<u>Rare Metals</u>

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Often categorized as rare earth elements or REEs, precious metals are chemical elements that are scarce on the Earth's crust and/or have limited availability due to concentration or extraction challenges. They are crucial for various high-tech applications including electronics, renewable energy and medical devices.

We must distinguish between metals and elements and minerals. Elements are the fundamental building blocks of matter, while minerals are naturally occurring inorganic solids with a specific chemical composition and crystalline structure. Metals are a subset of elements, typically known for their luster, conductivity and ability to be shaped. The topic was rare metals so we will address the rare metals but will find ourselves mentioning elements and minerals throughout the paper. Rare earth elements or REEs refers to a specific grouping of 17 metallic elements, including the 15 Lanthanides, plus Yttrium and Scandium that can often occur together in mineral deposits. The 15 rare earth metals are Lanthanum, Cerium, Praseodymium, Neodymium, Promethium, Samarium, Europium, Gadolinium, Terbium. Dysprosium, Holmium, Erbium, Thulium, Ytterbium, and Lutetium. These elements are not necessarily rare in abundance in the Earth's crust, but they are rarely found in economically viable concentrations. Rare metals is a broader term which includes various metallic elements that are scarce or difficult to extract, including some REEs but also other metals like niobium, tantalum, and indium.

Here is a quick review of some of the less than popular rare earth metals and their uses, that may affect you directly or indirectly on a daily basis.

Lanthanum is a silvery white metal the protype element of the Lanthanide series. It is a soft reactive nature and it can be cut with a knife. Typically used as a phosphate binder in medicines to treat kidney disease by preventing phosphate absorption. It is also used in Hybrid car batteries, petroleum cracking catalyst and high intensity lighting.

Cerium is the most abundant rare earth metal used in catalytic converters, polishing compounds, lighter fluids and electronics.

Praseodymium is a high strength alloy used in aircraft engines, magnets it colors glass and yellow-green hue that filters infrared in Welding glasses.

Neodymium forms the basis for the strongest permanent magnets used in electronic motors, wind turbines hard drives and speakers. It creates purple hues for Lasers.

Samarium is a chemical element, moderately hard silvery metal that slowly oxidizes in air. It is used to make carbon arc lights which are used in the motion picture industry for studio lighting and projector lights.

Europium is primarily used for its unique luminescent properties acting as a red phosphor in displays and fluorescent lamps and as a dopant for lasers and optical devices. It absorbs neutrons which makes it useful for control rods in nuclear reactors. Its fluorescent red glow serves as an anti-counterfeiting agent in modern currency.

Gadolinium provides Doctors and Radiologists with sharper, more accurate MRI images. It helps diagnose and monitor the progress of serious health conditions such as cancer. It is the active ingredient in GBCA which is injected into the body.

In it’s natural form it is toxic to humans, however, it goes through a process called chelation which makes it safe for use in the human body.

Erbium is used in fiber optics to amplify signals in lasers for medical and industrial applications, as a colorant for pink-colored glass and ceramics, in nuclear technology as a neutron absorber in control rods and in metallurgical applications to improve the properties of certain alloys.

Holmium is primarily known for its high magnetic strength making it useful in creating powerful magnets and Flux Concentrators for high-intensity magnetic fields such as those in MRI machines. It is also used in special lasers for medical procedures such as breaking up kidney stones and as coloring agent for glass and Cubic Zirconia.

Terbium is used to create green phosphors for fluorescent lamps and screens, high performance magnets for Hybrid Cars and wind Turbines and the Magnet strictive alloy for sonar systems, sensors and actuators.

Thulium used in portable Xray devices, lasers and a component in high temperature semiconductors.

Lutetium is used in targeted radionuclide cancer therapy; as a radioactive isotope it is linked to a molecule that binds cancer cells to deliver radiation and kill them. Also used on a limited basis as a catalyst in petroleum refining.

Scandium is primarily used as aluminum alloys for the aerospace industry and high -intensity lighting such as metal halide lamps for use in stadiums and film production.

Yttrium improves metal alloys, creates vibrant red phosphors for displays , manufacturing high temperatures superconductors like Yttrium Barium Copper

Oxide (YBCO), produces ceramic materials for jet engines and enable Lasers in medical and industrial applications.

Precious metals are rare, naturally occurring metallic chemical elements of high economic value. Precious metals, particularly the Noble metals, are erosion resistant and less chemically reactive than most elements. They are usually ductile (stretches into thin wires) and have a high luster. Historically, precious metals were important as currency, but they are now regarded mainly as an investment and industrial raw materials. Gold, Silver, Platinum and Palladium each have an ISO 4217 Code which are the agreed alphabetic and numeric codes for the representation of currencies standardizing global currencies in the Financial world. These codes are integral for Foreign Exchange trading, establishing currency pairs and determining exchange rates.

