Evaluation of Geological Exploration Data and Report on General Exploration(G-2)

(Using Artificial Intelligence (mineAIex Software) under S & T PRISM-2 program)

For Biarpali block in Biarpalli,

Taluk/tehsil-Biarpalli, District-Balangir, Odisha, India.

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सारांश

यह रिपोर्ट ओडिशा राज्य के बलांगीर ज़िले के बियारपाली तालुका/तहसील अंतर्गत बियारपाली ब्लॉक में किए गए G2 स्तर के अन्वेषण के निष्कर्ष प्रस्तुत करती है। इसमें भूवैज्ञानिक, भू-रासायनिक, भूभौतिकीय, और ड्रिलिंग डेटा का कृत्रिम बुद्धिमत्ता आधारित विश्लेषण (mineAlex सॉफ्टवेयर) शामिल है, जिससे प्रचुर मात्रा में ग्रेफाइट खनिजीकरण की पुष्टि होती है।

G-2 स्तर के अन्वेषण के लिए कुल 38 बोरहोल (11 भारतीय भूवैज्ञानिक सर्वेक्षण द्वारा और 27 MECL द्वारा) ड्रिल किए गए, जिनका उद्देश्य मैंगनीज अयस्क की स्ट्राइक दिशा एवं गहराई में निरंतरता की पुष्टि करना और संसाधनों का आकलन करना था। MECL द्वारा किए गए 27 बोरहोलों में से 7 में कोई मैंगनीज खनिजीकरण नहीं पाया गया।

मैंगनीज अयस्क निकाय अनियमित, लेंसनुमा और निम्न श्रेणी (low-grade) के हैं, जो फ्लोट्स, कैपिंग्स और पृथक लेंसों के रूप में पाए जाते हैं।

भूवैज्ञानिक संरचना:
यह क्षेत्र पूर्वी घाट सुपरग्रुप के उत्तरी भाग में आता है, जो प्रीकैम्ब्रियन काल की रूपांतरित खोंडलाइट चट्टानों से युक्त है। इसमें खोंडलाइट, कैल्क-सिलिकेट, कैल्क-ग्रैनुलाइट, चार्नोकाइट, ग्रेनाइट ग्नीस, और क्वार्ट्जाइट शामिल हैं, जिनमें ग्रेनाइट, पेगमैटाइट और क्वार्ट्ज वेन की अंतःप्रवेशीय संरचनाएं भी पाई जाती हैं।

खनिजीकरण का विवरण:
- मैंगनीज अयस्क आमतौर पर ऑक्साइड युक्त बड़े बोल्डरों के रूप में सतह पर दिखाई देता है, जिसमें मुख्य खनिज पाइरोलुसाइट और साइलोमिलेन हैं। ये खनिज आमतौर पर मुलायम और चूर्णयुक्त होते हैं।
- खनिजीकरण लेंस, वेन और विसरित रूपों में खोंडलाइट चट्टानों के भीतर पाया जाता है, जो अक्सर संरचनात्मक और शैलविज्ञानिक नियंत्रण में होता है। इसमें ब्रेक्सिएशन और अपक्षय (weathering) समृद्धि में सहायक होते हैं।
- प्रमुख अयस्क खनिजों में शामिल हैं: साइलोमिलेन, हॉलैंडाइट, बिक्सबाइट, हौस्मेनाइट, पाइरोलुसाइट और ब्राउनाइट; जबकि ग्रेफाइट मध्यम से सूक्ष्म परतदार (flakes) रूप में पाया गया है, जिसमें kink band और crenulation देखे गए।
- खनिजविश्लेषण (10 पॉलिश किए गए सेक्शन) से यह प्रमुख खनिज पाए गए:
  - गैथाइट: 34%
  - साइलोमिलेन: 27%
  - पाइराइट–पाइरॉटाइट–कैल्कोपाइराइट: 18%
  - ग्रेफाइट: 12%
  - अन्य: शेष

संसाधन वर्गीकरण:
बिखरे हुए खनिजीकरण, लगभग 100 मीटर की बोरहोल दूरी, और उपलब्ध आंकड़ों के आधार पर संसाधन को "संकेतित संसाधन" (Indicated Resource) के अंतर्गत UNFC कोड 332 में वर्गीकृत किया गया है।

- मैंगनीज संसाधन का अनुमान: 3.718 मिलियन टन (10% कटऑफ ग्रेड पर)
- ग्रेफाइट संसाधन का अनुमान: लगभग 3.7 लाख टन (2% FC कटऑफ ग्रेड पर)

1.2 English Summary

This report presents the findings of G2 level exploration conducted at the Biarpali block in Biarpalli, Taluk/tehsil-Biarpalli, District-Balangir, Odisha, India. It includes analysis of geological, geochemical, geophysical, and drilling data using artificial intelligence (mineAIex software) that confirm the presence of substantial graphite mineralization. A total of 38 boreholes (11 by GSI, 27 by MECL) were drilled for G-2 stage exploration to confirm strike and depth continuity of manganese ore and estimate resources. Out of 27 MECL boreholes, 7 did not intersect any manganese mineralization. The manganese ore bodies are irregular, lensoidal, and of low grade, occurring as floats, cappings, and isolated lenses. Geological Setting: The area lies within the northern Eastern Ghats Supergroup, characterized by metamorphosed Precambrian Khondalite rocks, including Khondalite, Calc-silicate, Calc-granulite, Charnockite, Granite Gneiss, and Quartzite, with granite, pegmatite, and quartz vein intrusions.

Mineralization Details: Manganese ore appears as oxide-rich bouldery outcrops with minerals like pyrolusite and psilomelane, generally soft and powdery.

- Mineralization occurs as lenses, veins, and disseminations within Khondalite rocks, often structurally and lithologically controlled, with brecciation and weathering aiding enrichment.

- Ore minerals include psilomelane, hollandite, bixbyite, hausmannite, pyrolusite, and braunite; graphite occurs as medium-to-fine flakes showing kink bands and crenulations. Mineragraphic analysis (10 polished sections) revealed major minerals: goethite (34%), psilomelane (27%), pyrite-pyrrhotite-chalcopyrite (18%), graphite (12%), and others.

Given the discontinuous nature, borehole spacing (~100 m), and available data, the resource fall under the Indicated Resource (UNFC Code 332) category. Estimated manganese resources is 3.718 million tonnes at 10 % cut off and graphite resource is around 370000 tonnes with 2% FC cutoff grade.

2. Introduction

2.1 The Biarpalli (G-2) Block Description

The Biarpalli (G-2) Block is situated approximately 30 km north-northwest of Balangir town in Odisha, India. The exploration block lies in the vicinity of Banipali village in Loisingha Tehsil, Balangir district. The block is mapped on Survey of India Toposheet No. 64 P/05. Accessibility is facilitated by State Highway No. 1 and seasonal roads, with Balangir serving as the nearest railhead.

The district of Balangir showcases a mix of hilly terrain in the west and south with plains in the north and east. The terrain includes undulating plains, ridges, and isolated hills, with elevations ranging from 194 meters to 372 meters above MSL as shown in Figure 1. The Suktel River, with its dendritic drainage pattern, dominates the hydrology of the region, contributing to fertile alluvial plains favourable for agriculture. Balangir experiences a sub-tropical climate with monsoon rains from June to September. The temperature ranges from 10° C in winter to 46° C in summer, with an average annual rainfall of 100 cm. The area is notably hot in the summer months.

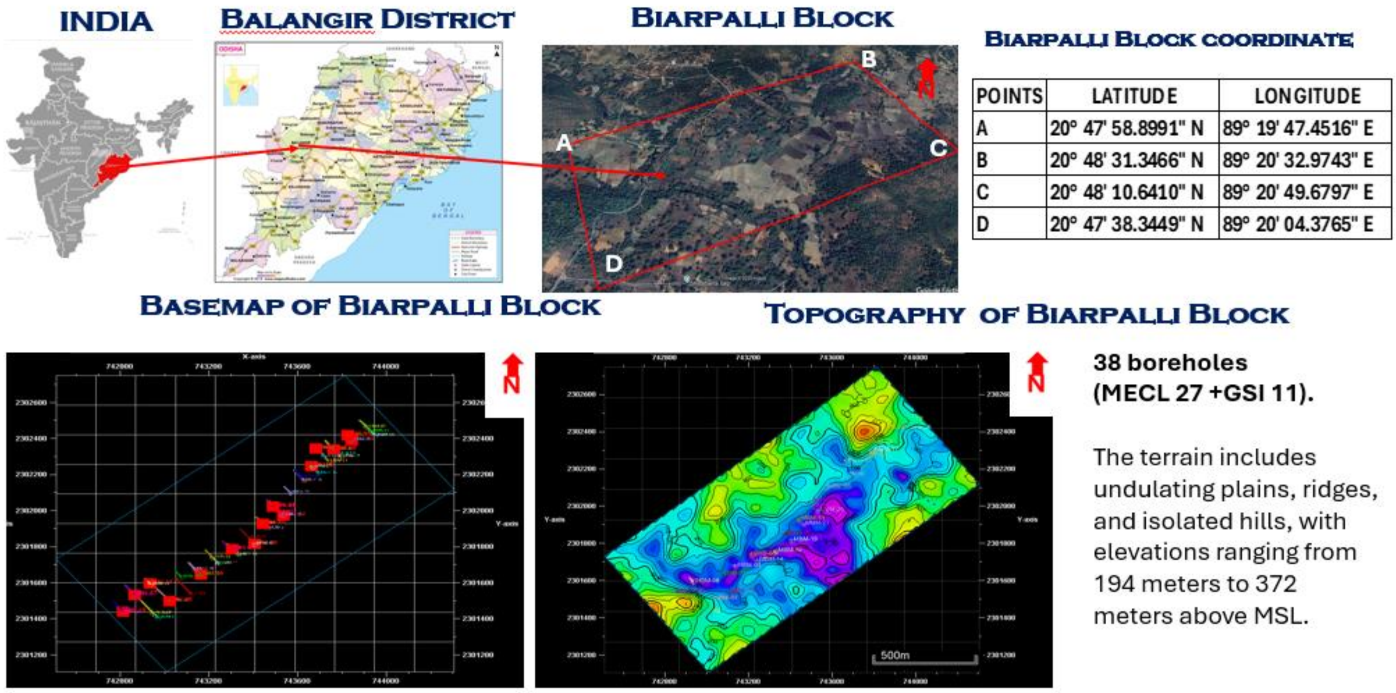

Figure 1. Base map and drilled bore hole (42 boreholes) along with topography map.

Forests cover approximately 23.48% of Balangir's geographical area. Although the Biarpalli block itself is not within a forest, it is surrounded by reserve forests like Kendukurpa and Sunadei. The local flora includes species such as Sal, Shishu, Neem, Tamarind, Jackfruit, and Mango. The fauna is limited but includes wild boars, rabbits, jackals, and various bird species. The district houses significant historical landmarks like the Ranipur-Jharial temple complex, famous for its 64 Yogini temples, and the Indralath brick temple. The Sailashree Palace in Balangir town stands as a notable heritage structure. The district boasts considerable infrastructure including national highways, state highways, railway lines, and healthcare facilities. Balangir hosts a district hospital, a medical college, and multiple commercial banks. Mining activities in the region include operational graphite, quartz, and manganese mines. As per the 2011 census, Balangir has a population of approximately 1.649 million, with a rural populace constituting 88.03%. The literacy rate stands at 64.72%, and the majority comprises Scheduled Tribes and Castes.

2.2 The General information about the Block.

1	**FEATURES**	
	Licence Type	Composite Licence
	Mineral	Graphite and Manganese
	Mineralised Area	19.25 Ha.
	Non-mineralised area	112.57 Ha.
	Area	131.82 Ha.
	Exploration Level	G2 (General exploration)
	Exploration Agency	Mineral Exploration and Consultancy Limited, Nagpur-440 006

	Morphology of the area	The area comprises of wide spread plain land, ridges, hillocks and mounds. The maximum height of the ridge is 372 m and minimum elevation of the plain land is 194 m above MSLas shown in figure 1.
2	**RESOURCE SUMMARY**	
	Resource (MT) & Grade	The total resources (332) estimated for graphite bearing mineralized/ore zones in Biarpalli block is 370000 tonnes with 2% FC cutoff grade. The total resource (332) estimated for Manganese bearing mineralized/ore zones in Biarpalli block is 3.718 million tonnes at 10 % cut-off grade.
3	**LOCATION DETAILS**	
	Location	The exploration block is located at about 30 Km north-north-west of Balangir town in the vicinity of Banipali village, LoisinghaTehsil, District Balangir, in the western region of Odisha.
	Toposheet Number	Toposheet No- 64P/05
	Connectivity	
	Rail	
	Road	The area is connected by fair weather road from the State Highway No. 1 (Balangir-Patanagarh Road).
	Airport	Raipur
4	**MINERALISATION & EXPLORATION DETAILS**	
	Mineralisation	The general trend is NNW-SSE to NE-SW direction. The general dip of the area is 60° to 80° towards south-east. Graphite: Four (04) graphite ore zones. Cumulative strike length is 1036.50 m and thickness ranges from 1.00 to 12.00 m Manganese: Five (05) manganese ore zones. Cumulative strike length is 3263 m and thickness ranges from 1.00 to 41.34 m.
	Pitting / trenching details	5 pits (1 m X 1 m X 1 m) for bulk density
	Hydrography	Rain-fed easterly flowing Suktel River along with its tributaries drain the area. The drainage is sub-parallel to sub-dendritic controlled by ridges
	Climate	100 cm

2.3 Summary of Biarpalli Block

Area	Biarpalli, Taluk/tehsil-Biarpalli, District-Balangir, Odisha, India
Contract Type	Auction type
Acreage	131.82 Ha
Working Interest	100%
Available data along with mineralogy, petrology,	**Nature of work** / **Quantum of Data**

and materials science data	**I. Geological Survey**	
	i) Detailed Mapping (1:2,000)	
	II. Technological Survey	
	a. Surface Exploration	
	i) PT	
	b. Sub surface Exploration	-
	i) Drilling	27 borehole(2450 m drilling) by MECL + 13 Borehole (1055 m drilling) by GSI
	III. Geophysical Survey	
	a) GP: Survey (IP, SP, Magnetic, Resistivity)	
	b) GP Borehole logging	
	IV. Sampling	Sample Preparation & Laboratory Studies
	i) Primary samples for 6 radicals i.e. Mn, SiO2, P2O5, Fe2O3, MnO2 and Insolubles	800 nos .
	ii) Primary samples for Graphite (Proximate analysis)	
	iii) Internal Check samples (5% of Primary samples) for analysis of 6 radicals i.e. Mn, SiO2, P2O5, Fe2O3, MnO2 and Insolubles	40 samples
	iv) External Check sample (5 % of Primary samples) for analysis of 6 radicals i.e. Mn, SiO2, P2O5, Fe2O3, MnO2 and Insolubles	80 samples
	Composite Samples (Core Samples)	
	i) composite samples will be analyzed for	80 samples

6 radicals i.e. Mn, SiO_2, P_2O_5, Fe_2O_3, MnO_2 and Insolubles	
Petrographic Studies	10 samples
Mineragraphic Studies	10 samples
Specific Gravity Determinations	15 samples
Bulk Density Determination	5 samples-
Report (Digital format)	1
Sample Preparation & Laboratory Studies	
Primary samples and Check samples for Graphite (Core Samples)	
i) Primary samples for Proximate Analysis (Ash, Moisture, V.M. and F.C.)	
ii) Primary samples for Proximate Analysis (Ash, Moisture, V.M. and F.C.)	
iii) External Check sample Proximate Analysis (Ash, Moisture, V.M. and F.C.)	
Composite Samples for Graphite (Core Samples)	
Composite Samples for Graphite (Core Samples)	
i) Proximate Analysis (Ash, Moisture, V.M. and F.C.)	229
ii) Internal Check samples for Proximate Analysis (Ash, Moisture, V.M. and F.C.)	15
iii) External Check sample Proximate Analysis (Ash, Moisture, V.M. and F.C.)	24
Composite Samples for Graphite (Core Samples)	
i) Proximate Analysis (Ash, Moisture, V.M. and F.C.)	4
ii) Total Sulphur (S)	4
Petrographic Studies	4
Report (Digital format)	3

<table>
<tr><td></td><td><table><tr><td></td><td>1</td></tr></table></td></tr>
<tr><td>Block Boundary</td><td>POINTS LATITUDE LONGITUDE
A 20° 47' 58.8991" N 89° 19' 47.4516" E
B 20° 48' 31.3466" N 89° 20' 32.9743" E
C 20° 48' 10.6410" N 89° 20' 49.6797" E
D 20° 47' 38.3449" N 89° 20' 04.3765" E</td></tr>
<tr><td>Most-likely Reserve/ Resources</td><td>Resource Estimation of Biarpalli prospect resource is under categories G2.
<table><tr><td>Commodities</td><td>Resource at cutoff grade</td><td>Million Tonnes</td></tr><tr><td>Graphite</td><td>2 %</td><td>370000 tonnes</td></tr><tr><td>Manganese</td><td>10 %</td><td>3.718</td></tr></table></td></tr>
<tr><td>Milestones</td><td>Exploration Period of 3 years, Mining and production 50 years.</td></tr>
<tr><td>Actual Work Completed</td><td>Collection & Interpretation of drilled 42 borehole data for different vintages as shown in Figure-1 and successfully completed G4, G3 and G2 stage of exploration.</td></tr>
<tr><td>PARTICULARS OF LAND</td><td>Total Concession Area 131.82 Ha, 1. Forest Land with Status Nil, 2. Government Land with Status 36.38 Ha, 3 Private Land with Status 95.44 Ha.
Block falls in the villages of Badipali, Biarpali and Belpali of Loisingha tehsil, Balangir District, Odisha</td></tr>
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3. Previous Exploration Work

Initial reports of manganese in Balangir date back to 1940 by B.C. Roy of GSI, who noted its association with calc-granulites and gneisses. Further work by A.G. Jhingran (1947) and S. Krishnaswamy (1950) confirmed manganese occurrences as low-grade ores with Mn contents ranging between 25.45% and 33.52%. Detailed geological mappings were later undertaken by Tak (1966), Bose (1967), and Mitra (1965), affirming the ore's sedimentary metamorphic origins. 40 boreholes has been done to target manganese and graphite in this area along with geological survey. Mineral exploration in this area has been successfully completed G4, G3 and G2 stages.

3.1 Past Resource Estimates and Recommendations

GSI's exploration between 1995 and 1997 in Biarpalli revealed a possible resource of 0.602 million tonnes with an average Mn grade of 24.40% at a 20% cut-off, up to a depth of 45 meters. They recommended further drilling to explore depth continuities. MECL's G-2 stage exploration initiative, supported by NMET funding, the gross in-situ resource of manganese ore is estimated at 3.732 million tonnes with an average grade of 18.63% Mn, 15.14% Fe, and 0.31% P. The net in-situ resource after accounting for geological losses stands at 3.358 million tonnes. The estimation confirmed moderate-grade manganese ore suitable for beneficiation and potential commercial mining. Graphite resources have been estimated at a gross in-situ figure of 0.335 million tonnes, grading an average of 3.71% fixed carbon. The net in-situ resource, considering losses, is 0.301 million tonnes. Graphite mineralization is widespread but low-grade, suggesting selective mining as an economically viable option.

4. Regional and Block Geology

The Biarpalli exploration block lies within the Eastern Ghats Supergroup, characterized by a complex metamorphic terrain of pre-Cambrian age. The region is dominantly composed of Khondalite Suite rocks interbedded with quartzite, calc-silicate rocks, granulites, and charnockites. These are further intruded by granites and pegmatites. The entire sequence has undergone high-grade metamorphism leading to the formation of granulite facies rocks with characteristic mineral assemblages.

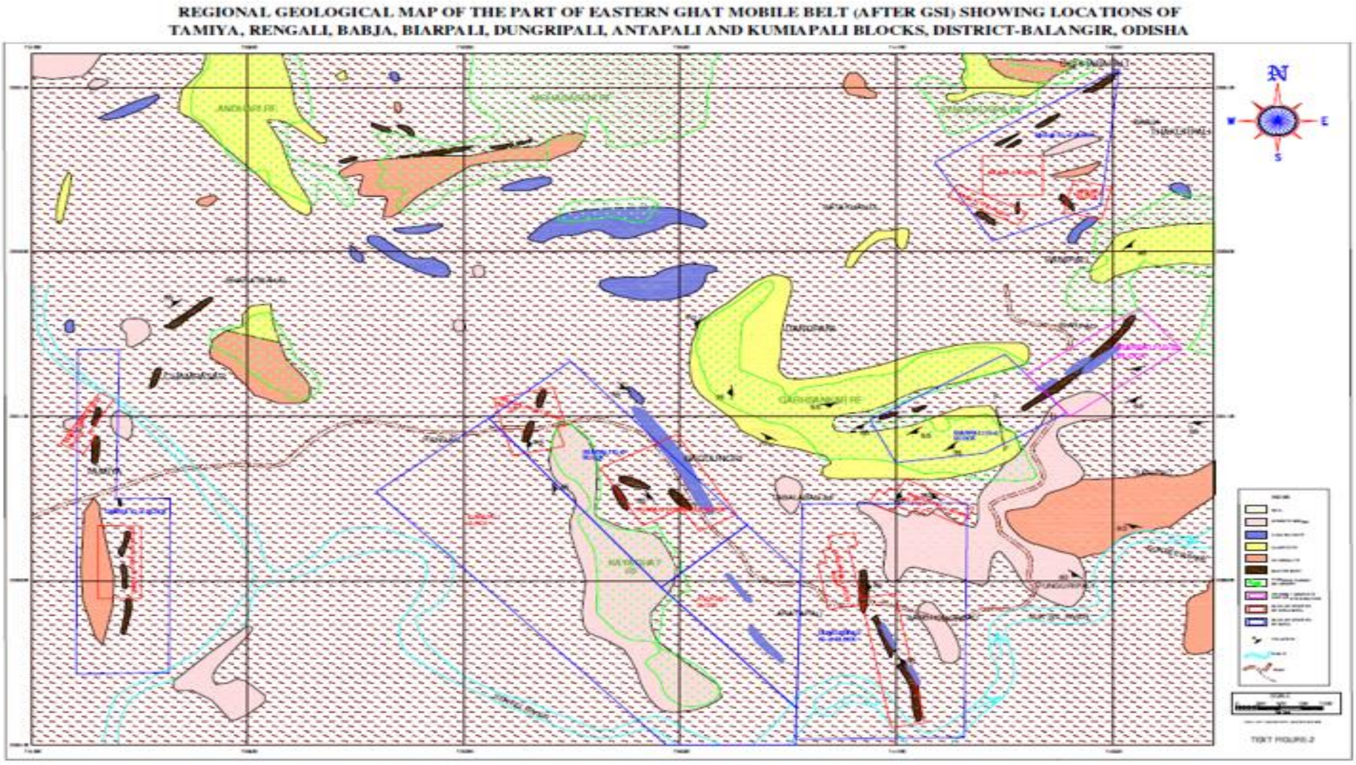


Figure 2. Regional geological map along with Biarpalli block.

