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Graphite Mineral Sovereignty for India: A Geopolitical and Geoscientific Perspective from Rodinia to Gondwana

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Abstract
Graphite is a key mineral for lithium-ion batteries, refractories, and lubricants. It is in huge demand because of its important role in clean energy technologies, especially electric vehicles (EVs) and renewable energy storage systems. This article offers an in-depth look at the global graphite market, highlighting production trends, demand factors, supply gaps, and India's strategic role. China leads the world with over 77% of graphite production, with Madagascar, Mozambique, Brazil, and India following. New producers like Turkey, Tanzania and Australia are ready to help diversify supply chains. India, the sixth-largest producer, has a significant supply gap and depends on imports for about 69% of its needs. Arunachal Pradesh and Tamil Nadu have large graphite resources, and Tamil Nadu Minerals Limited (TAMIN) plays a crucial role in production. The study highlights the crucial role of supercontinent assembly, specifically the Rodinia to Gondwana transition, in creating these deposits. By examining carbon isotopic signatures, India's graphite belts, is classified into three distinct classes as Eastern Ghat including Kerala Khondalite Graphite belt (KKG), Himalayan Graphite ranging from Jammu and Kashmir, Uttrakhand, Nepal, Sikking, Bhutan and Arunachal graphite and Chhotanagpur Granite Gneissis complex Graphite. The Rodinia and Gondwana land super-continental correlations of these mineralized provinces from Eastern Ghat and KKG with the graphites occurring in Sri Lanka, Madagascar, Mozambique, and Australia, underscoring a shared tectonic heritage from Precambrian supercontinent cycles. India's supply gap, strategies include expanding mining operations, improving processing technologies, and creating supportive policies. The article will help the policymakers, industry leaders, geologists, mining engineers, and mineral processing engineers for graphite mineral sovereignty for India.

Keywords: **Graphite; Critical Minerals; Supply Chain; India; Mineral Sovereignty; Gondwana Supercontinent; Eastern Ghats Belt; Lithium-ion Batteries; Electric Vehicles (EVs).**

INTRODUCTION

In a time marked by the growing use of electric vehicles and the global push for sustainable energy, graphite stands out as a key material. Its high electrical and thermal conductivity, lubricity, and thermal stability make it crucial for lithium-ion batteries that power electric vehicles and renewable energy storage systems. The global graphite market is valued at USD 8.4 billion in 2023 and is expected to reach USD 13.2 billion by 2033 due to increasing demand for clean energy solutions. However, China dominates this market, producing over 77% of the world's graphite and controlling 90% of battery-grade refining. This dominance, coupled with export restrictions in 2023, highlights significant supply chain risks (Investing News Network, 2025). India has substantial graphite reserves in Arunachal Pradesh and Tamil Nadu. It is at a critical moment, ready to turn its mineral resources into a source of national strength and global presence. Yet, domestic production meets only a small part of the rising demand. India relies on imports for about 69% of its graphite needs, mainly from China. This puts pressure on the country to better utilize its resources. This article outlines India's journey toward mineral self-reliance. It looks at global production trends, demand changes, supply shortages, and strategies to improve mining and processing capabilities. This article also identifies the new directions for helping policymakers, industry leaders, and technical experts secure India's role in the era of electric mobility.

GLOBAL GRAPHITE MARKET OVERVIEW

MARKET SIZE AND GROWTH

The growing need for lithium-ion batteries in EVs and energy storage systems is expected to propel the global graphite market's growth. According to research, the market is projected to grow at a compound annual growth rate (CAGR) of 4.8% from its estimated USD 8.4 billion in 2023 to USD 13.2 billion by 2033 (Allied Market Research 2025). A higher growth trajectory is suggested by alternative projections, which place the market size at USD 25.9 billion in 2023 and USD 58.6 billion by 2033 at a compound annual growth rate (CAGR) of 8.5% (Fact.MR, 2024). With a projected CAGR of 9.2% from 2025 to 2033, the Asia-Pacific region—led by China and India—holds a sizable share (Grand View Research 2025). Turkey boasts the largest graphite reserves in the world, with a staggering 90 million tonnes, which makes up about 27% to 35% of the global total. Some of the key deposits can be found in areas like Kütahya-Oysu, Balıkesir-Susurluk, Kastamonu-Doğanyurt, Bingöl-Genç,

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Adıyaman-Sincik, Muğla-Milas, Kahramanmaraş-Göksun, Konya, Yozgat-Akdağmadeni, and Kırklareli. However, despite having such extensive reserves, Turkey's current production levels are quite low, and the country mainly relies on imports to meet its domestic needs. The only active graphite mine, situated in the Kütahya-Altıntaş district, has the capacity to produce around 22,000 tonnes of raw graphite and 8,000 tonnes of enriched graphite each year. The challenges lie in the limited exploration knowledge and the technological infrastructure required to enhance ore grades. With its vast reserves and strategic location close to Europe, Turkey has a significant opportunity for future development (Alp et.al. 2020).

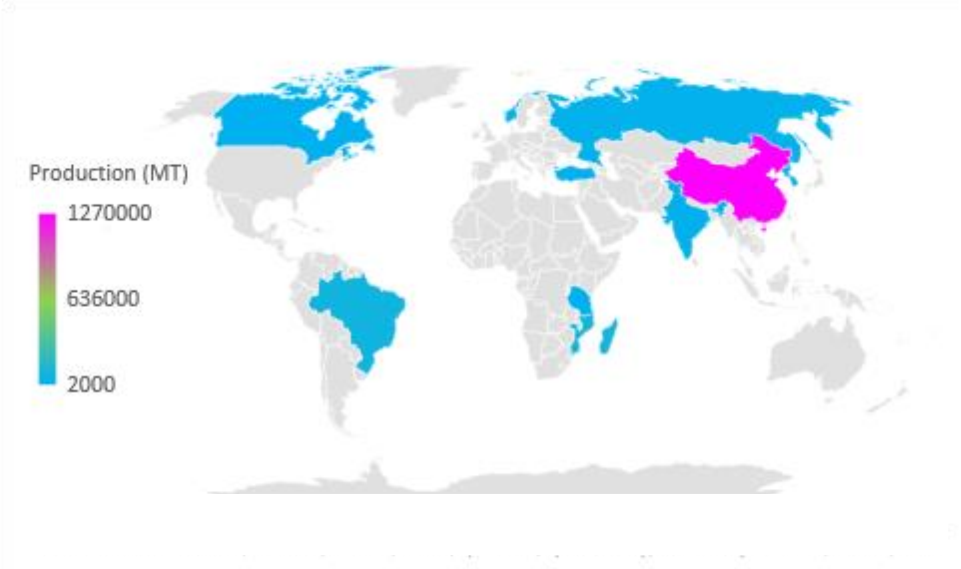

Fig. 1: Graphite producing major countries in world (after USGS 2024).

PRODUCTION TRENDS AND EMERGING PRODUCERS

MAJOR PRODUCERS

China produces 1.23 million metric tons annually, mainly flake graphite from Heilongjiang. It controls 90% of global battery-grade graphite refining (Investing News Network, 2025). Madagascar produces 100,000 metric tons of high-quality flake graphite from the Ambaton Delazaca region (East Carbon 2024). Mozambique's Balama Graphite Project is the world's largest high-grade flake deposit, producing 96,000 metric tons each year (Syrah Resources 2025). Brazil produces 73,000 metric tons of both flake and amorphous graphite, with reserves of 74 million metric tons (U.S. Geological Survey, 2023, 2024) Fig. 1. India produces 11,500 metric tons, with reserves of 8.6 million metric tons Table 1. The production occurs mainly in Odisha, Jharkhand, Tamil Nadu, and Kerala.

