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The Geopolitical Implications of Rare Earth Mineral Dependencies and Technological Rivalries

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Abstract

The critical minerals and raw materials are the backbone of modern technological innovations which power key industries i.e. renewable energy, electronics and defense. These minerals include rare earth elements lithium, cobalt and graphite are essential for used in semiconductors, manufacturing of long-lasting batteries and their use in renewable sources. Chinese dominance over the refining and processing of these minerals poses a critical threat to U.S and its allies. This paper explores how China's control over these supply chains of critical minerals give it a strategic edge over other states. This study examines the strategic implications of China's dominance by focusing on its leverage to influence international markets, price control of these and by giving them technological superiority. This paper highlights the vulnerabilities of competing nations particularly the United States and its allies who have been heavily reliant on Chinese exports of these minerals. Furthermore, the paper evaluates international efforts to deter the Chinese influence by using various means i.e. diversification of supply chains, recycling initiatives. It sheds light on the recommendations of the policy makers to promote technological resilience by establishing a framework for access to critical minerals. This research sheds light on the pivotal role of critical minerals in shaping future global power dynamics.

Keywords: China, United States, E.U, Critical minerals, Rare Earth Minerals, Military, Technology

Introduction

Critical minerals are at the heart of technological and economic transformations shaping the 21st century. The importance is being realized as the world is transitioning from fossil fuels towards more environment friendly fuel and also, they

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also play a vital role in advanced technologies to for further innovations. As the world pushes towards more and healthier environment the rare minerals namely neodymium and dysprosium are critical for the production of high-performance magnets used in wind-turbines (Alves Dias, P., et al., 2020) and electric motors because these elements we cannot combat climate change as we can't scale up our energy solutions. Similarly, the semiconductors which are at the heart of all digital devices rely on the gallium and indium (Swallow, Jack EN, et al., 2021) besides this the rise of artificial intelligence and quantum computing further enhances the demand of critical minerals. As this technology is becoming more and more prevalent a stable source is required for sustaining innovation and growth. It's been a decade that China has emerged as a major player in all the fields which has created dependency of all the states on China. One of the major fields is a strategically important field of rare Earth minerals which are critical for modern technologies. As the relations between United States and China are on downwards trajectory more and more concerns are being mounted that China can halt the supply of these minerals which can directly affect the prices of certain commodities. As the world is making efforts to transition towards a greener economy more and more legislations are being passed in order to keep the share of green energy market on global level. The United States Inflation Reduction Act of 2022 committed billions to manufacture, promote and advancement of clean green energy (House, White., 2022). Similarly, the European Union is also on the way towards a technological transition in green industries specially the renewables and the electric vehicle batteries (Terzi, Alessio, et.al., 2022). The importance of critical minerals is vital for the range of strategic sectors including the green sectors which has led International Atomic Energy Agency (IAEA) to conduct a study in which it is estimated that the demand for lithium will grow by 90%, nickel by 70%, and cobalt by 40% which also includes wind turbines and solar photovoltaics in coming two decades (IEA., 2022). As the world continues its transition towards a low-carbon economy, these minerals are becoming more and more important which highlights the need for careful planning to ensure their responsible use and fair distribution.

The deposits of these minerals cannot be found all over the world as they are limited to some countries primarily Lithium is found in Latin America and Australia, Copper can be found in Chile, Indonesia has vast majority of nickel reserves and China has a vast reserves of rare earth minerals which are primarily used in the clean energy applications (IEA., 2022). In this race of control for strategic minerals China doesn't dominate the global markets but it controls the refining process which is necessary