The best-known precious metals are the precious coinage metals which are Gold and Silver. Although both have industrial uses they are better known for their uses in Art, Jewelry, and Coinage. Other precious metals include the Platinum Group Metals PGM's Ruthenium's, Rhodium, Palladium, Osmium, Iridium, and Platinum of which is the most widely traded. The demand for Precious Metals is driven not by their practical use but also by their role as investment and a store of value. Historically, precious metals have commanded much higher prices than common Industrial metals. Osmium, Iridium, Palladium, Ruthenium and Rhodium are typically grouped with Platinum group metals or elements (PGMs or PGEs). PGM's are all chemically similar to each other and can substitute for each other in some applications.

Osmium is the most dense stable element. The Blue -Grey metal is highly reflective and is used in Space Mirrors.

Bullion is a metal deemed to be precious if it is rare. The discovery of new sources of ore or improvements in mining or refining processes may cause the value of a precious metal to diminish. The status of a "precious" metal can also be determined by high demand or market value. Precious metals in Bulk form are known as Bullion and are traded on the commodity markets. Bullion metals may be cast into Ingots or minted into coins. The defining attribute of Bullion is that it is valued by its mass and purity rather than by a face value of money.

The rarest naturally occurring metal on Earth is Rhodium. It's platinum group metal known for its rarity and high cost, often exceeding the price of Gold according to the Westminster Mint. Some schools of thought would list Osmium as the rarest, however, Rhodium is generally more rare because of its scarcity in the Earth's crust.

Palladium can be found in similar mineral settings as other PGM's. Most Palladium is used for catalytic converters, but other uses include jewelry, dentistry and surgical instruments. It was also used in older model Hammond Organs, the manuals and pedalboard of these Organs originally used solid Palladium alloy wire to ensure reliable electrical connections when the keys were depressed. This design was discontinued with the introduction of the transistor Organs. Some Lowery Organs actually used the Palladium model and used the name Palladium in their name. A Palladium coin was produced by the royal Canadian Mint. Palladium is an exchange traded metal and these coins are sought after by collectors and speculators.

We had a personal experience with Palladium a few short years ago we started finding abandoned Organs along the road, in the road, in front yards. This went on for about three years totaling around a dozen Organs. We could not figure out why this was happening where they were coming from and what was going on. We would call Allen County Highway Department and have them hauled them away and that would be the end of it until another Organ would appear. Then we discovered that the culprits were more than likely after the Palladium since it has such a high value. They would strip it out of the Organs and drop off the Organ wherever they felt comfortable, typically within about one mile radius of our home. We were never able to determine where they were selling the Palladium. We haven't had any Organ drop-offs for the last couple of years.

Iridium helped answer one of the Geologists biggest puzzles- what happened to the Dinosaurs? The rapid destruction of the Dinosaurs occurred 65 million years ago and marked the end of the Cretaceous Era known for the dominance and subsequent extinction of the non-avian Dinosaurs and the rise and diversification of florin plants (angiosperms). It also featured significant geological and climatic changes, including the breakup of Pangea and a warm high Sea level climate. The cause of the Dinosaur extinction has long intrigued Scientists. The Alvarez Hypothesis proposed that a thin layer of Iridium (rich clay) represented the impact of a colossal meteorite, which radically changed the climate and ended the era of the Dinosaurs. The actual site of the meteorite strike was high above the Red Deer River in south -central Alberta Canada.

Iridium is rare on the Earth , but much more abundant elsewhere in the Universe. The widespread Iridium rich clay is evidence of the pulverization of something very large of extra-terrestrial origin. Iridium anomalies have since been identified in a number of Meteor impact sites.

Ruthenium is used to harden Platinum and Palladium alloys to make highly resistant electrical contacts. It is also used as a plating metal.

Rhodium has similar applications but is much more expensive than Ruthenium, which is therefore usually used instead. Since it is very brittle it is usually purchased as a Powder instead of Bars or Coins which are available. Rhodium has been Exchange Traded and is currently the most expensive, trading around $7000. per ounce. It is a very rare and precious metal, its price can fluctuate significantly. While it is currently trading at $7000. per ounce it is important to note that it traded for nearly $30,000. per ounce in 2021. Its high value is due to its scarcity and unique properties making it desirable for industrial and investment purposes. It's uses range from catalytic converters to jewelry where it is a coating that preserves the shine and prevents tarnishing on White Gold and Sterling Silver. It is also used in several Industrial applications such as electrical contacts, high-temperature thermocouples and as an alloy with Platinum and Iridium.

