

**GEOLOGICAL REPORT ON THE G4 EXPLORATION FOR IRON ORE & MANGANESE
IN
JAMPANI-DULKIBURU-DANGUAPOSI BLOCK
BLOCK ID: ER_JH_01
WEST SINGHBHUM DISTRICT,
JHARKHAND
(UNDER NMET PROGRAMME)
(TEXT & ANNEXURE)**



**NMDC Limited,
(A Govt. of India Enterprise)
Khanij Bhavan, Masab Tank,
Hyderabad – 500028
August-2019**

GEOLOGICAL REPORT ON THE G4 EXPLORATION FOR IRON ORE & MANGANESE IN JAMPANI-DULKIBURU-DANGUAPOSI BLOCK, BLOCK ID: ER_JH_01, WEST SINGHBHUM DISTRICT, JHARKHAND

EXECUTIVE SUMMARY

1. Introduction:

In pursuance of National Mineral Exploration Policy-2016, Ministry of Mines, Govt. of India desired to explore the possibilities of expediting the exploration of 100 mineral blocks so as to filter out the auctionable blocks at the earliest under National Mineral Exploration Trust (NMET). In this connection, Ministry of Mines, Govt. of India vide meeting dated 05/08/2016 and 12/09/2016 had decided that, Geological Society of India (GSI) and Mineral Exploration Corporation Limited (MECL) would explore 30 blocks each in various States. Out of remaining 40 blocks, 20 mineral blocks were kept for Central PSU's/State PSU's and rest of 20 blocks will be explored through contractual exploration on revenue sharing model.

Jampani-Dulkiburu-Danguaposi Block (ER_JH_01) for Iron Ore & Manganese mineral in West Singhbhum, District of Jharkhand was one among the 20 mineral blocks kept for PSU's.

2. Property description

- Jampani-Dulkiburu-Danguaposi block is spread over 100.00 Sq Km in West Singhbhum District of Jharkhand and Keonjhar District of Odisha with major Part of the block ~93 sq. Km falling in Jharkhand and ~7 Sq. Km area falls in Odisha.
- Jampani-Dulkiburu-Danguaposi Block is bounded between villages Pachasai to the North West, Danko to the North East, Ramtirath(Tutsai) to the South East of West

Singhbhum district, Jharkhand and Samidih village to the South West in Keonjhar District of Odisha.

- The block falls in Toposheet No. 73F/12

Property boundary coordinates: - Datum- WGS84 & UTM (45 N zone)

Points No	WGS 84		UTM Coordinate	
	Longitude	Latitude	Easting	Northing
A	85°31'36"	22°10'00"	348263	2451984
B	85°38'13"	22°10'00"	359500	2451879
C	85°38'13"	22°05'00"	359437	2442662
D	85°31'36"	22°05'00"	348013	2442775

3. Location and accessibility:

Jampani-Dulkiburu-Danguaposi block is located in the South Eastern side of the Noamundi Iron ore Deposit of the Tata Steel Limited. The block can be approached both by rail and roadways. It is well connected through State highway. Nearest township Noamundi Iron Ore Project (Tata Steel) is located at about 5 km NW of the block. Network of forest road & black top road constructed under Pradhan Mantry Gram Sadak Yojna is connecting the block from surrounding villages. Nearest railway station is Noamundi at about 05 and Danguaposi is located in Northern part of the block respectively on branch line section of Tata Nagar – Rajkharsawan – Badbil on broad-gauge of South Eastern Railway. Road connecting Danguaposi to Ramtirth passes in the Eastern part of the block and road connecting Noamundi & Jainthgarh passes through Southern part the block. **(Plate-1)**

4. Previous work:

Preliminary assessment of Iron Ore in and around Silpunji-Kantoria area, West Singhbhum District (parts of T.S. 73F/08) was carried out by GSI during the field season 2010-12. Detailed geological mapping (1:12500 scales) and reconnaissance surveys identified occurrence of low grade (Fe values ranging from 39.89% to 63.35%) in the form of BHJ Hematite and laterites with subordinate occurrence of Manganese (11.00% to 50.58 %) in the west of Kantoria, Meralgara and west of Hesapi.

During field seasons 2012-2013 investigation of Iron ore and Manganese in Kotgarh and Lokesai, West Singhbhum District, Jharkhand by GSI reveals occurrence of ferruginous sandstone (FeT % is upto 65.49%) and laterite (FeT % upto 42.80%) developed over the volcanic rock of Jagannathpur Lava and Kolhan Group of rocks i. e. sandstone and shale.

Reconnaissance of Iron ore and Manganese in the rocks of Iron Ore Group and Kolhan Group in parts of Bambasai-Dumurjowa-Mongra block, West Singhbhum District Jharkhand during field seasons 2013-14 in parts of toposheet no 73F/11 and 73F/12 by GSI identified small isolated, detached outcrops of low grade iron ore mineralization in the form of BHQ, BHJ (enclaves) and laterites with Fe values between 16.62 % to 31.70%. Detrital clasts of jasper, vein quartz, BIFs, haematite quartzite, chert and sub-angular granite clasts observed within the Kolhan conglomerates. The clasts of BIF and hematite constitute less than 2 to 3% and its average size is also less than 5 centimeters hence such bodies are not potential for low grade iron ore. (Plate-3)

The proposed area very close to the juxtaposition of Danguaposi Lava and Kolhan Group of rocks and hence the proposed block Jampani-Dulkiburu-Danguaposi in the southwestern part of the Toposheet no. 73F/ 12 is likely to have high potential of occurrence of low grade Iron Ore as it lies to east of Noamundi Iron ore mines. As per the NGCM, Fe anomaly is also occurs in the NW part of the Block.