for using these minerals into vital applications but the major problem in supply chains is the capacity of China to disrupt it as the minerals extracted form the world are sent to China for refining process so that they can be used in the products (IEA., 2022). The world largest economies commonly called as G7 have taken serious considerations about the Chinese ability to disrupt the critical supply chains, the G7 announced that they will take individual and joint actions in order to avoid their dependency for disruption in critical supply chains (House, White.,2023). In 2010 a dispute between China and Japan led to the halt of export of critical minerals from China which showed that how a dominating state can leverage itself. This incident also led Japan to study its supply chain vulnerabilities and look towards alternative options (Evenett, Simon, and Johannes Fritz., 2023). The resources rich countries like Australia, Chile, Canada and Mexico have developed screening mechanisms and export restrictions(Office, critical minerals., 2023) and by Nationalizing (Pulice, Carolina and Nelson Bocanegra, 2023) these strategically important minerals in order to use these resources for their own benefit while many Asian states have signed various agreements with the resource rich Australia for supply of minerals which is also beneficial for Australia itself as it will bring the foreign investments and technological expertise as well which can strengthen the hold of Australia in the processing and refining sector of critical minerals.

Our Key argument in this paper is that how the critical minerals which are used for clean energy purposes can be used as a tool by the states to maintain a technological edge with its rivals especially when we see that there is a race between states to transition towards clean environment instead of using fossil fuels which have severely impacted the environment as uncontrolled carbon emissions have created havoc on a wider scale. Massive floods and changing patterns of weather are a source of serious concern because it directly impacts the human security as the population of the world increases more burden is coming upon the states to manage the adequate supply of food resources in order to feed their population. In the second section we will study the discovery and regulating the critical minerals industry. In the third section we will focus on the Chinese strategy that how they maintain their dominance in supply chain of critical minerals. In last we will discuss the G7 strategy that how these states have decided to response towards the Chinese dominance of these rare minerals.

Discovery & Regulation of Critical Minerals

Critical minerals have been known to humanity for centuries but their significance has been known for centuries but their importance has been highlighted with technological advancements the use of copper and tin can be traced back down to bronze age while iron has been used in the age of industrialization. However, the concept of "critical minerals" emerged in the late 20th century because of their need for technological advancements (Museum & Library, Science History Institute.,).

The discovery of lithium in late 20th century lead to its use in the manufacturing of batteries but now the use of lithium has grown because it's use has been expanded and is a backbone for transition of humankind towards the green energies to counter the impacts of climate change. Major reserves of lithium have been found in area called as "Lithium Triangle" which spans across Bolivia, Chile and Argentina (Ahmad, Samar., 2020). Similarly, the discovery of Cobalt and it's use in the development of high-capacity batteries and super alloys for the aerospace applications. With the expanded use of rechargeable batteries, the use of cobalt also increased. As more and more technological advancements happened they led to discoveries of minerals behind the permafrost of Greenland and Africa (Christiansen, Flemming G., 2022). The states have become dependent on the minerals for the production of goods and to use them in the infrastructure projects. These important minerals are scattered in different states around the globe which make them valuable because they are also in finite quantity. The discovery of these minerals has been blessing for the states because they get billions of dollars by selling them in the International market. These minerals are called critical because they are rare and in limited quantity and are used in the construction sector, industries, green energy production and various other industries which are essential for the states.

The regulation of these minerals includes the policy framework and curbs which are being used by the states in order to get maximum benefit from the use of their minerals. These regulations and strategies are implemented by governments and international organizations to overcome the challenges which are associated with these critical minerals. United States government has introduced critical minerals strategy to reduce dependence on foreign imports to develop the domestic mining industry besides this the relations between United States and China which holds a dominant position in controlling the refined products of minerals have seen a

downward trajectory has alarmed the U.S that in case of conflict the Chinese dominant can pose serious security threats due to use of these minerals in the production of semiconductors and in various other products (Baskaran, Gracelin., 2024). European Union's critical minerals act which was introduced in 2023 is aimed to secure a sustainable supply of critical minerals which are necessary for transition of EU's transition towards green and clean energy which will also help it in maintaining autonomy in a competitive landscape. With the introduction of this act the European nations want to reduce dependence on external suppliers, strengthen sustainable practices and unimpeded transition towards a healthier environment. The European nations have established the goals which they want to achieve but their transition towards these technologies will be a challenge because of the high costs of developing domestic mining operations, complex processes of refining these minerals and the resistance of local people which feel threaten by these mining activities (Europa.eu., 2024).