4.1. Structural Geology

The area showcases complex structural features due to multiple deformation phases. Primary bedding is mostly obliterated, though interbanding in Khondalite is evident. Foliation trends from NNW-SSE to NE-SW with moderate to steep dips. Multiple sets of joints and well-preserved secondary structures such as mineral lineations and folds (three generations) characterize the tectonic regime. Intense brecciation and faulting influence mineralization, as evident from silicification zones and brecciated quartzites.

4.2 Metamorphism

The region exhibits granulite facies metamorphism, marked by mineral assemblages like quartz-feldspar-garnet-sillimanite in khondalite, diopside-plagioclase-calcite in calc-silicates, and pyroxene-rich mineralogy in granulites and charnockites. The metamorphic transformations reflect high-grade thermal conditions indicative of deep crustal processes.

4.3 Surface Manifestations of Mineralization

Surface exposures of manganese occur as rugged, bouldery outcrops with features like botryoidal textures, box works, and colloform structures. Oxide minerals such as pyrolusite and psilomelane dominate, presenting in a granulitic fabric. Graphite occurrences are subtle at the surface, often embedded within Khondalite and detectable primarily through borehole intersections.

4.4 Geology of the Biarpalli Block

About 88% of the block is covered with soil overburden, with exposed lithologies including khondalite, calc-silicate rocks, quartzite, granite gneiss, and amphibolite. Manganese ore bodies trend NE-SW, both within calc-silicates and quartzite, with associated float ore deposits. The primary litho units mapped are soil, manganese ore, khondalite, calc-silicate, granulite, charnockite, granite gneiss, amphibolite, and quartzite. Quartz veins are widespread, often traversing manganese ore zones.

5.0 Drilling Campaigns

Initially, a total of 1055 meters 13 boreholes was drilled by GSI. Latter a total of 2360.50 meters of core drilling across 27 boreholes was undertaken by MECL. Drilling depths ranged from 50 meters to 150 meters, targeting down to 70 meters depth with detailed core recovery analysis. Drill holes were strategically planned based on structural interpretation and surface geological mapping.

5.1 Borehole Core Logging

Detailed core logging was performed with emphasis on lithological characteristics, structural features, mineralization styles, and alteration patterns. Core recovery was meticulously recorded, with manganese and graphite bearing zones logged for structural control, ore textures, and mineralogical compositions.

5.3 Sampling Methodology

Sampling included core samples, trench samples, and surface grab samples. Core samples were collected on a 1-meter basis, composited as per ore zone delineation. Strict chain-of-custody protocols were maintained with labeled sampling, sealed transportation, and documented dispatch to accredited laboratories.

6.0 Geochemical Analysis and QA/QC Procedures

MECL's Nagpur laboratory and JNARDDC performed the chemical analyses for manganese and graphite samples. Analytical parameters included Mn, MnO2, Fe2O3, P2O5, SiO2, acid insolubles for manganese, and moisture, ash, volatile matter (VM), fixed carbon (FC), total sulphur for graphite. Internal QA/QC involved 5% check samples while external checks constituted 10%, with all data validated statistically ensuring reliability.

6.1 Mineralization

The Mn ore mineralization is characterised by a rugged bouldery outcrop pattern. In general, oxide ore minerals such as pyrolusite and psilomelane show granoblastic to granulitic fabric. Gravity filling, stalactitic, botryoidal, box works and colloform structures are commonly observed within the ore. The ore is, in general, steel grey to dull grey in colour and is soft and powdery in nature. Pyrolusite, psilomelane and cryptomelane show replacing texture of one to the other.

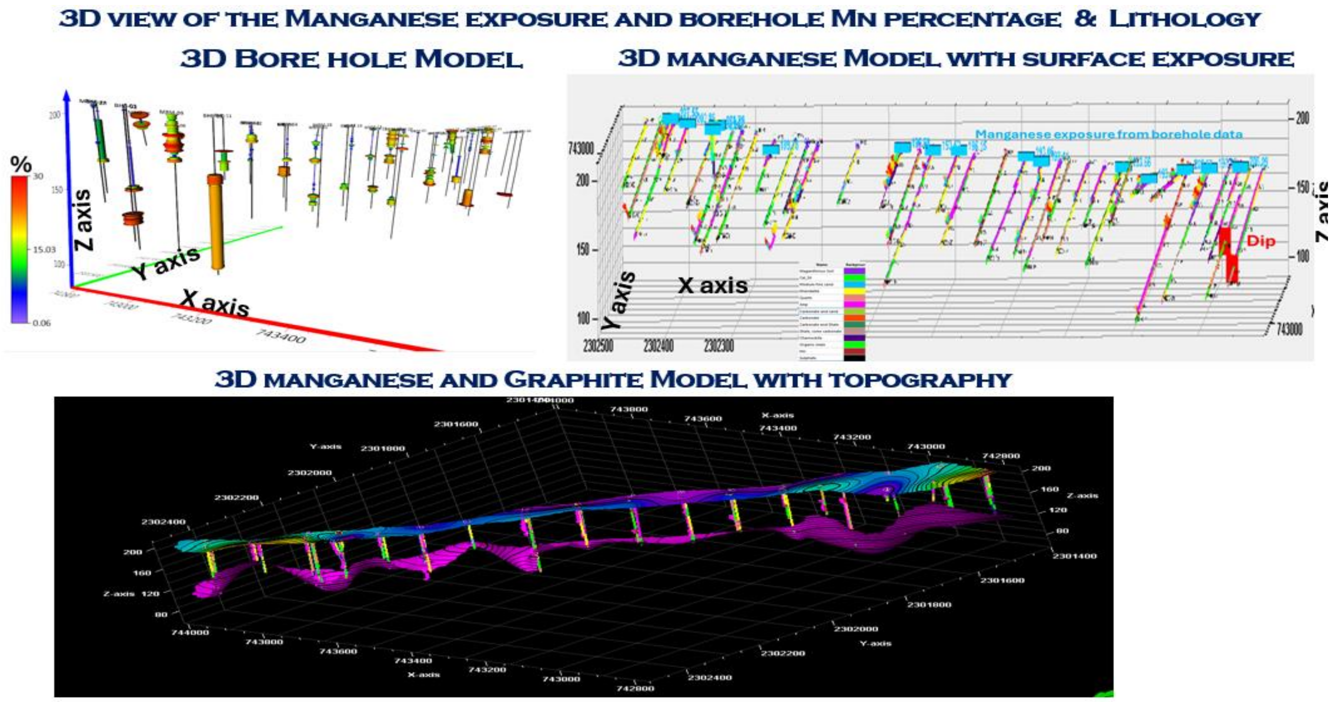


Figure 3. 3D borehole model, Manganese and Graphite model with Topography.

Manganese ore bodies occur as bands, lenses, pockets, veins, tabular bodies and disseminations within the khondalite group of rocks. The lensoidal/discontinuous ore bodies are arranged in an en-echelon pattern. These are lateritic and have been weathered to a considerable depth along with the enclosing rocks. The ore bodies are conformably interstratified with and enclosed in different stratigraphic levels with calc-granulite / calc-silicate at its contact with khondalite. Intense brecciation, shearing, fracture form the important loci for mineralisation. The lensoidal discontinuous ores owe their origin to the flowage or drag folds. The 3D view of the manganese and graphite, Mn % and lithology is illustrated in Figure 3.

7.0 Manganese Mineralisation

7.1 Mineralogical and Petrographic Features

Mineragraphic studies reveal a dominance of goethite (34%) and psilomelane (27%) in the manganese ore zones, accompanied by pyrite-pyrrhotite-chalcopyrite (18%), graphite (12%), haematite (5%), hollandite (2%), and limonite (2%). Cobaltite appears as an accessory mineral. Graphite is noted for its flaky, prismatic grains within the manganese matrix, while manganese oxides exhibit colloform and botryoidal textures. These observations affirm the polyphase nature of mineralization.

7.2 Borehole correlation

Manganese mineralization in Biarpalli is structurally and lithologically controlled, occurring as conformable lenses, veins, and disseminations within the khondalite suite as shown in Figure 4a to 4d. The ores exhibit significant supergene enrichment features due to weathering processes. Primary ore minerals include psilomelane, pyrolusite, hollandite, bixbyite, hausmannite, braunite, rhodonite, and rhodochrosite. The ore bodies are lateritised and show variable textural features such as stalactitic forms and granulitic fabric. The manganese bodies are not continuous occurring in alternating boreholes only in few places it is occurring in adjacent boreholes in strike direction. In dip direction it is having good correlation with adjacent boreholes depending upon the dip of the ore deposit.

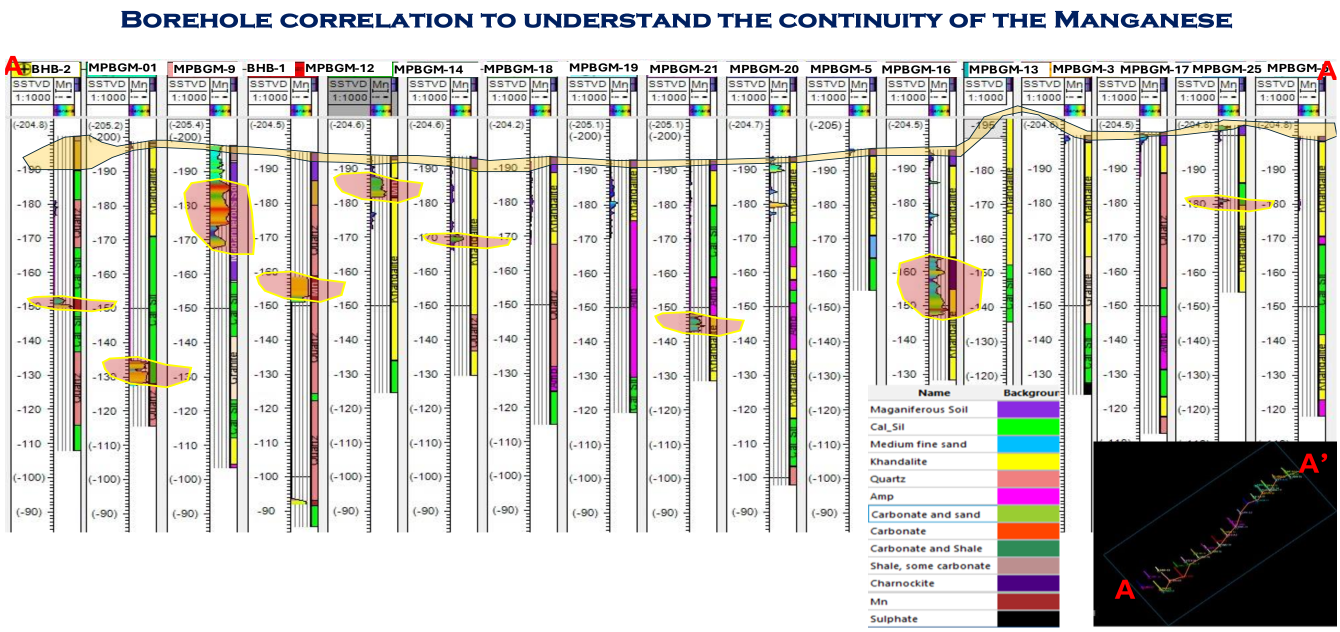


Figure 4. a

Borehole correlation to understand the continuity of the Manganese

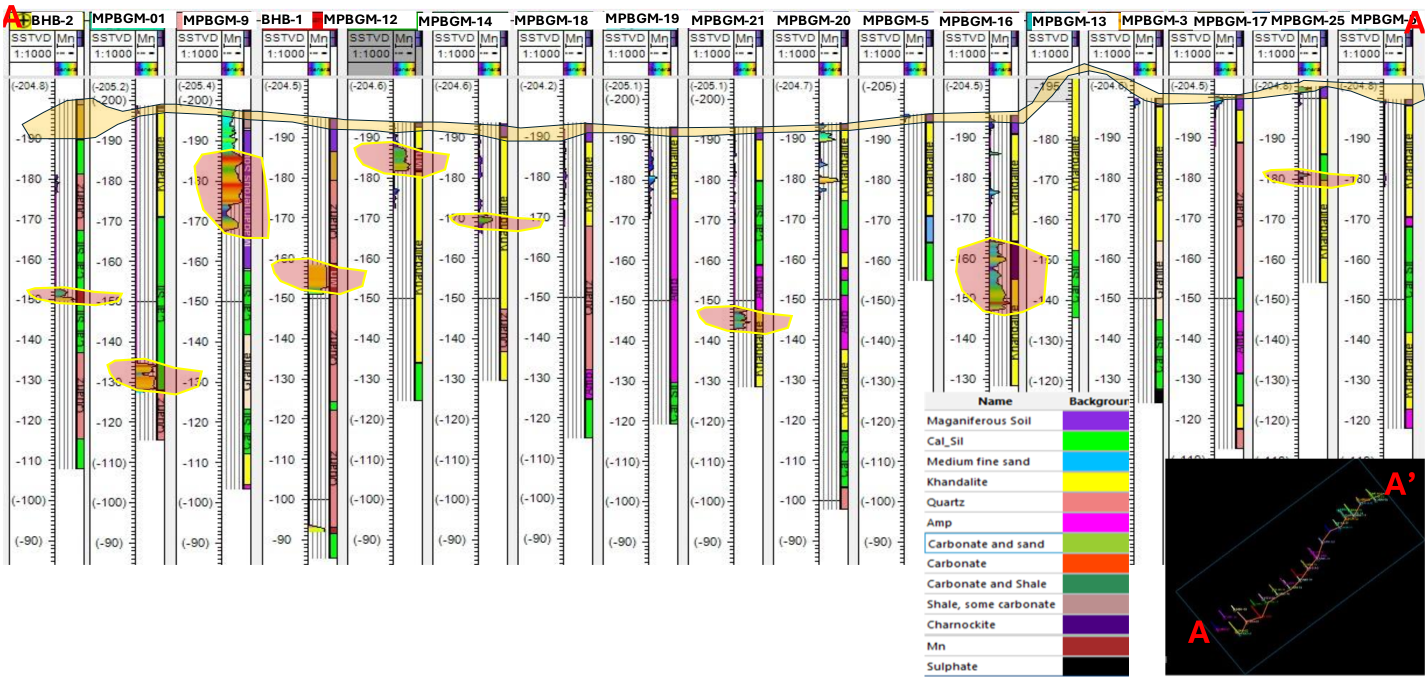


Figure 4. b

3D Borehole correlation to understand the continuity of the Manganese

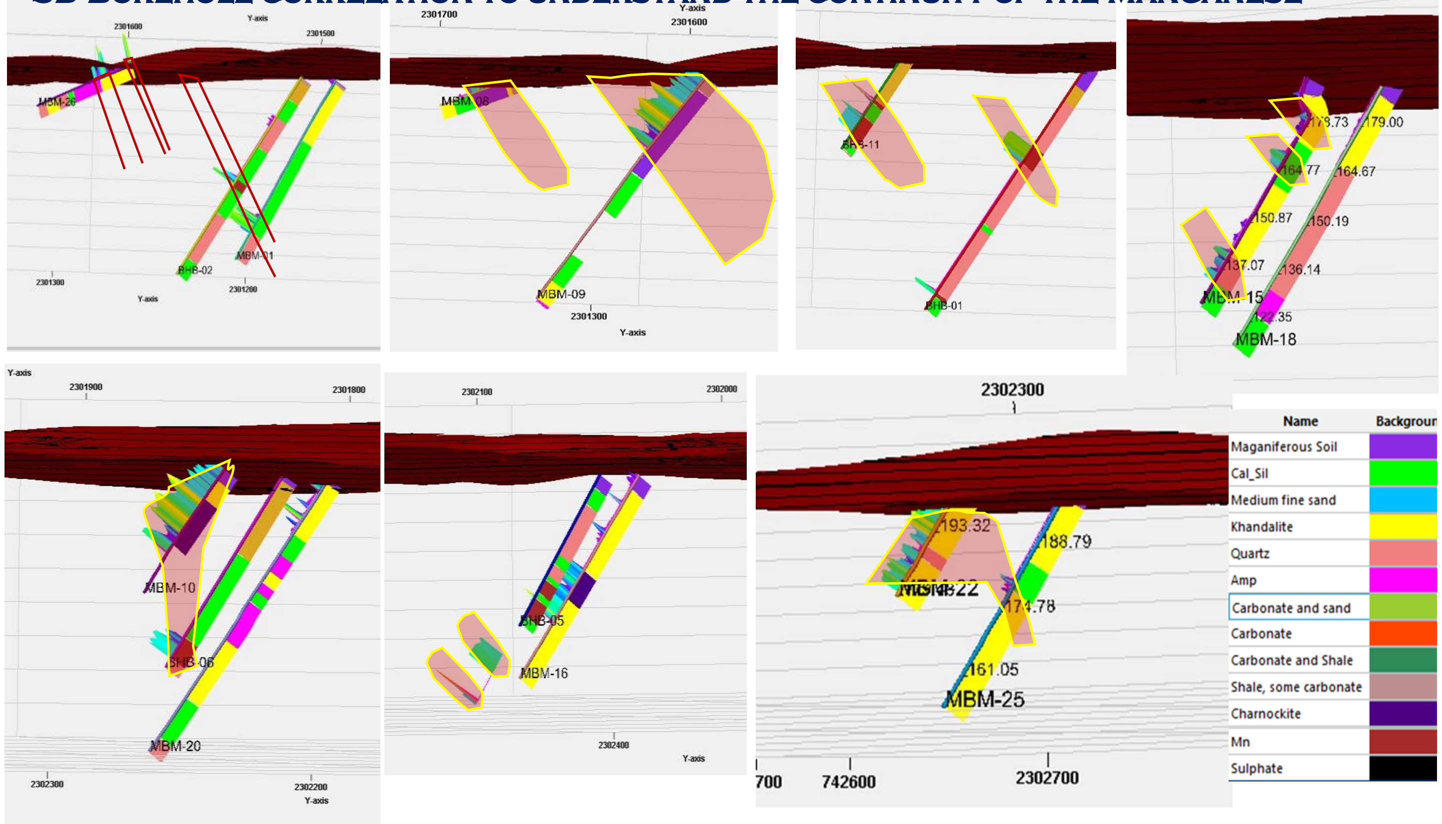


Figure 4. c

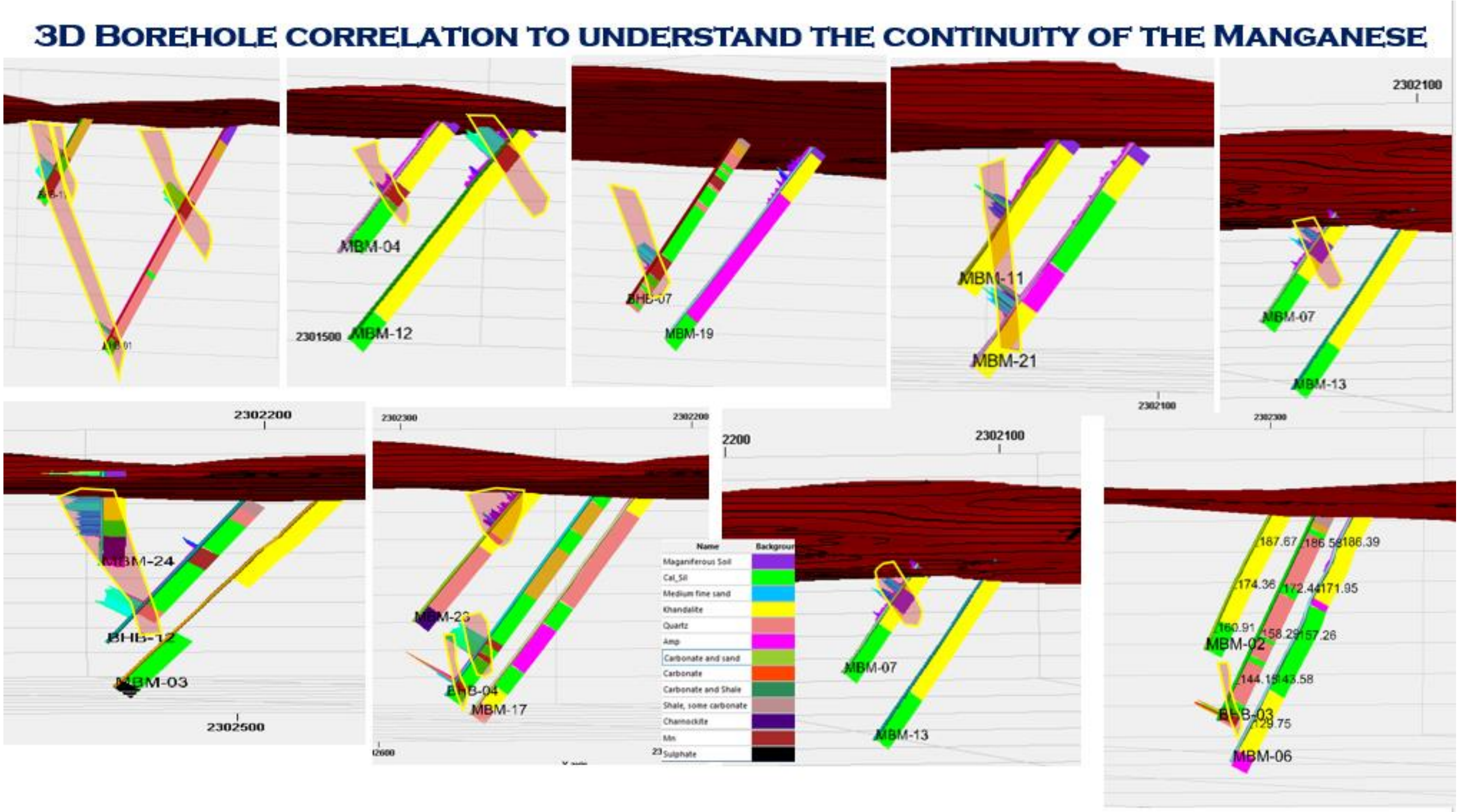


Figure 4. d

The depositional architecture of manganese ore is illustrating that it is not continuous shown in figure 5.

