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Assessing the Nature of India's Critical Minerals Vulnerabilities vis-à-vis China

Rakshith Shetty

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This study evaluates India's vulnerabilities in sourcing 30 critical minerals identified by the Ministry of Mines in 2023, with a focus on six minerals exhibiting high dependency on China. Using a six-test dependence-induced vulnerability assessment framework, the analysis identifies Silicon, Lithium, and Titanium as critical vulnerabilities. Meanwhile, Bismuth, Tellurium, and Graphite pose strategic vulnerabilities.

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This document has been formatted to be read conveniently on screens with landscape aspect ratios. Please print only if absolutely necessary.AuthorRakshith Shetty is a China Studies Research Analyst with the Indo-Pacific Studies Programme at the Takshashila Institution, Bengaluru, IndiaHe can be reached at rakshith@takshashila.org.inAcknowledgmentsThe Author would like to thank Manoj Kewalramani and Amit Kumar for their research support.

1 Executive Summary

This study evaluates India's vulnerabilities in sourcing 30 critical minerals identified by the Ministry of Mines in 2023, with a focus on six minerals exhibiting high dependency on China: Bismuth (85.6%), Lithium (82%), Silicon (76%), Titanium (50.6%), Tellurium (48.8%), and Graphite (42.4%).

Using a six-test dependence-induced vulnerability assessment framework, the analysis identifies Silicon, Lithium, and Titanium as critical vulnerabilities due to their direct national security implications and substantial capability gaps that require long-term efforts to bridge. Meanwhile, Bismuth, Tellurium, and Graphite pose strategic vulnerabilities that, while impactful, can be mitigated through medium-term technological investments.

2 Introduction

Critical minerals are essential for India's economic development, particularly in the rapidly expanding sectors of clean energy, smart technologies and advanced manufacturing. India's ambitious renewable energy targets[1], its push to become a global manufacturing hub for clean technologies, and its commitment to achieving net-zero emissions by 2070 necessitate a reliable and sustainable supply of these minerals[2].

Given the importance of these minerals, the government has taken a step towards identifying minerals critical to India's growth. The 'Report of the Committee on Identification of Critical Minerals,' published by the Ministry of Mines in June 2023[3], announced a list of 30 critical minerals deemed essential for India's economic growth and national security. The report emphasised the strategic importance of securing a sustainable and resilient supply chain for critical minerals, and highlighted the need to develop competitive value chains within India for critical minerals. It also acknowledged India's heavy reliance on imports for certain minerals, with some elements exhibiting 100% import dependency.

2.1 India's 30 Critical Minerals

No.	Mineral	No.	Mineral	No.	Mineral
1	Antimony	11	Indium	21	Selenium
2	Beryllium	12	Lithium	22	Silicon
3	Bismuth	13	Molybdenum	23	Strontium
4	Cadmium	14	Niobium	24	Tantalum
5	Cobalt	15	Nickel	25	Tellurium
6	Copper	16	PGE*	26	Tin
7	Gallium	17	Phosphorous	27	Titanium
8	Germanium	18	Potash	28	Tungsten
9	Graphite	19	REE*	29	Vanadium
10	Hafnium	20	Rhenium	30	Zirconium

While the Indian government has taken proactive steps to identify critical mineral needs, the global

*PGE (Platinum Group Elements): Platinum, Palladium, Rhodium, Ruthenium, Iridium, Osmium*REE (Rare Earth Elements): Lanthanum, Cerium, Praseodymium, Neodymium, Promethium, Samarium, Europium, Gadolinium, Terbium, Dysprosium, Holmium, Erbium, Thulium, Ytterbium, Lutetium, Scandium, Yttrium landscape of critical mineral supply chains presents significant challenges[4], particularly due to China's dominant position in the market[5]. China's dominance stems from its extensive investments[6] in mining, processing, and refining capabilities, coupled with its strategic control[7] over resources in several countries.