Table 1: Top Graphite-Producing Countries (2024)

Country	Production (MT)	Reserves (MT)	Graphite Type and Quality
China	1,230,000	78,000,000	High-purity flake, amorphous
Madagascar	100,000	26,000,000	High-quality flake
Mozambique	96,000	25,000,000	High-grade flake
Brazil	73,000	74,000,000	Flake, amorphous
South Korea	27,000	Not specified	Primarily synthetic, some natural
India	11,500	8,600,000	Flake, amorphous
Russia	16,000	Not specified	Flake graphite
North Korea	8,100	1,800,000	Limited data, quality unclear
Norway	7,200	Not specified	Flake graphite
Tanzania	6,000	18,000,000	High-quality flake

Source: U.S. Geological Survey (2024)

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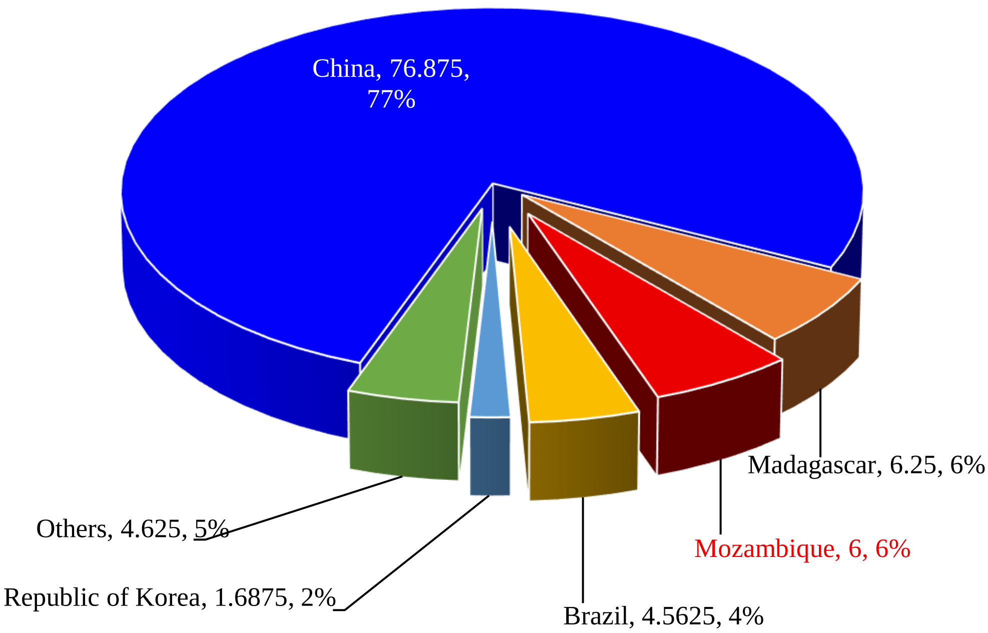

Figure 2: Global Graphite Production Shares by Country (2023).

The pie chart illustrates China's dominant share, emphasizing the need for diversified supply chains Fig.2.

SUPPLY-DEMAND GAPS

Research indicates that by 2025, the demand for graphite around the globe is expected to surpass supply, largely fuelled by the electric vehicle battery market. UBS projects that natural graphite demand could hit 6.3 million metric tons by 2030, while supply might only reach about 2.4 million metric tons, creating a potential shortfall of 1.2 million metric tons (Investor News 2023). Meanwhile, Macquarie Research anticipates that deficits will begin in 2024 and will continue to grow each year until 2030 (Investor News 2023). The line chart shows the growing gap between demand and supply. This highlights the need for more production capacity Fig. 3.

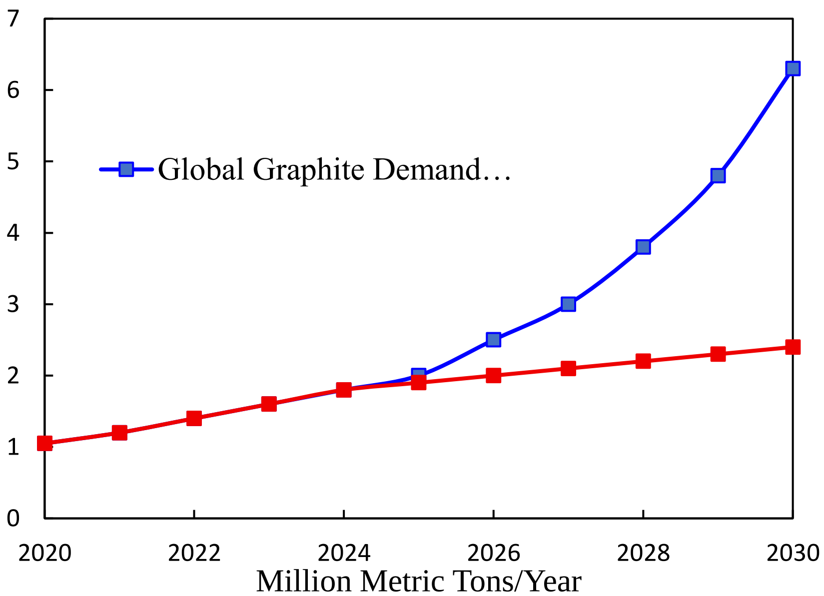

Figure 3: Global Graphite Demand vs. Supply (2020-2030)

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PRICE TRENDS AND FINANCIALS

Graphite prices depend on type, quality, and location. In 2025, flake graphite (94% C, -100 mesh, FOB China) was priced at USD 470-510 per ton, down from USD 830 per ton in 2023 because of oversupply (Fastmarkets 2023). Amorphous graphite prices ranged from USD 400-600 per ton. Mining costs for flake graphite are higher, with battery-grade graphite priced at USD 1,800-2,600 per ton due to complex purification processes (Grand View Research 2025). Regional price variations in Q2 2025 are shown in Table 2.

Table 2: Graphite Prices by Region (Q2 2025)

Region	Price (USD/MT)
USA	1,290
China	2,040
Germany	1,673
Brazil	1,890
UK	N/A

Source: IMARC Group (2024)

TYPES OF GRAPHITE AND THEIR APPLICATIONS

Globally, most natural graphite is used in electrodes, refractories, lubricants, foundries, batteries, graphite shapes, recarburising, steelmaking, and friction products such as brake linings (Fig. 4; Shaw, 2013). Prices of selected products are shown in Table 3.

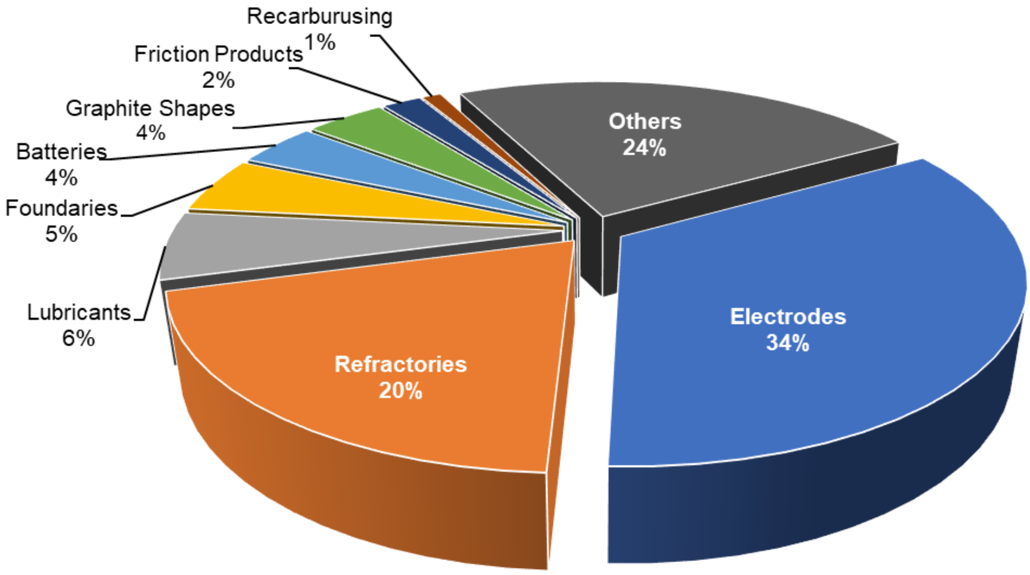

Fig. 4. Main uses of graphite for 2012. Based on data from Shaw(2013).

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Table 3. Prices of selected graphite products in US$/tonne. The purity of concentrate and, for some applications, size of crystalline flake are two key parameters.

