

**GEOLOGICAL REPORT ON PRELIMINARY  
EXPLORATION (G3) FOR MANGANESE AND GRAPHITE  
IN**

**BHARATBAHAL BLOCK (2.013 SQ KM)  
DISTRICT: BALANGIR, ODISHA**

**Report submitted under the Mineral (Evidence of Mineral Content) Rules-2015  
(Amended up to 2021)**

**TEXT, ANNEXURE**



**MINERAL EXPLORATION AND CONSULTANCY LIMITED**  
*(Formerly known as Mineral Exploration Corporation Limited)*

A Government of India Enterprises  
CORPORATE OFFICE, NAGPUR

**March 2025**

## LIST OF CONTENTS TEXT

CHAPTER NO.	DESCRIPTION	PAGE NO.
	<b>कार्यकारी सारांश</b>	<b>क-ि</b>
	<b>EXECUTIVE SUMMARY</b>	<b>i-v</b>
	<b>CHAPTER- 1</b>	
<b>1.0.0</b>	<b>INTRODUCTION</b>	<b>1-4</b>
	<b>CHAPTER- 2</b>	
<b>2.0.0</b>	<b>DETAILS OF THE QUALIFIED PERSON(S)/ EXPLORATION AGENCY</b>	<b>5-6</b>
2.1.0	Investigating agency	5
2.2.0	Qualified persons	5-6
	<b>CHAPTER- 3</b>	
<b>3.0.0</b>	<b>TITLE AND OWNERSHIP</b>	<b>7-8</b>
3.1.0	Title of the report	7
3.2.0	Details about period of prospecting	7-8
	<b>CHAPTER- 4</b>	
<b>4.0.0</b>	<b>DETAILS OF THE AREA</b>	<b>9-11</b>
4.1.0	Location and accessibility of the block	9
4.2.0	Details of the area with land use	9
4.3.0	Mineral(s) under investigation	10
	<b>CHAPTER- 5</b>	
<b>5.0.0</b>	<b>PHYSIOGRAPHY AND ENVIRONMENT</b>	<b>12-16</b>
5.1.0	Relief of the area with minimum and maximum elevation, drainage pattern, natural water courses, reservoirs, etc.	12
5.2.0	Roads, railway track, electric transmission line, telephone line, etc.	12-13
5.3.0	Socio demographic profile of the area and nearby	13-14
5.4.0	Historical sites and archaeological monuments, places of worship, public utilities etc.	14
5.5.0	Forest, sanctuaries, national park and wild life sanctuaries etc.	14
5.6.0	Flora and fauna	14-15
5.7.0	Water bodies	15
5.8.0	Climatic condition	16
	<b>CHAPTER- 6</b>	
<b>6.0.0</b>	<b>INFRASTRUCTURE AND ENVIRONMENT</b>	<b>17</b>
6.1.0	Local infrastructure, host population, historical sites, forests, sanctuaries, national park and environmental setting of the area	17

<b>CHAPTER NO.</b>	<b>DESCRIPTION</b>	<b>PAGE NO.</b>
	<b>CHAPTER- 7</b>	
<b>7.0.0</b>	<b>GEOLOGY OF THE AREA</b>	<b>18-24</b>
7.1.0	Regional geology	18-19
7.2.0	Regional structure	19-21
7.3.0	Metamorphism in the region	21
7.4.0	Regional mineralisation	22
7.5.0	Geology of the block	22-23
7.6.0	Description of rock types	23-24
7.7.0	Metamorphism	24
	<b>CHAPTER- 8</b>	
<b>8.0.0</b>	<b>PREVIOUS WORK</b>	<b>25-30</b>
8.1.0	Details of previous exploration carried out by other agencies/parties	25-30
	<b>CHAPTER- 9</b>	
<b>9.0.0</b>	<b>GEOPHYSICAL SURVEY</b>	<b>31-38</b>
9.1.0	Introduction	31-32
9.2.0	Geophysical activities	33-37
9.3.0	Conclusion and recommendations	38
	<b>CHAPTER- 10</b>	
<b>10.0.0</b>	<b>EXPLORATION UNDERTAKEN DURING CURRENT INVESTIGATION</b>	<b>39-57</b>
10.1.0	Introduction	39
10.2.0	Objectives of investigation	39-40
10.3.0	Details of exploration activity taken up	40-41
10.4.0	Survey	41
10.5.0	Geological mapping	42
10.6.0	Trench	42-44
10.7.0	Drilling	44-46
10.8.0	Data Spacing for Reporting of Exploration Results	46
10.9.0	Petrographic studies	46-48
10.10.0	Mineragraphic studies	48-50
10.11.0	Analysis of 34 elements by ICPMS	50
10.12.0	Raman spectroscopy	50-54
10.13.0	Mineralization	55-57
10.14.0	Outcomes of the investigation taken up	57-59
	<b>CHAPTER- 11</b>	
<b>11.0.0</b>	<b>LOCATION OF DATA POINTS</b>	<b>60</b>

CHAPTER NO.	DESCRIPTION	PAGE NO.
	<b>CHAPTER- 12</b>	
<b>12.0.0</b>	<b>SAMPLING TECHNIQUE</b>	<b>61-62</b>
12.1.0	Nature and quality of sampling and measures taken to ensure sample representativity	61-62
	<b>CHAPTER- 13</b>	
13.0.0	<b>DRILLING TECHNIQUES AND DRILL SAMPLING EMPLOYED</b>	<b>63-66</b>
13.1.0	Drilling Types and Details	63-64
13.2.0	Core recovery	64
13.3.0	Whether Core and Chip Sample Recoveries have been properly recorded and results Assayed	64-65
13.4.0	Measures taken to maximize sample recovery and ensure representative nature of the samples	65
13.5.0	Whether the relationship exists between sample recovery and grade	65
13.6.0	Core logging	65-66
	<b>CHAPTER- 14</b>	
<b>14.0.0</b>	<b>SUB SAMPLING TECHNIQUES AND SAMPLE PREPARATION</b>	<b>67-68</b>
	<b>CHAPTER- 15</b>	
<b>15.0.0</b>	<b>QUALITY OF ASSAY DATA AND LABORATORY TESTS</b>	<b>69-73</b>
15.1.0	The nature, quality and appropriateness of the assaying and laboratory procedures	69
15.2.0	Primary and check sample studies of trench and borehole sampling	70-73
15.3.0	Security and chain of control of samples should be clearly mentioned	73
	<b>CHAPTER- 16</b>	
<b>16.0.0</b>	<b>MOISTURE</b>	<b>74</b>
	<b>CHAPTER- 17</b>	
<b>17.0.0</b>	<b>SPECIFIC GRAVITY/BULK DENSITY DETERMINATION</b>	<b>75-76</b>
	<b>CHAPTER- 18</b>	
<b>18.0.0</b>	<b>BENEFICIATION STUDIES</b>	<b>77</b>
	<b>CHAPTER- 19</b>	

<b>CHAPTER NO.</b>	<b>DESCRIPTION</b>	<b>PAGE NO.</b>
<b>19.0.0</b>	<b>RESOURCE ESTIMATION TECHNIQUE</b>	<b>78-83</b>
19.1.0	Discussion on data density to assure continuity of mineralisation	78
19.2.0	Whether previous exploration data has been used	78
19.3.0	The nature and appropriateness of the estimation technique(s) applied and key assumptions	78-79
19.4.0	The basis for classification of the mineral resources	79
19.5.0	The assumptions made regarding recovery of by products	79
19.6.0	Detailed description of the method used and the assumptions made to estimate tonnage and grades	80-83
19.7.0	Description of basis for using or not using grade cutting or capping	83
19.8.0	Geostatistical methods	83
	<b>CHAPTER- 20</b>	
<b>20.0.0</b>	<b>REPORTING OF RESOURCES</b>	<b>84-86</b>
	<b>CHAPTER- 21</b>	
<b>21.0.0</b>	<b>SUMMARY AND RECOMMENDATIONS</b>	<b>87-89</b>
21.1.0	Summary	87-88
21.2.0	Recommendations	88-89
	<b>CHAPTER- 22</b>	
<b>22.0.0</b>	<b>PLATES AND MAPS</b>	<b>90</b>
	<b>CHAPTER- 23</b>	
<b>23.0.0</b>	<b>ANNEXURE / ENCLOSURES TO THE REPORT</b>	<b>91</b>
	<b>CHAPTER- 24</b>	
<b>24.0.0</b>	<b>ANY OTHER INFORMATION</b>	<b>92</b>
	<b>CHAPTER- 25</b>	
<b>25.0.0</b>	Certificate	93
	List Of Personnel Associated	94
	References	95

## LIST OF ANNEXURE

ANNEXURE No.	TITLE	PAGES
I	Project approval	2
II	Details of survey stations	1
III	Bed rock sample details and chemical analysis	1
IV	Trench sample details and chemical analysis	2
V	Details of boreholes drilled in Bharatbahal block	1
VI	Detailed lithologs of boreholes drilled during G4 work	16
VII	Summary of lithologs of boreholes drilled during G4 work	5
VIII	Detailed lithologs of boreholes drilled during G3 work	29
IX	Summary of lithologs of boreholes drilled during G3 work	9
X	Petrography study results	3
XI	Mineragraphy study results	1
XII	Details of primary borehole samples and chemical analysis for Mn during G4 work	2
XIII	Details of primary borehole samples and chemical analysis for graphite during G4 work	1
XIV	Details of primary borehole samples and chemical analysis for mn during G3 work	2
XV	Details of primary borehole samples and chemical analysis for graphite during G3 work	2
XVI	Comparison between primary vs. External for manganese	1
XVII	Comparison between primary vs. external graphite	1
XVIII	Geological resources estimated for manganese	1
XIX	Geological resources estimated for graphite	2
XX	Analytical results of borehole samples for 34 elements	1
XXI	Peer reviewer's comments	3
XXII	Raman Spectroscopy Study Results	15
XXIII	Peer reviewer's comments and complainces	2

## LIST OF PLATES

PLATE No.	TITLE	R.F.
I	Location Map	1:50,000
II	Topographical Map	1:2,000
III	Geological Map	1:2,000
IV	Trench Profile	1:100
V	Geological Cross Section	1:1000

## LIST OF TABLES

Table No.	Title	Page No.
Table 2.1	List of qualified persons involved in Exploration for manganese and graphite in Bharatbahal Block, Balangir District, Odisha.	6
Table 4.1	DGPS co-ordinates (WGS-84) of the boundary corner points of Bharatbahal block, Balangir district, Odisha.	9
Table 5.1	Stratigraphic succession of the area (after GSI),	19
Table 9.1	Geophysical instrument details	31-32
Table 9.2	Proposed boreholes interpreted through geophysical survey in Bharatbahal block, Balangir District, Odisha	38
Table 10.1	Quantum of work approved vs achieved in Bharatbahal block, Balangir District, Odisha	40-41
Table: 10.2	Details of trenches and mineralized details in Bharatbahal block, Balangir District, Odisha	44
Table 10.3	Boreholes drilled (G3) in Bharatbahal block, Balangir District, Odisha.	45
Table 10.4	Boreholes drilled (G4) in Bharatbahal block, Balangir District, Odisha.	46
Table 10.5	Details of sample studied under Raman Spectroscopy.	50
Table 10.6	Manganese ore intersected in the boreholes in Bharatbahal Bharatbahal block, Balangir District, Odisha.	55-56
Table 10.7	Graphite bands intersected in the boreholes in Bharatbahal block, Balangir District, Odisha.	57
Table 10.8	Details of mineralized bodies in the Bharatbahal block, Balangir District, Odisha.	58
Table-15.1	Comparison of primary vs. External check manganese samples In Bharatbahal block, Balangir District, Odisha.	70
Table-15.2	Comparison of primary vs. External check graphite samples In Bharatbahal block, Balangir District, Odisha.	72
Table 17.1	Details of specific gravity determination of borehole samples for graphite in kanaital block, Balangir District, Odisha.	75
Table 17.2	Specific gravity determination in the surrounding area	76
Table 19.1	Manganese Ore Resources Estimated By Geological Cross Section Method At 10.0% Manganese Threshold Value (1.5m Maximum Non-Ore Parting, Tonnage Factor 2.79), In Bharatbahal block, Balangir District, Odisha.	85
Table 19.2	Graphite Ore Resources Estimated By Geological Cross Section Method At 2.0% F.C. Threshold Value (1.00m Maximum Non-Ore Parting, Tonnage Factor 2.68), Bharatbahal block lock, Balangir District, Odisha.	86

## LIST OF TEXT FIGURES

FIGURE NO.	TITLE	PAGE NO.
Text Fig. 4.1	Google image showing location of the Bharatbahal Manganese and Graphite Block (G3), Balangir District, Odisha.	11
Text Fig. 7.1	Location of the Bharatbahal Block on regional geological map of Eastern Ghat Mobile Belt (EGMB).	18
Text Fig. 8.1	Map showing potential areas on regional geological map identified during G4 exploration of Larambha-Kanaital and Bharatbahal-Puddapadar Block, Balangir, Odisha.	30
Text Fig. 9.1	Sketch showing potential areas covered by geophysical survey during reconnaissance survey in Larambha-Kanaital and Bharatbahal-Pudapadar Block along with present Bharatbahal Block.	32
Text Fig. 9.2	Total Magnetic Intensity (TMI) map of Area-3 with in the Bharatbahal Manganese and Graphite Block (G3).	33
Text Fig. 9.3	Analytical signal of RTP response of magnetic data in Area-3 (Bharatbahal Block).	36
Text Fig. 9.4	50m upward continuation map of RTP in Area-3 (Bharatbahal Block (G3))	36
Text Fig. 9.5	Analytical Signal Map of TMI in the Bharatbahal Manganese and Graphite Block (G3) with proposed borehole locations	37
Text Fig. 9.6	SP response in Area-3 (Bharatbahal manganese and graphite Block)	37
Text Fig. 10.1	LRS peaks of sample No.-1(MBMGRS-1)	52
Text Fig. 10.2	LRS peaks of sample No.-1(MBMGRS-2)	53
Text Fig. 10.3	LRS peaks of sample No.-1(MBMGRS-3)	53
Text Fig. 10.4	LRS peaks of sample No.-1(MBMGRS-4)	54
Text Fig. 10.5	LRS peaks of sample No.-1(MBMGRS-5)	54
Text Fig. 15.1	Scatter Plot of Primary and External Check Samples for Mn%	71
Text Fig. 15.2	Scatter Plot of Primary and External Check Samples for FC%	72
Text Fig. 19.1	Typical geological cross section along sectin line S8-S8'	82



## LIST OF PHOTOGRAPHS

PHOTO No.	TITLE	PAGE NO.
10.1	Field photographs showing Trench 2	43
10.2	Photograph showing drill cores of Borehole No. MBMG-8	58
10.3	Photograph showing drill cores of Borehole No. MBMG-4	59
12.1	Photograph showing drill cores of Borehole No. MKMG-8	62
13.1	Photograph showing drill cores of Borehole No. MBMG-3	63
13.2	Photograph showing drill cores of Borehole No. MBMG-8	64

## LIST OF PHOTOMICROGRAPHS

PHOTO-MICROGRAPH No.	TITLE	PAGE NO.
Pmg – 1	Photomicrograph showing association of microcline, quartz and pyroxenes in pyroxene granulite as seen under crossed nicols. Specimen No.: MBMGP-01 (MBMG-02/ 12.50m – 12.60m) Magnification: 40X	47
Pmg – 2	Photomicrograph showing association of quartz, diopside, scapolite and feldspar in meta-calc silicate as seen under crossed nicols. Specimen No.: MBMGP-02 (MBMG-02/ 14.20m – 14.30m) Magnification: 40X	48
Pmg – 3	Photomicrograph showing fine to medium plates and flaky aggregates aligned along the foliation and associating fine to medium anhedral grains of pyrite as seen under reflected light. Specimen No.: MBMGM-01 (MBMG-08/70.40-70.50m) Magnification: 100X	48
Pmg – 4	Photomicrograph showing medium to moderately coarse flaky aggregates of graphite as seen under reflected light. Specimen No.: MBMGM-04(MBMG-05/76.10-76.20m) Magnification: 100X	49
Pmg – 5	Photomicrograph showing intermixed patches of psilomelane and goethite as seen under reflected light. Specimen No.: MBMGM-05(MBMG-05/11.60-11.70m) Magnification : 100X.	50

## भरतबहाल ब्लॉक में मैंगनीज और ग्रेफाइट के लिए प्रारंभिक गवेषण(जी3) पर भूवैज्ञानिक रिपोर्ट जिला: बलांगीर, ओडिशा

### कार्यकारी सारांश

#### परिचय

भारत में मैंगनीज अयस्क का गवेषण महत्वपूर्ण है क्योंकि मैंगनीज स्टील, बैटरी और उर्वरक सहित कई उद्योगों में एक महत्वपूर्ण घटक है। मैंगनीज मिश्र धातु स्टील उत्पादन का एक महत्वपूर्ण घटक है, और स्टील किसी देश की औद्योगिक अर्थव्यवस्था के विकास के सबसे महत्वपूर्ण संकेतकों में से एक है। भारत ने 2030-31 तक 300 मिलियन टन स्टील उत्पादन क्षमता का लक्ष्य रखा है। आने वाले वर्षों में मैंगनीज अयस्क की मांग में लगभग 10 मिलियन टन प्रति वर्ष की वृद्धि होने की उम्मीद है। उच्च श्रेणी के मैंगनीज अयस्क के भंडार सीमित हैं और मैंगनीज आधारित मिश्र धातु उद्योग की मांग को देखते हुए कुल उत्पादन बहुत कम और अत्यधिक अपर्याप्त है। उन्नत तकनीक के साथ लीन ग्रेड का उपयोग समय की मांग है।

संशोधित एमएमडीआर अधिनियम 2023 के अनुसार ग्रेफाइट राष्ट्र के लिए एक महत्वपूर्ण और रणनीतिक खनिज है। देश में उच्च श्रेणी के ग्रेफाइट भंडार सीमित हैं। ओडिशा, झारखंड, जम्मू और कश्मीर और केरल के ज्ञात क्षेत्रों में ग्रेफाइट भंडारों की विस्तृत गवेषण की जानी चाहिए ताकि अधिक से अधिक संसाधनों की स्थापना की जा सके और संसाधनों को भंडार में परिवर्तित किया जा सके और नए भंडारों की खोज की जा सके।

चर्चा के अंतर्गत परियोजना मैंगनीज और ग्रेफाइट की मांग को कुछ हद तक कम करने तथा ब्लॉकों को आगे खनन के लिए नीलामी योग्य बनाने का एक तरीका है।

#### स्थान और पहुंच

भरतबहाल मैंगनीज और ग्रेफाइट ब्लॉक ओडिशा के बलांगीर जिले में आता है। यह अक्षांश 20°48'49.32068"N और 20°47'53.99444"N तथा देशांतर 83°13'44.12474"E और 83°14'26.38448"E के बीच स्थित है। यह ब्लॉक 2.013 वर्ग किलोमीटर के क्षेत्र में फैला हुआ है और सर्वे ऑफ इंडिया टोपोगीट संख्या 64P/01 के अंतर्गत आता है।

यह ब्लॉक राज्य राजमार्ग 42 से अच्छी तरह जुड़ा हुआ है जो बलांगीर - पटनागढ़-कांताबंजी को जोड़ता है और भरतबहाल ब्लॉक से 10 किमी दक्षिण में गुजरता है। यह ब्लॉक जिला मुख्यालय बलांगीर से

लगभग 50 किमी दूर स्थित है। ब्लॉक तक पाटनगढ़ तहसील से पहुंचा जा सकता है जो ब्लॉक से 20 किमी दक्षिण-पश्चिम में स्थित है।

### **ब्लॉक का भूविज्ञान और संरचना**

इस क्षेत्र में विस्तृत समतल भूमि और न्यून पड़े हुए टीले हैं। ब्लॉक क्षेत्र में औसत ऊंचाई लगभग 221 mRL है। ब्लॉक क्षेत्र सुकटेल नदी के जलग्रहण क्षेत्र के बीच में आता है। गवेषण क्षेत्र पूर्वी घाट सुपरग्रुप के उत्तरी भाग में स्थित है और इस क्षेत्र में उजागर चट्टानें प्री-कैम्ब्रियन युग की हैं जो खोंडालाइट समूह द्वारा दर्शाए गए मेटा-अवसादीय अनुक्रम से संबंधित हैं।

ब्लॉक में मानचित्रित / बोरहोल में प्रतिच्छेदित महत्वपूर्ण लिथो इकाइयां मिट्टी, मैंगनीज अयस्क, खोंडालाइट, कैल्क-सिलिकेट / कैल्क-ग्रेन्यूलाइट, पाइरोक्सेनाइट ग्रेन्यूलाइट और क्वार्टजाइट हैं, जो ग्रेन्यूलाइट संलक्षणी स्थितियों के तहत उच्च श्रेणी के कार्यांतरण से गुजरे हैं, जो पूर्वी घाट सुपर ग्रुप ऑफ रॉक्स की विशेषता है।

ब्लॉक के मध्य भाग में असंतत लेंसोइडल बॉडी के रूप में पाया जाता है। उत्तर और दक्षिण बैंड के रूप में दो बैंड स्थापित किए गए हैं, जो संलग्न संरचनाओं के नतिलंब के समानांतर संरेखित हैं। उनके प्रदर्शन ऊबड़-खाबड़ बोल्टर के रूप में हैं। स्वस्थाने खनिज पिंड प्लोट अयस्कों से घिरा हुआ है। मैंगनीज अयस्क पिंड बैंड, लेंस, पॉकेट, बेंस, सारणीबद्ध पिंडों और चट्टानों के खोंडालाइट समूह (ज्यादातर खोंडालाइट और क्वार्टजाइट के साथ) के भीतर प्रसार के रूप में पाए जाते हैं। अधिकांश स्थानों पर ट्रेचिंग में प्रतिच्छेदित मैंगनीज बैंड में गहराई की निरंतरता नहीं है या सतह से कुछ मीटर नीचे पिचिंग हो गया है जिसका आकलन वेधनसे किया गया है। यह उपसतह में खनिज पिंड की लैटिकुलर प्रकृति के कारण हो सकता है। मैंगनीज खनिजकरण ब्लॉक के मध्य भाग में 930 मीटर की नतिलंब लंबाई में दो असंतत बैंड के साथ होता है। (उत्तरी बैंड- 488 मीटर और दक्षिण बैंड- 447.60 मीटर नतिलंब लंबाई)। अयस्क पिंड की पार्श्विक और ऊर्ध्वाधर रूप से पिचिंग और स्वेलिंग प्रकृति के कारण चौड़ाई 2.00 मीटर से 15.20 मीटर तक भिन्न होती है। ब्लॉक में 40 मीटर की ऊर्ध्वाधर गहराई तक मैंगनीज का संवर्धन विकसित किया गया है। (क्रॉस सेक्शन S1, S3, S4 और S6)। सामान्य तौर पर, ऑक्साइड खनिज यानी पाइरोलुसाइट और साइलोमेलन पाइराइट, चाल्कोपीराइट और मैग्नेटाइट से जुड़े होते हैं जो सुपरजीन संवर्धन निक्षेप का संकेत देते हैं। खनिजकरण की सामान्य प्रवृत्ति उत्तर-पूर्वोत्तर-दक्षिण-पश्चिम है और उत्तर-पश्चिम की ओर 50° से 80° की मात्रा के साथ नति है।

ब्लॉक में ग्रेफाइट के लिए मेजबान चट्टान खोंडालाइट है। ग्रेफाइट मध्यम से महीन परतदार/प्रिज्मीय कणों और फैले हुए समुच्चय के रूप में होता है, जो अक्सर मैग्नेटाइट, पाइराइट, चाल्कोपीराइट और

अन्य सल्फाइड से जुड़े किक बैंड दिखाते हैं। ग्रेफाइट खनिजकरण/ग्रेफाइट क्षेत्र सतह पर शायद ही उजागर होते हैं और मुख्य रूप से खाइयों और बोरहोल में प्रतिच्छेदित होते हैं। ग्रेफाइट खनिजकरण मैंगनीज खनिजकरण क्षेत्र के भीतर या बाहर होता है। ग्रेफाइट की सांद्रता 60 मीटर की ऊर्ध्वाधर गहराई तक विकसित हुई है, जिसमें पिंगिंग और प्रकृति में स्वेलिंग है। (उत्तरी बैंड- 150 मीटर और दक्षिण बैंड-100 मीटर नतिलंब लंबाई)।

### **वर्तमान जांच के दौरान किए गए गवेषण**

आसपास के क्षेत्रों में जी4 गवेषण के परिणामों और स्थापित क्षमता के आधार पर, ब्लॉक को जी3 चरण में उन्नयन के लिए लिया गया था। गवेषण गतिविधियों के प्रमुख घटकों में 1:2000 पैमाने पर विस्तृत भूवैज्ञानिक मानचित्रण और स्थलाकृतिक सर्वेक्षण, खनिज पिड़ों की नतिलंब निरंतरता स्थापित करने के लिए ट्रेचिंग (90 घन मीटर) और गुणवत्ता और मात्रा के साथ उपसतह में पार्श्व और ऊर्ध्वाधर निरंतरता साबित करने के लिए वेधन(08 बोरहोल में 496 मीटर) शामिल हैं। इसके अलावा, खाइयों और बोरहोल से क्रमशः मैंगनीज और ग्रेफाइट के लिए 84 और 93 प्राथमिक नमूने तैयार किए गए थे। मैंगनीज और ग्रेफाइट के लिए कुल 08 और 09 बाहरी जांच नमूने तैयार किए गए। अन्वेषण के दौरान पेट्रोग्राफिक, मिनराग्राफिक अध्ययन, विशिष्ट गुरुत्व निर्धारण और 34 तत्व विश्लेषण के लिए 05 नमूने हर एक कार्य के लिए तैयार किए गए। लेजर रमन स्पेक्ट्रोस्कोपी के तहत 05 नमूनों का अध्ययन किया गया। उपरोक्त के अलावा, 16 बेडरॉक नमूने, चुंबकीय और एसपी सर्वेक्षण के लिए 0.65 वर्ग किमी की सीमा तक भूभौतिकीय सर्वेक्षण और जी4 कार्य के दौरान ब्लॉक में किए गए 05 बोरहोल के साथ 259 मीटर वेधनपर भी विचार किया गया है।

### **खनिज**

ब्लॉक के मध्य भाग में असंतत लेंसोइडल बॉडी के रूप में पाया जाता है। दो बैंड उत्तर और दक्षिण बैंड के रूप में स्थापित किए गए हैं, जो संलग्न संरचनाओं के नतिलंब के समानांतर संरेखित हैं। उनके प्रदर्शन ऊबड़-खाबड़ बोल्टर के रूप में हैं। स्वस्थाने खनिजयुक्त बॉडी प्लोट अयस्कों से घिरी हुई है। मैंगनीज अयस्क पिड़ बेंड, लेंस, पॉकेट, वेंस, सारणीबद्ध पिड़ों और चट्टानों के खोंडालाइट समूह (ज्यादातर खोंडालाइट और कार्टजाइट के साथ) के भीतर प्रसार के रूप में पाए जाते हैं। अधिकांश स्थानों पर ट्रेचिंग में प्रतिच्छेदित मैंगनीज बैंड में गहराई की निरंतरता नहीं है या सतह से कुछ मीटर नीचे पिंगिंग हो गया है जिसका आकलन वेधनसे किया गया है। यह उपसतह में खनिजयुक्त बॉडी की लेंटिकुलर प्रकृति के कारण हो सकता है। मैंगनीज खनिजकरण ब्लॉक के मध्य भाग में 930 मीटर की नतिलंब लंबाई में दो असंतत बैंड के साथ होता है। (उत्तरी बैंड- 488 मीटर और दक्षिण बैंड- 447.60 मीटर नतिलंब

लंबाई)। अयस्क पिंड की पार्श्विक और ऊर्ध्वाधर रूप से पिंचिंग और सूजन प्रकृति के कारण चौड़ाई 2.00 मीटर से 15.20 मीटर तक भिन्न होती है। मैंगनीज का संवर्धन 40 मीटर की ऊर्ध्वाधर गहराई तक विकसित किया गया है। (क्रॉस सेक्शन S1, S3, S4 और S6)। सामान्य तौर पर, ऑक्साइड खनिज यानी पाइरोलुसाइट और साइलोमेलन, पाइराइट, चाल्कोपीराइट और मैग्नेटाइट से जुड़े होते हैं जो सुपरजीन संवर्धन निक्षेप का संकेत देते हैं। खनिजीकरण की सामान्य प्रवृत्ति उत्तर-पूर्व-दक्षिण-पश्चिम ढलान है, जो उत्तर-पश्चिम की ओर 50° से 80° तक है।