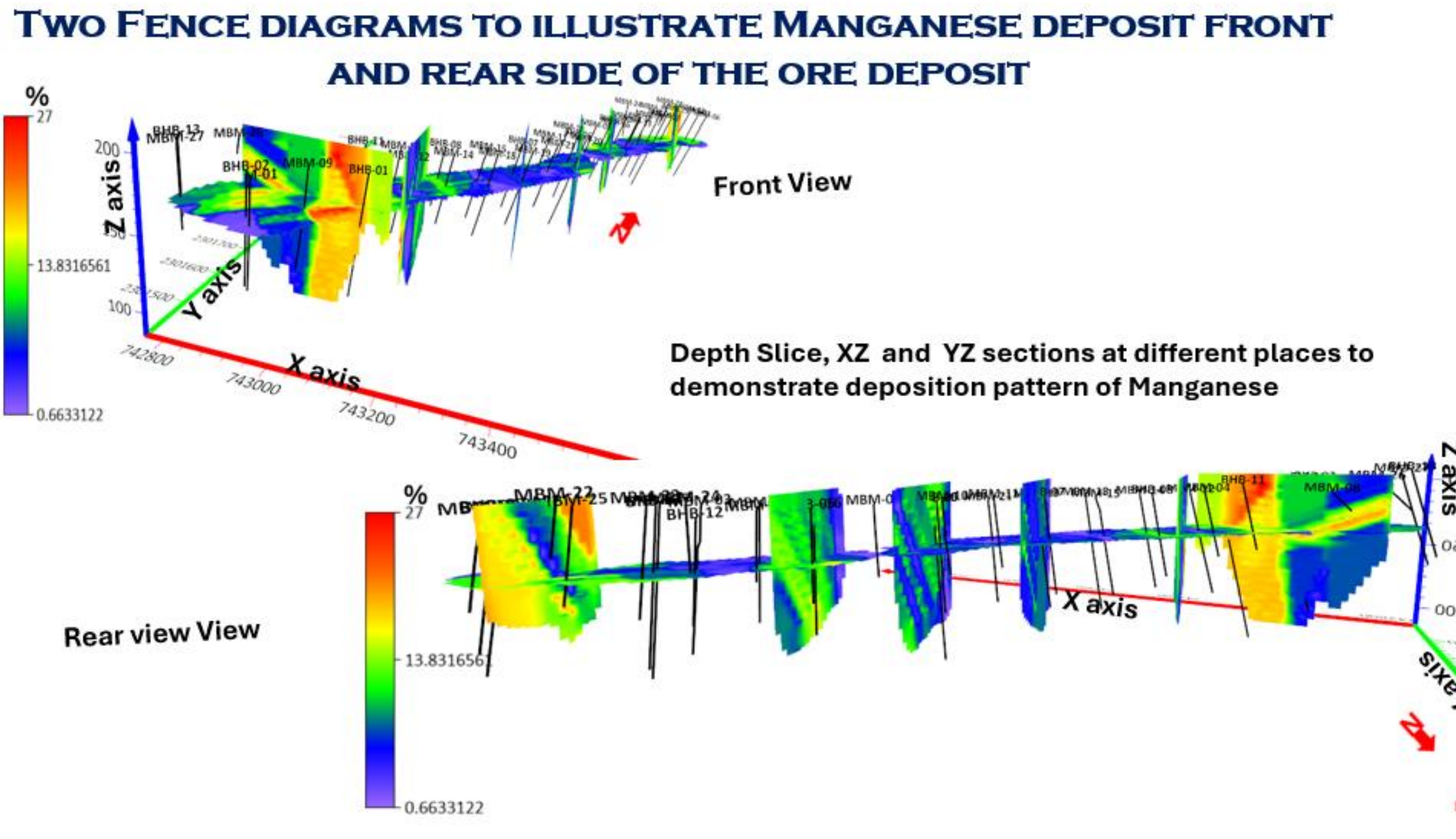


Figure 5. Depositional pattern and architecture of manganese ore.

The depositional pattern and architecture of manganese ore are illustrating trends in NNW-SSE to NE-SW direction with moderate to steep easterly to south-easterly dip.

7.2 Assessment of Manganese deposit.

Using collar, survey, and assay data, a robust 3D geological model, borehole model, solid model and ore model ware created for manganese zones with a 10 % cutoff grade with 2.87 gram/cc specific gravity using artificial intelligence mineAIex software. The model shows spatial discontinuity of manganese bodies, with significant mineralization (Figures 5 and 6). The general trend of the deposit Is NNW-SSE to NE-SW direction and dip of the deposit is 60 to 80 degree towards south east direction. In central region mineralisation is poor, however in the wester and eastern region shows good concertation of deposits, which is indicating mining areas.

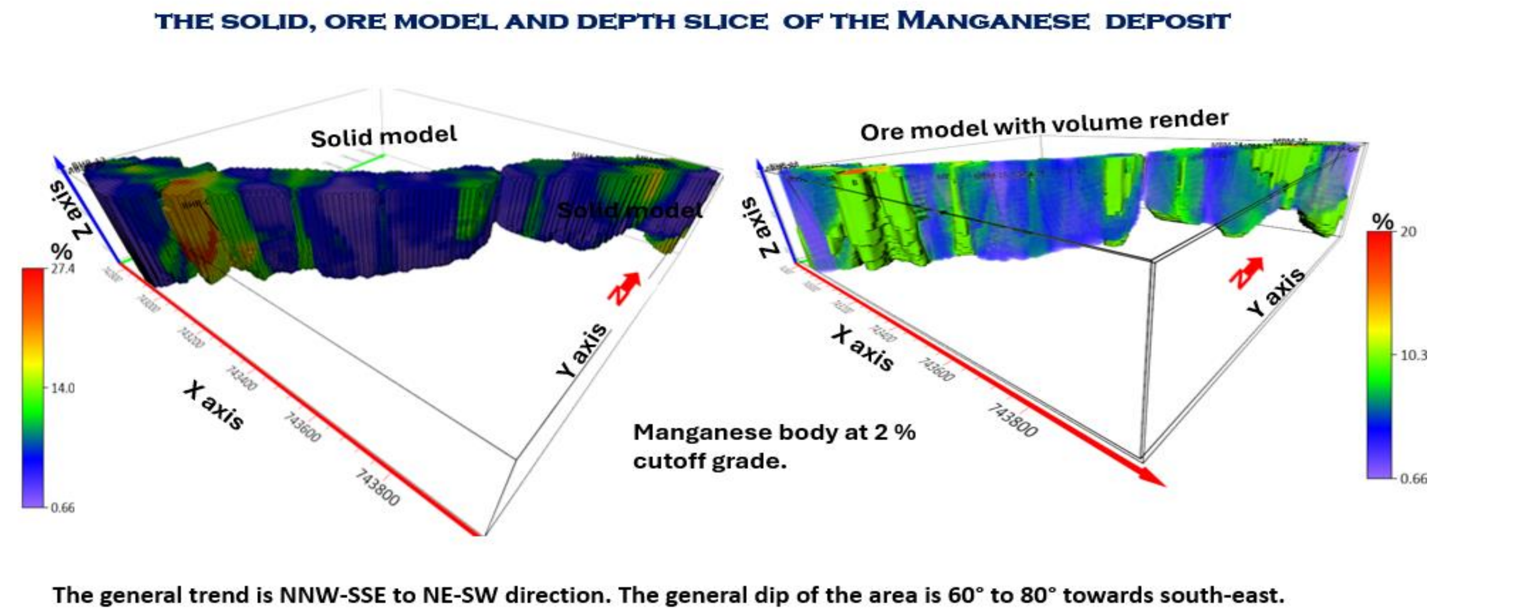
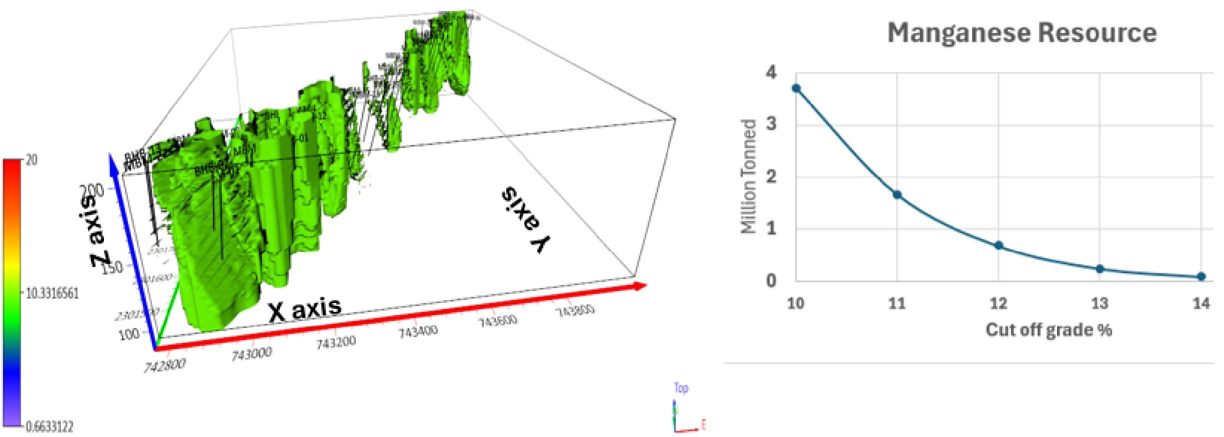


Figure 6. Solid model and ore model of manganese ore.

An AI-assisted model of manganese mineralization (Figure 7) reveals discontinuous manganese geo-bodies at a 10 % cutoff. Estimated manganese resources is 3.718 million tonnes at 10 % cut off.3D visualization facilitate pinpoint the best resource areas for mine planning other facilities arrangements to increase the profitability significantly without any wastage.

BIARPALLI MANGANESE RESOURCES ESTIMATION



Manganese - Resources	
Cut off grade	Million Tonnes
10	3.718
11	1.672
12	0.682
13	0.242
14	0.088

The Manganese resources is around 3.718 Million Tones at 10% cut off.

MinaAIex software, combined with 3D visualization, enables carry out resource estimation precisely for effective mine planning.

MECL resource estimation.

At a 10 % cut-off, the total cumulative resource is estimated at 3.358 million tones and Mn metal content is around 0.625792 @ 18.63 % Mn (cross section method) strike length is 3263 m and thickness ranges from 1.00 to 41.34 m.

Figure 7. Resource estimation of Mn ore at different cutoff grade

MECL estimated 3.358 Million Tonnes manganese resources at a 10% cut off and metal content is around 0.625792 @18.63% Mn using cross section method.

8.0 Graphite Mineralization

Graphite mineralization is primarily hosted within the khondalite rocks, characterized by flaky, disseminated graphite often showing kink bands. The mineralization is generally concealed beneath the surface and identified through core drilling. Graphite occurs both within and outside the manganese mineralization zones, adding complexity to the resource assessment.

8.1 Borehole correlation

The graphite bodies are discontinuous, appearing in alternating boreholes, and only occasionally found in adjacent boreholes along the strike direction. However, in the dip direction, they show good correlation between adjacent boreholes, depending on the dip of the ore deposit as shown in figure 8.a and figure 8.b.

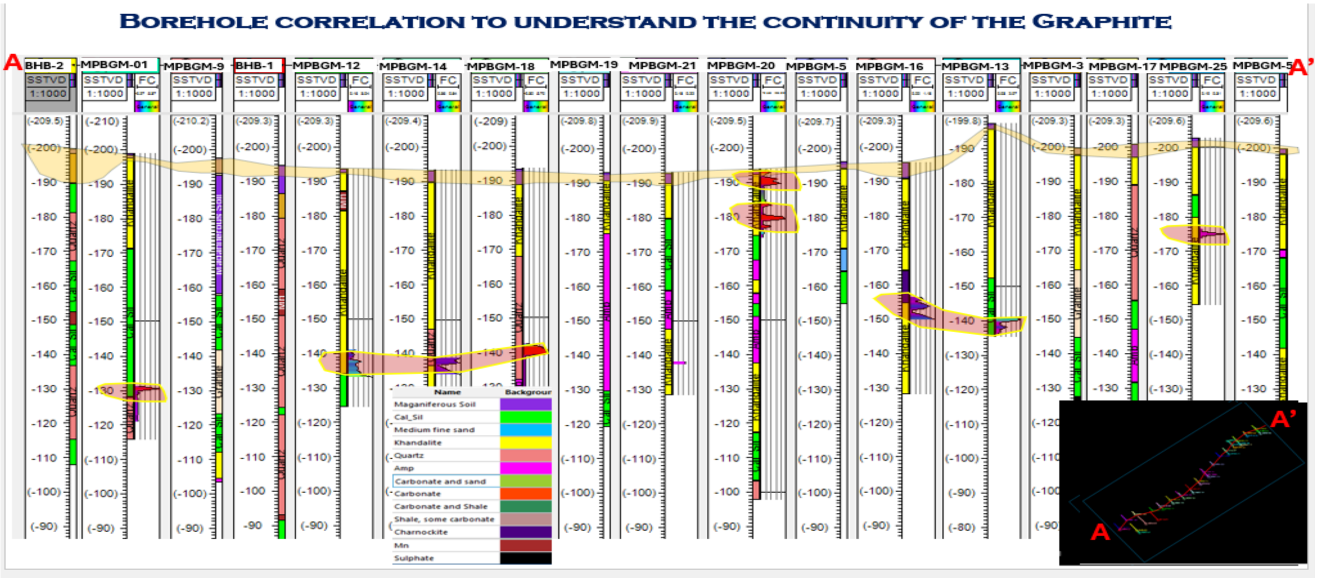


Figure 8. a

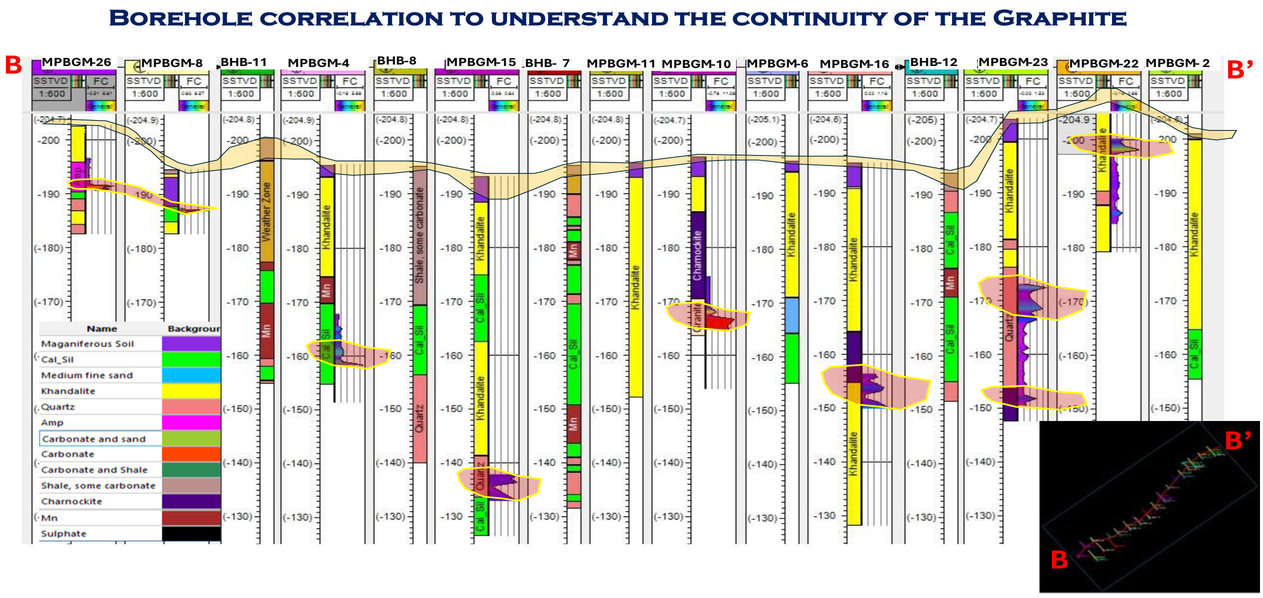


Figure 8. b

8.2 Assessment of Graphite deposit.

Using collar, survey, and assay data, a robust 3D geological model, borehole model, block model and ore model was created for graphite zones with a 10 % cutoff grade with 2.696 gram/cc specific gravity using artificial intelligence mineAlex software. The model shows spatial discontinuity of manganese bodies, with significant mineralization (Figures 9). The general trend of the deposit Is NNW-SSE to NE-SW direction and deep of the deposit is 60 to 80 degree towards south east direction.

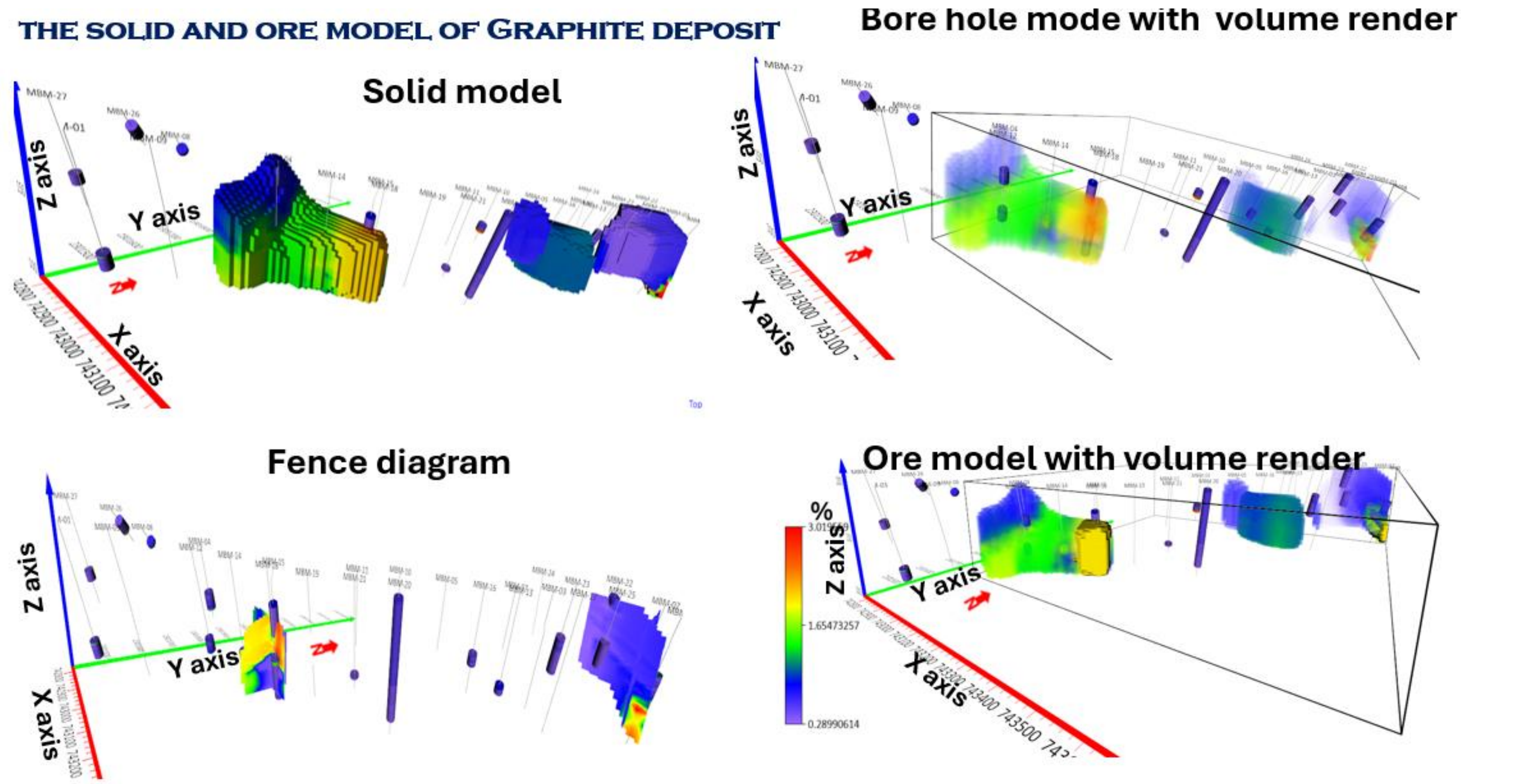
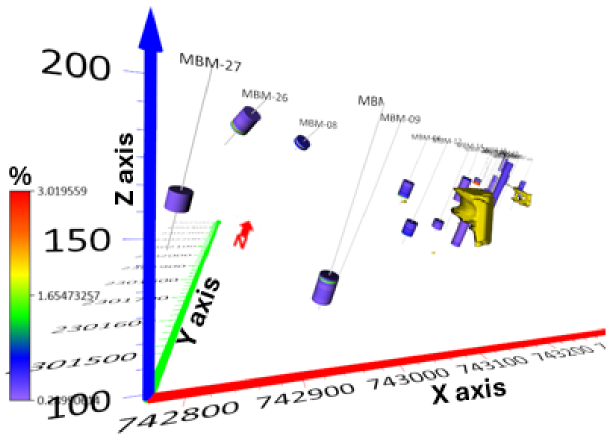
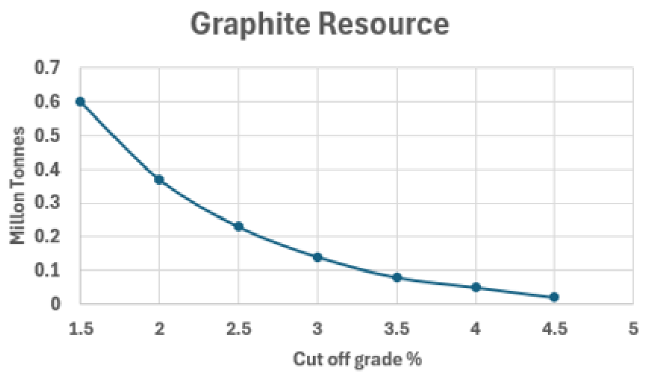


Figure 9. Solid model, ore model and fence diagram of Graphite deposit.

BIARPALLI GRAPHITE RESOURCES ESTIMATION





Graphite Resource	
cutoff %	Total Tonnage
1.5	0.6
2	0.37
2.5	0.23
3	0.14
3.5	0.08
4	0.05
4.5	0.02

The Graphite resource is around 370000 tonnes at 2 % cut off grade.

MinaAlex software, combined with 3D visualization, enables carry out resource estimation precisely for effective mine planning.

MECL Resource estimation

At a 2 % cut-off, the total cumulative resource of graphite is estimated around 301112 Millon tonnes.

Figure 10. Resource estimation of Graphite at different cutoff grade.

An AI-assisted model of Graphite mineralization (Figure 10) reveals four discontinuous manganese geo-bodies at a 2 % cutoff. Estimated resources is around 370000 tonnes. 3D visualization facilitate pinpoint the best resource areas for mine planning other facilities arrangements to increase the profitability significantly without any wastage.

MECL estimated 301112 Tonnes graphite resources at a 2 % cut off. 3D visualization facilitate pinpoint the best resource areas for mine planning other facilities arrangements to increase the profitability significantly without any wastage.