Graphite Types, Specifications	Updated Price (US$/tonne)
Vein (lump and chip)	
99.1% C, +1 mesh (>25.4mm), FOB Sri Lanka	3000-3500
93% C, +60 mesh, FOB Sri Lanka	1800-2200
Amorphous graphite	
80-85% C, -200 mesh, China, FCL, CIF European port	450-550
Ore, 70-75% C, ex-works Austria	550-650
Flake graphite	
85-87% C, +100 mesh -80 mesh, FCL, CIF European port	900-1100
90% C, +100 mesh -80 mesh, FCL, CIF European port	1100-1300
94-97% C, -100 mesh, FCL, CIF European port	950-1050
90% C, +80 mesh, CIF, European port	1200-1400
94-97% C, +100 mesh -80 mesh, FCL, CIF European port	1300-1500
94-97% C, +80 mesh, FCL, CIF European port	1500-1800
Spherical graphite, Battery-grade, General (CIF basis)	4000-4700
Synthetic graphite	
97-98%, CIF Asia	2000-2500
98-99%, CIF Asia	2200-2700
99.95% C, Switzerland	8000-15000

Abbreviations: FOB, free on board; CIF, Cost of Insurance and freight included; FCL, Full Container Load; ex-works, direct from the factory, excluding delivery costs, distribution costs, commission. Sources: Benchmark Mineral Intelligence (2025), Research and Markets (2025), Business AnalytIQ (2025), Asian Metals (2025).

In developed countries, graphite is a necessary component for high-tech and refractory applications. One of the market segments that is expected to grow the fastest is the high-tech applications of graphite. Lithium-ion batteries for electric cars, massive electric energy storage systems, and graphite derivatives like graphene, spherical graphite, expanded graphite, and graphite foil are examples of high-tech applications (Sadasivuni et al., 2014; Dickson, 2014). The graphite structure is made up of the aggregation of graphene, which is defined as a dense layer of carbon atoms that is one atom thick and connected in a hexagonal, honeycomb-like lattice. The potential uses of graphene in displays, conductive inks, composite materials, coatings and paints, electronics, energy generation, energy storage, membranes, 3D printing, sensors, photonics and optics, medicine, lubricants, and spintronics have earned it the moniker "wonder material" (Mertens, 2015). In many developed countries, graphene research has received significant government funding support (Janavika and Thangaraj, 2023; Chiu, 2015; Hughes, 2015; Spasenovic, 2015). The compound spherical graphite was first created for use in lithium-ion batteries. It can be made synthetically or from crystalline flake graphite concentrate by means of physical rounding, purification, surface treatment, and milling (Herstedt et al., 2003; Wu et al., 2006; Wang et al., 2008; Shaw, 2013). To produce 30 kg of spherical graphite with a purity of 99.9% C, about 100 kg of crystalline flake graphite concentrate (95% C) is needed (Shaw, 2013). This is enough to produce one electric vehicle's worth of batteries. By 2016, batteries are expected to account for about 5% of global graphite production (Shaw, 2013). In terms of availability, cost, and technical specifications, spherical graphite from crystalline flake concentration competes with its synthetic counterpart in this application. Another byproduct of crystalline flake graphite is expanded graphite. It is created by the insertion of non-graphitic atoms between graphite layers, or intercalation with sulfuric and nitric acids, and then expansion brought on by a sharp rise in temperature. There are currently over 70 graphite exploration and development projects worldwide, most of which are in Canada (Lismore-Scott, 2014; Salwan, 2014). We do not expect a natural graphite shortage before 2020, barring unanticipated political, military, or economic disruptions.

GEOLOGY OF GRAPHITE DEPOSITS

Natural graphite deposits of economic interest are grouped into three main categories: 1) microcrystalline; 2) vein graphite (lump and chip); and 3) crystalline flake graphite (Fig. 3). Deposit profiles by Simandl and Keenan (1998 a,b,c) provide an introduction to the main deposit types for exploration geologists and prospectors.

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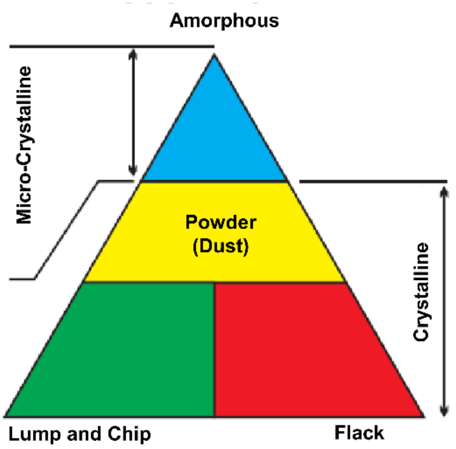

Fig. 5: Main categories of natural graphite currently available on the market. Modified from Simandl et al. (1995).

MICROCRYSTALLINE GRAPHITE DEPOSITS

Commercially, microcrystalline graphite is referred to as 'amorphous graphite'. This term is a misnomer because graphite has a crystal structure (readily detected by X-ray diffraction and Raman spectroscopy), which is lacking in truly amorphous materials. In the scientific community, partially ordered graphite is referred to as 'semi-graphite' (Kwiecinska and Petersen, 2004) or, more recently, 'graphitic carbon' (Beyssac and Rumble, 2014). Most microcrystalline graphite deposits are formed by sub-greenschist to greenschist contact metamorphism or regional metamorphism of coal seams (Taylor, 2006). Microcrystalline deposits consist mainly of small graphite particles intergrown with impurities. Typical deposits are stratiform or lens-shaped; beds may be deformed and/or repeated by folding and faulting. Pinching and swelling of beds are common. Deposits may consist of several beds, each up to a few metres thick. They may be exposed for hundreds of metres along strike. The ore contains from 30 to 95% graphite and, in many cases, more than 80%. Most mines producing microcrystalline graphite enrich ores only by hand sorting and milling. The product is sold mainly as forging lubricants and for applications where high ash content and low crystallinity is acceptable or preferred. An exception is the Kaiserberg deposit in Austria, where 92% graphite concentrate consisting of 2micron size particles is produced (Taylor, 2006). Amorphous graphite is a naturally occurring type of graphite characterized by its microcrystalline structure. It's commonly found in sedimentary rocks and is generally less pure and more powdery than other varieties. Amorphous graphite, with 60-85%. It is used in:

- Pencils: Affordable and sufficient for writing.
- Coatings: In steelmaking and foundries for heat resistance.
- Carbon Brushes: For electrical applications with moderate conductivity.

VEIN GRAPHITE DEPOSITS

The most economically significant vein-type graphite deposits are found in the same metasedimentary belts as crystalline flake graphite deposits, which are metamorphosed to upper amphibolite and granulite facies. In these belts, vein graphite deposits are found in skarn-type assemblages adjacent to igneous intrusions, in igneous intrusions, and in zones with a retrograde overprint (Simandl, 1992). This type is known for its high purity and has a more organized, flaky structure, making it suitable for premium applications. It contains over 90% carbon, is rare and is used in specialized applications like nuclear reactors and high-performance electronics. Graphite veins are currently mined only in Sri Lanka, where graphite is extracted mainly by underground mining methods, routinely to depths in excess of 600 metres. The thickness of individual or anastomosing veins varies from a few millimetres to over one metre, but most are less than 0.3 metres. Other graphite-filled open spaces form pods and lenses, irregular bodies, stockworks, and saddle reefs (Simandl, 1992; Simandl and Keenan, 1998b). Rosettes, coarse flakes, fibers or needles oblique or perpendicular to wall rock and, in some cases, schistosity subparallel to the vein walls are characteristic textures. Outside of upper amphibolite to granulite facies metamorphic terrains and related intrusive (e.g., Cirkel, 1907), graphite veins, breccias, and stockworks also cut a variety of mafic and ultramafic rocks (e.g., Strens, 1965; Barrenechea et al., 1997; Crespo et al., 2006). Vein graphite product (nearly monomineralic), graphite-rich fragments that are typically 0.5 to 0.8 cm in diameter are commercially referred to as 'lump' and 'chip' graphite, although 'lump' graphite may be much coarser (Table 3). Pre-2009 disruptions in the supply of chip and lump graphite due to unrest in Sri Lanka forced the refractory industry to switch from vein-derived graphite to crystalline flake graphite. Once this transition was made, vein deposits lost their economic prominence as the source of graphite for refractories.

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CRYSTALLINE FLAKE GRAPHITE DEPOSITS

The sizes of flakes are divided into these four categories:

1. Jumbo Flake: greater than 180 microns
2. Large Flake: 150 to 180 microns
3. Medium Flake: 100 to 150 microns
4. Fine Flake: 75 to 100 microns

In-situ ore grades fall between 2% and 30% total graphitic carbon (TGC), and after processing, concentrates generally exceed 90% TGC (Syrah Resources 2025). Flake graphite, which contains over 85% carbon, has a crystalline structure and high conductivity. It is used in:

- Battery Anodes: High-purity (99.9995%) spherical graphite for lithium-ion batteries, requiring 50-100 kg per EV battery (Grand View Research 2025).
- Refractories: High-temperature applications in steelmaking and cement production.
- Lubricants: Oils, greases, and fluid dispersions due to its layered structure.
- Nuclear Reactors: Requires 300 tons per 100 GW reactor initially (Investing News Network, 2025).