5. Objectives of investigation:

- ✓ Objective of the Investigation is to undertake G4 exploration for Iron ore & manganese according to UNFC guidelines/ MEMC, Rules and other existing laws framed from governing exploration works.
- ✓ To undertake remote sensing studies to identify the iron ore potential areas in the Jampani Block.
- ✓ Through Geological mapping on 1:12,500 scale to demarcate of the Iron and Manganese ore bodies in lateritic covers/ BHQ zone/ BIF formation with the structural features and geological formation to identify the extent of surface mineralization of the ore body.
- ✓ To collect surface samples and analyse for Fe & Mn In case if results are encouraging, then to undertake pitting, trenching, to undertake geophysical survey and to decide on further course of action.
- ✓ If regional exploration work at G-4 level gives encouraging results after completion of works, as per the directives of the Technical Committee of NMET, NMDC may take the future course of exploration activities at G-3/G-2 category of UNFC.

Details and nature and quantum of work proposed vs achievement

Sl. No.	Item of work	Unit	Proposed Quantum of Work	Achieved
1	Literature survey	lump sum	Undertaken	
2	Remote Sensing for Mineral Targeting & Structural Mapping	Scene	1 scene study in 100 Sq. km area	Undertaken using Aster Data
	LISS IV- (5.8 mtrs resolution)	Scene	1 scene	
	Cartosat-2 (1 mtr resolution)	Scene	3 Scene	
3	Topographical Survey (on 1: 12,500 Scale)	Sq. Km	100	Not Undertaken
	Fixation of Four Coordinate Points by DGPS	Nos.	4 nos	NA
	Bore Hole Fixation (Scout Boreholes)	Nos	5 Nos	NA
	RL & Coordinate Determination	Nos	5 N0s	NA
4	Geological Mapping (on 1:12,500 Scale)	Sq. Km	100 sq.km	100 Sq. Km.
5	Geophysical Survey			
	a)Magnetic	Line Km	30	Not advised
6	Surface Sampling			
	a) Grab/ Chip samples	N0s.	80Nos	39
	b) Pit samples	Nos.	10Nos.	Not advised
	c) Trenching samples	Nos.	10Nos.	Not advised
7	Test hole Drilling: (if required)	m	250 (5 Bhs)	Not under taken
	Geological work			
	a) Geological Core Logging & Supervision charges	m	250	Not undertaken
8	Laboratory Studies			
	i) Surface Sampling (Primary samples)	Nos.	100	33
	ii) Drill Core Primary & Check Samples	Nos.	250	NU
	* For 6 radicals viz Fe, Al ₂ O ₃ , SiO ₂ , LoI, P, S			Undertaken for Mn also
9	a) Preparation of Thin Section	Nos	10	6
	b) Study of Thin Section & Mineralogical studies	Nos	10	6

6. Climate

The area is characterized by humid to subtropical climate. The Noamundi and its surrounding areas recorded the maximum rainfall in Jharkhand. Since the block is located near to Noamundi, during the monsoon season block has good seasonal rainfall. Monsoon season is confined to the months from June to September with average annual rainfall of 2000 mm. In summer temperature increases up to 44°C and temperature drops to a minimum of 10°C during winter.

7. Physiography

The North and North Eastern & South West part of the block is characterized by rugged topography, comprising high undulating flat topped hillocks, having average elevation of 510m. The highest point on Bamai Buru is 583m above MSL. All through, these ridges support thick vegetation, the hills/ ridges, are mostly covered by Basaltic rock, Iron Ore group of rocks, quartzite. The Southern & South Eastern part of the area is marked by low/flat topography mainly plain cultivated land with average elevation of 400m. The RL of the area varies from 383m to 583m

8. Drainage:

The streams and rivers in the area together form a dendritic to subdendritic drainage pattern. The entire block area is a part of Baitarni river basin. Most of the streams/nalah/drainage originates from the hillocks in the North/ North East/ South West part of the block. These originated streams/nalah flows through the plain land in the South/ South Eastern part of the block where check dams/major ponds have been created for catering the needs of irrigation and wild animals such as elephants as this is part of major elephant corridor. Baitarani River is flowing in the South Eastern part of the Block and water flows from West to East. The major nala are Chendo nala and Sening nala tributaries of Baitarni River.

9. Flora/fauna

The block is falling in Noamundi forest Range of Chaibasa Forest Division of West Singhbhum District. Chaibasa of the West Singhbhum is well known for rich biodiversity. Of the total area, ~ 25% area (say 25 Sq. Km) areas falls in PF/Reserve forest area. With different Protected & Reserve Forest, block bears rich vegetation as well as adequate floral and faunal reserve.

The flora of the area includes Sarai (*Shorea robusta*), Tendu (*Diospyros melanoxylon*), Bija (*Pterocarpus marpupium*), Teak (*Tectonano granedis*), Bamboo (*Dendrocalanus strictus*), Sal (*Shorea robusta*), Mahua (*Madhuela latifolia*), Mango (*Magnifera indica*) and Bahera (*Tharminalia belerica*).

The *block* allocated forms the part of major elephant corridor. Apart from elephant, wild cats, Mongoose, Rabbit, snakes are some of the fauna reported in the allocated block.