China controls significant parts of the midstream processing industries, with nearly 50% of the market value from refining also concentrated therein[8]. For India, China's dominance in the global critical minerals market could result in significant reliance on Chinese imports across various stages of the supply chain, including mining, processing, and refining.

2.2 China's Share in Critical Minerals Supply Chain

Material	% of reserves in China	% of extraction in China	% of processing in China
Aluminium	-	-	58%
Cadmium	15%	-	42%
Cobalt	1%	1%	65%
Copper	3%	9%	42%
Graphite	16%	65%	-
Indium	-	-	59%
Lithium	8%	15%	58%
Manganese	16%	5%	-
Molybdenum	31%	40%	-
Nickel	2%	3%	35%

Material	% of reserves in China	% of extraction in China	% of processing in China
REEs	34%	70%	87%
Selenium	8%	-	41%
Silicon	-	-	68%
Vanadium	37%	70%	-

While existing literature highlights India's overall reliance on imports for critical minerals, there is a notable gap in analysing India's specific dependency and vulnerabilities vis-à-vis China for the 30 critical minerals identified by the Ministry of Mines in 2023. This study addresses this gap by systematically assessing the nature of India's critical minerals vulnerabilities concerning its imports from China.

3 China's Global Share in Critical Minerals Sector

The global critical minerals sector is undergoing a significant transformation driven by the surging demand for clean energy technologies and advanced manufacturing applications. This rapid growth has exposed vulnerabilities in critical mineral supply chains, raising concerns about potential bottlenecks and disruptions. At the centre of this evolving landscape, China has emerged as a dominant player, exerting considerable influence over global supply chains.

Till the end of the year 2022, a total of 173 kinds of minerals have been discovered[9] in China, including 13 kinds of energy minerals, 59 kinds of metallic minerals, 95 kinds of non-metallic minerals and six kinds of water and gases. In 2022, reserves[10] of nearly 40% of China's minerals increased, with significant growth observed in Copper, Lead, Zinc, Nickel, Cobalt, Lithium, Beryllium, Gallium, Germanium, Fluorite, and Crystalline Graphite.

There have been significant[11] exploration investments in the past few years, with the total investments in geological exploration reaching RMB 101.02 billion ($14.18 billion USD) in 2022, a 3.8% increase from the previous year. This investment surge led to the discovery of 132 new mineral deposits in 2022, including 34 large deposits, 51 medium deposits, and 47 small deposits[12].

China's dominance in the critical minerals sector extends well beyond its domestic resource base. The country has systematically[13] built substantial control over global mineral processing and refining capabilities through strategic investments and policy frameworks[14]. This control is most pronounced in minerals that are fundamental to modern technologies – including Lithium, Cobalt, Graphite, and Rare Earth Elements – which are vital for manufacturing advanced technology products like EV batteries, wind turbines, and solar panels.

Refined material production is set to remain highly concentrated in China. The figures for Graphite are based on battery-grade spherical Graphite and synthetic Graphite supplies. The figures for rare earth elements are for magnet rare earth elements only.

China's dominance in the critical minerals sector stems from a combination of factors, including vast domestic resource endowments, strategic investments in mining and processing infrastructure both domestically and internationally, advanced technological capabilities in mineral processing, and the use of export policies to maintain control over global supply chains. The country actively engages in bilateral partnerships with resource-rich nations such as Russia, Mongolia, Chile, Mexico, and Saudi Arabia, focusing on geological surveys, mineral exploration, and investment. Additionally, China participates in multilateral platforms like the DDE Open Science Forum, the United Nations Resource Management Expert Group, and the Global Environment Facility (GEF), further solidifying its influence. These efforts enable China to maintain a dominant position in critical mineral supply chains. This dominance has raised global concerns about potential vulnerabilities in supply chains, particularly for industries that rely heavily on these materials for advanced technologies, renewable energy, and defence applications. For India, this dominance poses significant challenges in securing stable supplies of these essential resources.

