year-end. We are advancing preconstruction engineering and aim to start construction by next summer. The project's unique aspects include being a gold mine with antimony as a byproduct and having the potential to be the only US supply of antimony. With gold prices at an all-time high of US$2,500 per ounce, the project's economics are promising. The mine plan will provide a net environmental benefit through proper implementation and reclamation.t ■

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Lithium Americas' Thacker Pass is on schedule to begin operations in 2027. Recent investments moved the project into major construction in 2024. General Motors will contribute US$625 million in cash and letters of credit, while the US Department of Energy will provide a US$2.26 billion loan under the Advanced Technology Vehicles Manufacturing Loan Program for financing the construction of the processing facilities. "The DOE's support to advance Thacker Pass to production will significantly improve domestic output of critical lithium supply to meet the growing domestic need. This essential loan helps Lithium Americas reduce dependence on foreign suppliers and secure America's energy future," said Evans.

The DOE is looking to the Silver State to supply the country long term, bringing another supplier to the table in 2024: American Battery Technology Company (ABTC). The DOE awarded ABTC US$ 57.7M to build a commercial-scale lithium hydroxide refinery, "to process claystone from our property into battery-grade lithium hydroxide. We completed the pilot plant in 2024 and recently began producing battery-grade lithium hydroxide" said Ryan Melsert, ABTC's CEO and CTO.

The plant will be supplied by the company's 21-million-ton LCE resource. The firm is working to build a commercial-scale refinery with a 30,000 t/y capacity.

In October 2024, Australian-based Ioneer received its federal permit for its Rhyolite Ridge lithium-boron project, making it first US lithium project approved by the Biden Administration as part of the county's efforts to accelerate domestic critical mineral production. "Our initial Phase One project is expected to produce about 22,000 t/y of lithium. This deposit can potentially supply enough lithium to power more than 50 million electric vehicles, assuming current efficiency levels," said Bernard Rowe the managing director.

The US relied on China for 70% of its lithium-ion batteries in 2023, according to an analysis by the Atlantic Council. Displacing this amount by 2030 is unlikely, to say the least. However, investments in lithium-ion batteries increased around 7-fold since the enactment of the Inflation Reduction Act in 2022. With president Donald Trump's claims of dismantling the IRA, this investment will likely dwindle.

Rare earths production and development

Rare earths are used in magnets, which underlie everything that powers modern technology, from electric vehicles and renewable energy systems to advanced medical devices and consumer electronics. China's REE production increased at the beginning of this century and peaked at 95% of the global share by 2010. It decreased to 60% in 2019, according to Brookings. This number may be an underestimate, however. "China controls 85% of the oxides and an alarming 97% of the metal used for magnets. This creates serious risks for global supply chains. If China were to limit exports, it could halt production in critical industries, such as defense and healthcare", said Nicholas Myers, CEO and co-founder of Phoenix Tailings, a company producing neodymium and dysprosium from recycled magnets.

The US has just over a 10% share of global REE production. MP Materials is the only significant REE producer. The company is minority owned by Shenghe Resources, a partly Chinese-state-owned company that is also the sole purchaser of its output.

Daniel Kappes

President & CEO

KAPPES, CASSIDAY & ASSOCIATES

> China controls over 60% of global production of critical metals like copper, steel, aluminum, and rare earths. China's dominance in metal smelting and refining is due not only to its investment in mines worldwide but also to its ability to overcome environmental and economic hurdles.

Creative measures are required to reduce the US's 95% import reliance. Energy Fuels saw this as an opportunity: "Past efforts by US, Australian, European and Canadian companies to compete in the critical minerals space, particularly against China, have been largely unsuccessful. Our solution involves creating a new supply chain using byproduct monazite and our Utah facility to produce advanced rare earth materials," explained Curtis Moore, SVP of marketing and corporate development.

So far, the effort has been successful. "In 2024, we installed a circuit capable of producing up to 1,000 t/y of neodymium praseodymium oxide (NdPr), enough for a million electric vehicles," Moore added.

Investors are still learning how to evaluate REE projects, as China dominated the market for so long. Some hold that China is using depressed prices to secure global offtake agreements with projects struggling to secure financing. Idaho Strategic Resources is being strategic in their approach to circumvent this, said Travis Swallow, stakeholder and corporate development lead: "Our cash flow from our gold operations allows us to advance our REE projects despite this downturn. The Idaho National Laboratory supports our approach, understanding that reprocessing waste will not meet future demand."

Antimony, manganese and zinc development

Manganese is a key component of EV batteries. Zinc creates protective coatings for solar panels and wind turbines. For perspective, a 100 MWh solar panel park requires 240 tons of zinc, according to the World Economic Forum. Manganese is a non-substitutable metal for all steel production. The U.S. is 100% import reliant for manganese and 76% for zinc. "China controls about 96% of the high-purity manganese sulfate monohydrate (HPMSM) market with only two HPMSM plants outside of China", said Brian Savage, CEO of Electric Metals,

an exploration company. HPMSM is a non-replaceable element in EV batteries and energy storage systems.

One of the few advanced mining projects in the US, South32's Hermosa manganese-zinc project in Arizona, was confirmed as the first FAST-41 mining project in May 2023, which will introduce efficiency into the federal permitting process. In 2024, South32's board approved a US$2.16 billion Final Investment Decision to develop the Hermosa project's zinc deposit. "It has the potential to be one of the world's largest zinc producers. The feasibility study for Hermosa's zinc-lead-silver deposit also showed an expected initial operating life for the mine of approximately 28 years, with potential for further exploration upside," said Pat Risner, president of Hermosa at South32.

Antimony is critical for national defense as the metal is used in ammunition, night vision goggles, infrared sensors, bullets, precision optics, and the electronics industry, including semiconductors, cables and batteries. In August 2024, China announced export restrictions on six antimony related products and gold-antimony smelting technology. 63% of US antimony imports are from China; now, the country must look elsewhere. A significant site exists within the country's borders, according to Jon Cherry, CEO and president of Perpetua Resources: "We plan to produce approximately 148 million lb/y of antimony, which will supply about 35% of the US demand."

With global tensions rising, the government is wasting no time: "In September 2024, Perpetua Resources received its Final Environmental Impact Statement and the Draft Record of Decision authorizing the Stibnite gold project. Perpetua is on track to receive our Final Record of Decision by the end of 2024. The US military invested US$75 million. We also received a letter of interest from the US Export-Import Bank for up to US$1.8 billion to assist with capital costs," continued Cherry.

Dynamics are already shifting: "With China limiting exports and dominating the global market, prices surged from US$12,000/t to US$25,000/t. This trend is likely to continue. An antimony bull market could be even more dramatic than a gold bull market due to its strategic importance and constrained supply", said Christopher Gerteisen, CEO of Nova Minerals, a firm advancing an antimony-gold project in Alaska with hopes of producing antimony trisulfide, essential for munitions, within 18 months.

There is no doubt that the US's supply of critical minerals is dominated by foreign control. President Donald Trump declares that narrative will change, with a potential 60% tariff on all Chinese imports. He walks a thin line. A domestic-only strategy for critical minerals is unfeasible. Geologically, many of the minerals are either not found in the US or are not economically viable to extract domestically. The US holds less than 1% of the world's nickel, cobalt, and graphite reserves, only 1.3% of the world's rare earth elements, and 1.5% of the world's manganese. Such dramatic measures will likely only raise national debt while elongating the timeline to achieve net zero. ■

Uranium Production and Development

America's new nuclear family

At the World Climate Action Summit of the 28th Conference of the Parties to the UN Framework Convention on Climate Change (COP28), 20 countries agreed on the Declaration to Triple Nuclear Energy. As the title suggests, the aim is to triple nuclear energy's share of the global electricity matrix by 2050 and was the first COP document backing nuclear energy. Nuclear energy has the lowest carbon footprint of any electricity source and is the least land intensive, according to the World Economic Forum; a thimble-sized pellet of uranium produces as much energy as almost three barrels of oil, more than 350 cubic meters of natural gas and about half a ton of coal.

The US aims to capitalize on a domestic nuclear advantage, according to Curtis Moore, senior vice president of marketing and corporate development at Energy Fuels, the firm he forecasts to be the largest domestic producer by 2026: "There is a significant effort to rebuild domestic nuclear fuel capabilities, particularly in uranium conversion and enrichment, indirectly benefiting mining."

In 2023, uranium purchases to fuel domestic nuclear power reactors increased 27% over 2022, according to the US Energy Information Administration. Most uranium was sourced from abroad, with 27% from Canada, 22% from Australia and Kazakhstan each, 12% from Russia and 10% from Uzbekistan. Only 5% was sourced domestically. This, however, will likely increase. In May 2024, President Biden signed the Prohibiting Russian Uranium Imports Act into law, unlocking US$2.72 billion in funding to build out the domestic nuclear fuel supply chain.

Energy Fuels operates the White Mesa mill in Utah, the only fully licensed and operating conventional uranium mill in the US. White Mesa had a 24% share of all US uranium production between 2012 and 2018. The mill's operational status has varied, often shifting between active production and standby modes, largely due to fluctuating uranium market prices and demand. During the Q2 2024, the White Mesa mill was on standby.

Despite these fluctuations, Energy Fuels plans to scale up uranium production by bringing their Sheep Mountain, Roca Honda and Bullfrog projects into production over the next 4 to 6 years. "Once operational, these projects could collectively produce 5-6 million pounds of uranium annually," said Moore.

The Trump energy plan aims to boost nuclear energy, which currently makes up only 18.6% of US electricity production. "Trump will support nuclear energy production by modernizing the Nuclear Regulatory Commission, working to keep existing power plants open and investing in innovative small modular reactors," said David Bernhardt, former Interior Secretary, on a press call.

These plans will bode well for New Mexico and Wyoming, as the top producers of uranium. They produced 347 and 250 million pounds respectively during 2024. As the world moves deeper into a new era, the importance of securing a reliable supply of essential energy materials cannot be overstated. ■

Image courtesy of Energy Fuels

Curtis Moore

SVP - Marketing & Corporate Development
ENERGY FUELS

What is Energy Fuel's current production footprint?
Energy Fuels is actively mining at Pinyon Plain in Arizona and La Sal and Pandora in Utah, expecting to produce 1.1-1.4 million lb/y uranium. The Pinyon Plain mine could be the highest-grade uranium mine in US history and is the lowest-cost uranium mine in the US, with all-in costs around US$35-40/pound.

We are shifting our focus from REEs back to uranium production. Nichols Ranch and Whirlwind are also being prepared for production, contingent on market conditions and securing contracts. We have three contracts with US utilities and are working on a fourth.

How does Energy Fuels plan to increase uranium production?
We resumed permitting at three large-scale mines: Sheep Mountain, Roca Honda and Bullfrog. We plan to bring these into production in 4-6 years. Once operational, these projects could collectively produce 5-6 million lb/y.

In our alternative feed recycling business, we process materials considered waste to extract valuable uranium. This process yields 100,000 to 400,000 lb/y, providing a very low-cost source, likely the cheapest in the world. We are also exploring ore purchases from other mines in the Four Corners region, as we are the only uranium mill in the area. ■

EXPLORATION

“Historically thousands of junior exploration companies would comb the Earth, one would make a viable discovery, and would be acquired by a major. Now, juniors are undercapitalized and miners are depleting their reserves. Technology is the only solution.”

Corrado De Gasperis
Executive Chairman and CEO
COMSTOCK INC

Image courtesy of Ivanhoe Electric

Western USA Exploration

In search of a new manifest destiny

Apart from numerous Native American tribes like the Yaqui, Hopi, Ute and Washoe, mineral explorers were some of the first to settle the Western US. As the country expanded, the West emerged as a vast, uncharted frontier, offering a new horizon for those daring enough to venture into its rugged landscapes. The region became a symbol of opportunity—a place where the bold could carve out their fortunes from the untapped riches buried beneath the earth. The allure of the West was about the prospect of discovering gold, silver and other precious metals that lay hidden in the mountains and valleys, waiting to be unearthed by those with the grit and determination to find them.

In 1890, the Census Bureau declared the Western frontier closed. 135 years later, the Western US has become a new symbol of opportunity for explorers: an untapped, mineral rich region with the ability to supply the ever-demanding globe.

The Western US's complex tectonic history, marked by subduction zones, volcanic activity, and crustal stretching, created the perfect conditions for the formation of mineral deposits. Key tectonic events shaped today's productive mining regions, with each era playing a role in concentrating metals in economically viable deposits.

Precious lands, precious metals

The western United States' prolific gold and silver deposits owe their origins to a rich tectonic history involving subduction, mountain building, and crustal extension. Starting in the Paleozoic, ancient Precambrian crustal blocks were accreted along North America's western margin, creating the foundation for mineral-rich volcanic arcs. Precambrian- aged rock are being discovered today at Silver One's Candelaria project in Nevada. These rocks contain high-grade silver, said Greg Crow, the firm's president and CEO: "Our property has seen historical high-grade polymetallic veins, and we are currently discovering new high-grade silver vein fragments through metal detecting, with the largest fragment weighing 417 pounds and estimated to contain about 70% pure silver."

In the Mesozoic, subduction of the Farallon Plate generated major orogenies, including the Nevadan and Sevier, which drove magmatic intrusions that injected gold-bearing fluids into fractures across Nevada, Idaho, and Utah. As these intrusions cooled, they emplaced veins of gold and silver within faults and fractures, leading to deposits like the Comstock Lode in Nevada. In 1859, the Comstock was the first site of silver discovered in the U.S. The legacy and reserves, continue to this day. "We have a fully permitted infrastructure and 12 square miles of contiguous mineral properties on the historic Comstock. Our Dayton Consolidated mine holds 250,000 to 300,000 oz of gold and 3-4 million oz of silver," said Corrado De Gasperis, executive chairman and CEO at Comstock Inc.

The Comstock Lode in Nevada was part of the wave of silver mining targeting carbonate replacement deposits (CRDs) across the West. These deposits form when mineral-rich hydrothermal fluids replace carbonate rocks with metal-rich sulfide minerals, creating zones of silver, lead and zinc. Their high grades make them attractive to this day, said Kit Marrs, co-founder, CEO and president of Western Alaska Minerals, who discovered a CRD containing 75 million oz of high-grade silver equivalent: "This high grade results in significant profit margins compared to low-grade copper deposits, which require extensive capital to develop. CRDs typically have a lower environmental footprint and involve lower capital costs, making them more appealing now that exploration priorities have shifted."

Though many of these deposits were mined a century ago, Barksdale Resources, also encountered CRD style mineralization in the Patagonia district of Arizona, adjacent to South32's Hermosa's CRD. "The first hole into the CRD area encountered 13 mineralized zones, though they were thinner than historic intercepts. Key highlights included a 1-meter intercept with 8% copper and polymetallic sulfide masses with 15-20% lead-zinc and up to 100 g/t silver," said Rick Trotman, president and CEO of Barksdale Resources.

During the Miocene, low-sulfidation epithermal gold and silver deposits formed due to extensional tectonics. Notable examples are found in the Great Basin region, including areas like Nevada's Carlin and Cortez Trends, creating the largest and richest gold regions globally. The hunt continues in the area, with NV Gold Corp's SW Pipe project covering 85 claims. "We have with excellent access and are situated in elephant country. The geochemical signature we observed, especially at the intersection of two major faults, is encouraging. The small surface gold deposit might be a surface indicator of a larger, deeper system," said John Watson, the president and CEO.

The meeting of the precious and the industrial

Before the Miocene, the Laramide orogeny moved the center of tectonic activity inland. Porphyry copper-gold systems emerged during this time as deeper magmatic intrusions were emplaced, forming extensive hydrothermal systems that introduced copper and gold into the crust. Most of Arizona's major porphyry copper systems are linked to the Laramide event, and the next one likely will be too. "Porphyry copper deposits are characterized by specific styles of alteration, mineralization, geophysical signatures and occur in Laramide age intrusives," said Elmer Stewart, president and CEO of Copper Fox Metals, whose three projects are in fertile Laramide age intrusives.

Porphyry copper-gold deposits are found in the Northern Cordillera, which extends through the Rockies and up to the Alaska Range. They form from hydrothermal fluids related to the cooling of magma deep within the Earth's crust. These fluids moved through fractures in the rock, depositing copper and other valuable metals like molybdenum and gold as they cooled. The result is vast, low-grade but highly concentrated deposits of copper, such as those found in Arizona's Morenci and Bingham Canyon mines. These deposits are so large and rich in copper that they have sustained mining operations for over a century, making them some of the most important sources of copper in the world. "Porphyry deposits are large, making them easier to locate than narrow high-grade veins. Their grade characteristics lend themselves to bulk tonnage, lower-grade mining operations with higher throughput. They are crucial for meeting the global demand for gold and copper," explained Tim Smith, CEO and president of U.S. GoldMining.

Porphyry deposits, while typically characterized by evenly distributed mineralization, can exhibit unique geological variations that influence their economic viability. For example, the CuMo deposit in Idaho, a hard rock copper porphyry, presents a distinctive stockwork system. "The nature of our orebody provides significant opportunities to lower CapEx. Unlike typical porphyrys where mineralization is evenly distributed throughout the ore body, our deposit has thin, finger-width veins containing the bulk of the copper, molybdenum, rhenium, and tungsten minerals," said Andrew Brodkey, chief operating officer at Idaho Copper.

A key aspect of porphyry systems is the presence of breccias— rock formations composed of broken fragments cemented together by a fine-grained matrix. Breccias, formed by intense hydrothermal activity, serve as both hosts and conduits for mineralizing fluids. As these fluids traveled through the fractured rock, they deposited copper and other metals, creating zones of higher-grade mineralization within

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Image courtesy of Western Alaska Minerals

Andrew Brodkey

COO

IDAHO COPPER

> By reducing the mill size from 150,000 t/d to around 25,000 t/d, we expect substantial cost savings and substantially improved economics versus the 2020 PEA.

Can you introduce Idaho Copper and discuss Idaho's benefits?
We are a US company based in Boise, Idaho, traded on the OTC Stock Exchange. Previously a subsidiary of Canadian MultiMetals Development Corp. We became an independent company in January 2023. Our flagship project, CuMo is in the Boise National Forest. This project is one of the largest undeveloped copper and molybdenum deposits in the Americas. The project has excellent road access, nearby water and power, and a skilled workforce available.

