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# Quest for Critical Minerals: An Indian Perspective

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## Introduction

Globally, critical minerals market size reached US$ 328.19 billion in 2024 and is expected to reach US$ 586.63 billion by 2032, growing with a CAGR of 7.53% during the forecast period 2025-2032 (Data M Intelligence, 2025). This unprecedented growth is an accelerating transition to clean energy technologies with big leap in demand for lithium, cobalt, and nickel.

Critical minerals are essential for a country's economic development and national security. The limited availability or concentrated extraction and processing in a few geographical locations can create supply chain vulnerabilities or disrupt critical industries. Critical minerals like Antimony, Beryllium, Bismuth, Cadmium, Cobalt, Copper, Gallium, Germanium, Graphite, Hafnium, Indium, Lithium, Molybdenum, Niobium, Nickel, PGE, Phosphorus, Potash, REE, Rhenium, Selenium, Silicon, Strontium, Tantalum, Tellurium, Tin, Titanium, Tungsten, Vanadium, and Zircon would influence global economies and are indispensable for sectors such as high-tech electronics, telecommunications, transport, and defence. They are also pivotal for the transition to a low-carbon economy to achieve global 'Net Zero' commitments through renewable energy technologies.

The demand of critical minerals is not just an economic prerogative but, it is a strategic focus and its emphasis in India gaining huge momentum towards sovereignty and commitment to sustainability with a greener and resilient immediate future.

A time bound global order has been set as a focused challenge and target-based narratives with huge emphasis on the mineral sector investments, strategy, exploration, exploitation, extraction, and beneficiation of critical minerals with advanced and latest ecofriendly technology input, as an emergent necessity for advanced technological applications in multiple sectors with growth, focusing on low-carbon footprint and greener tomorrow.

The race for critical minerals in energy-prioritizing and energy-driven countries have set the ball rolling through respective strategic entities, to meet the challenges and bridging the demand-supply gap in strict schedules of time and outcome. In response to these challenges, India has identified Thirty (30) minerals as crucial for its national and economic security. These minerals, including cobalt, lithium, nickel, copper, and rare earth elements, have importance beyond economic implications, collaborating strategic sectors like defense, space, telecommunications, automotives, high-tech electronics, renewable energy, and clean technologies. This strategy aligns with India's pursuit of self-reliance and inclusivity, integral to realizing its net-zero emissions target by 2070 (Manish Vaid, 2024).

### *Few Constraints and challenges in Indian context*

The critical minerals undisputably, in Indian pretext are important for the nation's technological advancement and energy transition goals. Further, have a strategic value that goes beyond industrial uses and affects national security and economic independence.

Major constraints and challenges in India are technological barriers in exploration and processing, environmental and social considerations and more significant is the geopolitical risks and supply chain vulnerabilities and it is crucial to overcome the challenges to maintain mineral security and technological sovereignty.

The dependency on the critical minerals in India is markedly influenced by import reliance, especially from countries like, China, for minerals such as amorphous graphite, cobalt oxides, and nickel oxides and hydroxides. It is further affected by potential supply disruptions, price volatility, and geopolitical risks due to their demand of these minerals for low-carbon technologies causing supply chain pressures and change in strategies.

Mining activities are often complex and time-consuming, capital-intensive, requiring up to a decade of development before operations begin. Exploration and development activities depend on several factors, such as the viability of mining, the concentration of required minerals in the ore, and the timeframes for site development and financing. During this period, the project managing entity requires massive funds for development and expansion. The strategy to ensure access to capital and leverage multi-national partnerships is necessary to secure critical mineral resources.

### *Indian Efforts for Critical Mineral resources*

Despite big challenges exist in technological, environmental, and geopolitical areas, country needs to address its limited processing abilities, environmental issues, and supply chain. The government has started a mission through initiatives like the National Critical Mineral Mission and KABIL (Khanij Bidesh India Limited) committing dedication to mineral security with substantial funding and strategic collaborations to boost domestic exploration, processing capabilities, and overseas mineral assets expecting fourfold rise in demand for Critical Minerals of India by 2030 through its resilient domestic capabilities.