4 Assessing the Magnitude of India's Dependency

As per the Ministry of Mines' 2023 report[15], India is 100% import-dependent for 10 critical minerals: lithium, cobalt, nickel, vanadium, niobium, germanium, rhenium, beryllium, tantalum, and strontium. This dependence extends to other crucial minerals like zirconium, with an 80% import reliance, and graphite, with a 60% reliance on imports. This heavy reliance on imports places India in a precarious position, susceptible to global supply chain disruptions, price volatility, and geopolitical tensions.

An in-depth examination of import data spanning 2019 to 2024 uncovers a diverse spectrum of dependencies across these minerals. Some exhibit concerning patterns of growing reliance on external sources, with China emerging as a primary supplier.

This study examines six critical minerals where India's (average) dependency on Chinese imports exceeds 40%: Bismuth (85.6%), lithium (82%), silicon (76%), titanium (50.6%), Tellurium (48.8%), and Graphite (42.4%). Using Kumar's six-test dependence-induced vulnerability assessment framework[16], the analysis systematically evaluates how these dependencies may evolve into strategic or critical vulnerabilities within the context of asymmetrical trade relationships between India and China.

Source: Amit Kumar, Defining Dependence-induced Vulnerabilities in an Asymmetrical Trade Interdependence: A Conceptual Framework, Takshashila Discussion Document No.ă2023-11, July 2023, The Takshashila Institution.

The framework distinguishes between dependence, vulnerability, strategic vulnerability, and critical vulnerability. The first four stages constitute the Strategic Vulnerability Test, which evaluates whether a dependency qualifies as a strategic vulnerability by examining factors such as adversarial relationships, availability of alternatives, societal impact, and cascading effects on other sectors. The final two stages, comprising the Critical Vulnerability Test, assess whether a strategic vulnerability escalates into a critical one by considering its implications for national security and the presence of significant capability gaps.

5 The Strategic Vulnerability Test

In this four-stage framework, a dependency is classified as a strategic vulnerability only if it passes the first two tests (adversary and alternative) and at least one of the remaining two tests (incidence or cascading effect).

5.1 The Adversary Test

The relationship between India and China has become increasingly adversarial, characterised by competition and volatility rather than cooperation. Three structural factors drive this tension: both are rising powers with expanding interests, there exists a deep power asymmetry favoring China, and the shifting global order affects their bilateral dynamics. China has demonstrated increased risk tolerance and willingness to use force, emboldened by perceptions of superiority in the bilateral balance of power. Over the past decade, Chinese policies have shifted from being unaccommodating of India's interests to being hostile, evident in the ongoing military standoff in Eastern Ladakh, China's blocking of Pakistan-based terrorists' listings at the UN, and its opposition to India's Nuclear Suppliers Group membership.

When it comes to China's approach to weaponising critical mineral exports, it is strategic and calculated, guided by five key criteria that shape its decision-making process. Beijing primarily targets minerals deemed critical by Western nations and their allies, especially those essential for semiconductors, batteries, and high-tech manufacturing, ensuring both symbolic and practical impact as retaliatory measures. The country is more likely to impose controls on minerals where it holds significant extraction and processing advantages, thus giving it substantial leverage.

However, China carefully balances these decisions against two constraining factors: it avoids controlling minerals where it heavily depends on Western raw material imports, and it refrains from actions that could significantly disrupt its domestic industrial enterprises or export-dependent sectors. This strategic calculus was evident in China's 2010 rare earth embargo against Japan, its December 2023 ban on rare earth extraction and processing technologies, and its recent export control on antimony, gallium, and germanium exports to the U.S., demonstrating Beijing's willingness to use its mineral dominance as a geopolitical tool while protecting its interests.

5.2 The Test of Alternatives

While examining a dependency vis-a-vis an adversary along with a test of alternatives, if any of the below-mentioned three case scenarios emerge, it can be classified as a strategic vulnerability.

Case 1: Dependency vis-a-vis an adversary is a result of an absence of alternatives (either source or product).