Idaho, like the other western states, has a strong mining tradition and a pro-mining environment. The Fraser Institute rated Idaho with an 86, and S&P's World Risk Report also gave it high marks.

How has the firm optimized CuMo's 2020 PEA?
In 2020, SRK Canada published a PEA for our project. This assessment revealed a vast resource of 2.3 billion mineable tons containing 3.8 billion lb of copper, 1.6 billion lb of molybdenum and hundreds of millions of oz of silver, all in the Measured and Indicated category. Using US$3/lb copper, US$ 12.50 silver, and US$ 15/ lb molybdenum, they valued the project at US$ 356 million using an 8% discount rate and US$1.7 billion at a 5% discount rate. Metal prices have risen significantly, so we anticipate improved economics in the updated PEA. CapEx was an estimated US$3.1 billion. Reducing CapEx has been the priority.

How will ore sorting reduce project CapEx?
The nature of our orebody provides significant opportunities to lower CapEx. CuMo is a hard rock copper porphyry deposit, typical of the Western US, but with a unique twist: it is a stockwork system. Unlike typical porphyrys where mineralization is evenly distributed throughout the ore body, our deposit has thin, finger-width veins containing the bulk of the copper, molybdenum, rhenium, and tungsten minerals. This lends itself perfectly to ore sorting, a technology that separates high-grade ore from waste and lower-grade materials. This allows us to design a smaller concentrator than the 150,000-t/d mill designed by SRK in 2020, which cost US$1.3 billion out of the total US$3.1 billion initial CapEx. By applying ore sorting, we can build a smaller mill to process only the high-grade fraction, maintaining the production rates SRK predicted but at a reduced cost. This approach supports a minimum 30-year mine life for CuMo. The stockpiled material can be leached or run through the mill later.

What steps has Idaho Copper taken in 2024 towards validating the ore sorting technology?
We hired Veracio, who are currently using mobile X-ray fluorescence (XRF) scanning equipment to scan up to 60,000 feet of core, at 1.5 cm intervals, which provides detailed metal grade data. Unlike homogenous copper porphyry deposits where ore sorting is not as effective, our deposit is variable and has metals concentrated in dark-colored veins, easily distinguishable from the gangue material. Results through June 2024 demonstrate variability of CuMo ore and amenability to ore sorting.

The next stage is evaluating MineSense's ShovelSense ore sorting technology, where broken, blasted material falls by XRF sensors installed in the shovel bucket to measure metal grades. We are sending samples to MineSense for testing.

We are also sending representative post-sorting ore samples to SGS's lab in Lakefield, Ontario, for further metallurgical confirmation. This information, along with the data from Veracio and MineSense, will feed into an updated PEA and Technical Report expected to be published in 2024, with SGS as the lead author. By reducing the mill size from 150,000 t/d to around 25,000 t/d, we expect substantial cost savings and substantially improved economics versus the 2020 PEA.

What catalysts does Idaho Copper have in the pipeline?
We are an undiscovered gem in Idaho, the Gem state. By late this year or early next, we aim to uplist to a major US exchange, likely the NYSE Amex or NASDAQ, which will help secure capital for a US$25-30 million PFS.

We are also preparing a white paper for the Department of Defense (DOD) to seek governmental funding, potentially covering half our PFS costs. The DOD is particularly interested in our rhenium, critical for F-35 fighter jets, along with our copper.

The Forest Service, our lead agency in the Boise National Forest, published our Environmental Assessment for the final drilling campaign last month. This, along with our new PEA and drilling plans, will drive our PFS. ■

Paul Harbidge

President and CEO

FARADAY COPPER

What were recent highlights for Faraday Copper?
In 2023, we delivered an updated Mineral Resource Estimate on Copper Creek. We also delivered an initial base case PEA to demonstrate an economically viable project and highlight areas of focus to drive value: metallurgy, exploration, resource expansion, and adding gold to the flow sheet.

In 2023, we performed a 10,000 m drill program to expand the mineral resource, primarily the near-surface open pittable material. We are currently drilling a +20,000 m program. Additionally, in 2023 we started analyzing historical core for gold, which will be included in future resource estimates.

How will results from 2024 metallurgical testing add value to the future technical report?
The new metallurgical results show the potential to increase throughput from the base case 30,000 t/day in the PEA to 45,000 t/day by adding a coarser grind size, as well as adding gold as a payable byproduct. The results also confirm high sulphide recoveries, above 94%, and a clean concentrate with grades above 30% copper.

What results have recent drilling programs yielded?
The key focus of our current drilling is testing new targets along the Holy Joe structure in the east of the property. ■

Elmer B. Stewart

President and CEO

COPPER FOX METALS

What are key highlights from Copper Fox's projects?
Copper Fox's project portfolio consists of two advanced stage and three exploration stage projects all located within the USA and Canada. Our advanced stage projects are our 100% owned Van Dyke project and our 25% interest in the Schaft Creek Joint Venture with Teck Resources. Both projects are transitioning to the PFS stage. On our exploration stage projects, the updated MRE on the Eaglehead project exceeded our expectation, yielding average metal grades typical of other porphyry copper deposits in British Columbia, and most importantly demonstrated the significant resource potential of this project. At Mineral Mountain this project has transitioned to the drilling stage and is currently in the permitting process to conduct a maiden drilling program to test the large porphyry footprint. Currently, our focus at the Sombrero Butte project is to advance this project to the drilling stage.

What are the next steps for the Sombrero Butte project?
Sombrero Butte is located 3 km south of the Copper Creek porphyry deposit and covers a portion of the same Laramide age intrusive that hosts the Copper Creek porphyry copper deposit. In Our focus is to develop an updated geological/exploration model to guide future exploration activities with the objective of advancing the project to the drilling stage. ■

Chris Gerteisen

CEO

NOVA MINERALS

Could you introduce Nova Minerals?
Nova Minerals' flagship operation, the Estelle gold project in Alaska, covers 514 square km of state mining claims. We identified nearly 10 million oz gold across the project, with 5.2 million oz as economic resources. We found 20 other prospects with high concentrations of antimony, copper, silver and other critical elements such as scandium, gallium, tungsten, indium, and some of the REEs.

What is Nova Minerals development approach?
We are open to strategic partnerships with major companies to scale up exploration and development quickly. We use one drill rig now, but larger companies could deploy 10 to 12 rigs to accelerate the project. Our 2023 Estelle wide JORC-compliant scoping study indicated a viable project with an almost 20-year LOM and less than one year payback period. At US$1,800 gold, NPV5% was US$654 million, which the study sensitivity analysis shows rises to ~US$1 billion at a US$1,980 gold price. Nearly US$400 million in CapEx is required for the Estelle wide project which might be challenging in this market. However, the project benefits from development optionality so we are currently laser focused on RPM for an initial lower capex, high margin, scale-able quick start-up option to achieve production and cash flow and then grow ourselves into the larger project organically and/or with a strategic partner. ■

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the broader porphyry system. At Faraday's Copper Creek, newly discovered at surface breccia are enhancing the economics of the deposit, said Paul Harbidge, president and CEO: "The first new target we drilled, Area 51, resulted in the discovery of a cluster of breccias exposed at surface with strong copper mineralization. Assay results include: 1.29% copper over 11.36 meters within 45.75 meters at 0.48% copper."

New copper discoveries are sparse, amid a global shift away from early-stage exploration. While copper exploration budgets grew 12% during 2023, most of this funding was directed toward brownfield exploration, according to S&P Global. In S&P Global's analysis of 239 copper deposits discovered between 1990 and 2023, the US and Canada combined accounted for only 10% of discovered copper.

Today's porphyry hunt is assisted by tools not available to the miners of the old west, revealed Eric Saderholm, managing director of exploration and co-founder of American Pacific Mining Corp.: "Radiometric data detects potassium, which is important for copper porphyry exploration. It highlighted key features and advanced our understanding of the project, allowing us to focus our efforts more effectively."

Barrick Gold is on the hunt for porphyry elephants, in the firm's move to increase copper exposure. "Copper is as strategic as gold is precious. As you grow as a gold miner, you have to embrace copper. To keep critical mass, you've got to go to the porphyries—porphyry gold deposits—and with those porphyries come copper as well," Mark Bristow, their CEO told Kitco in an interview.

This is evident in Barrick's strategic US$23.5 million investment to acquire a 12.5% stake in Hercules Metals Corp. in Idaho, following a geophysical survey that revealed a deep anomaly, which was later confirmed as a major porphyry copper system. "Barrick has a strong interest in this district due to its potential as a new porphyry copper discovery. Porphyry copper often occurs in clusters, so one discovery could lead to others. Barrick sees this potential and is actively supporting us with both capital and technical guidance," confirmed Chris Paul, CEO of Hercules.

Manifest destiny's legacy

In 1872, the United States government formalized the opportunity to exploit the US's geological riches through the mining law, a piece of legislation that opened the doors to the mineral resources on public lands. Anyone who could find valuable minerals could stake a claim. The mining law reflected the broader spirit of the time, a period when the nation was focused on growth, expansion, and the harnessing of its natural resources. "The law is still in effect and is old and complicated," emphasized Chris Summers, CFO of Burgex Mining Consultants.

Claims are also no longer free, continued Summers: "The basic maintenance fee has gone up from US$165 to US$200 per claim, which is significant when multiplied by thousands of claims. We are already seeing companies not renewing claims due to the fee increase. While the BLM is mandated to review fees every five years, the magnitude of this year's increase is significant. It is disheartening because we need this investment for the US to achieve its goals, particularly for the green energy transition."

Investment strategies, however, may shift as high commodity prices create new opportunities. Mike Sieb, president of Getchell Gold explained: "When investors realize profits from the established producers, they will seek undervalued opportunities in which to reallocate their gains."

To attract these investors, Getchell is preparing a PEA. "This will serve as a resource for investors, demonstrating the foundational value and upside potential that will position us for future M&A activities usually developed in the wake of a revitalized gold market," Sieb continued.

Mergers have been purposefully, explained Darrell Tweidt, client services manager at Premier Drilling Co:"The industry is experiencing consolidation, with smaller companies merging to share resources. Many investors are diverting funds to newer markets like AI and cryptocurrencies instead of mining."

Risk is being diverted to these newer markets at a time when mining needs it most. On top of that, M&A cannot be relied on to mobilize change. "M&A in the sector could bring capital, but true momentum requires more market risk appetite. Investors should look for companies actively advancing projects. Few companies with a US$30 million market cap are investing US$20 million in exploration," said Warwick Smith, CEO of American Pacific Mining.

This new chapter in exploration history is not just about conquering the land, but about responsibly harnessing its resources to build a more sustainable and self-reliant future for the United States. The stakes are high, but so too is the potential for a new kind of prosperity—one that respects both the land and the legacy of those who first ventured westward. ■

Highlighted Projects: Precious Metals and Copper

"The 2024 updated mineral resource estimate witnessed a significant increase, reporting approximately 650,000 oz of gold in the indicated category and an additional 1,670,000 oz in the inferred category, all at very respectable gold grades."

Mike Sieb, President, **GETCHELL GOLD**

"Our exploration thesis is that we have a world-class carbonate replacement system with significant resources at both ends: Illinois Creek in the west and Water Pump Creek in the northeast, boasting 75 million oz of high-grade silver equivalent."

Kit Marrs, Co-Founder, CEO and President, **WESTERN ALASKA MINERALS**

"30% of Whistler's value is copper. We have 1.1 billion lbs copper, (0.7 billion inferred, 0.4 billion indicated). We have 2 million oz of indicated and 4.7 million oz inferred gold. Silver is also present."

Tim Smith, CEO and President, **US GOLDMINING**

"Barksdale Resources has significant opportunity due to its strategic location in a 100-year mining district where billions of dollars are being invested in processing infrastructure. The company controls half of the Patagonia district, with a major mining company controlling the other half."

Rick Trotman, President and CEO, **BARKSDALE RESOURCES**

"This is a new mineral system with significant positive implications for developing a district-scale discovery in a tier-one jurisdiction. For this reason, the project's potential was validated by Barrick Gold's investment, a company not known for investing in juniors."

Chris Paul, CEO, **HERCULES METALS CORP.**

"In summer 2024, we invested US$20 million in exploration across projects in Alaska and Montana. This follows drilling in late 2023 with the four best copper holes on record at our Palmer project. In Montana, our underground sampling at Madison revealed significant ore remaining."

Warwick Smith, CEO, **AMERICAN PACIFIC**

Image courtesy of U.S Gold Corp.

Critical Minerals Exploration

Discoveries for domestic EV Batteries

The United States' rich geological landscape and infrastructure present a robust foundation for developing critical mineral resources essential for modern energy and technology applications.

Lithium

There are two types of lithium deposits in the Western US: brine and clay-rich sedimentary deposits. Clay-rich sedimentary deposits form from the weathering of lithium-rich volcanic rocks. In large volcanic calderas or sedimentary basins, volcanic ash and pyroclastic materials accumulate and alter over time into clay minerals. Lithium, released during weathering or hydrothermal alteration, is incorporated into these clays, with the depositional environment concentrating the lithium through sedimentation and chemical processes. Jindalee Lithium's McDermitt project is hosted in the volcanic caldera, a major benefit according to Ian Rodger, the CEO: "Lithium sedimentary deposits are the copper porphyries of the lithium world—huge, low-grade, generational assets. Our deposit is unique in that it outcrops at the surface and the rock is very soft, so no blasting or grinding is required. Mining will be very cheap and we expect the waste-to-ore ratio to be around one."

The dynamic geology of Nevada provides fertile ground for exploration, allowing for clay and brine hosted discoveries, and sometimes both, like at Grid Battery Metals' Clayton Valley, detailed Tim Fernback, president and CEO: "In the southern part of our project, there is more potential for brine as it gets closer to Albemarle's Silver Peak mine, North America's only producing lithium brine mine. To the north, there is significant potential for claystone lithium-bearing deposits at depth. We conducted geophysics and sampling, and now it is time to add more exploratory drill holes in the areas with high lithium signatures based on our understanding of the underground geology."

As host of Albemarle's Silver Peak mine, Nevada is the most significant player in lithium exploration. There is good reason for this in districts like Clayton Valley, said Steve Hanson, president and CEO of ACME Lithium: "The region has a history of lithium production since 1966, offering valuable infrastructure like roads, power, and a skilled workforce. The proximity to Albemarle's operation means we are not starting from scratch; there is already community and employment support for lithium production."

Nick Horsley, president and CEO of American Salars Lithium, agrees: "Nevada has everything you need within reach. There is power infrastructure and natural gas in the vicinity as well. If we were to move toward production, a large solar farm could be implemented; Nevada's desert is perfect for that. The access to infrastructure in this area makes it a fantastic place."

Manganese

The geologic history of the US also fed into the creation of Minnesota's Emily District, a major manganese-producing area for the US during the 1940s to 1960s, explained Brian Savage, CEO, Electric Metals: "The deposition of manganese dates back 1.8 billion years when it was an ocean-front area. An oxygenation event occurred which caused the precipitation of iron and manganese, forming these deposits."

Electric Metals was one of the first companies to revisit and consolidate the land package at Emily and plans to produce 300,000-500,000 t/y, with 100,000 t/y of high-purity manganese sulfate monohydrate (HPMSM), which is used in cathodes for electric vehicle batteries. "Establishing domestic production in the U.S. is crucial for national security and carbon reduction, and it positions us to become a leader in producing HPMSM used in electric vehicle batteries", Savage said.

Rare Earths

Geologically, the US's global share of rare earth elements is 1.3%. However, the Biden administration's 25% tariff, effective in 2026, on Chinese permanent magnets is accelerating exploration for these elements.

American Rare Earths is advancing the Halleck Creek project in Wyoming, with the goal of going into production just after Biden's tariff comes into effect. "We aim for an output of 1,200 t/y. Our approach is designed to provide cost and structural advantages, while focusing on developing existing infrastructure with a modular design. There is a strong need for a domestic rare earth supply chain, especially in processing", said Donald Swartz, the former CEO.

Nickel

To meet the demand for batteries, S&P Global estimates that 20 times more nickel will be needed than what is currently mined. Lithium-ion batteries contain five times more nickel than lithium. Finding nickel deposits is challenging, making it a bottleneck in EV production. Explorers like Alaska Energy Metals are working to reduce the bottleneck.

"Stantec calculated our mineral resource, with a conceptual pit shell at a 0.2% nickel equivalent cut-off. The higher-grade zones, exceeding 0.25% nickel equivalent with some over 0.3%, are concentrated in the center and trend southeast. The deposit contains over 8 billion pounds of nickel, along with copper, cobalt, platinum, and palladium", said Greg Beischer, CEO and president of Alaska Energy Metals

Large nickel deposits require abundant magma because it contains dissolved nickel. Millions of years ago in Alaska, magma repeatedly rose in layers, forming a large, bowl-shaped mafic-ultramafic intrusion. Over time, this magma reached the earth's surface, creating a vast basalt province. As the magma interacted with sulfur from sedimentary rocks, nickel sulfide droplets formed and joined to create rich sulfide deposits. "The Eureka deposit sits above the base of this massive intrusion, resembling a large cloud of disseminated nickel sulfide. We are currently drilling to locate high-grade pods within the conduits or at the base of the intrusion," explained Beischer.

With increasing government support, including tariffs to encourage domestic production and ongoing advancements in mining and processing technologies, the US mining sector is adapting to meet the challenges of the green energy transition. This momentum signifies not just a response to immediate demand but a long-term commitment to a sustainable and self-reliant supply chain. ■

Image by Robert Murray at Unsplash

Denis Phares
CEO
DRAGONFLY ENERGY

> "Extracting lithium from the ground is only the first step—it must be refined to battery-grade lithium carbonate and converted into cathode materials. This expertise, particularly outside of Asia, is largely lacking."

Ian Rodger
CEO
JINDALEE LITHIUM

Can you introduce Jindalee Lithium and the McDermitt lithium project?
Jindalee Lithium is a US Lithium development company focused on progressing our flagship McDermitt project located in SE Oregon. McDermitt is currently the largest lithium resource in the US, containing 21.5 million t of Lithium Carbonate Equivalent (LCE).

Since discovering the project in 2018, we have made significant progress building out the resource and de-risking the project. We commenced a PFS mid-2023, which is expected to demonstrate a competitive, large-scale source of lithium chemicals for over half a century.