Disseminated graphite flakes are found in several rock types, including marble, paragneiss, iron formation, quartzite, pegmatite, and syenite (Simandl, 1992; Simandl et al., 1995), and, in exceptionally rare instances, serpentinized ultramafic rocks (Crespo et al., 2006). The predominant hosts for economically significant crystalline flake deposits are paragneiss and marble that have undergone upper amphibolite to granulite facies metamorphism. Graphite deposits composed of extensive paragneiss sequences exhibit uniform mineralization, typically grading 2-3% graphite or lower. The Bissett Creek deposit in western Ontario exemplifies this, comprising 69.8 million tonnes of measured and indicated resources with a grade of 1.74% graphitic carbon (Cg) and 24 million tonnes of inferred resources with a grade of 1.65% Cg, both at a cutoff grade of 1.02% Cg (Northern Graphite Corporation, 2015). These resource estimations do not adhere to NI 43-101 standards. The most superior graphite grades in paragneiss-hosted deposits occur at or near paragneiss-marble interfaces, as demonstrated by the Hartwell opportunity in Quebec. Marble is delineated from biotite gneiss by calcsilicate rocks (clinopyroxenites) and graphite-bearing scapolite paragneiss, which contains graphite concentrations of 3-15%. The interface between the graphite-rich unit and the biotite-gneiss is gradual, with graphite concentration diminishing as the distance from the calcsilicate rocks increases.
The high-grade Lac Knife deposit, located in the Labrador Through Quebec, is described by Birkett et al. (1989), as referenced by Saucier et al. (2012), to contain calcsilicate strata predominantly composed of scapolite. Measured and indicated resources at Lac Knife amount to 9,576,000 tonnes with a grade of 14.77% graphitic carbon, alongside inferred resources of 3,102,000 tonnes at a grade of 13.25% carbon, based on a cut-off grade of 3% graphitic carbon (Desautels et al., 2014). In certain deposits like AA deposit, British Columbia, the highest-grade graphite is found at the peaks of folds, along with retrograde minerals such epidote and chlorite (Marchildon et al., 1993). Marbles in terrains transformed to granulite facies exhibit a granoblastic texture and typically contain less than 0.5% crystalline flake graphite, however concentrations of 1 to 3% crystalline graphite are prevalent. Graphite is uniformly distributed within the host rock, and the dimensions of graphite flakes exhibit a clear correlation with those of calcite or dolomite crystals. There is an absence of microscopic indicators of corrosion or overgrowth on the graphite flakes that would suggest disequilibrium. Minor ingredients, including diopside, magnesite, quartz, tremolite, fosterite, humite group minerals, garnets, scapolite, wollastonite, feldspar, phlogopite, muscovite, and serpentine, comprise less than 5% by volume of the rock. Marbles with porphyroblastic texture are uncommon. They comprise between trace amounts and 25% crystalline flake graphite. The most exemplary case is the old Asbury graphite mine located in Québec. At this location, near-surface deposits were assessed at 485,180 tonnes with a graphite concentration of 10.75% (Séguin, 1974), and the mine operated seasonally from 1980 to 1988.

QUALITY VS. PRICE

Higher-quality flake graphite, especially large-flake or high-purity types, commands premium prices due to its suitability for specialized applications. Amorphous graphite is cheaper, even with high carbon content, because it has simpler uses (Northern Graphite 2025). The cost of mining flake graphite is higher because it involves complicated processing to separate and purify the flakes, with prices reaching as much as USD 2,600 per ton for battery-grade graphite. In contrast, amorphous graphite, typically mined like coal, is cheaper but still needs processing to be turned into usable forms. The price comparison with specific carbon contents are given in Table 3.

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EMERGING PRODUCERS

Tanzania's production increased to 25,000 metric tons in 2024, driven by the Lindi Jumbo mine, which has reserves of 18 million metric tons (Investing News Network, 2025, Research and Markets (2024). Australia is developing graphite projects, with companies like Syrah Resources focusing on battery-grade graphite (Syrah Resources 2025). The United States is exploring domestic production through projects like the Coosa Graphite Mine in Alabama (Holley et. al 2025). Canada is also making strides with projects like the Lac Knife mine, which has reserves of 5.9 million metric tons (Natural Resources Canada, 2025).

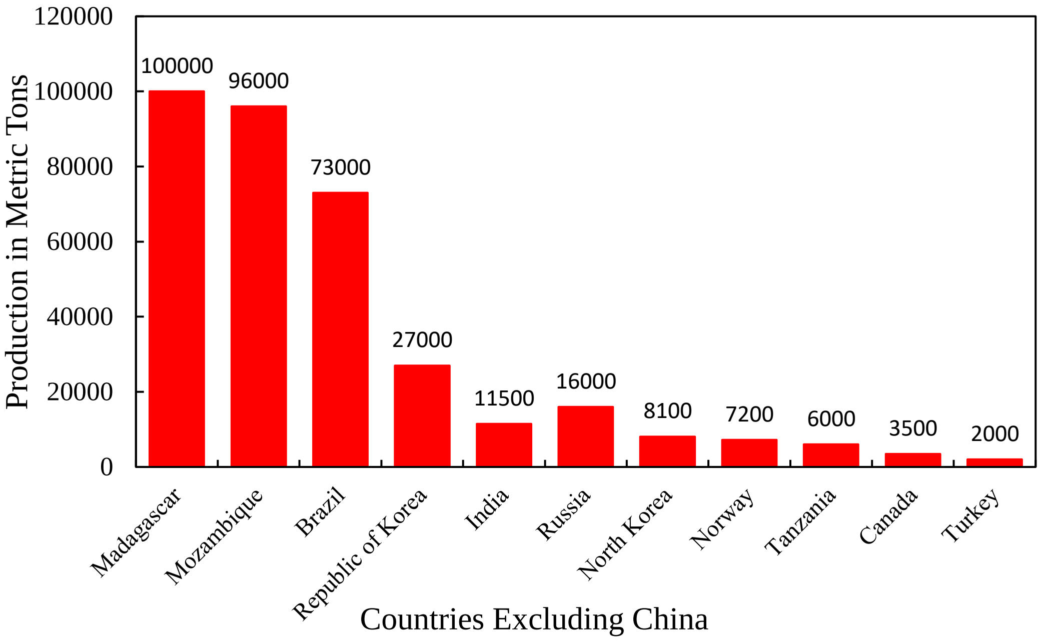

Figure 4: Graphite Production by Top Countries Excluding China (2023)

The bar graph highlights Madagascar and Mozambique as key players outside China Fig.4.

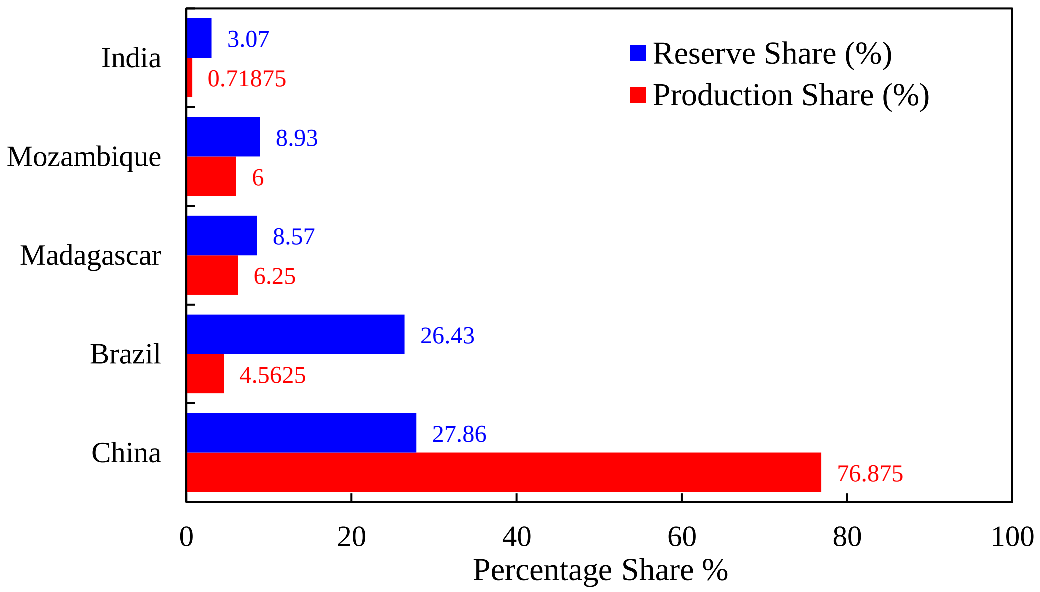

Figure 5: Comparison of Production and Reserves for Selected Countries (2023)

The chart compares production and reserve shares, highlighting Brazil's and India's potential for growth Fig. 5.