Case 2: Alternatives are available, but the scale is so large that it simply cannot be entirely met by others in the short run.

Case 3: Alternatives are available, but the 'switching cost' is too high.

5.2.1 Assessment of Six Critical Minerals

1. **Bismuth (Passes all three cases of the Alternatives Test)**
    - **Case 1:** Few alternative sources exist globally, with China controlling 72.99% of global production.
    - **Case 2:** While Bolivia, Mexico, Canada and Russia produce Bismuth, their output is insufficient to meet India's requirements in the short term.
    - **Case 3:** China's dominance in processing capabilities and cost efficiency makes switching costly and logistically challenging.
2. **Lithium (Passes Cases 2 and 3 of the Alternatives Test)**
    - **Case 1:** Significant alternative sources exist, including Australia, Chile, and Argentina, which are major lithium producers.
    - **Case 2:** Despite alternative sources, China's dominance in lithium processing (58% of global refining capacity) means that even if raw materials are sourced elsewhere, India would still rely on China for processing in the short to medium-term.
    - **Case 3:** High switching costs due to China's well-established and cost-efficient processing infrastructure. Developing new supply chains or domestic processing capabilities would

require significant investments.

3. **Silicon (Passes Cases 2 and 3 of the Alternatives Test)**
    - **Case 1:** Significant alternative sources exist globally, such as the United States, Norway, and Brazil, which have significant silicon production capacities.
    - **Case 2:** China controls a substantial share of global silicon refining and production capacity, making it difficult for other suppliers to meet India's large-scale demand in the short term. Additionally, China's established supply chains and economies of scale make it challenging for other countries to quickly ramp up production to meet India's needs.
    - **Case 3:** Shifting away from Chinese silicon imports would likely incur high switching costs for India.
4. **Titanium (Passes only Case 3 of the Alternatives test)**
    - **Case 1:** India imports titanium from multiple countries, including Mozambique, Malaysia, Sri Lanka, and Australia, in addition to China.
    - **Case 2:** The scale of demand can be met through diversification among existing suppliers without significant disruption in the short-term.
    - **Case 3:** Moderate switching costs are associated with transitioning away from Chinese suppliers due to differences in cost structures and processing capabilities.
5. **Tellurium (Passes Cases 2 and 3 of the Alternatives Test)**
    - **Case 1:** Significant alternative sources exist (Japan, U.S., Russia, Sweden, Canada and Bulgaria).
    - **Case 2:** Despite alternatives, China controls approximately 73.42% of global production, making it difficult for other suppliers to meet India's demand at scale in the short term.
    - **Case 3:** High switching costs arise due to China's advanced processing capabilities and cost advantages in producing refined Tellurium products.
6. **Graphite (Passes Cases 2 and 3 of the Alternatives Test)**
    - **Case 1:** Significant alternative sources exist, such as Madagascar and Mozambique, which are emerging Graphite producers.
    - **Case 2:** However, China controls approximately 67.21% of global Graphite production

(including battery-grade Graphite), making it challenging for other suppliers to meet India's demand at scale in the short term without disruptions to industries like EV batteries and steel manufacturing.

- **Case 3:** High switching costs are involved due to China's dominance in processing infrastructure for battery-grade Graphite and its cost advantages in refining technologies.

5.3 The Test of Incidence

This test evaluates the potential impact of supply disruptions on the general population by assessing two parameters: 1. The section of the population affected 2. The product's utility for the population

All six minerals pass the incidence test since they satisfy both parameters.

Mineral	Population Impact	Utility Assessment
Bismuth	Bismuth is primarily used in chemicals. While these industries are important, they do not directly affect a broad consumer base in their raw form.	Plays an important role in the manufacturing of chemical products. Bismuth compounds have been used extensively in medicine.
Lithium	Lithium is essential for electric vehicle (EV) batteries, energy storage systems, and consumer electronics, all of which directly affect a wide consumer base and India's clean energy transition goals.	It is important for manufacturing of renewable energy technologies, EVs, and batteries. Disruptions would severely impact India's energy security, climate goals, and mobility sector.