Can you elaborate on Jindalee's agreement with POSCO Holdings?
POSCO is a major Korean chemical company and cathode manufacturer, with operations around the globe. They are also a partner and supplier to General Motors in North America. We signed an MOU in February 2023, to work jointly on the project, with test work currently underway in Korea. There are no offtake or first rights; it is purely a collaboration agreement. As the current test work is finalized and we complete our PFS we will sit down with POSCO to discuss next steps.

What makes McDermitt's geology unique?
Our deposit is unique in that it outcrops at the surface, and the rock is very soft, so no blasting or grinding is required. As a result, mining will be very cheap with a very low strip ratio compared to most other lithium deposits.

What is Jindalee's approach to project financing?
On the government support side, we are well advanced on two non-dilutive grant funding applications, one with the Department of Defense (DoD) and the other with the Department of Energy (DoE). Size and scope vary, but these grants have the potential to materially co-fund feasibility studies, exploration drilling programs, and pilot scale testwork crucial for advancing from our current PFS to an FID. ■

Tim Fernback
President and CEO
GRID BATTERY METALS

Can you provide updates on Grid Battery Metals' activities from 2023 to early 2024?
Since September 2023, we have been actively exploring our lithium projects in Nevada. One key company project is the Clayton Valley lithium project, located near Albemarle's producing Silver Peak mine and Century Lithium's Angel Island Mine, which is currently at a bankable feasibility stage.

At our Texas Spring lithium project, located near Elko, we plan to launch a drilling campaign. The results of the 2024 drill campaign are expected to expand the existing inferred resource of 4.67 million t of lithium carbonate equivalent grading 2,839 parts per million lithium at a 1,250 ppm Li cut-off. Our exploration results at Texas Spring are on-trend with these results yielded average lithium grades of 2,010 ppm (applying a 1,000-ppm cut-off) and up to 5,610 ppm lithium.

We are also designing a work program for our Volt Canyon project in Monitor Valley. This area has been underexplored, and initial geophysics and soil sampling suggest potential for a larger lithium accumulating structure. We are assessing where to drill and are planning a drilling campaign by the end of the year.

We spun out our nickel projects in British Columbia into a new public company, AC/DC Battery Metals Inc. and Grid shareholders not only received a 5% share dividend in AC/DC, but the share price has more than doubled since listing.

We also aim to acquire additional lithium projects and are receiving daily opportunities for lithium properties in Nevada, Utah, New Mexico, and Arizona.

What are Grid Battery Metals' goals for the next 24 months?
We will focus on continuing exploration and drilling at Clayton Valley, Volt Canyon, and Texas Spring. We aim to acquire additional battery metal exploration targets in North America. Our long-term strategy includes diversifying into other metals and advancing our projects to enhance shareholder value. ■

Highlighted Projects: Critical Minerals

"A zone approximately 300 meters thick precisely exhibits the mineralization concentration of prior drilling—around 0.35% nickel equivalent. While not high-grade, Nikolai boasts continuity, homogeneity, and a consistent grade across each drilling, including nickel, copper, cobalt, chrome, iron, platinum and palladium."

Gregory Beischer, President and CEO, **ALASKA ENERGY METALS**

"Historic drill holes showed exceptional results, with manganese grades of 40-50%. Our current resource estimate, announced in May 2024, indicates over 6.2 million t of 19.27% manganese in the Indicated category, and about 4.9 million t at 17.5% in the inferred category at a cutoff grade of 10%."

Brian Savage, CEO, **ELECTRIC METALS**

"The March 2024 resource estimate is the initial phase of our efforts. Our near-term goal is drilling to better define and expand the resource. We are collaborating with several DLE providers who are testing our brine to determine if we can produce battery-grade lithium."

Steve Hanson, President and CEO, **ACME LITHIUM**

"Of 38 soil samples, 33 had lithium concentrations of over 100 ppm, with an average of 131 ppm and a high of 180 ppm at the surface. We will conduct auger drilling to reach the water table and geophysics to map the basin."

Nick Horsley, President and CEO, **AMERICAN SALARS LITHIUM**

"Halleck Creek has a zero-strip ratio and consistent mineralization up to 300 m. We achieved 90% reclamation of processed material. Geologic characteristics favor leaching recoveries at 75-90 °C, making it less energy-intensive and cheaper."

Donald Swartz, Former CEO, **AMERICAN RARE EARTHS**

Image by Craig Zerbeat Adobe Stock

ENGINEERING, CONSULTING, CONTRACTING

> Climate change adaptation is all about managing risk and, if companies do not adapt, the consequences can be severe. In the case of drought and flooding the risk is not operating. Mining companies must assess these risks against the costs of implementing adaptive technologies.

Randy Huffsmith
Senior Vice President - US Mining Sector Leader
WSP

Image courtesy of Rio Tinto Kennecott

Preparing Mining for the New Climate Frontier

How engineering and consulting firms provide support under new pressures

Storm events are now less predictable and more volatile. Droughts are intensified. Fires run rampant through the beetle killed pines across the Western US. Mining is no stranger to harsh climates; however, climate hazards will only become more frequent and intense, imposing greater challenges to mining operations. Moreover, the US was one of the 195 countries that pledged to limit global warming below 2.0 degree Celsius under the 2015 Paris Agreement.

Miner Rio Tinto reported that record snowfall, twice the historical Utah average, contributed to a 36% reduction in mined copper production in Q1 2023 compared to Q1 2022. 7.5 million acres of the US, primarily in the West, burned in wildfires in 2022, leading to temporary shutdowns of mines. Mining operations face a critical dilemma: increasing production to help the world mitigate climate impacts, while a changing climate lowers production volume. Engineering and consulting firms are working with miners to overcome these challenges.

Battling scarcity

The arid plains of the Western US were once a boon for miners, as sparse vegetation and fewer trees facilitated exploration for mineral resources of the exposed rock. This dryness, however, is no longer a boon, and for some mining operations it could even be a bust. 30%- 50% of production for copper, gold, iron ore and zinc are in areas of high-water stress, and those figures are predicted to rise, according to a recent study by McKinsey & Company. Within the Western US, the states of Arizona, Nevada and Utah are those most at risk. However, Colorado, Idaho and Wyoming are not exempt, as precipitation levels fluctuate drastically due to changing climate conditions.

Through utilization of innovative technologies, machine learning algorithms, storm prediction modelling, and other measures, engineering and consulting firms are trying to turn the future around for mining operations supplying domestic material for the USA's green energy transition. "Access to water is dwindling due to climate change's effects. The good news is that mining companies have long understood this issue and ensure they conserve these precious resources through immense pre planning for water use, closed-loop systems, dry stack tailings technologies, and other best management practices and conservation methods," said Steve Trussell, executive director at the Arizona Mining Association.

Dennis Papilion, executive president, global consulting at Ausenco, added: "At most sites, there are limitations on the amount of fresh water we can withdraw for operational use. Ausenco is deeply committed to mini- mizing freshwater demand and maximizing water reuse. We recently explored wastewater reuse on several projects; its adoption is increasing across the industry."

Adapting to extremes

Intensified storms and unpredictable weather patterns demand a fundamental shift in the approach to water management said Alan Driscoll, VP, and director of mining services at Forsgren Associates: "We are witnessing an increase in storm intensity and frequency, which has a direct impact on mining operations. Mines operate continuously and must adapt to varying conditions, including extreme weather. Operators are collaborating with regulators to enhance designs and plan for larger storm events, incorporating larger containment areas for processed water and improving stormwater management systems."

Droughts and excess precipitation from intensified storms have the potential for catastrophic effects. Randy Huffsmith, senior vice president and US mining sector leader at WSP elaborated: "Droughts affect water availability for mineral processing, while heavy rains and flooding can damage water and waste containment systems and delay operations."

The variability of these extreme events requires mining operations to develop flexible, proactive water management strategies. A shift toward predictive water management has emerged as a key adaptation strategy. "We encourage clients to adopt a predictive site-wide water balance rather than a traditional water inventory tool," noted Jeffrey Coffin, chief operating officer at Knight Piésold USA. "This approach allows for risk-informed decision-making regarding water needs, storage/freeboard requirements, and water inventory management. We aim to maintain operational water levels while avoiding excess inventory as the climate continues to change."

Machine learning is playing a pivotal role in these adaptive efforts, enhancing data-driven decisions across various water management aspects. Tom Meuzelaar, founder and owner of Life Cycle Geo elaborated: "Machine learning can aid significantly in the identification of various water types which supports management strategies such as monitoring potential impacts across project boundaries. It is an indispensable tool in supporting ongoing measurement of water quality throughout the life cycle, including water quality measured at tailings storage facilities and waste rock dumps."

Some firms are proactively integrating climate adaptation strategies in the planning stages, well before mining operations are underway, said Kevin Martindale, director of business development at Millcreek Engineering: "We account for potential storm impacts in feasibility studies, considering 10, 50, and 100-year storm fronts. This includes evaluating the need for infrastructure adjustments, such as covered equipment, to mitigate operational downtime due to extreme weather. The costs associated with these adaptations are crucial for project economics, efficiency, and safety."

Swept away: Reassessing historical climate norms

Global climate fluctuations are not new, as Earth's climate has always been dynamic; however, these fluctuations are intensifying with increased emissions, which trap heat and amplify natural phenomena like storms and droughts. Recent shifts are challenging established models, recounted Jeff Parshley, corporate consultant of environment and mine closure at SRK: "Traditionally, we analyze climatic records over a seven-year period to identify the wettest years for our designs. Last winter's extreme conditions did not align with this data, resulting in unexpected challenges."

Accurate predictions hinge on robust data, yet data acquisition itself presents obstacles: "A primary concern is gathering reliable data to predict changes in precipitation and extreme weather," said Rick Frechette, principal consultant, civil and geotechnical engineering at Haley & Aldrich.

Recognizing that climate extremes have historical precedents, SRK is expanding its data analysis to incorporate longer historical records. "We are expanding data analysis to include longer historical records, recognizing that periods of significant wetness occurred 100 years ago," said Parshley.

Probabilistic risk analysis is another critical tool for managing unpredictability, added Frechette: "Our hydrology team employs methods like probable maximum precipitation and probable maximum floods to manage water-related risks. We use available data to develop adaptable strategies for immediate and long-term climate impacts."

Paul Stockburger, VP sector leader, strategic pursuits, mining, minerals & metals at Stantec, agreed: "While we cannot predict every scenario, we apply probabilistic risk analysis to evaluate the likelihood of specific events. We aim to design for a high confidence level while focusing on re-

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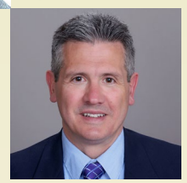
Image courtesy of Rio Tinto Kennecott

PS



RS

Paul Stockburger and Rob Simm

PS: VP and Sector Leader, Mining, Minerals & Metals
RS: SVP, Emergent Sector Leader, Water
STANTEC

How has demand evolved in the water space?
RS: Demand in the water space has definitely evolved: our clients are adopting comprehensive approaches, looking at entire hydro basins or watersheds. They are often required to negotiate with other water users within those basins to secure the necessary water resources for their operations. This shift is not only notable in mining but is also occurring across other industries, highlighting the critical need for a holistic approach to water management.

Mining clients are increasingly integrating climate change considerations and climate models into their water management strategies. Models are being used to project future water and chemical mass balances and whether water treatment will be needed. The mining industry is ahead of many municipal clients in this regard.

What trends you have noticed in the mining sector?
RS: There is a growing trend of collaboration between mining companies and other water users, focusing on innovative approaches like water trading. For instance, a mining company near the ocean might invest in an oversized desalination facility to supply water for both its operations and local communities. An initiative like this supports their social license to operate and highlights the need for such partnerships. We are already seeing a stronger emphasis on water recycling in mining, particularly in copper extraction, where techniques like bioleaching are being developed to extract more value from waste rock.

PS: The concept of "mining within a mine" is gaining traction, allowing us to economically extract additional value from waste rock. This method is less energy-intensive, requires less water, and is more environmentally sustainable in terms of permitting. Because this approach is cost-effective, it will help us to meet the rising demand for critical minerals that are vital for the energy transition.

What is the viability of tailings reprocessing in the Western USA?
PS: There are many technologies and approaches advancing towards commercialization that address recovery of minerals, metals and reagents of value from tailings. For tailings valorization, Stantec acts as a systems and solutions integrator. As an example, we have partnered with Auxilium Technology Group (ATG), a Tucson, Arizona-based company specializing in tailings valorization technologies. Partnerships like these and Stantec's world-class expertise in geotechnical, infrastructure, and water management allow us to holistically solve our clients' challenges in tailings management.

Can you discuss Stantec's viewpoint on reclamation?
PS: In reclamation and closure, we aim for value-added solutions, such as transforming sites into solar farms or pumped storage facilities. Planning for reclamation starts early, considering the site's future, environmental impacts, and community needs. Nature-based solutions are crucial for effective reclamation and closure when appropriate and can be effective methods for carbon sequestration.

How are mining operations adapting to climate change and what challenges do they face?
RS: The impacts of climate change are evident, particularly regarding tailings and waste rock management. We have developed water and chemical mass balance models that show how climate change affects these processes. Mining clients recognize these challenges and incorporate this modeling into their operations. Yet the inherent uncertainties in models pose challenges for navigating future conditions. No model is foolproof and they all require contingency plans. We work with clients to avoid significant capital commitments until model accuracy is confirmed.

PS: Traditional climate models may not be reliable anymore, so we must evaluate whether current structures can handle increased weather events over the mine's lifespan. While we cannot predict every scenario, we apply probabilistic risk analysis to evaluate the likelihood of specific events. We aim to design for a high confidence level to effectively protect operations.

What goals does Stantec have in the Western USA?
PS: We aim to attract and retain talent who share our mission, emphasizing our core values: prioritizing people, doing what is right, striving for excellence, and knowing what's possible when we work together.

RS: We use predictive modeling to understand climate change impacts on operations and apply models to manage watershed resources sustainably. As the global population increases, resource management will be critical. I envision mining companies evolving into commodity, recycling and energy firms, which are essential for a circular economy and a sustainable future. ■

Transforming Environmental Challenges

Turning abandoned mines into sustainable resource assets

RK

RH

Robert Kimball
SVP and Industrial Process Water Business Leader
Randal Huffsmith
SVP and US Mining Sector Leader
WSP USA

The US mining industry plays an increasingly critical role in supplying domestically sourced raw materials necessary for low-carbon energy production. Forward-thinking mining companies are pursuing additional ways to reduce environmental impact and add revenue streams after mining ends.

During open-pit surface mining operations for metals like copper and zinc, groundwater is continuously pumped from the pit so that mining can continue. Once the ore has been extracted and mining operations end, the pumping stops and the open pit fills with water, creating a 'pit lake'.

Pit lakes are usually filled with acid mine drainage and dissolved metals, making the water unusable in that state. As a result, abandoned mine sites have developed a reputation of becoming largely redundant, dirty and unsightly properties.

Fortunately, the technology to make these practices possible and practical is already in place for ESG-minded mining companies to implement. With many potential assets sitting unused, it just requires a commitment to change the approach to these properties and an understanding of what is possible.

Unconventional Water Source

Integrating reverse osmosis into the treatment approach makes it possible to remove dissolved salts, sulfate and other industrial effluents, so that otherwise unusable water can be safely reused or discharged.

WSP combines multiple pieces of water treatment (such as high-density sludge (HDS) water treatment plants) and applies it to reclaim contaminated pit water. HDS mixes sludge with lime, a neutralizing agent, to remove heavy metals from wastewater.

A responsible attitude toward the need to find sustainable uses for mining water will benefit all. Forward-thinking companies are using advanced treatment techniques to clean underground and open pit water, which in turn is successfully being repurposed to support irrigation districts for crops, particularly in drought-prone regions of the western US. Also, with more hydrogen power facilities being constructed in the west, owners are seeking unconventional water sources, since most water rights in these areas are claimed. Treated mine effluent water is viewed as an ideal alternative for these facilities.

Finding Hidden Critical Minerals

Today, many mining companies are implementing processes for the extraction of energy transition elements like lithium, copper and cobalt from traditional acid mine drainage sources and from mine waste. In addition, REEs, such as neodymium, a common metal used in mobile phones and wind turbines; lanthanum, used in lithium-ion batteries; praseodymium, used in EV magnets; and other critical minerals, are also being evaluated for removal from mine water and mine waste. This creates a domestic supply of these raw materials as well as a valuable revenue source.

WSP has been involved with plans for proposed metal recovery operations at two legacy pit lakes in the Western US containing acid mine drainage from former copper mining operations. Both of these pit lakes store water with high concentrations of dissolved metals and are actively managed as hydrogeologic sinks, with water inflow but no outflow. In our experience, technologies such as ion exchange, solvent extraction, electrowinning and sulfide precipitation can be used for both copper and zinc recovery and can have positive returns on investments for our mining clients.

That additional revenue is being used to offset maintenance costs while advancing corporate environmental-social-governance objectives for mining companies.

A Critical Need

Nearly all REEs are currently mined and processed by the Chinese government, which puts the US at a disadvantage in the event of a supply chain disruption. This risk came to the forefront during the Covid-19 pandemic, when supply lines were halted for an extended time and the US stopped receiving many raw materials required to produce vital things.

The use of previously unusable water and the recovery of critical minerals from pit lakes has the potential to significantly improve perceptions of abandoned mines and how they can be transformed from post-closure liabilities to future resource assets.

Fortunately, the technology to make these practices possible and practical is already in place for ESG-minded mining companies to implement. With many potential assets sitting unused, it just requires a commitment to change the approach to these properties and an understanding of what is possible. ■

Image by Dane Rhys, courtesy of American Rare Earths

> We increasingly acknowledge the need to factor extreme climatic events into our designs and operational plans.

Jeff Parshley

Corporate Consultant

SRK

Can you highlight recent milestones SRK achieved?
2023 was characterized by fluctuations in commodity prices, which have had a significant impact on our clients' operations and, consequently, our business. Nevertheless, we grew our practice, particularly in Nevada, where we are heavily involved in some key projects. Among those are several operations that are transitioning from open pit to underground operations—a continuing trend we have observed over the last decade. These transitions present new challenges such as dewatering, changes in geochemistry, and the complexities of permitting. This shift requires us to rethink not just the mining methods but overall operational and permitting strategies.