9. Acknowledgement

We gratefully acknowledge the invaluable support and encouragement for innovation extended by the Ministry of Mines, Government of India, in enabling access to critical geological and mineral resource data.

We extend our sincere gratitude to JNARDDC for the opportunity and to the expert committee of 25 members—comprising specialists from IBM, GSI, CSIR-NGRI, HZL, NALCO, three IITs, and other esteemed institutions—for their rigorous, year-long verification and validation under the S&T PRISM-2 program. We are deeply grateful for our selection under the S&T PRISM-2 program and for the invaluable opportunity to present and validate the mineral estimation results generated by our AI-powered software solution, *MineAIex*, before a distinguished panel of technical experts and stakeholders appointed by the Ministry.

This collaborative engagement has played a crucial role in testing and enhancing the robustness, accuracy, and compliance of *MineAIex* with the evolving standards of mineral resource reporting in India and abroad. We look forward to continued collaboration in advancing innovation in the field of mineral exploration and estimation.

Evaluation Geological Exploration Data and Report on General Exploration(G-2)

(Using Artificial Intelligence (mineAIex Software)under S & T PRISM-2 program)

For Golighat Graphite Block,

Betul District, Madhya Pradesh

Prepared by: OGPEX Geoscience & AI Solutions

Date: August 2025

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CONTENTS

अध्याय 1

सारांश

एफएसपी आइटम आईडी M2ASMIF-MEP/NC/CR/SU-MP-BHO/2018/21176 के अंतर्गत, भारतीय भूवैज्ञानिक सर्वेक्षण (मध्य क्षेत्र, भोपाल) ने मध्य प्रदेश के बैतूल जिले के गोलिघाट, माकड़ा और जुनवानी क्षेत्रों में ग्रेफाइट के G-3 चरण के अन्वेषण की शुरुआत की (एफएस: 2018–19; टोपोशीट: 55G/09)। बाद में, इस अन्वेषण को एफएस: 2019–20 में गोलिघाट ब्लॉक में निर्बाध रूप से G-2 चरण में उन्नत किया गया (आइटम आईडी: M2ASMIF-MEP/NC/CR/SU-MP-BHO/2019/27911)।

G-3 चरण के अंतर्गत, 0.8288 वर्ग किमी क्षेत्र में 1:2,000 स्केल पर विस्तृत मैपिंग और 200 मीटर की दूरी पर 16 बोरहोल में कुल 1,353.70 मीटर ड्रिलिंग की गई। इसके साथ ही गड्ढाकरण, ट्रेंचिंग, सैंपलिंग, भूभौतिकीय और पेट्रोकेमिकल अध्ययन भी किए गए। G-2 चरण के दौरान 20 बोरहोल में 100 मीटर दूरी पर 1,735.60 मीटर की इंफिल ड्रिलिंग और ब्लॉक के पूर्वी भाग में तीसरे स्तर के बोरहोल की ड्रिलिंग की गई। अतिरिक्त विश्लेषणों में बेनिफिसिएशन, XRD, बल्क डेंसिटी/स्पेसिफिक ग्रैविटी, और रमन स्पेक्ट्रोस्कोपी शामिल हैं।

मैपिंग से पता चला कि क्षेत्र मुख्यतः मृदा से ढका हुआ है, जिसमें पोरफाइरोब्लास्टिक ग्रेनाइट ग्नीस, फोलिएटेड और मैसिव ग्रेनाइट, और विविध मेटासेडिमेंट्स जैसे कि क्वार्ट्जो-फेल्ड्सपैथिक-माइका शिस्ट, कैल्केरियस क्वार्ट्जाइट, कैल्क-सिलिकेट रॉक, और ग्रेफाइट माइका

शिस्ट की अलग-अलग चट्टानें हैं। इन चट्टानों में कम से कम तीन विरूपण चरणों के साक्ष्य मिले, जिनकी प्रमुख फोलिएशन दिशा N55°E–S55°W से N85°E–S85°W तक है और झुकाव 48°–65° उत्तर-पश्चिम की ओर है। ब्रेक्सिएशन और घुमाए गए क्लास्ट्स जैसी शीयरिंग विशेषताएं देखी गईं।

गोलिघाट ब्लॉक के पूर्वी भाग में दो ग्रेफाइट माइका शिस्ट बैंड पाए गए जो लगभग 40 मीटर ग्रेनाइट/ग्नीस से अलग हैं। बैंड-I (उत्तरी) पतला और असतत है, जबकि बैंड-II (दक्षिणी) मुख्य अयस्क क्षेत्र है, जिसकी मोटाई 1–9 मीटर और स्ट्राइक लंबाई 1,400 मीटर है।

ड्रिलिंग से ग्रेफाइट बैंड्स के ब्रांचिंग और ब्रेडेड संरचनाएं सामने आईं, जो कि मेटासेडिमेंट्स में ग्रेनाइट/ग्नीस के समांतर अंतःप्रवेश से बनी हैं। भूभौतिकीय सर्वेक्षणों (IP, SP, रेसिस्टिविटी, मैग्नेटिक) से 10–21 mV/V की चार्जेबिलिटी पाई गई, जो N75°E–S75°W से N85°E–S85°W की दिशा में फैली हुई है और माकड़ा ब्लॉक की ओर बढ़ती है।

कुल 3,089.30 मीटर ड्रिलिंग 36 बोरहोल (19 पहले स्तर, 15 दूसरे स्तर, 2 तीसरे स्तर) में की गई। सतह और उप-सतह डेटा के आधार पर चार खनिजीकृत ग्रेफाइट ज़ोन (I–IV) की पहचान की गई। ज़ोन I, III, और IV पतले और लेंस जैसे हैं, जबकि ज़ोन II प्रमुख ग्रेफाइट युक्त बैंड है, जो लगभग सभी बोरहोल (MPBGM-04 और 40 को छोड़कर) में पाया गया। ज़ोन II दो लेंस में विभाजित है: पूर्वी (555.41 मीटर स्ट्राइक) और पश्चिमी (959.30 मीटर), कुल मिलाकर 1,514.71 मीटर। मोटाई 0.43 से 17.38 मीटर के बीच है, जिसमें पिंच-एंड-स्वेल संरचनाएं देखी गईं।

ग्रेफाइट खनिजीकरण क्वार्ट्जो-फेल्ड्सपैथिक-माइका शिस्ट (±गार्नेट, क्लोराइट, ट्रेमोलाइट/एक्टिनोलाइट) में निहित है, जो अक्सर ग्रेनाइट/ग्नीस से जुड़े होते हैं। ग्रेफाइट छोटे, परतदार, चिकने, स्टील-ग्रे प्लेटी खनिजों के रूप में फोलिएशन सतहों पर पाया गया है, जिसका उत्पत्ति काल संजन्य है, जो कि ग्रीनशिस्ट से एंफीबोलाइट फेसिज़ तक के अंतर्गत आता है, और यह फ्लेक-प्रकार ग्रेफाइट के रूप में वर्गीकृत है। पेट्रोग्राफी और रमन स्पेक्ट्रोस्कोपी ने उच्च क्रिस्टलीकृत फ्लेक ग्रेफाइट की पुष्टि की।

संपूर्ण ड्रिलिंग स्तरों से लिए गए कोर नमूनों के समेकित मिश्रित नमूने पर बेनिफिसिएशन परीक्षण में पाया गया: 6.25% FC, 4.76% VM, 0.49% नमी, और 88.5% राख। प्रमुख खनिजों में क्वार्ट्ज, फेल्ड्सपार, ग्रेफाइट, माइका और अल्प मात्रा में कार्बोनेट और सल्फाइड्स हैं। वैनाडियम मुख्यतः बायोटाइट (75%) और मस्कोवाइट (25%) में उपस्थित है, जिसमें V_2O_3 की मात्रा 0.01–2.73% तक है। REEs और Cu-Pb-Zn सल्फाइड्स ट्रेस मात्रा में पाए गए।

प्रसंस्करण में मैग्नेटिक सेपरेशन, फ्रोथ फ्लोटेशन, ग्रैविटी सेपरेशन, और फाल्कन कंसंट्रेशन शामिल थे। ग्रेफाइट कंसंट्रेट (4th क्लीनर) में 62.12% FC और 59.0% रिकवरी प्राप्त हुई। समेकित कंसंट्रेट में 57.93% FC और 76.4% रिकवरी पाई गई। वैनाडियम कंसंट्रेट (मैग्नेटिक भाग) में 0.39% V_2O_5 और 17.7% रिकवरी प्राप्त हुई। फाल्कन हेवीज़ में 0.15% V_2O_5 (21.6% रिकवरी) और WHIMS द्वारा ट्रीटेड रूफर टेल्स से अतिरिक्त वैनाडियम प्राप्त हुआ। अंतिम समेकित वैनाडियम उत्पाद में 0.22% V_2O_5, 55.9% रिकवरी, और 33.3% वज़न उपज प्राप्त हुई।

एक प्रक्रिया पथ विकसित किया गया जिससे ग्रेफाइट को उन्नत किया गया और वैनाडियम को सह-उत्पाद के रूप में एकत्रित किया गया। हाइड्रोमेटलर्जी के माध्यम से वैनाडियम की रिकवरी की संभावना है। REE खनिजों की उपस्थिति से सह-उत्पाद पुनर्प्राप्ति की संभावनाएं भी दर्शाई गई हैं।

यह रिपोर्ट बैतूल जिले के गोलिघाट ग्रेफाइट ब्लॉक में G2 स्तर के अन्वेषण की निष्कर्ष प्रस्तुत करती है। इसमें भूवैज्ञानिक, भू-रासायनिक, भूभौतिकीय, और ड्रिलिंग डेटा सम्मिलित है, जो ग्रेफाइट खनिजीकरण की पुष्टि करता है। UNFC श्रेणी 332 के अंतर्गत 2% कटऑफ पर 4.28 मिलियन टन संसाधन का अनुमान लगाया गया है, जिसमें 8.46% तक स्थिर कार्बन और 88–90% FC कंसंट्रेट रिकवरी की संभावना है। वैनाडियम को भी सह-तत्व के रूप में देखा गया है। इसके लिए 560 ppm कटऑफ पर 3 मिलियन टन संसाधन का आकलन किया गया है।

1.2 English Summary

In accordance with FSP Item ID M2ASMIF-MEP/NC/CR/SU-MP-BHO/2018/21176, the Geological Survey of India (Central Region, Bhopal) initiated a G-3 stage graphite exploration in the Golighat, Makra, and Junawani areas of Betul District, Madhya Pradesh (FS: 2018–19; Toposheet 55G/09). The exploration was later seamlessly upgraded to G-2 stage in the Golighat block during FS: 2019–20 under Item ID M2ASMIF-MEP/NC/CR/SU-MP-BHO/2019/27911. Under the G-3 stage, detailed mapping over 0.8288 sq.km (1:2,000 scale) and 1,353.70 m of drilling across 16 boreholes at 200 m spacing were completed, along with pitting, trenching, sampling, geophysical, and petrochemical studies. The G-2 stage involved 1,735.60 m of infill drilling across 20 boreholes at 100 m spacing and a third-level borehole in the eastern part of the block. Additional analyses included beneficiation, XRD, bulk density/specific gravity, and Raman spectroscopy.

Mapping revealed mostly soil-covered terrain with isolated outcrops of porphyroblastic granite gneiss, foliated and massive granite, and various metasediments, including quartzofeldspathic-mica schist, calcareous quartzite, calc-silicate rock, and graphite mica schist. These rocks, often enclosed in granite, show evidence of at least three deformation phases, with dominant foliation trending N55°E–S55°W to N85°E–S85°W and dipping 48°–65° NW. Shearing features such as brecciation and rotated clasts are observed. Two graphite mica schist bands were identified in the eastern Golighat block, separated by ~40 m of granite/gneiss. Band-I (northern) is thin and discontinuous; Band-II (southern) is the main ore zone, with 1–9 m thickness and a 1,400 m strike length.

Graphite exploration in the Golighat block revealed branching and braided graphite bands, resulting from concordant granite/granite gneiss intrusions into metasediments. Geophysical surveys (IP, SP, resistivity, magnetic) identified a moderate chargeability zone (10–21 mV/V) trending N75°E–S75°W to N85°E–S85°W, aligning with graphite mica schist bands and extending westward into the Makra block. A total of 3,089.30 m of drilling was completed in 36 boreholes (19 first-level, 15 second-level, 2 third-level) across a 1,400 m strike length. Based on surface and subsurface data, four mineralized graphite zones (I–IV) were identified. Zones I, III, and IV are thin and lens-like, while Zone II is the main graphite-bearing band, occurring in nearly all boreholes except MPBGM-04 and 40. Zone II is split into two lenses: one in the east (555.41 m strike) and one in the west (959.30 m), totalling 1,514.71 m. Thickness varies from 0.43 to 17.38 m and shows pinch-and-swell structures.

Graphite mineralization is hosted in quartzofeldspathic-mica schist (±garnet, chlorite, tremolite/actinolite), often associated with granite/gneiss. Graphite appears as small, flaky, greasy, steel-grey platy minerals along foliation planes, with a syngenetic origin under upper greenschist to amphibolite facies, and is classified as flake-type graphite. Petrography and Raman spectroscopy confirm well-crystallized flake graphite. Beneficiation tests on a composite subsurface sample (split core from all drilling levels) showed 6.25% FC, 4.76% VM, 0.49% moisture, and 88.5% ash. Major minerals include quartz, feldspar, graphite, mica, and minor carbonates and sulphides. Vanadium is primarily hosted in biotite (75%) and muscovite (25%), with V_2O_3 ranging from 0.01–2.73%. REEs and Cu-Pb-Zn sulphides were present in trace amounts.

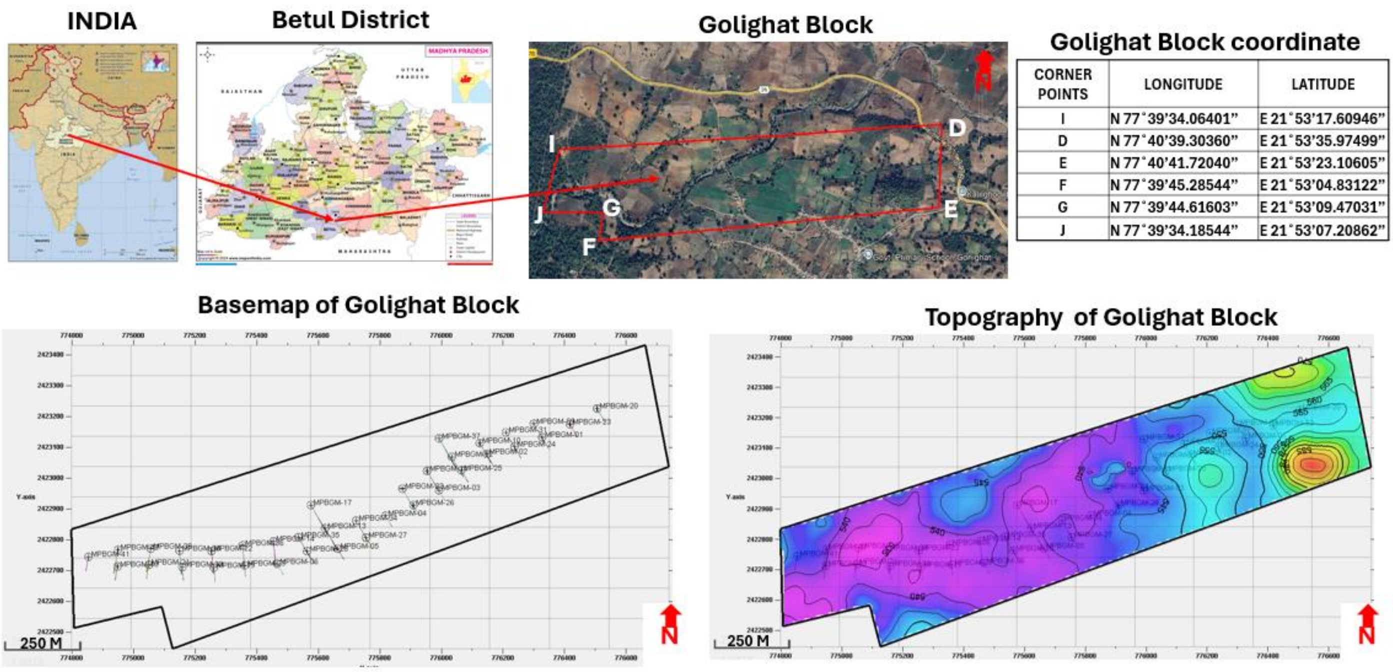
Processing included magnetic separation, froth flotation, gravity separation, and Falcon concentration. Graphite concentrate (4th cleaner) achieved 62.12% FC with 59.0% recovery. Composite concentrate had 57.93% FC and 76.4% recovery. Vanadium concentrate (magnetic fraction) yielded 0.39% V_2O_5 with 17.7% recovery. Falcon heavies contained 0.15% V_2O_5 (21.6% recovery); WHIMS-treated rougher tails yielded additional V_2O_5. The final composite vanadium product achieved 0.22% V_2O_5 with 55.9% recovery and 33.3% weight yield. A process route was developed for upgrading graphite and pre-concentrating vanadium as a co-product, with potential for vanadium recovery via hydrometallurgy. Presence of REE minerals suggests scope for by-product recovery.

This report presents the findings of G2 level exploration conducted at the Golighat graphite block in Betul district, Madhya Pradesh. It includes geological, geochemical, geophysical, and drilling data that confirm the presence of substantial graphite mineralization. Resources have been estimated at 4.28 million tonnes at 2 % cut off under UNFC category 332, with fixed carbon content up to 8.46% and beneficiation results showing 88–90% FC concentrate recovery. Vanadium is also observed as an associated element. Resources have been estimated at 3 million tonnes at 560 ppm cut off under UNFC category 332.

2. Introduction

The present report documents a comprehensive investigation into the geology, geophysics, geochemistry, resource potential, and economic viability of graphite and vanadium mineralization in the Golighat block, situated in the Betul district of Madhya Pradesh, India. The study area lies within the western part of the Betul Belt, a tectonically significant terrain composed of Precambrian crystalline and metamorphic rocks, interspersed with Gondwana sediments and Deccan Traps. The Betul Belt, known for its mineral potential, has been subjected to a series of geological, geochemical, and geophysical surveys, culminating in a G-2 level (General Exploration) investigation as per the United Nations Framework Classification (UNFC) system. The area falls under Survey of India Toposheet 55G/09, and the mapped region measures approximately 0.8288 sq.km, with coordinates ranging from 77°39′34″E to 77°40′39″E longitude and 21°53′17″N to 21°53′35″N latitude.

The investigation integrates data from using mineAIex software:
- Detailed study of Geological Mapping data
- Drilling and Borehole Analysis
- Geophysical Surveys (IP, SP, Magnetic, and Resistivity)
- Petrographic, SEM-EDX, and XRF-based Geochemical Studies
- Ore Beneficiation Tests, and
- Water and Soil Quality Assessments



CORNER POINTS	LONGITUDE	LATITUDE
I	N 77˚39’34.06401”	E 21˚53’17.60946”
D	N 77˚40’39.30360”	E 21˚53’35.97499”
E	N 77˚40’41.72040”	E 21˚53’23.10605”
F	N 77˚39’45.28544”	E 21˚53’04.83122”
G	N 77˚39’44.61603”	E 21˚53’09.47031”
J	N 77˚39’34.18544”	E 21˚53’07.20862”

Figure 1. Base map and drilled bore hole (42 boreholes) along with topography map.

The objective of the report is not only to summarize the findings of intensive field and laboratory work but also to serve as a scientific and economic basis for mineral resource management, industrial exploitation, and further research. It is also to ensure compliance with the reporting standards necessary for UNFC categorization, specifically targeting category 332 (Inferred Mineral Resources). The offered block is about 82.00 Ha. Forty two boreholes have been drilled within the block area of the block as shown in figure 1. The block comprises of rugged and undulated terrain with lithologically and structurally controlled small hillocks, mounds and valleys trending in ENE-WSW to NE-SW direction with elevation varying from 535 m to

590 m above MSL. as shown in figure 1 . Mineral exploration in this area has been successfully completed G4, G3 and G2 stages.

2.1 General information about the Block.

1	**FEATURES**	
	Licence Type	Composite Licence
	Mineral	Graphite and Vanadium
	Area	82.00 Ha
	Exploration Level	G2 (General exploration)
	Exploration Agency	Geological Survey of India, Central Region, State Unit: Madhya Pradesh, Bhopal
	Morphology of the area	The area in Golighat-Makra main block mostly represented by rugged and undulated terrain with lithologically and structurally controlled small hillocks, mounds and valleys trending in ENE-WSW to NE-SW direction as shown in figure 1.
2	**RESOURCE SUMMARY**	
	Resource (MT) & Grade	The total resources (332) estimated for graphite bearing mineralized/ore zones in Golighat block is 4.28 million tonnes with 2% FC cutoff grade. The total resource (332) estimated for vanadium bearing mineralized/ore zones in Golighat block is 3 million tonnes at 560 ppm cut-off grade.
3	**LOCATION DETAILS**	
	Location	Village-Golighat, Taluk/tehsil-Betul, District-Betul, Madhya Pradesh.
	Toposheet Number	Toposheet No- 55G /09..
	Connectivity	
	Rail	The nearest railway station is Betul Railway Station.
	Road	The Golighat block is located 35 km west of Betul town. The block area is connected with Betul through Betul-Indore (NH56A) road via Khedi Savilgarh.
	Airport	Nagpur Airport
4	**MINERALISATION & EXPLORATION DETAILS**	
	Mineralisation	Four graphite bands have been identified, with bedding strike orientations ranging from N55°E–S55°W to N75°E–S75°W. The dip is moderate to steep (50°–75°) toward the north. The average thickness of the graphite mineralization is approximately 9.90 meters, while the associated vanadium-bearing zone has an average thickness of 10.18 meters
	Pitting / trenching details	• 07 trenches (Trench GLT-I to GLT-VII) • 10 pits (Pits GLP-I to GLP-X)
	Hydrography	The study area in and around is drained by Betul River, which is a tributaries of Tapti River. The drainage is mostly dendritic in nature.
	Climate	Mean annual rainfall is around 1085.2 mm.