Mineral	Population Impact	Utility Assessment
Silicon	Silicon is vital for semiconductors, solar panels, and electronics manufacturing, which underpin digital infrastructure, renewable energy technologies, and consumer devices used by nearly all segments of the population.	Critical utility as it supports India's solar energy targets, electronics industry, and digital economy. Disruptions would have far-reaching consequences across multiple sectors.
Titanium	Titanium is primarily used in aerospace, defence manufacturing, medical implants, and high-performance alloys for industrial applications. These sectors are strategic but do not directly affect a large proportion of the population.	Has a high utility in defence applications (aircraft, naval vessels), medical implants, and industrial uses. This makes it strategically important but less impactful for everyday public utilities or consumption patterns.
Tellurium	Tellurium is mainly used in solar panel production and thermoelectric devices for niche applications like advanced materials research and metallurgy. While important for renewable energy technologies, its direct impact on a broad population segment is limited compared to other minerals like lithium or silicon.	Important for renewable energy technologies, but less critical than other minerals like silicon or lithium due to limited end-use applications affecting public utilities or mass consumption patterns.

Mineral	Population Impact	Utility Assessment
Graphite	Graphite is crucial for EV battery anodes, steel manufacturing using Graphite electrodes, lubricants, nuclear reactor components, and advanced materials production—all of which have widespread industrial and consumer implications as India transitions toward electrification and industrial modernisation.	Graphite has a critical utility for energy storage systems (batteries), industrial processes (steel), and emerging technologies like EVs, thus making it highly impactful for both industrial growth and consumer adoption of clean technologies.

5.4 The Test of Cascading Effect

This test seeks to assess the cascading effect of an adversary's weaponisation of a dependency on other domestic sectors within the supply chain or beyond. All six minerals demonstrate significant cascading effects across multiple sectors, with lithium and silicon showing the most severe cross-sectoral impacts owing to their role in emerging technologies and clean energy transition.

Mineral	Primary Applications	Cascading Effects
Bismuth	Chemicals, pharmaceuticals and casting of iron	Disruption in Bismuth supply would impact pharmaceutical production, particularly antacids and other digestive medicines, hence affecting healthcare delivery and exports. Manufacturing of low-melting alloys used in safety devices and electrical equipment would be disrupted, potentially compromising industrial safety standards. Electronics manufacturing reliant on Bismuth-based components could face slowdowns, affecting broader industrial production.
Lithium	Electric vehicles, batteries, glassware, ceramics, fuel manufacturing and lubricants	Disruption of the entire electric vehicle manufacturing ecosystem Slowdown in charging infrastructure development Impact on renewable energy integration projects Setback to India's Clean Energy Transition Goals Disruption in electronics manufacturing requiring lithium-ion batteries Effect on emerging battery manufacturing industry and associated job creation

Mineral	Primary Applications	Cascading Effects
Silicon	Semiconductors, electronics, transport equipment, paints and aluminium alloys	Disruption in the electronics manufacturing supply chain Impact on domestic semiconductor production initiatives Slowdown in solar energy deployment affecting renewable energy targets Disruption in defense electronics manufacturing Impact on (public) digital infrastructure development Effect on emerging electronics manufacturing under the PLI scheme
Titanium	Aerospace and defence applications, chemicals and petrochemicals, pigments and polymers	Disruption in defence equipment production Impact on aerospace manufacturing and maintenance A slowdown in medical implant manufacturing Effect on high-performance alloy production Disruption in paint and coating industries using titanium dioxide

Mineral	Primary Applications	Cascading Effects
Tellurium	Solar power, thermoelectric devices, rubber vulcanising	Solar panel efficiency and production would decline due to tellurium shortages, slowing renewable energy deployment in India. Thermoelectric device manufacturing used in niche applications like cooling systems would be disrupted. Advanced materials research relying on tellurium-based compounds could face setbacks
Graphite	Batteries, lubricants, fuel cells for EVs, electric vehicles	Disruption in EV battery anode production Impact on steel manufacturing using Graphite electrodes Effect on lubricant manufacturing Slowdown in nuclear reactor component production Disruption in advanced materials and composites manufacturing

Having established the strategic vulnerabilities of India's dependency on China for critical minerals through the four-stage test, it is evident that these dependencies pose varying degrees of risks to India's economic and strategic interests.