What is a recent case study where SRK added value for a client in the Western USA?
We worked with several key clients in the Western US on long-term operational and project expansion services. For one, we helped to optimize throughput capacity for in situ leaching operations. Our design engineers collaborated closely with hydrogeologists to conduct detailed water balance analysis, which enabled us to optimize the size of the water management features on site. As a result, the client increased throughput without incurring significant additional operating or capital costs. Our integrated approach can deliver value to clients in a short time frame.

How has climate change affected mining operations in the Western USA?
We increasingly acknowledge the need to factor extreme climatic events into our designs and operational plans. Regulatory agencies are also beginning to realize traditional storm return period designs may not be adequate for the long-term scenarios we encounter during mine closure. Closure is a perpetual concern; it is critical to incorporate potential larger storm events into our planning processes. The primary challenge we face is managing water effectively, especially considering the possibility of extended periods of extreme wetness or dryness that can disrupt established water balances. Our designs must now accommodate these extreme events, ensuring we can manage water flows and mitigate potential environmental impacts effectively.

What role does technology play in tailings management and monitoring?
Digital technologies are essential in tailings management and monitoring, particularly in the wake of increased scrutiny following several high-profile tailings failures. Even before the Global Industry Standard on Tailings Management (GISTM) was introduced, we were developing remote monitoring technologies for tailings impoundments. Over the past few years, we have seen significant advancements in this monitoring systems. For example, radar technologies that can detect minor movements in tailings and embankments have been effectively utilized to ensure safety and stability.

What innovations in closure technology have emerged recently?
We have seen innovations in the materials and methodologies used for mine closure. As we have gained experience and data on the performance of closure systems, we are reevaluating the synthetic materials used. The longevity of these materials is critical, as they often have limited design lives. Our focus has been on developing cover systems that can effectively limit infiltration into mine waste while ensuring durability over the long term. We have been working on passive drainage management systems for over 30 years and are now analyzing their long-term performance. This led us to redesign some of these systems based on the data we collected, particularly regarding subsurface evaporation systems.

How does SRK assist clients with regulations?
We provide technical support to clients as they navigate the permitting process. While impact assessments are typically conducted by others, our long-standing relationships with regulatory agencies allow us to facilitate technical communication and understanding between clients and regulators. Our team includes high-level technical experts who can assist regulators in understanding complex site-specific information, helping clients to effectively address regulatory concerns without overwhelming them with unnecessary data collection.

What are SRK's objectives in the Western USA?
Our focus is on organic growth of our technical team, seeking to attract the right talent at the right time. We value our smaller, nimble structure, which allows us to concentrate on projects that align with our expertise and interests. This approach fosters a collaborative and enjoyable working environment, enabling us to maintain our culture and provide high-quality services to our clients. As we celebrate 50 years in the industry, we believe this strategy reinforces our commitment to providing tailored, innovative solutions rather than competing with larger consultancies. ■

David Swisher

VP Mining, Minerals and Metals, US Operations

WORLEY

What services does Worley offer mining clients, and which are driving demand?
In May-June 2023, we underwent a reorganization focused on enhancing our credibility and branding within the US market. Our service offerings include consulting, digital solutions, front-end and early-phase studies, detailed studies and project execution.

What challenges are mining clients facing in the Western US?
Clients face challenges due to complex regulatory systems at both state and federal levels. These regulations extend project timelines from 5 years to 15-20 years. This longer duration strains client capital as they invest heavily to navigate an unfriendly regulatory environment. Additionally, meeting community and environmental requirements is difficult. Worley focuses on helping clients address these challenges to ensure project delivery is on time and within budget.

What benefits does Worley's broad expertise bring to mining clients?
With the industry's struggle to find experienced personnel, we provide our own skilled team to support client operations.

How are does Worley help mining operations in the Western USA adapt to climate change?
We account for historical climate data in engineering work to minimize risks associated with climate change. Regulations also focus on climate considerations, making it crucial for us to design projects that adapt to changing weather patterns. This ensures that operations are resilient to climate impacts and aligns with responsible environmental stewardship.

What is Worley's approach to technology and innovation in the mining sector?
Worley is committed to integrating new technologies to provide cost-effective, environmentally friendly solutions. Our technology team supports client technologies under strict confidentiality and focuses on proactive innovation to deliver the best solutions for clients. ■

Jeffrey Coffin

COO USA

KNIGHT PIÉSOLD

Can you introduce Knight Piésold in the USA and the services you provide?
Knight Piésold USA is a geo-environmental consultancy specializing in large civil projects, primarily in the mining and renewable energy space, including hydroelectric and pump storage facilities.

How has demand for your services in the Western US mining sector changed recently?
Tailings management is evolving rapidly, especially with GISTM requirements increasing demand for compliance from owners, operators, financers, and insurers.

What considerations should clients have when planning mine closure?
The big thing is just the cost and effort associated with closure. The industry has underestimated those costs and efforts for a long time. It is essential to take an honest view of what those closure requirements will be, how long they will take to implement, and the associated costs. We emphasize the need for progressive closure during mine operations and proper characterization to understand long-term water management needs. We are looking at the geochemical constituents, the potential for acid rock drainage, and ensuring that we optimize material placement on the mine site to contain any bad-acting materials. Our aim is to render those materials benign or control them so that we do not have to rely on mechanical means for mitigation of long-term environmental impacts.

Can you provide an example of how you incorporate climate change models into design?
The biggest impact of climate change models is in the water balance and freeboard design criteria. We encourage clients to adopt a predictive site-wide water balance rather than a traditional water inventory tool. This approach allows for risk-informed decision-making regarding water needs, storage/freeboard requirements, and water inventory management. We aim to maintain operational water levels while avoiding excess inventory as climate continues to change. ■

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alistic scenarios to protect operations effectively."

The rapid pace of climate change is prompting firms to look beyond the historical record, making a clear case for adaptive strategies over rigid reliance on past data. "Over the past decade, there have been significant shifts in mining project design due to climate change. We can no longer rely solely on historical data for storm predictions. For instance, while working on drainage in Mexico, we faced a storm much more severe than expected," warned Patterson.

Given this uncertainty, models are increasingly being supplemented with contingency plans, especially for high-risk projects. While data and models are invaluable, they must be paired with flexible, practical measures to ensure operations remain resilient against the unknown, said Rob Simm, senior vice president and emergent sector leader for water at Stantec: "Our models are not foolproof. In a project in Alaska, we are developing contingency plans in case our predictions are inaccurate."

Why adapt?

The mining industry is already navigating tight capital constraints, with the combined capital expenditure of the top 19 mining companies projected to reach US$71.0 billion in 2024, an increase of 10.6% compared to 2023. Climate adaptation can be difficult to justify financially, as much of it involves speculative investment.

Randy Huffsmith, senior vice president and US mining sector leader at WSP, explained the stakes: "If companies do not adapt, the conse- quences can be severe. In the case of drought and severe flooding the risk is not operating. Mining companies must assess these risks against the costs of implementing adaptive technologies. The key is finding where investments offer the greatest value while protect- ing shareholders."

Balance is key, added Driscoll: "It is crucial to strike a balance between implementing sufficient protective measures and managing costs. In a rapidly changing climate, determining the right level of investment in preventative measures can be tricky, but it is necessary to anticipate potential risks. As conditions evolve, so will the strategies required to manage them effectively."

Mining is, after all, a long-term industry. Although initial costs may be daunting, the return on preventive investments can be substantial. "Investing in preventative measures upfront is essential as it can save costs in the long run," noted Martindale.

Damage to waste containment systems can impact an operation's surroundings long after mining stops, which make climate change considerations even more necessary said David Swisher, VP mining, minerals and metals, US Operations at Worley: "Considering climate change in engineering and design is crucial for minimizing long-term environmental impacts. Operations typically have limited lifespans, and it is essential to plan for land reclamation, water protection, and community benefits post-operation."

Expertise developed by some companies in challenging conditions can be applied in the development of new adaptive techniques. For example, M3 Engineering, frequently faces challenges related to harsh environments in remote projects. Weather conditions, such as heavy snow, are the norm at these sites. "M3's clients relied upon our experienced staff to deliver a process and plant design that could be constructed in a remote area with the Western US and during harsh cold-weather climate conditions. M3's expertise in challenging project conditions proves vital in delivering complex projects in remote locations", said Matthew Sletten the general manager.

Sharing this expertise to meet climate challenges in regions with the potential for abnormally intense snowfall, like those experienced at Rio Tinto's Kennecott, could help the industry adapt to a changing climate.

The challenges posed by climate change to the mining industry are formidable, but not insurmountable. As extreme weather events become more frequent and water resources dwindle, the need for innovative solutions is more critical than ever. The future of mining in the Western US hinges on the industry's ability to innovate and adapt, ensuring resilience in the face of an uncertain climate. ■

Tom Meuzelaar

Founder

LIFE CYCLE GEO

> "Machine learning is an indispensable tool in supporting ongoing measurement of water quality throughout the life cycle."

Can you provide updates on Life Cycle Geo's growth in 2023 and any milestones reached?

In 2023, Life Cycle Geo had a very busy year. We doubled in size, starting with five employees and finishing with eleven by year-end. One significant area of expansion has been our diversification into sectors outside mining, though mining remains our core focus. Our growth includes a deeper portfolio of digital transformation work across various sectors, especially in water, where we see numerous opportunities.

We are engaged in a number of IoT workflow-related projects. This includes implementation of sensors to measure high-frequency water data, such as quality, flow and temperature. These sensors can be coupled with edge computing devices for local data analytics or data can be sent to the cloud for advanced analysis. Ultimately, this feeds into dashboarding and intelligence solutions for our clients. We are particularly involved in optimizing water treatment systems and monitoring waste facility seepage.

Are there any projects in the Western USA that highlight your work?

We have worked with operators in late-stage mining or early closure who have various water quality issues. Our innovative approaches include using unsupervised machine learning methods to analyze years (even decades) of spatially distributed water quality and isotope data. This helps operators differentiate between pre-mining impacts and mining-related impacts, aiding in development of long-term closure strategies.

How do you see machine learning optimizing the entire mining life cycle?

Machine learning has significant potential to enhance water and materials optimization throughout the mining life cycle. Our focus is primarily on water and materials management rather than broader applications like autonomous haulage. We have developed mature workflows for optimizing material handling, allowing operators to accurately identify and estimate volumes of waste, ore and borrow materials with various associated environmental risk. This helps in mine planning strategies, such as evaluating alternatives for waste facility construction or operational water treatment strategies, which results in more informed decisions early in the project.

On the water management side, machine learning can aid significantly in the identification of various water types which supports management strategies such as monitoring potential impacts across project boundaries. It is an indispensable tool in supporting ongoing measurement of water quality throughout the life cycle, including water quality measured at tailings storage facilities and waste rock dumps. The increasing amount of data from sensors will continue to facilitate more intelligent water management-related decision-making. Machine learning is already frequently used to optimize performance active or passive water treatment systems both in operations and closure.

Additionally, for clients discharging water, machine learning can be used predict difficult to measure parameters such as toxicity, bioaccumulation, microbial activity and dissolved metal reactivity, which can help operators make proactive decisions related to treatment and compliance with regulatory standards. Overall, we are excited about the opportunities in water and materials management through the application of machine learning.

Have you observed improvements in machine learning model performance with increased data access?

Yes, we have seen that model performance improves as operators collect more data. However, gaining buy-in and trust from operators when it comes to machine learning is typically a gradual process. Operators need to see tangible benefits—such as time and cost savings— and understand how a machine learning approach improves upon established practices before fully committing to new models. Additionally, regulatory acceptance of these models remains a challenge.

What future opportunities do you see for Life Cycle Geo?

We want to diversify and continue to grow in water resources, as there is tremendous opportunity there. Our focus will heavily be on machine learning and identifying the right people to engage with regarding these technologies. We are seeing a significant influx of AI investment, akin to a gold rush, but our services are highly specialized. We envision developing a services team with instrumentation specialists, data scientists, and domain experts to help clients optimize water and materials management and improve their data collection systems. Over the next couple of months, I plan to put more effort into these goals and continue engaging with great people to shape the organization's direction. ■

Chris Summers

CFO

BURGEX MINING CONSULTANTS

> We help clients succeed by understanding the complexities of US mining law and leveraging our experience.

Can you update us on recent developments from Burgex?
The biggest highlight is no lost time incidents. We focus heavily on safety, and despite being in rough terrain over the past 18 months, our teams have executed safely. In 2023, we were busy with lithium claims and sampling. We also did extensive mapping for uranium exploration. In 2024, our field crews have been out 85-90% of the time from January through June, primarily working on copper and gold, with growing interest in uranium. Gold and copper prices have been strong, signaling continued demand for copper. However, funding for junior exploration companies is lagging, with majors being more active. We are advocating for the domestic supply chain of critical minerals through articles, webinars, and education. I have been involved in developing the American Exploration Mining Association's new campaign, "I Am Mining," which launched on July 8th. It is a fantastic initiative that I encourage everyone in the industry to support.

Can you discuss the BLM's public land rule and the current permitting atmosphere in the Western US?
The BLM has become increasingly difficult to work with. The land rule is particularly challenging, and we are actively pushing back, supporting litigation against it. This rule makes it difficult for companies to invest in US projects.

Fees have also increased, which impacts exploration companies with tight budgets. The basic maintenance fee has gone up from US$165 to US$200 per claim, which is significant when multiplied by thousands of claims. We are already seeing companies not renewing claims due to the fee increase. While the BLM is mandated to review fees every five years, the magnitude of this year's increase is significant. It is disheartening because we need this investment for the US to achieve its goals, particularly for the green energy transition.

How do you assist international clients with US permitting?
The mining law of 1872 is old and complicated. We help clients understand what they can and cannot do, whether it is load claims versus placer claims, public land, federal land, state land, private land, or forest service land. We have been doing this for a long time and work closely with BLM state offices to get questions answered. Being based in Salt Lake City allows us to deploy quickly to the entire west. Most of our projects are in Nevada, Arizona, and Idaho, with significant claim maintenance in California. We help clients succeed by understanding the complexities of US mining law and leveraging our experience.

Can you discuss the AI solutions you are developing for exploration and their benefits for target generation?
AI has exploded in the last 12 months, transforming from a side discussion to a necessity. At Burgex, we are integrating GIS with AI to create visual targets. We are in the early stages, but we see this as the future. We are also close to partnering with a major university for project work. As technology evolves, we adapt our approach. Our goal is to help clients expedite processes; ideally, we want to reduce project timelines from 10-15 years down to just a few.

What factors led to Utah's jump in the 2024 Fraser institute Mining Attractiveness index?
Utah provides access to amazing resources. The state has strong legislative support, with leaders like Representative John Curtis who are supportive of the industry. We also have a strong mining association with Brian Summers and his team working hard for us locally and in DC. Overall, we have a great economy and workforce that understand the importance of mining and mineral exploration.

What are Burgex's goals and objectives for the next two years?
Our primary purpose is to solve the challenges of mining, as new issues arise daily in this industry. We aim to reduce reliance on foreign sources, addressing concerns like child labor and human rights. If we truly stand for our values as a country, we should prioritize domestic mining. Currently, we have 24 team members and expect to grow significantly. As a small mining consulting company, we recognize that margins can be tight, but we are committed to being flexible and responsive to our clients' needs. We are focused on doing our best in the face of any challenges that come our way. ■

> We recently completed a 10-year mine plan with over 5,000 excavations and production schedule alternatives for economic evaluation. These detailed plans and flexibility were unimaginable 30 years ago.

Dagny Odell

Owner

PRACTICAL MINING

Can you discuss key milestones for Practical Mining in 2023 and early 2024?
We are currently working on projects in Nevada, Idaho and Mexico. Most of our work is gold and silver but we have worked on base metal and industrial mineral projects. Recently, we added lithium and gemstone producers to our client list.

How has demand for your services evolved over the past year?
Our forte lies in geological modeling, mineral resource and mineral reserve estimates, mine planning, and tying these together with economic analysis. If required, we also prepare public disclosure reports either under Canadian NI 43-101 or US SK-1300 regulations. The need for these services is growing and we will continue to produce high quality results in these areas.

How have you seen mine planning evolve over the years?
It has evolved from simple ore and waste plans produced manually, to highly detailed computer assisted plans tracking many various rock types, metallurgical characteristics and even royalty positions. We recently completed a 10-year mine plan that contained over 5,000 excavations, with several production schedule alternatives for economic evaluation. These detailed plans and flexibility were unimaginable thirty years ago.

How has the labor shortage affected Practical Mining and the industry?
The labor shortage has impacted everyone in the industry. To counter this, we strive to leverage technology to produce quality results for our clients faster than in the past. We focus on increasing our client's productivity through detailed mine planning and using technologies like LiDAR to streamline processes. For example, a drone survey can map an underground mine excavation in about 10 minutes without exposing the pilot to potential hazards or interfering with mine operations.

What challenges do deeper mines pose, and how does Practical Mining address them?
Rock temperature and in situ stress increase with depth below the surface. It is not uncommon on deep mines for the heat index to exceed 100°. Mine engineers must include plans to deliver enough fresh air volume to the lowest levels of the mine to insure safe working conditions. In extreme cases quantity alone may not be enough to counter the high temperatures and cooling plants will be required. It is important to recognize the need for temperature mitigation early in the design phase of a project and adjust the design specifications accordingly.

High in situ stresses can lead to potentially fatal rock falls, pillar crushing or rock bursts. Engineers must recognize these hazards and employ the appropriate mitigation plan. This may require altering the size, orientation and sequence of extraction of mine excavations. Additional ground support may also be needed.

How does Practical Mining contribute to environmental stewardship in the mining industry?
Environmental stewardship, like safety, must be part of the overall strategy from the start. A simple example would be to incorporate reclamation plans in the design and construction of waste rock disposal facilities. Another common issue faced by many mines is identifying rock types that may be potentially harmful to the environment, determining the quantities of each that may be encountered over the life of the mine and including mitigation measures in the early design of a project. These practices help our clients achieve their environmental goals while maintaining operational efficiency.

How can mining companies stay profitable during economic changes?
Maintaining profitability starts with having the right metrics and tracking productivity, costs, and consumption rates. These factors should be built into the budget, one-year, three-year and life-of-mine plans. By closely monitoring these metrics, companies can recognize the source of cost increases and adopt appropriate measures to maintain profitability.

