

2023 : Why are critical minerals essential for the economic development and national security in India ?

Critical minerals are elements and compounds that have diverse, irreplaceable industrial applications but face severe supply chain vulnerabilities due to geographical concentration or sourcing challenges.

The Ministry of Mines has identified **30 critical minerals** for the country, with 24 specific strategic minerals (including Lithium, Cobalt, Nickel, Graphite, and Rare Earth Elements) brought under the exclusive auctioning jurisdiction of the Central Government. To secure these, the Union Cabinet approved the **National Critical Minerals Mission (NCMM)** to aggressively advance domestic exploration, processing, and recycling.

Geographical Distribution of Critical Minerals in India and Their Geological Origins

The distribution of critical minerals in India is highly correlated with specific geological formations, ranging from ancient cratonic rocks to coastal plains.

Beach Placer Deposits (Coastal Belts)

- Coastal sand stretches of **Kerala** (Chavara), **Tamil Nadu** (Manavalakurichi), **Andhra Pradesh**, and **Odisha** (Chatrapur).
- **Rare Earth Elements (REEs)** bound in Monazite sands, Titanium (Ilmenite, Rutile), and Zirconium.
- Intense tropical weathering of inland granitic and metamorphic rocks over millions of years released heavy minerals. Rivers transported these sediments to the coast, where high-energy wave action selectively sorted and concentrated the heavy, dense minerals (placers) along the beaches, leaving lighter quartz behind.

Ultramafic Complexes and Lateritic Belts

- **Sukinda Valley** in Jajpur district (Odisha).
- **Nickel** and **Cobalt** (occurring primarily as overburdens of chromite ores).
- These deposits are associated with Proterozoic ultramafic igneous rocks. Prolonged, intense chemical weathering under hot and humid tropical conditions (lateritization) leached away highly soluble elements, causing a secondary, supergene enrichment of nickel and cobalt in the residual profile.

Hard-Rock Inland Alkaline & Carbonatite Complexes

- **Rajasthan** (Sirohi, Bhilwara, Balotra, and Nagaur's Degana block) and **Gujarat** (Amba Dongar in Chhota Udepur, Kachchh).
- Inland REEs (Neodymium, Dysprosium), Tungsten, Lithium, and Glaucosite (Potash source).
- Formed during deep-seated magmatic differentiation and hydrothermal activity. Residual, volatile-rich fractions of magma injected into ancient crustal faults and rift zones, crystallizing into rare-metal pegmatites, carbonatites, and hydrothermal veins.

Metamorphic Terrains and Cratonic Margins

- **Arunachal Pradesh** (Pakke-Kessang), **Chhattisgarh** (Balrampur), **Jharkhand**, and **Odisha** (Rayagada, Kalahandi).
- **Graphite**, Vanadium, and Titanium-bearing Magnetite.
- Formed due to high-grade regional metamorphism. Pre-existing organic carbon-rich sedimentary rocks in ancient Archean-Proterozoic cratons underwent extreme heat and pressure, recrystallizing into structural graphite sheets.

Hydrothermal Pegmatites and Bauxite Residuums

- **Locations: Jammu & Kashmir** (Reasi district), **Karnataka** (Mandya), and **Chhattisgarh** (Katghora).
- **Lithium** and associated rare metals (Niobium, Tantalum).
- In Mandya, lithium is hosted in granitic pegmatites formed via fractional crystallization of residual magma. In J&K, lithium is associated with bauxite-bearing horizons, where it accumulated through the intense leaching and weathering of aluminous limestone terrains.

ANSWER

Essential for Economic Development

Critical minerals are the bedrock of India's modern industrial ambitions, fueling sustainable growth across three primary frontiers:

The Clean Energy Transition

India has set ambitious targets of achieving **500 GW of non-fossil fuel capacity by 2030** and reaching **Net Zero emissions by 2070**.

- **Electric Vehicles (EVs):** Lithium, Cobalt, and Nickel are indispensable raw materials for manufacturing high-energy-density Lithium-ion batteries.

- **Wind & Solar Power:** Rare Earth Elements (like Neodymium and Dysprosium) are vital for the permanent magnets used in wind turbine generators. Silicon, Tellurium, Gallium, and Indium are critical for manufacturing highly efficient Solar Photovoltaic (PV) cells.

High-Tech Manufacturing and Electronics

India's digital transformation depends on advanced electronics, semiconductors, and telecommunications equipment (5G/6G grids).

- Minerals like **Gallium, Germanium, and Indium** are essential components in semiconductor chips, fiber-optic cables, LEDs, and touchscreens.
- A steady domestic supply of these minerals acts as a multiplier for the "Make in India" initiative and Electronic Manufacturing Clusters.