However, not all strategic vulnerabilities are of equal severity. Some dependencies transcend the threshold of strategic vulnerability to become critical vulnerabilities, characterised by their profound implications for national security or the presence of significant capability gaps that cannot be bridged in the short to medium term. To identify such critical vulnerabilities, an additional two-stage framework—the

Critical Vulnerability Test—is applied, focusing on the minerals' direct impact on national security and the technological or industrial capacity required to mitigate dependency. This test refines the analysis by isolating the most severe vulnerabilities that demand immediate and sustained attention.

6 The Critical Vulnerability Test

6.1 National Security Threat

This test evaluates whether the dependency on China for these minerals poses a direct threat to national security. A mineral passes this test if a disruption in its availability will compromise critical sectors such as defence, energy, digital infrastructure, or other strategically vital areas.

Among the six minerals assessed, lithium, silicon, and titanium emerge as critical vulnerabilities that pose direct threats to India's national security. Lithium's critical role in energy storage systems makes it indispensable for India's energy security, defence applications, and clean energy transition goals. Silicon's importance in semiconductor manufacturing directly impacts defence electronics, digital infrastructure, and critical communications systems used in Command, Control, Communications, Computers (C4) and Intelligence, Surveillance and Reconnaissance (ISR) operations. Titanium's extensive use in aerospace applications, military aircraft, naval vessels, and armour plating makes it vital for India's military modernisation programs and defence capabilities.

In contrast, Bismuth, Tellurium, and Graphite, while strategically important, do not meet the threshold of critical vulnerabilities from a national security perspective. Bismuth's primary applications in pharmaceuticals and electronics manufacturing, Tellurium's role in solar panels and thermoelectric devices, and Graphite's use in EV batteries and industrial applications are significant for India's industrial growth and emerging technologies. However, disruption in their supply chains would not directly compromise India's core strategic sectors like defence or digital infrastructure. Their impact would be primarily economic rather than posing immediate national security concerns, and alternative sources or technologies could potentially mitigate supply disruptions in the medium term.

7 Conclusion

India has a high dependency on China for six critical minerals – Bismuth, Lithium, Silicon, Titanium, Tellurium, and Graphite – each exceeding a 40% import reliance. Among them, silicon, lithium, and titanium emerge as critical vulnerabilities due to their indispensable roles in national security sectors and the presence of substantial capability gaps that cannot be bridged in the short to medium term. These minerals are vital for semiconductor manufacturing, energy storage systems, and defence applications.

The remaining three minerals – Bismuth, Tellurium and Graphite – are classified as strategic vulnerabilities. While they do not pose immediate national security threats or insurmountable capability gaps, their disruption could significantly impact industrial growth and the production of modern technologies.

India faces a significant challenge in reducing its dependency on China for critical minerals. To address this, India is bolstering domestic production through increased exploration, mining, and processing capabilities, diversifying international supply chains by strengthening partnerships with countries like Australia and joining initiatives like the Minerals Security Partnership (MSP) and the Critical Raw Materials Club. India is also fostering innovation and efficiency through investments in research and development, promoting recycling and circular economy practices, improving technology efficiency, and implementing comprehensive policy and governance measures. These efforts include developing a national critical minerals strategy, creating dedicated institutions like a Centre of Excellence on Critical Minerals (under the Ministry of Mines), and ensuring sustainable and responsible mining practices. Transitioning away from dependence on China for critical minerals will require significant investment and long-term commitment.

Endnotes

Notes

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