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INDIAN GRAPHITE:

Indian graphite can be classified in three be broad categories by based on their geographic and genetic aspects.

1. Eastern Ghat Type
2. Himalayan Type
3. CGGC Type

EASTERN GHAT TYPE

The Eastern Ghats Mobile Belt (EGMB) and Kerala Khondalite Belt (KKB) graphite from eastern and southern India is primarily crystalline flake-type but is associated with epigenetic vein-like occurrences in Andhra Pradesh. It is found in the Proterozoic Eastern Ghats Mobile Belt and Kerala Khondalite Belt, having been deposited during the Pan-African orogeny (~550–650 Ma), stages during which high-grade granulite facies metamorphism and CO_2-rich mantle-derived fluids remobilised biogenic carbon. Its carbon isotopic signature is key to understanding its complex origin, with δ13C values ranging widely from -2.4‰ to -26.6‰. This suggests a mixed origin, where the primary source is the metamorphism of organic-rich sediments (biogenic), but a contribution from inorganic sources mantle CO_2 or decarbonation cannot be ruled out (Sanyal et al., 2009). They yield flakes from fine to large size and contain 85 to 98% carbon after beneficiation. They are the suitable candidate materials for lithium-ion batteries, refractories, and electronics. Odisha accounts for approximately 3-5% of the total reserves in India and is the leading producer, followed by Tamil Nadu, which has about 5% of reserves and contributes about 37% to the total production. Andhra Pradesh and Kerala have alternate high-grade deposits, with Odisha and Tamil Nadu leading the maximum production. Andhra Pradesh supplies to Kerala and smaller high-purity pockets (including vein types in AP). The genesis relates Gondwana reconstructions to Pan-African events and consequently correlates the Indian Eastern Ghats Mobile Belt (EGMB) and Kerala Khondalite Belt (KKB) deposits with Sri Lanka's Highland Complex as well as Madagascar (Anosyan Domain) and Mozambique belts (Balama flake graphite) by shared granulite metamorphism and mantle-fluid processes. Issues are environmental impacts, the need for beneficiation, and how to mine sustainably to satisfy demands for EV batteries.

HIMALAYAN TYPE

The graphite deposits in the Indian Himalayas, spanning from Jammu & Kashmir to Arunachal Pradesh, represent a much younger formation event.

- Origin: The formation of Himalayan graphite is directly linked to the India-Asia continental collision. The intense pressure and temperature of this Cenozoic orogeny metamorphosed ancient, organic-rich sedimentary rocks from the Tethys Ocean basin into crystalline graphite.
- Carbon Isotopic Signature: The δ13C values of Himalayan graphite are consistently and strongly negative (-23‰ to -32‰). This uniformity provides conclusive evidence for a purely biogenic origin, distinguishing it from the mixed-source Eastern Ghats deposits (Sharma & Rawat, 2011).

Arunachal Pradesh graphite is largely crystalline flake but has subordinate amorphous variety occurrences in the Proterozoic Himalayan belt metasedimentary rocks. Formed along with the Himalayan orogeny 50-10 million years ago under greenschist to amphibolite facies conditions, the deposits include the Indian Himalayan states. Such stratabound deposits completely have been derived from the biogenic carbon into the transported-around-a-small-amount sediments. These have medium to large flakes (>0.1 mm) and fixed carbon in the range of 8-20% which could be up-graded by beneficiation to around 95% for high-value applications, like battery anodes, refractories, and electronics. This has geologically feasible style across J&K, Sikkim, and Uttarakhand as both Lesser and Greater Himalayan sequences show comparable tectonometamorphic settings, inverted metamorphic gradients, and thrust dominance.

In Arunachal Pradesh, which contains about 43% of the total Indian graphite (~8.6 million MT), the most significant deposits are that found within the carbonaceous phyllites and schists of the Bomdila Group, and they are highly pure after beneficiation; however, environmental and terrain restrictions bar exploitation: J&K has ~37% of reserves and similar deposits in the Salkhala Group but remains underexplored owing to terrain and security concerns; Sikkim enjoys about 1-2% of reserves from the Lesser Himalayan calcareous suites and mica schists, having both flaky and lumpy types, while Uttarakhand has minor occurrences in the Kumaon region with on-going but small-scale exploration. Exploration is hampered here by rules and regulations, remote terrain, and competition with larger minerals. The homogeneous geological structure, however, suggests a potential to be uncovered through targeted geophysical surveys and mapping. This suggests that there is a uniform prospect of high-purity, medium-to-large-flake graphite throughout the Himalayan belt.

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CGGC TYPE

The graphite deposits within the CGGC are hosted in metasedimentary enclaves. The graphite in the CGGC is predominantly of a biogenic origin. The carbon comes from the metamorphism of carbonaceous sediments, with minimal evidence of an inorganic source (Mahadevan, 2002). The deposits occur as disseminated flakes and veins within schists and calc-silicate rocks, reflecting a distinct local metamorphic history. The graphite is microcrystalline or mainly amorphous; it is present in low to medium-grade metamorphosed carboniferous sediments or coals, belonging to Archean to Proterozoic cratonic rocks, ca. 2.5 to 1.6 Ga. On the other hand, Himalayan Type 2 or Eastern Ghats Type 3 crystalline flake graphite is present in schists, gneisses, and Gondwana coal fields as disseminated material, lenses, or beds, with a carbon content of about 70–90%. To this extent, it is more suitable for low-purity application as lubricants and foundries than for applications in high-purity batteries. Jharkhand has the potential to boast about 6% of India's graphite reserves, while it produces over 30% of the country's total graphite output as a byproduct of coal. The CGGC trends northeast to the Shillong-Meghalaya Gneissic Complex. Amorphous in Palamu, small workable in Garhwa, co-mined with coal in Latehar (Chiaki area), reconnaissance-like in Oranga-Revatipur (CG) all these small deposits are present in metamorphosed graphitic schists and gneisses. In Meghalaya, the graphite is present as amorphous to semi-crystalline small disseminations in migmatites and schists of the Shillong Plateau. All these deposits are poor in purity and small flakes-size, so they face import competition and regulatory and logistic challenges. However, there are possibilities for beneficiation and linked "integrated" exploration with coal and REE, utilizing cratonic stability, but no connection with the Pan-African belts. The comparison of these belts is given in Table 4.

Table 4: Comparison of Indian Graphite belts

Feature	**Himalayan Graphite (Arunachal, Sikkim, etc.)**	**Eastern Ghats & Kerala Graphite**	**Chhotanagpur Granite Gneissic Complex Graphite**
Origin of Carbon	Purely biogenic	Mixed (Biogenic + Inorganic/Mantle)	Primarily biogenic
Carbon Isotopes (δ13C)	Highly negative (-23‰ to -32‰)	Wide range (-2.4‰ to -26.6‰)	Predominantly negative (similar to Himalayan)
Metamorphic Grades	High-grade regional metamorphism, amphibolite to granulite facies,	Granulite facies (very high-temperature metamorphism).	Amphibolite to granulite facies, but the graphite-bearing rocks are enclaves within a larger gneissic body.
Tectonic Setting	Himalayan Orogeny (Tertiary)	Precambrian EGMB (older)	Proterozoic CGGC (older)
Primary Host Rocks	Schists and gneisses of Lesser/Higher Himalaya	Khondalites, Granulites, Gneisses	Metasedimentary enclaves in a granite-gneissic complex
Key Difference	Uniformly biogenic origin tied to a single, major tectonic event.	Complex, mixed origin reflecting multiple carbon sources and high-temperature fluid-rock interaction.	Biogenic origin but in a distinct geological setting with metasedimentary enclaves.

GLOBAL CORRELATIONS: RODINIA TO GONDWANALAND ASSEMBLY

The geological history of India's graphite belts provides a crucial window into the supercontinent cycles of the past. The EGMB and its graphite deposits are particularly significant in this context.

