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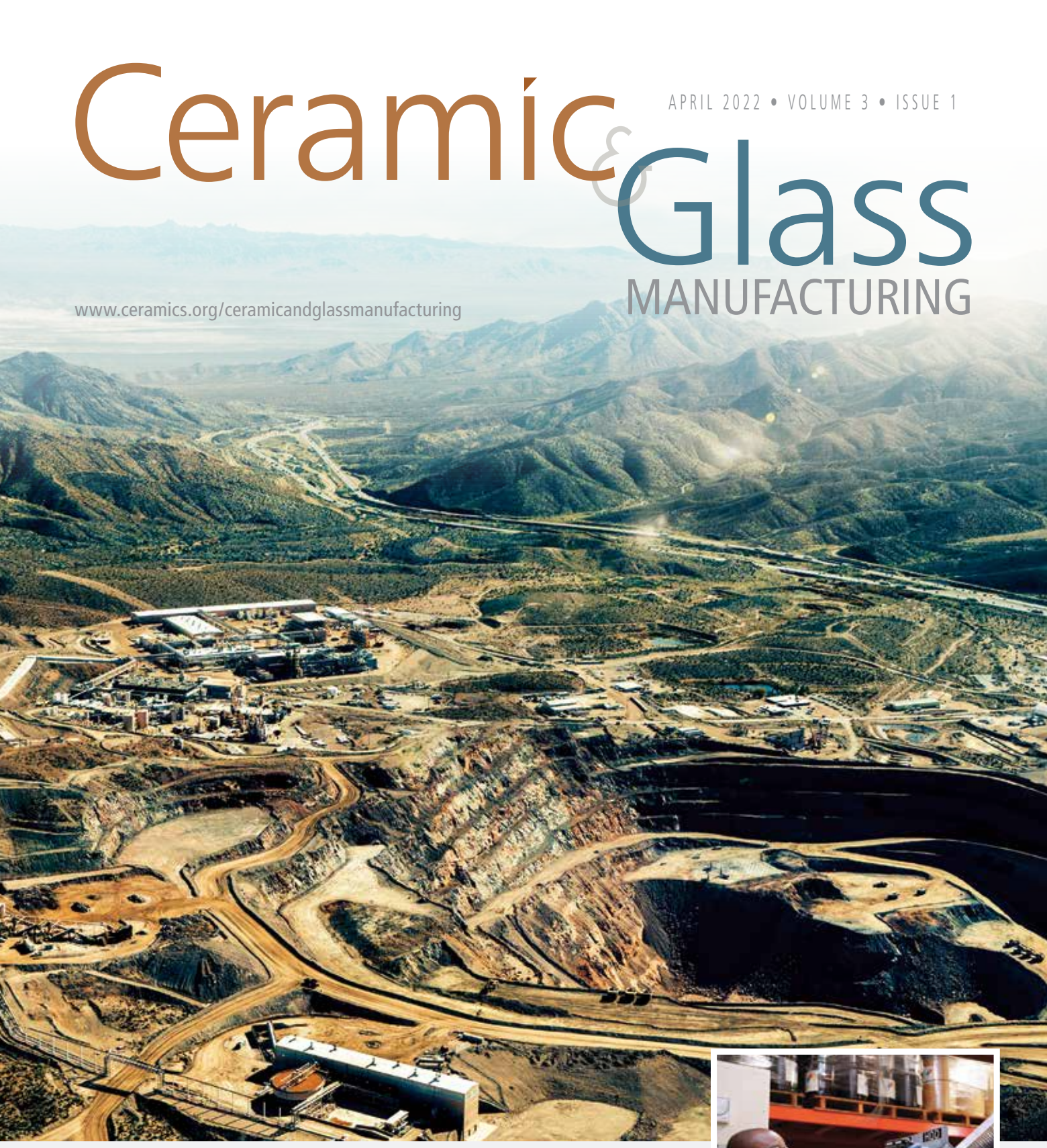
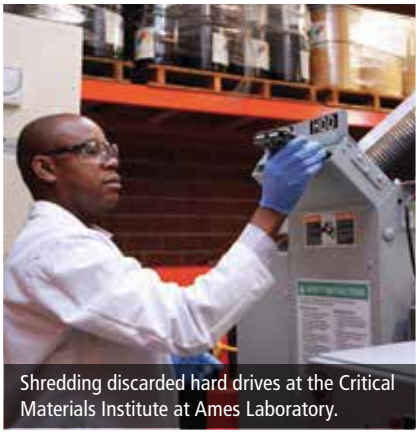


THE RARE EARTHS ECONOMY: CAN SUPPLY KEEP UP WITH GROWING DEMAND?