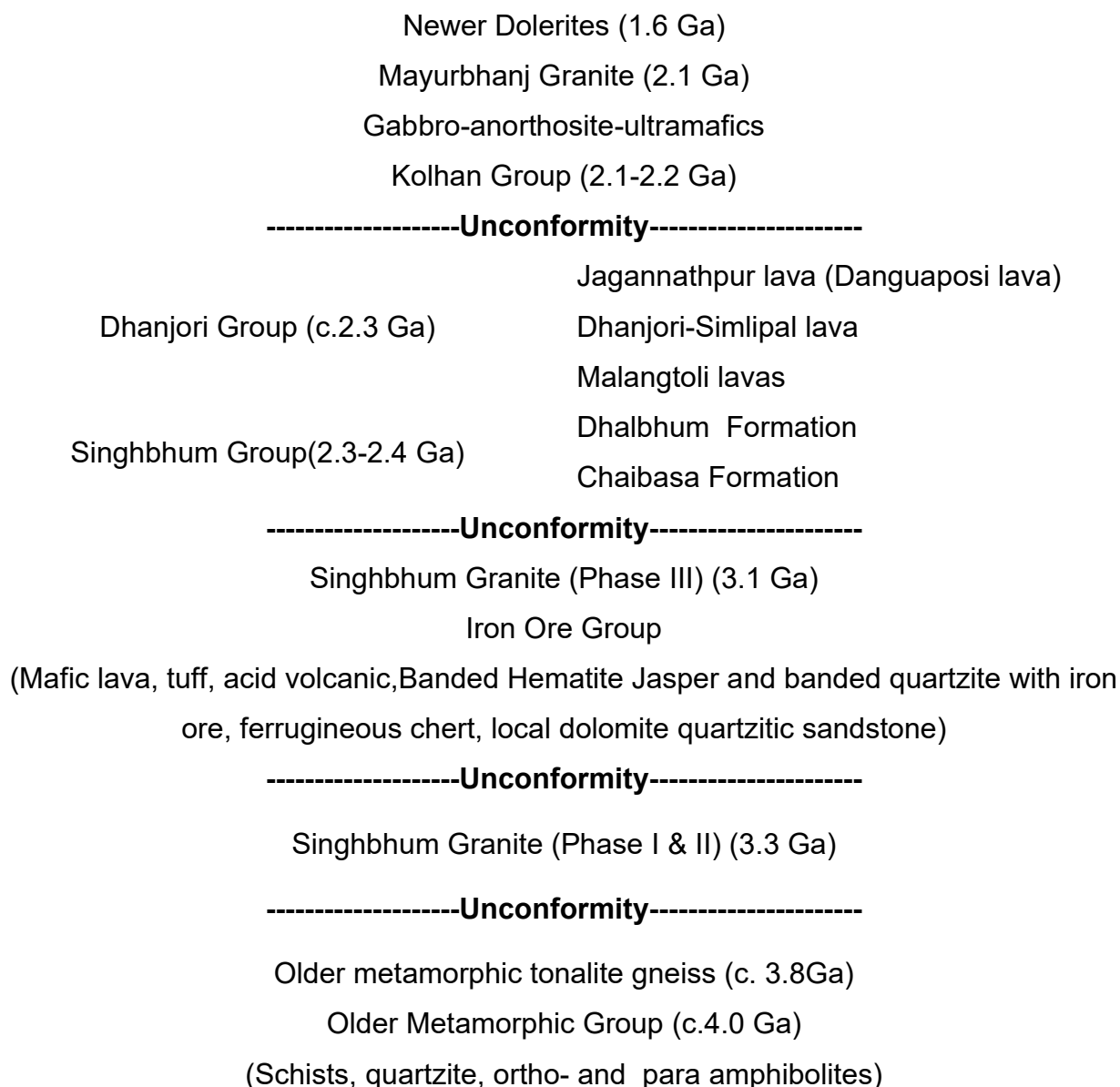
10. Regional Geology of the Area:

Precambrian Singhbhum cratonic nucleus of eastern India falls in the states of Jharkhand and Odisha and preserves imprints of several geological cycles spanning from the early Archaean to early Neoproterozoic (Saha 1994). The ancient cratonic block, Singhbhum Craton or as Singhbhum-Orissa Iron Ore Craton remained a major attraction for geoscientists and miners for the immense potential of this belt in terms of Major mineral deposition such as copper, uranium, iron, manganese, chromites, and limestone amongst others.

The geological knowledge on the Singhbhum region was established through the work of Ball(1881), Dunn(1929), Jones (1934), and Dunn and Dey (1942). Although Ball for-the first time, mapped the Singhbhum area, the first geological details were: published by Dunn (1929) and Jones (1934). Real stimulus, however, came from

Dunn and Dey (1942) who provided comprehensive stratigraphic details of the region. **(Plate No-2)**

Stratigraphy of the Singhbhum Greenstone-Granite terrain (after Sarkar, S. N. and Saha, 1983, Saha et al. 1988)



11. Geology of the Block

The Jampani-Dulkiburu-Danguaposi block is located to the East to the Bonai synclitorium's Eastern limb (in the extreme North Eastern part of the limb).

The rocks exposed in the South & South East part of the blocks part of Older Metamorphic formation of Singhbhum Craton, it comprises of metapelite and quartzofeldspathic gneiss. In the Northern, Central part is covered by Jaganathpur lava comprising of Basaltic flow. Between basalt and older metamorphic rocks, patches of Iron ore group of rocks such as ferruginous shale, banded cherts and BIF are observed. Further in the North Western Corner to the Iron ore group of rock Ferruginous Sandstone is observed. In patches in Southern side and in North western part with in the Ferruginous Sandstone observed Conglomerate rock. Apart from these lithologies quartz reef and dolerite intrusion are also observed in the block. (Fig-3)

Stratigraphic succession of the block, West Singhbhum District, Jharkhand.

Laterite

Dolerite

Conglomerate (with hematite clast/matrix)

Quartz Reef??

-----Unconformity-----

Jagannathpur lava (Danguaposi lava)

-----Unconformity-----

Iron Ore Group

(Tuff (ferruginous Shale), banded ferruginous chert, Banded Iron Formation, Ferruginous quartzite sandstone.)