ब्लॉक में ग्रेफाइट के लिए मेजबान चट्टान खोंडालाइट है। ग्रेफाइट मध्यम से महीन परतदार/प्रिज्मीय कणों और फैले हुए समुच्चय के रूप में होता है, जो अक्सर मैग्नेटाइट, पाइराइट, चाल्कोपीराइट और अन्य सल्फाइड से जुड़े किंक बैंड दिखाते हैं। ग्रेफाइट खनिजकरण/ग्रेफाइट क्षेत्र सतह पर शायद ही उजागर होते हैं और मुख्य रूप से ट्रेचिंग और बोरहोल में प्रतिच्छेदित होते हैं। ग्रेफाइट खनिजकरण मैंगनीज खनिजकरण क्षेत्र के भीतर या बाहर होता है। ग्रेफाइट की सांद्रता 60 मीटर की ऊर्ध्वाधर गहराई तक विकसित हुई है, जिसमें पिंचिंग और स्वेलिंग प्रकृति है। (उत्तरी बैंड- 150 मीटर और दक्षिण बैंड-100 मीटर नतिलंब लंबाई)।

### संसाधन

मैंगनीज और ग्रेफाइट इस क्षेत्र में खोंडालाइट्स से जुड़े असंतत बैंड के रूप में पाए जाते हैं। ज्यादातर ग्रेफाइट, ग्रेफाइट समृद्ध शिस्ट के रूप में होता है। खनिज क्षेत्र पार्श्व और ऊर्ध्वाधर दिशा में अनियमित हैं। असंतत, लेंसोइडल, पॉकेट प्रकार के मैंगनीज और ग्रेफाइट खनिजकरण और डेटा बिंदुओं के अंतराल को ध्यान में रखते हुए, ब्लॉक के कुल संसाधनों को UNFC प्रणाली के अनुसार कोड 333 के साथ "अनुमानित खनिज संसाधन" के रूप में वर्गीकृत किया जा सकता है और खनिज (खनिज सामग्री के साक्ष्य) नियम-2015 में दिए गए विनिर्देशों को 2021 तक संशोधित किया जा सकता है।

भूवैज्ञानिक क्रॉस सेक्शन विधि द्वारा अनुमानित मैंगनीज अयस्क संसाधन 0.45 मिलियन टन है 10% Mn थ्रेशोल्ड मान पर 19.62% Mn की औसत ग्रेड के साथ 930 मीटर की नतिलंब लंबाई पर।

भूवैज्ञानिक क्रॉस सेक्शन विधि द्वारा अनुमानित ग्रेफाइट अयस्क संसाधन 250 मीटर की लंबाई पर 0.59 मिलियन टन (एमटी) है, जिसका औसत ग्रेड 2 % एफसी थ्रेशोल्ड मान पर 4.10% FC है।

## सिफारिश

भरतबहाल ब्लॉक में मैंगनीज और ग्रेफाइट खनिज निम्न श्रेणी का है। हालांकि, इसमें ऐसी क्षमता है जो व्यवस्थित वैज्ञानिक खनन के लिए उपयुक्त होगी। गवेषण के वर्तमान चरण में, ब्लॉक को समग्र लाइसेंस के रूप में नीलाम किया जा सकता है।

गवेषण के अगले चरण में परतदार ग्रेफाइट की प्राप्ति को अधिकतम करने के लिए ऐसे निम्न-श्रेणी के ग्रेफाइट अयस्कों पर लाभकारी अध्ययन किया जा सकता है।

खनिजयुक्त पिंडों की असंतत और लेन्टीक्यूलर प्रकृति के कारण, गुणवत्ता और मात्रा के साथ-साथ अयस्क पिंडों के त्रि-आयामी व्यवहार का आकलन करने के लिए निकट अंतराल वेधन (50 मीटर नतिलंब अंतराल) की योजना बनाई जा सकती है।

आस-पास के ब्लॉक ( लारम्भा और कनैताल जी3 ब्लॉक) में वैनेडियम (लगभग 500 पीपीएम) की रिपोर्ट की गई है, जो हमेशा ग्रेफाइट से जुड़ा होता है। इसलिए, वेधनके अगले चरण के दौरान नियमित अंतराल पर सैंपलिंग की जा सकती है ताकि ग्रेफाइट के भीतर वैनेडियम समृद्ध क्षेत्रों को चित्रित किया जा सके और इसकी गुणवत्ता और मात्रा का आकलन किया जा सके। इसके अलावा, खनिज चरण अध्ययन भी किए जा सकते हैं।

**GEOLOGICAL REPORT ON PRELIMINARY EXPLORATION (G3) FOR  
MANGANESE AND GRAPHITE IN BHARATBAHAL BLOCK  
DISTRICT: BALANGIR, ODISHA**

**EXECUTIVE SUMMARY**

**INTRODUCTION**

Manganese ore exploration in India is important because manganese is a key component in many industries, including steel, batteries, and fertilizers. Manganese alloys are an important component of steel production, and steel is one of the most important indicators of a country's industrial economy's growth. India has set a production capacity target of 300 million tonnes of steel by 2030-31. The demand for manganese ore is expected to raise commensurately to about 10 million tonnes per year in the coming years. The reserves of high-grade manganese ore are limited and the overall production is very low and highly inadequate, considering the demand of the manganese-based alloy industry. Utilization of lean grade with advanced technology is need of the hour.

Graphite is a critical and strategic mineral for the nation as per the ammended MMDR Act 2023. The high grade graphite reserves are rather limited in the country. Detailed exploration of graphite deposits in the known areas Odisha, Jharkhand, Jammu & Kashmir and Kerala should be carried out to establish more and more resources and conversion of resources to reserves and finding of new deposits is the need of the hour.

The project under discussion is an approach to mitigate the demand of the manganese and graphite to some extent and make the blocks auctionable for further mining.

**LOCATION AND ACCESSIBILITY**

Bharatbahal Manganese and Graphite Block falls in Balangir district, Odisha. It lies between latitudes 20°48'49.32068"N and 20°47'53.99444"N and longitudes 83°13'44.12474"E and 83°14'26.38448"E. The block covers an area of 2.013 sq km and falls within the Survey of India Toposheet No 64P/01.

The block is well connected with the State Highway 42 which connects Balangir –Patnagarh-Kantabanji and passes 10km south of the Bharatbahal block. The block is located around 50km from the district head quarter Balangir. The block can be approached from Patnagarh tehsil which is located 20km south-west of the block.

## **GEOLOGY AND STRUCTURE OF THE BLOCK**

The area comprises wide spread plain land and low lying mounds. Average elevation in the block area is around 221 mRL. The block area falls in between the catchment area of Suktel River. The exploration area lies in the northern part of the Eastern Ghats Supergroup and the rocks exposed in the area are of Pre-Cambrian age belonging to the meta-sedimentary sequence represented by Khondalite Group.

The important litho units mapped in the block / intersected in the boreholes are soil, manganese ore, khondalite, calc-silicate/calc-granulite, pyroxenite granulite and quartzite which has been undergone to high grade metamorphism under granulite facies conditions characterizes the Eastern Ghats Super Group of rocks.

In the area manganese occurs as discontinuous lensoidal body in the central part of the block. Two bands have been established as North and South Bands, which align parallel to strike of the enclosing formations. Their exposures are in rugged boulder form. Insitu mineralized body is surrounded by float ores. Manganese ore bodies occur as bands, lenses, pockets, veins, tabular bodies and disseminations within the khondalite group of rocks (mostly with khondalite and quartzite). In most of the places manganese bands intersected in the trenches have no depth continuity or pinching out within few meters below surface which has been assessed from the drilling. This may be due to lenticular nature of the mineralized body in subsurface. Manganese mineralization occurs over a strike length of 930m in the central part of the block with two discontinuous bands. (North Band- 488m and South Band-447.60m strike length). Due to pinching and swelling nature of the ore body laterally and vertically the width varies from 2.00m to 15.20m. Enrichment of manganese has been developed up to a vertical depth of 40m in the block. (Cross section S1, S3, S4 and S6). In general, oxide minerals i.e, pyrolusite and psilomelane associated with pyrite, chalcopyrite and magnetite indicate supergene enrichment deposit. General trend of the mineralization is NNE-SSW and dip with an amount 50° to 80° towards NW.

The host rock for graphite in the block is khondalite. The graphite occurs as medium to fine flaky/ prismatic grains and as disseminated aggregates, often showing kink bands associated with magnetite, pyrite, chalcopyrite and other sulphides. The graphite mineralization / graphite zones are hardly exposed on surface and mainly intersected in the trenches and boreholes. The graphite mineralisation occurs within or outside the manganese mineralization zone. Concentration of graphite has been developed up to a vertical depth of 60m with pinching and swelling in nature. (North Band- 150m and South Band-100m strike length).



## **EXPLORATION UNDERTAKEN DURING CURRENT INVESTIGATION**

On the basis of the outcomes of the G4 exploration in the surrounding areas of present block and the potentiality established, the block was taken up for up gradation to G3 stage. Major components of exploration activities include detailed geological mapping and topographical survey on 1:2000 scale, trenching (90 cu m) to establish the strike continuity of the mineralized bodies and drilling (496m in 08 boreholes) to prove the lateral and vertical continuity in subsurface along with the quality and quantity. In addition, to these 84 and 93 nos. of primary samples had been generated for manganese and graphite respectively from trenches and boreholes. A total of 08 and 09 nos. of external check samples were generated for manganese and graphite. 05 nos. of samples each for petrographic, mineragraphic studies, specific gravity determination and 34 element analysis were generated during the exploration. 05 nos. of samples were studied under Laser Raman Spectroscopy.

Apart from above, 16 bedrock samples, geophysical survey over an extent of 0.65 sq km for magnetic and SP survey and 259m of drilling with 05 boreholes carried out in the block during G4 work have also been considered.

## **MINERALIZATION**

Manganese occurs as discontinuous lensoidal body in the central part of the block. Two bands have been established as North and South Bands, aligned parallel to strike of the enclosing formations. Their exposures are in rugged boulder form. Insitu mineralized body is surrounded by float ores. Manganese ore bodies occur as bands, lenses, pockets, veins, tabular bodies and disseminations within the khondalite group of rocks (mostly with khondalite and quartzite). In most of the places manganese bands intersected in the trenches have no depth continuity or pinching out within few meters below surface which has been assessed from the drilling. This may be due to lenticular nature of the mineralized body in subsurface. Manganese mineralization occurs over a strike length of 930m in the central part of the block with two discontinuous bands. (North Band- 488m and South Band-447.60m strike length). Due to pinching and swelling nature of the ore body laterally and vertically the width varies from 2.00m to 15.20m. Enrichment of manganese has been developed up to a vertical depth of 40m. (Cross section S1, S3, S4 and S6). In general, oxide minerals i.e, pyrolusite and psilomelane associated with pyrite, chalcopyrite and magnetite indicate supergene enrichment deposit. General trend of the mineralization is NNE-SSW dip with an amount 50° to 80° towards NW.

The host rock for graphite in the block is khondalite. The graphite occurs as medium to fine flaky/ prismatic grains and as disseminated aggregates, often showing kink bands associated with magnetite, pyrite, chalcopyrite and other sulphides. The graphite mineralization / graphite zones are hardly exposed on surface and mainly intercepted in the trenches and boreholes. The graphite mineralisation occurs within or outside the manganese mineralization zone. Concentration of graphite has been developed up to a vertical depth of 60m with pinching and swelling nature. (North Band- 150m and South Band-100m strike length). Raman Spectroscopy of few borehole samples from graphite mineralization indicates flaky to massive nature of graphite.

## **RESOURCES**

Manganese and Graphite occurs in the area as discontinuous bands associated with khondalites. Mostly graphite occurs as graphite rich schist. Mineralized zones are irregular in lateral and vertical direction. Considering the discontinuous, lensoidal, pocket type of manganese and graphite mineralization and the interval of the data points, the total resources of the block may be categorized as “Inferred Mineral Resources” with Code 333 as per UNFC system and the specifications given in the Mineral (Evidence of Mineral Contents) Rule-2015 amended up to 2021.

The manganese ore resource estimated by Geological Cross Section Method is 0.45 million tonnes over a strike length of 930 m with an average grade of 19.62% Mn at 10% Mn threshold value.

The graphite ore resource estimated by Geological Cross Section Method is 0.59 million tonnes (m.t.) over a strike length of 250 m with an average grade of 4.10% FC at 2% FC threshold value.

## **RECOMMENDATION**

Manganese and graphite mineralization in Bharatbahal Block is of low grade of nature. However, it has potential that would be amenable for systematic scientific mining. On the present stage of exploration, the block may be auctioned as composite license.

Beneficiation studies on such low-grade graphite ores may be carried out to maximize the recovery of flaky graphite in the next phase of exploration.

Due to discontinuous and lenticular nature of the mineralized bodies close space drilling (50 m strike interval) may be planned to assess the three-dimensional behavior of the ore bodies along with quality and quantity.

In the nearby blocks (Larambha and Kanaital G3 Blocks) vanadium (around 500ppm) has been reported which is invariably associated with the graphite. Hence, sampling at regular interval during next phase of drilling may be carried out to delineate the vanadium rich zones within the graphite and assess the quality and quantity of the same. In addition, mineral phase studies may be carried out.

## CHAPTER-1

### 1.0.0 INTRODUCTION

- 1.0.1 Manganese is one of the most common elements in the Earth's crust and is widely distributed across the planet's surface. It is very hard, brittle, gray-white transition metal that is found in variety of minerals, but never occurs as free element in nature; it is often found in minerals in combination with iron. Manganese ore is the basic source to provide manganese as indispensable input in making of iron and all types of steels. So far there is no technology which can substitute manganese in steel making. Manganese attributes the twin benefits of relatively low price with outstanding technical usage.
- 1.0.2 The world's manganese reserves were estimated at around 1.9 billion metric tons in 2023. South Africa has the largest manganese reserves in the world (600 million metric tons in 2023), accounting for an estimated 70% of the world's manganese resources. Also, South Africa is the world's largest producer of manganese, accounting for 36% of global production. In 2023, South Africa's manganese mine production was 7.2 million tons. The other top manganese-producing countries are: Gabon, Australia, Ghana, China, Ukraine and India. Reserves for India has been estimated about 34 million metric tons and in 2023 manganese production was 0.72 million metric tons. (Source: statista.com and USGS-Mineral Commodity Summaries 2023 - Manganese)
- 1.0.3 In India, the Manganese Ore deposits mainly occur as metamorphosed bedded sedimentary deposits associated with Gondite Series in Madhya Pradesh (Balaghat, Chhindwara & Jhabua districts), Maharashtra (Bhandara & Nagpur districts), Gujarat (Panchmahal district), Odisha (Sundargarh district), Kodurite Series (Archaeans) in Odisha (Ganjam & Koraput districts) and Balangir district associated with khondalites of Eastern Ghat Mobile Belt and Andhra Pradesh (Srikakulam & Vishakhapatnam districts).
- 1.0.4 Based on the 37th issue of the series "Statistical Profiles of Minerals" issued by Indian Bureau of Mines the total reserves and resources of manganese ore in the country was provisionally estimated 503624 thousand tonnes in 2019-20 and production of manganese ore in 2020-21 was 2703 thousand tonnes. Major manganese ore produced

states are Madhya Pradesh, Maharashtra, Odisha, Karnataka and Andhra Pradesh. Domestic consumption of manganese ore in 2019-20 was 2616 thousand tonnes.

- 1.0.5 As per World Steel Association, in 2019-20 India's per capita steel consumption is about 74.7 kg as against the world's per capita consumption of 230.3 kg. This difference in the per capita consumption of steel in itself reflects opportunities that are bound to occur for Steel Industry which in turn would positively impact the demand for manganese ore. Production of crude steel is the single most important factor that influences the demand for manganese ore. Steel Industry accounts for approximately 90% of the world demand for manganese. India's crude steel production grew from 89.79 million tonnes in 2015-16 to 109.14 million tonnes in 2019-20 registering a CAGR of 5 per cent. This indicates strong growth of Steel Industry in the country as steel is the principal market accounting for 65 to 70% manganese consumption. India has set a production capacity target of 300 million tonnes of steel by 2030-31. The demand for manganese ore is expected to raise commensurately to about 10 million tonnes per year in the coming years. (Source: Indian Mineral Yearbook 2020 on Manganese ore, February 2022)
- 1.0.6 The reserves of high-grade manganese ore are limited and the overall production is very low and highly inadequate, considering the demand of the manganese-based alloy industry. Needing thereby, a major boost in exploitation activity to enhance overall productivity after revamping the entire mining sector in the country and utilization of lean grade with advanced technology is need of the hour.
- 1.0.7 Graphite, also known as plumbago or black lead or mineral carbon, is a stable form of naturally occurring carbon. Structurally, graphite is known to crystallize in hexagonal system and occurs in layered & lamellar form with grey-to-black metallic luster and a greasy feel. Natural graphite is categorized into two commercial varieties (i) crystalline (flaky) graphite and (ii) amorphous graphite. Both flaky and amorphous varieties of graphite are produced in India. Besides natural graphite, there is synthetic or artificial graphite which is manufactured on a large-scale in electric furnaces, using anthracite or petroleum coke as raw feed.
- 1.0.8 The world resources of graphite are believed to exceed 800 million tonnes of recoverable graphite. However, world reserves of graphite have been placed at 280

million tonnes of which Turkey accounts for 24% followed by China (28%), Brazil (26%), Madagascar & Mozambique (8% each), Tanzania 6%, and India (3%) [Source: USGS mineral commodity summary 2024].

- 1.0.9 World graphite production has fluctuated slightly in recent years. In 2023, the total worldwide production of graphite amounted to 1.6 million metric tons. In the past decade, China has consistently been the leading global graphite producer. In 2023, China produced an estimated 1.2 million metric tons of graphite. Following China, was Mozambique in a distant second place, with a production volume estimated at 100,000 metric tons that year. India ranks 7<sup>th</sup> position in the top graphite producing countries.
- 1.0.10 Graphite occurrences are reported from various States but the deposits of economic importance are located in Arunachal Pradesh, Chhattisgarh, Jharkhand, Odisha and Tamil Nadu. Arunachal Pradesh accounts for 36% of the total resources which is followed by Jammu & Kashmir (29%), Jharkhand (9%) Madhya Pradesh (5%) Odisha (9%), and Tamil Nadu (4%). However, in terms of reserves, Tamil Nadu has the leading share of about 36% followed by Jharkhand (30%) and Odisha (33%) of the total reserves (Mineral Year Book-2021). The graphite reserves having +40% Fixed Carbon is rather limited in the country. In view of this, detailed exploration of graphite deposits in Odisha, Jharkhand, Jammu & Kashmir and Kerala should be carried out.
- 1.0.11 Based on 37th issue of the series “Statistical Profiles of Minerals” issued by Indian Bureau of Mines the total reserves and resources of graphite in the country was provisionally estimated 211623 tonnes in 2019-20 and production of graphite in 2020-21 was 30168 tonnes.
- 1.0.12 Worldwide demand for combined natural and synthetic graphite is expected to rise along with improvements in the global economic conditions. Demand is also expected to augment further with the development of non-carbon energy applications, such as, batteries used in electric vehicles, electric devices and energy storage devices that use graphite. The graphite reserves having +40% Fixed Carbon are rather limited in the country. Cost-effective beneficiation technologies for low-grade graphite ore need to be developed. Silicon carbide graphite crucibles are being diversified and manufactured to improve upon the use of inferior grade material with less quantity and at the same time ensuring longer life of crucible. Of late, a few emerging & important specialized

applications of exfoliated graphite have been reported especially in the manufacture of sealings, gaskets, braids and brushes. New products of synthetic graphite, such as, graphite fibers/ropes and graphite insulation blankets have been introduced. In the world scenario, there seems to be a rapid diversification in respect of potential large volume end-use for natural graphite, such as, in heat sinks, also called spreader shield, which is a graphite foil material that conducts heat only in two directions. It has thermal conductivity above aluminum and almost equal to copper. These are used for dissipating heat in laptop computers, flat-panel displays, wireless phones, digital video cameras, etc. Such emerging & high growth applications of graphite are certainly causing noticeable impacts on the demand & consumption patterns within the country & globally. The demand for high purity graphite is increasing exponentially due to increase in the demand of lithium-ion batteries for electric vehicles, laptops, smart phones, home/business applications and traditional uses for expanded graphite foils are also the potential areas that are expected to be major drivers for graphite consumption. It represents 23% of global flake graphite demand. The demand for graphite in the Battery segment is forecasted to double in the next six years.

- 1.0.13 At present graphite is a critical mineral for the nation as per the MMDR amendment Act 2023. The high grade graphite reserves are rather limited in the country. Detailed exploration of graphite deposits in the known areas of Odisha, Jharkhand, Jammu & Kashmir and Kerala should be carried out to establish more and more resources and conversion of resources to reserves and finding of new deposits is the need of the hour.
- 1.0.14 The project under discussion is an approach to mitigate the demand of the manganese and graphite to some extent and make the blocks auctionable for further mining.

## **CHAPTER-2**

### **2.0.0 DETAILS OF THE QUALIFIED PERSON(S) / EXPLORATION AGENCY**

#### **2.1.0 INVESTIGATING AGENCY**

2.1.1 The block was explored by Mineral Exploration And Consultancy Limited (formerly Mineral Exploration Corporation Limited)-MECL during field execution from March 2024 to January 2025 and the exploration programme was funded by National Mineral Exploration Trust (NMET). MECL was established as an autonomous Public Sector Company in October 1972, under the administrative control of Ministry of Mines, Government of India for systematic exploration of minerals, to bridge the gap between the initial discovery of a prospect and its eventual exploitation.

2.1.2 Experience: MECL has completed over 1654 projects/reports and established 219.84 billion tonnes of ores / mineral reserves of minerals like Coal, Lignite, Bauxite, Copper, Gold, Lead-Zinc, Iron Ore, Limestone, Manganese, Magnesite, Chromite, Fluorspar and several other Industrial Minerals since inception (As on March 2024).

2.1.3 MECL's registered address is:

Mineral Exploration And Consultancy Limited  
(Formerly Known as Mineral Exploration Corporation Limited)  
(A PSE under Ministry of Mines, Govt. of India)  
Dr. Babasaheb Ambedkar Bhawan, Highland drive road, Seminary Hills,  
Nagpur- 440006, Maharashtra, India.

#### **2.2.0 QUALIFIED PERSONS**

Exploration agency: Mineral Exploration and Consultancy Limited

Experience: 52 Years, Since 1972

Email: cmd@mecl.gov.in; gm-exploration@mecl.gov.in

List of qualified persons involved in the project are tabulated below:



**Table 2.1**  
**List of qualified persons involved in exploration of the Bharatbahal Manganese and Graphite (G3) Block, Balangir District, Odisha.**

Sl No.	Name
1	Shri P. Ravindran, GM (Exploration)
2	Shri S. K. Satpathy, Sr. Manager (Geology)
3	Shri Rajesh Patel, Manager (Geology), Project Management.
4	Shri Sujit Kumar Jena, Asst. Manager (Geology)
5	Shri Deepak Kumar Behera, Sr. Geologist
6	Smt. Rajanya Roy, Sr. Geologist
7	Shri Kolluri Sudheer, Geologist
8	Smt. Aayushi Saraswat, Geologist
9	Shri Rohit Sharma, Manager (Chemical lab)
10	Shri Sayantan Pal, Manager (Geology)

### **CHAPTER-3**

#### **3.0.0 TITLE AND OWNERSHIP**

##### **3.1.0 TITLE OF THE REPORT**

“GEOLOGICAL REPORT ON PRELIMINARY EXPLORATION (G-3 STAGE) FOR MANGANESE AND GRAPHITE IN BHARATBAHAL BLOCK (2.013 SQ KM) DISTRICT- BALANGIR, ODISHA”

3.1.1 Ownership: Government of Odisha

3.1.2 Name of Prospector: MINERAL EXPLORATION AND CONSULTANCY LIMITED  
(Formerly Mineral Exploration Corporation Limited)  
A Govt. of India Enterprise; A Miniratna-I CPSE  
Ministry of Mines, Govt. of India.

3.1.3 Address of Prospector: Mineral Exploration And Consultancy Limited  
(Formerly Known as Mineral Exploration Corporation Limited)  
(A PSE under Ministry of Mines, Govt. of India)  
Dr. Babasaheb Ambedkar Bhawan, Highland drive road,  
Seminary Hills, Nagpur- 440006, Maharashtra, India.

3.1.4 E-mail of Prospector: cmd@mecl.gov.in; gm-exploration@mecl.gov.in

3.1.5 Telephone numbers of Prospector: 0712-2510289; 0712-2511829

##### **3.2.0 DETAILS ABOUT PERIOD OF PROSPECTING**

3.2.1 Preliminary exploration (G3) for manganese and graphite in Bharatbahal block, Balangir district, Odisha was discussed and recommended in 61<sup>st</sup> Technical-Cum-Cost Committee (TCC), NMET held on 30<sup>th</sup>-31<sup>st</sup> January and 07<sup>th</sup> February 2024. The project was approved in the 33<sup>rd</sup> Executive Committee (EC), NMET meeting held on 19<sup>th</sup> February 2024 and approval issued vide. letter no. F.No. 23/425/2024-NMET/532, dated 28.02.2024 with designated time duration of 08 months. Project approval order is attached as Annexure I. Field operation was initiated by MECL on 14<sup>th</sup> March 2024 with the commencement of drilling where the mineralization has already been established during G4 exploration. Simultaneously, detailed geological mapping (1:2000), contouring and trenching were carried out to established continuity of the mineralization followed by drilling. The said work was carried out phase wise and reviewed the status of the block before TCC, NMET. The project was reviewed for technical and others by the TCC, NMET in its 65<sup>th</sup> after completion of 1<sup>st</sup> phase of work (Drilling-04 boreholes, geological mapping, contouring, trenching and analysis of

samples). Drilling of remaining 04 boreholes and other associated work could not be completed within the time limit due to standing crops in the area. Hence, it was reviewed in the 70<sup>th</sup> meeting for time extension up to March 2025 to complete the block including field and report writing. Field work was completed on 12.01.2025. Based on the data generated from the block a draft geological report was prepared for peer review. The report was peer reviewed by Shri M. Mohan, Retd DDG, GSI. Peer reviewer's comment is provided in Annexure XXI and reply in Annexure XXIII After incorporating suggestions of the peer reviewer, final geological report has been prepared.

## CHAPTER-4

### 4.0.0 DETAILS OF THE AREA

#### 4.1.0 LOCATION AND ACCESSIBILITY OF THE BLOCK

4.1.1 Bharatbahal block falls in Balangir district, Odisha. It lies between latitudes 20°48'49.32068"N and 20°47'53.99444"N and longitudes 83°13'44.12474"E and 83°14'26.38448"E. The block covers an area of 2.013 sq km and falls within the Survey of India Toposheet No 64P/01. Location map of the block is provided in the Plate-I and google earth image showing the location of block with respect to major cities in the surroundings.

4.1.2 The block is well connected with the State Highway 42 which connects Balangir – Patnagarh-Kantabanji and passes 10km south of the Bharatbahal block. The block is located around 50km from the district head quarter Balangir. The block can be approached from Patangarh tehsil which is located 20km south-west of the block.