POLICY RECOMMENDATIONS: US MUST LEAD IN BUILDING THE WESTERN SUPPLY CHAIN



Shredding discarded hard drives at the Critical Materials Institute at Ames Laboratory.

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CONTENTS

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INDUSTRY NEWS


Schott expects to complete its expansion in China by the end of 2022.

SCHOTT SETS PLANS FOR CONTINUED EXPANSION TO MEET HEALTHCARE NEED

Mainz, Germany-based Schott says it delivered glass vials for more than 5 billion doses of COVID-19 vaccine worldwide in 2021. Last year, the company tripled its capacity for presterilized, ready-to-use glass vials in the U.S. and expanded the capacity of prefillable glass syringes by 50% in Switzerland. This spring, a new production site for prefillable, polymer syringes will open in Germany. Schott also says it plans to triple its production capacity in China for glass vials and ampoules by the end of 2022.

HWI PLANS TO CONVERT CLOSED PLANT IN ALABAMA

HarbisonWalker International says it plans to invest approximately $25 million to convert its closed plant in Fairfield, Ala., into a manufacturing, service, and distribution hub for steel customers in the southern U.S. Construction will begin during the first quarter, and the 200,000-square-foot facility, called Alabama One, is expected to open before the end of 2022. The plant will produce magnesia-carbon brick refractories engineered for steel-making applications, such as steel ladles and low-emission electric arc furnaces. Initially, production will add 15,000 metric tons annually and eventually up to 30,000 metric tons.


HWI plans to hire 50 technicians and other staff for the facility.


Lithoz's second production facility will mean increased capacity and more efficient warehousing.

LITHOZ OPENS SECOND CERAMIC 3D PRINTING PRODUCTION SITE

Lithoz GmbH says it began production at a new ceramic 3D printing site in Vienna, Austria. The location is the second production site for Lithoz and its fourth location worldwide, after its headquarters in Vienna and bases in the United States and China. The company says a new central warehouse will mean quicker turnaround of orders, scalable production, and expanded storage capacity for raw materials. The facility includes a monitored production environment and a central quality assurance laboratory.

ASTM BEGINS PROJECTS TO ADVANCE ADDITIVE MANUFACTURING

ASTM International's Additive Manufacturing Center of Excellence is participating in three new America Makes projects aimed at advancing the adoption of additive manufacturing. The projects, totaling more than $1 million, address training, inspection, qualification approaches, and in-process monitoring. Formed in 2018, the ASTM Center is a partnership among ASTM International and organizations from industry, government, and academia. The Center supports standardization, develops training and certification programs, and provides market intelligence and advisory services.


ASTM International's headquarters in West Conshohocken, Pa.


CoorsTek's plant in Gumi, South Korea.

COORSTEK PLANT IN SOUTH KOREA EARNS CHEMICAL SAFETY AWARD

CoorsTek's plant in Gumi, South Korea, won an award from Korea's National Institute of Chemical Safety for its safety protocols and chemical accident prevention plan. The plant produces high-performance ceramics engineered for semiconductor processing applications, and a range of hazardous materials are used in the production process. The plant is subject to regular inspections to review safety procedures and chemical spill prevention plans. Plant manager BW Han says the Gumi team established a mobile-based wireless network to prevent the leakage of hazardous chemicals into nearby bodies of water.


American Rare Earth is focused on recycling products such as rare earth permanent magnets and lithium-ion batteries.