-----Unconformity-----

Older Metamorphic
(Schists, quartzite)

The Geological map of the block is attached in the **(Plate No-4)**

12. Geological Mapping:

Systematic Geological mapping in 1:12500 Scale was carried out in the block during Financial Year 2018-19. The aim of geological mapping was to undertake regional mapping of the block to identify iron/ Manganese ore body (BHJ/BHQ) (if any) in the block.

During Geological mapping the following lithologies were identified.

- I. The block is mostly covered by (basaltic lava) Danguaposi lava correlatable with Jagannathpur lava excepting Southern & South Eastern part of the block.
- II. In Southern & South Eastern part of the block is covered by metapelite & the Quartzo feldspathic gneiss is occurring as patches within the metapelite. Metapelite & Gneiss is correlatable with Older Metamorphic. The metapelite is unconformably overlain by basalt.

Both basalt and metapelite are the most dominant lithology observed in the block. Apart from basalt & metapelite following lithologies are also observed in the block:

- III. Ferruginous Shale/banded chert (sometimes grades to BIF) correlatable to the iron Ore Group of rocks is occurring either 'as sandwich between Metapelite and basalt' or 'as outliers within the basalt'. The iron ore group is unconformably overlain by basalt and unconformably underlain by metapelite.
- IV. All the 3 major lithologies, basalt, Metapelite and Iron ore group have been intruded by Quartz.
- V. Apart from the quartz reef, Dolerite dyke is the other intrusion observable in the block. Dolerite has intruded in Metapelite and Basalt only. It is inferred that, dolerite dyke intrusion may be post to the quartz reef.

VI. Unconformable to the basalt, Metapelite and quartz reef, Iron clast/ground mass bearing conglomerate/sand stone has been deposited.

VII. With weathering of ferruginous sandstone of Iron ore group and basalt, lateritic soil has formed and with weathering of basalt & metapelite, clay has formed.

The Geological map of the block is attached in the **Plate No- 04**

13. Iron ore/ Manganese Mineralization in the block:

Iron/Manganese ore Mineralization in the block was expected in 3 lithologies viz.

1. In the Iron ore group comprises of Ferruginous shale, banded chert and BIF.
2. Conglomerates and
3. Lateritic Soil

Lateritic soil is occurring over the basalt/ ferruginous Sandstone implying that it is produced from weathering of these lithologies. The lateritic soil is not having an indication of conversion from iron ore.

In Iron ore group of rocks, surface indication of iron ore/ manganese ore mineralization is poor. The Fe% in BIF group of varies from 8.39 % to 46.22% However, in certain places Hematite is occurring as floats (rolled pieces) shows analytical results show High Fe% of 64%, 54% & 52.14% value. In the remaining places, where the Fe% is more than 45% are all reported in Banded Hematite Jasper, which are not mappable (Annexure-I).

With respect to the conglomerate samples, the value in one of the samples is more than 60% Fe. However; the occurrence of the conglomerate is not persistent and mappable in the area.

In the BIF Group of Rocks, Manganese (pyrolusite) is noted as vein intrusion, possibly as replacement minerals in vugs formed in Ferruginous Shale. In 5 samples

Mn% is noted to be positive in nature & the same varies from 15.56 % to 44.37%. Of the 5 samples only one sample is collected from insitu rock whose value is 15.56%. All the remaining samples are collected from floats whose source rock could not be traced.

14. Conclusion and Recommendations:

Conclusion:

- Based on the remote sensing studies, Principle Component Analysis and Band Ratio Imaging, Could segregate 3 major lithologies viz, basalt, ferruginous Shale/chert band/BIF and the Metapellitic terrain.
- During the course of mapping, No Iron/Manganese ore enrichment areas have been noticed in the block.
- The chemical analysis of rock samples show Fe % ranging from 8.39% to 54% with majority of the samples falling less than 45%. The rock samples where the Fe% are higher than 45% is of BIF rock, but the BIF are not in the mappable scale.
- In conglomerate rocks, either 'the chemical analysis values of Fe% & Mn % are not encouraging' or 'the continuity of conglomerate is not there'. Further the hematite % in conglomeritic Clast is less. Hence, conglomerate could not be considered for exploration.
- Laterite soil due to its association with basalt and ferruginous sandstone and Basalt, it is inferred that the laterite would be below the sub-grade ore category.
- The persistence of ore & chemical analytical data of Manganese data are also not encouraging.

Recommendations:

The G-4 stage exploration have been carried out in JAMPANI-DULKIBURU-DANGUAPOSI block West Singhbhum District, Jharkhand employing large scale mapping on 1:12,500 scale and rocks/ ore sampling, analysis have not given any encouraging results for Iron as well as manganese.

In view of the absence of any promising mineralization of iron ore and manganese ore, the chances of encountering large scale mineralization are poor in the block. Most of the area is covered by Danguposi lava.

No potential Iron/Manganese Ore body is found for further exploration.

Hence, no further exploration work for Iron Ore & manganese is recommended in the Jampani-Dulkiburu-Danguaposi block.