4.1.3 Bharatbahal village along with small hamlets are located within the block.

4.1.4 Details of the boundary corner points of the block are given in the table below:

**Table 4.1**  
**DGPS co-ordinates (WGS-84) of the boundary corner points of Bharatbahal Manganese and Graphite Block (G3), Balangir District, Odisha.**

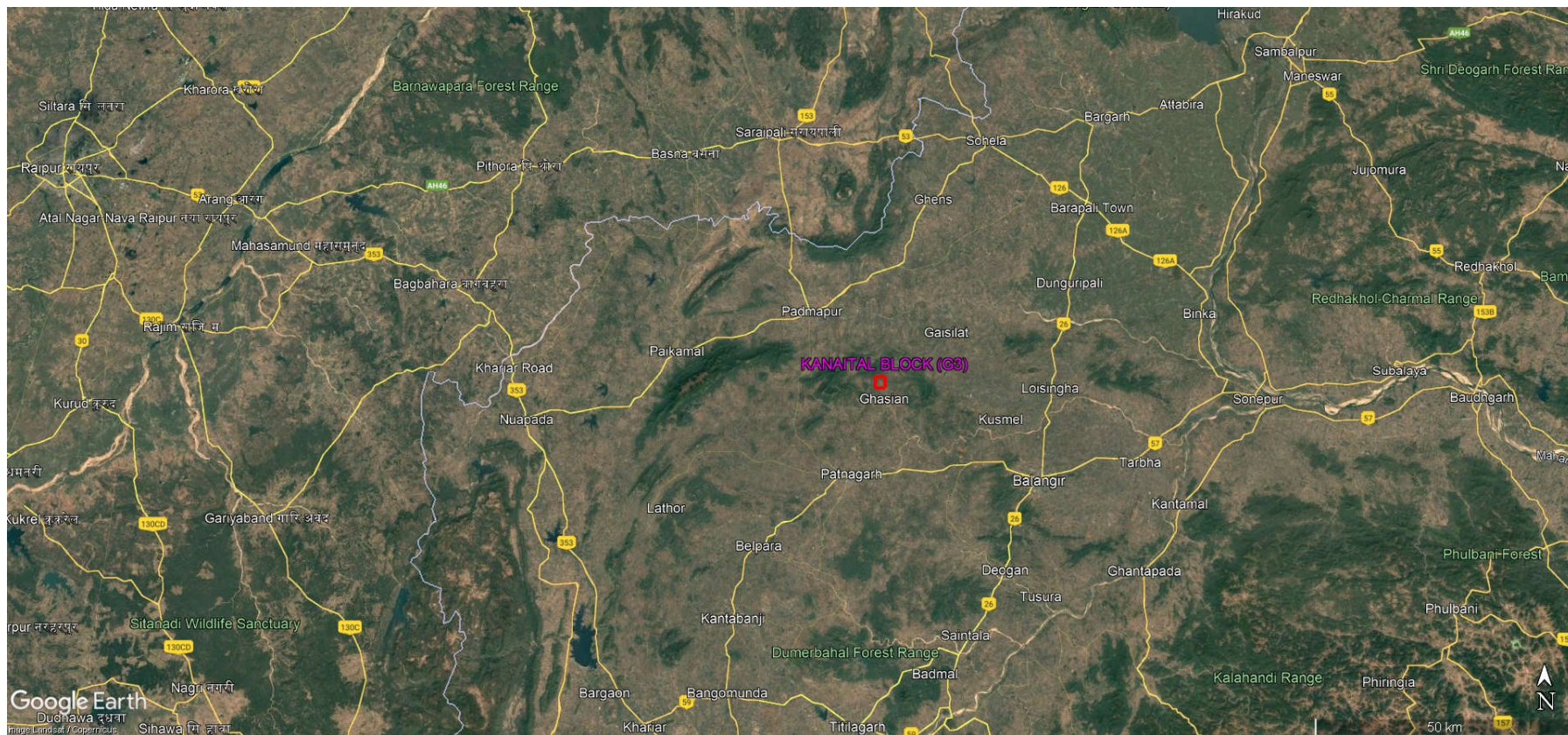
Sl No.	DMS Co-ordinates		UTM Co-ordinates		Description of Corner Points
	Latitude (N)	Longitude (E)	Northing (m)	Easting (m)	
1	20°48'49.32068"	83°13'45.27475"	2303133.913	732012.899	“A”
2	20°48'48.78544"	83°14'26.38448"	2303133.937	733202.076	“B”
3	20°47'53.99444"	83°14'25.57376"	2301448.271	733202.05	“C”
4	20°47'54.52386"	83°13'44.12474"	2301447.944	732002.942	“D”

#### 4.2.0 DETAILS OF THE AREA WITH LAND USE

4.2.1 Mostly the block is occupied by agricultural lands. A small area in the eastern part of the block falls in forest.

**4.3.0 MINERAL (S) UNDER INVESTIGATION OR GRANTED UNDER LICENSE  
OR LEASE APPLIED FOR**

4.3.1 Manganese and Graphite.



□ Bharatbahal Block

Text Figure: 4.1 Google image showing location of the Bharatbahal Manganese and Graphite Block (G3), Balangir District, Odisha.



## **CHAPTER-5**

### **5.0.0 PHYSIOGRAPHY AND ENVIRONMENT**

#### **5.1.0 RELIEF OF THE AREA WITH MINIMUM AND MAXIMUM ELEVATION, DRAINAGE PATTERN, NATURAL WATER COURSES, RESERVOIRS, ETC.**

5.1.1 The area comprises wide spread plain land and low-lying mounds. Average elevation in the block is around 243 mRL. Maximum elevation recorded in eastern part of the block is around 266 mRL whereas minimum elevation recorded in the southwest corner of the block i.e 210mRL. The block area falls in between the catchment area of Suktel River. Suktel river flows near to the southwestern corner point of the block. The drainage pattern is dendritic. Most of the area is occupied by thick soil.

#### **5.2.0 ROADS, RAILWAY TRACK, ELECTRIC TRANSMISSION LINE, TELEPHONE LINE, ETC.**

5.2.1 The area is well connected with the State Highway-42 (Balangir-Patanagarh-Kantabanji Road) in the south, the National Highway-26 (Bargarh-Balangir) in the east and the State Highway-3 in the north by all weathered asphalt road. A Village Road (Asphalted) runs in the central part of the block which connects major villages in the surrounding.

5.2.2 No railway tracks are within the block. The nearest railhead is Balangir which is 50km from the block in the southeast which is part of the Jharsuguda–Vizianagaram line. It connects Jharsuguda, on the Howrah-Nagpur-Mumbai line, and Titlagarh, which in turn is connected with Vizianagaram, on the Howrah-Chennai main line, and Raipur. There are several branch lines, like the one connecting Rayagada with Koraput on the Kothavalasa-Kirandul line.

5.2.3 Nearest port is Paradip Port which is 445km east of the block

5.2.4 The Jharsuguda Airport at Jharsuguda is the nearest airport which is 210km in the northeast while Swami Vivekananda Airport at Raipur, Chhattisgarh is 220 km away in

the west. Biju Patnaik International Airport in the state capital, Bhubaneswar is 360 km towards east.

5.2.5 No major electric transmission line, telephone line and others passing through the block.

### **5.3.0 SOCIO DEMOGRAPHIC PROFILE OF THE AREA AND NEARBY**

5.3.1 The area falls in Balangir district. Hence, information has been provided for the district on the basis of Census 2011.

5.3.2 In 2011, Balangir had population of 1,648,997 of which male and female were 830,097 and 818,900 respectively. In 2001 census, Balangir had a population of 1,337,194 of which males were 673,985 and remaining 663,209 were females.

5.3.3 Average literacy rate of Balangir in 2011 were 64.72% compared to 64.72% of 2001. If things are looked out at gender wise, male and female literacy were 75.85 and 53.50% respectively. For 2001 census, same figures stood at 71.67% and 39.51% in Balangir District. Total literate in Balangir District were 927,260 of which male and female were 545,672 and 381,588 respectively. In 2001, Balangir District had 638,048 in its district. Literacy rate in rural areas of Balangir district is 62.11 %. Gender wise, male and female literacy stood at 73.85 and 50.32 percent respectively. In total, 780,657 people were literate of which males and females were 464,882 and 315,775 respectively.

5.3.4 With regards to Sex Ratio in Balangir, it stood at 987 per 1000 male compared to 2001 census figure of 984. The average national sex ratio in India is 940 as per latest reports of Census 2011 Directorate. In 2011 census, child sex ratio is 955 girls per 1000 boys compared to figure of 967 girls per 1000 boys of 2001 census data.

5.3.5 The density of Balangir district for 2011 is 251 people per sq. km. In 2001, Balangir district density was at 203 people per sq. km. Balangir district administers 6,575 square kilometers of areas.

5.3.6 As per census, 88.03 % population of Balangir districts lives in rural areas of villages. The total Balangir district population living in rural areas is 1,451,616 of which males and females are 728,770 and 722,846 respectively. In rural areas of Balangir district, sex ratio is 992 females per 1000 males.



5.3.7 To facilitate the administration, Balangir consists of three Sub-Divisions viz. Balangir, Patnagarh and Titlagarh. One Sub-Collector is in charge of each Sub-Division. For the convenience of revenue administration, the district is divided into 14 tahasils viz. Patnagarh, Kantabanji, Titlagarh, Tushura, Loisinga, Balangir, Khaprakhol, Belpara, Bangomunda, Muribahal, Saintala, Deogaon, Puintala and Agalpur with one Tahasildar in charge of each tahasil. For development of rural areas consisting of 1789 villages in 285 Gram Panchayats, the district is divided into 14 Community Development Blocks with one Block Development Officer in charge of each Block.

5.3.8 Most of the block area falls in the Bharatbahal village, Patnagarh tahasil.

#### **5.4.0 HISTORICAL SITES AND ARCHAEOLOGICAL MONUMENTS, PLACES OF WORSHIP, PUBLIC UTILITIES ETC.**

5.4.1 No historical sites, archaeological monuments are located within the block. Gandhamardhan Hill Range in Bargarh and Balangir district as a Biodiversity Heritage Site (BHS) is located 55km west of the block.

#### **5.5.0 FORESTS, SANCTUARIES, NATIONAL PARK AND WILD LIFE SANCTUARIES ETC.**

5.5.1 No sanctuaries, national park and wild life sanctuaries are exist within the block and the surrounding area.

#### **5.6.0 FLORA AND FAUNA WITHIN AND NEARBY**

5.6.1 **FLORA:** The flora of Balangir district consists of many families, which are common in tropical climate. On the open country areas mango groves are numerous. Tal and Khajuri are seen topping the canopy. On the fields, Mahua, Babul and other miscellaneous species such as Harida, Bahara are found.

5.6.2 Besides, at the outskirts of the village Tamarind, Jamun, Maya, Badhal, Bara, Aswattha species are commonly found. Amongst the flowering species the followings are commonly noticed: -

- i. Sunari – The Indian laburnum tree with long pendular of yellow flowers.
- ii. Chakunda – With panicles of yellow recome.

- iii. Palasa – Remarkable for its brilliant scarlet or orange flowers in summer on the leafless tree.
- iv. Siris – Remarkable for its green canopy on the top of which are greenish yellow flowers.
- v. Kanchan - Which has large blossoms of four white or pink petals.
- vi. Kantapalasa – Conspicuous for its large yellow flower.
- vii. The flora of economic importance are Sal, Teak, Gambhari, Sisoo, Bahara, Harida, Anla, Kusum, Simul, Khair, Siali, Sunari and Kendu.

5.6.3 The district has a good source of fodder grasses. The following are some of the important grasses that are commonly found. Dub grass, Murial, Sukla, Panasi, Kaila and Khas etc. Bamboos are abundant in some blocks of the district. Sabai grass is also found in many blocks, which are used for rope making and also used for paper manufacturing.

5.6.4 **FAUNA:** Much of the wild fauna is fast vanishing because of the limitless hunting by the ‘Shikaris’ and destruction of forests. The wild mammals include “Kalara Patria” tigers which are plentiful in every part of the district and are usually seen near the small hills of cultivated lands, where they prey upon the goats and sheep. Also, the following animals are found in the district: Felis chaw (Bana Biradi), Bear, Mongoose, Baliakukura, Jackal, Hyena, Saliapatani, Katash, Jhinka, barking deer (Kutura), Spotted deer, Blackbuck, Sambar, Bison, and monkeys of different kinds.

5.6.5 Most of the birds found in other districts of Odisha are also found in Balangir district. They are Domestic Crow (Damarakua), Peacock, Sari, Chila, Koyal, Bulbul and Spotted Dove. The district has its own share of reptiles including a variety of snakes. These are Crocodile, Tortoise, Monitor lizard (Godhi), Cobra, Chitti, Rana, Ajagara, Domundia.

#### **5.7.0 WATER BODIES SUCH AS RIVER, NALA, STREAM, RESERVOIR, ETC**

5.7.1 No Major water bodies such as river, nala reservoirs are located within the block. However, a large pond is located in the northern part of the block. Suktel river flows very nearer to the southwestern part of the block.

## **5.8.0 CLIMATIC CONDITIONS**

- 5.8.1 The Balangir and adjacent areas are in the north-eastern corner of the Deccan plateau. The year may be divided into four seasons. The hot season is from March to May and is followed by monsoon till the end of September. October and November are post monsoon period. The cold season is from December to February.
- 5.8.2 The climate of the district is extreme. It is hot and dry in summer, hot and humid in rainy season and cold and dry in winter. In summer the temperature rises up to high of 44°C, and in winter it falls as low as 7°C. During 1998 the temperature of Titlagarh rose up to 49°C, which was one of the hottest places in India. Also, Balangir district experienced sunstroke deaths during the year 1998.
- 5.8.3 There are two meteorological observatories; one at Titlagarh and the other at Balangir. The hot season generally starts from beginning of March, when the maximum temperature reaches at 41°C. During May and at early part of June the maximum temperature rises to 47°C. From November the temperature decreases, the drop in night temperature being more rapid. December and January usually are the coldest month in the district. Sometimes the minimum temperature comes down to 3°C.
- 5.8.4 The relative humidity is high in the south-west monsoon and post-monsoon months. The air becomes gradually drier. Thereafter summer is driest part of the year with the relative humidity particularly in the afternoons.
- 5.8.5 Generally monsoon period in the district is from June to September. The average rainfall of the district is 1423.5 mm. The too wide variation in the annual rainfall and its erratic distribution often spells crop failure in the district. Barring the irrigated areas due to Hirakud irrigation system, most part of the districts are drought prone and often experiences scarcity conditions.

## CHAPTER 06

### 6.0.0 INFRASTRUCTURE AND CONSUMER INDUSTRIES

- 6.0.1 The exploration block lies 55km north-west of Balangir town, District Balangir, Odisha. The 177 kms railway line connecting Sambalpur-Titlagarh of Sambalpur Division, East Coast Railways passes through the district. National Highway nos. NH-26 (Bargarh-Bhawanipatna), NH-57 (Balangir-Sonepur) and NH-59 (Belgan-Khariar) passes through the district. The length of NH-26, NH-57 and NH-59 are 85km, 25 km and 60km respectively within the district. The length of State Highways SH-42 (Balangir-Khariar via Patnagarh) is 100km. The medical facilities are available at Balangir, Patnagarh and Loisinga. There is a medical college and one government district hospital in Balangir. The government primary hospitals are available at Balangir, Patnagarh and Loisinga. Besides, many private health care facilities are available in the district. There are 151 branches of commercial banks and 82 rural bank branches. There is an Ordinance factory at Badamal, Tehsil-Saintala, District-Balangir. Other infrastructures like, market, workshops etc. are available at Patanagarh and other tehsil places and Balangir district town. As far as mining industry in the area is concerned, at present graphite, manganese and quartz are being commercially exploited.
- 6.0.2 The consumption of manganese ore in all industries was about 2.62 million tonnes in 2019-20 as against 2.89 million tonnes in 2018-19. Ferroalloys industries accounted for about 91% consumption followed by Iron & Steel (8%). The remaining (1%) was shared by battery, electrode, Chemical, Zinc Smelter and Alloy Steel industries.
- 6.0.3 The demand for manganese is tightly tied to demand from the steel industry, and production of manganese ore follows steel production.
- 6.0.4 Traditional uses of graphite are in crucibles, foundries, pencils, etc. More sophisticated applications of graphite are in refractories that are used in the manufacture of steel, cement and glass, expanded graphite-based sealing gaskets, graphitised grease, braid, brushes, brake lining, etc.
- 6.0.5 Many end-user industries for manganese and graphite are located in the surrounding districts nearer to the block.

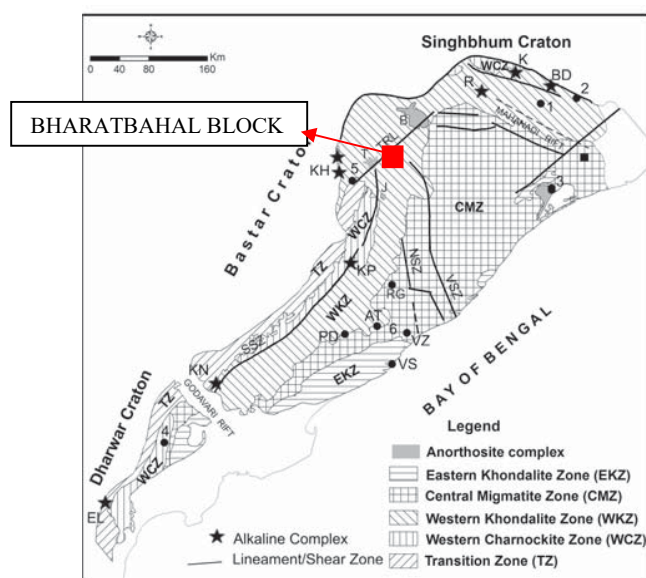
## CHAPTER 07

### 7.0.0 GEOLOGY OF THE AREA

#### 7.1.0 REGIONAL GEOLOGY

7.1.1 The geological background described here for the sake of clarity in local geology, is taken from earlier workers and from traverses made in the areas.

7.1.2 The exploration area lies in the northern part of the Eastern Ghats Supergroup and the rocks exposed in the area are of Pre-Cambrian age comprising of meta-sedimentary sequence represented by Khondalite Suite (calc-silicate granulite / calc-granulite-gneiss + garnetiferous sillimanite bearing quartzofeldspathic schist or gneiss  $\pm$  graphite + quartzite). The sequence of para-metamorphics is made up of pelitic, psammitic and calcareous formations, which are represented by khondalite, quartzite and calc-silicate rocks which are intruded by granites. The hill ranges in this area are composed of either khondalite or garnetiferous quartzites or both. Calc-silicate bands adjoining to the ore horizons form denudational hillocks or mounds. Granite gneiss occupies the valleys. The whole meta-sedimentary sequence has been metamorphosed to granulite facies. Structurally the area exhibits a complex picture. Location of the block on the regional geological map is provided in the following text figure 7.1



Text Fig. 7.1 Location of the Bharatbahal block on regional geological map of Eastern Ghat Mobile Belt (EGMB).

- 7.1.3 On the basis of contact relationship, presence of xenoliths/caught up patches of one particular unit within the other and structural and stratigraphical relationship, the tentative stratigraphic succession of the area given by GSI is as follows:

**Table -5.1**  
**Stratigraphic Succession of the Area (After GSI), District-Balangir, Odisha**

Age	Formation	Lithology
Quaternary	-	Alluvium, soil and latsol
Tertiary	-	Laterite
Precambrian (Eastern Ghat Supergroup)	-	Aplite, Pegmatite and Quartz veins
	Granitoids	Equigranular, non-garnetiferous granite gneiss, garneti-ferous granite gneiss and granulite, leptinitic gneiss Migmatite
	Charnockite Suite	Hypersthene bearing gneisses and granulites (mostly acid to intermediate charnockitic type)
	Khondalite Suite	Pyroxene granulite, quartzite, Khondalite with manganiferous horizons Calc-silicate rocks with manganese ore
Base Not Seen		

## 7.2.0 REGIONAL STRUCTURE

- 7.2.1 The area exhibits a complex structural fabric as the whole sequence has been subjected to multiple cycles of deformations. As a result, the existing primary structural elements are completely altered rendering it difficult to decipher the complete structural geometry. However, the secondary planar structural elements like foliation, gneissosity and joints are well preserved in the rock types of the area. The different structural features as observed are described below:
- 7.2.2 **Primary structures:** The primary structures have been mostly obliterated due to granulite facies metamorphism. However, relict bedding is observed along the contact between Khondalite, quartzite and Calc-silicates. Interbanding of different litho units within the Khondalite Group is seen clearly in many outcrops.
- 7.2.3 **Secondary structures:** The secondary planar structures such as foliation, gneissosity, schistosity, joints and cleavages are well preserved in rocks.  $S_1$  is defined by

compositional banding, preferred orientation of prismatic, acicular and flaky minerals in the rock.

- i. **Foliations:** Foliation ( $S_1$ ) is most pervasive and trends in NNW-SSE to NE-SW direction with moderate to steep easterly to south-easterly dip. Planar arrangement of minerals like garnet, biotite, sillimanite, graphite, quartz and feldspar mark the foliation plane in khondalite, quartzite, calc-silicate rocks and granite.
- ii. **Joints:** Altogether, two sets of joints are observed in the area. These are E-W trending with dip  $70^0$  to  $80^0$  towards south and N  $65^0$  E - S  $65^0$  W trend with dip  $60^0$ - $80^0$  towards southeast.
- iii. **Lineations:** Two types of lineation are noted in the area:
  - Slickenside lineation: This is observed in manganiferous quartzite and calc-silicate rocks.
  - Mineral lineation: The mineral lineation is defined by minerals like sillimanite, biotite and garnet in khondalite and granite gneisses.
- iv. **Slickensides:** This is observed in manganiferous quartzite and calc-silicate rocks.
- v. **Mineral lineations:** The mineral lineation is defined by minerals like sillimanite, biotite and garnet.
- vi. **Folding:** Folds have been preserved conspicuously in calc silicate rocks and to a lesser degree in quartzites. The area exhibits atleast 3 generations of folding. The first generation of fold (F1) is tight to isoclinal, intra folial, upright and reclined in nature. The axial planes of F1 fold have a general trend in NNE-SSW to NE-SW direction. However, its attitude is variable in different directions due to subsequent foldings. The F1 fold exhibits plunge reversal from NNE to SSW in the southern part of the area to N $55^0$ - $70^0$ E to S $55^0$ - $70^0$ W in northern part (Plate-I). The plunge amount varies from  $20^0$ - $47^0$  in southern parts. Pink granite gneiss north of Phatamunda exhibits recumbent fold. Comparable to (F1) folds the second generations of folds (F2) are more prevalent in the area. It is southerly overturned, asymmetric, open to broad type and moderate to steeply plunging to both SSW and NNE directions in the Larambha area but to

northwest and southeast in Uchhabapali area. The axial surfaces are variable from inclined to vertical. F2 folds with subvertical axis plunging  $85^{\circ}$  south westerly in calc silicate rocks are noted west of Uchhabapali ridge (W-7 line). The axial planes of F2 folds have a general trend in  $N50^{\circ}W-S50^{\circ}E$  to  $N65^{\circ}W-S65^{\circ}E$  direction with steep dip towards southwest and occasionally to northeast. The third-generation fold F3 is characterized by upright, open to broad warps with N-S trend in Uchhabapali area. It is less observed in Larambha-Kanaital area. At places the warp axis trends in  $N65^{\circ}E-S65^{\circ}W$  direction and plunges  $85^{\circ}$  towards  $S65^{\circ}W$ . The superposition of F2 over F1 and F3 over F1 and F2 have produced double plunging and dome and basin interference pattern of folds (Biswal et. al, 1998). 'M' type folds are observed in granite gneisses and calc silicate rocks in Ladangabhata and Pudapadar areas respectively. The calc granulites and associated calcite rich bands exhibit flowage structure. The manganese ore bands display complex fold pattern.

vii. **Faults and Shear:** Faulting and shearing are evidenced by brecciation, silicification, vug-fillings, slickensides and mylonitisation in quartzite and khondalites. Quartzites and khondalites are intensely silicified and brecciated resembling chert breccia in the vicinity of manganese ore bands in a number of places such as near Uchhabapali, northeast of Babja and west of Kanaital, Larambha, and Bharatbahal areas. Secondary chert veins were found intruding ore bodies in a criss cross patterns. Manganese mineralisation is confined mostly to the minor fault and shear zones in the area.

### **7.3.0 METAMORPHISM IN THE REGION:**

7.3.1 High grade metamorphism under granulite facies conditions characterizes the Eastern Ghats Super Group of rocks. The mineral assemblages of Khondalite (quartz-feldspar-garnet-sillimanite+graphite), Granulite (plagioclase-hypersthene-diopside) and calc-silicate (diopside-plagioclase-calcite-quartz-scapolite) indicate pyroxene granulite sub-facies under granulite facies of Eskola.

### **7.4.0 REGIONAL MINERALISATION:**

7.4.1 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 and is soft and powdery in nature. Pyrolusite, psilomelane and cryptomelane show replacement texture of one to the other.

7.4.2 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 mineralization. The lensoidal discontinuous ores owe their origin to the flowage or drag folds.

7.4.3 The graphite mineralisation is mainly associated with khondalite and is of flaky nature. The graphite occurs as medium to fine flaky/ prismatic grains and its disseminated aggregates, often showing kink bands associated with hematite, magnetite, pyrite and other sulphides. The graphite mineralization / graphite zones are hardly exposed on surface and mainly intercepted in the boreholes. The graphite mineralization occurs within or outside the manganese mineralization zone.

#### **7.5.0 GEOLOGY OF THE BLOCK**

7.5.1 The area comprises widespread plain land with low lying mounds. About 80% area of the block is covered by soil and remaining area is occupied by exposures of Calc silicate rock, quartzite, manganese float ore and manganese ore bodies. Soil occurs as loose cover on the parent rocks with thickness varies from 0.50m to 5.50m. The predominant soil covered area is under extensive cultivation. The calc silicate rock and khondalite are exposed as discontinuous patches.

7.5.2 The manganese ore bodies are surrounded by floats of manganese ore characterized by rugged boulder outcrop and oxide minerals such as pyrolusite and psilomelane. observed. Exposures of graphite bodies are scanty due to soil cover. Two prominent mineralized bodies were identified in the central part of the block. The mineralized bodies have both manganese and graphite mineralization. They are discontinuous lensoidal. General trend of the mineralization is NNE-SSW dipping towards NW with an amount 50° to 80°. The important litho units mapped in the block / intersected in the

boreholes are soil, manganese ore, khondalite, calc-silicate, calc-granulite, pyroxenite granulite and quartzite. The detail description of the different litho units occurring in the block is given in the following paragraphs. Geological map of the block is provided as Plate III.

#### **7.6.0 DESCRIPTION OF ROCK TYPES**

7.6.1 The detail description of the different litho units occurring in the block is given in the following paragraphs.

7.6.2 **Soil:** Most of the block area is covered by soil with limited exposures. It occurs as loose cover over parent rocks with varying thickness. Soil is fine to medium grained, earthy to reddish brown, clayey at places and contain coarse grained manganese bearing garnet and plant roots. The soil occurring in the area is product of the weathering of parent rock underneath and there is no transported soil in the area. The soil near outcrop area of manganese ore body is dark grey colour because of the manganese ore particles. The colour of soil varies from dark brown to brownish grey with presence of spessartite.

7.6.3 **Khondalite:** (Quartz-feldspar-garnet-sillimanite±graphite schist/gneiss): Khondalite is the most abundant rock in the block in the form of weathered bouldery outcrop which is inter banded with calc-silicate rocks and is intimately associated with quartzite and grade into each other along as well as across. It is exposed on low lying small mounds. It is medium to coarse grained, yellowish brown to reddish grey, foliated, highly weathered and kaolinised rock, mainly composed of sillimanite-garnet-feldspar-quartz schist with or without graphite and manganese minerals. The colour of rock varies due to varying degree of weathering and kaolinisation. It becomes lighter and whitish with increasing degree of kaolinisation. Khondalite is feebly manganese bearing at places and manganese minerals occur along the foliation, fracture and joints plane.

7.6.5 **Calc-silicate rocks/Calc gneiss/Calc granulite:** It is the second most abundant rock in the block and occurs as bands and lenses within khondalites and shows the sharp contact with it. It is exposed in patch all over within the block. and their trend generally confirms the regional trend direction. It is dark grey to greenish, fine to medium grained, hard and massive to foliated rocks mainly containing calcite, green diopside,

plagioclase, garnet, quartz, Scapolite and Sphene. The rocks are intricately folded and exhibit rib and furrow weathering structure and crude layering. Surface exposure of the calc-silicate is provided in the following Field Photograph 7.1

7.6.6 **Quartzite:** Quartzite occurs as bands within khondalite and calc-silicates rock along foliation planes. It is medium to coarse grained, white to buff coloured, granular to massive, invariably garnetiferous and predominantly made up of large xenoblastic grains of quartz with pale pink garnet. Brecciated and feldspathised quartzite are common and contains manganese mineralization at places. A prominent quartzite body exposed in the eastcentral part of the block.

7.6.7 The block is by and large covered by soil except a few bouldery outcrops of the khondalite, calc silicate and quartzite in the northern and eastern parts. Practically no structural features or attitude of beds could be traced in the block.