- Eastern Ghats - Sri Lanka - Madagascar - Mozambique: These regions were once a continuous metamorphic tract during the assembly of Gondwana. They are all characterized by high-grade metamorphic graphite deposits formed during the Pan-African Orogeny (550-530 Ma). While sharing a common tectonic origin, their mode of occurrence varies:
  - Eastern Ghats: Mixed disseminated flake and minor vein graphite.
  - Sri Lanka: Unique, high-purity vein graphite, likely formed from fluid precipitation (Simandl, 2015).
  - Madagascar & Mozambique: Extensive, large-flake graphite deposits. The biogenic origin of Madagascan and Mozambican graphite contrasts with the mixed origin of the Eastern Ghats, suggesting subtle differences in the fluid regimes during metamorphism (Simandl, 2015).

- Eastern Ghats - Australia Linkage: The geological belts of the EGMB and those in the Eyre Peninsula of Southern Australia share an older connection, possibly dating back to the supercontinent Rodinia (~1.1 billion years ago). They were later reunited during the assembly of Gondwana. Both regions feature similar biogenic, disseminated flake graphite within high-grade metamorphic rocks, which provides a strong geological argument for a once-continuous mineralized terrain.

INDIA'S POSITION IN THE GRAPHITE MARKET

PRODUCTION AND RESERVES

India is making its mark on the global stage by ranking sixth in graphite production, churning out an impressive 11,500 metric tons in 2023. The country boasts reserves estimated at 8.6 million metric tons, according to the U.S. Geological Survey (2024). Arunachal Pradesh stands out as the state with the richest graphite resources, holding about 35-43% of India's total. The Geological Survey of India highlights major deposits in areas like Bopi, Lamdak, Taliha, Tai, Hunli, and Lalpani, especially in the Tai-Tachidoni region of West Siang district (Geological Survey of India, 2013). However, despite these abundant resources, Arunachal Pradesh's deposits are still largely untapped due to limited exploration and infrastructure, presenting a golden opportunity to enhance domestic production. Tamil Nadu also plays a crucial role, with Tamil Nadu Minerals Limited (TAMIN) operating graphite mines and a beneficiation plant in the Sivaganga region, particularly in the villages of Pudupatti, Kumaripatti, and Senthiudayanathapuram. TAMIN oversees over 600 acres of graphite-rich land, with an estimated reserve of three million tonnes of graphite ore, yielding around 300,000 tonnes of recoverable graphite at an average fixed carbon content of 14% (Tamin Graphite, 2023, IBM 2023). In October 2024, Tamil Nadu's graphite production was reported at 4,020 tonnes, a drop from 5,791 tonnes in September, with an average annual output of beneficiated graphite flakes at 6,000 tonnes from TAMIN's plant, which has a capacity of 8,400 tonnes per year (Tamin Graphite, 2023, Indian Bureau of Mines (IBM) 2023). Other notable states in graphite production include Odisha, with 1.35 million tons of recoverable reserves, as well as Jharkhand and Kerala, which have historically been strong producers due to their higher recoverable reserves (U.S. Geological Survey, 2024). Key players in the industry include Tirupati Carbons & Chemicals, Chhotanagpur Graphite Industries, Graphite India Limited, and TAMIN. Recent news also highlights Coal India Limited's entry into the graphite market, signalling exciting developments ahead.

QUALITY OF GRAPHITE

India is known for producing both flake and amorphous graphite, with the quality varying from one region to another. In Arunachal Pradesh, the graphite tends to be fine to medium flaked, with fixed carbon content ranging between 5% and 25%. This makes it a promising feedstock for high-value uses, like lithium-ion battery anodes, especially after some downstream processing. Over in Tamil Nadu, the Sivaganga graphite, which is overseen by TAMIN, has a flaky texture and an average fixed carbon content of 14%. This graphite is processed to reach up to 96% fixed carbon content, making it suitable for a variety of applications, including refractory bricks, crucibles, carbon brushes, lubricants, and even pencils (Tamin Graphites, 2023, IBM 2023). The TAMIN beneficiation plant located in Senthiudayanathapuram, which has been operational since 1994, processes 200 tonnes of ore each day to produce 20 tonnes of high-quality graphite daily, maintaining a moisture content of 0.2% to 0.5% (Tamin Graphites, 2023). Odisha also contributes high-quality flake graphite to the mix, but the absence of advanced processing technologies hampers India's ability to consistently produce battery-grade graphite (99.9995% purity) needed for electric vehicle batteries, despite the promising feedstock available from Arunachal Pradesh and Tamil Nadu.

The demand for graphite in India is on the rise, fuelled by the rapid growth of its electric vehicle, automotive, and steel industries. Estimates suggest that by 2025, the demand will reach 60,000 metric tons, with projections indicating it could hit 150,000 metric tons by 2030. However, domestic production is only expected to be around 12,500 metric tons in 2025, which covers just 20% of the demand. As a result, India will depend on imports for 69% of its graphite needs, mostly from China. This trend is clearly depicted in Table 3.

Table 3: India's Graphite Demand and Production (2020-2030)

Year	Demand (MT)	Production (MT)	Supply Gap (MT)
2020	30,000	8,300	21,700
2021	35,000	8,300	26,700
2022	40,000	8,300	31,700
2023	45,000	11,500	33,500
2024	50,000	12,000	38,000
2025	60,000	12,500	47,500
2026	75,000	13,000	62,000
2027	90,000	13,500	76,500
2028	110,000	14,000	96,000
2029	130,000	14,500	115,500
2030	150,000	15,000	135,000

Source: IBM Mineral Year Book 2023, Research and Markets (2024)

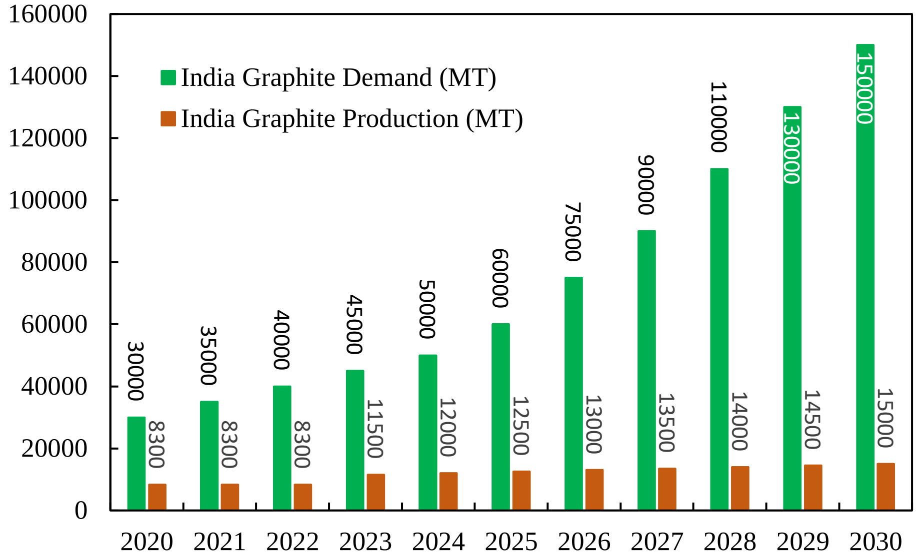

Figure 6: India Graphite Demand vs. Production (2020-2030)

The bar chart illustrates (Fig. 6) the increasing gap between what India requires and what it can produce, highlighting the urgent need for strategic measures Research and Markets (2024).

RECENT DEVELOPMENTS

Coal India Limited (CIL) has officially been chosen as the preferred bidder for the Khattali Chhoti Graphite Block in Madhya Pradesh's Alirajpur district, marking a significant milestone as it embarks on its first venture into non-coal mineral mining. This expansive block covers nearly 600 hectares and features graphite with a fixed carbon content ranging from 1.99% to 6.50%. CIL has committed to a mining premium of 150.05% of the mineral dispatch value to the Madhya Pradesh government. The block is also rich in resources, containing approximately 9.28 million tonnes of graphite and 0.70 million tonnes of vanadium. Furthermore, CIL has agreed to a mining premium of 189.75% of the mineral dispatch value to the state government and is set to execute a mining lease deed within three years, following the deposit of performance security and the completion of tender formalities. Dalmia Bharat Refractories Limited has successfully secured the Iluppakudi Graphite Block in Tamil Nadu through an e-auction, which is a significant step for the company. To move forward, the block needs 15 different clearances, such as forest and environmental approvals, mining plan endorsement, an explosives license, permission to open the mine, groundwater clearance, and consent from the Gram Sabha. The initial tender also comes with a hefty 45% auction premium. Dalmia Bharat is waiting for Letter of Intent (LOI) till date.