The Town of Telluride, Colorado was named after a hope for the discovery of Tellurium. That big strike never occurred. Tellurium is associated with Gold as the Minerals Calaverite and Krennerite it is also found as a native metal. Tellurium is most often found combined with Gold, Copper and Lead. Most production is as a by-product of refining these metals, particularly Copper. The supply of Tellurium varies depending on the quality of the Ore it's recovered from in Processing Plants that may not recover the Tellurium from the waste stream unless it is economically viable. This makes it particularly difficult to estimate the Tellurium reserves. Tellurium is in demand for the Fiber Optic cables that modern telecommunications depend on. It is also used in Alloys to improve malleability and in the semi-conductor industry. It is a key component of Cadmium-Tellurium Photo-Voltaic Power Cells.

Rhenium is a rare, high-melting point metal with variety of uses. It is critical in Jet Engine components and a catalyst for lead-free gasoline production. It is also used in Alloys with Tungsten and Molybdenum as Filaments in Mass Spectrographs and as an electrical material. The Alloy is crucial for maintaining structural integrity at high temperatures, enhancing Engine performance and durability. Rhenium improves the creep strength of nickel-based Alloys allowing it to withstand extreme conditions. It can also be found in Heating Elements, Vacuum Tubes, certain medical applications and Rocket thrusters for small Satellites.

On April 4th of this year China's Ministry of Commerce imposed export restrictions on seven Rare Earth elements and magnets used in defense, energy and automotive sectors this was in response to U.S. President Trump's Tariff increases on Chinese products. The new restrictions apply to 7 of the 17 REE's Samarium, Gadolinium, Terbium, Dysprosium, Lutetium, Scandium, and Yttrium and it requires companies to secure special export licenses to export the mineral and magnets.

So why do we care?

The United States is particularly vulnerable for these supply chains. Until 2023 China accounted for 99 percent of global heavy REE's processing, with only minimal output from a refinery in Vietnam. Unfortunately, that facility has been shut down for the past year due to a tax dispute, effectively giving China a monopoly over the supply.

REE's are crucial for a range of defense technologies including F-35 Fighter Jets, Virginia and Columbia -Class Submarines , Tomahawk Missiles, Radar Systems Predator unmanned aerial vehicle and the Joint Direct Attack Munition series Smart Bombs. Just as an example, the F-35 Fighter Jet contains 900 pounds of REE's, an Arleigh Burke-Class DDG-51 Destroyer requires approximately 5,200 pounds of REE's, while Virginia-Class Submarines use around 9,200 pounds.

China is rapidly expanding its munitions production and acquiring advance weapons systems and equipment at a pace five to six times faster than the United States. Even before the latest restrictions the U.S. defense industrial base struggled with limited capacity and lacks the ability to scale up production to meet defense technology demands. Further bans on critical mineral inputs will only widen the gap, enabling China to strengthen its military capabilities more quickly than the U.S.

There are no heavy rare Earth separation sites happening in the U.S. at the present time. Just recently the Defense Department placed a substantial stake in a company named MP Materials. It is the West's largest Rare Earth Materials mining company to speed up the building of domestic Rare Earth Magnet supply chain and cut the U.S. dependency on China. Rare Earth Magnets are one of the most strategically important components in advanced technology systems from the F-35 Fighter Jets and Navigation equipment to automobiles. Yet the U.S. relies almost entirely on foreign sources. The U.S. Government is the largest single shareholder of MP Materials with 15%. MP Materials will begin commercial production of magnets this year for its main customer General Motors. The goal is to produce 10,000 metric tons of magnets by 2028.

China is the global leader in mining and processing rare Earths and they have threatened to limit exports after the President Trump's Tariffs in April 2025. The Impact to the U.S. was immediate and felt around the world. Regaining access to Chinese rare Earths was the main bone of contention in U.S.- China trade negotiations. In 2024 China mined about 270,000 metric tons of the world's 390,000 metric tons of rare earth oxides. China controls 85 % of global refining capacity.

So the question then is how did China become the world's leader in rare earth elements? China wasn't always the leader, for most of the second half of the 20^{th} Century the U.S. controlled the market on rare earth elements. This came about as Prospectors discovered them in Mountain Pass California in 1949.