Chinese Strategy to dominate the Critical Minerals Industry

China dominates the supply chain of critical minerals presently. The Chinese monopoly over the Rare elements have caused concerns for the states which are heavily dependent on Chinese imports. Besides this these minerals are also having strategic importance which include lithium, copper, cobalt, silicon and nickel as more and more states tend to transition towards a green economy. The devastating impacts of climate change has alarmed the states and more states are transitioning towards the cleaner green energy a race has been started to secure the supply of these critical minerals. For a long time, the Chinese companies have invested in Africa in infrastructural projects while enhancing their footprint in the region to secure the supply of critical minerals. Similarly, China has also enhanced its presence in the South America which also contains one of the world's largest reserve of these critical minerals (Jangra, Renu, 2024). Chinese position as a dominant player in the global supply chain and the souring relations have led the states to form a "de-risking" strategy from China. China dominates in the refining sector because it is the largest importer of raw products which it processes and then supplies to the rest of the world. The Chinese critical minerals strategies emerged in the late 1970s with the rare earth industry and it achieved relative success and efficiency while it also faced several challenges that included illegal mining, overproduction, smuggling and pollution ((Zhou, Weihuan , 2024).Since then the Chinese government has maintained a balanced approach which emerged to facilitate

industrial reforms while also working to protect the natural resources and the environment by using sustainable technologies and development (Zhou, Weihuan , 2024). The recently announced National Plan for Mineral Resources 2016-2024 focused on 24 "strategic minerals" which included metallic, non-metallic and energy resources as it outlined the Chinese strategy for the minerals industry by joining the domestic and international policies. Domestically, Chinese government has focused on the mining activities, efficient use of minerals, upgrading the industrial infrastructure and to transition towards the green development of the industry. While at the foreign level the Chinese enterprises have focused on international cooperation to secure the safe and reliable source of supply for these minerals (Zhou, Weihuan, 2024).

According to the estimates China refines about 68 percent nickel, 40 percent of copper, 59 percent of cobalt and 73 percent of lithium which are further used in refined products. Besides this the refined products i.e. cells of manufactured batteries including 85 percent of anodes, 66 percent of separators and 62 percent of electrolytes (Castillo, Rodrigo, and Caitlin Purdy, 2022). Most notably the Chinese dominance over cell manufacturing used in EV batteries is complicating the situation because it gives Chinese companies leverage to enhance their footprint in global EV market. The country also includes three-fourths of the world lithium-ion mega factories. There have been many instances in which Chinese side have restricted the exports of these critical minerals which have hinted at the coercive measures but at the deeper level those Chinese restrictions were aimed at reducing the export level as these restrictions did not targeted a specific country. Recently, the Chinese imposed the control on Gallium and Germanium (Holderness, Alexander., 2023) which are used in the semiconductor industry but these measures were seen as a response to U.S restrictions which targeted the Chinese semiconductor industry.

Technological Rivalries and Use of Critical minerals

The modern technologies are dependent upon the rare earth elements (REEs) which include lithium, cobalt and nickel. The electric vehicles and portable batteries which are used in wide variety of applications are considered essential for the long use of battery while at the same time rare earth minerals are vital for the use in high-performance magnets which are used in defense systems and wind turbines critical. The transition from fossil fuels towards the green energy has led their demands to

skyrocket because more and more states have started to adopt the digital technologies. International Energy Agency (IEA), the critical minerals supplies will increase six-fold by 2040 in order to achieve the carbon emissions target set by 2050. The distribution of these critical minerals is uneven as countries like China, Australia and Democratic Republic of Congo which dominate the production and processing of these minerals. This concentration of minerals in limited countries has exacerbated the technological race which has led to secure these resources (IEA, 2021).