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Contents

Chapter-I	1
1.1 Introduction:	1
1.2 Details of project:	1
1.3 Investigating agency	2
1.4 Objectives of investigation:	3
1.5 Basis for taking up investigation	3
1.6 Personal involved:	3
1.7 Property description:	4
1.8 Land use/cover:	5
1.9 Forest with type of Forest:	5
1.10 Location and accessibility:	6
1.11 Climate	7
1.12 Physiography	7
1.13 Drainage:	7
1.14 Flora/fauna	8
1.15 Previous work:	8
Chapter II	10
2.1 Regional Geology of the Area:	10
Chapter III	12
3.1 Remote Sensing Study using ASTER Image	12
3.1.1 Objective of the study:	12
3.1.2 ASTER Imagery in Mineral Exploration	12
3.1.3 Image source and specification	14
3.1.4. Software used:	15
3.1.5 Pre-processing	15
3.1.6 Enhanced color composite	15
3.1.7 Digital Elevation Model (DEM):	18
3.1.8 Principal Component Analysis – PCA	19
3.1.9 Band Ratio	22
3.1.10 Conclusion:	23

Chapter-IV	24
4.1 Geology of the Block:	24
4.2 Detailed description of Lithologies:	26
4.2.1 Older metamorphic Rocks:	26
4.2.2 Iron Ore Group of Rock:	27
4.2.3 Amygdaloidal Basalt (Danguaposi Lava):	33
4.2.4 Quartz Reef:	34
4.2.5 Dolerite Dyke:	36
4.2.6 Conglomerate:	36
4.2.7 Lateritic Soil:	39
Chapter-V	40
5.1 Petrographic Study of Rock Samples	40
5.1.1 Introduction	40
5.1.2 Test Plan	40
5.1.3 Microscopic Observation and Rock Identification Based On Minerals Observed	41
Chapter-VI	46
6.1 Quantum of work	46
Chapter-VII	48
7.1 Exploration Methodology	48
7.1.1 Geological Mapping:	48
7.1.2 Sampling/Chemical Analysis:	48
7.1.3 Sample preparation and analysis:	48
Chapter-VIII	50
8.1 Conclusion & Recommendations:	50
8.1.1 Conclusion:	50
8.1.2 Recommendation:	51
Chapter-IX	52
9.1 Expenditure:	52
Reference:	54

LIST OF TABLES

Table 1: The details of NMDC mineral block.....	2
Table 2: Property boundary coordinates	4
Table 3: The details of the Protected Forest in the Jampani-Dulkiburu-Danguaposi block.....	6
Table 4: ASTER satellite system: sensor characteristics.....	12
Table 5: ASTER satellite system: band characteristics	14
Table 6: ASTER Level 1B scene characteristics	15
Table 7: Eigen Vectors.....	20
Table 8: PCA Eigen Cumulative Details.....	21
Table 9 Details and nature and quantum of work proposed vs. achievement.....	46
Table 10: Details of Expenditure for G4 level exploration in Jampani-Dulkiburu-Danguaposi block	52

LIST OF FIGURES

Figure 1: ASTER bands superimposed on model atmosphere	13
Figure 2: RGB color composite of Bands7, 3, & 1 of the ASTER scene.....	16
Figure 3: RGB color composite of Bands2, 3, & 1 of the ASTER scene.....	17
Figure 4: False color composite of Bands 3, 2, & 1 of the study area.....	18
Figure 5: DEM Map of the Block	19
Figure 6: RGB color composite of PCA 4, 3 & 2 of the study area	22
Figure 7: Map of iron ratio image of the study area	23
Figure 8: Surface exposure of Metapelites	26
Figure 9: Sectional View of Quartzo Feldspathic Gneiss.....	27
Figure 10: Surface exposure of (old quarry exposure) of Ferruginous Sandstone	28
Figure 11: Ferruginous Sandstone with Cross bedding.....	29
Figure 12: Ferruginous Shale with limonitisation	31
Figure 13: Banded Chert.....	31
Figure 14: Banded Hematite Jasper	32
Figure 15: Occurrence of Manganese as vug filling in shale	32
Figure 16: Amygdaloidal basalt	33
Figure 17: Stone Quarry for Road metal in Amygdaloidal basalt.....	34
Figure 18: Quartz reef with other secondary/syn deformational veins.....	35
Figure 19: Milky white Quartz reef, near Durita village.....	35
Figure 20: Milky white Quartz reef, near Durita village.....	36
Figure 21: Conglomerate in Quartz reef	37

Figure 22: Conglomerate with bedding and cross bedding	38
Figure 23: Conglomerate in Southern part of the block	38
Figure 24: Lateritic Soil near Padampahar Station.....	39
Figure 25: The photo-micrograph shows Plagioclase Feldspar (Pl, Olivine(Ol) and few Augite(Aug). The ground mass is medium to fine subhedral to an-hedral in shape. t.	43
Figure 26: The photo-micrograph shows only Quartz(Qtz) grains with coarse to medium in size, sub hedral to an-hedral in shape in the sample.....	43
Figure 27: The photo-micrograph shows Labradorite (Lab), Augite(Agt) and few Olivine(Ol).	44
Figure 28: The photo-micrograph shows Anorthite (An), Biotite(Bt) and few Quartz(Qtz).....	44
Figure 29: The photo-micrograph shows Bytownite(Byt), Augite(Agt), few Olivine (Ol) and Quartz(Qtz)....	45
Figure 30: The photo-micrograph shows Quartz(Qtz). Few minute opaque iron oxide grains also observed..	45

PLATES

Plate-1: Location Map of Jampani Dulkibur Danguaposi Block

Plate-2: Generalised Geological Map of Iron ore deposit , Singhum Craton, India

Plate-3: Geological Map of Dulkibur Danguaposi Block provided by GSI

Plate-4: Geological Map of Jampani Dulkibur Danguaposi Block prepared by NMDC. Ltd

ANNEXURE

Annexure-I: Analytical result of collected rock samples in Jampani Dulkibur Danguaposi Block

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Chapter-I

1.1 Introduction:

In pursuance of National Mineral Exploration Policy-2016, Ministry of Mines, Govt. of India desired to explore the possibilities of expediting the exploration of 100 mineral blocks so as to filter out the auctionable blocks at the earliest under National Mineral Exploration Trust (NMET). In this connection, Ministry of Mines, Govt. of India vide meeting dated 05/08/2016 and 12/09/2016 had decided that, Geological Society of India (GSI) and Mineral Exploration Corporation Limited (MECL) would explore 30 blocks each in various States. Out of remaining 40 blocks, 20 mineral blocks were kept for Central PSU's/State PSU's and rest of 20 blocks will be explored through contractual exploration on revenue sharing model.