RARE EARTHS RECYCLING VENTURE GAINS INVESTMENT

HG Ventures, a venture capital firm and division of Indianapolis-based The Heritage Group, took an ownership stake in American Rare Earth LLC, a subsidiary of American Resources Corp., to scale up recycling of batteries, magnets, and e-waste to recover and supply rare earth metals to U.S. and global markets. American Rare Earths' first purification facility is expected to be operational in the first half of 2022. The Heritage Group is a fourth-generation, family-owned business managing a portfolio of companies specializing in heavy construction and materials, environmental services, and specialty chemicals.

ŞIŞECAM BUYS REFRACTORIES MANUFACTURER

Turkey-based glass producer Şişecam is acquiring the Italian company Refel, a leading refractory materials manufacturer. Şişecam says it wants to eliminate risks related to supply chain disruptions and secure its refractory supply so it can fully realize its new investments in glass manufacturing. Şişecam's products include flat glass, glassware, glass packaging, and glass fiber, as well as soda and chromium compounds. Şişecam operates 42 production plants in 14 countries.


Şişecam is one of the top glass-packaging producers in Europe.

HUBER ENGINEERED MATERIALS FINALIZES MAGNIFIN PURCHASE

Atlanta-based Huber Engineered Materials closed on its acquisition of RHI Magnesita's 50% ownership stake in a 50/50 joint venture, Magnifin Magnesiaprodukte GmbH & Co. KG. Magnifin products are sold globally by Martinswerk GmbH as part of Huber's fire-retardant additives business unit, which produces halogen-free fire retardants, smoke suppressants, and specialty aluminum oxides. Based in Breitenau, Austria, Magnifin has produced magnesium hydroxide products since 1990. Huber says the acquisition fits with its mission "to own and operate specialty chemical and mineral companies with market leading positions."


Magnifin's plant in Breitenau, Austria.

THE RARE EARTHS ECONOMY: CAN SUPPLY KEEP UP WITH GROWING DEMAND?

By David Holthaus

On Sept. 7, 2010, three Japan Coast Guard ships were patrolling the disputed waters around the Senkaku Islands in the East China Sea, responding to reports of increased fishing by Chinese and Taiwanese boats. The rich fisheries around the islands had long been claimed by Japan, China, and Taiwan, and an uneasy truce had evolved over the years.

On this day, however, faced with a spike in the number of Chinese trawlers, the Japan Coast Guard ordered the vessels to leave the area. Most complied, but one, the Minjinyu 5179, refused. And when the Coast Guard moved to board the recalcitrant trawler, the Chinese vessel collided with one of the Japanese ships. Minutes later, the trawler rammed a second Coast Guard ship.

The incident might have been just another minor drama in a long dispute over bountiful fishing waters. No shots were fired, and no one was injured. But Japan responded strongly, arresting the skipper under charges that carried a possible three-year sentence and detaining the other 14 crew members, according to the Asia Maritime Transparency Initiative.

Things escalated. Diplomats from both countries began firing missives back and forth, and their negotiations faltered. Previously arranged discussions on joint China–Japan economic initiatives were cancelled. Political, economic, and cultural exchanges that had been in the works were also scotched.

The rest of the world took note when China began enforcing an embargo on the export of rare earth metals to Japan. At the time, China accounted for nearly all the world's rare earths exports, and Japan had been importing a substantial portion of them for processing, manufacturing, and use in its auto industry.

It is unclear whether China choked off the supply of the metals to punish Japan, or whether it was reserving the materials to be used to fuel its own rapidly growing economy. In either case, China's move rattled the world's industrial economies, which were startled enough to begin to see the importance of developing their own rare earth supply chains.

But developing supply chains is a painstakingly slow process. And regarding rare earths, this industry faces an additional challenge—while rare earth elements are relatively abundant in the Earth's crust, it is not common to find these minerals in concentrations large enough to mine, according to the U.S. Geological Survey (USGS).

CHINA DOMINATES THE RARE EARTHS MARKET

Rare earth ores are found all over the world, but the largest concentrations occur in China, followed by the United States and Australia. But getting these materials out of the earth and processing them to be used in industry presents environmental challenges, beginning with mining. Processing the ore and extracting the metals also requires repeated use of acids and other chemicals, and the disposal of huge amounts of hazardous wastewater.