Agrarian Productivity and Food Security

- India is traditionally 100% import-dependent on **Potash**. The discovery and development of domestic **Glaucinite** (a potassium-rich mineral) blocks in states like Bihar and Uttar Pradesh are vital to reducing input costs for indigenous fertilizer manufacturing, thereby safeguarding India's long-term agricultural sustainability.

Essential for National Security

In an increasingly volatile geopolitical landscape, critical minerals are strategic assets directly tied to territorial defense and economic resilience.

Defense Systems and Aerospace

Modern military hardware requires high-strength, lightweight, and heat-resistant materials.

- **Aviation & Missiles:** Titanium, Beryllium, and Tantalum are used to build fighter jet airframes, missile casings, and rocket engines.
- **Guidance and Surveillance:** REEs are central to manufacturing precision laser rangefinders, night-vision optics, sonar equipment, and radar communication systems.

Breaking Geopolitical Strangleholds (Supply Chain Resilience)

The global critical mineral supply chain is highly monopolized. **China controls nearly 60% of worldwide extraction and over 85% of rare earth processing and magnet production.**

- **Mitigating Vulnerabilities:** Relying on a single nation leaves India exposed to "resource nationalism," sudden export bans, or maritime blockades during geopolitical friction (e.g., in the Indo-Pacific region).

- Developing domestic deposits provides India with **strategic autonomy**, insulating its industrial grid from international price volatility and supply weaponization.

Transitioning Energy Security

As India transitions away from a heavy reliance on imported fossil fuels (crude oil from the Middle East), it must avoid replacing that vulnerability with a dependency on imported green tech minerals. Securing domestic minerals ensures that India's energy transition is self-sustaining.

Way Forward Recognizing these stakes, India has shifted into high gear with proactive mineral diplomacy and domestic policy overhauls:

Domestic Infrastructure:

The Government announced **Dedicated Rare Earth Corridors** across Odisha, Kerala, Andhra Pradesh, and Tamil Nadu to seamlessly link mining, refining, and manufacturing ecosystems. These corridors directly complement the existing presence of **IREL (India) Limited** in Odisha and Kerala.

Long-term significance of rare earth corridors for India

Over the long term, rare earth corridors have the potential to transform India's position in global supply chains by enabling value addition and technological capability. If implemented effectively, the corridor approach can:

- reduce dependence on critical mineral imports
- support electric mobility and renewable energy goals
- generate high-skilled employment
- attract foreign investment and technology partnerships
- enhance economic resilience and national security

IREL (India) Limited, formerly Indian Rare Earths Limited, has been operating under the Department of Atomic Energy since 1963. With a processing capacity of **10 lakh tonnes per annum**, it produces strategic minerals such as ilmenite, rutile, zircon, sillimanite, and garnet.

Importantly, IREL runs a **Rare Earth Extraction Plant in Odisha Chhatrapur** in the **Ganjam district** and a **Rare Earth Refining Unit at Aluva in Kerala**, both of which align with the corridor initiative. By integrating IREL's established facilities with the new corridors, the government aims to expand domestic rare earth capacity, foster advanced manufacturing, and accelerate India's transition toward self-reliance and clean energy.

Strategic Importance and Resource Potential of Rare Earth Permanent Magnets in India

Rare Earth Permanent Magnets (REPMs) are among the **strongest types of permanent magnets**, known for their high magnetic strength and stability. Their compact size and powerful performance make them indispensable for advanced engineering applications such as **electric**

vehicle motors, wind turbine generators, consumer and industrial electronics, aerospace systems, defence equipment, and precision sensors.

As India expands its manufacturing footprint in clean energy, advanced mobility, and strategic sectors, a **reliable domestic supply of REPMs** is critical. It not only reduces import dependence but also strengthens India's competitiveness in global value chains for advanced materials.

Global Collaborations:

Through **KABIL** (Khanij Bidesh India Limited), **KABIL** is a joint venture of **National Aluminium Company Ltd. (NALCO)**, **Hindustan Copper Ltd. (HCL)**, and **Mineral Exploration & Consultancy Ltd. (MECL)** under the Ministry of Mines.

India has secured overseas lithium brine assets in Argentina and exploration blocks in Australia. Bilaterally, India signed a critical minerals framework agreement with the US under the **Quad Critical Minerals Initiative** to coordinate public-private investments and secure a resilient, friendly supply loop outside monopolized markets.

Environmental and strategic concerns of Rare Earth Corridors

While rare earth elements are essential for clean and advanced technologies, their extraction and processing raise significant environmental and strategic concerns. Rare earth mining generates large volumes of waste and often involves radioactive elements such as thorium and uranium, posing risks to ecosystems and human health if not properly managed. The key concerns associated with rare earth elements include:

- generation of toxic and radioactive waste
- environmental degradation of mining regions
- health risks to workers and nearby communities
- strategic vulnerability due to global supply concentration
- geopolitical leverage exercised by dominant producers