2.2 Summary of Golighat Graphite and Vanadium Block:

Area	Golighat, Taluk/tehsil-Betul, District-Betul, Madhya Pradesh, India
Contract Type	Auction type
Acreage	82.00 Ha
Working Interest	100%

Available data along with mineralogy, petrology, and materials science data

Nature of work	**FS: 2018-19**	**Cumulative achievement, FS: 2018-19 & 2019-20**
I. Geological Survey		-
i) Detailed Mapping (1:2,000)	1.2788 sqkm	1.2788 sqkm-
II. Technological Survey		-
a. Surface Exploration		-
i) PT	75 cu m.	75 cu m.
b. Sub surface Exploration	-	-
i) Drilling	1746.30 m	3481.90 m-
III. Geophysical Survey		-
a) GP: Survey (IP, SP, Magnetic, Resistivity)	Survey line: 4.8 L km Magnetic survey: 4.8 L km SP survey: 4.8 L km IP survey: 4.8 L km Resistivity: 4.8 L km GP survey 0.60 sq.km	Survey line: 4.8 L km Magnetic survey: 4.8 L km SP survey: 4.8 L km IP survey: 4.8 L km Resistivity: 4.8 L km GP survey 0.60 sq.km
b) GP Borehole logging	763.35 m	1844.00 m
IV. Sampling		
a) PS	15 nos	15
b) PCS	10 nos	10
c) PTS/ channel samples	19 nos	19
d) Core Samples (including 10% check samples)*	531 nos	1009
e) SEM-EDX ^	5 nos	5
f) Ore microscopy	6 nos	6
g) XRD	5 nos	5
h) Ore beneficiation 1 no.(150-200 kg of samples from all mineralised zones)	1 no. (150-200 kg of sample from all mineral zone)	1
i)Bulk density	5 nos.	5
V. Chemical Analysis *	-	
a) PCS @	10 nos	10

<table>
<tr><td></td><td><table>
<tr><td>b) PTS/channel samples # (Fixed Carbon)</td><td>19 nos</td><td>19</td></tr>
<tr><td>c) Core samples # (Fixed Carbon)</td><td>531 nos</td><td>1009</td></tr>
</table></td></tr>
<tr><td>Block Boundary</td><td>I) 77˚39’34.06401” 21˚53’17.60946”, D) 77˚40’39.30360” 21˚53’35.97499”, E) 77˚ 40’41.72040” 21˚53’23.10605”,F) 77˚39’45.28544” 21˚53’04.83122”, G) 77˚39’ 44.61603” 21˚53’09.47031”, J) 77˚39’34.18544” 21˚53’07.20862</td></tr>
<tr><td>Most-likely Reserve/ Resources</td><td>Resource Estimation of Golighat prospect resource is under categories G2.
<table>
<tr><th>Commodities</th><th>Resource at cutoff grade</th><th>Millon Tonnes</th></tr>
<tr><td>Graphite</td><td>2 %</td><td>4.28</td></tr>
<tr><td>Vanadium</td><td>560 ppm</td><td>3</td></tr>
</table></td></tr>
<tr><td>Milestones</td><td>• Exploration Period of 3 years, Mining and production 50 years.</td></tr>
<tr><td>Actual Work Completed</td><td>Collection & Interpretation of drilled 42 borehole data for different vintages as shown in Figure-1 and successfully completed G4, G3 and G2 stage of exploration.</td></tr>
<tr><td>PARTICULARS OF LAND</td><td>Total Concession Area 82.00 Ha, 1. Forest Land with Status 11.434 Ha, 2. Government Land with Status 20.414 Ha, 3 Private Land with Status 50.152 Ha.</td></tr>
</table>

3. Location and Accessibility

3.1 Geographic Location and Coordinates

The Golighat block lies within the Betul district of Madhya Pradesh, located in the central part of India. It forms part of the western segment of the Betul Belt, a region known for its Precambrian lithologies and favourable conditions for hosting strategic mineral deposits, particularly graphite and vanadium.

The surveyed area extends across latitude N21°53’17.6” to N21°53’35.9” and longitude E77°39’34.1” to E77°40’39.3”, covering a mapped area of approximately 0.8288 square kilometres. This region is prominently featured in the Survey of India Toposheet No. 55G/09, which has been the base for geological mapping, drilling layout planning, and mineral exploration zoning.

The regional terrain exhibits a dendritic drainage pattern, with relatively moderate relief, and falls under a temperate climatic zone. The climate is marked by hot summers, general dryness, and significant rainfall during the monsoon season, which slightly limits fieldwork during peak rain periods.

3.2 Toposheets and Climate

The Toposheet 55G/09, issued by the Survey of India, has served as the foundation for detailed geological and geophysical plotting. The mapped area includes essential geomorphological features, including minor seasonal streams, lateritic patches, and low undulating hills. These features have influenced the layout of boreholes, trenches, and pitting during exploration.

Climatically, the region experiences:
- Hot summers (peak temperature often exceeding 40°C,
- A monsoon season between June and September (with average annual rainfall of ~1100–1200 mm),
- Mild winters, and
- General dryness in the post-monsoon months.

3.3 Access Routes and Infrastructure

The Golighat block is accessible via the National Highway NH-47, situated approximately 185 kilometres from the block area. The block is well-connected by both road and rail networks from major towns such as Betul, Nagpur, and Bhopal. The closest major urban hub, Nagpur, is equipped with a railway junction and an airport, supporting swift transport of field teams, instruments, and core samples.

On-site access is facilitated by rural motorable roads and foot tracks linking the block to nearby settlements, including Junawani and Golighat villages. These logistical corridors have enabled the mobilization of drilling rigs, geophysical equipment, and excavation machinery.

The presence of power supply lines, water sources (including dug wells and stream water), and moderate population density makes the area suitable for long-term mineral development activities and future mining operations, once resources are fully exploited and auctioned.

4. Geological Setting

4.1 Regional Geology of the Betul Belt

The Betul Belt, part of the Central Indian Tectonic Zone (CITZ), is geologically significant due to its diverse lithological assemblages, tectonic complexity, and potential for hosting a wide range of mineral deposits, including graphite and vanadium. It lies within the Precambrian craton and represents a tectonically active region with a complex geological history involving multiple episodes of sedimentation, metamorphism, and deformation.

The belt is primarily composed of:
- Precambrian crystalline and metamorphic rocks,
- Gondwana Supergroup sediments, and
- Overlying Deccan Trap basalts.

Three main litho-assemblages define the geology of the Betul Belt:
1. Temni Formation – Characterized by impure marble and calc-silicate rocks.
2. Sonaghati Formation – A linear ENE–WSW trending lithounit composed of quartzites and phyllites.
3. Ranipur Formation – Contains graphitic schists and associated metasediments.

One of the distinguishing features of the Betul Belt is the presence of volcanic rocks, setting it apart from the nearby Sausar Belt, which is notably free of such volcanism.

Key geological studies and correlations have been carried out by researchers such as Chaturvedi (2001) and Roy et al. (2002), forming the basis for the stratigraphic framework adopted in the present study.

4.2 Local Lithostratigraphy and Tectonics

The Golighat block, the main focus of this report, lies within the western Betul Belt and presents a rich and varied lithology predominantly comprising metamorphic and granitic rocks. The block exposes the following rock types:
- Foliated granite
- Grey and pink granite
- Pegmatoidal granite
- Quartz-mica schist
- Graphite mica schist
- Calc-silicate rocks
- Quartzite

These lithologies occur as interbanded, foliated sequences with varying degrees of deformation and mineralization. Particularly important is the presence of graphite-bearing schist bands, which have been structurally remobilized along foliation planes, creating favorable sites for graphite concentration as shown in figure 2. The lithological units exhibit typical features of high-grade metamorphism and have undergone significant recrystallization. This metamorphic signature is reflected in the development of schistosity, foliation, and gneissosity across large portions of the mapped area. The area is tectonically bounded and dissected by several shear zones and faults, contributing to the remobilization of graphite and associated minerals. The tectono-litho stratigraphic context supports the mineralization model and justifies further exploration and resource development in the block.

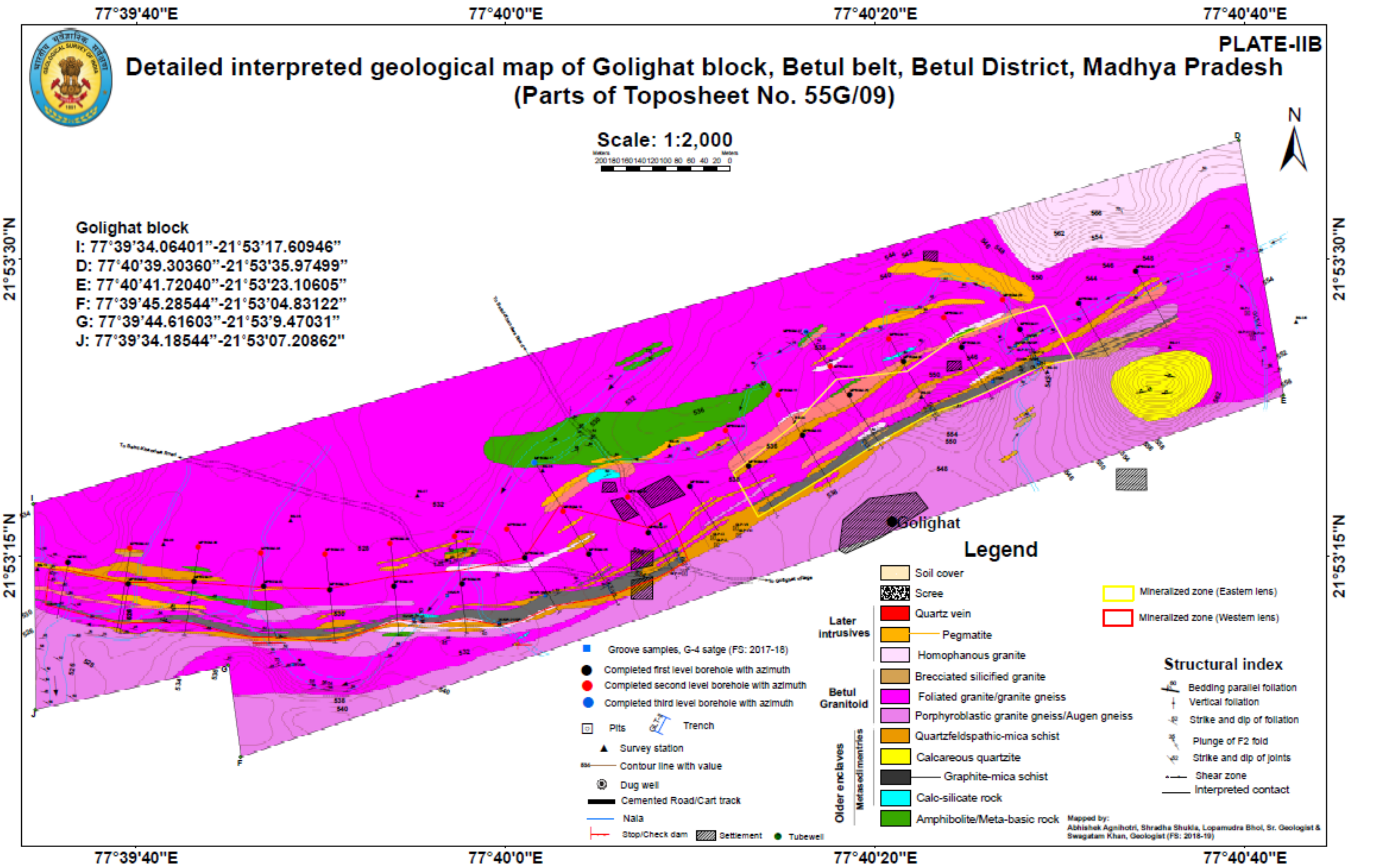


Figure 2. Detailed interpreted geological map of Golighat block.

4.3 Structural Features and Deformational History

The structural configuration of the Golighat block is complex and records multiple deformation events. The following features are prominent:

- Dominant schistosity and foliation, particularly in graphite mica schist and quartz-mica schist units.
- Macroscopic folding, especially evident in quartz-mica schist exposures.
- Pinch-and-swell structures, observed in graphite-rich bands both in the field and core samples.
- Jointing and fracturing, often associated with weathering and secondary mineral infill.

The foliation planes in the area typically strike N75°E–S75°W and dip moderately to steeply (50°–75°) towards the north. These structural orientations correspond well with the trend of geophysical anomalies and mineralized zones identified during exploration.

The deformational history indicates a polyphase metamorphic terrain, where ductile deformation has played a key role in the redistribution of graphite and vanadium. Such structural reworking has created lensoidal and banded morphologies, which have critical implications for both the estimation of resources and the selection of beneficiation strategies.

These features collectively influence the geometry, grade distribution, and accessibility of the graphite and vanadium-bearing zones, thereby playing a vital role in the block's economic appraisal.

4.4 Graphite Mineralization in Golighat Block

In the Golighat block, graphite mineralization is primarily associated with quartzo-feldspathic mica schist (±argentiferous, chlorite, tremolite/actinolite), occurring as lenses and layers within or interbedded with granite/granite gneiss and related schists. Graphite typically appears as small, flaky grains along foliation planes.

The host rocks are metamorphosed to the upper greenschist to lower amphibolite facies, and fixed carbon content ranges from 1% to 21.74%. as shown in figure. 3.

X-ray diffraction analysis reveals that the graphite is well-crystallized, flake-type, evidenced by sharp diffraction peaks. Beneficiation studies (IBM, 2021) confirm the presence of flaky graphite grains, ranging from 50 µm to 320 µm, supporting a syngenetic origin and classifying the deposit as a flake graphite prospect.

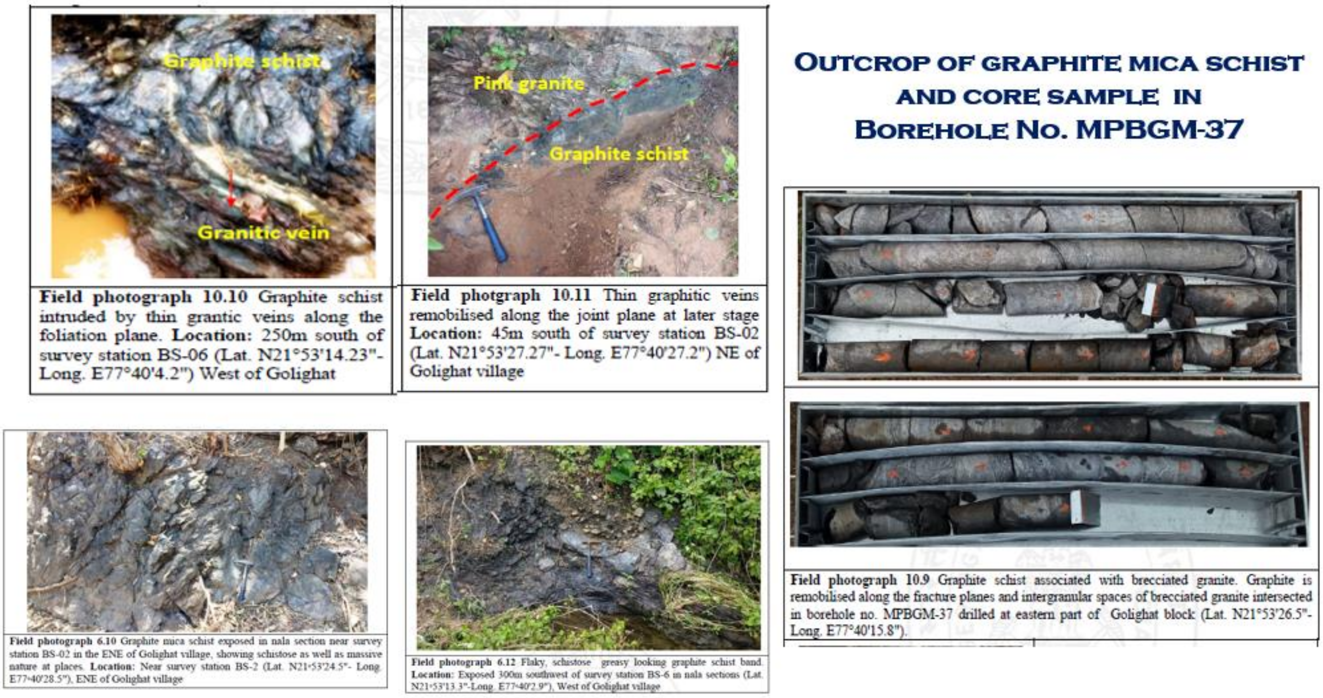


Figure 3. Field photograph shows graphite schists associated with brecciated granite and graphite is mobilised along the fracture planes and inter granular spaces of brecciated granite.

In contrast, amorphous (microcrystalline) graphite typically forms under lower-grade metamorphism of carbon-rich sediments and contains 50–90% carbon. Flake graphite deposits, like Golighat's, occur in Precambrian crystalline metamorphic rocks, usually of Neoarchaean to Proterozoic age, and have a carbon content typically between 3% and 60%, commonly 8–15%. Surface and subsurface data indicate the graphite is hosted in graphite-bearing quartz mica schist (±garnet, chlorite, tremolite/actinolite), intruded by granite along foliation planes. Graphite appears as thin layers or lensoidal bands, is greyish-black to steel grey, soft, greasy, flaky, and micro- to cryptocrystalline. Under the microscope, graphite flakes are intergrown with mica, aligned along foliation, occasionally forming globular cryptocrystalline masses. Pyrite is commonly associated with the graphite.

The detailed geological mapping on 1:2,000 scale in Golighat block (0.80sq.km) reveals that most of the area is soil covered with isolated scattered outcrops of amphibolite/metabasic rock, granitoids (represented by porphyroblastic granite gneiss, foliated granite and granite gneiss), brecciated silicified granite and metasediments. Later intrusive are represented by pink coloured massive granite, quartz vein, quartzofeldspathic veins and pegmatites of different generations. The outcrop of graphite mica schist is very few and just exposed at three places in Golighat area. In the eastern part of Golighat block near survey station BS-2 (figure 2) two graphite mica schist bands separated by 40 m wide partings of granite/granite gneiss are present in a nala section which is marked as northern band (Band-I) and southern band (Band-II). They are striking in N55°E-S55°W direction dipping 50° to 55°due NW. They are confined to the granite gneiss and occur as enclaves.

The granitoids of the area are represented by granitic gneiss, porphyroblastic/augen gneiss, pink foliated granite and crudely foliated grey granite and coarse-grained pegmatoidal granite. These granites are grouped as Betul Granitoid. The metasedimentary, with all lithological variations occur as discontinuous bands and as enclaves within the crystalline rocks. Very few outcrops of metasedimentary rocks in scattered and isolated form are exposed in the area. The contact with pink foliated granite and granite gneiss show an intrusive relationship with metasedimentary. The general trend of rocks varies from ENE-WSW to WNW-ESE with moderate dip due north. At places NW-SE trend is also recorded.
The Golighat block is located between the Son-Narmada lineament in the north and Tapti lineament in the south, which roughly trend in ENE-WSW to E-W direction. The regional foliation of the rocks observed in the area follow the same structural trends i.e. N60°E-S60°W to N75°E –S75°W with moderate to high dip (50°-75°) due NW. Major part of the area is covered by the granitoids and along with metasedimentary which occur as disruptive enclaves within granitoids.

In Golighat block, host rock for graphite mineralisation is quartzofeldspathic-mica schist (±garnetiferous, chlorite, tremolite/actinolite) which is intermittently associated with granite/granite gneiss. The graphite bearing mica schist occur as thin laminated bands, thin layers and lenses within quartzofeldspathic-mica schist or at the contact of quartzofeldspathic-mica schist and granite/granite gneiss. In mineralized zone partings of granite/granite gneiss or quartzofeldspathic mica schist are invariably present. In mineralized zones graphite found to occur as small flakes along the foliation and mixed with mica flakes.

The petrography of graphite mica schist reveals that graphite is microcrystalline in nature and occurs as small platy minerals or thin flakes, intermittently mixed with micaceous minerals along the foliation planes and shear planes. It also occurs in broken, irregular, angular edges found in association with mica flakes at grain boundaries/ in intergranular spaces as isolated flakes. At places, globular masses of graphite at grains boundary or in interstitial spaces are also present.

5. Summary of Past Findings

Earlier exploration efforts revealed the presence of multiple graphitic schist bands associated with quartz-mica schists, granite gneiss, and pegmatitic intrusions. These studies emphasized the structural control on graphite mineralization, with evidence of remobilization along foliation and shear zones. Macroscopic folding and pinch-and-swell structures were also observed, indicating tectonically influenced redistribution of graphite.

Geochemical assays from the past investigations confirmed elevated fixed carbon values and enriched vanadium content in the graphite schist zones. In addition, preliminary petrographic analysis pointed to the presence of flake-type graphite and its association with biotite, chlorite, quartz, and feldspar. These findings reinforced the mineral potential of the Golighat block and recommended further systematic exploration.

6. Detailed Geological Mapping

6.1 Rock Types and Distribution

The Golighat block exhibits a complex lithological framework that includes a wide variety of metamorphic and igneous rock types. The major rock types mapped in the area are:
- Quartzofeldspathic-mica schist
- Graphite mica schist
- Granite gneiss
- Calc-silicate rock
- Pink pegmatite
- Quartzite
- Grey and foliated granite

The distribution of graphite-bearing schist is a critical component of the geological framework. Graphite schist bands occur discontinuously with prominent pinch-and-swell structures along their strike. These bands are intercalated with quartz-mica schists and granite gneiss, forming the host rock assemblage in the mineralized zones.

6.2 Surface Structures and Foliation Patterns

The area is dominated by structural features typical of high-grade metamorphic terrains. The prominent structural elements include:

- Well-developed foliation in graphite mica schist
- Macroscopic folding patterns in quartz-mica schist
- Fractured and jointed zones in granite and pegmatite bodies
- Pinch-and-swell structures within graphite-rich bands

Foliation and schistosity are nearly ubiquitous in the graphite-bearing schists and quartz-mica schists, controlling the geometry and continuity of mineralized zones. The strike of foliation generally trends N75°E–S75°W with dips ranging between 50° and 75° due north. These structures have facilitated the structural remobilization of graphite, enhancing its concentration along shear zones and schistose planes.

6.3 Mapping Coordinates and Survey Techniques

The geological mapping of the Golighat block was carried out using conventional field survey techniques, supported by GPS-based coordinate logging and topographic reference to Survey of India Toposheet No. 55G/09. The mapping area is bounded by:

- Latitude: N21°53′48.3″ to N21°54′05.2″
- Longitude: E77°40′28.3″ to E77°42′36.5″

Detailed lithological boundaries and structural orientations were recorded in the field using compass-clinometer and were later compiled into georeferenced base maps. The data collected formed the foundation for laying out trenches, pitting locations, and borehole alignments. The total cumulative strike length of the graphite schist bands mapped during this phase amounted to approximately 1547.1 meters.