#### 7.7.0 **METAMORPHISM**

7.7.1 Few borehole samples in the block have been subjected to petrographical studies and identified as i) Calc silicate, ii) Pyroxene granulite and physical observation of lithounits like khondalite, calc silicate granulite, quartzite and quartzo-feldspathic rocks it is ascertained that the mineral assemblages of khondalite (quartz-feldspar-garnet-sillimanite + graphite), granulite (plagioclase-hypersthene-diopside) and calc-silicate (diopside-plagioclase-calcite-quartz) indicate pyroxene granulite subfacies under granulite facies of Eskola. High grade metamorphism under granulite facies conditions characterizes the Eastern Ghats Super Group of rocks.

## **CHAPTER-8**

### **8.0.0 PREVIOUS WORK**

#### **8.1.0 DETAILS OF PREVIOUS EXPLORATION CARRIED OUT BY OTHER AGENCIES/PARTIES**

- 8.1.1 A number of geoscientists from different organizations such as Geological Survey of India, Directorate of Geology, Govt. of Odisha etc. have carried out prospecting and preliminary exploration in the Balangir district of Odisha and discovered numerous occurrences of manganese ore and graphite in the area. A brief account of the efforts and findings of various organizations/workers is given in the following paragraphs.
- 8.1.2 Roy, B.C. (1940) of Geological Survey of India, first reported the manganese ore deposits in Balangir district. He observed that: (i) the manganese ore deposits occupy summits and plains (ii) the manganese ore bodies have definite strike and dip (iii) the manganese ore comprises mainly of pyrolusite and psilomelane as ore minerals with chert, limonite and wad, (iv) the ore bands are associated with calc-granulites and garnetiferous gneisses.
- 8.1.3 Jhingran, A.G. (1947) of GSI, investigated manganese in Balangir district. Krishnaswamy (1950) of GSI observed numerous occurrences of Mn ore mainly as lenses and pockets in calc-silicates and estimated the ore resource to the tune of 650 thousand tonnes up to 15 m depth in T.S. 64P/1 & 5. He described them as low-grade ores with Mn % varying from 25.45 to 33.52%.
- 8.1.4 Tak, M.W. (1966), Bose, P. (1967) and Mitra, D. (1965) had carried out geological mapping on 1:63,360 scale in Toposheet No. 64 P/5, P/6 & P/9, 64 P/5, and 64 P/1 & P/5 respectively. Tak, M.W. (1966) of GSI carried out mapping in the northern part of the present area and found that Mn mineralisation is associated with calc-gneiss, diopside granulite and highly weathered khondalite. He analyzed two grab samples of Mn ore and found Mn% varying from 24.83 to 26.81. P. Bose (1967) observed numerous lensoidal and pocket type deposits within khondalite and partly in calc-silicate rocks. Mitra, D. observed the occurrences of Mn ore within khondalite suite of rocks. He envisaged that the presence of quartz-garnet-rhodonite association in deposits

indicate probably a gonditic rock and closeness of calc-silicate rock within ore deposits suggest a calc-magnesian association common in sedimentary environment.

- 8.1.5 Patel, N.K. et al., (1983) of D.M.G., Odisha carried out systematic mapping of 60 sq km on 1:25, 000 scale in Babja-Dumerijharam area and 2.5 sq km detailed mapping on 1:2000 scale in Bijapatti east of Belpali-Bhaludungri area. He computed the total probable / inferred resource of all grades to be 95,677 tonnes up to a depth of 3m. They observed that Mn ore occurs at the contact of khondalite and calc-granulites in the form of discontinuous bands and pockets of irregular dimensions. Twelve numbers of Mn ore occurrences were reported in the area such as near SE of Banipali, NW of Dandapani, NW of Dumerijharam, NE of Gerdi and SE of Thakurpalli. Besides, disintegrated manganese float ores were reported near Barkani, Babja and Uchhabpalli. They had done 410 cum of trenching and pitting and 249 no of channel and grab sampling.
- 8.1.6 Jena, S.K. et al., (1995) carried out large scale mapping on 1:25,000 scale in Gadashankar-Dandapani area of Balangir district between latitude 20° 44' to 20° 55' N and longitude 83° 15' to 83° 21'E and delineated four major ore zones.
- 8.1.7 Patel, M.C. (1996) initiated preliminary exploration work by drilling in 1994-95 F.S. Mishra, U.S. and Hussain, A. (1997) carried out E-1stage (G-3 of UNFC, Ref: letter No 2692/K-1(Vol-II)/TC/ODS/2017 dated 07/11/2017 of GSI) exploration work in the area for the four blocks, such as, Biaripalli, Khagsabahal, Tabalbanji and Dunguripalli (north).
- 8.1.8 P.K Swain and Ajijul Hussain (2002) reported a possible reserve of 13,250 tonnes in Uchhabapalli block, 98590 tonnes in Babja block, 3,58,770 tonnes in Thakurpalli block and 10,6,000 tonnes in Tamiya block and estimated at cut-off grade of 28% Mn up to a vertical depth of 45 m. As such the total possible reserve of Mn ore for these four blocks amounts to the tune of 5,76,610 tonnes at cut-off grade of 28% Mn as repored in their final report on the exploration of manganese in Uchhabapalli, Babja and Thakurpalli Blocks, Balangir, Odisha.

- 8.1.9 B. N. Jayaram (1962), GSI carried out preliminary investigation of graphite deposits in the Balangir-Patna district, Orissa covering the toposheets 64 L and 64 P (5560 sq km). Graphite occurrences established in Balangir, Kalahandi, Sambalpur districts.
- 8.1.10 During field season 2022-23 and 2023-24, MECL carried out reconnaissance survey (G4) over an extent of 135 sq km area for manganese and garaphite in Larambha-Kanaital and Bharatbahal-Pudapadar Block falling in Survey of India Toposheet No. 64P/01. Geological mapping, surface sampling, geophysical survey (Self Potential (SP) and Magnetic), trenching and drilling (498m) in the block established 05 potential areas (Area 1 to 5) around the villages Larambha, Kanaital, Bharatbahal and puddapadar. The present block, (Bharatbahal Manganese and Graphite Block is one of them. Outcomes of the said work are provided in the following paragraphs.
- **Area-1 (Larambha):** Five mineralized zones were identified with cumulative strike length of 1058m and average width is 24m. Mineralized zones are discontinuous and lensoidal. Trend of the mineralization is NNE-SSW and dips towards SE with an amount 45° to 65°. Bedrock samples collected from this area shows 1.34% to 20.07% Mn. Trenching across the mineralized zone lie southwest corner of the area revealed the considerable thickness of the manganese and graphite zones. Two manganese zones (width: 15m and 5m) and 01 graphite zones (width: 14m) trending for about 230m have been established which includes of float ore.
  - **Area-2 (Kanaital):** It lies to the northeast of Larambha. There are 10 (Ten) discontinuous lensoidal manganese zones identified having a cumulative length of 1598m and average width of 16m. The in-situ manganese zone is surrounded by floats of manganese ore as bouldery outcrop. Actual width of the ore body in the individual zones may vary. Trend of the host rock is NE-SW to NW-SW and at places E-W which is different from the regional trend due to folding and dips SSE to south with an amount 50° to 80°. Bed rock samples collected from this area shows 1.08% to 31.79% Mn and graphite 0.29% to 5.07% FC. Manganese and graphite are associated with each other. Two manganese zones (width: 36m

and 2m) and 04 graphite zones (width: 11m, 7m, 2m and 1m) trending NW-SE for about 230m have been established which includes thickness of float ore.

- **Area-3 (Bharatbahal):** It is located in the south eastern part of the block. Three mineralized zones have been identified with cumulative strike length of 979m and average width is 15m. Two prominent zones trending NNE-SSW in the central part having considerable length compared to zones in other potential areas. Bed rock samples collected from this area show 5.76% to 33.32% Mn and 4.74% to 6.56% FC. Five boreholes have been drilled (259m) to prove the subsurface and lateral continuity of the mineralization for the two prominent zones. Subsurface drilling established the following dimension of the mineralization

**Dimension of the Mineralized Zone in Area-3**

Sl No.	Mineralization	(Area -3) Zone	Strike length (m)	Avg. Width (m)	Floor Level vertical from surface (m)
1	Manganese	Northern Zone	424	9.35	21
2	Graphite		424	4.90	35
3	Manganese	Southern Zone	385	9.30	23
4	Graphite		370	4.20	42

- **Area-4 (Puddapadar):** Northwest of Bharatbahal lies the potential block viz Puddapadar. Four mineralized zones have been identified with cumulative strike length of 1212m and average width is 9m. Out of which, two prominent zones in the central part are trending NNE-SSW. Bed rock samples collected from this area shows 17.26% to 37.81% Mn and 0.47% to 2.60% FC. Concentration of Mn% in this zone, is higher. Trend of the zones is NNE-SSW and dipping towards east with 60° to 85°. Five boreholes have been drilled to prove the subsurface and lateral continuity of the mineralization for the two parallel zones. Sub surface data revealed that mineralization is mostly surficial. No zones (Mn and Graphite) of considerable thickness have been intersected in the borehole except in the borehole MLB-08 where graphite zone having 3.15m at 2% FC

threshold value has been intersected. No resources for manganese ore have been estimated for the Area-4.

- **Area-5:** It lies northeast side of the Puddapadar. The area is occupied by a hillock where khondalite is the prominent rock type. Along the foot hills few discontinuous lensoidal manganese mineralized zones trending in various directions have been identified. Bed rock samples collected from this area shows 0.05% to 42.71% Mn. No drilling has been carried out in the area.
- **Resources** established in the Larambha-Kanaital and Bharatbahal-Pudapadar Block (G4 stage) is as follows:

**Summary of manganese resources estimated in Larambha- Kanaital and Pudapadar- Bharatbahal (G4) block, Balangir District, Odisha**

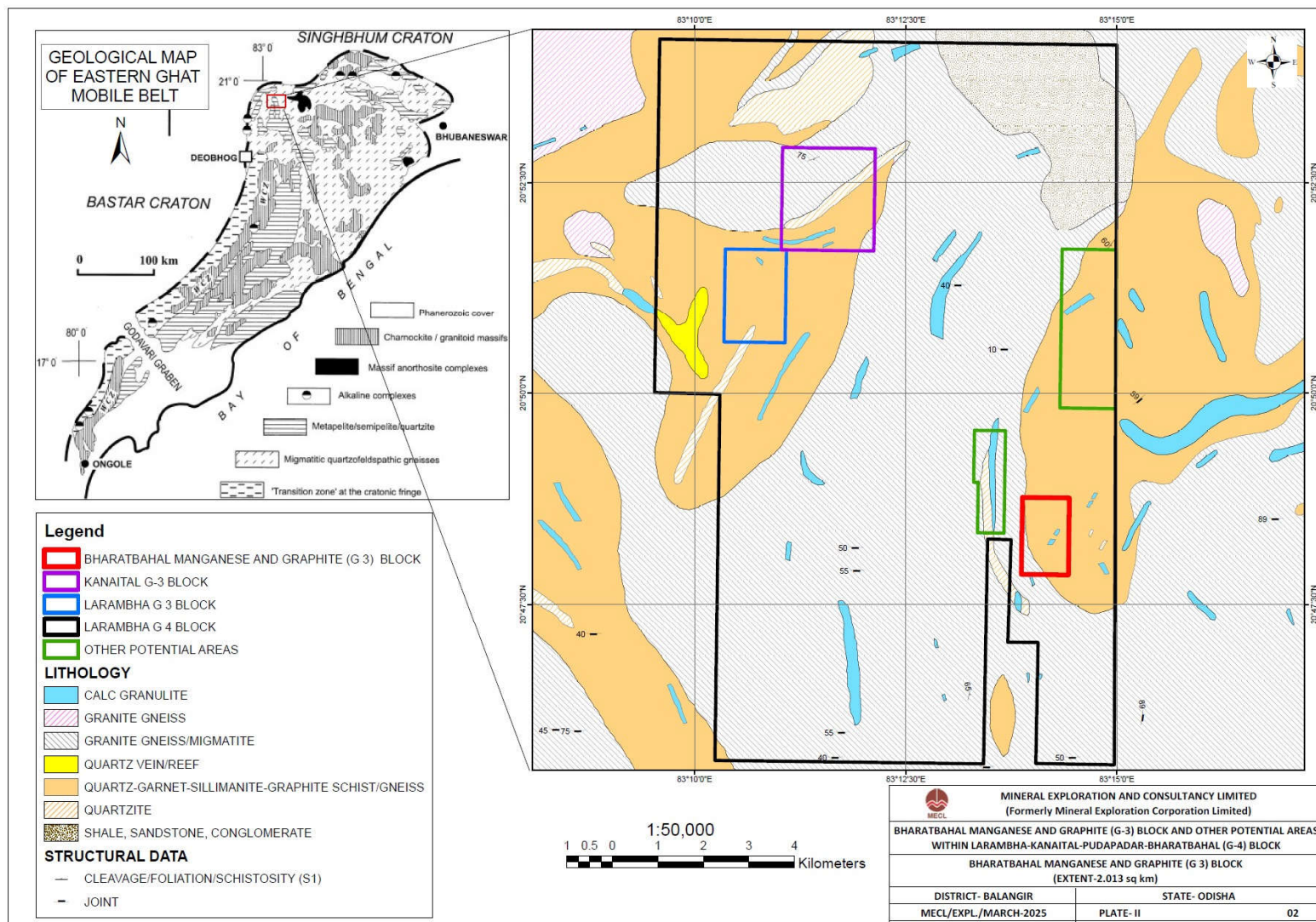
Resource Category	Cut-off	Area-1	Area-2	Area-3	Total Resource (Tons)	Mn%
G-4	10-25% Mn	28100.00	40745.00	-	68845.00	17.42
	>25% Mn	-	12645.00	-	12645.00	25.81
	<b>Total (@10% Mn Cutoff)</b>				<b>81490.00</b>	<b>18.72</b>
G-3	10-25% Mn	-	-	1260786.34	1260786.34	16.74
	>25% Mn	-	-	128495.30	128495.30	30.56
	<b>Total (@10% Mn Cutoff)</b>				<b>1389281.64</b>	<b>18.02</b>
<b>Total (G-4+G-3) Gross resource in Tons</b>		<b>1470771.64</b>				<b>18.06</b>
<b>Total net resource in tons(at 10%Mn)</b>		<b>1323694.48</b>				

**Summary of graphite resources estimated in Larambha-Kanaital and Pudapadar- Bharatbahal (G4) block, Balangir District, Odisha.**

Resource Category	Cut-off	Area-1	Area-2	Area-3	Area-4	Total Resource (Tons)	FC %
G-4	2% FC	6725	32280	-	-	39005.00	2.70
	Total	6725	32280	-	-	39005.00	2.70
G-3	2% FC	-	-	516817.62	65890.23	516817.62	4.19
	Total	-	-	516817.62	65890.23	582707.85	3.71
Total (G-4+G-3) resource in Tons		621712.85					4.09
Total resource in million ton		0.62					

8.1.11 Location of the potential areas on geological map is provided in the following Text figure 8.1





Text Figure 8.1 showing potential areas on regional geological map identified during G4 exploration of Larambha-Kanaital and Bharatbahal-Pudapadar Block, Balangir, Odisha.

## CHAPTER-9

### **9.0.0 GEOPHYSICAL SURVEY**

#### **9.1.0 INTRODUCTION:**

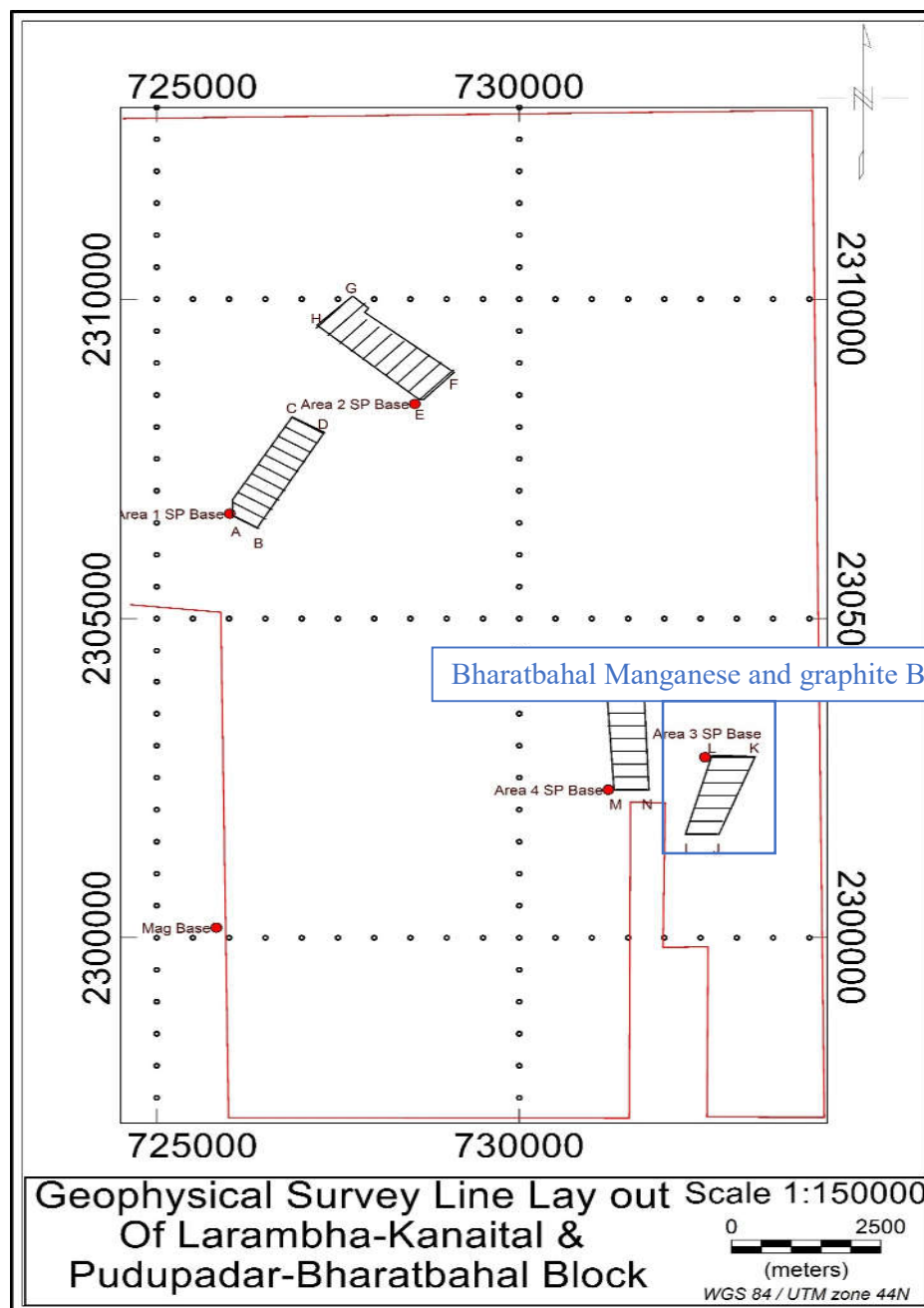
9.1.1 Geophysical Survey in Bharatbahal Manganese and Graphite block at G3 stage has not been carried out recently. However, the area was covered during reconnaissance survey (January 2023) in Larambha-Kanaital and Bharatbahal-Pudapadar Block over an extent of 135 sq km. The objective was to demarcate concealed graphite and manganese ore bodies by carrying out surface Geophysical survey i.e. Self Potential (S.P) and Magnetic after delineation of the mineralized bodies on the surface by geological mapping. Five potential areas (Area-1 to Area-5) were identified by geological mapping and surface sampling in the said G4 block. Geophysical work was concentrated to these potential areas except Area-5. The present block is one of them as Area-3 around the village Bharatbahal. Sketch showing location of the potential areas covered by geophysical survey during reconnaissance survey in Larambha-Kanaital and Bharatbahal-Pudapadar Block is shown in the Text figure 9.1.

9.1.2 The Geophysical survey was commenced on 03-01-2023 and concluded on 31-01-2023. Total area covered in the block by geophysical survey is 3.58 line km over an extent of 0.65 sq km where the lines were kept at spacing of 200 meter with 20 meter as station spacing for recording data. Demarcations of block boundaries were carried by DGPS survey and fixation of points in 20m X 200m grid with hand held GPS. Magnetic data has been acquired with EnviPro Magnetometer and SP data with IRIS Syscal R2. Geophysical instrument details are provided in the following Table 9.1

**Table 9.1: Geophysical Instrument Details**

<b>MAGNETOMETER</b>	
Type	Proton Precision Magnetometer (PPM)
Make	Scintrex (ENVI Pro MAG)
Sensitivity	0.1 nT
Accuracy	+1nT
Range	23000 to 100000 nT
<b>RESISTIVITY METER</b>	
Type	SYSCAL R2 Resistivity meter with IP & SP measurements
Make	IRIS Instrument
Input impedance	100 M0hm
Voltage resolution	1 $\mu$ V/0.2%
Voltage accuracy	0.2%

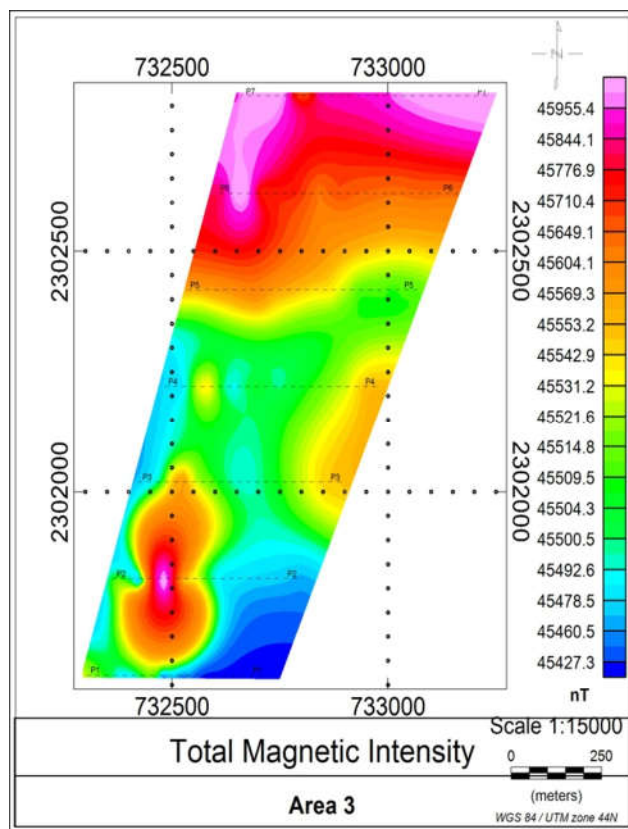
Automatic compensation of SP	-5V to +5V
<b>SURVEYING</b>	
Type	Hand held GPS
Make	Trimble Juno



Text figure 9.1 Sketch showing potential areas covered by geophysical survey during reconnaissance survey in Larambha-Kanaital and Bharatbahal-Pudapadar Block along with present Bharatbahal Block.

## 9.2.0 GEOPHYSICAL ACTIVITIES

9.2.1 **Magnetic Survey:** The total magnetic intensity (TMI) as well as magnetic anomaly (MA) has indicated characteristic variations of magnetic response over different litho units. The magnetic anomaly map is characteristics in revealing changes in the magnitude of anomaly, trend and alignments attributable to known and unknown surface and subsurface geological situations. In Bharatbahal block i.e Area-3 magnetic intensity decreasing (paramagnetic to diamagnetic) at the central portion of block. The high anomaly values in the magnetic maps shows the presence of some magnetic ore body with feeble iron content like Khondalite, Rhodonite etc. with decreasing contents in paramagnetic to diamagnetic region indicates presence of Mn ore associated with Graphite in geological contact of calc-silicate and Khondalite. The feebly magnetic responses in quartzite may indicate Mn bearing zone as they are expected to show detectable magnetic response. Total magnetic intensity (TMI) map of the area is shown in the Text Figure 9.2.



Text Figure 9.2: Total Magnetic Intensity (TMI) map of Area-3 with in the Bharatbahal Manganese and Graphite Block (G3).

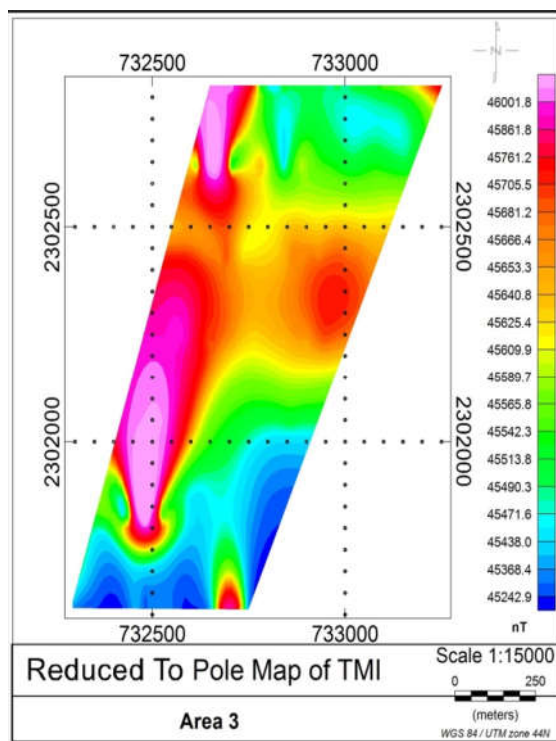
**9.2.2 Reduced to Pole (RTP):** Because of the dipolar nature of geomagnetic field, the magnetic sources observed anywhere except magnetic poles are asymmetric; this feature makes the interpretation of magnetic data difficult. The reduced to pole (RTP) technique is implemented over the Magnetic anomaly grid in order to convert magnetic anomaly to symmetrical shape so that the angle of inclination is 90 degree and declination is zero and hence, the effect of dipoles were eliminated. In the present study reduced to pole is applied on the diurnally corrected Magnetic data. From the RTP image of the Total Magnetic Intensity, it can be observed that the anomalous zone has been slightly shifted towards NNW direction, by which it overcomes the asymmetric effect of magnetic sources. The entire anomalous zone has been shifted to northern direction and confined to a single body which was parsley scattered in TMI map in the block. Thus, the Reduced to pole (RTP) method is used to interpret the extend of causative bodies in the block by analysing of only vertical effect of total magnetic field by removing the effect of inclination and declination by assuming effect if it were to be present at pole. Hence RTP gives the symmetric pattern of body by which it is easy to correlate the anomaly pattern with the lateral extend of the causative bodies. Analytical signal of RTP response of magnetic data for the block is provided in the Text Figure 9.3.

**9.2.3 Residual Magnetic Anomaly:** In geophysical studies, the observed total magnetic field intensity is the sum of magnetic fields generated from all subsurface sources. The goal of a particular magnetic interpretation often involves the delineation of small-scale targets buried at a specific depth, and the magnetic responses of these targets are merged with a regional field which is typically the responses of more extensive or deeper magnetic sources than the shallower targets. The residual fields created by the target sources are usually extracted from the regional field using the residual-regional anomaly separation technique. The high and short-wavelength components of the magnetic anomaly are termed regional and residual anomalies, respectively. The residual anomalies are seen as small, local patterns but of considerable importance. The detected anomalies on the residual magnetic anomaly map (Text Figure 9.4) of 50m upward continuation strongly reflect the geological features / structures. The smaller anomalies in the Total Magnetic Intensity map (Text Figure 9.2) in areas of strong regional disturbances are more readily apparent on the residual Magnetic anomaly map

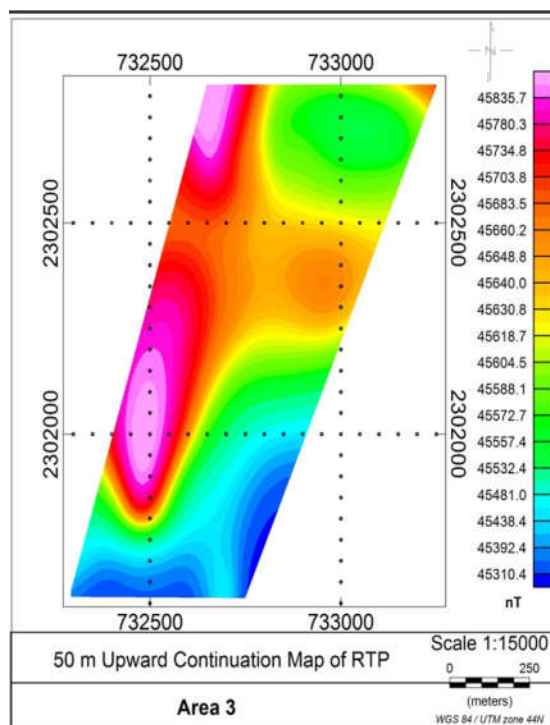


(Text Figure 9.4). It can be observed that the anomaly zone at northern part of the block was mainly dominated by regional geology and magnetization of targeted mineralized body was suppressed due to regional anomaly. The residual anomaly map shows the targeted mineralized body at the centre of the block elongated from NW to SE with minor discontinuity.