Rare earth oxides. Clockwise from top center: praseodymium, cerium, lanthanum, neodymium, samarium, and gadolinium. *Credit: Peggy Greb, USDA-ARS*

Rare earth elements are used in the manufacture of advanced ceramics and glass production. Their use in ceramics and glass accounts for 10% of the end distribution of rare earth elements in the U.S., according to the USGS.

The geology, environmental issues, and costs of overcoming these obstacles has meant that, to date, there is only one rare earth facility operating in North America.


In 2020, the Mountain Pass mine supplied more than 15% of the world's rare earths production. *Credit: MP Materials*

Las Vegas-based MP Materials operates the Mountain Pass mine near San Bernardino, Calif., 50 miles southwest of Las Vegas. It is an open-pit mine that began operating in the 1950s, and from the 1960s to the 1980s, it was the world's dominant source of rare earths oxides, according to the USGS. But rising demand, coupled with growing environmental concerns and costs, resulted in production there tailing off. By 1990, production in the U.S. was falling quickly, while production in China was accelerating.

Ownership of Mountain Pass changed hands a few times, but in 2015 the mine was idled. In 2017, it was acquired by MP Materials, a company that was formed by investment firms JHL Capital Group and QVT Financial. By the end of 2017, mining operations were restarted, and in 2018 the first sales of rare earths concentrates were made.

The operation has scaled up since then. In 2020, production volume of rare earths oxides increased 39% from the year before to 38,503 metric tons, according to its year-end financial report. That represented about 15% of primary global production and was an all-time high for U.S. production, says Matt Sloustcher, MP's senior vice president for communications and policy.

Driving that progress has been the soaring demand for the minerals and the magnets that are made with them, a demand largely driven by growth in the electric vehicle market.

RAPID GROWTH IS EXPECTED

Stepped-up domestic production is considered critical not only for national and economic security purposes, but simply to meet what is forecast to be exponential demand for rare earths materials.

Toronto-based Adamas Intelligence forecasts that total magnet rare earth oxide demand will grow at a rate of 9.7% annually through 2030. Because of an expected undersupply of neodymium, praseodymium, and dysprosium oxide, the company forecasts global shortages of neodymium–iron–boron alloy and powder to amount to 48,000 metric tons annually through 2030, "roughly the amount needed for some 25 to 30 million electric vehicle traction motors," the company says.

"A flood of investment is imminently needed to develop new sources of supply and downstream value chains to convert that supply into metals, alloys, magnets, and other materials used by high-tech industries globally," the company says in a September 2020 market report.

Rare earth elements, including neodymium and dysprosium, are used to make the powerful permanent magnets found in electric vehicles. Electric vehicle sales have grown rapidly over the last decade, and in 2020 alone, sales grew 67% worldwide over 2019, according to the World Resources Institute. President Biden has set a goal of making all vehicles sold in the U.S. zero-emission by 2030, and most would be electric-powered.

Green energy is also expanding the market for rare earths. Neodymium and dysprosium are used in wind turbine generators. In 2020, $24.6 billion was invested in new wind power projects, according to the U.S. Department of Energy. President Biden has set a goal of reaching 100% clean energy by 2035.

But China is still a critical link in the supply chain. The rare earth concentrate MP Materials produces currently is exported to a distributor, that sells that product to customers in China who refine the concentrate into separated rare earth products. The company is planning to restore the capacity to separate and process rare earths at the Mountain Pass facility sometime late this year, Sloustcher says.

And in December, MP Materials announced plans to build a 200,000-square-foot metal, alloy, and neodymium–iron–boron magnet manufacturing facility in Fort Worth, Texas. The company says the facility will have the capacity to produce 1,000 metric tons of magnets a year, with the potential to power about 500,000 electric vehicle motors annually.


A rendering of MP Materials' planned magnetics facility in Fort Worth, Texas. *Credit: MP Materials*

Those magnets will have a waiting customer in General Motors, which announced a preliminary agreement with MP Materials to source finished magnets to be used in more than a dozen of its electric vehicle models, with production ramping up in 2023.