China versus United States

China and United States are the two major players in global technological landscape. Both the states are trying to dominate the global market by registering new patents in every field most notably are artificial intelligence (AI), 5G telecommunications and renewable energy technologies. The competition is not about the technological supremacy but they also aim to control the supply chains in order to dominate these vital industries. China dominates the supply chains of these minerals due to years of its investments in this vital sector globally in the minerals rich areas which include Africa and Latin America. The United States recognized its vulnerabilities and to reduce its dependence on China it had introduced legislations and partnerships with its allies in Australia and Canada i.e. Inflation Reduction Act (2022) which is focused on to create alternative sources of critical minerals (Department, Energy., 2022).

China is one of the major producers of clean electricity which include hydropower generation, solar energy and wind power. To maintain its position as a dominant state in the renewable sector and to maintain technological edge over its rival states china has to keep a safe and secure supply of these minerals which are necessary for its national security as well. These minerals are also used in the military sector as they are considered a fundamental component in making of the cutting-edge military equipment. The use of Lithium and Cobalt in Electric Vehicle Batteries and energy storage systems also makes them very important because their use has been increased similarly Copper and Nickel are used in energy infrastructure (Hund, Kirsten, et al.,2023). We can see that the usage of these critical minerals in these all sectors make them necessary for a state to keep up with the modern innovations and in its pursuit for cleaner environment. Besides United States another major player in the critical minerals Countries heavily investing in renewable energy are

simultaneously seeking to secure their critical mineral supplies. China's dominance in solar panel manufacturing is a direct result of its investments in critical mineral refining and processing. Similarly, the European Union (EU) is implementing strategies such as the "Raw Materials Act"(Europa.eu., 2024) to ensure sustainable access to these minerals.

Military Applications of Critical Minerals

The critical minerals as discussed above are used in various application which make them necessary to keep up with modern advanced technologies for latest innovations. The use of these minerals in military applications highlight their importance due to increased tensions between China and United States as these minerals are essential for advanced military technologies which include military precision-guided missiles, stealth aircraft and other weapons. These minerals are also critical in making permanent magnets which are used in radar systems, fighter jets and drones. Besides this the alloys of these minerals and used to enhance the durability and to get best performance from the military equipment.

The use of Dysprosium and neodymium in the magnets which are used in missile guidance systems shows how these minerals present a strategic challenge if supply chains of these minerals are affected (Laje, Diego.,2023). Over 80 percent of U.S rare earth imports come from China which represent a significant challenge to its military capabilities and are at the risk of disruption (Keys, Cameron M., 2023). The main reason behind this is that U.S lags in domestic capability to process and refine these minerals because this is a complex and expensive process. The Chinese military doesn't have any fear of supply chain disruptions because China has the dominance on processing these critical minerals and they are using to enhance their military capabilities by using them in hypersonic weapons, quantum computing, AI, autonomous systems and in modernizing their military capabilities. The control of these minerals by China can get it trade concessions and leverage in geopolitical tensions as U.S has been looking to reduce its dependence on China to avoid giving it these concessions (Keys, Cameron M., 2023). The competition over critical minerals between China and United States will continue to alter the strategic balance between them.

Chinese Domination of critical mineral and response of G7 U.S Minerals Security Partnerships

U.S and likeminded states had experienced the consequences of depending upon rival states for commodities such as gas and oil so therefore they had launched Minerals Security Partnership (MSP). Minerals Security Partnership (MSP) is a coalition of European Commission and 14 nations that was launched in June 2022 (Sheppard, David., 2024). It is also known as Critical Minerals Alliance (Lukmaanias,2024). It is constituted by Australia, Canada, Finland, France, India, Germany, Estonia, Japan, the Republic of Korea, Sweden, the United Kingdom, and the European Commission. It had formed in Toronto during annual Prospector and Developers Association of Canada (U.S Department of State). It is essential for US and its allies to maintain its leadership in energy without relying on China for critical minerals. They required new strategy to lead the energy transition, creating alliances which can produce, process and reuse critical minerals. India is only developing state in this alliance. India is trying to reduce it dependency from China (U.S Department of State). MSP is to improve the partner human health, financial transparency, environmental protection, and indigenous consultation. The MSP will continue support in the mineral industry technology and improve standards continuously. The common goals of MSP are to promote sustainable, secure, and equitable supply of critical minerals and technology related to this industry. The main focus areas of MSP are global supply chain of critical minerals, strengthening the skills of workforce, developing the new technologies, reduce the cost, attract private sector for long term investment (by helping in national development and growth), lower the cost of projects of partner state, ensure the processing, manufacturing and developing strategically important projects (Australian Government, Department of Industry, Science and Resources, 2023). Lithium, Cobalt, rare earth elements, Graphite, Nickel, and Copper are focus of Minerals Security Partnership (Reuters, 2022). The ambition of this initiative is to boost the supply chains of critical minerals, reduce the current dependence on China