Jampani-Dulkiburu-Danguaposi Block (ER_JH_01) for Iron Ore & Manganese mineral in West Singhbhum, District of Jharkhand was one among the 20 mineral blocks kept for PSU's.

1.2 Details of project:

Jampani-Dulkiburu-Danguaposi Block (ER_JH_01) demarcated for undertaking G4 exploration for Iron ore and Manganese over an area of 100 Sq Km area located in Singhbhum District of Jharkhand.

1.3 Investigating agency

Ministry of Mines, Govt. of India vide letter dated 27th Oct. 2016, allocated 5 mineral blocks to NMDC. The details of the mineral blocks are as follows:

Table 1: The details of NMDC mineral block

SN	Name of the Block & Block ID:	District/ State	Mineral	Area (Sq. KM)
1	Jampani-Dulkiburu- Danguaposi (ER_JH_01)	West Singhbhum, Jharkhand	Iron Ore and Manganese	100
2	Degve-Kalna- Asaniya (CR_MH_01)	Sindhudurg, Maharashtra	Iron Ore and Manganese	93
3	Matmari, (SR_KAR_05)	Raichur & Kurnool, Karnataka	Gold & associated elements	511
4	Bukkapatna (SR_KAR_09)	Tumkur & Chitradurga Karnataka	Gold & associated elements	168
5	Nandgaon–Gora- Mahewa (CR_MP_05)	Chhatarpur, Madhya Pradesh	Gold & Base metals	100

1.4 Objectives of investigation:

- ✓ Objective of the Investigation is to undertake G4 exploration for Iron ore & manganese according to UNFC guidelines/ MEMC, Rules 2016 and other existing laws framed from governing exploration works.
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- ✓ If regional exploration work at G-4 level gives encouraging results after completion of works, as per the directives of the Technical Committee of NMET, NMDC may take the future course of exploration activities at G-3/G-2 category of UNFC.

1.5 Basis for taking up investigation

GSI, Eastern Region had reported occurrence of Iron ore & Manganese in and around the demarcated block Jampani-Dulkiburu-Danguaposi block. Based on the same at the time of demarcating 100 mineral blocks for exploration under NMET GSI had earmarked the block for Iron ore and Manganese exploration.

1.6 Personal involved:

The literature survey, Remote Sensing Studies and Geological mapping was undertaken during the FY 2018-19 by Investigation Division of NMDC. Since the block required detailed attention NMDC has deputed following four executives during the course of these studies they are viz.

Sh. Md Nasim Ansari,	Sr. Manager (Geology),	Hyderabad
Dr. K Sriramguru,	Sr. Manager (Geology),	Hyderabad

Sh. Swaminathan S, Sr. Manager (Geology), Hyderabad
 Sh. Sanjay Kumar Chaudary. Manager (Geology), Ranchi

1.7 Property description:

- Jampani Dulkiburu Danguaposi Block is spread over 100.00 Sq Km in West Singhbhum District of Jharkhand and Keonjhar District of Odisha. With major Part of the block ~93 sq. Km falling in Jharkhand & ~7 Sq. Km area falls in Odisha.
- Jampani Dulkiburu Danguaposi Block is bounded between villages Pachasai to the North West, Danko to the North East, Ramtirath(Tutsai) to the South East, village, West Singhbhum district, Jharkhand and Samidih village to the South West in Keonjhar District of Odisha.
- The block falls in Toposheet No. 73F/12

Property boundary coordinates: - (Datum- WGS84 & UTM 45 N Zone)

Table 2: Property boundary coordinates

Points No	WGS 84		UTM Coordinate	
	Longitude	Latitude	Easting	Northing
A	85°31'36"	22°10'00"	348263	2451984
B	85°38'13"	22°10'00"	359500	2451879
C	85°38'13"	22°05'00"	359437	2442662
D	85°31'36"	22°05'00"	348013	2442775

1.8 Land use/cover:

Out of the total 100 Sq. Km area more than 50 Sq. Km. area is covered by basaltic rock /Iron ore group of Rocks which are forming hillocks and remaining area is cultivated land with mostly clayey soil and lateritic soil.

The study area is mainly covered by protected forests and fairly dense jungle. Protected Forests include Jampani P.F, Dauberia P.F, Rengarbera P.F, Kuchibera P.F etc. The forest area is more than 25% while the agriculture and settlement area contributes to the rest. In the study area, the erosion is minimum due to dense forest cover in the Northern, western, south western part of the study area.

The block has semi-urban areas, rural areas and jungle villages with tribal population. Danguaposi is only the semi-urban settlement and rest are rural areas comprising many small villages. The villages Jampani, Lupang, Dhipasai, Bhangaon, Gitiliphi Siyaljora Deogaon, Ramtirth, Tutsai, Byhatu, Nandosai, Kundiyasai, Gardisai, Juginanda, Padampur in Jharkhand & Purushotampur, Naya Krishnapur, Panchannpur, Narayanpur & Samidhih are comparatively flat and mainly covered by agricultural fields are depended on agriculture. Remaining Villages mostly depended on both Forest & agriculture related activity.