What does the 20th anniversary mean for Practical Mining, and how will you celebrate?
We will just keep doing what we do best: focusing on providing high-quality services to our clients. This milestone is a testament to our passion for the work and our commitment to overcoming challenges and delivering for our clients.

What are Practical Mining's goals for 2024 and into 2025?
We are working on developing internal software to streamline portions of the design workflow. Our workload is seeing an increase in merger and acquisition activities along with our planning and mineral reserve and mineral resource disclosure reporting services. We are looking forward to meeting the evolving needs of our long-term client base and adding new clients too. ■

Industry Insights: Prioritizing Climate Change Adaptation

"Investing in preventative measures upfront is essential as it can save costs in the long run. There is a shift in mindset among mining executives to consider the cost impacts of not adapting to climate change."

Kevin Martindale, Director of Business Development, **MILLCREEK ENGINEERING**

"In a rapidly changing climate, determining the right level of investment in preventative measures can be tricky, but it is necessary to anticipate potential risks. As conditions evolve, so will the strategies required to manage them effectively."

Alan Driscoll, VP, Director of Mining Services, **FORSGREN ASSOCIATES**

"Tailings management is crucial and often gets attention only when issues arise. We are building a strong tailings team to help clients adapt their designs to evolving standards. As climate change leads to more intense weather events, it is essential that we take proactive stewardship in this area."

Dennis Papilion, Executive President, Global Consulting, **AUSENCO**

"It is essential for the industry to think strategically to meet regulatory demands while incorporating long-term climate resilience. We assist clients in navigating these requirements and developing sustainable strategies that align with current and future climate scenarios."

Dustin Wasley, Principal / Mining Market Leader, **HALEY & ALDRICH**

"The mining industry is not immune to the impacts of climate change and M3 continues to affect change through the design of state-of-the-art facilities to improve emissions capture, water usage and carbon footprint."

Matthew Sletten, Vice President, **M3 ENGINEERING & TECHNOLOGY**

Image by Stephen at Adobe Stock

Contractors

Providing automated solutions to the US industry

As we have seen throughout this report, constructing a mine in Western US is no easy feat. The shift towards energy independence, coupled with recent policy shifts aimed at reducing reliance on foreign sources, has created urgency around accelerating mining projects into production. However, the retirement wave among skilled workers over the next five years could leave a significant workforce gap, stressing the importance of operational efficiency with limited resources. As inflation drives mining costs up, firms are squeezed to maximize efficiency.

The firms responsible for mine construction face additional challenges due to unique conditions in the US, explained Gareth Sheppard, chief operating officer at Master Drilling: "The US mining industry tends to offer shorter-term contracts, often just for one or two holes at a time. This is different from other regions where longer-term contracts of a year or more are common, providing better planning and stability. This difference impacts the sustainability and planning of mining operations."

There is no doubt that long term contracts provide greater benefits: "long-term relationships allow us to understand our clients, their employees, and their operations in greater detail. Familiarity helps us address their sustainability goals and operational challenges more effectively, making us a valuable partner in their long-term success" expanded Dagny Odell, owner of Practical Mining.

However, the US mining industry favors shorter-term contracts due to economic, regulatory and operational challenges. US mining firms prioritize flexibility to adapt to volatile commodity prices and stringent environmental regulations, which can disrupt projects. Short-term contracts allow companies to manage capital risk by avoiding prolonged financial commitments and focusing on specific project milestones. Labor shortages and high turnover in the industry make it difficult to maintain long-term commitments, while short-term agreements shift financial and operational risks onto contractors. These challenges increasingly drive contractors toward adopting automation as a solution.

Automation is becoming a necessary investment, particularly in the US and Canada, where clients—especially large-scale operators—are recognizing its long-term benefits, noted Eric Smith, managing director of Cementation Americas, a firm serving both regions. "Both US and Canadian clients, particularly larger ones, demand high levels of sophistication from contractors and understand that new technology may require upfront investment but yields long-term payoffs."

The payoffs of autonomous technology are indeed substantial, said Darrell White, group executive – Americas at

Image courtesy of Idaho Strategic Resources

Thiess: "Autonomous technology is a significant focus as it increases efficiency, leading to lower consumption of diesel and, ultimately, fewer emissions. It also reduces safety risks for workers during drilling and blasting activities and when operating machinery. We are increasingly seeing mines trialing and adopting autonomous technologies."

Mining Magazine Intelligence's Automation Report provides tangible evidence of these benefits. One study found that a Caterpillar automated truck model drove a 30% improvement in productivity, reduced operating costs by 73%, and significantly lowered emissions. Epiroc's automated drill trial further illustrated automation's advantages, with equipment utilization rising from 45-50% to 80%, alongside a 30% increase in productivity. In addition, automated loaders showed a 24% reduction in operating costs, with daily tons per loader increasing by 23%, and loader utilization rising to more than 22 hours/day due to automation. These compelling results of automation are driving market growth, with projections indicating the mining automation sector could expand from US$2.2 billion in 2017 to US$4 billion by 2026, as reported by Statista.

Underground automation

Connectivity has historically been a significant bottleneck in automating underground mining operations. Traditional communication systems, such as Wi-Fi, often struggled with the complex and evolving layouts of underground mines, leading to unreliable connections and limited coverage. This unreliability hindered the deployment of automation technologies that require consistent and robust communication networks. "Fortunately, underground internet connectivity is becoming increasingly common, facilitating data flow and timely responses," said Smith.

Advanced communication technologies, especially 4.9G/LTE and 5G networks, are beginning to resolve these issues by providing improved coverage, higher data transfer rates, and lower latency, all of which make these technologies more suitable for demanding underground environments. This shift is enabling innovations in underground automation.

Lok Home, president of Robbins, said: "Our goal is to automate machines and reduce the number of people needed underground, aiming to minimize human presence per kilometer or meter of tunnel."

The machines he is referring to are Tunnel Boring Machines (TBMs), which can be three to four times quicker at tunnel creation than the traditional drill and blast alternative, honed Home, a company that invented TBMs for civil industry but is adapting this technology to mining. "These machines offer several advantages: enhanced safety, reduced underground workforce, and TBMs act as primary crushers opening better options for efficient rock transport. The rock comes away from the tunnel face already crushed, ready to be conveyed up shafts or vertical conveyor belts."

Automation continues to expand within the industry, with companies like Small Mine Development benefiting from the technology. "We employ autonomous mucking and computerized long-hole drilling, where machines execute engineered drill plans. Face drilling is becoming more automated with these systems although human input remains crucial due to varying geological conditions," said Keith Jones, the general manager.

While automation can reduce the need for human intervention, the technology still relies on human oversight for accountability and safety, as Smith explained: "While the machines make more autonomous decisions, each one still operates under human supervision for accountability and safety."

The remote control enabled by automation has been beneficial in the raise boring space said Sheppard: "This allows us to remotely control equipment from the surface or anywhere in the world, provided there is adequate internet connectivity."

Collaboration between contractors and OEMs is essential in delivering automation benefits. "We rely heavily on the latest equipment technology from OEMs and dealer partners for specialized support. A prime example is our Komatsu mining fleet we recently procured in Arizona, equipped with the iVolve system. This system provides real-time production data, enhancing operational efficiency, safety and maintenance monitoring remotely from our Indiana office," said Keaton Turner, founder, president and CEO of Turner Mining.

Adoption

Autonomous technology adoption is poised to grow in North America. White predicts: "We see a tremendous opportunity for autonomous technology adoption in both North and South America. The South American market is more mature, with more functioning autonomous installations, and almost all OEMs and technology providers operate on the continent. North America has been lagging somewhat in adopting autonomous technologies, but we are seeing mines transforming into the autonomous space."

Darrell White
Group Executive - Americas
THIESS

> "Autonomous technology is a significant focus as it increases efficiency, leading to lower consumption of diesel and, ultimately, fewer emissions. It also reduces safety risks for workers during drilling and blasting activities and when operating machinery."

Automation efforts in other markets have paved the way for the US, as Jon Torpy, general manager and president at Epiroc USA, observed: "Technology has matured, and companies better understand its business benefits, making adoption easier. US companies are increasingly ready to embrace automation, especially in the last two to three years, having observed and learned from automation's evolution in Australia."

By integrating automation, the industry can offset workforce challenges, control rising operational costs, and enhance safety. As the US mining sector continues to embrace automation, it can anticipate improved productivity and a more sustainable approach to resource extraction. ■

Eric Smith

Managing Director
CEMENTATION AMERICAS

> We are optimistic about long-term opportunities in both Ontario and the Western US. Our strategy centers around developing and maintaining capacity and preparing for when projects start flowing in.

How has Cementation Americas performed in 2024?
In 2024, Cementation Americas had an excellent year, maintaining a strong safety record and exceeding revenue and profitability targets. Ontario continues to be a robust market, and we have held solid projects there, with several exciting developments in the pipeline. Despite the positive trajectory, we are still not seeing the expected volume of greenfield project offerings. While commodity prices are favorable, which typically drives mining investments, market uncertainty remains. We are hopeful that the market will stabilize post-election, allowing companies to plan their capital expenditures more confidently.

We recently completed a major shaft project in Ontario, which was the deepest ever in the Sudbury Basin. This project was technically challenging and required extensive engineering. Additionally, we wrapped up a major development project in the Western US, which we were involved in for over 11 years.

Developing an increasingly skilled local workforce remains a priority for us, benefiting both the client and the community even after our work concludes. We are also excited to be back in Nevada after about five years, working on a new project for a large client, and we are optimistic about future opportunities in that region.

What challenges are contractors facing in 2024, and how does Cementation Americas manage risk?
At Cementation, we prioritize building meaningful and lasting partnerships rather than transactional relationships with clients. This approach allows us to adopt a truly collaborative approach to project planning, inevitable challenge mitigation, and proactive risk management. Together, we develop a comprehensive risk budget that covers both time and money to prepare for contingencies, particularly in complex projects such as underground excavation.

What are some of the key factors driving the rising cost of mining?
Inflation has undoubtedly impacted mining costs across North America, especially in terms of labor and materials. Skilled employees are crucial to nearly everything we offer clients, so we prioritize paying competitive wages and benefits while being mindful of project budgets. We aim to be an employer of choice and maintain a progressive outlook on the employee experience and strives to supported by competitive pay structures, including project retention payouts, a unique benefit that rewards employees for their commitment to long-term projects, and leading-edge benefits packages.

On the materials side, it is challenging since we have less control over these costs. We attempt to mitigate these pressures by ordering materials in bulk whenever it's feasible.

How is Cementation Americas implementing data and digitization to improve project efficiency?
We have partnered with a software provider in California to develop customized reporting and data-tracking solutions central to our short-interval control system. We estimate labor, materials, equipment needs, and expected productivity when budgeting. As work progresses, we track performance against these estimates, allowing us to pinpoint areas for improvement quickly. This data-driven insight helps us address potential issues before they impact the entire project schedule. Tablets are available on every piece of equipment, and employees use them to log activities, downtime, and task durations and more. This data is uploaded in real time, enabling us to take swift action. Happily, underground internet connectivity, once rare, is becoming increasingly common, facilitating data flow and timely responses.

We have also started using autonomous equipment. While the machines make more autonomous decisions, each one still operates under human supervision for accountability and safety. This setup eliminates exposure to dangerous energy and significantly reduces downtime, leading to increased utilization and productivity rates.

How do you intend to grow in Ontario and Western US markets?
This year will likely to be more challenging than the last in terms of keeping our project pipeline full and securing revenue. However, we are optimistic about long-term opportunities in both Ontario and the Western US. Our strategy centers around developing and maintaining capacity and preparing for when these projects start flowing in. While it is tempting in lean times to cut costs or accept lower-margin projects, we will remain focused on sustainable pricing to avoid long-term issues. We are also working diligently improve efficiency and cost-effectiveness while taking this time to further develop our employees—something difficult to focus on during nonstop projects. ■

> With a growing demand for contract mining among junior miners, we see immense opportunities in the Western and Southwestern regions, spanning Arizona, Nevada, New Mexico, Colorado, Wyoming and Idaho.

Keaton Turner

Founder, President and CEO
TURNER MINING GROUP

What is driving growth at Turner Mining?
Turner Mining Group has been in a significant growth phase, both in corporate structure and operations. We added a new multi-year turnkey mining operation in Soda Springs, Idaho, and were recently awarded a six-year copper mining contract with Origin Mining in Arizona. Over the past two years, we've been engaged in a heap leach mining campaign for Origin and have since expanded to on-site civil infrastructure projects in preparation for the new mill commissioning and mining ramp up activities in early 2025. Our scope of services, which are set to commence again in early 2025, includes drilling, blasting, mining of waste and ore, along with stockpile management, pioneering activities, and other ancillary activities.

Additionally, we have expanded our services to deliver material processing and contract mobile crushing nationwide for various mining customers. Through this new service offering, we have also added multi-year turnkey aggregate and industrial sand operations in Texas. It has been a busy period, and we are fortunate to continue our growth path. Witnessing the diverse materials, we produce across America is truly rewarding and we are incredibly proud of our contributions to the mining industry.

Which services are driving the demand for Turner Mining?
We have expanded our focus on metals, particularly precious metals such as gold and silver, and essential base metals such as copper and molybdenum, which are crucial to domestic supply chains. We have seen a growing demand for contract mining among junior metal mining companies. We see immense opportunities in the Western and Southwestern regions, spanning Arizona, Nevada, New Mexico, Colorado, Wyoming and Idaho.

Our strategy involves offering comprehensive supply chain solutions. Our team is equipped to manage everything from pre-stripping, drilling, and blasting to ore hauling, load-haul-dump operations, and stockpile management in a turnkey fashion. Our goal is not just moving dirt; we focus on adding value by fully integrating into our client's operations reducing risk, capital expense, and offering flexible scalability. This approach also includes staffing our customers operations through Turner Staffing Group, or utilizing our own equipment for mining and processing, making us a more appealing option than assembling various smaller contractors.

What is the importance of integral solutions in the industry?
Being vertically integrated provides control over the quality of employees we bring on site, the training they receive, and the culture we instill. We are proud of our values and mission, and when working with subcontractors, there can often be a misalignment in values. When multiple contractors work for one owner, it can also lead to internal conflicts or finger-pointing when one contractor's scope or schedule affects the performance of another contractor downstream of those activities.

Can you talk about Turner Mining's approach to labor?
At Turner Mining Group, we do not believe in the labor shortage. This year, we are on track to receive over 20,000 employment applications, a significant increase from last year's 11,000. This surge reflects our robust social media efforts to not only promote our brand but also highlight opportunities within the mining sector, particularly in the USA. We have successfully recruited from all 50 states, filling roles from operators and project managers to geologists and IT professionals. Our proactive stance extends to Turner Staffing Group, an experienced recruiting and staffing firm that provides tailored hiring solutions to the top mining and aggregate producers nationwide.

Investing in our brand on platforms like Instagram, LinkedIn, YouTube, and TikTok has also enhanced our visibility and highlights our commitment to showcasing the opportunities and challenges of mining, attracting passionate individuals eager to contribute to our industry's growth and success.

What are Turner Mining's goals?
Our objectives span various metrics like growth and revenue targets, as well as exploring new verticals. However, my primary focus is on developing our leadership teams and fostering high-functioning dynamics. We welcomed Jeff Turner as our CFO, bringing invaluable experience from the heavy civil industry. Tucker Jensen, our new director of operations, also brings expertise from a major copper mine, driving our shift towards data-driven decision-making. Our strategy centers on cultivating top-tier teams. This people-centric approach underscores our belief that success in mining hinges on mastering the human element, both in the field and behind the scenes. ■

> We understand each client's goals and adapt our strategies accordingly. At times, we may focus on development to access ore bodies, while other times, we concentrate on production to meet annual goals in ounces.

Keith Jones

General Manager

SMALL MINE DEVELOPMENT (SMD)

Can you detail SMD's evolution?
In late 2022, we were at our peak. We faced challenges in 2023 due to the shutdown of Jerritt Canyon and Idaho Cobalt. However, we managed to stabilize our operations, focusing on major clients, particularly Nevada Gold Mines and I-80 Gold, and some copper projects. Despite challenges, we have had a stable year and remain focused on the underground mining space in the US.

How has automation advanced in the underground sector?
We employ autonomous mucking and computerized long-hole drilling, where machines execute engineered drill plans. Face drilling is becoming more automated with these systems although human input remains crucial due to varying geological conditions.

To tackle workforce challenges, we established a training center equipped with ThoroughTec's Cybermine simulators for underground haul truck operators and muckers. This simulator allows trainees to practice in a safe environment, experiencing real-world scenarios, including emergencies, without any risk.

Our primary focus is on safety; we develop a safety culture through comprehensive onboarding and convergence training. Although we have only used the training center for about seven months, we are already noticing positive changes in the trainees.

How do rock characteristics change and the importance of understanding them?
The rock varies significantly from state to state and across different regions, such as the basin and range compared to the Rockies, affecting rock composition. We work with openings averaging 300 square feet. Our team drills holes for explosives and rock bolt installations, gaining insights into the rock's characteristics through the drilling process. They might encounter hidden features, like a clay seam just three feet away, which are not visible. Their expertise allows them to decide on the need for additional ground support or adjustments based on what they uncover while drilling. Understanding the dynamic nature of rock characteristics is crucial for our safety and success, and our miners' adaptability. Geotechnical engineers, often referred to as "rock doctors," play a key role in our operations.

How does SMD approach sustainability and minimize its environmental impact?
We regularly conduct emissions-based exhaust testing as part of our preventative maintenance program. This involves measuring emissions parameters like carbon monoxide and nitrogen oxides using a tailpipe analyzer, which helps diagnose engine issues.

These tests have become essential for our routine maintenance and are complemented by other initiatives to minimize our environmental footprint. For example, we recycle used oil for road construction and use it for heating at operations, ensuring no oil is disposed of offsite.

How has becoming 100% employee-owned shaped company culture?
In 2020, we transitioned to a 100% employee-owned company, which coincided with COVID-19. We initially anticipated this change would positively impact our long-term employees, but we faced increased turnover due to broader labor market trends. While our Employee Stock Ownership Plan (ESOP) aims to retain employees with five to 15 years of service as a long-term retirement benefit, heightened turnover post-COVID has diluted its impact, particularly among newer hires who may not engage with these long-term benefits.