The Canadian Critical Minerals Strategy

Canada had felt their supply chain of critical minerals is under threat MSP will protect its supply chain and will increase its production of critical minerals (Government of Canada, 2024). Canada created bilateral partnership with key users of critical minerals. Main focus of bilateral partnership is to maintain global supply

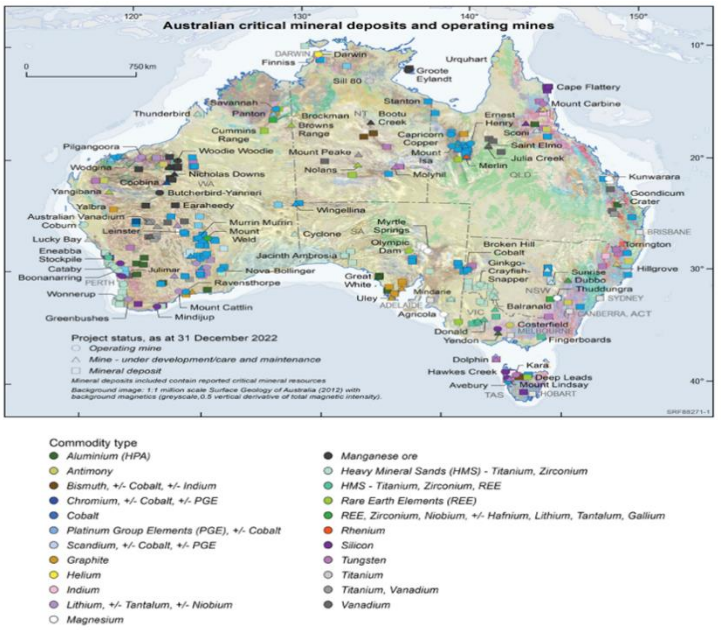
chains, share the invocation by creating joint research and development, align with policies, create friendly environment which will encourage new partners for investment and raise global social, economic and governance. The Canada-U.S. Joint Action Plan on Critical Minerals was launched on January 9, 2020 (Government of Canada, 2024). U.S-Canada bilateral mineral trade is valued at $95.6 billion. Aim of joint action plan is to secure supply chain to fulfill defense, aerospace, communication technology and clean energy needs, share information, and cooperate in multilateral forums.

The Canada had established Strategic Partnership with EU on Raw Materials (Government of Canada, 2024). The objective of this partnership is to secure and value the sustainability of investment and trade into minerals for green economy. EU and Canada have agreed to enhance the cooperation in area of raw material value chains, innovation collaboration; science, technology and, collaboration in multilateral forums to improve Environmental, Social and Governance (ESG) standards. The Japan-Canada Sectoral Working Group on Critical Minerals objectives is to facilitate commercial activities between Japan and Canada. The aim of working group is to share information and secure supply chain for industrial use. This working group is part of Japan-Canada Energy Policy Dialogue (Government of Canada, 2024).

Australia 2023-2030 Critical Mineral Strategy

The objective of Australia critical minerals strategy is to create diverse, sustainable supply chains with international partnerships by build capability and use critical minerals for renewable energy, create jobs, and create economic opportunities (Australian Government, Department of Industry, Science and Resources, 2023). According to the Australian department of resources the country had 81 major critical minerals projects as of December 2022 which have an estimated value of $30 billion and $42 billion. The numbers have risen as the projects have been increased from 71 and were estimated at $22 billion to $36 billion in 2021 (Australian Government, Department of Industry, Science and Resources, 2022). Main focus area of Australia's strategy is on communities, industries, states and territories investors, research and innovation sector, and international partners. The Australian government has maintained the stance that the critical mineral reserves are vital for the defense and regional security of their region besides this they aim

to achieve their decarbonizing targets by 2050 which will help the environment globally.