CHALLENGES

India's graphite industry is grappling with some serious challenges that are holding it back from satisfying the rising domestic demand. Currently, production only covers about 20% of what's needed, which means India is heavily dependent on imports—especially from China, which provides around 69% of the country's graphite needs. This reliance puts India at risk due to geopolitical tensions. Additionally, the absence of advanced processing technologies limits the country's ability to produce high-purity, battery-grade graphite that's crucial for electric vehicle batteries, even though there's plenty of suitable feedstock available, like the fine to medium flaked graphite found in Arunachal Pradesh. On top of that, significant graphite reserves in Arunachal Pradesh, which make up about 35-43% of India's total resources, are still largely untapped because of limited exploration and poor infrastructure, preventing the state from reaching its potential as a major producer (Geological Survey of India, 2013).

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STRATEGIES FOR INDIA

India needs to take a diversified approach in order to close its supply gap and take advantage of its significant graphite resources, especially in Arunachal Pradesh. India needs to take a well-rounded approach. First off, expanding mining operations is essential, which begins with thorough geological surveys to pinpoint new deposits in Arunachal Pradesh, Odisha, Jharkhand, and Kerala. A key area to focus on is Tai-Tachidoni in Arunachal Pradesh's West Siang district, known for its significant fine to medium flaked graphite that's perfect for high-value uses like lithium-ion battery anodes. Boosting production at existing mines, such as the Gaura Graphite Mines in Jharkhand, and establishing new mines in Arunachal Pradesh through public-private partnerships with companies like Tirupati Graphite (2025) can really ramp up output. It's also vital to enhance processing technology, which means investing in flotation, purification, and spheroidization techniques to create battery-grade graphite. Additionally, funding research and development for cost-effective processing methods tailored to Indian deposits is crucial. Supportive policies can speed up progress by providing subsidies, tax incentives, and simplified regulations to draw in investment, especially in less developed areas like Arunachal Pradesh. Including graphite in India's critical minerals framework can help prioritize its growth. Promoting exports of value-added graphite products can also help diversify revenue streams. Sustainability is key, too, with eco-friendly mining practices needed to meet global environmental, social, and governance standards. Engaging local communities in Arunachal Pradesh through job creation and infrastructure development can ensure that they benefit as well. Lastly, collaborating internationally with countries like Australia or Canada for technology transfer and diversifying imports from emerging producers like Tanzania and Madagascar can lessen India's dependence on China, boosting mineral security and positioning India as a strong competitor in the global graphite market.

CONCLUSION

Increased demand for electric vehicles and renewable energy storage systems is driving significant upheaval in the global graphite market. China's dominance, coupled with its export limitations, underscores the urgent necessity for more diversified supply chains. Emerging producers like Turkey, Madagascar, Mozambique, Tanzania, and Australia are becoming good options, while India, with its large graphite reserves—especially in the old rocks of Arunachal Pradesh, Jammu & Kashmir, Sikkim, and Uttarakhand—has the potential to play an important role. The CGGC type possesses significant promise in Palamu, Jharkhand; Surguja, Chhattisgarh; Sonbhadra, Uttar Pradesh; and adjacent regions in Meghalaya. There are still unexplored regions in Andhra Pradesh, Tamil Nadu, and Kerala within the Eastern Ghats. By addressing its production issues, enhancing processing capabilities, and implementing supportive policies, India can reduce its dependence on imports and significantly contribute to global graphite supply chains. We have discovered key trends and gaps, providing useful insights for stakeholders. By strategically investing in the undiscovered resources of Arunachal Pradesh, alongside technology advancements and regulatory enhancements, India might become a significant contender in the worldwide graphite market, propelling the clean energy revolution.

REFERENCES

Allied Market Research (2025): Graphite market size, share, competitive landscape and trend analysis report by type, application, and region: Global opportunity analysis and industry forecast, 2024-2033. Accessed on April 2025. https://www.alliedmarketresearch.com/graphite-market

Alp Ilhan, Ramazan Sari, and Yonca Yildirim (2020): Hidden graphite resources in Turkey: a new supply candidate for Europe? European Geologist, The Journal of the European Federation of Geologists. pp.31-36.

Asian Metals (2025). Graphite Price. https://www.asianmetal.com/Graphite/

Barrenechea, J.F., Luque, F.J., Rodas, M., Pasteris, J.D., (1997). Vein-type graphite mineralization in the Jurassic volcanic rocks of the external zone of the Betic Cordillera (southern Spain). The Canadian Mineralogist, 35, 1379-1390.

Benchmark Mineral Intelligence (2025): Natural Graphite Prices. https://www.benchmarkminerals.com/natural-graphite/prices

Beyssac, O., and Rumble, D., (2014). Graphitic carbon: a ubiquitous, diverse, and useful geomaterial. Elements, 10, 415-120.

Birkett, T., Godue, R., and Marchildon, N., (1989). The Knife lake graphite deposit, geology, mineralogy and mineral textures, 1989 field and laboratory investigations. Unpublished documents, Québec Géosciences Center.

Buchanan, M.J., (2014). NI 43-101 technical report on the Lac Knife graphite feasibility study Quebec-Canada. Focus Graphite Inc., 293p. http://www.focusgraphite.com/wp-content/uploads/largeReport/Lac-Knife-Feasibility-Study-Technical-Report-August-2014.pdf. Accessed July 15, 2015.

Business Analytiq (2025). Artifical graphite price index. https://businessanalytiq.com/procurementanalytics/index/artificial-graphite-price-index/. September 2025.

Chiu, G., (2015). Perfection of the pursuit: the Canadian option for graphene's commercialisation. Industrial Minerals, no. 571, 25-26.

Crespo, E., Luque, F.J., Rodas, M., Wada, H., and Gervilla, F., (2006). Graphite-sulfide deposits in Ronda and Beni Bouser peridotites (Spain and Morocco) and the origin of carbon in mantle-derived rocks. Gondwana Research, 9, 279-290.

Desautels, P., D'Anjou, N., Skiadas, N., Cassoff, J., Pengel, E., Bilodeau, M.L., and Dickson, J.S., (2014). Talga eyes graphene potential. Industrial Minerals, no. 567, pp. 35-36.

East Carbon (2024). Top ten graphite producing countries. Accessed on January 2025. https://www.eastcarb.com/top-ten-graphite-producing-countries/

Fastmarkets (2023). Industrial minerals: Natural and synthetic graphite market guides. Accessed on April 2025. https://www.fastmarkets.com/industrial-minerals/graphite/

Geological Survey of India. (2013). Assessment of graphite resources in India. https://www.gsi.gov.in/

Global Data (2025). Graphite Mining Market Analysis by Reserves, Production, Assets, Demand Drivers and Forecast to 2030. Accessed on July 2025. Report Code: GDMMGGP0020MR-ST. Accessed on 06/08/2025. https://www.globaldata.com/store/report/graphite-mining-market-analysis/

Grand View Research (2025): Graphite market size, share & trends analysis report by type (natural, synthetic), by application (batteries, refractories, lubricants), by region, and segment forecasts, 2024-2030. Report ID: GVR-4-68040-142-0, Accessed on July 2025. https://www.grandviewresearch.com/industry-analysis/graphite-market

Herstedt, M., Fransson, L., and Edström, K., (2003). Rate capability of natural Swedish graphite as anode material in Li-ion batteries. Journal of Power Sources, 124, pp. 191-196.

Holley E. A., Fahle L., Smith N.M., Deberdt R., Calderon J., Gibbs G., Bazilian M., (2025) Graphite and manganese mining in the U.S.: Proposed projects and federal battery mineral policies. Resources Policy Volume 108, p. 105689. https://doi.org/10.1016/j.resourpol.2025.105689

Hughes, E., (2015). The importance of Manchester's "Graphene City". Industrial Minerals, no. 571, 27-28.

IMARC Group (2024). Graphite market: Global industry trends, share, size, growth, opportunity and forecast 2024-2032. Accessed on April 2025. https://www.imarcgroup.com/graphite-market

IMRAC Group (2025). Graphite Prices, Trend, Chart, Demand, Market Analysis, News, Historical and Forecast Data Report 2025 Edition. https://www.imarcgroup.com/graphite-pricing-report

Indian Bureau of Mines (2023): Mineral year book 2022: Part- III : Mineral Reviews Graphite. 60th Edition, Government of India Ministry of Mines Indian Bureau of Mines pp. 14-1 -14.13.