7. Petrography and Ore Microscopy

7.1 Host Rock Characteristics

Petrographic analysis of core and surface samples from the Golighat block confirms that the primary host rock for graphite mineralization is graphite mica schist. These schists are rich in flaky graphite and occur as bands interlayered with quartzofeldspathic mica schist and granite gneiss. The schists are strongly foliated, and the graphite occurs along schistosity planes, often in association with biotite and chlorite. Calc-silicate rocks and pegmatites are also observed within the mapped sections, acting as both bounding units and structural markers.

The granite and granite gneiss units, found adjacent to the schist bands, show varying degrees of foliation and recrystallization. These granitoids often serve as footwall or hanging wall rocks for the graphite-bearing sequences, marking the lithological boundaries of mineralized zones.

7.2 Microscopic Texture and Mineral Assemblages

Ore microscopy and petrographic thin section analysis reveal that the graphite mica schist exhibits typical schistose textures, with well-aligned mineral grains and flaky graphite aligned along foliation. The dominant minerals identified under the microscope include:

- Quartz
- Chlorite
- Graphite
- Muscovite and Biotite
- Hypersthene
- Andalusite

The textures observed include holocrystalline and glomeroporphyritic in the granitic units, while the schists display foliated and lepidoblastic textures. These textures confirm the metamorphic origin and dynamic recrystallization associated with regional tectonic activity. Graphite is generally found as platy or bladed aggregates aligned along cleavage planes, suggesting structural remobilization during deformation.

7.3 Graphite and Associated Minerals

Graphite is the principal economic mineral in the block and occurs in flaky and platy forms, predominantly oriented along shear planes and schistosity surfaces. The mineralization is structurally controlled and shows evidence of remobilization during ductile deformation events. The graphite is often associated with biotite and chlorite, forming part of the matrix or occurring as discrete lamellae.

Minor but significant associated minerals include hypersthene, andalusite, and muscovite/biotite, which contribute to the overall metamorphic mineral assemblage. Pyrite is also observed as specks or stringers in certain graphite-bearing bands, suggesting late-stage sulphide mineralization.

The petrographic and ore microscopy results are vital in confirming the nature of mineralization, estimating the mode of occurrence of graphite, and assessing the mineralogical composition for beneficiation planning.

8. Geochemical Investigations

8.1 Petrochemical Analyses (XRF, CIA, ICV)

Petrochemical investigations were conducted on rock samples from the Golighat block using X-ray fluorescence spectrometry (XRF) to determine the concentration of major and trace elements. The analysis revealed a significant enrichment of vanadium in the graphite mica schist, with values approximately 9–10 times higher than those found in quartzofeldspathic-mica schist. Other notable trace elements identified include yttrium (Y) and zirconium (Zr).

To evaluate the degree of chemical weathering and alteration, the Chemical Index of Alteration (CIA) and the Index of Chemical Variation (ICV) were calculated. The CIA value for tremolite/actinolite schist was determined to be 25.52, indicating a low degree of chemical weathering. The ICV values ranged between 2.20 and 0.95, suggesting a transition from immature to moderately mature sediments.

8.2 SEM-EDX Results

Scanning Electron Microscopy coupled with Energy Dispersive X-ray Spectroscopy (SEM-EDX) was performed on selected samples to confirm the elemental composition and textural characteristics of the mineral phases. SEM-EDX analysis verified the presence of graphite along foliation planes and provided microstructural insights into the mineral associations in the graphite-bearing schists.

The analysis confirmed that graphite occurs as discrete flaky grains intergrown with quartz, feldspar, and biotite. It also revealed the presence of vanadium-bearing mica phases and minor sulphide inclusions, aiding in the mineralogical and beneficiation evaluation.

8.3 Soil and Water Sample Analyses

Geochemical investigations were extended to abiotic environmental samples to assess potential contamination and environmental impact. Six soil samples were analyzed for trace elements, revealing low concentrations of silver (Ag) and other elements. Parameters such as pH, electrical conductivity (EC), and total dissolved solids (TDS) were measured, indicating generally non-toxic soil conditions. One representative sample showed:

- pH: 190
- EC: 145
- TDS: 520
- Ca: 15, Mg: <1, Na: <10, HCO_3: 125

Water samples, including those from dug wells and nearby streams, were analyzed to determine concentrations of major ions and potential contaminants. Fluorine content was particularly noted, with a maximum value of 1.4 ppm found in one dug well sample. TDS values ranged from <300 ppm (desirable to less desirable) to 300–500 ppm (unpleasant for drinking).

Overall, the water and soil geochemistry of the region remain within permissible limits, with localized variations that warrant further monitoring, particularly in proximity to mineralized zones.

9. Geophysical Survey and Interpretation

9.1 IP, SP, Magnetic, and Resistivity Surveys

Ground geophysical surveys were conducted across the Golighat block using a combination of techniques, including Induced Polarization (IP), Self Potential (SP), Magnetic, and Resistivity methods. These techniques were employed to identify the lateral and vertical continuity of graphite schist bands and to delineate zones of economic interest.

The IP survey revealed chargeability values ranging from 1 mV/V to 21 mV/V, which were closely associated with graphite-bearing zones. The SP survey highlighted broad low-potential anomalies over metasedimentary units, particularly aligning with mapped graphite schist occurrences. Magnetic and resistivity data further supported the presence of structural discontinuities and lithological boundaries. The strike length of prominent anomalies extended up to 120 meters, notably northeast of Junawani.

9.2 Anomaly Trends and Correlation with Geology

The geophysical anomalies observed during the surveys correlate strongly with geological features mapped on the surface. The anomaly trends, predominantly oriented N75°E–S75°W, mirror the structural grain and foliation observed in the graphite mica schist. High-chargeability zones correspond to graphitic bands identified during detailed geological mapping and trenching operations.

The integration of IP and SP data overlaid with geological boundaries facilitated the identification of two major mineralized zones:

- N20/W 4000
- N20/E 1600–S0/E 1600

These zones represent target areas where geophysical anomalies and surface/subsurface geological features are in strong agreement, warranting further exploration and drilling.

9.3 Geophysical Logging Results and Interpretation

Geophysical borehole logging was carried out using the RG Micrlogger-II system, which recorded Self Potential (SP), Single Point Resistivity (SPR), and Natural Gamma logs for selected boreholes intersecting mineralized zones. These logs were instrumental in identifying subsurface continuity of graphite and vanadium mineralization.

The SP logs revealed low potential values (ranging from -518 to -105 mV), which were consistent with graphite-rich intervals. SPR values varied between 0–3494 Ω-m, with lower resistivity zones corresponding to conductive graphite-bearing strata. Natural Gamma logs assisted in identifying lithological changes and differentiating between graphite schist and adjacent non-conductive rocks.

Boreholes such as MPBGM-13, MPBGM-24, and MPBGM-25 demonstrated strong correlations between logging signatures and mineralized intersections. These results validated surface geophysical interpretations and reinforced confidence in the 3D continuity of the graphite lenses.

10. Exploration by Drilling

10.1 Drilling Methodology and Equipment

Exploration drilling was carried out in the Golighat block under both G-2 and G-3 stages of investigation to delineate the subsurface continuity of graphite and vanadium mineralization. A total of 3481.90 meters was drilled through 42 boreholes during FS 2018-2019 an 2019-2020, using NX/NWT and BX/BWT coring techniques. Drilling operations were executed using diamond core drilling rigs equipped with water circulation systems to optimize core recovery. Standard drilling protocols were followed for casing, logging, and core handling to ensure data integrity and to minimize core loss.

10.2 Borehole Locations and Spacing

Boreholes were systematically placed across the mapped graphite schist zones with a nominal spacing of 200 meters along strike, consistent with G-2 stage guidelines. The boreholes targeted areas of high surface graphite concentration, as identified from geological mapping, trenching, and geophysical surveys as shown in the figure 4.

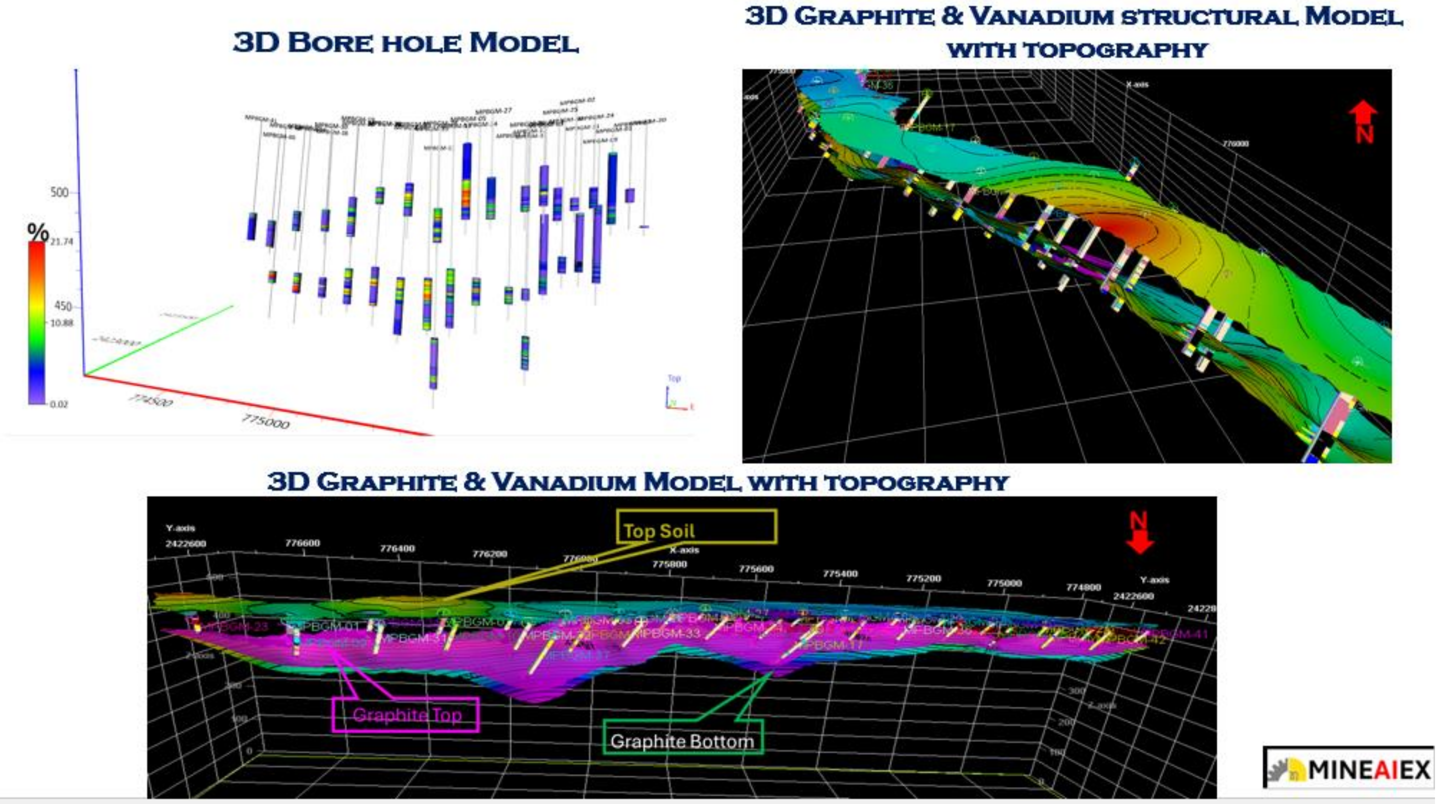


Figure 4. 3D borehole model, Graphite & Vanadium model with Topography.

The layout of boreholes also considered structural controls such as foliation trends and folding, ensuring coverage across all potential mineralized zones. The geological cross-sections generated from these boreholes helped in validating the geometry and extent of the graphite-bearing schist bands. Detailed interpreted geological map shows graphite mica schist are extended to the surface on the basis of bore hole data and dip of the graphite mica schist, where BRS, Pit and trench samples also confirm this observation. Two trenches GLT-VI and GLT-VII were laid in front of borehole MPBGM-02 and MPBGM-05 respectively to check the surface continuity of graphite band. In addition to that, four pits (GLP-VII, GLP-VIII, GLP-IX and GLP-X) were also excavated to check the continuity of graphite schist band as shown in figure 2 in the interpreted geological map.

10.3 Mineralized Intersections and Core Recovery

Several boreholes intersected significant graphite and vanadium-bearing zones. For instance, borehole MPBGM-13 recorded fixed carbon values ranging from 1.1% to 8.46%, with an average of 4.10% over a 6.9-meter intersection. Borehole MPBGM-32 showed 5.67% FC over 8.05 meters. Vanadium concentrations in some boreholes, such as MPBGM-22 and MPBGM-36, reached up to 1998 ppm and 1339 ppm, respectively.

Graphite schist was often associated with granite, granite gneiss, and quartzofeldspathic mica schist, sometimes brecciated or interbedded with calc-silicate rocks. Core recovery from the mineralized zones ranged between 70% to 96%, which is considered satisfactory for resource evaluation. Detailed logging included lithology, structure, mineralogy, and physical characteristics of the core.

The borehole data formed the foundation for resource estimation and Artificial Intelligence modelling, confirming the spatial continuity of mineralization and aiding in classifying resources under UNFC category 332.

11. Borehole Correlation and Geological Cross-Sections

11.1 Borehole Correlation and Subsurface Interpretation of Graphite

Multiple bore hole correlations and geological cross-sections were prepared using detailed borehole data from 42 drill holes (MPBGM-01 to MPBGM-42) across the Golighat block. These sections allowed for visualizing the disposition of graphite and vanadium-bearing mineralized zones in the subsurface, aiding in the interpretation of their geometry and continuity. The correlations were drawn between boreholes drilled at different levels and across various strike sections and dip direction to delineate ore zones with higher geological confidence. The graphite schist bands extend from west to east as three separate lensoidal bands and together they formed a cumulative strike length of 1550 m (figure 5. a, b, c &d). The graphite schist is associated with quartz-mica schist/mica schist are disposed as discontinuous bands within the host granite/granite gneiss in the form of lensoidal bodies and occur along the same strike continuity. The central region graphite is high grade with better thickness compared to eastern western region.

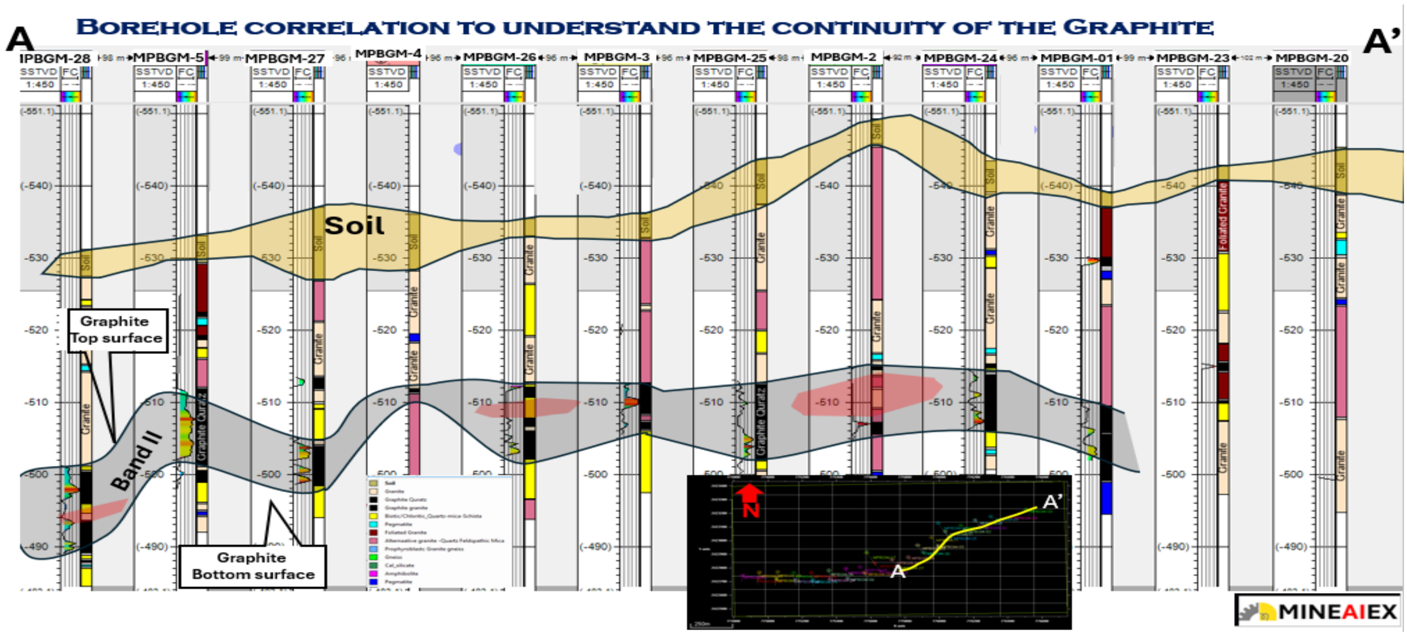


Figure 5. a

The southern band (Band-II) is about 1 m to 9 m in thickness and exposed at three other places in well section and nala sections. At this location (near survey station BS-2) the graphite mica schist band looks little massive in nature and intermixed with younger granite. The central region graphite is higher thickness and better grade compare to eastern region. Nevertheless Wester region also depict good thickness compare to eastern region.

The southern graphite band (Band-II) ranges in thickness from approximately 1 to 9 meters and is exposed at three additional locations in well and nala sections. Near survey station BS-2, the graphite mica schist appears slightly massive and is intercalated with younger granite. In the central region, the band exhibits greater thickness and higher graphite grade compared to the eastern part. The western region also shows better thickness than the eastern sector inferred from borehole correlation as shown in figure. 5 b.

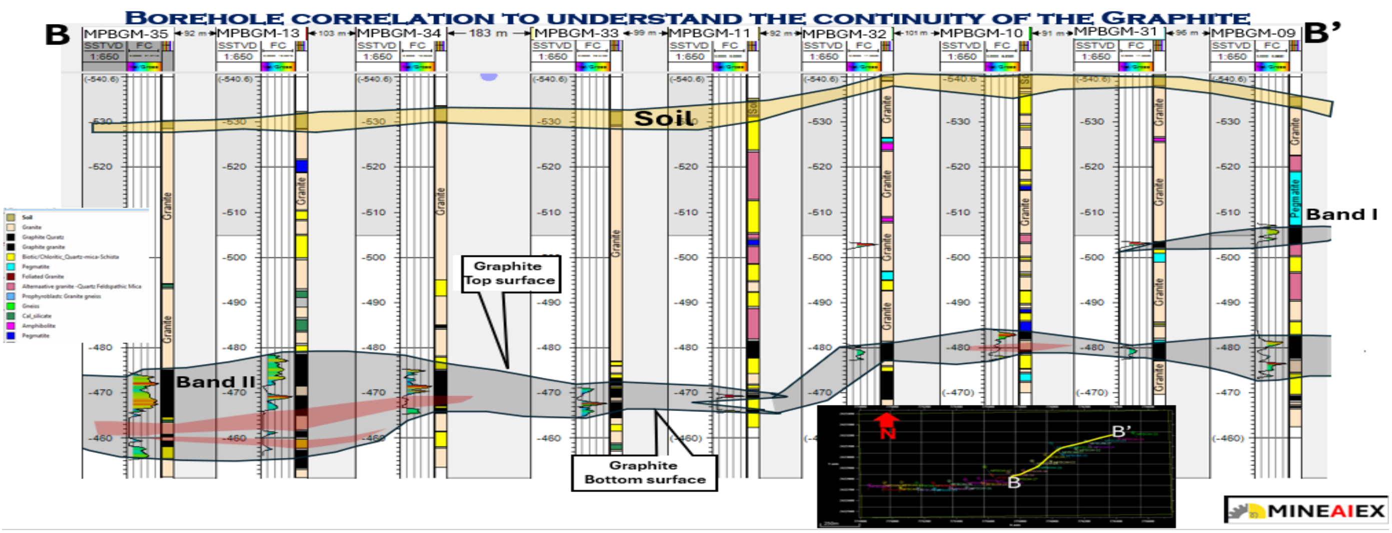


Figure 5. b

The northern band (Band-I) as shown in figure 5 b, is about 0.5 m to 1.5 m in in two boreholes thickness trending in N60°E-S60°W . In the eastern part of the Golighat block at 50 m northwest of survey station BS-02 in nala section, exposures of graphite-mica schist are exposed in two places in nala section, which are 50 m apart in same strike continuity. By this, it is inferred that band- I is having cumulative strike length of 50 m in eastern part of Golighat block. Graphite schist exposed in the area is soft to moderately hard, schistose and flaky.

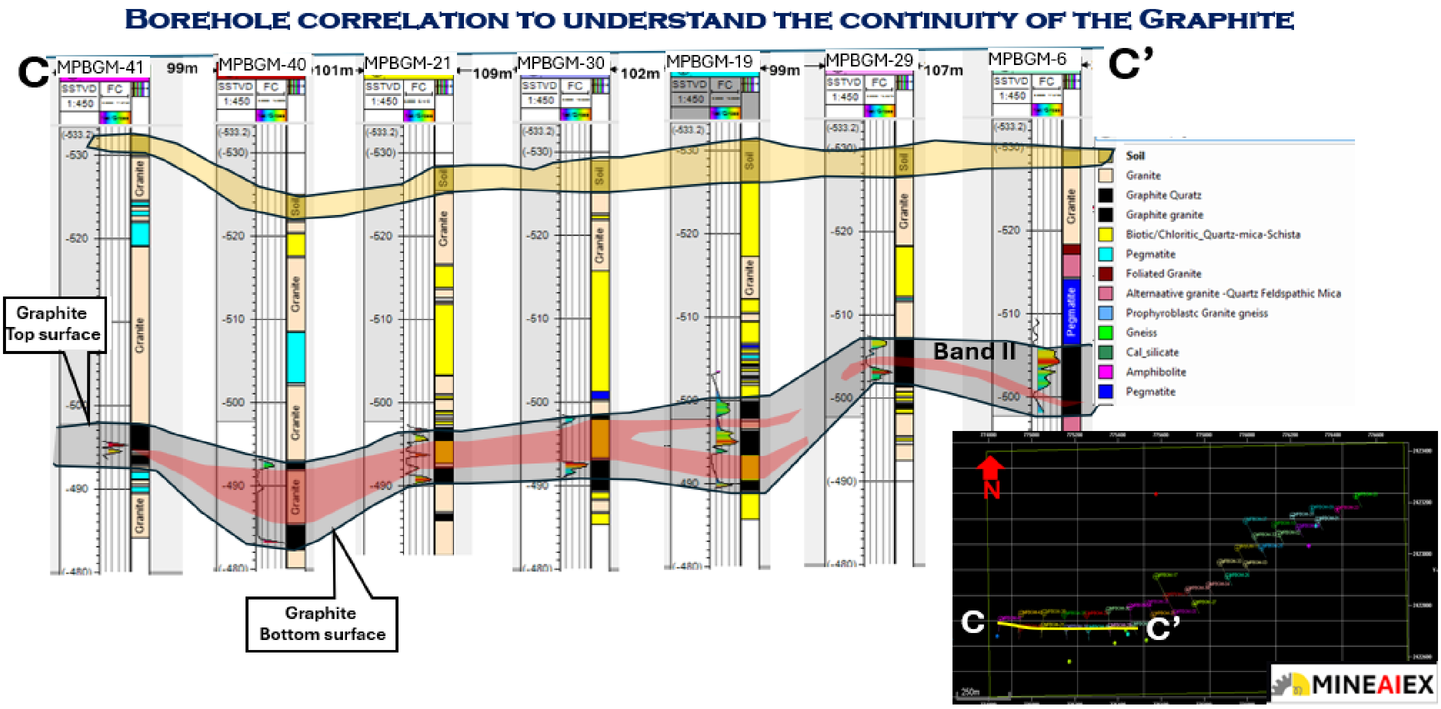


Figure 5. c

Mineralized zone-III is intersected only three boreholes (second level) i.e. borehole MPBGM-13 to MPBGM-14 located in the central part of the Golighat block. Based on subsurface data, it is interpreted that this graphite mica schist band is varying in thickness from 1.22 m to 5.80 m (true width) with strike length of 250 m.