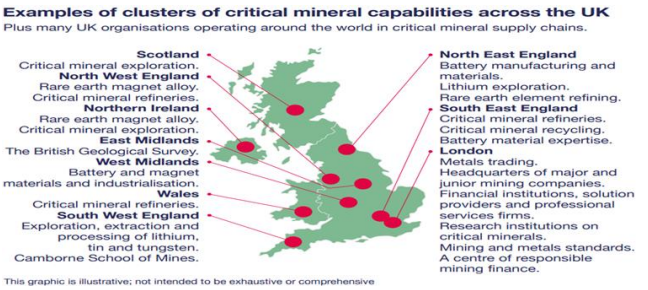
Source: *https://www.ga.gov.au/scientific-topics/minerals/critical-minerals*

In addition, the Australian government and U.S agreed for the establishment of climate, critical minerals and clean energy as a cornerstone of the Australia–US Climate, Critical Minerals, and Clean Energy Transformation Compact. Therefore, a ministerial-level task force was also created which was headed by U.S National Security council and the Commonwealth minister of Resources of Australia. Australia is also in negotiations with European Union and India separately for a free trade agreement and Comprehensive Economic Cooperation Agreement, in which both sides will work closely to consider the critical minerals (Australian Government, 2023).

Critical Minerals Strategy of The United Kingdom

The Former National Security Advisor, of U.K Lord Sedwill said that "critical minerals, semiconductors and data are the oil, steel and electricity of the 21st century" (GOV.UK, 2022). United Kingdom is having vast experience in mining but due to limited resources it had to rely on foreign suppliers for the critical minerals.

In July 2022, United Kingdom had launched Critical Mineral Strategy with titled "Resilience for the Future". The strategy launched by U.K sets out a new approach called A-C-E which stands for Approach Accelerate, Collaborate and Enhance (GOV.UK, 2022).



Source: Resilience for the Future: The United Kingdom's Critical Minerals Strategy

The strategy aims firstly accelerating domestic growth capabilities in refining, mining, and producing of critical minerals, improve reuse and recycling process critical minerals, secondly secure, diversifying improves the supply chain, support the domestic companies, and develop the trading partners, lastly collaborating with likeminded states to secure the global supply chain, make international market transparent, and responsible (GOV.UK, 2022). The new approach presented by British Government incorporates tools to boost global environment, social and governance policies. The government will be working to carry out advanced research to overcome the challenges mounted by the supply chains of critical minerals. Besides being at the cornerstone of energy transition these minerals are also vital for national security. The use of these minerals in cutting-edge military equipment requires high-purity and high-value materials. The U.K Ministry of Defense (MOD) has developed plans to work with key suppliers to overcome the challenges of supply-chain. Because in case of conflict these supply chain issues can restrict or limit any states credible deterrence.

Conclusion

The interaction of technological rivalries and their usage in critical minerals highlights the complicated relationship which has been shaping the global economies and geopolitics simultaneously. As all the major states gear up to dominate in emerging technologies the strategic importance of critical minerals will grow. To Address these challenges of interdependence, environment friendly methods require a coordinated response by global community. This is possible only

through innovation, cooperation, and sustained practices can guide this world to achieve a balanced and innovative future. The competition between the states for these critical minerals will grow as they will try to insulate them from supply chain disruptions which can have negative effects on their economies. This competition will also create competition for China in global mineral market, reduce the China's global market share as more and more nations have already started to look for alternative options.

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- All authors **Conceptualization, and intellectual revisions. Data collection, interpretation, and drafting of manuscript**
- The authors agree to take responsibility for every facet of the work, making sure that any concerns about its integrity or veracity are thoroughly examined and addressed
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