Indian Bureau of Mines (2025): Mineral Production: Tamil Nadu: Volume: Non-Metallic Minerals: Graphite. https://www.ceicdata.com/en/india/mineral-production-tamil-nadu/mineral-production-tamil-nadu-volume-non-metallic-minerals-graphite#:~:text=Bureau%20of%20Mines-,Mineral%20Production%3A%20Tamil%20Nadu%3A%20Volume%3A%20Non%20Metallic%20Minerals%3A,5%2C880.000%20Ton%20for%20Jan%202025.

Investing News Network. (2025). Top 10 graphite-producing countries. Accessed on June 2025. https://investingnews.com/daily/resource-investing/battery-metals-investing/graphite-investing/top-graphite-producing-countries/

Investor News (2023). Graphite supply and demand forecast: The growing deficit. Accessed on February 2025. https://investornews.com/graphite-market-forecast/

Janavika K.M., Thangaraj, R.P.,(2023). Graphene and its application: A review. Materials today: Proceedings. https://doi.org/10.1016/j.matpr.2023.05.446.

Kwiecińska, B., and Petersen, H.I., (2004). Graphite, semi-graphite, natural coke, and natural char classification—ICCP system. International Journal of Coal Geology, 57, 99-116.

Lismore-Scott, S.L., (2014). Graphite projects and reserves – are we facing an oversupply situation? Industrial Minerals, no. 567, 29-32.

Mahadevan, T. M. (2002). Geology and petrology of the Chhotanagpur Granite Gneiss Complex, Jharkhand. Geological Society of India.

Marchildon, N., Simandl, G.J., and Hancock, K.D., (1993). The AA graphite deposit, Bella Coola area, British Columbia: exploration implications for the coast plutonic complex. In: Geological Fieldwork 1992, British Columbia Ministry of Energy and Mines, British Columbia Geological Survey Paper 1993-1, 389-397.

Moores, S., (2015). Battery grade graphite set for record year. Mining. com http://www.mining.com/web/battery-grade-graphite-set-forrecord-year/ Accessed July 22, 2015.

Natural Resources Canada (2025). Graphite facts. Accessed on June 2025. https://www.nrcan.gc.ca/our-natural-resources/minerals-mining/minerals-metals-facts/graphite-facts/24029

Northern Graphite (2025). Graphite pricing and markets. Accessed on June 2025. https://www.northerngraphite.com/graphite-pricing/

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
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Research and Markets (2024). Global Graphite Mining Industry Report 2024-2030: Reserves, Production, Major Operating Mines, Competitive Landscape, Major Projects, Exports and Imports. Accessed on 08/08/2025. https://www.globenewswire.com/news-release/2024/05/29/2889609/28124/en/Global-Graphite-Mining-Industry-Report-2024-2030-Reserves-Production-Major-Operating-Mines-Competitive-Landscape-Major-Projects-Exports-and-Imports.html

Research and Markets (2025). The Global Market for Graphite 2025-2035. https://www.researchandmarkets.com/report/graphite?srsltid=AfmBOorICYY3TmVCWmDnTRRUSHQbKIWs5L8uUBZlWaZY_SaFV4Spb_tj

Sadasivuni, K.K., Ponnamma, D., Thomas, S., and Grohens, Y., (2014). Evolution from graphite to graphene elastomer composites. Progress in Polymer Science, 39, 749-780.

Salwan, S., (2014). The Indian graphite industry – why we need to take notice. Industrial Minerals, no. 567, 32-34.

Sanyal, P., Goswami, S., Saha, G., & Sarkar, G. (2009). Origin of graphite, and temperature of metamorphism in Precambrian Eastern Ghats Mobile Belt, Orissa, India: A carbon isotope approach. Journal of Asian Earth Sciences, 36(4-5), 252-260.

Saucier, G., Lyons, E., and Baril, F., (2012). NI 43-101 technical report on the Lac Knife graphite project. Focus Metals Inc., 87p. www.focusgraphite.com/french/wp-content/uploads/2012/07/43-101Report_Lac-Knife.pdf Accessed July 10, 2015.

Séguin, E., (1974). Preliminary report on the projected operation of a graphite mine at Notre-Dame-du-Laus, Québec. Somex Ltd., 16p.

Sharma, R., & Rawat, R. S. (2011). Carbon isotopic evidence for the origin of Himalayan graphite from Almora crystallines. Journal of the Geological Society of India, 78(6), 576-578.

Shaw, S., (2013). Graphite demand and growth: the future of lithium-ion batteries in EVs and HEVs. Proceedings of 37th ECGA General Assembly. http://www.saintjeancarbon.com/files/2513/7157/3343/Graphite_demand_Li ions_April_2013.pdf Accessed June 30, 2015.

Simandl, G. J. (2015). Graphite deposit types, their origin, and economic significance. BCGS Paper, P2015-03-19.

Simandl, G.J., (1992). Gîtes de graphite de la région de la Gatineau, Québec. Unpublished Ph.D. thesis, Université de Montréal, Montréal, Canada, 383p.

Simandl, G.J., and Keenan, W.M., (1998a). Microcrystalline graphite. In: Geological Fieldwork 1997, British Columbia Ministry of Energy and Mines, British Columbia Geological Survey Paper 1998-1, 24O-1-24O-3. http://www.empr.gov.bc.ca/Mining/Geoscience/PublicationsCatalogue/Fieldwork/Documents/1997/simandl_kenan_po3.pdf Accessed June 30, 2015.

Simandl, G.J., and Keenan, W.M., (1998b). Vein graphite in metamorphic terrains. In: Geological Fieldwork 1997, British Columbia Ministry of Energy and Mines, British Columbia Geological Survey Paper 1998-1, 24Q-1-24Q-3. http://www.empr.gov.bc.ca/Mining/Geoscience/PublicationsCatalogue/Fieldwork/Documents/1997/simandl_kenan.pdf Accessed June 30, 2015.

Simandl, G.J., and Keenan, W.M., (1998c). Crystalline flake graphite. In: Geological Fieldwork 1997, British Columbia Ministry of Energy and Mines, British Columbia Geological Survey Paper 1998-1, 24P-1-24P-3. http://www.empr.gov.bc.ca/Mining/Geoscience/PublicationsCatalogue/Fieldwork/Documents/1997/simandl_kenan_po4.pdf Accessed June 30, 2015.

Simandl, G.J., Paradis, S., Valiquette, G., and Jacob, H.L., (1995). Crystalline graphite deposits, classification and economic potential. Proceedings of 28th Forum on the Geology of Industrial Minerals, Marinsburg, West Virginia, May 3-8, 1992, pp.168-174.

Spasenovic, M., (2015). Leavin lab status: Graphene's various routes to industrial application. Industrial Minerals, no. 571, pp. 23-25.

Strens, R.G.T., (1965). The graphite deposits of Seathwaite in Borrowdale, Cumberland. Geological Magazine, 102, pp. 393-406.

Syrah Resources (2025). Balama graphite operation, Cabo Delgado Mozambique. Accessed on May 2025. https://www.syrahresources.com.au/our-operations/balama-graphite-operation/

TAMIN Graphite (2023). Graphite mining, beneficiations and processing. https://tamin.co.in/service/graphite/

Taylor, H.A., Jr., (2006). Graphite. In: Kogel, J.E., Trivedi, N.C., Barker, J.M., and Krukowski, W.T., (Eds.), Industrial Minerals and Rocks. Society for Mining, Metallurgy, and Exploration, Inc., Littleton, Colorado, pp. 507-518.

Tirupati Graphite (2025). India operations. Accessed on May 2025 https://tirupatigraphite.co.uk/

U.S. Geological Survey (2023). Global distribution of graphite producing countries. Accessed on August 2025.

U.S. Geological Survey (2024). Mineral commodity summaries 2024. Accessed on 05/08/2025. https://www.usgs.gov/centers/nmic/mineral-commodity-summaries

Wang, X., Gai, G.-S., Yang, Y.-F., and Shen, W.-C., (2008). Preparation of natural microcrystalline graphite with high spericity and narrow size distribution. Powder Technology, 181, pp. 51-56.

Wu, Y.-S., Wang, Y.-H., and Lee, Y.-H., (2006). Performance enhancement of spherical natural graphite by phenol resin in lithium-ion batteries. Journal of Alloys and Compounds, 426, pp. 218-222.