Then the Chinese recognized the real value of rare earth elements in the 1960's. They sent Chinese executives to Mountain Pass Mine California, the U.S. company working the Mine at that time was Molycorp a rare Earth Processing company. Mark Smith the CEO of Molycorp at that time hosted the touring Chinese officials in the 1980's and the 1990's he explained their operation totally, allowed them to take pictures and everything else. They took it all back to China. Strangely enough, the Chinese refineries improved their technology, took advantage of cheap electricity in China allowing literally hundreds of lucrative mining and processing firms popped up to service mostly domestic demand for rare earths. It was a very unregulated and chaotic industry these small operations competed against one another and drove each other out of business.

Chinese government unleashed unrestrained mining which was very harmful to the environment. Thick black smoke was a tell tail sign of one of these facilities along with the huge piles of toxic, metallic by-products of other industrial processes sitting on the bare ground. This small scale mining was most prevalent in southern China which is where the most valuable natural deposits of heavy rare earth elements exist.

In 2012 Chinese media investigation compared the rare earths industry in China during this time to trafficking drugs. The media actually stated: "There are generally two types of people who can deal with rare earths: the first is someone who has just been released from prison and the other is someone who can get someone out of prison. Those who are not afraid of death and leading cadres are all involved."

The domestic price wars and local pollution was all Beijing could handle by the late 1990's. It started to impose production and export quotas to encourage more advanced processing of rare earths. In an attempt to protect the industry from foreign intervention they imposed caps on production and forced reduced pollution. The quotas resorted in two -tier pricing when the exports were limited to the rest of the world it resulted in lower prices for domestic Chinese users. The other things that occurred was a thriving smuggling industry; up to 30% of the country's rare earth products in the mid 2000's was illegal and smuggled out of China this was driven by demand from both Japan and the U.S.

Once it became apparent what was going on the WTO ruled that China could not do this. As you would guess China continued pressing forward. They were set on global dominance in rare earths but not through controlling volumes but by controlling which firms could operate. It became a "secret war" Chinese officials dubbed it "one plus five" it was an ambitious and ruthless effort to wind down the rare earth industry to just six consolidated companies. It was their war against illegal production of rare earth companies. The Chinese provincial authorities were told to perform unannounced inspections of the Mines, seize any contraband ore and by-products and if necessary, dynamiting and destroying the illegal mining operations. Within a few short years China claimed success by squeezing out the private sector by whatever means necessary. China announced that it had closed dozens of smaller operations and forced mergers of surviving companies into six mega size state-owned firms and became the Big Six in China. This move allowed China to now, for the most part, control both supply and price.

This results in Chinese companies having the ability to cause significant price fluctuations depending on how much they want to produce or export. This instability has caused investors to become wary of putting money into new U.S. ventures. Making it virtually impossible to raise the necessary capital to build refining plants in the U.S. and put the U.S. back on track to world dominance or at least eliminate our reliance upon foreign entities. This continual mining left China's terrain scarred with ground water and soil pollution. Local residents complained but the government was reaping financial benefits from the mining so the complaints fell on deaf ears.

Currently there is no heavy rare-earth separation happening in the U.S. today.

The Department of Defense in 2024 set a goal to develop a complete mine-to-magnet REE supply chain that can meet all U.S. defense needs by 2027. Dating back to 2000 the Department of Defense has committed over $439 million toward domestic supply chains. Additionally, the Pentagon awarded two grants to MP Materials totaling $44.6 million for two facilities; one for light rare earths separation and one for heavy rare earth separation.

The difference between heavy and light rare earth separations is based on the chemical properties of each. Those with lower atomic numbers versus those with higher atomic numbers. Those numbers are based primarily on their ionic size and charge density. Together they would be the first of their kind in the U.S. fully integrating the rare earths supply chain from mining, separating and leaching in Mountain Pass to refining and magnet production in Fort Worth Texas. Once fully operational MP Materials will be producing 1,000 tons of neodymium-boron-iron (NdFeB) magnets by the end of 2025 which is less than 1 percent of the 138,000 tons of NdFeB magnets China produced in 2018. In 2024 MP Materials produced

1300 tons of Neodymium-praseodymium NdProxide in the same year China produced 300,00 tons of NdFeb magnets.

The Department of Defense has also given out Grants to Lynas Rare Earth's U.S. a subsidiary of Lynas USA for over $150 million to build two facilities both a light REE's and a heavy REE's processing facility. Once again with the goal of building a completely independent supply chain for REE's Magnets.