"We are building a resilient and sustainable EV manufacturing value chain in North America," Shilpan Amin, GM's vice president for global purchasing and supply chain, says in a news release.

The companies also say they would collaborate "to seek policies that are supportive of the establishment of a secure, U.S. rare earth supply chain."

The Lynas Rare Earths mine in Western Australia. *Credit: Lynas Rare Earths*

US GOVERNMENT SUPPORTS, FUNDS NEW SOURCES

The effort has the support of the U.S. government, which, through executive orders and grants, has lent its weight to the effort.

President Trump issued two executive orders concerning rare earths in 2017 and 2020. With the 2020 order, he declared a national emergency to "reduce our vulnerability to adverse foreign government action, natural disaster, or other supply disruptions."

President Biden followed with an order in 2021 requiring new government assessments of supply chains across several sectors, including rare earths elements.

Government funding followed the orders. The Department of Defense in November 2020 awarded $9.6 million to MP Materials to support its plans to add processing and separation capabilities to its Mountain Pass facility.

In February 2021, the defense department awarded $30.4 million to Australia-based Lynas Rare Earth Ltd. The grant supports the company's wholly-owned subsidiary, Lynas USA LLC, which is developing a rare earths separation and processing facility in south Texas. The U.S. facility will process light rare earths from Lynas-owned facilities in Australia and Malaysia, the Department of Defense says.

Established in 1983, Lynas Rare Earths is the most significant producer of rare earths materials outside of China. It operates a mine in Western Australia and a large processing plant in Malaysia. It is constructing a $500 million processing facility in Western Australia that will supply the advanced processing plant in Malaysia and the planned facility in Texas, the company says.

Lynas is developing the Texas plant in partnership with San Antonio-based Blue Line Corp., a developer and manufacturer of specialty inorganic chemicals.

Texas is also the location of another promising development in the U.S. USA Rare Earths LLC owns the Round Top Heavy Rare Earth, Lithium and Critical Minerals Project in West Texas. The company says the Round Top mine should begin operating in 2023. It says the deposit there contains 16 of the 17 rare earths, as well as lithium and gallium. Company officials say the Round Top deposit has enough resources to last 100 years.

Ikenna Nlebedim shreds discarded hard drives at the Critical Materials Institute at Ames Laboratory. CMI has licensed the technology for extraction of rare earth metals and other useful elements from electronic waste. *Credit: Critical Materials Institute and the U.S. Department of Energy's Ames Laboratory*

The company is also developing a pilot plant processing facility near Denver, Colo. Workers at the plant will separate ore into heavy rare earths such as dysprosium and terbium, as well as light rare earths such as neodymium and praseodymium. It will also be used to recover non-rare earth critical minerals such as lithium, uranium,

beryllium, and gallium, the company says. The plant has received its required permits and is in the process of being commissioned.

In April 2020, USA Rare Earth purchased equipment necessary for manufacturing neodymium–iron–boron magnets from Hitachi. The equipment came from a plant that Hitachi formerly owned and operated in North Carolina.

Officials say the equipment should provide most of what the company needs to establish rare earth magnet production and complete the company's domestic mine-to-magnet strategy. When completed, the company estimates, its plant will be able to produce 2,000 metric tons of magnets a year.

"We did not want the United States to lose this key equipment," CEO Pini Althaus said at the time. "So when it became clear that was an imminent possibility, we moved quickly to ensure that this essential part of the critical minerals supply chain remains in the U.S."

RESEARCH AND DEVELOPMENT EFFORTS HOLD PROMISE

Along with these greenfield projects, the domestic rare earths supply is also the focus of innovative research efforts. The Critical Materials Institute at the Ames Laboratory in Ames, Iowa, was launched in 2013, partly in response to the 2010 embargo by China.

CMI research focuses on rare earth materials, as well as battery materials (lithium, cobalt, manganese, graphite), indium and gallium. It is a public–private partnership that collaborates with private industry, as well as with universities and other national laboratories.

According to CMI director Tom Lograsso, the institute's research and development efforts are focused in three areas: diversifying sources of rare earths and critical materials; recycling and reuse; and developing substitutes.