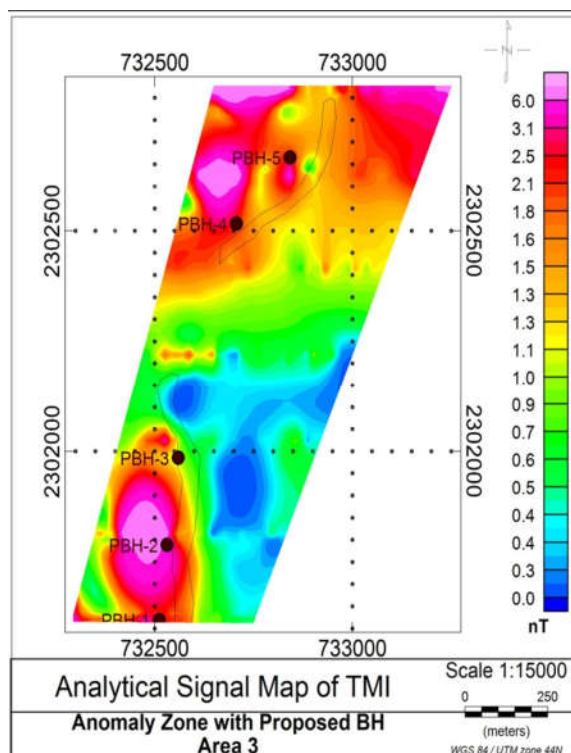
**9.2.4 Analytical Signal Analysis:** The Analytical signal analysis known as total gradient method is useful in demarcating the edges/lithological boundaries of source of magnetic bodies. The shape of the analytical signal of the magnetic field is nearly independent of field orientation, direction of magnetization and remanence. The analytical signal analysis map of the study area helped in inferring lithological boundaries in the form of high intensity analytical signal amplitude along the contacts and shallow anomalous bodies. The analytical signal analysis is very useful for interpretation as the causative bodies in the block are of shallow depth and it is easy to delineate the magnetic body boundaries. As in the analytical signal analysis the signal determined is mainly affected by the vertical bodies and hence on its analysis it become easy to locate changes in basement structures and their trends. The analytical signal map of the TMI was analyzed. The analytical signal map reveals the sources and the disposition of the magnetic anomalies in the block. The analytical map showed magnetic intensity ranging from 0.0 nT to 8.0 nT in the area and surrounding. The sources of the high magnetic anomalies in the study area are the charnockites, granite gneiss, quartzite veins, and migmatitic rocks. In contrast, the weathered basements rocks constitute the overburden in the study area with low magnetic anomalies. The general lineament orientations are well collaborated with the regional geology of the study area. It became clear from the analysis of lineaments observed in the analytical signal map that the manganese mineralization zones in the area are structurally controlled. They are associated with fractures and fault like structures in granite gneiss, migmatitic gneisses, and quartzite veins and along with the geological contact of Cal-Silicate and Khondalite as well as shear/fracture are also the important sites of mineralization. The signatures of known locations of the manganese in the study area were used to predict other occurrences of the manganese mineral ores in the area leading to the delineation of three locations in the study area. Proposed boreholes are also marked in the Analytical Signal Analysis map. Analytical Signal Analysis map of the block is shown in the Text Figure 9.5.



Text Figure 9.3: Analytical signal of RTP response of magnetic data in Area-3 (Bharatbahal block).

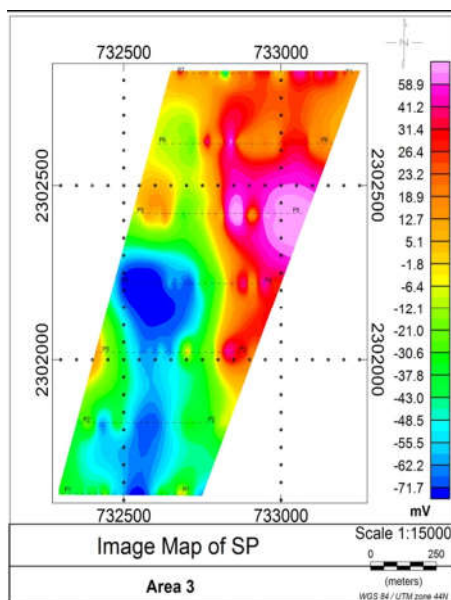


Text Figure 9.4: 50m upward continuation map of RTP in Area-3 (Bharatbahal block (G3)).



Text Figure 9.5: Analytical Signal Map of TMI in the Bharatbahal Manganese and Graphite block (G3) with proposed borehole locations.

9.2.5 **Self Potential Survey:** In area 3 High negative SP anomaly value at the central to southern boundary of the area indicates presence of Graphite Ore and its association with Mn ores at the geological contact of Khondalite and calc-silicate.



Text Figure 9.6: SP response in Area-3 (Bharatbahal manganese and graphite block)



**9.3.0 CONCLUSION AND RECOMMENDATIONS:** On the basis of combined study of magnetic and SP methods, targeted mineralized zones are successfully identified with different lithological units and their contacts. The large amplitude and the narrow shape of the anomaly on profile plots indicate that the body is at shallow depth and steeply dipping and almost near vertical in the area. Hence, the indicated zones may be checked by drilling for the presence of mineralization. Proposed borehole locations are provided in the following Table 9.2.

**Table 9.2**  
**Proposed Boreholes Interpreted Through Geophysical Survey In Bharatbahal**  
**Manganese And Graphite (G3) Block, Balangir, Odisha**

<b>Proposed BH No.</b>	<b>Proposed Depth (m)</b>	<b>Angle</b>	<b>Azimuth</b>	<b>Northing (m)</b>	<b>Easting (m)</b>
PBH-1	50	50°	S55°E	2301619.03	732511.69
PBH-2	50	50°	S85°E	2301788.75	732531.03
PBH-3	50	50°	S85°E	2301985.24	732559.68
PBH-4	50	50°	S45°E	2302516.25	732706.85
PBH-5	50	50°	N45°E	2302665.44	732842.41

## **CHAPTER-10**

### **10.0.0 EXPLORATION UNDERTAKEN DURING CURRENT INVESTIGATION**

#### **10.1.0 INTRODUCTION**

10.1.1 Balangir and adjoining district in the northwestern part of the Odisha which is part of the Eastern ghat mobile Belt (EGMB) is well established for the occurrences of manganese and graphite associated with the khondalite suite of rocks. In field seasons 2022-23 and 2023-24 reconnaissance survey in part of the survey of India Toposheet No. 64P/01 was taken up over an extent of 135.00 sq km as Larambha-Kanaital and Bharatbahal-Puddapadar manganese and graphite block. Five potential areas were identified on the basis of geological mapping (1:12500), surface sampling, geophysical survey (SP and magnetic), trenching and drilling (498m). The present block, Bharatbahal manganese and graphite block at G3 stage is one of them over an extent of 2.013 sq km. Three mineralized zones had been identified with cumulative strike length of 979m and average width is 15m including float ores. Two prominent zones are trending NNE-SSW in the central part were identified. Five boreholes have been drilled (259m) to prove the subsurface and lateral continuity of the mineralization for the two prominent zones during G4 exploration.

10.1.2 Further, to establish the lateral and vertical continuity and to assess the quality and quantity of the mineralization identified during the reconnaissance survey, up gradation of the block to G3 stage around the Bharatbahal village was taken up. Activities undertaken for up gradation along with the objectives are as follows:

#### **10.2.0 OBJECTIVES OF INVESTIGATION**

10.2.1 The objectives of the preliminary exploration in the block are as under:

- i. Detailed Geological mapping on 1:2000 scale to delineate mineralized bodies and other lithounits in the area.
- ii. Topographical survey on 1:2000 scale, by means of surface contouring at 2 m interval to record the elevation details along with the other features within the block.
- iii. Trenching at suitable interval in the anomalous zone marked by geophysical survey to establish the continuity of the mineralization which is covered by soil.
- iv. Drilling to intersect the mineralized bodies at 30m vertical depth with 100m strike interval and at 60m vertical depth at places.

- v. Assessment of quality and quantity of the manganese and graphite resources (333) as per UNFC norms & Minerals (Evidence of Mineral Contents) Rules- 2015.

### 10.3.0 DETAILS OF EXPLORATION ACTIVITIES TAKEN UP

10.3.1 To meet the above objectives, activities mentioned in the following table were planned. The table also shows a comparison between approved and achieved quantum in the block.

**Table 10.1**

**Quantum of work approved vs achieved in Bharatbahal Manganese and Graphite Block (G3), Balangir district, Odisha**

Sl. No.	Item of Work	Unit	Approved	Achieved
1	Geological Mapping (on 1:2000 Scale)	Sq Km.	2.013	2.013
2	Topographical Survey (1:2000 Scale)	Sq Km	2.013	2.013
3	DGPS survey of Boreholes and Block Boundary	Nos.	13 (09 BH + 04 Boundary Points)	12 (08 BH + 04 Boundary Points)
4	Trenching	Cu m	90	90
5	Core Drilling	m	500	496 (08)
6	Construction of Pillar	Nos.	09	08
7	Core preservation	m	250	250
8	Sample Preparation & Chemical Analysis			
A.	Primary samples for Manganese (Trench/Borehole)			
	i) Primary samples for 6 radicals i.e. Mn, SiO <sub>2</sub> , P <sub>2</sub> O <sub>5</sub> , Fe <sub>2</sub> O <sub>3</sub> , MnO <sub>2</sub> and Acid Insoluble	Nos.	160	84
	ii) External Check sample (10% of Primary samples) for 6 radicals	Nos.	16	8
B.	Primary samples for Graphite (Trench/Borehole)			
	i) Proximate Analysis of Primary samples for Graphite for 4 parameters i.e. Fixed Carbon (FC), Ash (A), Moisture (M) and Volatile Matter (VM)	Nos.	70	93
	ii) External Check sample (10 % of Primary samples) for Graphite for 4 parameters	Nos.	7	9
9	Petrographic Studies	Nos	5	5
10	Mineragraphic Studies	Nos	5	5
11	Digital Photography	Nos.	5	5
12	Specific gravity studies	Nos.	5	5

Sl. No.	Item of Work	Unit	Approved	Achieved
13	34 element analysis (ICPMS)	Nos.	5	5
14	Raman Spectroscopy	Nos.	5	5
15	Report Preparation	Nos.	1	1

#### 10.4.0 SURVEY

- 10.4.1 The entire survey work has been carried out with the help of Differential Global Positioning System (DGPS) and Total Station (Trimble Make, Model R8s). The topographical survey i.e., leveling/contouring was carried out on 2m contour interval in the entire block area of 2.013 sq km. The coordinates and reduced levels of all the base stations, boreholes and cardinal points of the block boundary have been recorded by DGPS. Surface features in the block i.e. roads, village boundaries, temples/mosque, ponds, river/nalas etc. were also surveyed and presented on the Topographical Map which is provided as Plate II.
- 10.4.2 The survey work was carried out by using (DGPS) and total stations of Tremble make having accuracy of 0.10m and with WGS 1984 datum. At first, base stations was fixed in the west central part of the block named as Base. The coordinates of base station are N20°48'14.53901"- E83°13'49.66113" and RL 214.198m. Reduced levels and coordinates of all data points were recorded with DGPS and Total stations in WGS-84 datum in UTM (m) Zone-44N.
- 10.4.3 In the initial part network of stations were also established all around the block for contouring and borehole fixation with the help of DGPS. List of major stations established in the area has been provided in Annexure-II
- 10.4.4 Boreholes were fixed on the ground with the help of base and triangulation stations and the same had been surveyed again after drilling by DGPS for the final location. Co-ordinates of Boundary corner points were also fixed by DGPS which is provided in the Table 4.1. Co-ordinates and RL details of the drilled boreholes have been provided in Annexure-V.

## **10.5.0 GEOLOGICAL MAPPING**

10.4.1 MECL carried out detailed geological mapping on 1:2000 scale, by taking traverses over an extent of 2.013 sq km. Available large scale map (1:12500) of the area prepared during G4 exploration by MECL was utilized for updation to 1:2000 scale. Lithological units and litho-contacts have been mapped with the help of total station. Attitude and structural features of rocks like bedding, foliation and joints were recorded by Brunton Compass. The geological map was prepared by plotting the different litho units and structural features i.e., strike & dip of foliations. Geological map of the area is provided as Plate III.

## **10.6.0 TRENCHING**

10.6.1 Five nos. of trenches have been excavated (118 cu. m) at locations based on the geological mapping, anomalous values of surface sampling, geophysical interpretation. Trenches were made to prove the strike continuity of the mineralized body. All the trenches were excavated across the strike of the mineralized bodies. Samples were collected from the floor of these trenches at 1m interval by cutting channels, after proper geological mapping of the wall of the trenches. Trench profiles have been prepared in 1:100 scales along with other details and provided as Plate IV.

10.6.2 A total of 30 samples were collected from 05 trenches for analysis of Mn, SiO<sub>2</sub>, P<sub>2</sub>O<sub>5</sub>, Fe<sub>2</sub>O<sub>3</sub>, MnO<sub>2</sub> and acid insolubles on the basis of manganese ore occurrences. Threshold value of 10% Mn has been considered for manganese mineralization. Samples from Trench 2 to 3 have equal to or more than the threshold value of Mn. Thickness and quality of the graphite bands exposed in the said trenches are provided in the following Table 10.2. Analytical results of 30 samples for manganese are provided in Annexure IV.

10.6.3 A total of 30 trench samples from 05 trenches (Trench 1 to 5) were collected for proximate analysis (Moisture, Volatile Matter, Ash and Fixed Carbon) on the basis of graphite mineralization. Threshold value of 2% Fixed Carbon (FC) has been considered for graphite mineralization. Samples from Trench 2 to 3 have more than the threshold value of 2% FC. Thickness and quality of the graphite bands encountered in the said trenches are provided in the following Table 10.2. Analytical results of 30 samples for proximate analysis are provided in Annexure IV.

10.6.3 Trench mapping has revealed that, surface and near surface manganese bodies are weathered and are of oxide facies mostly of pyrolusite and psilomelane. Manganese occurs with or without association of graphite. Both manganese and graphite are associated with the khondalite (weathered). Graphite occurs as flakes and are found randomly distributed within the host rock, and are usually 1–5 mm in size. The flakes are oriented parallel to the foliation.

10.6.4 Field photographs of the trenches with mineralization are shown in the following Figures:



**Field Photograph 10.1** Field photographs showing Trench 2 (Left) and close view of manganese mineralization (Right)

10.6.4 Details of the trench and mineralized zones encountered in the trenches are provided in the following Table 10.2.

**Table: 10.2**  
**Details of trenches and mineralisation details in Bharatbahal Manganese and Graphite (G3) block, Balangir, Odisha.**

Sl. No.	Trench Name	Trench Location/ Direction	No of Samples Collected (Manganese and Graphite)	Mineralization Thickness (Avg. Grade) at ( $\geq 2\%$ FC) for Graphite/ ( $\geq 10\%$ Mn) for Manganese
1	Trench 1	N45°W-S45°E	02	-
2	Trench 2	N43°W-S43°E	12	<b><u>Manganese</u></b> Thickness-10m Avg. Grade- 12.29% FC
3	Trench 3	N45°W-S45°E	12	<b><u>Graphite</u></b> Thickness-1m Avg. Grade- 2.90% FC Thickness-1m Avg. Grade- 5.60% FC  <b><u>Manganese</u></b> Thickness-3m Avg. Grade- 11.08% Mn Thickness-2m Avg. Grade- 13.37% Mn
4	Trench 4	N70°W-S70°E	02	-
5	Trench 5	N92°E-S92°W	02	-

## 10.7.0 DRILLING

10.7.1 G4 exploration in the area and recent geological mapping, and trenching has established 02 mineralized zones (North and South Band) alongwith other isolated/small/ uncorrelated zones. These mineralized bands are discontinuous lensoidal and form an arcuate shape in the central portion of the block. To prove the lateral and vertical continuity of the mineralized bodies, 09 core boreholes were planned with an

approved meterage of 855m. Out of 09 boreholes, 08 boreholes were drilled. 06 boreholes for 1<sup>st</sup> level of intersection (30m vertical depth) and 02 boreholes for 2<sup>nd</sup> level of intersection (60m vertical depth). These boreholes were planned along the sections where mineralization had been intersected during G4 work, along the trenches which have positive manganese and graphite mineralization and to prove the strike continuity of the mineralized bodies, at 100m strike interval. Due to local swing of the mineralized bodies, azimuth and angle of the boreholes varies with location. The data of these boreholes are depicted in eight geological cross sections (S1 to S8).

10.7.2 Drilling commenced on 14.03.2024 with the borehole MBMG-01 and concluded on 12.01.2025 with the closure of MBMG-08. Two conventional core drill rigs (MEC-332 and 334) were deployed for drilling in the block. Eight (08) boreholes were drilled with a meterage of 496m.

10.7.3 Details of the boreholes drilled in the block are provided in the Annexure V and summary of the same is in the following Table 10.3.

**Table 10.3**  
**Boreholes drilled in Bharatbahal Manganese and Graphite (G3) Block, Balangir District, Odisha.**

SL. NO.	BH. NO.	REDUCED LEVEL (m)	TOTAL DEPTH (m)	AZIMUTH	ANGLE FROM HORIZONTAL
1	MBMG-01	218.127	49.50	95°	50°
2	MBMG-02	215.586	68.00	95°	50°
3	MBMG-03	213.769	65.00	125°	50°
4	MBMG-04	220.902	55.00	135°	50°
5	MBMG-05	217.215	99.00	95°	50°
6	MBMG-06	219.056	42.00	135°	50°
7	MBMG-07	222.598	35.50	135°	50°
8	MBMG-08	220.060	82.00	135°	50°
<b>Total</b>			<b>496.00</b>		

10.7.4 During G4 exploration 05 boreholes were drilled in the are at a strike interval of 200m with a total meterage of 259m. Details of the boreholes drilled are provided in the Annexure V and summary of the same is in the following Table 10.4.



**Table 10.4**

**Boreholes drilled in Bharatbahal Manganese and Graphite (G3) block, Balangir District, Odisha.**

SL. NO.	BH. NO.	REDUCED LEVEL (m)	TOTAL DEPTH (m)	AZIMUTH	ANGLE FROM HORIZONTAL
1	MLB-01	213.59	66.00	125°	50°
2	MLB-02	219.15	50.50	135°	50°
3	MLB-03	216.52	46.00	95°	50°
4	MLB-04	219.70	46.50	95°	50°
5	MLB-05	221.59	50.00	135°	50°
<b>Total</b>			<b>259.00</b>		

#### **10.8.0 DATA SPACING FOR REPORTING OF EXPLORATION RESULTS**

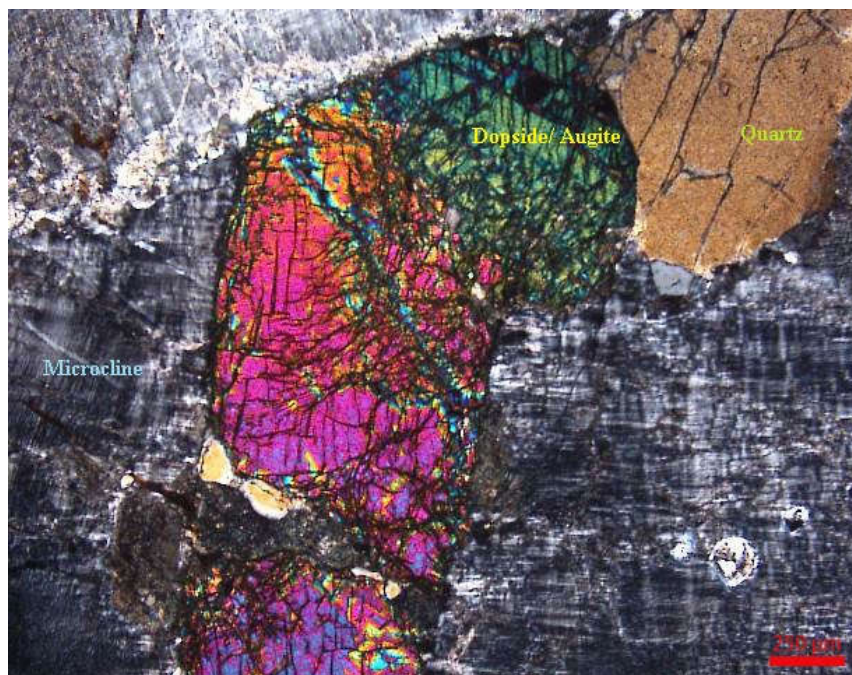
10.8.1 Five nos of trenches were made across the mineralized bodies with an interval of nearly 200m. Thirteen boreholes have been drilled in the block at nearly 100m strike interval to intersect the mineralized bodies in subsurface. Eleven boreholes are for 1<sup>st</sup> level and two boreholes are for 2<sup>nd</sup> level intersection. Mineralised bodies established by geological mapping, trenching and drilling are discontinuous lensoidal shape. Pinching and swelling nature was observed along the strike length on surface.

#### **10.9.0 PETROGRAPHIC STUDIES**

10.9.1 A total of 5 nos of borehole samples of various litho-units intersected in the boreholes, were subjected to petrographic studies at Petrology Laboratory, MECL Nagpur. Thin sections were prepared and petrographic studies of the same were carried out using Leitz and Ortholux II microscopes to know the mineral composition, texture, characteristics of individual minerals and the rock type. Litho-units identified by petrographic studies are granite gneiss, calc-silicate, and quartzite. Details of the petrographic studies of borehole samples are provided in Annexure X. Descriptions of the litho units identified by petrographic studies are as follows:

10.9.2 **Pyroxene granulite:** Microcline/ orthoclase occur as medium to coarse subhedral grains showing crypto-perthitic exsolutions. Quartz occurs as anhedral grains and patches. Diopside/ augite are present as medium to fine subhedral prismatic grains. Sphene is seen present as fine wedges. Plagioclase occurs as fine anhedral patches showing myrmekitic intergrowths. Sericite has intruded as very fine fillings cutting

across feldspar grains. Kaolinite is noted as very fine dirty particles developing after feldspar alterations.



**Pmg – 1:** Photomicrograph showing association of microcline, quartz and pyroxenes in pyroxene granulite as seen under crossed nicols. Specimen No.: MBMGP-01 (MBMG-02/ 12.50m – 12.60m) Magnification: 40X

**10.9.3 Calc silicate:** Quartz occurs as fine to medium anhedral grains. Diopside is present as fine subhedral to anhedral grains. Scapolite is present as fine to medium subhedral grains. Microcline/ orthoclase are present as medium subhedral grains. Calcite occurs as fine to medium anhedral to subhedral grains. Wollastonite is seen present as fine to medium subhedral grains in association with calcite. Sphene is found present as very fine wedges in dissemination. Tremolite occurs as fine subhedral prismatic grains. Plagioclase is noted as fine anhedral patches showing myrmekitic texture. Opaques occur as very fine to fine anhedral grains as accessories. Photomicrographs of borehole sample MBMGP-02 from MBMG-02 (14.20 – 14.30m) is provided in the following figure Pmg-2



**Pmg – 2:** Photomicrograph showing association of quartz, diopside, scapolite and feldspar in meta-calc silicate as seen under crossed nicols. Specimen No.: MBMGP-02 (MBMG-02/14.20m – 14.30m) Magnification: 40X

#### 10.10.0 MINERAGRAPHIC STUDIES

10.10.1 A total of 05 borehole samples were subjected to mineragraphic studies at Petrology Laboratory, MECL Nagpur. Polished sections of mineralised samples were prepared and mineragraphic studies were carried out using Leitz and Ortholux II microscopes to know the mineral composition, percentage of minerals present in polished section, characteristics of individual minerals and their paragenesis. The results of mineragraphic studies are given in Annexure- XI.

10.10.2 The study of these sections reveal that the samples have graphite more than 50% and associated with magnetite, jacobsonite, chalcocopyrite, pyrite as accessory minerals. Graphite is present as fine to medium flakes and flaky aggregates. At places, graphite occurs as fine to medium disseminated flakes and flaky aggregates showing crude alignment Graphite is present as fine disseminated flakes, often seen being entrapped within psilomelane-goethite patches where it is associated with manganese. Pyrite occurs as fine to medium anhedral patches, streaks and stringers aligned along the foliation as a major mineral. Magnetite/ jacobsonite are seen present as fine subhedral prismatic and anhedral grains. Chalcocopyrite occurs as very fine specks in accessories associating bluish covellite patches in areas. Also, chalcocopyrite is noted as very fine

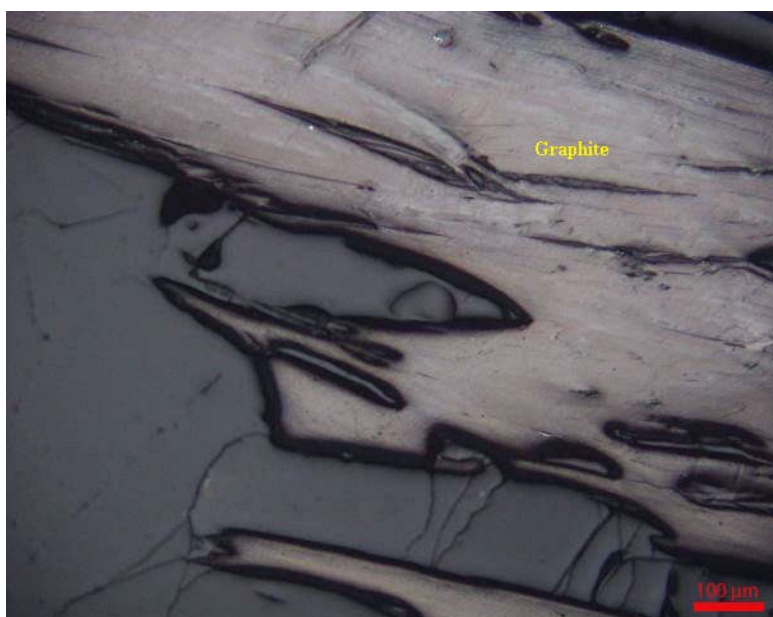


hairline fillings and streaks in accessories. Psilomelane and goethite together occur as intermixed patches and fillings showing colloform texture in areas.

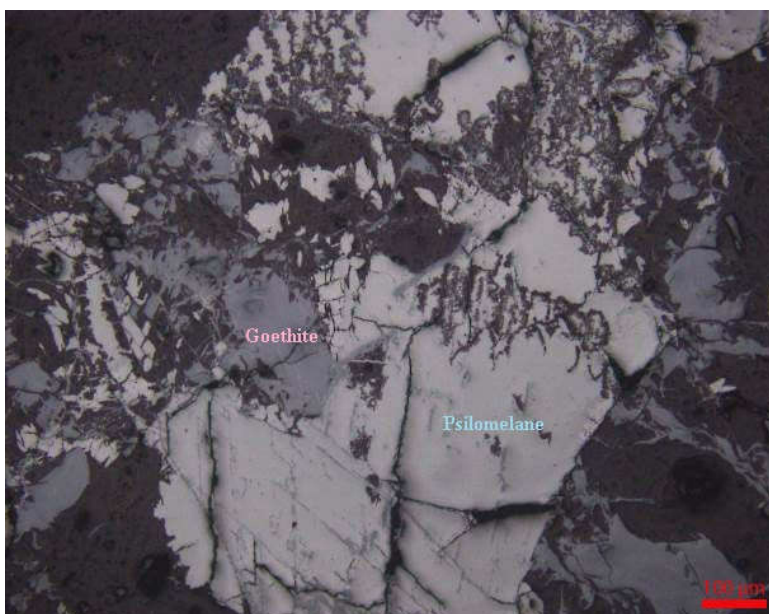
10.10.3 Photomicrographs of thin sections under reflected light are given in the below figure Pmg 3 to 5.



Pmg – 3: Photomicrograph showing fine to medium plates and flaky aggregates aligned along the foliation and associating fine to medium anhedral grains of pyrite as seen under reflected light. Specimen No.: MBMGM-01 (MBMG-08/70.40-70.50m) Magnification: 100X



Pmg – 4: Photomicrograph showing medium to moderately coarse flaky aggregates of graphite as seen under reflected light. Specimen No.: MBMGM-04(MBMG-05/76.10-76.20m) Magnification: 100X



**Pmg – 5:** Photomicrograph showing intermixed patches of psilomelane and goethite as seen under reflected light. Specimen No.: MBMG-05(MBMG-05/11.60-11.70m) Magnification : 100X.