Mineralized zone-IV is intersected only in one second level borehole no. MPBGM-14. It indicates that band-IV is small and lensoidal in nature and has not much significance. Based on subsurface data, it is interpreted that this mineralized zone occur as a small lens of 50 m strike length with average width of 0.60 m.

Cross-sections clearly demonstrate the occurrence of graphite lenses within schistose sequences, structurally enclosed by granite and granite gneiss. Mineralized zones exhibit lensoidal to banded forms, with gradual thickness variation, confirming the influence of structural remobilization and tectonic controls.

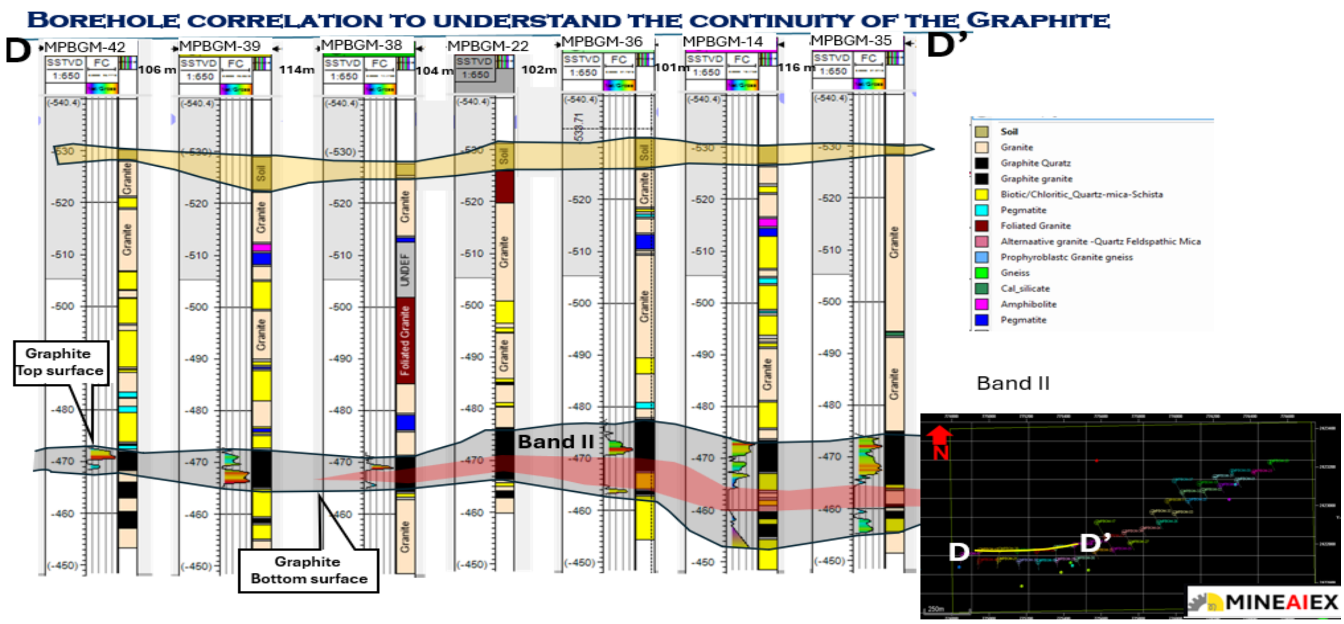


Figure 5. d

11.2 Strike and Dip Continuity of Ore Zones

The graphite mineralized zones identified in the cross-sections show a strong structural coherence along the N75°E–S75°W trend, which is consistent with surface geological and geophysical observations. The mineralized bodies exhibit continuity both along strike and down dip, with some pinching and swelling along their length as illustrate in figure 6.

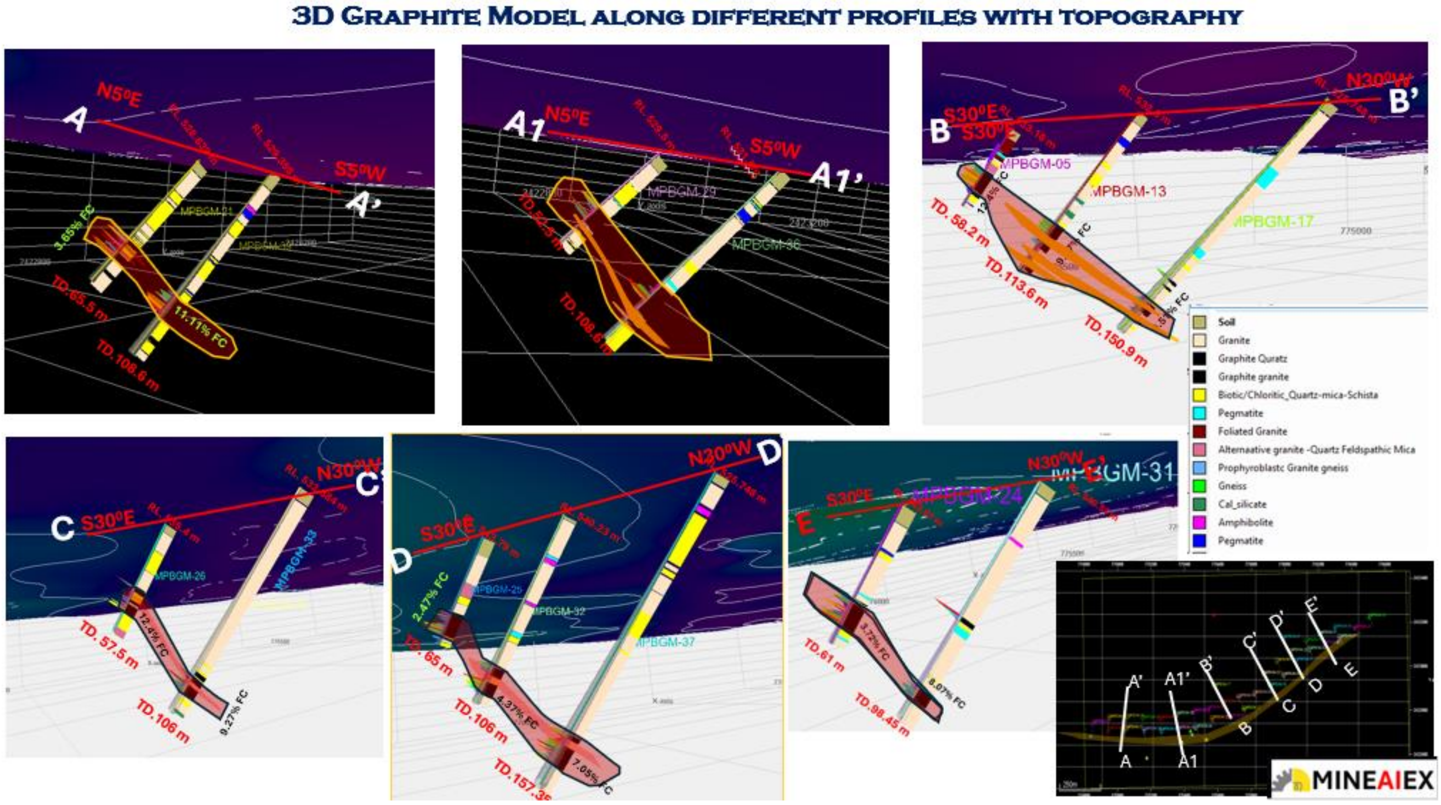


Figure 6. 3D borehole correlation and ore modelling to understand the depositional architecture, areal extent, dipping of graphite and vanadium ore body and depth of mineral deposit.

The vertical continuity of zone II was confirmed up to 30 meters in most boreholes. Additional zones, including Zone-I and smaller lenses, were also mapped, highlighting the multi-lens character of the graphite occurrences.

11.3 Mineral Habitat

The mode of occurrence, lithological setting, and mineralogical associations suggest that graphite in the Golighat block is of syngenetic origin, formed under upper greenschist to amphibolite facies metamorphism. Based on its texture and occurrence, it is classified as a flake-type graphite prospect. Petrographic studies of graphite mica schist reveal a mineral assemblage of quartz, K-feldspar, biotite, muscovite, and graphite, with occasional presence of pyroxene and hornblende. Graphite is predominantly microcrystalline, occurring as fine flakes aligned along foliation planes and interspersed with micaceous minerals. In some cases, globular graphite masses are observed at grain boundaries or within interstitial spaces.

Shearing is especially prominent in the eastern Golighat block, where graphite mineralization is associated with brecciated cherty granite. Boreholes (MPBGM-02, 10, 11, 25, 32, 37) in this area show evidence of remobilization and relocation of graphite along fracture planes in granite and granite gneiss. In the central and western parts, graphite is commonly associated with foliated granite gneiss. Highly fractured and sheared granite/granite gneiss and garnetiferous chlorite-bearing quartz-mica schist occur in the hanging wall and footwall of the graphite bands, indicating that the mineralization is shear-controlled, with significant remobilization along shear zones (as illustrated in Figure 3)

Based on surface and subsurface data it can be postulated that in Golighat block, graphite mica schist occurs as concordant linear and/or lenticular bodies of variable thickness and length. On surface, in eastern part of Golighat block, two bands of graphite schists are noticed separated by about 40 m granite/granite gneiss partings. However, in boreholes 3 to 4 bands of graphite mica schist are intersected, which vary in thickness and strike extension, but graphite band is ubiquitous and present in almost all boreholes. Based on detailed mapping and pitting/trenching, two graphite mica schist bands are postulated in Golighat block on the surface i.e. Band-I and Band-II.

12. Resource modelling, Ore modelling and Resource Estimation of graphite.

12.1 Graphite Resource Calculations

Resource estimation for the Golighat block was conducted based on borehole data, fixed carbon assays, and geological cross-sections by using Artificial Intelligence mineAIex software. A total mineralized strike length of 959.30 meters was considered, primarily from Zone-II. The tonnage was calculated by volumetric block modelling and ore modelling using MineAIex software. Fixed carbon content across mineralized zones averaged between 3% and 6%, with individual boreholes recording as high as 8.46% FC over 6.9 meters (e.g., MPBGM-13).

Using collar, survey, and assay data, a robust 3D solid model and ore model was created for graphite with a 2 % cutoff grade with 2.696 gram/cc specific gravity using artificial intelligence mineAIex software as shown in figure 10. The model shows spatial continuity of graphite bodies, with significant mineralization (Figures 7 and 8). The general trend of the deposit from the east-northeast (ENE) to the south-southwest (SSW), intersecting the central part of the graphite ore body and continuing in an east-west (EW) direction until the end of the ore zone and dip of the deposit is around 50 degree towards North.

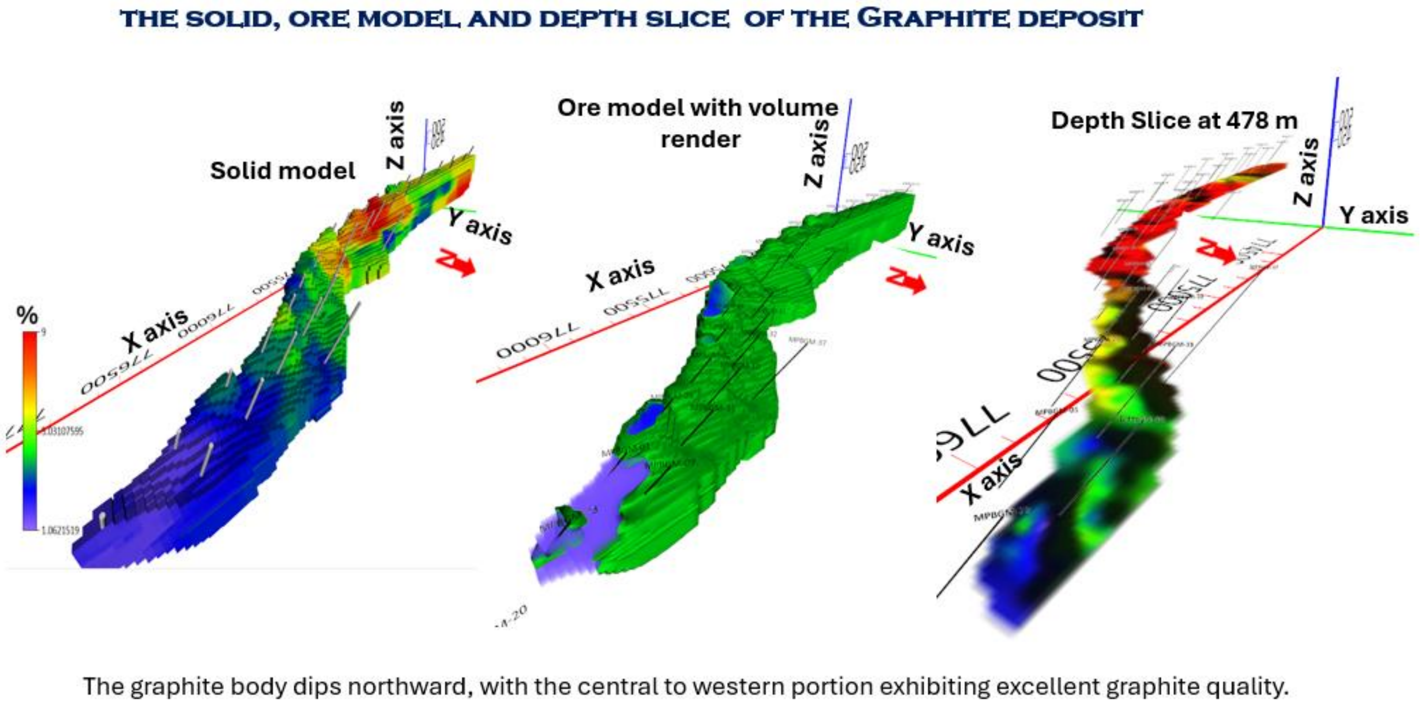


Figure 7. Solid model and ore model of graphite deposit.

12.2 Cut-off Grades

A fixed carbon cut-off grade of 2% was adopted for delineating mineralized zones based on beneficiation and market viability. The cut-off selection is guided by mostly core quality, core recovery, and lithological characteristics that support selective mining and beneficiation of graphite-rich intervals. These parameters ensured that the estimated resources are both technically and economically viable.

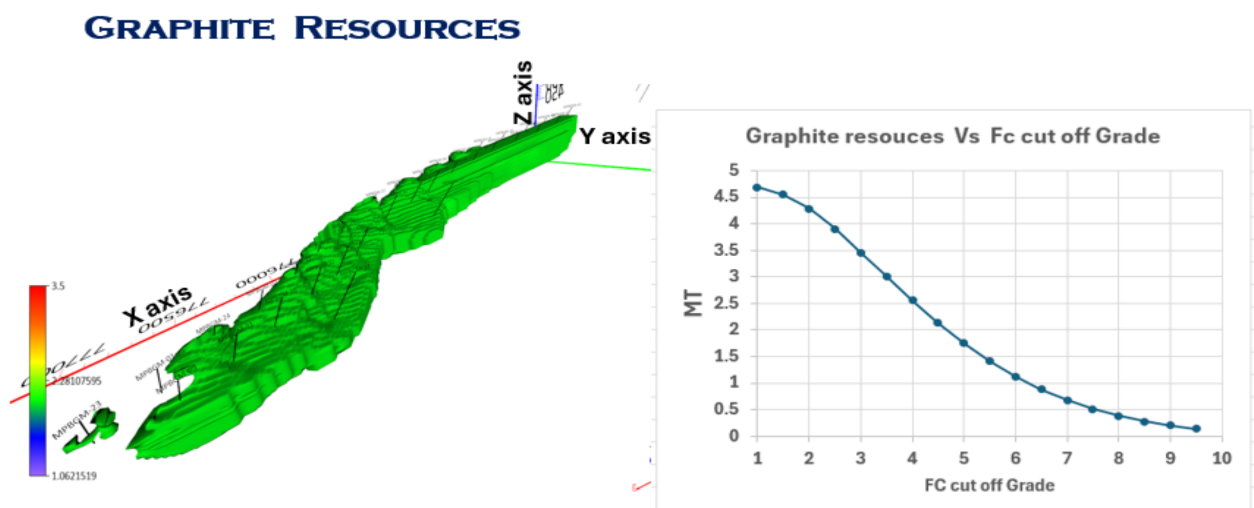
12.3 UNFC Classification (Category 332)

Based on the detailed geological, geophysical, and drilling data, the estimated resources were classified under UNFC Category 332 — indicated resource 'Probable Mineral Resources'. This classification is justified on the basis of:

- Adequate geological evidence from detailed mapping and trenching.
- Subsurface data from grid-spaced boreholes and assays.
- Reasonable confidence in continuity of mineralized zones along strike and depth.

Resource estimation of graphite was carried out through resource modelling using mineAIex (AI software), delineating ore bodies at a cut-off grade of 2% FC, resulting in an estimated 4.28 million tonnes. Additionally, metal content was calculated for various cut-off grades to support comparative analysis and economic evaluation as shown in figure 7.

The total resources (332) estimated by GSI for graphite bearing mineralized/ore zones in Golighat block by cross section method is 3160508.06 Tonnes(3.16 million tonnes) with 2% FC cutoff grade and an average grade of fixed carbon 6.86%.



Graphite Resources	
FC cutoff %	Million Tonnes
1	4.69
1.5	4.55
2	4.28
2.5	3.9
3	3.46
3.5	3.01
4	2.56
4.5	2.13
5	1.75
5.5	1.41
6	1.12
6.5	0.88
7	0.68
7.5	0.51
8	0.38
8.5	0.28
9	0.2
9.5	0.14

The Graphite resource is around 4.28 MT at 2 % Fc cut off grade

GSI resource estimation.
At a 2% FC cut-off and 2 m stopping width, the total cumulative resource for both eastern and western lenses is estimated at **3.16 million tones @ 6.86% FC** (cross section method) with an average thickness of **9.90 m** over a **1514.71 m** strike length.
Using the **LV section method**, the resource is estimated at **2.87 million tones @ 6.70% FC** over the same strike length.

Figure 8. Resource estimation of Graphite at different cutoff grade .

The graphite resource is around 4.28 Millon tonnes at 2 % FC. Additionally, resources are calculated for various cut-off grades to support comparative analysis and economic evaluation. 3D visualization facilitate pinpoint the best resource areas for mine planning other facilities arrangements to increase the profitability significantly without any wastage.

With further exploration and feasibility studies, these resources hold the potential to be upgraded to a higher category (e.g., 331).

13. Geological Cross-Sections of Vanadium

13.1 Borehole Correlation and Subsurface Interpretation of Vanadium

Vanadium was observed as an associated element within the graphite schist. Vanadium concentrations ranged from 500 ppm to 1998 ppm in select intersections (e.g., MPBGM-22 and MPBGM-36). While not estimated separately at this stage, vanadium occurrence has economic significance and warrants further evaluation. EPMA study revealed that a few plagioclase (albite) grains are vanadium bearing and V_2O_3 content ranges from 0.03 to 0.22 and also very few chlorite grains are vanadium bearing. Based on this, only the demarcated graphite bearing mineralized zones in various boreholes are analysed for its vanadium content and subsequently vanadium bearing zones are also demarcated. A total of 655 nos. of core samples from graphite bearing mineralized zone analysed for vanadium content. For demarcation of the vanadium bearing mineralized zone, only those samples are taken into consideration having vanadium content >100 ppm However, if any sample within the mineralized zone have less than 100 ppm vanadium content, but overall grade of the mineralized zone does not fall below 100 ppm, is taken into consideration for demarcation of the mineralized zone as illustrate in the figure 8. a,, b, c and d.