In a bid to gain access to critical minerals reserves, India has auctioned several strategic mineral blocks for the deposits of minerals such as cobalt, phosphorite, graphite, vanadium, rare earths and pursuing the acquisition of critical mineral assets in resource-rich countries. Exploration projects have also increased in manifold with the dedicated efforts of several private, state, and central exploration agencies to reform mining policy to enable the recovery of critical minerals from primary and secondary sources including tailings or mining by-products, encourage best practices, and establish a state mining index. Since domestic critical minerals resource establishment would take prescribed time, and exploration strategies are being executed in right direction, the dependence on imports may continue.

India needs to develop the critical mineral supply chain is comprised of upstream (extraction and separation), midstream (processing metals and alloys), and downstream (manufacturing of end-products) elements.

### *Geological perspective*

The geological, geochemical, and geophysical datasets along with remote sensing data can be integrated by using the GIS software for preparation of the predictive mineral potential maps. However, understanding the overall geological evolution the terrain and correlation of lithology and structure can be effective with the aid of field detailed observations.

Indian geological terrain comprising Archean-Proterozoic cratons like Dharwar, Bastar, Singhbhum, Bundelkhand, Meghalaya and Aravalli cratons craton fringed by Proterozoic mobile belts like, the Aravalli–Delhi Mobile Belt (ADMB), the Central Indian Tectonic Zone (CITZ)/or the Satpura Mobile Belt (SMB), the Singhbhum Mobile Belt (SMB), the Eastern Ghats Mobile Belt (EGMB), Nellore Mobile Belt, Pranhita-Godavari Belt and the Pandyan Mobile Belt (PMB) and widespread Cenozoic mobile belt of Himalaya, (Jain et.al, 2020), Proterozoic and Phanerozoic sedimentary basins, Deccan traps and tertiary sequences are hosting several metallogenic epochs and mineral systems including critical minerals depending upon geological, geochemical, structural criteria's in different stratigraphic sequence.

The Greenstone belts are significant exploration targets known to host rich iron ore resource in the form of Banded Iron Formations (BIF) and most of the gold resources. The orogenic gold and associated mineral deposits occur in subduction-related convergent margin settings or in collisional orogenic belts. The Cr Ni-PGE concentration in the mafic- ultramafic rocks resulted directly due to the orthomagmatic processes associated with the formation of the greenstone belts. Subsequent processes involving deformation, metamorphism and associated ore bearing hydrothermal activity mobilized metals like gold, silver, and copper concentration in the greenstone belts, resulting in concentration of these elements. Proterozoic basins host several significant mineral deposits in India. Apart from limestone, an important industrial mineral, the mineral deposits explored in the Proterozoic basins of Peninsular India are barytes, base metals, dolomite hosted uranium with molybdenum as a by-product, diamondiferous kimberlites and lamproites and glauconite bearing sandstone. Granulite belts adjoining the margins of cratons are also important for base metal and associated mineralisation. Geological environments associated with Rajasthan, Madhya Pradesh, Gujarat, Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu, Kerala, Goa, Orissa, Jharkhand, Bihar, Meghalaya, Assam, Mizoram, Arunachal Pradesh, and extra-terrestrial Himalayan region are favorable centres for mineral systems hosting variety of critical minerals including rare earths and rare metals. The impetus and focus need be impressed on primary and secondary sources for critical minerals including rare earths.

With the advent of big boost to the momentum of national critical mineral mission, Government of India, keeping Geological Survey of India (GSI) as nodal agency, is thrusting upon auctioning of favorable block for various stages of exploration, to achieve the set targets for critical mineral resources involving different exploration agencies in government and public and private sector. India's Green Energy Transition through lithium, cobalt, and nickel are indispensable for India's shift towards renewable energy and EV adoption forming backbone of technologies such as lithium-ion batteries, solar panels, and wind turbines. Critical minerals advancements in cutting-edge sectors like AI, robotics, and space technology, support India's vision for technological self-reliance under "Atma nirbhar Bharat." India's Chandrayaan-3 mission (2023) and the Gaganyaan mission highlight the strategic importance of beryllium, tungsten, and rare earths in aerospace and defence. Minerals like, vanadium and graphite are integral to energy storage technologies like flow batteries and supercapacitors.

### *Bottom line*

Critical minerals regulate energy transition, economic growth, and strategic autonomy of India. Systematic and aggressive exploration, processing, and recycling with collaboration of global agencies may possibly reduce import dependency. A multipronged integrated approach with sustainable practices, focus on infrastructure and research-based investments would strengthen supply chain.

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