Despite these challenges, we believe the ESOP has significant potential for employees committed to a long career with us. We have prioritized creating a work environment where employees feel valued. My management team, especially the superintendents, genuinely care for our staff, which helps foster a pleasant workplace.

What are the company's plans?
Our priority is excellent customer service and meeting client needs. Predicting future job opportunities is challenging due to market fluctuations. Recent discussions on cobalt indicate a potential shift towards a two-tiered pricing system, addressing environmental and ethical concerns, especially regarding practices in China and the DRC. Additionally, we have seen market shifts in palladium, with companies like Stillwater reducing operations due to price drops, which also impacted on our cobalt operations. This highlights the industry's uncertainty, so we aim to excel in our core business and remain aware of underground mining trends.

Our approach starts with understanding each client's goals and adapting our strategies accordingly. At times, we may focus on development to access ore bodies, while other times, we concentrate on production to meet annual goals in ounces. This focus can shift throughout the year based on changing circumstances. Our role is to collaborate closely with clients, adapt to their planning processes, and help them achieve their objectives. ■

Gareth Sheppard

COO

MASTER DRILLING

What are the key highlights from 2023 and early 2024?
We secured our first contract in Nevada with an underground gold mining company. We completed two projects: one involving two holes and another with eleven holes. We faced a steep learning curve due to the different geology in Nevada compared to other regions. Master Drilling's revenue increased by 17% from last year, and our pipeline is robust at approximately US$600 million. We invested in new technologies, including a revolutionary shaft boring system, which is currently being tested in South Africa.

How does Western US mining differ from other regions where Master Drilling operates?
The US mining industry tends to offer shorter-term contracts, often just for one or two holes at a time. This is different from other regions where longer-term contracts of a year or more are common, providing better planning and stability. The geology in the Western United States, particularly with softer rock types, differs from other areas like the Sudbury Basin, where rocks are very hard and abrasive.

What innovations is Master Drilling using to boost productivity of mining operations?
We focus on integrating remote control and automation technologies in our core raise boring operations. This allows us to remotely control equipment from the surface or anywhere in the world, provided there is adequate internet connectivity. A significant challenge we face is ensuring the infrastructure supports these operations.

How does Master Drilling ensure that its operations minimize environmental impact?
Our rigs are primarily electro-hydraulic, which means they draw power from the grid rather than relying on diesel, except in rural areas without grid access. Regarding water usage, we employ a closed-loop system that recirculates water rather than letting it flow into the environment. We use water tanks to manage this and ensure solid removals are handled similarly to tunnel boring operations. ■

Lok Home

President

ROBBINS

Can you introduce Robbins' presence in the mining industry?
Robbins is known for raise boring machines. Historically we supplied raise boring machines to numerous mines in the Western US, including mines owned by Hecla Mining.

We have made efforts to introduce mechanical excavation for tunnels and have been active in shaft drilling. Notably, we have had tunnel boring machines working in the Stillwater mine in Montana. A few years ago, we had Robbins Tunnel Borings Machines (TBMs) operating for mine development in Colorado and Arizona. We are currently involved in a few projects, primarily in the study stages to take advantage of the proven high rates of monthly advance.

What are recent trends in the Western USA?
There will be a shift from open pit to underground mining. The capital required for these deeper mines is substantial, running billions of dollars, and big mining companies are interested in speeding up development of such projects.

If companies can reach ore bodies sooner using mechanical excavations, TBMs and mechanical blind-shaft bores they will likely adopt these methods. Mechanical excavations with TBMs are three to four times faster than drill and blast methods. However, adapting these machines to mining is a challenge. The mining industry must adjust their plans to incorporate these technologies, and we must modify our machines from civil to mining applications.

We are conducting studies worldwide to mine ore with tunnel boring machines. These machines offer several advantages: enhanced safety, reduced underground workforce, and TBMs act as primary crushers opening better options for efficient rock transport. The rock comes away from the tunnel face already crushed, ready to be conveyed up shafts or vertical conveyor belts. We supply horizontal and vertical conveyor systems and believe that vertical muck conveyance up to 1,000 to 2,000 meters is feasible in the future. ■

EQUIPMENT, TECHNOLOGY AND SERVICE PROVIDERS

> Decarbonization, like automation, cannot be achieved through a mere transactional relationship—it requires a partnership with a long-term vision.

Jon Torpy
President and General Manager
EPIROC USA

Image courtesy of Freeport-McMoRan

Decarbonization: Movement and Energy

How OEMs, Material Handling and Power Management firms are slashing emissions

The challenges to achieving decarbonization road maps in the mining industry need to be tailored by operation, addressing the key pillars of decarbonization: energy efficiency, hybrid power, microgrid integration, alternative vehicles, mine design, and process adaptation to alternative energy sources. OEMs, equipment component manufacturers, power management and material handling firms are working diligently to find ways to reduce emissions.

De-fleeting carbon footprints

The mining fleet is one of the primary sources of on-site GHG emissions. For surface mines, mobile mining equipment can account for up to 30% of GHG emissions. This rises to 80% for mines lacking onsite smelting or refinery facilities. Large mining trucks alone represent more than 50% of a surface fleet's emissions. Electrifying a single truck reduces emissions to save 3,000 m2/y of artic ice, eliminates the same amount of CO2 it takes 46,000 trees to absorb, and lowers oceans CO2 absorption by 1,000 t/y, according to research by ABB.

"While electrification is on the horizon, the transition in the US is likely to be slower compared to other markets due to concerns about battery life, infrastructure investments, and the need for companies to evaluate the best return on decarbonization strategies. Some companies may prioritize other technologies, like automating existing fleets to achieve carbon footprint reductions," said Jon Torpy, general manager and president at Epiroc.

Decarbonization through automation does seem to be the priority, as exemplified by Arizona-based Freeport-McMoRan. In 2023, the miner approved a new project to convert the fleet of 33 haul trucks at the Bagdad operation in Arizona to become fully autonomous by 2028. Emissions from haul trucks are projected to decline due to reductions in idle time and increased efficiency. Idle time is estimated to decrease by 10,000 hours, according to the firm's Climate Report. Full autonomy is also an important step to electrification, explained Joshua Olmsted, president and COO, Freeport-McMoRan Americas, "As haulage electrification progresses over the next 5 to 10 years, managing an electric fleet will introduce complexities like charging schedules and logistics. Autonomous systems will streamline this transition, making electric haulage more feasible and efficient."

Automation will play a major role no matter the energy source, echoed Diederik Lugtigheid, general manager of surface mining automation – haulage at Epiroc: "Automation will be key in managing battery, trolley, or hydrogen-powered trucks, ensuring their connection to power grids and

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Image courtesy of Michelin

Jon Torpy

President and General Manager

EPIROC USA

> Success comes when OEMs and customers collaborate closely. Whether it involves reducing fuel consumption, offering purely electric solutions or utilizing digital tools, OEMs can offer extensive support.

What are Epiroc's developments in the US market?
As part of our strategy for 2022 and 2023, we made targeted investments in key markets, with a focus on mining in Arizona and Nevada. Although we have always had a presence in Elko and Tucson, we decided to enhance our efforts. Epiroc Elko houses our Competency Center for Underground Mining, with increased investments in training, application expertise, and parts to support underground equipment rebuilding. Our Tucson location has been upgraded to the Competency Center for Surface Mining, emphasizing expertise in surface equipment, technology training, and parts support for both Arizona and other areas. Both Elko and Tucson will still service Underground and Surface Mining in their regions, but each will also have enhanced specialties in Surface and Underground mining respectively with these investments. We boosted our commitment to parts and service nationwide by optimizing logistics and stocking parts closer to customers – something that is a continued focus for Epiroc USA.

What recent technology or equipment launches you would like to highlight?
The Boltec M10 is particularly exciting. Its pump resin bolting solution has generated significant interest among our underground customers due to its ease of use, cleanliness, speed, and reliability. Customers describe it as an exceptional piece of equipment. The Boltec M Battery comes with a battery-electric driveline and is also generating excitement in the region as a hybrid alternative. Another highlight is the Pit Viper line of drills, especially with the introduction of the Automatic Bit Changer, which improves both safety and productivity. The Pit Viper was designed for a lifespan of up to 20 years. Through the RCS system it progressively increases productivity as we integrate new digital and autonomous solutions over its lifespan. We also continue to expand our aftermarket capabilities and with our Pit Viper overhaul program we have extended drill life to over 100,000 frame hours in many cases.

How do Epiroc's recent acquisitions positively position the company in the automation space?
Our focus after each acquisition is to align their technologies with our customers' needs. For example, our investment in ASI Mining extended our automation capabilities beyond traditional equipment to include haul trucks, light vehicles, and other assets. Acquisitions like RCT bolster our automation offerings in surface and underground operations. The acquisition of Mernok gives us the ability to offer Level 7-9 collision avoidance which could be of great value to our customers in the US.

How has the labor shortage affected the Western U.S. market?
The labor shortage is having a major impact on the mining industry, affecting everything from sales to equipment maintenance and overall operations. The shortage also presents an opportunity to improve diversity with a need for broader recruitment efforts to meet the labor demands.

How does battery electric vehicle adoption in the Western USA compare to other markets?
There is interest in electrification, but the US is advancing more slowly compared to markets like Chile, Australia and Canada. For underground mining, there is general agreement that electrification is part of the future, but US customers are not fully convinced that current solutions meet their needs. They are waiting for further developments. Hybrid solutions, such as our Boltec M SG Battery bolter and MT66 S eDrive hybrid truck, are expected to be more popular in the U.S. than fully electric options.

What role do OEMs play in helping to decarbonize mining operations?
Decarbonization, like automation, cannot be achieved through a mere transactional relationship—it requires a partnership with a long-term vision. Success comes when OEMs and customers collaborate closely. Whether it involves reducing fuel consumption, offering purely electric solutions, or utilizing digital tools to measure the impact of these efforts, OEMs can offer extensive support. One challenge for customers is accurately measuring the impact of their decarbonization efforts, and that is where our digital solutions can come into play to help quantify it.

How does Epiroc prioritize people?
We believe that a strong people and culture strategy sets us apart and will improve as we continue integrating our acquisitions in the US. We are thrilled with the recognition of being named a Top Workplace by USA Today in 2024. This accolade, based on employee feedback, validates the significant effort we have invested in building a strong, supportive culture. ■

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energy systems is seamless. Automation and electrification need to work together to help the industry meet sustainability goals."

In the US, hybrid solutions provide an emission reducing alternative, said Torpy: "Hybrid solutions, such as our Boltec M SG Battery bolter and MT66 S eDrive hybrid truck, are expected to be more popular in the US than fully electric options."

Fleet emissions can be reduced without investing in new equipment. Tire manufacturing firms Michelin and Bridgestone are aiding this effort. "We introduced the Michelin XDR 4 SPEED ENERGY, designed to improve fuel efficiency by 3.6% compared to the Michelin XDR 250 C tire, savings about 5,300 gallons/y of fuel and reducing CO2 emissions by 2,600 t/y for a fleet of 50 trucks," said Adam Murphy, senior vice president, Michelin Global Mining.

With their new Smart On-site initiative, Bridgestone increases resource productivity, lowering emissions and reducing downtime. Utilizing data and predictive AI-based algorithms, Bridgestone "supports customers in potentially reducing the number of trucks needed for operations and increasing haul cycles, which leads to a more efficient operation overall", said Rob Seibert, president, Bridgestone Americas.

Trucks, or course, are not the only material handling method, and, given shifts in the Western US mining sphere, they are not the most efficient solution either. Steffen Gjorvad, president of Takraf USA, elaborated: "Emissions from trucks are significantly reduced by using conveying systems, and the logistics of moving trucks in tunnels is complicated. We see more applications using conveyors due to their efficiency, requirement for higher volumes due to decreasing ore grades and the trend to move from open-pit mines to underground operations."

Energy: Decarbonization's capital

Decarbonization is expensive; the combined capital expenditure of the top 19 mining companies is expected to reach US$71.0 billion in 2024, rising 10.6% compared with 2023, with many citing decarbonization as a leading cause of increase. BHP, for one, will allocate US$4 billion towards decarbonization efforts by 2030. Energy has become the industry's most significant form of capital; "Energy costs comprise 15-30% of a mining company's expenses, with a significant portion of that being electricity. Producing a ton of copper ore requires 30-100 kilowatt-hours of energy, depending on the mine", said Willem Van Twembeke, CEO of Inkia Energy.

Traditional conveying systems can account for 80% of a mine's energy consumption, increasing Scope 3 emissions. Takraf utilized innovation through partnership with ABB to introduce gearless drive technology, which reduces energy consumption 6-10% and reduces direct emissions: "A study showed that CO2 emissions compared to diesel truck engines for the same copper production volume were reduced by 66% when using gearless drive technology," highlighted Gjorvad.

At Freeport-McMoRan's Chino mine, Bosch Rexroth replaced aging gearboxes and electric motors with advanced drive systems. Ashok Amin, segment manager Americas of bulk material handling, explained the benefits: "Replacing a single 1,500 HP drive with a modular system of three 300 HP motors enables us to shut off motors during lower demand periods, resulting in substantial energy savings. This modular approach enhances operational efficiency and newer technologies are specifically designed to reduce energy consumption."

As energy costs climb and mining operations increasingly require deeper resource extraction, optimizing electrical efficiency is essential. Peter Rowland, Canada solution sales manager at Yokogawa, echoed the sentiment: "It is all about efficiency and optimization now, whether in production, safety or environmental aspects."

Microgrid utilization is increasing in the industry as a steppingstone for resilient, cleaner operations. Marc Elliott, marketing director of mining, metals and minerals at Eaton elaborated: "Our microgrid solutions enable customers to minimize reliance on carbon-intensive energy sources. By facilitating the transition to cleaner energy options and improving overall energy management, we help clients become more resilient and less dependent on fossil fuels."

Digital decarbonization

When it comes to energy efficiency, digitalization allows for better management of energy consumption, and asset efficiency. Yokogawa's Collaborative Information Server allows operations to remotely monitor data from a mining opera-

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Steffen Gjorvad

President

TAKRAF USA

> We expect many projects we have been involved in at the feasibility or budget level to move forward in 2025.

What trends is TAKRAF seeing in the market?

We have seen an increase in aftermarket support, primarily for inspections, spare parts, and smaller engineering projects. We have been involved with certain clients providing feasibility support, pricing, and have completed a couple of paid studies for projects in the Western US. Additionally, we continue to work with some of our client base for engineering support on smaller items.

The large mining projects seem to be pushed out to 2025. Some reasons for that are mostly due to geopolitical environments and budgeting reasons. There are a lot of projects being planned, but we have not seen those come to fruition yet.

So, 2023 and 2024 have been somewhat slow, but we expect business to increase in 2025 and 2026.

Can you highlight a few projects TAKRAF has worked on, with a focus on the Western USA?

We have worked on many projects for clients requiring the movement of material from underground to the surface. Currently, we are working with a company for a 6.6 km conveyor going from underground to the surface using hanging conveyor modules. These modules provide maintenance access underneath the conveyor and also reduce the footprint and emissions compared to other haulage systems. This project is in Mexico, but we received the order from a company in Arizona.

How will TAKRAF and ABB's partnership deliver a sustainable and resource-efficient future?

We are one of only two companies globally with active references on the gearless conveyor drive technology in operation. We have collaborated with ABB on various high-capacity and technical gearless drive projects in the past.

Notably, we delivered the world's most powerful belt conveyor system for Codelco's Chuquicamata in Chile. This mega project features an 11,000 t/h conveying system moving copper ore from underground to an above-ground processing plant using gearless conveyor drive technology. The system includes two large underground conveyors, each consisting of four 5 MW gearless synchronous motors, transporting crushed ore from an underground storage bin to the surface through a 7 km tunnel with a 1 km vertical elevation. There is a 6 km overland conveyor on the surface with three 5 MW gearless synchronous motors. Total drive power for the entire system including smaller feeder conveyors and such totals 58 MW. This system reduces the need for gearboxes, increasing efficiency, reliability, and reducing maintenance. Further advantages include a reduction in the drive system footprint and emissions. A study showed that CO2 emissions compared to diesel truck engines for the same copper production volume were reduced by 66% when using gearless drive technology.

What sustainability initiatives does TAKRAF have?

We adopt dry stack tailings (DST) to enhance safety and environmental practices, being one of only two firms globally providing the entire DST value chain. We support resource conservation through advanced maintenance and recycling practices, such as our tungsten carbide overlays for sizers. Our gearless drive technology and intelligent maintenance solutions reduce energy consumption and wear. This year, we will publish our first sustainability report, underscoring our commitment to these goals.

How has the atmosphere surrounding technological advancement changed in recent years?

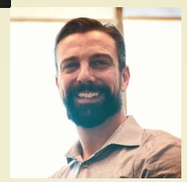
The mining industry is conservative, and most processes are based on deterministic rules rather than model-based approaches. However, there is a shift towards using artificial intelligence (AI) due to the increasing amount of data available. We are partnering with outside companies to provide digital twins for better system predictions and detections. We also offer 3D models of stockpiles and chutes for fully automated systems and inventory tracking. The trend is also towards fully automated systems, especially in material handling for stockpiles.

What objectives does TAKRAF have for 2025?

We expect many projects we have been involved in at the feasibility or budget level to move forward in 2025. The demand for copper is not going away, with significant contributions from Chile, Arizona, and Nevada.

On the process side, we are already seeing movement, with a number of requests for quotes for our DELKOR thickeners, especially in Arizona and Nevada. We will continue to focus on providing customers with our X-TREME class sizers for hard rock applications, such as those earmarked for a large iron ore project in Guinea. Additionally, we see potential growth in our aftermarket services. ■

GH



PR

> Our goal is to stabilize mining operations by managing fluctuations in material quality and throughput with our control systems.

Greg Heiges and Peter Rowland

GH: Mining Business Development Manager
PR:Canada Solution Sales Manager
YOKOGAWA

What opportunities has North America presented Yokogawa?
GH: We have some very exciting opportunities with one of our global customers which operates throughout the Western USA and the eastern part of Canada. We are installing our Collaborative Information Server within their operations, and it has been quite a successful implementation. This server allows them to gather information all in one space for actionable results. By integrating the handling of all kinds of data from plant equipment, devices, and systems, this solution facilitates the optimized management of production activities across an entire enterprise.