#### 10.11.0 ANALYSIS OF 34 ELEMENTS BY ICPMS

10.10.0 A total of 05 borehole samples were subjected to 34 element analysis by ICPMS method. Most of the samples were collected from the graphite mineralization from borehole intersections. Analytical results show vanadium (V) is associated with graphite and show up to 486.24ppm.

#### 10.12.0 RAMAN SPECTROSCOPY

10.12.1 A total of 05 borehole samples were subjected to Raman spectroscopy studies to assess the physical nature of the graphite mineralization. Samples were studied for Raman spectroscopy at Laser Raman Spectroscopy (LRS) Laboratory, Central Petrological Laboratory, Geological Survey of India, Kolkata. Details of the samples studied under LRS are provided in the following Table 10.5.

**Table 10.5**

**Details of sample studied under Raman Spectroscopy**

SL NO	Sample No.	Lab. No.	Borehole No. (Depth)	Lithology
01	MBMGRS-01	Sample 1	MBMG 01 (40.90-41.00m)	Graphite Schist
02	MBMGRS-02	Sample 2	MBMG 02 (43.90-44.00m)	Graphite Schist
03	MBMGRS-03	Sample 3	MBMG 02 (52.00-52.10m)	Graphite Schist
04	MBMGRS-04	Sample 4	MBMG 07 (28.40-28.50m)	Graphite Schist
05	MBMGRS-05	Sample 5	MBMG 08 (76.50-67.60M)	Graphite bearing calc-silicate

10.12.2 Nature of Sample: Samples (05-10cm) were collected from the graphite horizons intersected in the boreholes. Further, the samples were processed to make polished rock slab of with 10mm thickness. Length and width of the samples were 1.5-2cm.

#### 10.12.3 Analyzing setup:

Laboratory:	Laser Raman spectroscopy, NCEGR, CHQ
LASER:	514 nm edge Ar <sup>+</sup> laser (gratings: 2400 lines/mm)
Spot beam Diameter:	~ 1.2 $\mu$ m
Focus Energy:	12 – 15 mW
Spectrum Accumulations time:	20 s.

The room temperature was maintained at  $22 \pm 1^\circ\text{C}$ . The peak positions of Raman spectra were determined by the Wire program (Version 3.4). The spectral resolution for each Raman vibrational mode is on the order of  $\pm 1\text{-}2\text{ cm}^{-1}$ .

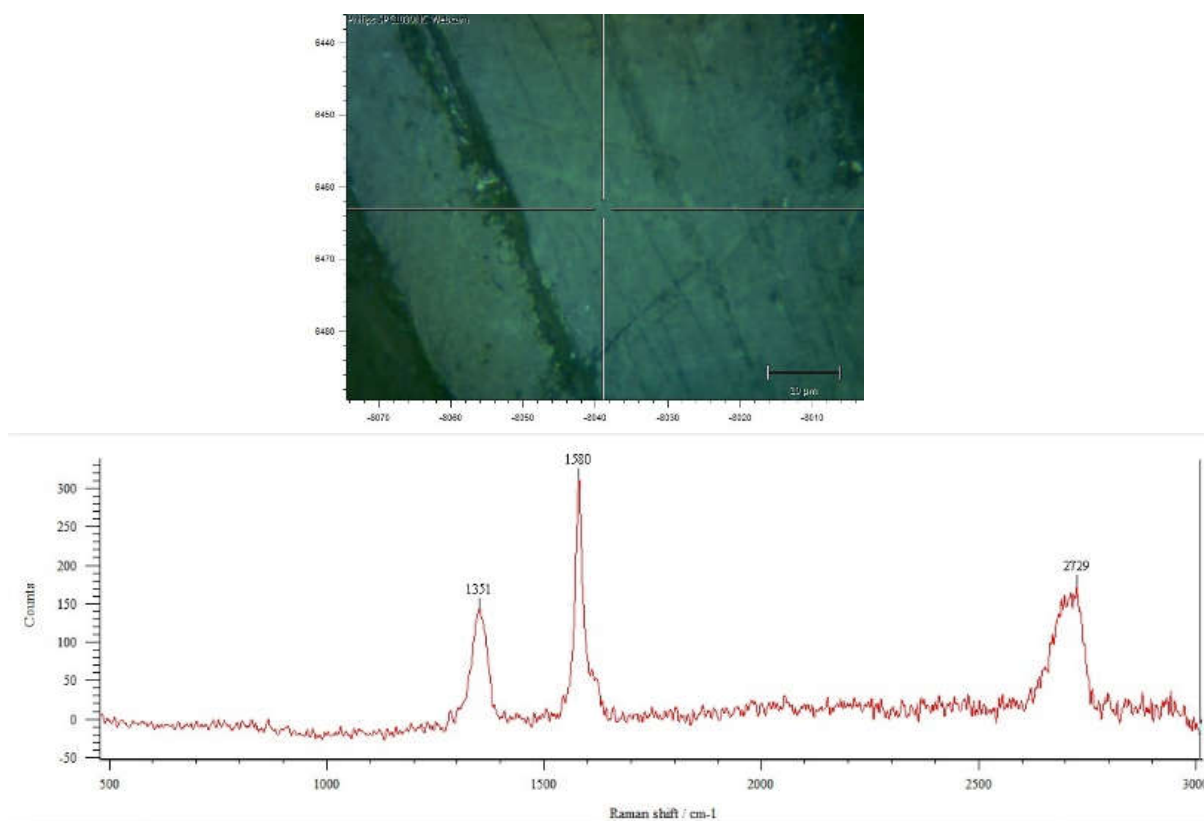
10.12.4 **Instrument:** Renishaw Invia Reflex Laser Raman Spectrometer.

10.12.5 **Results:** Laser Raman spectroscopy studies of 05 samples in Bharatbahal block are provided in Annexure XXII and summary is as follows:

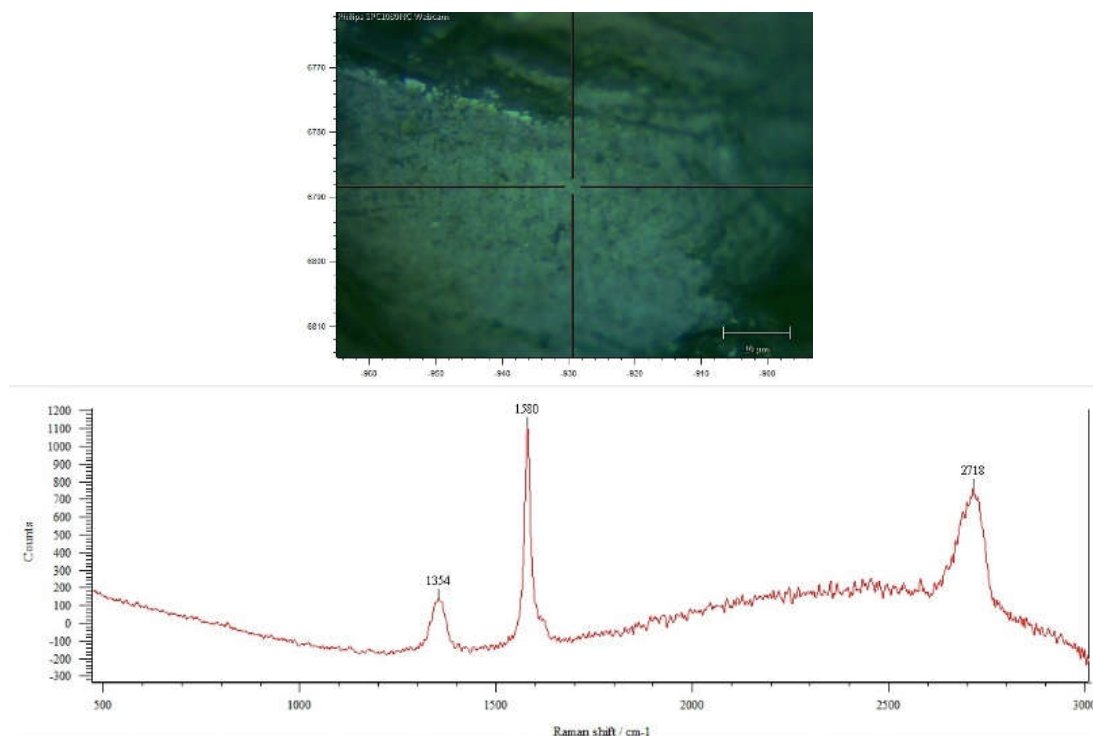
- **Sample 1:** The sharp peak at  $1580\text{ cm}^{-1}$ ,  $1581\text{ cm}^{-1}$ , or  $1582\text{ cm}^{-1}$ , with shoulder peaks at  $1621\text{ cm}^{-1}$ , or  $1622\text{ cm}^{-1}$ , along with the smaller peaks at  $1350\text{ cm}^{-1}$ ,  $1351\text{ cm}^{-1}$ ,  $1353\text{ cm}^{-1}$ ,  $1354\text{ cm}^{-1}$ , or  $1355\text{ cm}^{-1}$ , and second-order peaks at  $2713\text{ cm}^{-1}$ ,  $2716\text{ cm}^{-1}$ ,  $2720\text{ cm}^{-1}$ , and  $2729\text{ cm}^{-1}$ , represent **graphite**.
- **Sample 2:** The peak at  $1580\text{ cm}^{-1}$  or  $1581\text{ cm}^{-1}$ , with shoulder peaks at  $1618\text{ cm}^{-1}$ ,  $1623\text{ cm}^{-1}$ , or  $1624\text{ cm}^{-1}$  along with smaller peaks at  $1350\text{ cm}^{-1}$ ,  $1352\text{ cm}^{-1}$ , or  $1354\text{ cm}^{-1}$ , and second-order peaks at  $2714\text{ cm}^{-1}$ ,  $2718\text{ cm}^{-1}$ ,  $2720\text{ cm}^{-1}$  or  $2725\text{ cm}^{-1}$ , represent **graphite**.
- **Sample 3:** The peak at  $1580\text{ cm}^{-1}$ , or  $1581\text{ cm}^{-1}$  with shoulder peaks at  $1620\text{ cm}^{-1}$ ,  $1622\text{ cm}^{-1}$  or  $1623\text{ cm}^{-1}$ , along with smaller peaks at  $1348\text{ cm}^{-1}$ ,  $1349\text{ cm}^{-1}$ ,  $1350\text{ cm}^{-1}$ , or  $1352\text{ cm}^{-1}$ , and second-order peaks at  $2711\text{ cm}^{-1}$ ,  $2716\text{ cm}^{-1}$ ,  $2726\text{ cm}^{-1}$ , or  $2728\text{ cm}^{-1}$ , represent **graphite**.
- **Sample 4:** The peak at  $1581\text{ cm}^{-1}$ , with shoulder peaks at  $1620\text{ cm}^{-1}$ , or  $1622\text{ cm}^{-1}$  along with smaller peaks at  $1352\text{ cm}^{-1}$ ,  $1354\text{ cm}^{-1}$ , or  $1358\text{ cm}^{-1}$ , and second-order peaks at  $2712\text{ cm}^{-1}$ ,  $2718\text{ cm}^{-1}$ ,  $2729\text{ cm}^{-1}$ , or  $2731\text{ cm}^{-1}$ , represent **graphite**.
- **Sample 5 :** The peak at  $1580\text{ cm}^{-1}$ , or  $1581\text{ cm}^{-1}$  with shoulder peaks at  $1618\text{ cm}^{-1}$ ,  $1620\text{ cm}^{-1}$ ,  $1621\text{ cm}^{-1}$ ,  $1623\text{ cm}^{-1}$ , or  $1625\text{ cm}^{-1}$ , along with smaller peaks at  $1349$

$\text{cm}^{-1}$ ,  $1354 \text{ cm}^{-1}$ ,  $1355 \text{ cm}^{-1}$ , or  $1357 \text{ cm}^{-1}$ , and second-order peaks at  $2714 \text{ cm}^{-1}$ ,  $2715 \text{ cm}^{-1}$ ,  $2718 \text{ cm}^{-1}$ ,  $2718 \text{ cm}^{-1}$ , or  $2728 \text{ cm}^{-1}$ , represent **graphite**.

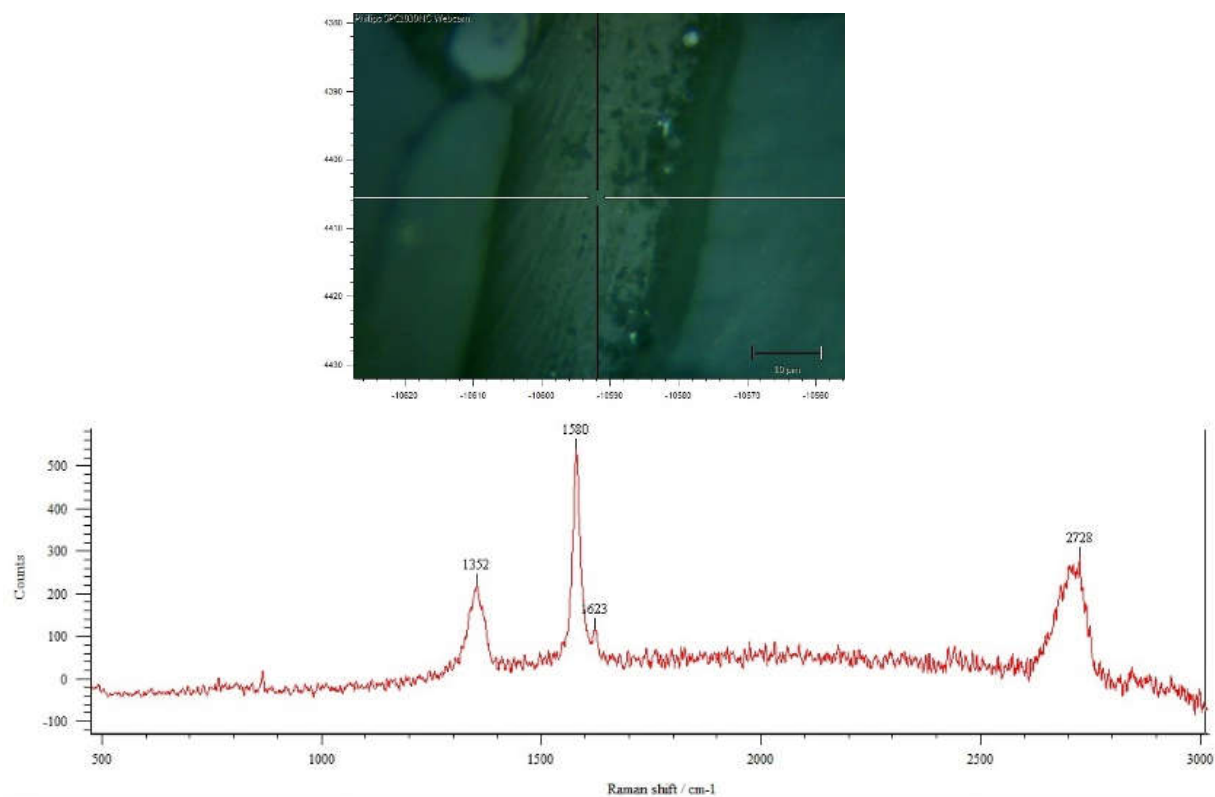
- The single LRS peaks at  $1580 \text{ cm}^{-1}$ , or  $1581 \text{ cm}^{-1}$  represent the **flaky/massive nature of graphite** (Neubeck et al., 2020). Peaks at  $1580 \text{ cm}^{-1}$ , or  $1581 \text{ cm}^{-1}$ , along with shoulder peaks at  $1618 \text{ cm}^{-1}$ ,  $1620 \text{ cm}^{-1}$ ,  $1621 \text{ cm}^{-1}$ ,  $1622 \text{ cm}^{-1}$ ,  $1623 \text{ cm}^{-1}$  or  $1624 \text{ cm}^{-1}$  and smaller peaks at  $1348 \text{ cm}^{-1}$ ,  $1349 \text{ cm}^{-1}$ ,  $1350 \text{ cm}^{-1}$ ,  $1351 \text{ cm}^{-1}$ ,  $1353 \text{ cm}^{-1}$ ,  $1354 \text{ cm}^{-1}$ , or  $1355 \text{ cm}^{-1}$ , represent vein-type graphite.



Text Figure. 10.1: LRS peaks of sample No.-1(MBMGRS-1)

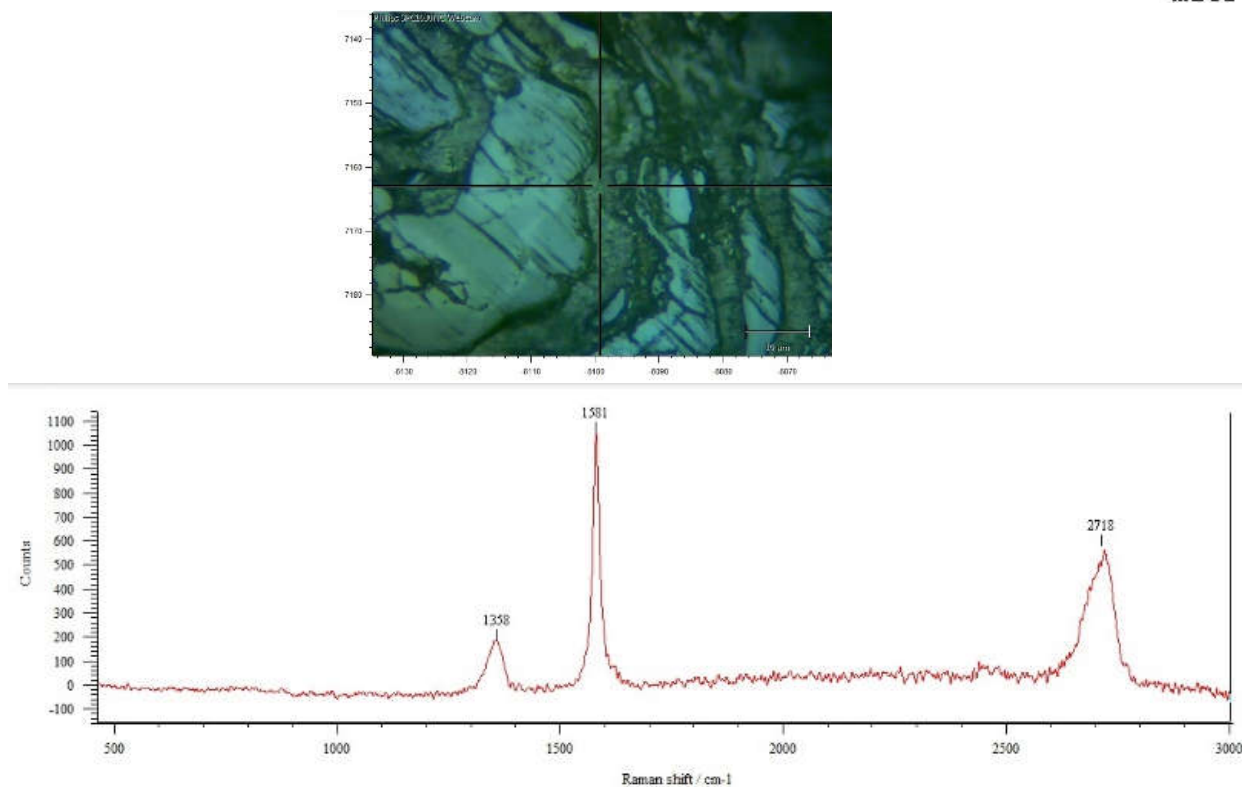


Text Figure. 10.2: LRS peaks of sample No.-1(MBMGRS-2)

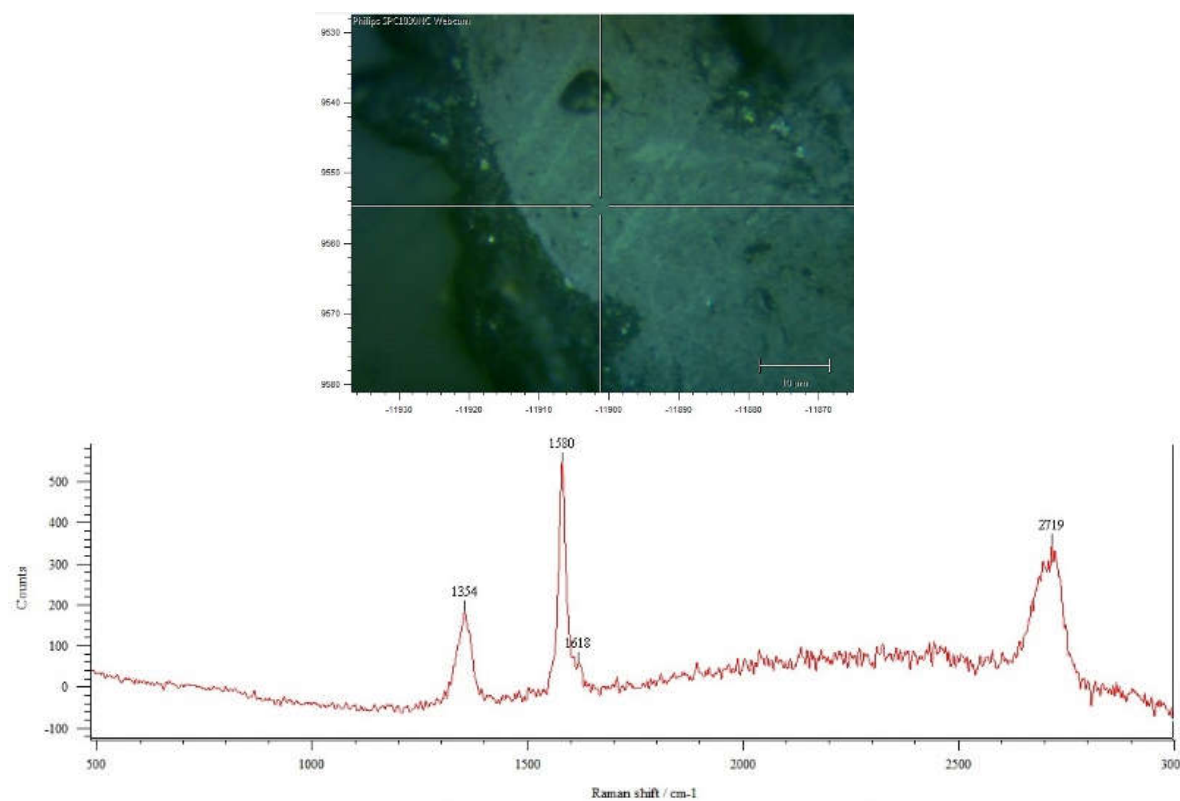


Text Figure. 10.3: LRS peaks of sample No.-1(MBMGRS-3)





Text Figure. 10.4: LRS peaks of sample No.-1(MBMGRS-4)



Text Figure. 10.5: LRS peaks of sample No.-1(MBMGRS-5)

### 10.13.0 MINERALIZATION

10.12.1 **Manganese:** In the block manganese occurs as discontinuous lensoidal bodies in the central part of the block. Two bands have been established as North and South bands. Also, aligned parallel to strike of the enclosing formations. Their exposures are in rugged boulder form. Insitu mineralized body is surrounded by float ores. Manganese ore bodies occur as bands, lenses, pockets, veins, tabular bodies and disseminations within the khondalite group of rocks (mostly with khondalite and quartzite). They have weathered to considerable depths along with the enclosing rocks as intersected in the trenches and boreholes. In general, oxide minerals i.e, pyrolusite and psilomelane associated with sulphides and iron oxides indicate supergene enrichment deposit. Manganese oxides show granoblastic to granulitic fabric. It shows gravity filling, botryoidal structures. The ore, in general, is steel grey to dull grey, grayish to dark grey to black colour and is soft and is invariably in powdery form. In most of the places manganese bands intersected in the trenches have no depth continuity or pinching out within few meters below surface as from drilling. This may be due to lenticular nature of the mineralized body in subsurface. Intense brecciation, shearing, fracturing are the important locales of mineralisation. These processes increase the permeability and fluid flow of the rocks and a favourable environment for mobilization, transporation and deposition of manganese minerals. Manganese rich solutions migrate along these spaces downward and deposition occur when pH, redox state favor. The lensoidal discontinuous ores bodies owe their disposition either due to flowage or due to drag folds. Hence it may be concluded that manganese ores in the study area are lithologically and structurally controlled. Summary of the manganese mineralization intersected in the trenches and boreholes are provided in Table 10.2 and 10.6 respectively.

**Table 10.6**  
**Manganese ore intersected in the boreholes in Bharatbahal Block, Balangir**  
**District, Odisha.**

Sl. N o.	Borehole ID/ Trench No.	From (m)	To (m)	Thick-ness (m)	True Thick-ness (m)	Mn %	SiO <sub>2</sub> %	P <sub>2</sub> O <sub>5</sub> %	Fe <sub>2</sub> O <sub>3</sub> %	MnO <sub>2</sub> %	Acid Insol-uble %
1	Trench-2	0.00	10.00	10.00		12.29	46.52	0.10	14.77	10.56	
2	Trench-3	1.00	3.00	2.00		11.08	37.25	0.26	17.35	8.76	

Sl. No.	Borehole ID/ Trench No.	From (m)	To (m)	Thickness (m)	True Thickness (m)	Mn %	SiO <sub>2</sub> %	P <sub>2</sub> O <sub>5</sub> %	Fe <sub>2</sub> O <sub>3</sub> %	MnO <sub>2</sub> %	Acid Insoluble %
3	Trench-3	6.00	8.00	2.00		13.37	40.09	0.69	20.53	9.24	
4	MLB-02	19.89	29.49	9.60	8.70	14.21	30.63	0.71	21.19	13.82	39.63
5	MLB-03	11.50	28.00	16.50	14.29	19.26	28.03	0.38	25.75	18.87	32.01
6	MLB-04	21.00	27.00	6.00	5.20	15.24	32.83	1.22	16.49	15.12	44.01
7	MLB-05	11.00	23.00	12.00	10.88	24.24	17.43	1.27	26.92	18.53	27.88
8	MBMG-1	0.00	1.00	1.00	0.91	11.98	41.66	0.17	15.07	10.11	59.62
9	MBMG-2	1.00	2.00	1.00	0.91	10.39	29.00	0.07	18.76	8.23	41.77
10	MBMG-4	1.00	3.00	2.00	1.82	10.56	32.52	0.09	17.56	8.15	47.28
11	MBMG-4	34.00	38.20	4.20	3.81	29.69	18.59	0.88	14.56	19.00	26.70
12	MBMG-6	5.00	6.00	1.00	0.91	10.61	40.43	0.19	21.70	10.03	56.25
13	MBMG-6	9.00	12.00	3.00	2.72	18.03	31.43	1.09	25.94	18.32	37.00
14	MBMG-7	21.50	24.00	2.50	2.27	15.69	28.59	0.60	26.06	16.43	34.42

10.13.2 As per previous and present work in different blocks of Balangir manganese belt, the ore characters indicate origin of manganese as syngenetic. Later remobilization by meteoric water and secondary enrichment, along litho contacts, foliations, fractures, shear planes, joints and fold closure of host rocks khondalites, quartzites give rise to economic concentrations. In general, the manganese ore bands/bodies show swelling and pinching structure along the strike due to drag folds where deposition at fold closures is thicker than limb. Deep seated weathering may have caused absence primary minerals, due to conversion of primary oxides into secondary minerals. Enrichment of manganese has been developed up to a vertical depth of 40m in the block. (Cross section S1, S3, S4 and S6)

10.13.3 **Graphite:** The host rock for graphite is khondalite. Graphite occurs as medium to fine flaky/ prismatic grains and its disseminated aggregates, often showing kink bands associated with magnetite, pyrite, chalcopyrite and other sulphides (Pmg 3 to 5). The graphite mineralization / graphite zones are hardly exposed on surface and mainly intercepted in the trenches and boreholes. The graphite mineralisation occurs within or outside the manganese mineralization zone. The graphite mineralization in the block may be formed by syngentic deposition of carbonaceous host rocks followed by high grade metamorphism of carbonaceous rock and shearing and fracturing. Concentration of graphite has been developed up to a vertical depth of 60m with pinching and

swelling in nature. Details of the graphite bands intersected in the boreholes is provided in Annexure IX. Summary of that is provided in the following Table 10.6.

