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Critical Minerals: Definition, Importance, and Geopolitical Dynamics

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Abstract

Critical minerals are essential raw materials required for modern technologies, energy transitions, and industrial growth. They form the backbone of renewable energy systems, electric mobility, and digital infrastructure. This paper examines the definition and significance of critical minerals, their global and Indian contexts, their essential role in the modern world, and the geopolitics surrounding their extraction and trade. It also highlights environmental and ethical challenges and evaluates pathways for sustainable management. The discussion demonstrates how these minerals often termed the "new oil" of the twenty-first century are reshaping global power dynamics.

Keywords: Critical Minerals, Energy Transition, Supply Chain Security, Geopolitics, India

Introduction

Critical minerals are natural resources vital to economic development, technological innovation, and national security, but which face supply-chain risks from scarcity, reserve concentration, or geopolitical tensions (USGS, 2022). They typically include rare earth elements (REEs), lithium, cobalt, graphite, nickel, and other materials essential to renewable energy, defense, and advanced electronics.

The concept of *criticality* depends on both economic importance and supply risk. The European Union's 2020 Critical Raw Materials Action Plan identified 30 materials vital to its green and digital transitions (European Commission, 2020). Similarly, the U.S. Department of the Interior published its 2022 List of Critical Minerals, comprising 50 commodities considered essential to national and economic security (U.S. Department of the Interior, 2022).

In India, the Ministry of Mines and NITI Aayog have emphasized the need for domestic exploration and international cooperation to secure supplies of minerals such as lithium, cobalt, and nickel (NITI Aayog, 2021). Thus, criticality is both economic and strategic, grounded in the materials underpinning clean energy and high technology.

Global Context

Critical minerals are unevenly distributed across the globe, creating strategic dependencies. The top three producing nations control over 80% of global output for many key minerals, such as lithium, cobalt, and rare earths (IEA, 2021). China dominates the processing and refining stages, accounting for approximately 60–90% of global capacity (USGS, 2022).

According to the International Energy Agency's "The Role of Critical Minerals in Clean Energy Transitions" (2021), demand for lithium, graphite, cobalt, and nickel is projected to rise four- to six-fold by 2040 under sustainable development scenarios. However, investment in new mining and refining capacity has lagged behind projected demand, raising concerns of supply bottlenecks.

The World Bank (2020) similarly warns that without diversification and recycling; shortages of these minerals could delay the global shift to renewable energy and increase geopolitical tensions.

Indian Context

India's growing energy and manufacturing ambitions make critical minerals a strategic priority.

- Exploration Efforts: The Geological Survey of India (GSI) has identified occurrences of lithium in Jammu & Kashmir and Karnataka, vanadium in Arunachal Pradesh, and significant graphite and REE deposits in northeastern states (GSI, 2021).
- Policy Initiatives: The National Mineral Policy 2019 and subsequent strategies highlight the need to develop domestic resources and strengthen international partnerships for resource security (Ministry of Mines, 2019).
- International Cooperation: Through platforms like the Quad and bilateral agreements with Australia and Japan, India seeks access to critical mineral supply chains (MEA, 2021).
- Challenges: Despite policy progress, domestic exploration remains limited, and private investment in critical mineral mining is modest due to geological and infrastructural constraints (NITI Aayog, 2021).

Importance in the Modern World

Critical minerals enable a sustainable, technologically advanced society:

- Energy Transition: Lithium, cobalt, and nickel are essential for electric vehicle (EV) batteries, solar panels, and wind turbines (IEA, 2021).
- Digital Technologies and Defense: Rare earth elements are integral to smartphones, computers, jet engines, radar systems, and renewable energy generators (U.S. DoD, 2021).
- Supply Risks: High concentration of processing capacity in a few countries poses strategic vulnerabilities. The IEA (2021) notes that disruptions in critical mineral supply chains could significantly raise the cost of batteries and slow clean-energy deployment.
- Strategic Importance: Nations are increasingly viewing access to critical minerals as a matter of national security, prompting new alliances and investment in alternative supply sources (World Bank, 2020).

Geopolitics of Critical Minerals

The geopolitics of critical minerals reflects broader shifts in global power:

- Chinese Dominance: China's integrated control of mining, processing, and manufacturing provides it with strategic leverage over supply chains (USGS, 2022).
- Western Responses: The United States and European Union are investing in domestic refining, recycling, and international partnerships to reduce dependence on Chinese supply (European Commission, 2020; U.S. DoE, 2021).
- Strategic Alliances: Multilateral cooperation through forums such as the Minerals Security Partnership (MSP) and the Quad seeks to build resilient, transparent supply chains (MEA, 2021).

- Indian Strategy: India's engagement with Australia, Japan, and the U.S. aims to secure access to critical resources while promoting domestic value addition (NITI Aayog, 2021).

Critical Review

Despite their economic and strategic importance, critical mineral extraction raises major sustainability concerns:

- Environmental and Social Issues: Cobalt mining in the Democratic Republic of Congo has been linked to child labor and unsafe working conditions, while lithium extraction in South America's "lithium triangle" stresses local water systems (Amnesty International, 2019; World Bank, 2020).
- Recycling and Circularity: Less than 1% of lithium and rare earths are currently recycled, underscoring the need for circular-economy models (OECD, 2021).
- Supply Chain Vulnerability: Over-concentration of processing in a few countries makes global markets susceptible to disruptions and price volatility (IEA, 2021).

Addressing these challenges requires international cooperation, technological innovation in recycling and substitution, and adherence to responsible mining standards.

Conclusion

Critical minerals are foundational to the modern economy, enabling renewable energy, digital technologies, and defense systems. Yet their uneven distribution and concentrated processing pose supply and geopolitical risks. For India, integrating sustainable exploration, recycling, and international cooperation into its mineral strategy is essential. Going forward, balancing economic growth, environmental stewardship, and technological self-reliance will define the global trajectory of critical mineral governance.

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