Even with all these investments the U.S. is still far behind China and even further behind rivaling foreign adversaries in this strategic industry. The U.S.is largely in its' infancy. For example, in January of 2025 USA Rare Earths produced its' first sample of dysprosium oxide purified to 99.1 percent. It was produced using Ore from the Round Top deposit in Texas and processed at a research facility in Wheat Ridge, Colorado, the company declared it a breakthrough development for the rare earths industry. Unfortunately, much work still remains to be able to turn production samples in a Laboratory into full scale commercial production that can reduce reliance upon China. This simply means that the U.S. will be playing catch-up for quite some time.

Australia, Brazil, South Africa, Saudi Arabia, and Vietnam all have initiatives and investments underway to bolster key REE mining, processing and research and development as well as Magnet manufacturing. If the U.S. wants to see these programs be successful, they must continue to provide financial and diplomatic support to the sourcing partners for long term chain security.

Australia for example is in the process of developing its Brown Range to become the first significant Dysprosium producer outside of China. The deposit has estimated to have Dysprosium reserves of 2,294 tons, which unlocked in phases over time will result in 279,000 tons of Dysprosium per year. Once again much work lies ahead to be able to surpass China in that regard. Strangely enough

Australia's Lynas Rare Earth is the largest producer of separated rare earths outside of China but still sends oxide to China for refining. It is expected that Australia will still need China to do that until at least 2026.

Working with International partners will be key in over-coming gaps in technological knowledge when it comes to REE separation and processing. A few other countries continue to lead the development in critical mineral and REE's specific R &D initiatives to support the development of this sector. The Australian Critical Minerals Research and Development Hub is leading the way with Industry and Universities to boost technical capacity.

Japan has what they call the Center for Rare Earths Research based in the Muro ran Institute of Technology. It is also working with Vietnam at the Rare Earth Research and Technology Centre in Hanoi. This effort is focused on improving the REE extraction and processing procedures. Japan has been a leader in this area dating back to 2012 when they started to work on strengthening and diversifying it's REE supply chains as a result China's REE export Ban in 2010.

As a result of China's action my curiosity was aroused on whom that may impact locally. First name that came to mind was Fort Wayne Metals. As a Commissioner I was invited at attend a Tour of a couple of their facilities here in Fort Wayne a couple of years ago. I was amazed to see what the Technology and breadth of Manufacturing that takes place there. I made a call to Fort Wayne Metals to learn more about their efforts with rare earth metals and what the move by China might mean to them.

I met with Adam Griebel a Senior Research Engineer at Fort Wayne Metals. He indicated that typically Fort Wayne Metals use the following metals for customized products for their medical clients, Magnesium, Yttrium, Scandium, Lanthanum, NE Odium and Dysprosium. Of the seven Rare Earths that China has placed restrictions on only three are actually used by Fort Wayne Metals, Dysprosium, Scandium, and Yttrium. Griebel indicated that they had ample supply of those three REE's that it was unlikely the restrictions would impact Fort Wayne Metals. Magnesium is used for Bone Screws since they dissolve in the body over time. Nitinol is not a natural element on Earth it is created by combining Nickel and Titanium. Fort Wayne Metals is one of few places in the World that actually has Melting Pots located in Columbia City where they create Nitinol. The exact formula mixture is driven by the intended use of the Nitinol. Depending upon the attributes needed to meet the clients' requirements. Nitinol is used in Stents in the Leg, Heart and Brain. They are also experimenting with Nitinol since it has the ability to be bent out of shape and with mild warmth it will resume its original shape. This is being experimented with the wheels on the Mars Mobile Probe as opposed to Rubber Tires.

What is the future of Rare Earth Metals?

Rare Earth Metals will remain a very important part of the future covering the area of Quantum Computing, Material Sciences to Medical Devices and advances in Green Technology. If the demand for Electric Vehicles increases so will the demand for Rare Earth Batteries and Magnets.

To prepare for this increasing demand Mining Companies are proposing opening new mines and processing plants all over the world. Some of these plans seem unrealistic, like deep Sea mining or extracting Rare Earths from Acidic Waste Water draining from abandoned Mines. These production techniques might become a reality if a large increase in demand drives up the prices or if Governments decide to subsidize these efforts.

Others are considering ways to better design the technologies so as to reduce the need for Rare Earths. Since 2010 auto makers have been designing vehicles to use less Rare Earths. The Consumer electronics could be designed to be more easily repaired and upgraded rather than being discarded. Research should be done to discover ways to recover Rare Earths from electronic waste that too would reduce the amount of metals that need to be produced by mining and refining.

Sustainable and socially fair production of Rare Earth Metals really depends on the willingness of consumers and manufacturers to pay more for materials that are produced ethically. Entities on both sides of the issue must ensure that sustainable production methods are actually implemented.

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