10.13.3 Drill core photographs of the graphite mineralization intersected in the boreholes are presented in the following figures 10.3 and 10.4

**Table 10.7**

**Graphite bands intersected in the boreholes in Bharatbahal Block, Balangir District, Odisha.**

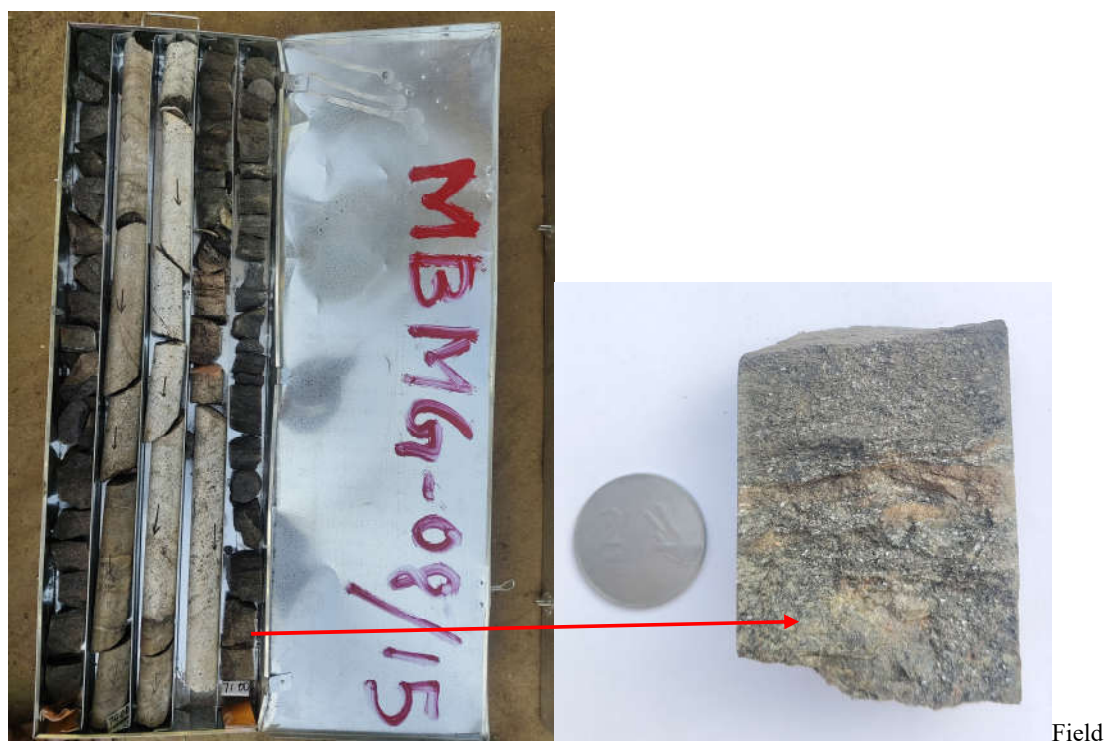
Sl. No.	Borehole ID/ Trench ID	From (m)	To (m)	Thick-ness (m)	True Thickness (m)	Moist %	Ash %	VM %	F.C. %
1	Trench-3	0.00	1.00	1.00		2.90	83.80	8.80	2.90
2	Trench-3	10.00	11.00	1.00		1.20	87.00	6.20	5.60
3	MLB-01	58.70	62.70	4.00	3.06	0.33	88.09	7.36	4.23
4	MLB-02	40.79	43.39	2.60	2.36	1.67	80.35	11.99	5.98
6	MLB-03	35.50	37.00	1.50	1.30	0.75	88.31	8.50	2.44
7	MLB-03	39.00	43.00	4.00	3.46	2.93	83.99	9.34	3.75
8	MLB-05	39.10	47.55	8.45	7.66	2.13	84.56	9.38	3.93
9	MBMG-1	39.00	44.00	5.00	4.33	2.63	87.48	6.66	3.22
10	MBMG-2	43.00	44.00	1.00	0.87	2.70	82.20	7.10	8.00
11	MBMG-2	52.00	55.00	3.00	2.60	1.73	85.00	9.53	3.73
12	MBMG-2	61.20	62.40	1.20	1.04	1.80	89.30	5.80	3.10
13	MBMG-2	63.80	64.80	1.00	0.87	1.10	89.30	4.30	5.30
14	MBMG-4	41.40	50.40	9.00	8.16	1.51	88.38	5.91	4.19
15	MBMG-6	12.00	13.00	1.00	0.91	0.75	91.38	5.76	2.11
16	MBMG-6	15.00	16.50	1.50	1.36	0.76	94.99	2.27	1.99
17	MBMG-7	29.00	33.00	4.00	3.63	3.69	83.94	9.61	2.76
18	MBMG-8	62.50	63.50	1.00	0.98	1.33	66.87	17.26	14.55
19	MBMG-8	67.00	71.00	4.00	3.94	2.23	83.29	9.42	5.06
20	MBMG-8	77.00	78.00	1.00	0.98	0.68	75.38	14.60	9.34

#### 10.14.0 OUTCOME OF THE INVESTIGATION TAKEN UP

10.14.1 On the basis of geological mapping, and mineralized zones intersected in the trenches and boreholes two mineralized bodies named as North and South Band has been established. Mineralized zones and pockets have been marked in the geological map as Plate III. Dimensions of the mineralized bodies are provided in the following Table 10.8

**Table 10.8**  
**Details of mineralized bodies in the Bharatbahal Manganese and Graphite G3**  
**Block, Balangir District, Odisha**

Sl No	Band Details	Mineralization	Length (m)	Width	Avg. Grade
1	North Band	Graphite	150	Max.- 5.00m Min.- 1.00m	2.09% FC
		Manganese	488	Max.- 12.00m Min.- 2.46m	19.62% Mn
2	South Band	Graphite	100	Max.- 4.7m Min.- 1.4m	2.09% FC
		Manganese	447.60	Max.- 15.20m Min.- 2.06m	19.62% Mn



Photograph 10.2: Photograph showing drill cores (Quartz-graphite schist) of Borehole No. MBMG-8 and close view of the core at 70.80m



Field Photograph 10.3: Photograph showing drill cores of (Khondalite associated with manganese mineralization) Borehole No. MBMG-4 and close view of the core at 35.25m

## **CHAPTER-11**

### **11.0.0 LOCATION OF DATA POINTS**

#### **11.1.0 ACCURACY AND QUALITY OF SURVEY USED TO LOCATE DRILL HOLES**

11.1.1 Location of data points like boreholes, trenches, litho contacts and elevation details of the area have been recorded by using DGPS and Total Station instruments. Details of the survey carried out in the block have been elaborated in the paragraph 10.4.0 of Chapter 10. Locations of boreholes are provided in Annexure V.

#### **11.2.0 QUALITY AND ADEQUACY OF TOPOGRAPHIC CONTROL**

11.2.1 The detailed Topographical Map of Bharatbahal Manganese and Graphite (G3) Block has been prepared by MECL on 1:2,000 scale and the same is enclosed as Plate-II.



## **CHAPTER-12**

### **12.0.0 SAMPLING TECHNIQUE**

#### **12.1.0 NATURE AND QUALITY OF SAMPLING AND MEASURES TAKEN TO ENSURE SAMPLE REPRESENTATIVITY**

12.1.1 During trenching work, channel samples were meticulously collected from trench walls. To ensure sample quality, the initial step involves removing weathered portions, opting for sampling from the fresh sections of the channels. For unbiased representation, samples were systematically taken from channels, exercising caution to prevent contamination and mixing with other rock types. Approximately 1 to 1.5 kg samples were carefully selected for each sample and packed in high-quality cotton bags.

12.1.2 The sampling and analyses were carried out for entire mineralized zones/length intersected in the boreholes drilled. The primary sample had been marked in the mineralized zones intersected in the borehole based on type & concentration of mineralization/lithology and in general the sample length has been kept as 1.00 m which varied in some instances because of variation in length of core recovered, lithology and type and concentration of mineralization. The mineralized core has been split into two equal halves in such a way that the concentrations of ore minerals are uniform in both the equal halves. One half of the core arranged (book pattern) in the G.I. core boxes with all relevant details has been kept at core repository for future reference and the other half core sample has been crushed to (–) 200 mesh size. Field photograph for the preservation of half split core is shown in the following photo 12.1

12.1.3 The half split drill core of one complete borehole as well as skeletonised drill core of other boreholes will be handed over at Regional Core Library, GSI for stratigraphic correlation purpose and for future reference. The ready availability of drill core will be of significant help to exploration/mining agencies in formulation of exploitation strategy and programme.





Field Photograph 12.1: Photograph showing drill cores of Borehole No. MKMG-8 (From 65.00 to 70.00m)

## CHAPTER-13

### **13.0.0 DRILLING TECHNIQUES AND DRILL SAMPLING EMPLOYED**

#### **13.1.0 DRILLING TYPES AND DETAILS**

13.1.1 A total of 13 boreholes with meterage of 755m have been drilled in the block which includes 05 boreholes (259m) during reconnaissance survey. The details of boreholes drilled by MECL are given in Annexure-V and summary of borehole is given in Table-10.3 and 10.4

13.1.2 Drilling in the block was carried out by deploying RD 100 conventional drills (MEC 332 & 334). Core recovery of more than 90% was achieved except in sheared formation, fault zones and weathered zone. Wet drilling method was adopted. However, dry and wet drilling method was used for the mineralized zone and on the basis of hardness. After closure, all the boreholes have been properly plugged and sealed with cement pillars. Drill cores samples were preserved in core boxes to protect them from physical damage and to maintain their integrity for scientific investigation. Book pattern style was adopted to keep the cores in the boxes. Photograph of a core box with drill core in shown in the following figure 13.1 and 13.2.



Field Photograph 13.1: Photograph showing drill cores of Borehole No. MBMG-3 (From 51.50 to 56.50m)



Field Photograph 13.2: Photograph showing drill cores of Borehole No. MBMG-8 (From 65.00 to 70.00m)

- 13.1.3 Q series induction hardened NQ rods and double-tube diamond core bits were used for the drilling. The outer diameter (OD) of the drill rods is 69.9 mm and inner diameter (ID) is 60.3 mm and that of bit (OD) is 75.44 mm & 47.75 mm (ID). The diameter of recovered core is 47.60 mm.

### 13.2.0 CORE RECOVERY

- 13.2.1 The average core recovery in the mineralized zones is 90% excluding in few places. The quality of drilling was ensured during the operation. The short runs were drilled as per necessity so that optimum core recovery is maintained. The core recovery in the mineralized zones is around 90% which is quite satisfactory except in a few cases. Whenever core recovery is less, the grade of the recovered portion has been extrapolated over the non-recovered section. Sludge collection was done in poor core recovery zones.

### 13.3.0 WHETHER CORE AND CHIP SAMPLE RECOVERIES HAVE BEEN PROPERLY RECORDED AND RESULTS ASSAYED

- 13.3.1 The core samples have been recorded properly and the details run wise lithology for boreholes drilled by MECL are given in Annexure- VI and VIII. The logging of run wise core have helped in discerning the physical characters like colour, shape, size and nature of manganese and graphite mineralization as well as texture, structural features

such as joints, fractures, foliations etc. and their attitude with respect to core axis and identification of different litho units.

- 13.3.2 The mineralized zones /length recorded during the geological core logging were sampled and analysed for manganese and proximate analysis. The primary sample had been marked in the mineralized zones intersected in the borehole based on ore type and concentration of mineralization/lithology and in general the sample length has been kept as 1.00 m which varied in some instances because of variation in lithology and type and concentration of mineralization. The details of analysis of primary core samples are given in Annexure-XII to XV for manganese and graphite which includes samples collected during G4 work.

#### **13.4.0 MEASURES TAKEN TO MAXIMIZE SAMPLE RECOVERY AND ENSURE REPRESENTATIVE NATURE OF THE SAMPLES.**

- 13.4.1 The short runs were drilled as per necessity so that optimum core recovery is maintained. The core recovery in the mineralized zones is more than 90% excluding at places which is weathered, fractured or brecciated. Whenever core recovery is less, the grade of the recovered portion has been extrapolated over the non-recovered section. The quality of drilling was ensured during the operation.

#### **13.5.0 WHETHER THE RELATIONSHIP EXISTS BETWEEN SAMPLE RECOVERY AND GRADE**

- 13.5.1 The average core recovery in the mineralized zones is more than 90% except in sheared formation, fault zones and weathered zone which is satisfactory. The entire mineralized zones / length recorded during the geological logging on visual basis have been analyzed for manganese and graphite mineralization. In general, the recovery percentage in the mineralized zones is satisfactory; hence there is no negative effect on the core recovery.

#### **13.6.0 CORE LOGGING**

- 13.6.1 The standard procedure of core logging was followed in the block. Details like grain size, nature of grains & flakes, colour, mineralogy, nature of mineralization, structural features, rock quality designation (RQD) and other microscopic details were recorded.

RQD studies have been carried out in all the boreholes. RQD percentage has been arrived at by using the formula:

$$\text{RQD \%} = \frac{\text{Summed up length of core pieces} > 100 \text{ mm}}{\text{Total core run length}} \times 100$$

Detailed and summarized litho logs of the 13 boreholes are provided in the Annexure VI to IX.

## **CHAPTER-14**

### **14.0.0 SUB SAMPLING TECHNIQUES AND SAMPLE PREPARATION**

#### **14.1.0 SAMPLE PROCESSING FOR CHEMICAL ANALYSIS**

- 14.1.1 All the primary samples were marked and prepared from mineralized cores. During the preparation of primary samples, the mineralized cores were studied meticulously and samples were marked properly. The length of individual samples was kept generally at 1.0m interval with minor adjustments depending on the intensity of mineralization and change in lithology.
- 14.1.2 During sample preparation, adherence to standard operating procedures is paramount. Samples are powdered to -200 mesh size using sample crusher, pulveriser, mortar and pestle. Rigorous cleaning procedures for all the instruments used in sample processing including sample tray, brush, and all tools, are implemented after each sample is processed, maintaining a contamination-free environment.
- 14.1.3 Standard sampling procedure adopted and the samples were prepared at centralized sampling unit.
- 14.1.4 Following the initial crushing, representative samples of around 100 grams are drawn through successive reduction using coning and quartering method. This technique involves pouring the bulk sample onto a flat surface, forming a cone, and systematically dividing it into four quadrants. Two opposite quadrants are selected for further processing, and the method is repeated, reducing the sample size while preserving representatives. The resulting 300 grams are then packed into three separate packets, each containing 100 grams, for primary and check analyses. The remaining powdered samples are carefully stored for future reference, with preventive measures in place to avoid sample mixing. Thorough cleaning of all tools used in the sampling, drawing, and packaging processes further ensures the integrity of the collected samples.
- 14.1.5 In accordance with the standard sampling procedures, it has been observed that smaller particle size leads to higher homogeneity of samples as well as higher dissolvability

during chemical analysis. As a result, cores having diameter NQ size have been reduced to -200 mesh size (75 microns) for chemical analysis.

- 14.1.6 On the basis of mineralization samples have been analyzed for 6 radicals (Mn, MnO<sub>2</sub>, P<sub>2</sub>O<sub>5</sub>, Fe<sub>2</sub>O<sub>3</sub>, SiO<sub>2</sub> and Acid Insolubles) for manganese and Proximate Analysis i.e. Moisture, Ash, VM and FC for graphite at MECL's Chemical Laboratory, Nagpur.
- 14.1.7 A total of 84 samples (30 trench and 54 borehole core) as primary samples have been analyzed for 6 radicals for manganese mineralization. The primary sample analysis details of trench and borehole core samples are given as Annexure-IV and Annexure-XIV respectively.
- 14.1.8 A total of 93 samples (30 trench and 63 borehole core) as primary samples have been analyzed for Proximate Analysis i.e. Moisture, Ash, VM and FC and results are provided in the Annexure-IV and Annexure-XV respectively.



## CHAPTER-15

### **15.0.0 QUALITY OF ASSAY DATA AND LABORATORY TESTS**

#### **15.1.0 THE NATURE, QUALITY AND APPROPRIATENESS OF THE ASSAYING AND LABORATORY PROCEDURES**

**15.1.1 Laboratory Procedure for manganese samples:** The chemical analyses of primary samples have been carried out in MECL's Chemical laboratory for determining six radicals i.e, Mn, MnO<sub>2</sub>, P<sub>2</sub>O<sub>5</sub>, Fe<sub>2</sub>O<sub>3</sub>, SiO<sub>2</sub> and Acid Insoluble (for MECL boreholes). The analysis was initially carried out with wet classical method followed by instrumental (XRF) determination. First, the instrument is calibrated using wet classical method along with CRMs and then the samples are run on the instrument (XRF). Mn, Fe<sub>2</sub>O<sub>3</sub>, SiO<sub>2</sub> radicals are analyzed by Rigaku ZSX Primus II XRF instrument by pallet press method. P<sub>2</sub>O<sub>5</sub> is analyzed by Analytik Jena Make UV-VIS Spectrophotometer. However, MnO<sub>2</sub> and Acid Insoluble are wholly analyzed by wet classical method.

**15.1.2 Laboratory Procedure for graphite samples:** The chemical analysis of primary samples was carried out in Chemical Laboratory of MECL for Proximate Analysis i.e. Moisture, Ash, VM, FC. The analysis has been carried out by Advance made APA2 instrument. Moisture content and Volatile Matter were determined at 110°C and at 900°C respectively. For ash content determination, 0.80g sample was taken in a crucible and heated to reach 850°C for 30 min. After that the temperature was increased to 880 °C for 1.5 hours and finally the ash content was calculated.

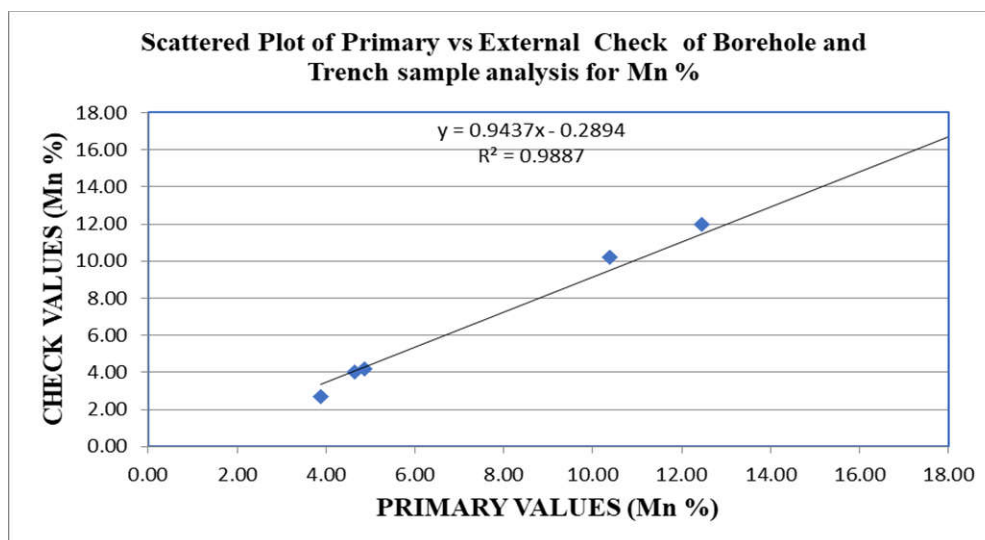
**15.1.3 Accuracy of Sampling Procedure:** The grade estimates of the deposit are based on the results of samples of the boreholes and trenches. Each sample undergoes the process of sample preparation and analysis. Since, sampling and analysis are two complimentary links of quality estimation chain, the possible source of errors, if any, could be from the bias in sample preparation and inaccuracies in assaying or both. The sampling was carried out by observing prevailing standard procedure. Thus, the reliability of the sampling process is very high and has not been compromised at any stage.

## 15.2.0 PRIMARY AND CHECK SAMPLE STUDIES OF TRENCH AND BOREHOLE SAMPLING

- 15.2.1 **External Check sample Analysis for manganese** A total of 08 samples as external primary check samples were analyzed in the Chemical Laboratory of Jawaharlal Nehru Aluminium Research Development and Design Centre, for 6 radicals (Mn, SiO<sub>2</sub>, P<sub>2</sub>O<sub>5</sub>, Fe<sub>2</sub>O<sub>3</sub>, MnO<sub>2</sub> and Acid Insoluble). Results and comparison with primary samples are provided in the Annexure XVI.
- 15.2.2 **External Check sample Analysis for graphite:** A total of 09 samples as external primary check samples have been analyzed in the Chemical Laboratory of Jawaharlal Nehru Aluminium Research Development and Design Centre, (JNARDDC) Nagpur (A NABL accredited Laboratory) for Proximate Analysis i.e. Moisture, Ash, VM and FC). Results and comparison with primary samples are provided in the Annexure XVII.
- 15.2.3 In order to assess the bias and inaccuracies in analytical determination as well as to check the repeatability of analysis, 08 borehole samples were analysed for external check analysis out of 84 primary samples for manganese. The comparative studies for manganese external check samples are tabulated in Table-15.1 and scatter plot are represented as Text Figure-15.1.

**Table-15.1**  
**Comparison of Primary vs. External Check Manganese Samples**  
**in Bharatbahal Manganese and Graphite (G3) Block, Balangir, Odisha**

Comparison of Primary v/s External Check sample analysis (Borehole and Trench Samples)		
Comparison Index	Mn %	
	Primary	Check
No. of sample pairs	8	
Arithmetic mean	13.256	12.220
Standard Deviation	7.829	7.325
Standard error of mean	2.768	2.590
Variance	61.301	53.657
Mean of deviation	1.036	
Standard Deviation (Error)	0.960	
Correlation Co-efficient	0.994	
Mean absolute error	1.059	
Mean relative random error	10.870	
Paired T-value	3.052	
F- test value	1.142	



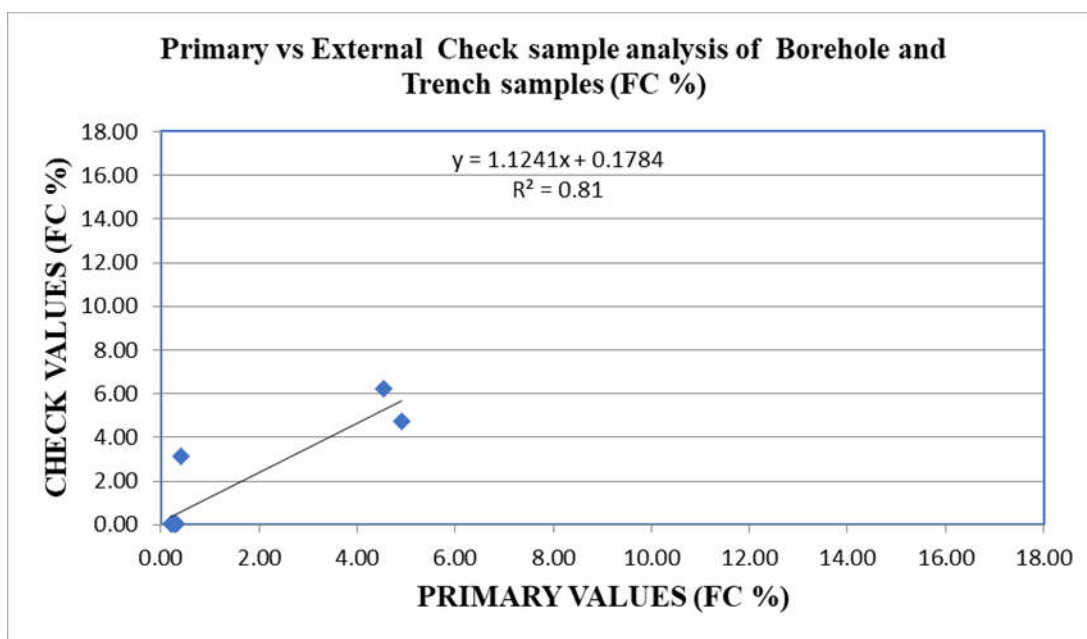
TextFigure 15.1: Scatter Plot of Primary and External Check Samples for Mn%

- 15.2.4 The  $R^2$  value = 0.9887, which is very close to 1. This means that 98.87% of the variation in the check values can be explained by the primary values. It indicates a strong linear correlation between the two datasets. Since the slope is close to 1 and  $R^2$  is high, the check samples are highly consistent with the primary values. The small deviation (slope slightly  $<1$ ) suggests that the check values tend to be slightly lower than the primary values on average. This could indicate minor systematic differences between primary and check sample analyses, such as small lab measurement biases.
- 15.2.5 The intercept of -0.2894 suggests that when the Primary Value (Mn%) is 0, the predicted Check Value (Mn%) is slightly negative. In reality, Mn% cannot be negative, so this is likely a small systematic measurement error in the check sample analysis. Different labs were used to obtain primary and check values, slight differences in their calibration has lead to a small offset in values.
- 15.2.6 The data set for primary Vs external check analysis comprises 08 pairs of samples. The Table-15.1 shows that the difference in arithmetic mean is negligible. Correlation coefficient is 0.994, which is in the range of 0.90-1.00 which is very high positive correlation and indicates a good correlation in primary and external check analysis.
- 15.2.7 The overall statistical studies for primary Vs external check samples show the repeatability of the analysis i.e. insignificant differences between both the analyses.

15.2.8 In order to assess the bias and inaccuracies in analytical determination as well as to check the repeatability of analysis, 09 borehole samples were analysed for external check analysis out of 93 primary samples for graphite (Proximate analysis). The comparative studies for graphite external check samples are tabulated in Table-15.2 and scatter plot are represented as Text Figure-15.2.

**Table-15.2**  
**Comparison of Primary vs. External Check Graphite Samples**  
**in Bharatbahal Manganese and Graphite (G3) Block, Balangir, Odisha**

Comparison Index	FC %	
	Primary	Check
No. of sample pairs	9	
Arithmetic mean	1.262	1.597
Standard Deviation	1.841	1.978
Standard error of mean	0.614	0.659
Variance	3.390	3.913
Mean of deviation	-0.335	
Standard Deviation (Error)	1.035	
Correlation Co-efficient	0.900	
Mean absolute error	0.648	
Mean relative random error	136.082	
Paired T-value	-0.971	
F- test value	1.154	



Text Figure 15.2: Scatter Plot of Primary and External Check Samples for FC%

15.2.9 This means that for every 1% increase in the primary FC%, the check FC% increases by 1.1241% on average. Since the slope is greater than 1, it suggests that check values tend to be slightly higher than primary values. When the primary FC% is 0, the check value is predicted to be 0.1784%. A small positive intercept like this suggests minor systematic variation in measurements rather than a major bias. The  $R^2$  value is 0.81, meaning 81% of the variation in check values can be explained by the primary values.  $R^2 = 0.81$  suggests a strong, but not perfect, correlation. Some variation exists, likely due to measurement inconsistencies, sampling differences, or lab analysis errors.

15.2.10 The data set for primary Vs external check analysis comprises 09 pairs of samples. The Table-15.1 shows that the difference in arithmetic mean is negligible. Correlation coefficient is 0.900, which is in the range of 0.70-0.90 which is high positive correlation and indicates a good correlation in primary and external check analysis.

15.2.11 The overall statistical studies for primary Vs external check samples show the repeatability of the analysis i.e. insignificant differences between both the analyses.

### **15.3.0 SECURITY AND CHAIN OF CONTROL OF SAMPLES**

15.3.1 The security and chain of control of samples from the field unit to sampling unit and finally to the chemical laboratory undergoes through a meticulous and well-organized process. The samples were prepared at centralized mechanized sampling unit under the supervision of qualified sampling technician. The samples were meticulously labeled and tagged before being sent to the chemical laboratory under the direct supervision of the technician. During transportation, the samples were securely sealed in bags, and the integrity of the seals was verified at the sampling unit before the bags were opened. Adhering to standard procedures, the sampling unit implemented robust precautionary measures to prevent any potential contamination, ensuring the reliability of the sample analysis. Additionally, the remaining samples were appropriately preserved and tagged for future reference, highlighting a commitment to maintaining a secure and traceable chain of control under the company's custody. At the sampling unit, standard procedure is followed and all the precautionary measures are taken to avoid contamination. The sampling unit is separate from the chemical laboratory, so there is no chance of contamination.