What mining services do you offer, and which have been most in demand recently?
GH: Our goal is to stabilize mining operations by managing fluctuations in material quality and throughput with our control systems. We address the natural peaks and valleys in mining by understanding and adjusting for variations in material to ensure consistent and efficient operations.

PR: Yokogawa offers a complete range of solutions from sensors to boardroom management, all of which are essential for mining operations.

How is the shift from industrial automation to autonomy progressing in North America?
PR: The shift from industrial automation to autonomy is accelerating. For instance, trends in Chile will influence North America and the rest of the world. We share advancements and insights across regions; they are supported by tools such as the Collaborative Information Server, which provides remote data access, benefiting both us and our customers. Many of our users are transitioning to autonomous operations across broad geographical areas.

GH: As we move from automation to autonomy, we offer customers flexible engagement levels, addressing human capital challenges in mining. Operators can work remotely rather than on-site or fly-in/fly-out. Our Collaborative Information Server allows real-time global data access, such as monitoring a US plant from a remote operations center in Australia, ensuring visibility into safety, production, and performance.

How is Yokogawa ensuring cybersecurity?
PR: With the rise of autonomy, cybersecurity has become essential. As the value of information grows, so does the need for robust security. The cyber threat landscape has certainly changed and is a key topic in all customer discussions. We offer a comprehensive range of cybersecurity solutions and services, including security operations centers (SOCs), which are rooted in a sound risk management strategy.

How does Yokogawa ensure safety in mining with current labor shortages?
GH: First, we are adopting robotics in dangerous environments through our Yokogawa platform, Robotics Management Core, integrated with Collaborative Information Servers for data collection. We also offer safety platforms for our distributed control systems, with safety integrity levels from SIL 2/3 to SIL 4. Our work platforms support safe entry and process execution with electronic safety checklists.

PR: We are enhancing safety by partnering with or acquiring technologies that prioritize safety, such as robotics in hazardous areas. The advancement of technology to improve safety and efficiency is a major goal for us and our customers, making our solutions increasingly popular.

How does Yokogawa view the future of mining?
PR: Technological advances are allowing Yokogawa to deliver top-tier products and services globally, from sensors to boardroom solutions, across various industries including mining.

GH: Yokogawa's co-innovation approach involves actively engaging with customers to understand their needs. For the mining and metals industry, our solutions enhance safety and support remote work, which are crucial for maintaining a safe working environment. Mining will continue to be vital, whether for rare earth elements or battery minerals, and we are excited to be a part of this essential industry.

What are key objectives for Yokogawa in North America?
PR: Looking to the future, technology will keep advancing at an ever-increasing pace. This progress in industrial control technology allows us to enhance our services globally, with our products accessible in Eastern and Western Canada, as well as the US. Our goal is to co-innovate with customers to continually improve.

GH: Yokogawa's growth in North America's mining and metals sector benefits from our global network. I collaborate with colleagues in Australasia and South America on shared customers and applications, introducing these solutions to our US operations. ■

Adam Murphy

Senior Vice President
MICHELIN GLOBAL MINING

What innovations did Michelin release at MINExpo 2024?
We introduced the Michelin XDR 4 SPEED ENERGY, designed to improve fuel efficiency by 3.6% compared to the Michelin XDR 250 C tire, saving about 5,300 gallons of fuel and helping to reduce CO2 emissions by 2,600 t/y for a fleet of 50 trucks. This efficiency increase is designed to significantly extend fuel or battery life and support customers' carbon-reduction goals. We launched the world's largest radial tire, the 70/70 R57, specifically designed for the largest loaders in mining operations. Weighing 6 t, this tire helps to enhance productivity by allowing loaders to operate 3x faster than the previous bias-ply tire.

We introduced our 'Better Haul Roads' service, broadening our role beyond tire manufacturing to address customer challenges related to road conditions in mines. We provide tailored recommendations for road design and upkeep, helping customers reduce tire damage, enhance fuel efficiency, and minimize CO2 emissions.

What opportunities does the Western US mining sector present Michelin?
We are bullish on mining in the US. While growth in mining globally looks promising, we project nearly double the growth rate in the US and Canada compared to global averages over the next two decades.

How is Michelin advancing its internal sustainability goals?
By 2030, Michelin will have pushed the average renewable and recycled content of its tires up to 40%. In 2050, that figure will be 100% for all of its tires without any adverse effect on tire performance, an ambitious but critical goal for us. Through a partnership with Bridgestone, we are establishing a circular economy, particularly in areas like Carbon Black. We are also taking steps to reduce carbon and water usage across operations, logistics, and manufacturing processes. ■

Rob Seibert

President, Off The Road: North America
BRIDGESTONE

What innovations did Bridgestone launch at MINExpo?
The MasterCore line is designed for increased performance and productivity in the mining industry. We showcased the new MasterCore 59/80R63 MVREV and the MasterCore 53/80R63 MVZTB, which reflect our commitment to application-specific tires tailored for different environments, like hard rock operations and traction needs.

We also debuted two new tires for the underground hard rock segment, the VMMS and VMDL. These new additions to our subterranean portfolio utilize the latest technologies to enhance durability, improve traction, and maximize performance in the most challenging underground mining environments.

The centerpiece of our booth was our new Smart On-site program. It combines our premium tires, digital solutions and the expertise of our team to bring greater levels of connectivity to operations so our customers can Move More with Less.

How does Smart On-site help customers enhance productivity and reduce downtime?
Our iTrack system enables real-time monitoring of tire temperature, pressure, and other data, essential for providing insights into tire performance and overall operational efficiency. Smart On-site extends beyond monitoring basic metrics. We are also developing predictive algorithms that utilize customers' operational data in conjunction with ours, helping us optimize equipment utilization and availability, leading to better operational efficiency. By integrating this data, we support customers in a variety of ways including potentially reducing the number of trucks needed for operations and increasing haul cycles.

What sustainability initiatives does Bridgestone implement internally?
We aim for 100% sustainable materials in our tires and 100% carbon neutrality by 2050.

We implemented several methods across our supply chain to reduce emissions including leveraging rail transport instead of trucking to Western Canada, which led to a reduction of 200 t/y of CO2 emissions. Our 2030 goal is to reduce Scope 1 and 2 emissions by 50%. ■

90 >>

tion, allowing companies to identify leaks and optimize energy usage, said Greg Heiges, mining business development manager: “By integrating the handling of all kinds of data from plant equipment, devices and systems, this solution facilitates the optimized management of production activities across an entire enterprise.”

Eaton’s solution is the Brightlayer Industrial suite. “This offers intelligent software solutions that integrate into existing systems, enabling real-time monitoring and control of energy usage”, said Elliot.

Net zero is a paradigm shift that requires collaboration among all industry players: “The transition to sustainable energy and addressing climate change are global issues far beyond any single company's balance sheet. To tackle these challenges effectively we will need a higher level of partnership between mining companies and external agencies over the next 20 to 30 years than we have seen in the past century”, emphasized Nathan Foster, managing director Kennecott at Rio Tinto.

Collaborative efforts have brought dramatic change. Takraf partnered with ABB. Eriez created a consortium with the University of Queensland including industry leaders like Rio Tinto, Newmont, Newcrest, Anglo American and Oz Minerals to develop CPF technology. Decarbonization in the mining industry will be a global effort, as we all share one planet. The industry is making headway, only time will tell if it will be enough. ■

Marc Elliott
Marketing Director –
Mining, Metals & Minerals
EATON

> “As energy costs climb and mining operations increasingly require deeper resource extraction, optimizing electrical efficiency is essential, as it can represent up to 30% of operational expenses.”

Ashok Amin

Segment Manager, Americas,
Bulk Material Handling
BOSCH REXROTH

Can you provide updates and highlights from the last couple of years?
In 2023, we launched advanced products that replace outdated technology, significantly enhancing efficiency, power, speed, and achieving a 40% reduction in weight. These innovations are more compact and reliable, featuring additional ports to connect more pump lines, thereby minimizing pressure drop and power loss. Our CB motors were rebranded as QMX & QMP, reflecting a new generation of compact models. This provides an improved more efficient and reliable solution for Conveyors, Drums, HPGR, Sizers, Crushers, Surface miners, Mixers etc.

We introduced the Fusion self-contained drive system, manufactured in Sweden and Ohio, primarily for mining applications like feeders and conveyors across the Americas. This localized production allows for tailored engineering and assembly. Recognizing the gap in electro-hydraulics education, we have expanded our training programs to build expertise and confidence in the workforce.

How is data impacting operations and predictive maintenance?
Our hardware captures and logs data that customers can download for production analysis, revealing how effectively they are utilizing our equipment. If they find they are operating at 82% efficiency, they can identify ways to boost production without new investments. We also use condition monitoring to assess machine performance against design specifications, allowing us to implement predictive maintenance that extends equipment life. We provide insights on when to upsize drives or motors based on operational data.

What are the challenges faced by clients, and how does Bosch Rexroth address them?
We observe is high turnover rates among trained personnel in the mining sector. This leads to a knowledge gap as experienced workers retire and are replaced by less experienced individuals. We view this as an opportunity to provide education and training, ensuring that our clients are equipped with the necessary skills to operate and maintain their equipment effectively. ■

Decarbonization: Drill through Mill

Driving down emissions and costs

The United Nations’ Intergovernmental Panel on Climate Change indicated that to limit the global temperature rise to 1.5°C will require rapid, far-reaching, and unprecedented changes: human- caused CO2 emissions must decrease 45% by 2030 and reach net- zero by 2050. Mining accounts for 4-7% of global greenhouse-gas emissions, according to McKinsey. The path to net-zero carbon emissions is a global, multi-sector challenge, and developing road maps to achieving that goal requires industry commitment, innovation and new technological solutions. In the Western US, the mining services ecosystem is determined to provide these solutions.

Drill through mill
For traditional drill and blast methods, each ton of explosives is approximately equivalent to a thousand liters of emitted CO2. Typical consumption rates for explosives in underground mines can range from 0.5 to 1.0 kg/t of rock mined. If a mine processes 10 million t/y of rock, for example, the explosives required could range from 5,000 to 10,000 kg. This amount multiplied by emitted CO2 per ton becomes significant. Innovations at Dyno Nobel are aimed at changing this narrative, said Braden Lusk, chief technology and marketing officer: “Our technology, like Delta E2 (ΔE2), is instrumental because it allows us to adjust the energy and density of bulk emulsion in the hole based on insights from drilling. We can modify the density up to six times within a single borehole, ensuring explosive energy is applied precisely where needed.”

Applying this solution to operations at Rio Tinto’s Kennecott led to immense benefits. “Using TITAN bulk explosives and ΔE2 methodologies, we effectively delivered explosive energy, leading to a 15% increase in mill throughput and a 5-10% rise in the minus half-inch size fraction. Kennecott saved US$58.1 million as a result”, said Lusk.

By increasing mill throughput, energy consumption per ton of ore processed decreases due to more efficient use of equipment and processes, leading to lower emissions. This is crucial as crushing and grinding can consume up to 53% of the total energy used in a mining operation and account for approximately 46% of the total GHG emissions from the entire mining and processing operation, according to a study published in Nature. Gabi Knesel, vice president mining and minerals processing at Locus Mining delves into this further: “By enhancing recovery, mining clients can process less material to achieve the same output, which directly translates to lower CO2 emissions.”

Big benefits from bio-based solutions
100% biobased and made from renewable raw materials with a low carbon footprint,” Knesel emphasized.

Czech Republic based Draslovka also found a muse in mother nature in their Glycine Leaching Technology (GLT). “GLT utilizes glycine, which is nontoxic, biodegradable and recyclable, as a reagent. This amino acid was discovered by scientists at Curtin University in Perth, Australia, who found that plants absorb gold through the soil in the presence of glycine,” explained Greg Warren, group chief commercial officer and executive director.

Both solutions enhance the capabilities of current processes in gold leaching. For Locus Mining, the micelle size of biosurfactants, 20 times smaller than traditional surfactants, allows them to transport cyanide through smaller pores. For Draslovka, glycine allows cyanide to act as a targeted pistol extracting gold from a mixture of ores while it absorbs other materials like copper and gang metals.

What do these bio-based additives achieve?

“Draslovka’s GLT processes can reduce carbon emissions by approximately 35-36% per ounce of gold produced across the entire value chain... With our technology, we optimize cyanide use to ensure it is fully consumed, leaving only glycine in waste streams. This results in an 80-90% recycling rate of glycine for our customers and reduces cyanide usage by 30-80%, improving gold recovery without degrading it”, said Warren.

“At Locus Mining we conducted successful industrial trials with our biosurfactants in gold recovery, achieving improvements of over 3% in recovery rates. Depending on the size of the customer and the current price of gold—around US$2,500/oz—this can translate in increased revenue to our customers of over US$25 million,” said Knesel.

Image courtesy of Rio Tinto Kennecott

Flotation solutions skimming off emissions

Focusing on flotation provides upstream benefits in the mill circuit. Coarse particle flotation (CPF) is a relatively new technology used to recover particles larger than 150 micrometers. Eriez pioneered the technology through development of HydroFloat. "HydroFloat allows for flotation at a coarser size, reducing the need for fine grinding during roughing. This reduces the required grinding size by about two and a half times for typical copper ore. Depending how CPF is implemented, it can reduce concentrator grinding energy by more than 20% and can increase metal recovery by 3 to 6%", said Eric Wasmund, vice president of Eriez's global flotation business.

Eriez also offers magnetic mill liners. According to, Jose Marin, director of minerals and materials processing: "These can last three to five times longer than rubber or metallic liners. This reduction in the frequency of liner replacement can represent big savings to any plant."

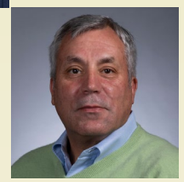
This longer lifespan reduces the carbon emissions needed to manufacture new mill liners.

Monitoring systems are becoming increasingly important to maximize efficiency and minimize emissions in the flotation and leaching circuits, driving new innovations. Specialty chemical firm Solenis launched a new line of patented and patent-pending antiscalants, the Zalta 12 series, with this in mind: "These antiscalants are designed to operate effectively under challenging conditions and are paired with our unique monitoring systems to maximize operational runtime while reducing chemical usage. This approach also minimizes transportation needs, reducing carbon dioxide emissions," said Shane Capazorio, corporate account executive.

A previous version of the technology, the Zalta MA11-556 patented heated slurry anti-scalant, helped address scale formation in a gold processing operation. "This allowed us to optimize the dosage, reducing cleaning frequency, translating to a 12-17 day increase in production, eliminating 8 to 13 cleaning procedures annually and addressing sustainability metrics like water usage," added Renata Vinhas, applications project manager.

In the race to decarbonize mining, innovative solutions across the blasting, milling and processing stages are paving the way toward a more sustainable future. The mining industry is proving that meaningful reductions in CO_2 emissions are possible. Through tailored approaches, data-driven monitoring and bio-based advancements, mining operations are not only aligning with global climate targets but also unlocking cost savings and boosting operational resilience. Decarbonization, while challenging, is achievable and essential for the future of mining. The urgency to decarbonize mining is compounded by increasing regulatory pressures and growing public awareness of the environmental impacts of the industry. These innovative solutions offer not only environmental benefits but also significant economic opportunities, enhancing operational efficiency and reducing long-term costs. ■

EW



JM

Eric Wasmund and Jose Marin

EW: Vice President Global Flotation Business
JM: Director, Minerals and Materials Processing
ERIEZ

Can you introduce Eriez to our readership?

EW: Eriez supplies proprietary process equipment for mining, specializing in various types of separation, including magnetic separation and flotation. We support customers through test-work, flowsheet development, equipment sales, installation, commissioning, service agreements, maintenance, and optimization. We maintain vendor service agreements with key customer sites throughout the world.

What solutions does Eriez's metals processing division provide?

JM: Every mining plant, apart from iron ore operations, use magnetic separation in the crushing circuit. Our products help customers keep their plants operating continuously.

We continually upgrade our magnetic separators and optimize magnetic circuits. Our products use both permanent magnets and electromagnets. Eriez offer magnetic equipment for milling equipment as well. We also offer magnetic mill liners, that can last three to five times longer than rubber or metallic liners. This reduction in the frequency of liner replacement can represent big savings to any plant.

Can you provide a case study of Eriez's work in the Western USA?

EW: A great success has been with Rio Tinto's Kennecott operation. We tested and demonstrated our coarse particle flotation equipment there, from lab scale to demonstration unit. We built and tested our equipment on their site and then scaled it up to treat a part of the plant, evaluating its scalability. Rio Tinto is exploring business opportunities at Kennecott and considering applying the innovations developed there to other operations worldwide. This collaboration gave Kennecott and Rio Tinto a competitive edge, allowing them to leverage new technology across their operations.

How does Eriez's R&D investments help client's improve operations?

JM: Eriez invests significant amount money and time in R&D to improve processes and explore new applications. Without this research, we risk stagnation and missing out on opportunities that could be detrimental to the growth of the business. Allow me to give a good example where R&D has paid off. Eriez developed a medium to high intensity magnetic separator for fine dry and high value powders called Dry Vibrating Magnetic Filter (DVMF). This product had limited applications when it was developed. However, the development of lithium-ion batteries created new opportunities as the DVMF is the only piece of equipment that can bring extremely high levels of purity to the final product. In a typical application, these units can help producers market their products such as lithium carbonate, hydroxide, or chloride with extremely low levels of metallic contamination, typically less than 50 ppb. Now we provide advanced units that generate operational data, such as coil temperature, canister displacement, cooling data and everything is monitored with a PLC that easily communicates with central control rooms. These innovations and product improvements demonstrate our commitment to the mining industry by developing more efficient and environmentally friendly products.

What does the future hold for Eriez?

JM: I believe Eriez is a solid and innovative company. We offer great products, and our clients appreciate how reliable our products are. As my colleague Eric Wasmund mentioned, Eriez has manufacturing facilities on every continent, this allows us to reach our customers in their time zone. Most importantly, we communicate with most of our customers in their native language. We have two sales approaches, our flotation division works directly with customers, while our magnetics division uses agents. While our agents are diligently visiting customers and offering our products, our success relies on their technical ability to sell our products. We hold training activities on a regular basis to keep their knowledge up to date. Eriez continues to focus our mining experts on increasing Eriez's visibility and reputation.