Tom Lograsso

"There's a lot of places to locally source materials. That's the good news," Lograsso says. "Whether we can do it environmentally and economically are the challenges that remain. We can address the economics through technical innovations."

CMI has focused its research on the separation and processing links in the supply chain, Lograsso says. Such work evolved to China because of the lower cost of labor and the less-stringent environmental regulations there, he says.

Among CMI's projects is one to improve the efficiency of the separation processes. Doing so could cut the number of separation stages needed, and it would make the process environmentally safer by reducing the amount of acids and other hazardous chemicals used.

WORLD MINE PRODUCTION AND RESERVES

Rare earths are relatively abundant in the Earth's crust, but minable concentrations are less common than for most other mineral commodities. In North America, measured and indicated resources of rare earths were estimated to include 2.4 million tons in the United States and more than 15 million tons in Canada. This chart shows mine production and reserves in metric tons for 2020 and 2021.

	2020	2021	Reserves
United States	39,000	43,000	1,800,000
Australia	21,000	22,000	94,000,000
Brazil	600	500	21,000,000
Burma	31,000	26,000	NA
Burundi	300	100	NA
Canada	—	—	830,000
China	140,000	168,000	44,000,000
Greenland	—	—	1,500,000
India	2,900	2,900	6,900,000
Madagascar	2,800	3,200	NA
Russia	2,700	2,700	21,000,000
South Africa	—	—	790,000
Tanzania	—	—	890,000
Thailand	3,600	8,000	NA
Vietnam	700	400	22,000,000
Other countries	100	300	280,000
World total (rounded)	240,000	280,000	120,000,000

Source: U.S. Geological Survey, 2022

Researchers are also working to scale up the recycling of rare earths. The institute developed an acid-free, rare-earth magnet recycling process that recovers more than 99% purity rare-earth elements from recycled electronic waste, such as computer hard drives.

"This has gone to demonstration scale, to tens of thousands of kilograms" Lograsso says.

New domestic sources, expanded production from companies in allied countries, and continued technical innovations will all be needed as demand grows for the metals that will power the green economy. As the Adamas Intelligence report says, "The rapid demand growth of the 2020s will soon be dwarfed by the astronomical demand growth of the 2030s—and therein lies the real defining challenge and opportunity facing the global rare earth industry today."

Policy recommendations: US must lead in building the Western supply chain

This is an excerpt of an article that originally appeared in the June 22, 2021, edition of Orbis, the Foreign Policy Research Institute's quarterly journal of world affairs. Republished with permission.

By Ariel Cohen and James C. Grant

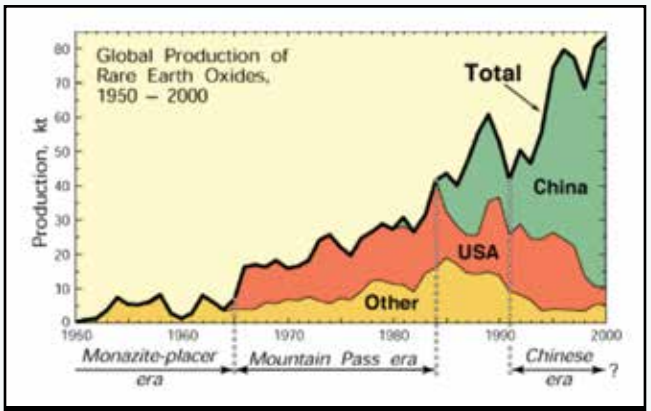
As it stands, Chinese domination of the critical mineral supply chains dwarves the U.S. by all conceivable metrics: China commands 85% of the rare earths elements (REE) export market, producing 62% of global raw mineral materials and importing $2 billion worth of critical minerals and REEs. In the event of an acute international crisis, China would likely use its leverage to further geostrategic aims by imposing critical mineral embargos. Considering the United States derives roughly 80% of its REEs from China, these would likely be catastrophic for the economy, including the high-tech, computers, electronics, electric mobility, aerospace, and military-industrial complex.