## **CHAPTER-16**

### **16.0.0 MOISTURE**

**16.1.0** Determination of moisture has not been carried out.

## CHAPTER-17

### 17.0.0 SPECIFIC GRAVITY DETERMINATION

17.1.0 A total of 05 borehole samples were subjected to specific gravity determination and carried out at Petrology Laboratory, MECL Nagpur. The results of specific gravity determination are presented in Table 17.1. Most of the samples are from graphite zone since manganese ore intersected in the boreholes are quite less. An attempt was made to find out depth wise variation of specific gravity from graphite zones. The average specific gravity of 04 nos. of graphite bearing samples as determined is 2.70.

**Table 17.1**  
**Details of Specific Gravity Determination of Borehole Samples for Graphite in**  
**Kanaital Manganese and Graphite G3 Block, Balangir, Odisha**

Sl.No.	Sample No.	Location	Specific Gravity	Lithology
1	MBMGSG-01	MBMG-08 (70.40-70.50m)	2.67	Graphite Schist
2	MBMGSG-02	MBMG -08 (67.60-67.70m)	2.99	Graphite Schist
3	MBMGSG-03	MBMG -04 (49.70-49.80m)	2.53	Graphite Schist
4	MBMGSG-04	MBMG -05 (76.10-76.20m)	2.62	Graphite Schist
	<b>Average Specific Gravity</b>		<b>2.70</b>	
5	MBMGSG-05	MBMG -06 (11.60-1170m)	2.72	Mn bearing Khondalite

17.1.2 For manganese ore specific gravity determined in the adjacent and/or surrounding blocks like Rengali (G2), Tamiya (G2), Babja (G2) and Biarapalli (G2) explored by MECL was considered to arrive an average specific gravity of the manganese and graphite. Specific gravity determined in the said block has same geological setup and mode of occurrences for manganese and graphite mineralization. Details of the specific gravity determined in the said blocks are provided in the following Table 17.2. The average specific gravity so determined for manganese and graphite has been considered for resource estimation which 2.79 and 2.68 respectively.



**Table 17.2**

**Specific Gravity Determination in the surrounding area**

<b>Sl. No.</b>	<b>Block Name</b>	<b>Average Specific Gravity considered for Manganese</b>	<b>Average Specific Gravity considered for Graphite</b>
1	Rengali (G2)	2.85	2.69
2	Babja (G2)	2.94	
3	Biarpali (G2)	2.87	
4	Tamiya (G2)	2.57	
5	Kanaital (G3) Block	--	2.35
6	Larambha (G3) Block	--	2.98
7	Bharatbahal Block	2.72	2.70
<b>Average</b>		<b>2.79</b>	<b>2.68</b>

## **CHAPTER-18**

### **18.0.0 BENEFICIATION STUDIES**

**18.1.0** The present exploration is at preliminary stage (G3). Beneficiation study has not been carried out at this stage.

## **CHAPTER-19**

### **19.0.0 RESOURCE ESTIMATION TECHNIQUE**

#### **19.1.0 DISCUSSION ON DATA DENSITY TO ASSURE CONTINUITY OF MINERALISATION**

19.1.1 MECL drilled 13 boreholes covering a strike length of 1000m with around 100m borehole spacing along the sections S1-S1' to S11-S11' for the discontinuous mineralized body in the central part. The said boreholes were planned on the basis of surface geological mapping, surface sampling, geophysical survey (SP and Magnetic) and trenches. The objectives of the boreholes drilled in the block to assess the continuity of the mineralization laterally and vertically along with the quality and quantity. Dimensions of the mineralized zones established in the block are provided in the Table 10.7

#### **19.2.0 WHETHER PREVIOUS EXPLORATION DATA HAS BEEN USED**

19.2.1 Previously, the block was covered under the reconnaissance survey over an extent of 135 sq km around Larambha-Kanaital and Bharatbahal-Puddapadar. During the investigation collection of bed rock samples, geophysical survey and drilling of 259m with 05 boreholes were carried out in the Bharatbahal area. The same data has been incorporated in the present exploration for interpretation of mineralized bodies on the surface. Location of bed rock samples along with the analytical values and trench with mineralization details are plotted on the recent geological map. Geological map of the block is provided as Plate III.

#### **19.3.0 THE NATURE AND APPROPRIATENESS OF THE ESTIMATION TECHNIQUE(S) APPLIED AND KEY ASSUMPTIONS**

19.3.1 The manganese and graphite resources of the block has been estimated by “**Geological cross-section Method**” (as principal method), certain axiomatic assumptions are inherently involved in estimation of overall grade and resource of the deposit, which are given below.

1. The rule of gradual change or law of linear function has been applied (Constantine C. Popoff, 1966) along with the rule of nearest points for application of influence of half way between successive boreholes.

2. The boreholes which did not intersect any mineralization have been considered as negative boreholes and completely eliminated from resource estimation.
3. The thickness and grade of each mineralized zone intersected in the borehole have been considered as it is for the entire influence area of the borehole.

#### **19.4.0 THE BASIS FOR CLASSIFICATION OF THE MINERAL RESOURCES**

19.4.1 During field season 2021-22 and 2022-23 the present block and the surrounding areas were undertaken by MECL under reconnaissance survey (G4) to establish the mineralized bodies on the surface by means of large scale geological mapping, surface sampling, geophysical survey and trenches. On the basis of the outcomes of the G4 stage exploration Bharatbahal Block was taken up for upgradation to G3 stage which involves detailed geological mapping, trenching and drilling at nearly 100m strike interval. Mineralized bodies established in the area are of discontinuous lensoidal in nature over a strike length of 1000m. In addition, localized enrichment of manganese and graphite bodies occur over limited extent. A total of 05 trenches and 13 boreholes were drilled in the area to assess the continuity of the mineralization in subsurface and along the strike direction. The said work revealed that Manganese ore bodies in this area occur as lenses, pockets, and narrow discontinuous bands. The ore is often interbanded with quartzite and manganiferous khondalite. Graphite occurs in the area as discontinuous bands associated with khondalites as graphite rich schist. Continuity of bands is irregular in lateral and vertical direction. Considering the discontinuous, lensoidal, pocket type of manganese and graphite mineralization and the interval of the data points, it fulfills the preliminary exploration (G3 stage) as per MEMC Rules 2015, the total resources of the block may be categorized as “Inferred Mineral Resources” with Code 333 as per UNFC system and the specifications given in the Mineral (Evidence of Mineral Contents) Rule-2015 amended up to 2021.

#### **19.5.0 THE ASSUMPTIONS MADE REGARDING RECOVERY OF BY PRODUCTS**

19.5.1 During exploration no other minerals associated with manganese and graphite have been observed to be a byproduct.

## **19.6.0 DETAILED DESCRIPTION OF THE METHOD USED AND THE ASSUMPTIONS MADE TO ESTIMATE TONNAGE AND GRADES**

19.6.1 The manganese and graphite resources of the block has been estimated by “**Geological cross-section Method**” (as principal method) considering the following parameters and assumptions.

1. **Threshold Value:** For the purpose of estimation of grade vis-à-vis resource of the manganese ore, threshold value published by Indian Bureau of Mines (IBM) i.e 10% Mn has been considered for resource estimation in the block. For graphite threshold value published by IBM i.e 2% FC for flaky graphite has been considered.
2. Considering the open cast potentiality of the block, minimum parting of 1.50 m has been considered for delineation of manganese and graphite bands for resource estimation.
3. Based on the above threshold value, mineralized zones have been delineated on the cross section.
4. Strike influence for the sections was considered up to the midpoint of the next section on either side of section line. In the absence of next section line sectional influence is considered 25m. The average grade of the manganese or graphite bands intersected in the borehole has been assigned throughout the section influence.
5. The up dip influence of the mineralized bodies intersected in the boreholes was considered up to the surface in case of mineralized body exposed or established on the surface. In case of soil cover and not established by any means the up dip influence has been restricted up to 25m from the borehole intersection. The dip influence in down dip has been considered up to 25 m from the bottom borehole intersection. The average grade of the mineralized bodies intersected in the borehole has been assigned to its influence zones.
6. **Specific Gravity:** The average specific gravity determined from manganese and graphite mineralized zones have been considered for determination of specific

gravity for resource estimation. The average specific gravity of 2.79 and 2.68 was considered for manganese and graphite respectively for the resource estimation.

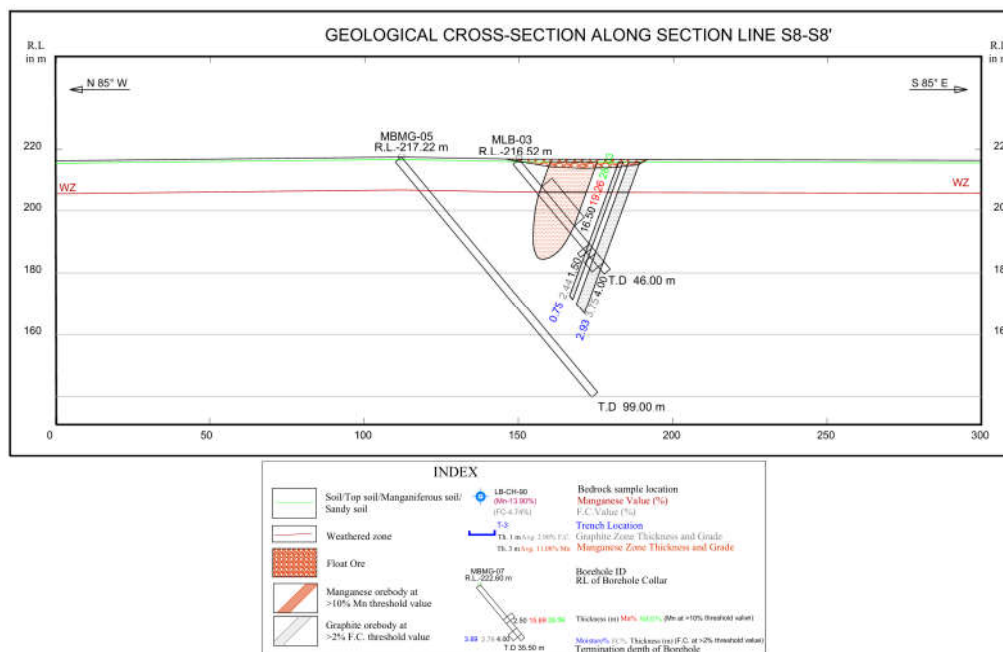
7. An overall deduction of 10% is applied to the total gross tonnage to arrive at the net in-situ geological resource of manganese and graphite to account for geological reasons i.e., data gaps, core recovery zones, irregular nature of deposit and abrupt change in zone thickness etc.

19.6.2 Manganese and graphite resources have been estimated at various parameters based on the bands/zones deciphered and delineated from qualitative data of primary samples along with the separate resources in weathered zone and below the weathered zone. The bands/zones have been delineated on the basis of assay of chemical analysis i.e., 10% Mn and 2% FC threshold value for manganese and graphite respectively, considering minimum parting of 1.50m. The bands/zones intersected in boreholes have been plotted on the geological cross sections (Plate-V).

19.6.3 **Methodology adopted in Cross-Section Method of Resource Estimation:** Following methodology has been adopted while computation of resources by Geological Cross-Section Method.

1. A total of 11 Geological Cross Sections numbered as S1-S1' to S11-S11' perpendicular to general strike of the mineralised body which varies due to local swing were prepared. Cross sections were drawn, based on the interpretation of surface and sub-surface geological data i.e., litho-units intersected in the borehole and its attitude i.e., foliation angle along with thickness and qualitative data.
2. The cross-sections have been prepared by marking surface geology on the profile and the borehole data such as lithology, thickness and analytical data of mineralized bands. The path of the inclined boreholes has been plotted manually or in Autocad 2020 software along the Geological Cross Sections by considering the total depth, azimuth and inclination. Typical cross section for the block is provided in the Text Figure 19.1

Text Figure 19.1



4. Ore resource has been estimated based on the manganese and graphite bands deciphered and demarcated on earlier mentioned parameters of resource estimation.
5. The area measurements have been made with the help of computer aided AutoCAD Map 2020 software.
6. The area of influence has been summed up to arrive at the band wise total area for the cross-section.
7. Thus, the area obtained has been multiplied by cross sectional influence (strike influence) to obtain the sectional volume.
8. After obtaining volume at threshold value it has been multiplied by the average specific gravity to arrive at the resource in tonnes.
9. Thus, the sum of commodity wise cross-sectional resources is the total geological gross in-situ resource.



#### **19.7.0 DESCRIPTION OF BASIS FOR USING OR NOT USING GRADE CUTTING OR CAPPING**

- 19.7.1 The present exploration was carried out for manganese and graphite mineralization in the Bharatbahal block. The mineralization in the block area is not showing erratic analytical value or outlier and overall, the analyses are homogenous. Considering the nature of mineralization in the block, there is no grade cutting or capping has been used.

#### **19.8.0 GEOSTATISTICAL METHODS**

- 19.8.1 Geostatistical method has not been used for the resource estimation in the block.

## **CHAPTER-20**

### **20.0.0 REPORTING OF RESOURCES**

#### **20.1.0 RESOURCE AND GRADE**

20.1.1 Manganese and graphite resource estimation has been made by the Geological Cross Section Method section wise, commodity wise at threshold value of manganese and graphite are provided in the Annexure- XVIII and XIX respectively.

20.1.2 The manganese ore resource estimated by Geological Cross Section Method is 0.45 million tonnes and over a strike length of 930 m with an average grade of 19.62% Mn at 10% Mn threshold value. Resource estimation chart has been provided in the following Table 19.1

20.1.2 The graphite ore resource estimated by Geological Cross Section Method is 0.59 million tonnes (m.t.) and over a strike length of 250 m with an average grade of 4.10% FC at 2% FC threshold value. Resource estimation chart has been provided in the following Table 19.2

**Table 19.1**

**MANGANESE ORE RESOURCES ESTIMATED BY GEOLOGICAL CROSS SECTION METHOD AT 10% MANGANESE THRESHOLD VALUE (1.5M MAXIMUM NON-ORE PARTING, TONNAGE FACTOR 2.79), IN BHARATBAHAL MANGANESE AND GRAPHITE (G3) BLOCK, BALANGIR DISTRICT, ODISHA.**

Section No.	Borehole No.	Depth of Intersection(m)		Thick-ness (m)	True Thick-ness (m)	Strike Influence (m)	W.Z. Area (333)	Other Area (333)	W.Z. Resource (333)	Other Resource (333)	Total Resources Tonnes	Mn (%)
		From	To									
S-1	MBMG-07	21.50	24.00	2.50	2.27	71.67	63.08	49.13	12613.4	9824	22437.433	15.69
S-2	MLB-05	11.00	23.00	12.00	10.88	99.53	93.49	220.34	25961.1	61185.93	87147.045	24.24
S-3	MBMG-04	34.00	38.20	4.20	3.81	108.17	34.71	208.07	10475.3	62794.34	73269.62	29.69
S-4	MLB-02	19.89	29.49	9.60	8.70	106.12	88.83	335.65	26300.3	99377.51	125677.83	14.21
S-5	MBMG-06	5.00	6.00	1.00	0.91	75.81	23.03	9.73	4871.07	2057.991	6929.0643	10.61
S-5	MBMG-06	9.00	12.00	3.00	2.72	75.81	59.79	39.92	12646.2	8443.475	21089.652	18.03
<b>Resources (North Band)</b>											<b>336550.65</b>	<b>20.44</b>
S-6	MLB-04	21.00	27.00	6.00	5.20	77.64	70.56	176.66	15284.4	38267.31	53551.709	15.24
S-8	MLB-03	11.50	28.00	16.50	14.29	100.70	148.33	257.60	41673.8	72373.49	114047.25	19.26
<b>Resources (South Band)</b>											<b>167598.96</b>	<b>17.98</b>
<b>Gross Geological Resources</b>											<b>504149.61</b>	<b>19.62</b>
<b>Net Geological Resources</b>											<b>453734.64</b>	
<b>Net Geological Resources (in Million Tonnes)</b>											<b>0.45</b>	

**Table 19.2**  
**GRAPHITE ORE RESOURCES ESTIMATED BY GEOLOGICAL CROSS SECTION METHOD AT 2% FC THRESHOLD VALUE**  
**(1.00M MAXIMUM NON-ORE PARTING, TONNAGE FACTOR 2.68),**  
**BHARATBAHAL MANGANESE AND GRAPHITE (G3) BLOCK, BALANGIR DISTRICT, ODISHA.**

Section No.	Borehole No.	Depth of Intersection(m)		Thick-ness (m)	True Thick-ness (m)	Strike Influence (m)	W.Z. Area (331)	Other Area (331)	W.Z. Resource (331)	Other Resource (331)	Total Resources Tonnes	F.C. (%)
		From	To									
S-1	MBMG-07	29.00	33.00	4.00	3.63	71.67	101.09	105.05	19416.92	20177.54	39594.46	2.76
S-2	MLB-05	39.10	47.55	8.45	7.66	99.53	-	375.36		100123.68	100123.68	3.93
S-2	MBMG-08	62.50	63.50	1.00	0.98	99.53	-	42.76		11405.82	11405.82	14.55
S-2	MBMG-08	67.00	71.00	4.00	3.94	99.53	-	175.63		46847.62	46847.62	5.06
S-2	MBMG-08	77.00	78.00	1.00	0.98	99.53	-	43.97		11728.58	11728.58	9.34
S-3	MBMG-04	41.4	50.4	9.00	8.16	108.17	-	472.50		136975.67	136975.67	4.19
S-4	MLB-02	40.79	43.39	2.60	2.36	106.12	10.57	124.51	3006.12	35410.84	38416.97	2.33
S-5	MBMG-06	12.00	13.00	1.00	0.91	75.81	15.06	14.76	3059.75	2998.80	6058.55	2.11
S-5	MBMG-06	15.00	16.50	1.50	1.36	75.81	28.50	25.69	5790.37	5219.46	11009.83	2.00
<b>Resources for North Band</b>											<b>402161.17</b>	<b>4.26</b>
S-7	MBMG-01	39.00	44.00	5.00	4.33	98.76	117.11	146.76	30996.30	38843.97	69840.27	3.22
S-8	MLB-03	35.5	37	1.5	1.30	100.70	14.09	48.84	3802.55	13180.74	16983.30	2.44
S-8	MLB-03	39	43	4	3.46	100.70	35.66	136.70	9623.78	36892.05	46515.83	3.75
S-9	MBMG-02	43.00	44.00	1.00	0.87	94.25	-	49.20		12427.43	12427.43	8.00
S-9	MBMG-02	52.00	55.00	3.00	2.60	94.25	-	158.59		40058.25	40058.25	3.73
S-9	MBMG-02	61.20	62.40	1.20	1.04	94.25	-	64.81		16370.36	16370.36	3.10
S-9	MBMG-02	63.80	64.80	1.00	0.87	94.25	-	51.33		12965.44	12965.44	5.30
S-10	MLB-01	58.7	62.7	4.00	3.06	66.22	-	206.92		36722.01	36722.01	4.23
<b>Resources for South Band</b>											<b>251882.88</b>	<b>3.83</b>
<b>Gross Geological Resources</b>											<b>654044.05</b>	<b>4.10</b>
<b>Net Geological Resources</b>											<b>588639.64</b>	
<b>Net Geological Resources (in Million Tonnes)</b>											<b>0.59</b>	

## **CHAPTER-21**

### **21.0.0 SUMMARY AND RECOMMENDATIONS**

#### **21.1.0 SUMMARY**

- 21.1.1 Bharatbahal Manganese and Graphite Block falls in Balangir district, Odisha. It lies between latitudes 20°47'53.99444"N and 20°48'49.32068"N and longitudes 83°13'44.12474" E and 83°14'26.38448" E. The block covers an area of 2.013 sq km and in the part of the Survey of India Toposheet No 64P/01.
- 21.1.2 Most of the area is agricultural land except in the western part. Bharatbahal village is located in the central part of the block area.
- 21.1.3 The area comprises wide spread plain land and low lying mounds. Average elevation in the block area is around 221 mRL. The block area lies in between the catchment area of Suktel River.
- 21.1.4 The exploration area lies in the northern part of the Eastern Ghats Supergroup and the rocks exposed in the area are of Pre-Cambrian age belonging to the meta-sedimentary sequence represented by khondalite Group.
- 21.1.5 Geological mapping and mineralized zones intersected in the trenches and boreholes have established two mineralized bodies named as North and South Band. In addition, at places manganese and graphite occur as pockets at places. Strike of the mineralization is NNE-SSW with an amount of 50° to 80° towards NW.
- 21.1.6 In the block manganese occurs as discontinuous lensoidal in the central part of the block. Two bands have been established as North and South Bands. Also, aligned parallel to strike of the enclosing formations. Their exposures are in rugged boulder form. Insitu mineralized body is surround by float ores. Manganese ore bodies occur as bands, lenses, pockets, veins, tabular bodies and disseminations within the khondalite group of rocks (mostly with khondalite and quartzite). In most of the places manganese bands intersected in the trenches have no depth continuity or pinching out within few meters below surface which has been assessed from the drilling. This may be due to lenticular nature of the mineralized body in subsurface. Manganese mineralization

occurs over a strike length of 930m in the central part of the block with two discontinuous bands. (North Band- 488m and South Band-447.60m strike length).

21.1.8 The host rock for graphite in the block is khondalite. The graphite occurs as medium to fine flaky/ prismatic grains and its disseminated aggregates, often showing kink bands associated with magnetite, pyrite, chalcopyrite and other sulphides. The graphite mineralization / graphite zones are hardly exposed on surface and mainly intercepted in the trenches and boreholes. Concentration of graphite has been developed up to a vertical depth of 60m with pinching and swelling in nature. (North Band- 150m and South Band-100m strike length). Raman Spectroscopy of few borehole samples from graphite mineralization indicates flaky to massive nature of graphite.

21.1.9 The manganese ore resource estimated by Geological Cross Section Method is 0.45 million tonnes and over a strike length of 930 m with an average grade of 19.62% Mn at 10% Mn threshold value. Resource estimation chart has been provided in the following Table 19.1

21.1.10 The graphite ore resource estimated by Geological Cross Section Method is 0.59 million tonnes (m.t.) and over a strike length of 250 m with an average grade of 4.10% FC at 2% FC threshold value. Resource estimation chart has been provided in the following Table 19.2

## **21.2.0 RECOMMENDATIONS**

21.2.1 Generally, the type of deposit in Bharatbahal Manganese and Graphite (G3) Block is of low grade in nature. However, it has potential that would be amenable for systematic scientific mining. On the present stage of exploration, the block may be auctioned as composite license.

21.2.2 Beneficiation studies on such low-grade graphite ores may be carried out to maximize the recovery of flaky graphite in the next phase of exploration.

21.2.4 Due to discontinuous and lenticular nature of the mineralized bodies close space drilling (50 m strike interval) may be planned to assess the three-dimensional behavior of the ore bodies along with quality and quantity.

21.2.5 In the nearby blocks (Larambha and Kanaital G3 Blocks) vanadium up to 500ppm has been reported which is invariably associated with the graphite. Also, with in the block vanadium values shows up to 486.24ppm in graphite samples. Hence, sampling at regular interval during next phase of drilling may be carried out to delineate the vanadium rich zones within the graphite and assess the quality and quantity of the same. In addition, mineral phase studies may be carried out.



## **CHAPTER-22**

### **22.0.0 PLATES AND MAPS**

- 22.1.0 Location Map of the block showing various topographic and physiographic features on SoI toposheet is given as Plate-I in 1:50,000 Scale.
- 22.4.0 Topographical Map in 1:2000 is given as Plate- II
- 22.5.0 Block Geological Map on 1:2000 is given as Plate-III.
- 22.7.0 Trench mapping and Sampling data from Trenches at 1:100 scale is given as Plate-IV.
- 22.8.0 Geological cross section in 1:1000 is given as Plate-V

## **CHAPTER-23**

### **23.0.0 ANNEXURE / ENCLOSURES TO THE REPORT**

23.1.0 The report includes all the relevant annexure and maps, plans, sections, photographs & photomicrograph etc. List of annexures, tables, maps/plans/sections, photographs, Text figures & photomicrograph etc are provided before the start of the text part of the Geological Report.

## **CHAPTER-24**

### **24.0.0 ANY OTHER INFORMATION**

### **24.1.0 ANY OTHER INFORMATION**

No Such information is required to be mentioned additionally.

## **CHAPTER-25**

### **CERTIFICATE FROM THE QUALIFIED PERSON WITH NAME, DATE AND SIGNATURE**

This is to certify that geological report has been prepared on preliminary exploration (G-3) for Manganese and Graphite in Bharatbahal Block, Balangir district, Odisha by Mineral Exploration and Consultancy Limited (MECL) on behalf of National Mineral Exploration Trust. The report has been prepared in accordance with the Minerals (Evidence of Mineral Contents) Rule 2015 specified under Mineral Auction Rule, 2015 and amended up to 2021.

**NAME: P. RAVINDRAN**

**DESIGNATION: GENERAL MANAGER (EXPLORATION)**

**DATE: 31.03.2025**

**LIST OF PERSONNEL ASSOCIATED WITH BHARATBAHAL MANGANESE AND GRAPHITE (G3) BLOCK, DISTRICT- BALANGIR, ODISHA**

Overall guidance	Shri P. Ravindran, GM (Exploration)
Overall Planning, Co-ordination & Supervision	Shri S. K. Satapathy, Sr. Manager (Geology)
Project Management	Shri Rajesh Patel, Manager (Geology) / Project Manager
Physical Execution of work	
a) Geology	Shri Sujit Kumar Jena, Asst. Manager (Geology)
	Shri Deepak Kumar Behera, Sr. Geologist
	Shri Kolluri Sudheer, Geologist
	Smt Aayushi Saraswat, Geologist
b) Drilling	Shri Rishabh Kumar, Asst. Manager (Drilling)
c) Survey	Shri N.K.N. Choudhari, Survey & Map Officer
Sample Processing	Shri Pitta Simhachalam, Sr. Technician (Sampling)
Chemical Laboratory	Shri Rohit Sharma, Manager (Chemical Lab)
	Dr. Deepti Rahangdale, Manager (Chemical Lab)
Petrographic Studies	Shri Sayantan Pal, Manager (Geology)
Documentation	Shri S. K. Satapathy, Sr. Manager (Geology)
Non-Coal Geological Report Cell	Ms. Rajanya Roy, Sr. Geologist
	Shri Uday Patil, Sr. Computer Operator
	Shri Shivanand, Sr. Computer Operator
Reprography and Printing	Shri Jagdish Kumar, Sr. Survey & Map Officer
	Shri Durgesh Devarshee, Assistant Survey & Map Officer
Hindi Translation	Shri Shreekant Rai, Hindi Officer

## REFERENCES

1. Popoff, USBM, 1965 Computing reserves of Mineral deposits: Principles and Conventional methods. Constantine C.
2. K. K. Chatterjee, Uses of Metals and Metallic Minerals.
3. Market Survey on Manganese ore, Indian Bureau of Mines, June 2014.
4. Manganese- Critical Mineral Resources of the United States—Economic and Environmental Geology and Prospects for Future Supply, Professional Paper 1802–L, USGS.
5. “GEOLOGICAL REPORT ON GENERAL EXPLORATION (G-2) FOR MANGANESE AND GRAPHITE IN TAMIYA BLOCK, DISTRICT-BALANGIR, ODISHA” October 2019-MECL
6. GEOLOGICAL REPORT ON GENERAL EXPLORATION (G-2) FOR MANGANESE RENGALI BLOCK, DISTRICT-BALANGIR, ODISHA- December 2019-MECL
7. GEOLOGICAL REPORT ON RECONNAISSANCE SURVEY (G4) FOR MANGANESE ORE AND GRAPHITE IN LARAMBHA-KANAITAL AND PUDAPADAR-BHARATBAHAL BLOCK, DISTRICT: BALANGIR, ODISHA- October 2023
8. Indian Minerals Yearbook 2021 (Part- III: MINERAL REVIEWS), 60th Edition MANGANESE ORE (ADVANCE RELEASE), INDIAN BUREAU OF MINES, January 2023
9. Igor M. Varentov, 1996, Manganese Ores of Supergene Zone: Geochemistry of Formation.
10. J Hoefs and M. Frey, 1976, Isotopic composition of carbonaceous matter in a metamorphic profile from the Swiss Alps, J Hoefs and M. Frey, 1976, Cosmochimica Acta, Volume 40, Issue 8, August 1976, Pages 945-951.
11. B. N. Jayaram (1962), GSI, preliminary investigation of graphite deposits in the Balangir-Patna district, Orissa covering the toposheets falling in 64 L and 64 P (5560 sq km).
12. Census 2011
13. District Survey Report of Balangir, March 2011