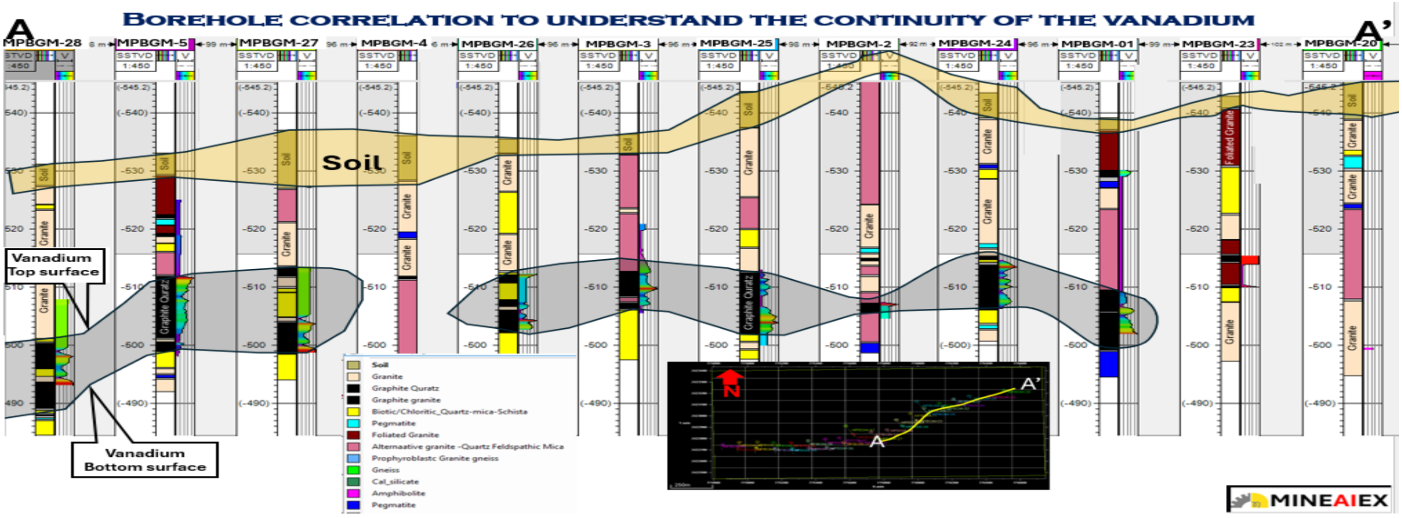


Figure 9. a

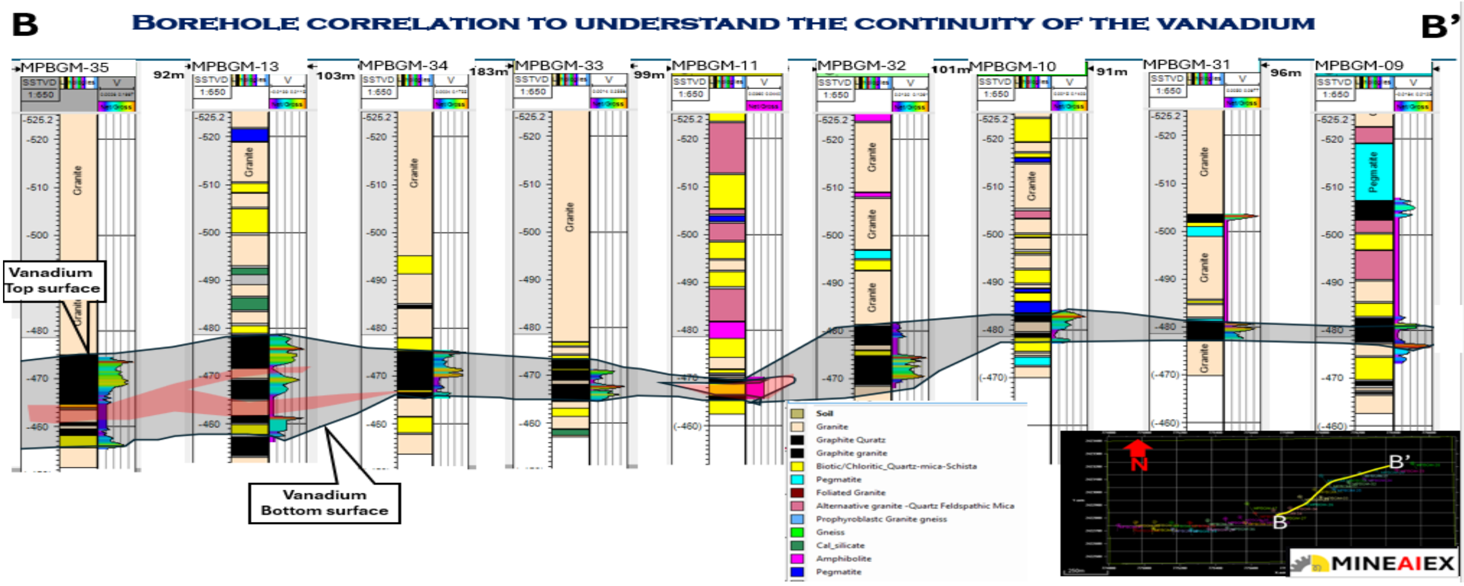


Figure 9. b

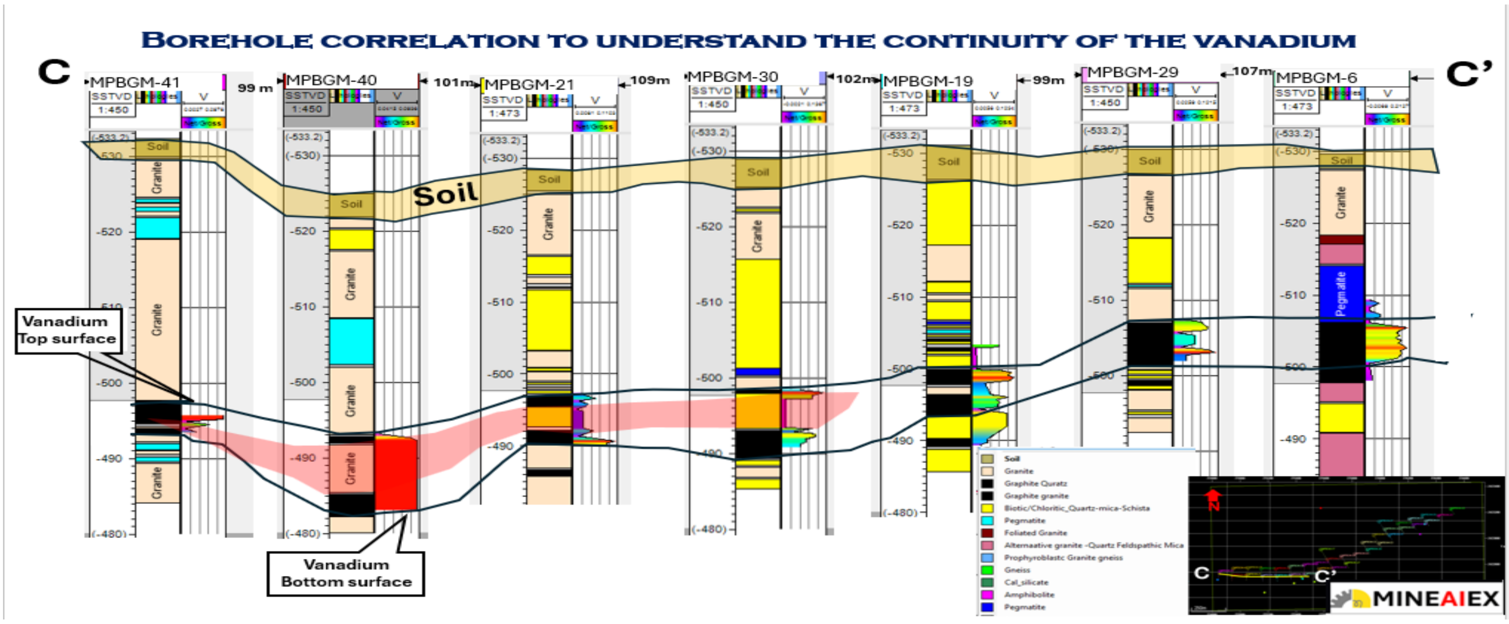


Figure 9. c

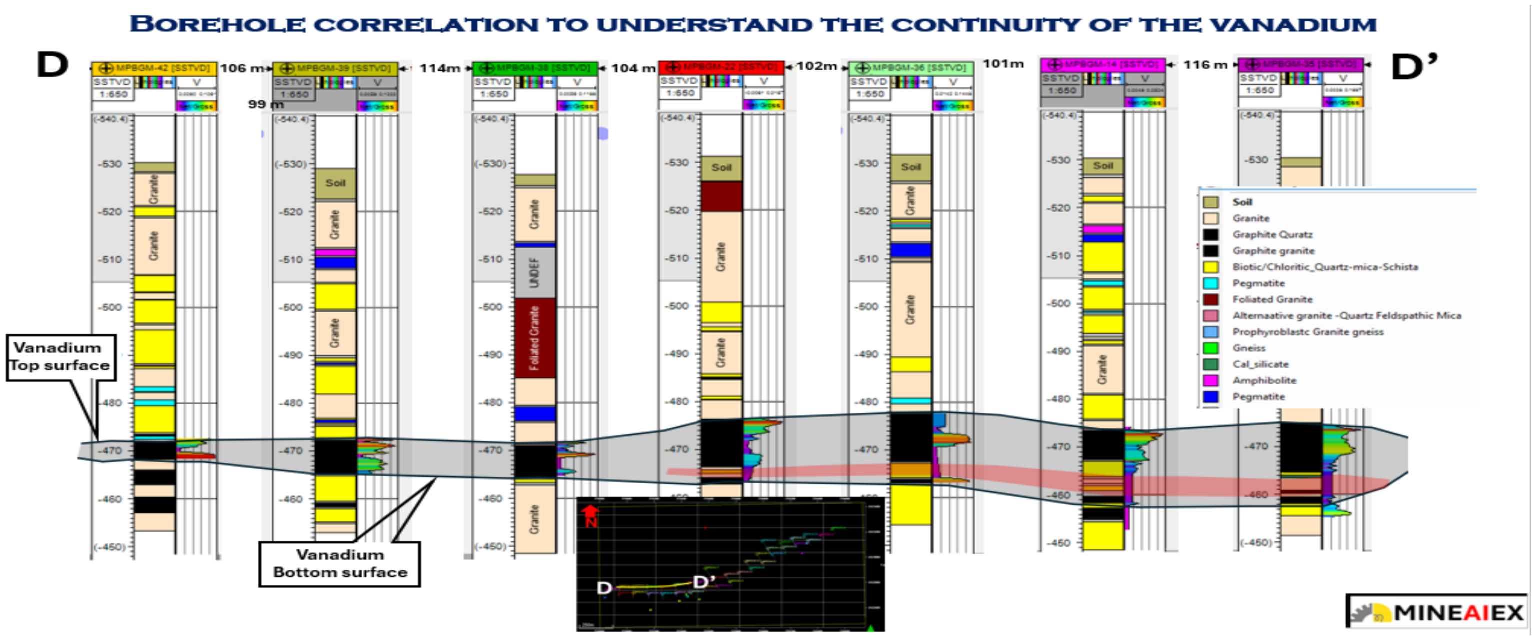


Figure 9. d

14. Mineral Habitat

During G4 stage followed by G-3 stage of investigation, groove bedrock samples and petrochemical samples analysed for its vanadium content and subsequently higher values of vanadium recorded in graphite mica schist. However, no distinct vanadium bearing mineral phase had been identified in the XRD studies therefore possibility for vanadium being concentrated in the interstitial spaces of graphite flakes/ micro crystals (Suryavanshi, 2019 et. Al.) Based on this, only the demarcated graphite bearing mineralized zones in various boreholes are analysed for its vanadium content and subsequently vanadium bearing zones are also demarcated. Graphite content in the sample is about 10%. Majority of the graphite occurs as flaky grains. At -65 mesh, about 70 % of the graphite are free and rest is interlocked, intermixed and present as inclusions within quartz, carbonate, feldspar and mica. Mica is the principal vanadium bearing mineral and the sample contained about 10% mica (Biotite and muscovite). The ratio of biotite and muscovite is 75:25. EPMA study revealed that all the biotite are Vanadium bearing, ranging from 0.07 % to 2.73% V2O3, where as approximately 50% of the muscovite are vanadium bearing, ranging from 0.01% to 1.27% V2O3. At -65 mesh, about 80% of the mica grains are free from interlocking. Besides, the sample also contained very minor to trace amounts of REE (Monazite) minerals and Cu-Pb- Zn bearing sulphide minerals.

15. Vanadium Resource Calculations

15.1 Vanadium Resource Calculations

Resource estimation for the Golighat block was conducted based on borehole data, fixed carbon assays, and geological cross-sections. A total mineralized strike length of 959.30 meters was considered, primarily from Zone-II. The tonnage was calculated by volumetric block modelling, considering the average bulk density of 2.437 t/m^3. Fixed carbon content across mineralized zones averaged between 3% and 6%, with individual boreholes recording as high as 8.46% FC over 6.9 meters (e.g., MPBGM-13).

In addition, vanadium was observed as an associated element within the graphite schist. Vanadium concentrations ranged from 500 ppm to 1998 ppm in select intersections (e.g., MPBGM-22 and MPBGM-36). While not estimated separately at this stage, vanadium occurrence has economic significance and warrants further evaluation.

Using collar, survey, and assay data, a robust 3D solid model and ore model was created for vanadium with 560 ppm cut off grade using mineAIex software. The model shows spatial continuity of vanadium bodies, with significant mineralization vanadium (Figures 10 and 11). The general trend of the deposit Is E - W to NE-SW direction and dip of the deposit is around 50 degree towards North.

15.2 Cut-off Grades

A fixed carbon cut-off grade of 560 ppm was adopted for delineating mineralized zones based on beneficiation and market viability. The cut-off selection is guided by mostly core quality, core recovery, and lithological characteristics that support selective mining and beneficiation of graphite-rich intervals. These parameters ensured that the estimated resources are both technically and economically viable.

15.3 UNFC Classification (Category 332)

Based on the detailed geological, geophysical, and drilling data, the estimated resources were classified under UNFC Category 332 — indicated resource 'Probable Mineral Resources'. This classification is justified on the basis of:

- Adequate geological evidence from detailed mapping and trenching.
- Subsurface data from grid-spaced boreholes and assays.
- Reasonable confidence in continuity of mineralized zones along strike and depth.

The vanadium content varies from place to place and borehole correlation show the deeper area the quality of the vanadium decreases compare to shallower depths. The vanadium content varies from 105 ppm to 2347 ppm across the depth of borehole(assay data) as shown in figure 10.

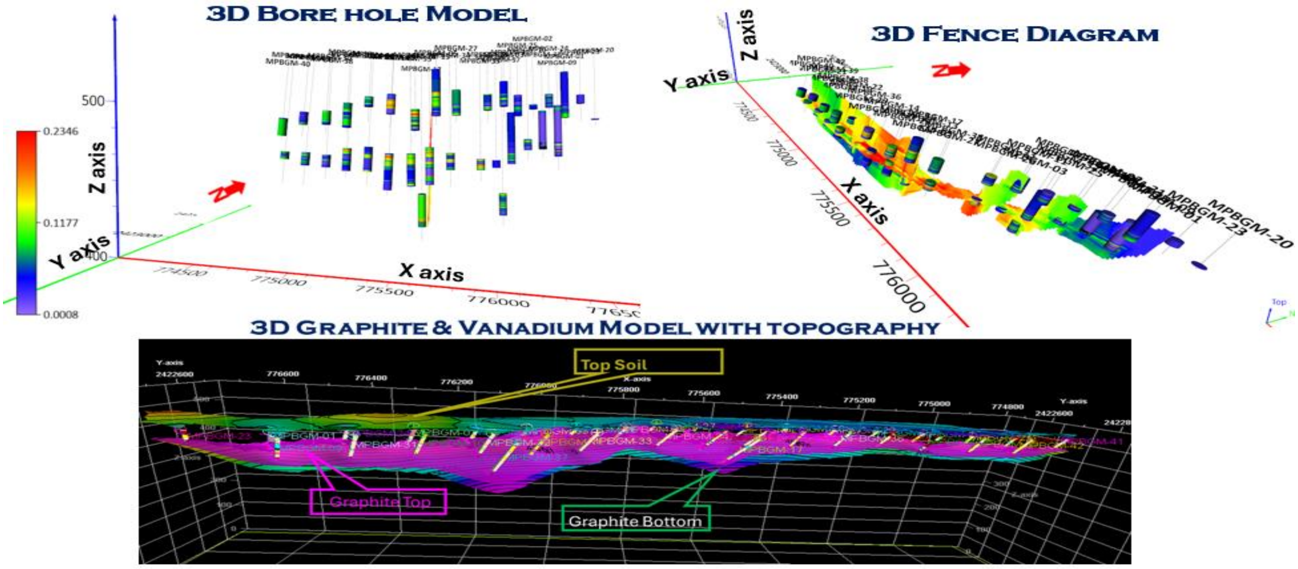
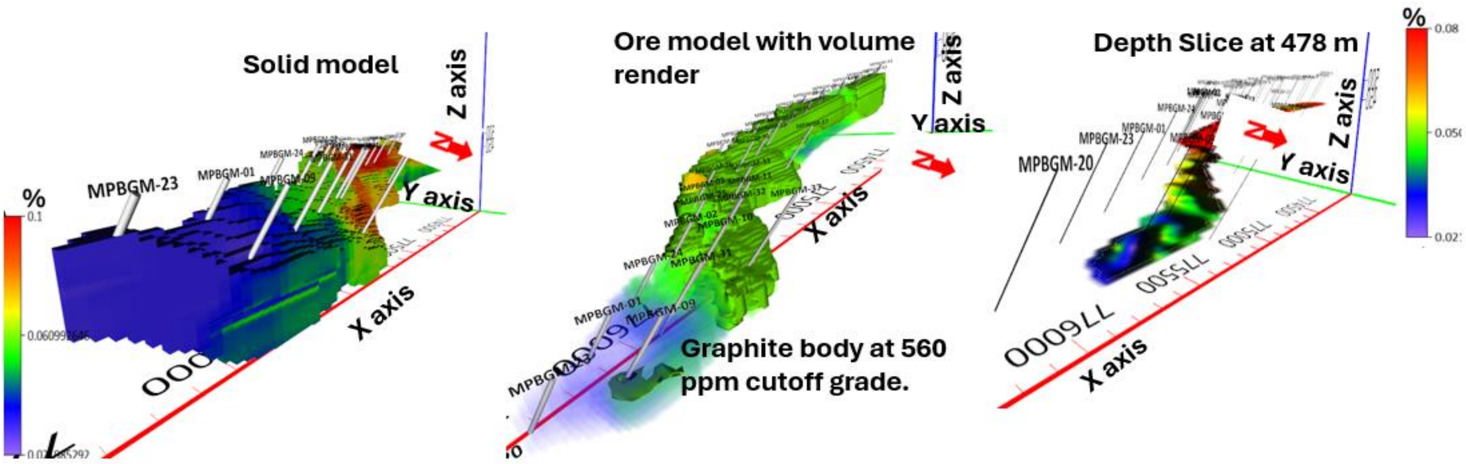


Figure 10. Borehole model, geological model and fence diagram of graphite deposit.

The vanadium resource in the Golighat block is calculated by GSI solely using the cross-section method. The total estimated resource for vanadium (V) in the Golighat block amounts to 2.72 million tones at a cut-off grade of 560 ppm (V2O5-999.712 ppm), with an average grade of 820 ppm (V2O5-1463.864 ppm) of vanadium across a strike length of 1292.75 m and an average thickness of 10.18 m.

Using collar, survey, and assay data, a robust 3D geological model, borehole model, solid model and ore model ware created for vanadium   zones using a 500 ppm cutoff grade with 2.437 gram/cc specific gravity using artificial intelligence mineAIex software as shown in figure 11. The resulting model depicts a continuous solid ore body extending from the east-northeast (ENE) to the south-southwest (SSW), intersecting the central part of the vanadium ore body and continuing in an east-west (EW) direction until the end of the ore zone and and dip of the deposit is   around 50 degree towards North. as shown in figure 11.

THE SOLID, ORE MODEL AND DEPTH SLICE OF THE VANADIUM DEPOSIT



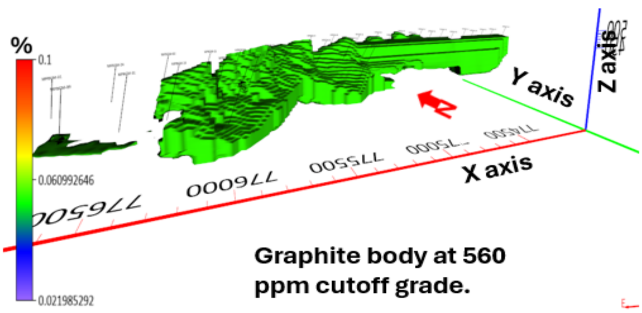
The vanadium body dips northward, with the central to western portion exhibiting excellent vanadium quality.

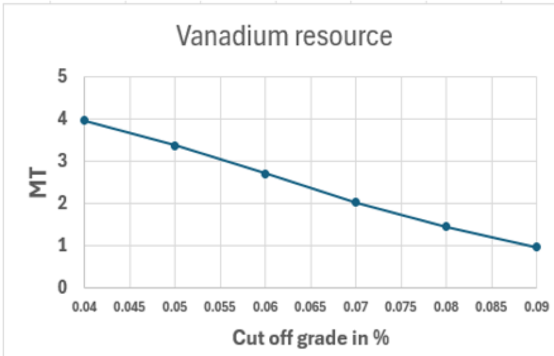
Figure 11. Solid model and ore model of Vanadium.

Resource estimation of vanadium within the graphite ore was carried out through resource modelling, delineating ore bodies at a cut-off grade of 560 ppm resulting in an estimated 2.71 million tonnes as shown in figure 12. Additionally, resources are calculated for various cut-off grades to support comparative analysis and economic evaluation.

VANADIUM RESOURCES ESTIMATION

Graphite body at 560 ppm cutoff grade.





Vanadium Resource	
Cut off %	Millon Tonnage
0.04	3.96
0.05	3.37
0.06	2.7
0.07	2.03
0.08	1.44
0.09	0.96

The vanadium resource is around 3 MT at 560 ppm cut off grade. 3D visualization enables more accurate resource estimation and planning.

GSI resource estimation
The vanadium resource in the Golighat block is calculated solely using the cross-section method. The total estimated resource for vanadium (V) in the Golighat block amounts to 2.72 million tones at a cut-off grade of 560ppm (V_2O_5-999.712 ppm), with an average grade of 820 ppm (V_2O_5-1463.864 ppm) of vanadium across a strike length of 1292.75 m and an average thickness of 10.18 m.

Figure 12. Resource estimation of Vanadium ore at different cutoff grade.

The vanadium resource in the Golighat block is calculated by GSI solely using the cross-section method. The total estimated resource for vanadium (V) in the Golighat block amounts to 3 million tones at a cut-off grade of 560 ppm (V_2O_5-999.712 ppm), with an average grade of 820 ppm (V_2O_5-1463.864 ppm) of vanadium across a strike length of 1292.75 m and an average thickness of 10.18 m.

The Vanadium resource is around 3 Millon tonnes at 560 cut off grads. Additionally, resources are calculated for various cut-off grades to support comparative analysis and economic evaluation. 3D visualization facilitate pinpoint the best resource areas for mine planning other facilities arrangements to increase the profitability significantly without any wastage.

With further exploration and feasibility studies, these resources hold the potential to be upgraded to a higher category (e.g., 331).

16. Acknowledgement

We gratefully acknowledge the invaluable support and encouragement for innovation extended by the Ministry of Mines, Government of India, in enabling access to critical geological and mineral resource data.

We extend our sincere gratitude to JNARDDC for the opportunity and to the expert committee of 25 members—comprising specialists from IBM, GSI, CSIR-NGRI, HZL, NALCO, three IITs, and other esteemed institutions—for their rigorous, year-long verification and validation under the S&T PRISM-2 program. We are deeply grateful for our selection under the S&T PRISM-2 program and for the invaluable opportunity to present and validate the mineral estimation results generated by our AI-powered software solution, *MineAIex*, before a distinguished panel of technical experts and stakeholders appointed by the Ministry.

This collaborative engagement has played a crucial role in testing and enhancing the robustness, accuracy, and compliance of *MineAIex* with the evolving standards of mineral resource reporting in India and abroad. We look forward to continued collaboration in advancing innovation in the field of mineral exploration and estimation.