Given China's track record and threats in this space, the potential for future embargos is realistic. Like the Strategic Petroleum Reserve (SPR), the stockpiling of rare earths and critical minerals would provide sustainability in the face of international crisis. Supply delays during the COVID-19 pandemic exposed the U.S. lack of preparedness and supply chain bottlenecks, which is beginning to have short-term ramifications for U.S. semiconductors, appliances, autos, and other industries. Current semiconductor shortages in car and appliances factories are threatening to interrupt production and are leading to wait periods of up to six-month delivery times.

In the event of a critical minerals embargo, U.S. companies would be left stranded with limited REE stockpile capabilities. To counter the strategic vulnerabilities associated with reliance on Chinese critical mineral and REE supply chains, the United States must immediately establish a reserve of critical minerals like that of the SPR for oil imports. The capacity of such a reserve is open to discussion, but one-third to half of annual REE demand seems appropriate at the first stage, later expanding the reserve to a whole year of supply.

Developing domestic capacities to mine and refine critical minerals across the United States should be a priority for the U.S. government agencies, yet the private sector should be the primary driver behind REE exploration and production, like other mineral mining and processing. The sole Mountain Pass mine in California will not be sufficient for long-term aims of decoupling from Chinese critical mineral supply. Plans made by Lynas and Blue Line Corp. to build domestic REE refinement facilities in the United States should be the pioneering projects, leading to bigger and better ones throughout North America. The Biden administration should also reauthorize the Defense Production Act to speed up the planning, construction, and operation of these facilities, as expanding domestic mineral projects addresses a key strategic vulnerability.

U.S. corporations should be encouraged to expand rare earths extraction operations in Africa, Asia, and Latin America. The construction of mining infrastructure in African nations would be relatively inexpensive, given lower labor costs and less stringent environmental regulations. Africa's rich mineral reserves make it an ideal destination for supply chain diversification. However, the security challenges, from al-Shabaab to Boko Haram, will require U.S. and its allies to project power to protect the supply chain. Importantly, the African governments and audiences should be aware of U.S. efforts to address developmental needs of host countries, regions, and communities—in competition with China. Roads,



Credit: United States Geological Survey

schools, medical facilities, and environmental protection should be front and center for U.S. REE operations in Africa.

Finally, U.S. policymakers must set specific targets to decrease reliance on Chinese REEs and critical minerals. Targeting specific non-China reliance goals will increase intergovernmental and business sector cooperation and signal clear intent to international partners to build robust levels of Western REE self-reliance.

The United States and its allies should pursue policies that guarantee dependable access to these critical resources at affordable prices, like those in response to the 1970s Arab embargo-triggered energy crisis. President Richard Nixon launched Project Independence after the 1973 oil embargo, attempting to ensure that the U.S. would increase its capacity to refine and extract oil domestically while promoting a union of consumer countries to study the industry, and influence oil pricing. The International Energy Agency arose from such cooperative efforts of oil-consuming democracies.

Similarly, the U.S. must now explore critical mineral supply expansion while gathering allies into an REE "consumer club" to develop policies and build strategic cooperation and partnerships in the diversification of extraction and refinement facilities.

Critical minerals are the lifeblood of the 21st century, fueling high-tech manufacturing and renewable energy transition. These resources are the keystones of economic progress and industrial leadership in building 21st century defenses. The U.S. and her allies must diversify their critical mineral supply chains. Governments who underestimate their importance do so at their own risk.

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CENTER FOR PROTOTYPE MANUFACTURING

The Alfred University Center for Prototype Manufacturing, located one mile off the Alfred campus, serves as an industrial pilot plant and user facility helping companies scale up lab developed processes to commercialization.

The Center maintains a Class 10,000 cleanroom housing a suite of KEKO multilayer ceramic processing equipment including casting, cutting, drying, stacking, and screen printing.

The center also provides users with access to:

Various Mixing & Milling Processes
Spray Drying
Pressing (up to 80 ton)
Tape casting
Warm Isostatic Pressing
High Temperature Processing (to 1800oC)
Cost Share for NYS-based Firms

For more information, or to schedule a tour:
www.Alfred.edu/CACT or call (607) 871-2486

CACT Center for Advanced Ceramic Technology