1.9 Forest with type of Forest:

The area falls under the Chaibasa Forest Division in West Singhbhum District of Jharkhand. About 25 Sq. Km of the area falls under forest. The forest area falling in the block are mostly protected forest & the total 25 Sq. Km forest land also include, forest of land in Odhisa state

The details of the PF are mentioned here under:

Table 3: The details of the Protected Forest in the Jampani-Dulkiburu-Danguaposi block

SI No.	Name of the Protected Forest	Approx. Area in Sq. Km
1.	Jampani P.F.	5.21
2.	Rengarbera P.F.	5.61
3.	P.F. No.173	1.08
4.	P.F. No.176	1.60
5.	Dauber P.F.	2.68
6	Kuchibera P.F.	0.44
7	Acasia Plantation	0.39
8	Plantatio area in PF	0.17
	Odhisa	7.32
	Total	24.5

Since the block had sufficient Protected Forest Land, NMDC obtained permission to carry out the mapping from DFO, Chaibasa Division.

1.10 Location and accessibility:

Jampani-Dulkiburu-Danguaposi block is located in the South eastern side of the Noamundi Iron ore Deposit of the Tata Steel Limited. The block can be approached both by Rail and roadways. It is well connected through State highway. Nearest township Noamundi Iron Ore Project (Tata Steel) is located at about 15 km NE of the block. Network of forest road & black top road constructed under Pradhan Mantry Gram Sadak Yojna is connecting the block from surrounding villages. Nearest major railway station is Noamundi and Danguaposi at about 15 and 12 km. respectively on

branch line section of TATA NAGAR – RAJKHARSAWAN – BADBIL on broad-gauge of South Eastern Railway. Road connecting Danguaposi to Ramtirth passes in the Eastern part of the block and road connecting Noamundi & Jainthgarh passes through Southern part the block.

The area is bounded by Latitudes N 22° 05'-N 22° 10'/E 85°31'36" –E 85°38'13" longitude included in the Survey of India Toposheet no. 73F/12. **(Plate No: 1)**

1.11 Climate

The area is characterized by humid to subtropical climate. The Noamundi and its surrounding areas recorded the maximum rainfall in Jharkhand. Since the block is located near to Noamundi, during the monsoon season block has good seasonal rainfall. Monsoon season is confined to the months from June to September with average annual rainfall of 2000 mm. In summer temperature increases up to 44°C and temperature drops to a minimum of 10°C during winter.

1.12 Physiography

The North and North Eastern & South West part of the block is characterized by rugged topography, comprising high undulating flat topped hillocks, having average elevation of 510m. The highest point on Bamai Buru is 583m above MSL. All through, these ridges support thick vegetation, the hills/ ridges, are mostly covered by Basaltic rock, Iron Ore group of rocks, quartzite. The Southern & South Eastern part of the area is marked by low/flat topography mainly plain cultivated land with average elevation of 400m. The RL of the area varies from 383m to 583m

1.13 Drainage:

The streams and rivers in the area together form a dendritic to subdendritic drainage pattern. The entire block area is a part of Baitarni river basin. Most of the streams/nalah/drainage originates from the hillocks in the North/ North East/ South West part of the block. These originated streams/nalah flows through the plain land in the South/ South Eastern part of the block where check dams/major ponds have been

created for catering the needs of irrigation and wild animals such as elephants as this is part of major elephant corridor. Baitarani River is flowing in the South Eastern part of the Block & water flows from West to East. The major nala are Chendo nala and Sening nala tributaries of Baitarni River.

1.14 Flora/fauna

The block is falling in Noamundi forest Range of Chaibasa Forest division of West Singhbhum District. Chaibasa of the West Singhbhum is well known for rich biodiversity. Of the total area, ~ 25% area (say 25 Sq. Km) areas falls in PF/Reserve forest area. With different protected & reserve forest, block bears rich vegetation as well as adequate floral and faunal reserve.

The flora of the area includes Sarai (*Shorea robusta*), Tendu (*Diospyros melanoxylon*), Bija (*Pterocarpus marpupium*), Teak (*Tectonano granedis*), Bamboo (*Dendrocalanus strictus*), Sal (*Shorea robusta*), Mahua (*Madhuela latifolia*), Mango (*Magnifera indica*) and Bahera (*Tharminalia belerica*).

The block allocated forms the part of major elephant corridor. Apart from elephant, wild cats, Mongoose, Rabbit, snakes are some of the fauna reported noted in the allocated block.

1.15 Previous work:

Preliminary assessment of Iron Ore in and around Silpunji-Kantoria area, West Singhbhum District (parts of T.S. 73F/08) was carried out by GSI during the field season 2010-12. Detailed geological mapping (1:12500 scales) and reconnaissance surveys indentified occurrence of low grade (Fe values ranging from 39.89% to 63.35%) in the form of BHJ Hematite and laterites with subordinate occurrence of Manganese (11.00% to 50.58 %.) in the west of Kantoria, Meralgara and west of Hesapi.

During field seasons 2012-2013 investigation of Iron ore and Manganese in Kotgarh and Lokesai, West Singhbhum District, Jharkhand by GSI reveals occurrence of ferruginous sandstone (FeT % is upto 65.49%) and laterite (FeT % upto 42.80%) developed over the volcanic rock of Jagannathpur Lava and Kolhan Group of rocks i. e. sandstone and shale.

Reconnaissance of Iron ore and Manganese in the rocks of Iron Ore Group and Kolhan Group in parts of Bambasai-Dumurjowa-Mongra block, West Singhbhum District Jharkhand during field seasons 2013-14 in parts of toposheet no 73F/11 and 73F/12 by GSI identified Small isolated, detached outcrops of low grade iron ore mineralization in the form of BHQ, BHJ (enclaves) and laterites with Fe values between 16.62 % to 31.70%. Detrital calsts of jasper, vein quartz, BIFs, haematite quartzite, chert and sub-angular granite clasts observed within the Kolhan conglomerates. The clasts of BIFs and hematite constitute less than 2 to 3% and its average size is also less than 5 centimetres hence such bodies are not potential for low grade iron ore.