EW: The Western US has a promising future in mining, beyond its historical focus on gold. Geologically, the Pacific coastal region stretching from Alaska to Chile, sits along tectonic plate boundaries, making it the world's largest copper-producing area. Analysts predict a strong demand for copper, with a potential supply shortfall, especially during the global energy transition. States like Arizona and Utah are well-positioned to benefit from this demand, along with producers of other metals like nickel and lithium. This could bring the US back to the forefront of global mining. As a US-based company, Eriez is keen to collaborate with customers in these regions to support this growth. ■

JS

DT

James Stephens and Darrell Tweidt

Client Services Managers

PREMIER DRILLING CO.

What projects has Premier Drilling Co. worked on and how has project volume changed recently?
JS: Our projects include drilling, abandonments, and well-deepening for I-80 Gold. We are collaborating with Centerra Gold on greenfield exploration in Idaho and Nevada, utilizing core and mid-sized RC rigs. To meet Centerra Gold 's specific needs, we acquired a mid-sized RC rig for RC sampling. We also worked with Nevada Gold Mines.

We observed a drop in core drilling demand and large water-well and dewatering projects, despite higher gold prices. Rising costs across the board impacted our clients, particularly junior clients, who are struggling with funding. Material sourcing has become challenging too, with vendors now proactively reaching out—something that did not happen a year ago when demand was so high that we had difficulty getting quotes.

How does Premier Drilling Co. attract and retain skilled labor?
JS: Our leadership's firsthand experience on drill rigs helps us understand the challenges our crews face. Our president emphasizes respect and values each team member, recognizing their role in generating revenue. We avoid contacting support crews during their off-hours, provide per diem allowances, and provide health, life, and dental insurance, ensuring they can focus on their work without financial stress.

How does Premier Drilling Co. approach safety?
JS: Safety is our top priority, supported by a comprehensive and evolving safety program. We now utilize tablets for easy access to safety documents, and each project has a tailored health and safety plan to address its unique challenges. We promote a "brother's & sister's keepers" mentality, encouraging everyone to look out for each other and ensure everyone returns safely.

DT: We have declined projects when conditions posed safety risks, like extreme heat. Scheduled breaks and time off are essential for crew safety and morale.

How are market dynamics affecting the drilling sector?
JS: We observed a decline in greenfield drilling due to rising funding costs, while brownfield projects are more active. Budget transparency is crucial, as we work with vendors for competitive rates and share these details with clients to build trust. Although costs are increasing, the green energy transition presents opportunities. Spending scrutiny is intensifying across all projects.

DT: The industry is experiencing consolidation, with smaller companies merging to share resources. Many investors are diverting funds to newer markets like AI and cryptocurrencies instead of mining. Market volatility affects demand despite high gold prices. It is unusual to see such high commodity prices alongside low activity levels. Some investors appear hesitant due to new investment opportunities, but the fundamentals of commodities will draw interest back. The industry needs time to adjust.

What is Premier Drilling Co's competitive advantage?
JS: Our competitive advantage comes from having 'A teams' on every project, ensuring consistent quality across the board. We are confident in our ability to handle challenges professionally, maintaining open communication with clients. From the bidding stage, we meticulously prepare and estimate each project, using weekly budget meetings and KPI reviews to track our progress. This feedback loop promotes continuous improvement and transparency, ensuring that clients are kept informed about budget constraints and project goals.

DT: Every project has its challenges, but we address them directly and collaborate closely with clients. Our proactive communication helps clients anticipate issues, and our teams are well-equipped to respond without external resources. We work as a team, sharing responsibility and improving communication. Some projects may exceed budgets due to challenging ground conditions, especially in Nevada, where drilling can vary significantly over short distances. Experienced drillers who understand the local terrain are crucial for success; our team's local expertise allows us to navigate these complexities effectively with the right tools and strategies. Our emphasis on quality people distinguishes us from others in the industry.

What are Premier Drilling Co's objectives for 2025?
JS: Our focus is to establish a strong project backlog to keep all crews and five rigs operational at least 90% of the time. We want to bring in new team members but need to ensure we have a stable workload first.

DT: Building a backlog is essential. We have had skilled drillers from other companies expressing interest in joining us, but we want to ensure they will have consistent work. ■

Braden Lusk

Chief Technology and Marketing Officer

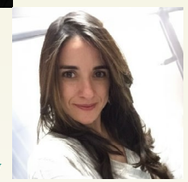
DYNO NOBEL

What milestones did Dyno Nobel reach in 2023 and 2024?
We launched the DigiShot XR series, which includes three new electronic detonators: DigiShot XR, DigiShot Plus XR, and DigiShot Plus XRS. These detonators are engineered to resist shock and electromagnetic pulse, which greatly enhances safety and operational efficiency. We are actively engaged in Drill to Mill projects in the Western mining sector.

Can you detail a recent case study?
We built a strong partnership with Rio Tinto Kennecott. Our focus was on increasing the fines percentage, especially in the minus half-inch size fraction, to boost mill throughput. We identified bottlenecks and optimized blast designs. Using TITAN bulk explosives and Delta E2 (ΔE2) methodologies, we effectively delivered explosive energy, leading to a 15% increase in mill throughput and a 5-10% rise in the minus half-inch size fraction. Kennecott saved US$58.1 million as a result.

What is the role of data in blasting operations?
Our ΔE2 technology uses data from drilling and other sources to characterize rock properties, enabling targeted energy placement within blast holes. This technology allows us to implement up to six different density profiles in a single borehole, significantly enhancing control over fragmentation and overall blasting efficiency. We leverage existing data from mines and integrate it into our Preload software to develop load plans that guide our trucks in real time. Differential GPS technology in our detonators ensures precise timing for each blast hole, while our Nobel Fire platform offers tools for predicting vibrations and modeling fragmentation before blasting occurs. The platform includes a mobile app for real-time data entry during drilling and loading and post-blast analysis features. This comprehensive data-driven approach allows us to visualize and assess explosive performance trends, making data critical to continuous improvement in our operations. We envision incorporating machine learning and AI to refine decision-making processes further. ■

SC



RV

Shane Capazorio and Renata Vinhas

SC: Corporate Account Executive

RV: Applications Project Manager

SOLENIS

What were key highlights at Solenis during 2023?
SC: Solenis has seen significant activity, particularly in the mining sector where we focus on mineral processing chemicals essential for the circular and green economy. We acquired BASF's flocculent and mining chemistries, enhancing our position as a leading chemical provider and broadening our technological offerings and product range.

RV: We witnessed a surge in demand for our innovative solutions, particularly in antiscalants and flocculants. Many operators are utilizing our products to enhance profitability by reducing reagent costs and increasing throughput. We are engaged in projects focused on critical minerals and expanded our workforce in strategic locations. Our patented antiscalant technology improved process throughput for clients by extending runtime and minimizing downtime. Our advanced automation programs optimize chemical dosing in real-time, addressing the growing challenges posed by water scarcity.

Can you provide recent case histories in the USA mining industry?
RV: One significant case involved a gold processing operation that struggled with scale formation in their tanks and pipelines, necessitating cleaning every 3-4 weeks, causing production losses and excessive water and cleaning product use. Our Zalta MA11-556, a patented heated slurry anti-scalant, allowed us to optimize the dosage, reducing cleaning frequency, translating to a 12-17 day increase in production, eliminating 8 to 13 cleaning procedures annually and addressing sustainability metrics like water usage and manpower.

Our Zalta MA12-027 anti-scalant, combined with OnGuard 3S Analyzer enabled early detection of scalant formation for another client, optimizing dosage and reducing costs while improving the acidification of the plant.

We assisted another copper plant in the Western United States that was processing varying ore types, leading to difficulties with their tailing thickeners. We maintained and stabilized the process while achieving a 20% lower dosage over 40 days of trial. ■

A Date with Data

Technology firms help miners find love at first byte

Facing the challenge of increasing production without opening new mines in the Americas, Freeport-McMoRan turned to artificial intelligence, starting at their Bagdad mine in Arizona. Data access was not the problem— a data warehouse stores sensor data collected on a second-by-second basis from the company's trucks, shovels and stationary machines. The problem was creating and deploying an AI model at scale. McKinsey took the reins creating a model that boosted production by 5-10% and mitigated US$1.5-2 billion of losses to build a new processing facility. "The project taught us to be more receptive to what the data was telling us," said Bertrand Odinet, chief information officer and chief innovation officer at Freeport-McMoRan in the McKinsey case study.

Data has long been a buzzword in the industry, much like AI, with vendors touting it as the key to optimizing operations, reducing energy consumption, cutting CO_2 emissions, and boosting productivity. Without a doubt, data is the backbone of the industry's advancements; it powers autonomy, AI, machine learning models, and nearly every modern shift in mining. "One of the biggest mistakes we see across the mining industry is doing things the way they have always been done, or worse, relying on "experience" to make decisions in the field without considering the data behind the decision. Sometimes our gut lies to us and the data disproves our initial reaction to a problem we are trying to solve," said Keaton Turner, founder, president and CEO of Turner Mining Group.

However, data alone is not enough. The collection, type, manipulation and application of data will provide the benefits vendors promise. Data simply provides the 'what.' Technology providers in the Western US are working to use data to supply the 'why' and 'how.'

Swipe Left

Data in the mining industry is like dating; just because there are billions of bits does not mean you will strike gold with every byte. Many vendors increased the number of sensors in hopes of collecting more data. Looks, however, are not everything: "Adding more sensors increases data volume, but not all data is useful, and if data is not enhancing decisions, the effort may not be worthwhile. To be effective, data must be captured, analyzed and actionable for decision makers," said Derek Cooper, vice president US and Canada at Hexagon.

That's my type

The key is not the amount of data, but rather knowing exactly what type of data you need. High-quality, unbiased data are best for training models (the AI kind). VerAI Discoveries, an AI-based mineral asset generator, leverages AI and machine learning algorithms to analyze geophysical data profiles— from magnetic, gravimetric, electromagnetic and seismic sources— of known economic ore bodies. By training their algorithms on this data, VerAI enhances the probability of identifying new economic mineral deposits.

Here is Lorraine Godwin, vice president commercial, on why unbiased data is so important: "Our improved success rate is primarily attributed to our rigorous approach to data utilization and AI model refinement. We prioritize high-quality, unbiased geophysical data. This approach minimizes interpretation errors and ensures our AI models are trained on the most accurate and reliable information available. By continuously advancing our AI algorithms through rigorous validation, we achieve higher success rates across different geological settings and mineral types."

Made to perform

Once you find the right data match, it is all about performance. With the right data foundations in place, technology firms across the Western US are tailoring their models to specific deposits, thereby boosting productivity and saving valuable time. When given the proper data training, AI and machine learning (ML) are transforming the industry from the ground up.

Maptek is helping mining companies understand the true value of their resources by using AI to dig deeper. "We are witnessing significant AI adoption with Maptek DomainMCF, where ML analyzes drill holes or other sample data to create unbiased resource models. By considering structural elements and assessing data comprehensively, our cloud-based technology saves geologists from labor-intensive and time-consuming data manipulation. This innovation allows clients to generate preliminary models in hours instead of months," said Clayton Fritz, sales manager of North America at Maptek.

Micromine is also playing the field with ML, streamlining the resource geologist's workflow with Micromine Origin Grade Copilot, launched in November 2023. Ben McDonald, mining solutions manager, explained how the model leverages data to speed up resource estimation: "By leveraging advanced neural networks, Grade Copilot learns complex patterns in geological data to create comprehensive and robust models swiftly and autonomously. What once took weeks to accomplish manually can now be achieved in hours, and in some cases, mere minutes, freeing up valuable time for higher-level thinking."

MST Global is all about creating a safe space, allowing clients to feel the connection, literally. "Core to our mission is ensuring seamless connectivity for equipment and personnel, especially in the challenging underground environment where traditional GPS tracking is not feasible," said Jon Larson, general manager – Americas.

This takes the form of the AXON suite, providing network infrastructure and the Helix platform, allowing for advanced visualization and tracking.

Taking things slow

Some players, like Asterra, were a bit late to the game, having kept their eyes on the stars. Originally, the firm's propriety technology was designed to find water on Mars. The company, however, understands that good relationships require time and patience: "When entering new markets, spending time getting to know user base is a requirement," said James Perry, executive vice president marketing and Earthworks Division.

Asterra took their time with the courting phase. Perry continued: "Through travel and interviews, we broadened our understanding of what our solution could achieve in the mining industry. This effort helped us evolve our solution, making our data timelier and more useful."

To win over partners, Asterra became a down-to-earth firm, using synthetic aperture radar in the microwave L-band spectrum. "We identified an entry point where we could monitor and help maintain tailings dams. Since our technology can penetrate below ground, we provide the first line of sight for detecting moisture that might be leaching or piping through these dams."

Performance anxiety

In the world of data-driven solutions, it is easy to feel overwhelmed, especially when every provider seems to have a different idea of what is best. The lack of standardization among technology providers only adds to the complexity. As Matt Blattman, director of technical ser-

Image courtesy of Strayos

vices at Hecla Mining, pointed out in Seequent's 'Beyond the Hype: How technology can drive mining operations' performance' Insights Paper: "We would like to standardize, but within our own company, with four different mines, four different types of deposits and four different mining methods, it is hard to find something that fits every situation."

This challenge has led data solution providers to fine-tune their approaches, ensuring they are not just offering a one-size-fits-all solution, but something more personalized. As Ravi Sahu, CEO at Strayos, puts it: "During onboarding we understand the specific problems and KPIs the client wants to address. Within the first six months, we achieve at least one KPI improvement. The AI model becomes more calibrated to the specific site as we gather more data—around 5,200 data sets are required to achieve accuracy."

This gradual, get-to-know-you approach allows operators to dip their toes in before taking the plunge. And it is paying off: "When clients see the value, they are more inclined to extend their contracts and integrate our platform further into their operations," Sahu added.

Life Cycle Geo, a firm specializing in ML services, observed a similar trend, said Tom Meuzelaar, the owner: "Model performance improves as operators collect more data. However, gaining buy-in and trust from operators when it comes to ML is typically a gradual process. Operators need to see tangible benefits—such as time and cost savings— and understand how a machine learning approach improves upon established practices before fully committing to new models."

Ultimately, finding the right solution is like finding the right partner—it is a journey that requires exploring different options and assessing how well they align with your needs. Sometimes, you need to go on a few 'data dates' before you find the perfect match. In the end, the key to a lasting relationship is finding a partner that not only meets your needs today but is adaptable enough to grow with you into the future. ■

Lorraine Godwin

Vice President Commercial

VERAI

How do you envision AI bridging the gap between environmental stewardship and mining?

AI has the potential to revolutionize mining practices by integrating environmental stewardship with operational efficiency. It enables mining companies to maximize resource utilization and minimize the ecological footprint. By accurately identifying mineral deposits and streamlining exploration activities, AI contributes to sustainable mining practices that align with global environmental regulations and community expectations.

How will AI and machine learning (ML) contribute to addressing supply shortages?

We believe the next big discoveries will be made in areas of significant cover and we need to think differently about how we find these in such environments. By analyzing the right types of geoscience data and identifying mineral signatures, AI and ML can accelerate the discovery-to-production timeline for critical mineral deposits. Given the industry's persistent challenges in securing funding, it is crucial to achieve greater visibility for our efforts to de-risk early-stage discoveries and improve the probability of finding significant mineral deposits. Increased exposure can expedite exploration initiatives and reignite investor confidence in the sector.

What role does the Western U.S. play in VerAI's overall growth strategy?

VerAI views the Western United States as strategically vital in our global growth strategy, owing to its abundant mineral resources, solid regulatory framework, and advanced technological infrastructure. ■

Ravi Sahu

CEO

STRAYOS

Can you share recent highlights and major milestones?

We released four new product lines focused on ore dilution and waste reduction. Our aim is to deliver a 'mine to metal' solution, enabling customers to better control dilution during metal extraction. We also added two AI solutions for mobile devices. The first, FieldR, allows for drill plan design and drilling data collection, and the second, FragR, enables quick on the spot fragmentation analysis. The mobile apps make data collection more accessible and efficient.

Why is reliable geotechnical data critical in mining operations?

Reliable geotechnical data is critical for the proper monitoring and planning of mining operations and deriving incredibly valuable insights into how to optimize those operations. The problem, however, is the geotechnical data collected by mining operations is rarely reliable due to poor quality, insufficiency, or the amount of time it takes to conduct a traditional survey. By the time the data collection is finished the data is already obsolete. Using drones for surveying significantly accelerates this process while enhancing quality and resolution.

What are your objectives and expansion plans for Strayos?

In the Western USA, we continue to expand our presence and have recently added new customers. We hope our partnership with Wingtra, which has a significant footprint in that region, can help customers in the Western USA explore our solutions. ■

Industry Insights: Find your Match

"If a client plans to use 20 trucks, we can build a digital twin, calibrate it with actual data, and use it for scheduling outputs. In one operation, we reduced cycle time by 2–3 minutes, saving approximately US$5 million in operational expenses for the year."

Ben McDonald, Mining Solutions Manager, **MICROMINE**

"A single poor decision can lead to a loss of production and increased diesel consumption from just one idling truck. We can monitor trucks and shovels simultaneously, eliminating the errors with human dispatching."

Derek Cooper, Vice President, US and Canada, **HEXAGON**

"We partner with clients to develop application specific algorithms and ML solutions, particularly in data collection and analysis. Our AI-integrated products and data solutions empower clients to interpret and utilize data more effectively."

Rob Hardman, President and General Manager, North America, **MAPTEK**

"Since our technology can penetrate below ground, we provide the first line of sight for detecting moisture that might be leaching or piping through tailings dams. Moisture can cause failures that threaten both human safety and mine operations."

James Perry, EVP Marketing & Earthworks Division, **ASTERRA**

"We implemented our technologies with a precious metals producer to provide data communications underground, enabling the tracking of vehicle and personnel movements and ventilation on demand. This led to measurable increases in productivity, safety, and power savings within their operations."

Jon Larson, General Manager – Americas, **MST GLOBAL**

Image courtesy of Rio Tinto Kennecott

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