The proposed area very close to the juxtaposition of Danguapasi lava and Kolhan Group of rocks and hence the proposed block Jampani-Dulkiburu-Danguaposi in the South Western part of the Toposheet no. 73F/ 12 is likely to have high potential of occurrence of low grade Iron Ore as it lies to east of Noamundi Iron ore mines. As per the NGCM, Fe anomaly is also occurs in the NW part of the Block.**(Plate-03)**

Chapter II

2.1 Regional Geology of the Area:

Precambrian Singhbhum cratonic nucleus of eastern India falls in the states of Jharkhand and Odisha and preserves imprints of several geological cycles spanning from the early Archaean to early Neoproterozoic (Saha 1994). The ancient cratonic block, Singhbhum. Craton or as Singhbhum-Orissa Iron Ore Craton remained a major attraction for geoscientists and miners for the immense potential of this belt in terms of Major mineral deposition such as copper, uranium, iron, manganese, chromites, and limestone amongst others.

The geological knowledge on the Singhbhum region was established through the work of Ball(1881), Dunn(1929), Jones (1934), and Dunn and Dey (1942). Although Ball for-the first time,-mapped the Singhbhum area, the first geological accounts were: published by Dunn:(1929) and Jones (1934). Real stimulus, however, came from Dunn and Dey (1942) who presented a comprehensive stratigraphic account of the region.

The Singhbhum Craton is characterized by Granite-Greenstone belts as well as platformal meta-sedimentary assemblages. According to the workers on Singhbhum geology (Saha 1994, Mukhopadhyay 2001) the three principal components which make up the Archaean nucleus of the Singhbhum Craton (SC), stabilized at about 3000-2700 Ma, are:

1. The Older Metamorphic Group (OMG) of supracrustal rocks and the Older Metamorphic Tonalite Gneiss (OMTG),
2. The Singhbhum Granite massif with various other granitoid-gneissic bodies such as the Bonai Granite, the Nilgiri Granite, the Kaptipada Granite, the Mayurbhanj Granite and the Pallahara Granite Gneiss
3. Greenstone belts comprising of the rocks of the Iron Ore Group (IOG).

4. The OMG supracrustals and OMTG occur as enclaves within the Singhbhum Granite, the Iron Ore Group (IOG) rocks occur surrounding the Singhbhum Granite.

Stratigraphy of the Singhbhum Greenstone-Granite terrain (after Sarkar, S. N. and Saha, 1983, Saha et al. 1988)

Newer Dolerites (1.6 Ga)	
Mayurbhanj Granite (2.1 Ga)	
Gabbro-anorthosite-ultramafics	
Kolhan Group (2.1-2.2 Ga)	
-----Unconformity-----	
Dhanjori Group (c.2.3 Ga)	Jagannathpur lava (Danguaposi lava)
	Dhanjori-Simlipal lava
	Malangtoli lavas
Singhbhum Group(2.3-2.4 Ga)	Dhalbhum Formation
	Chaibasa Formation
-----Unconformity-----	
Singhbhum Granite (Phase III) (3.1 Ga)	
Iron Ore Group (Mafic lava, tuff, acid volcanic, Banded Hematite Jasper and banded quartzite, with iron ore, ferruginous chert, local dolomite quartzitic sandstone)	
-----Unconformity-----	
Singhbhum Granite (Phase I & II) (3.3 Ga)	
-----Unconformity-----	
Older metamorphic tonalite gneiss (c. 3.8Ga)	
Older Metamorphic Group (c.4.0 Ga) (Schists, quartzite, ortho- and para amphibolites)	

(Regional Map attached as **Plate No -02**),

Chapter III

3.1 Remote Sensing Study using ASTER Image

3.1.1 Objective of the study:

The main objective of the present study is identification and mapping of litho structural features and probable mineral prospect areas from satellite image for Jampani-Dulkiburu-Danguaposi Block

The present study is carried out with the following scope:

- 1) Identification of different lithological units at 1:25,000 scale.
- 2) Identification of mineral target areas for Iron Ore.

3.1.2 ASTER Imagery in Mineral Exploration

ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) is an imaging instrument flying on Terra, a satellite launched in December 1999 as part of NASA's Earth Observing System (EOS). ASTER is a cooperative effort between NASA, Japan's Ministry of Economy, Trade and Industry (METI) and Japan's Earth Remote Sensing Data Analysis Center (ERSDAC).

Table 4: ASTER satellite system: sensor characteristics

Launch Date	18 December 1999 at Vandenberg Air Force Base, California, USA
Equator Crossing	10:30 AM (north to south)
Orbit	705 km altitude, sun synchronous
Orbit Inclination	98.3 degrees from the equator
Orbit Period	98.88 minutes
Grounding Track Repeat Cycle	16 days

ASTER provides high-resolution images of the planet Earth in 14 different bands of the electromagnetic spectrum, ranging from visible to thermal infrared light. The three bands of the VNIR (Visible and Near-Infrared) cover the spectral range between 0.52 to 0.79 μm providing a spatial resolution of 15m. In the SWIR (Shortwave Infrared) there are six bands between 1.60 and 2.43 μm with a spatial resolution of 30m. The TIR (Thermal Infrared) has five bands between 8.125 and 11.65 μm and a 90m spatial resolution. Each ASTER scene covers an area of approximately 60 x 60 km (3600 sq.km).

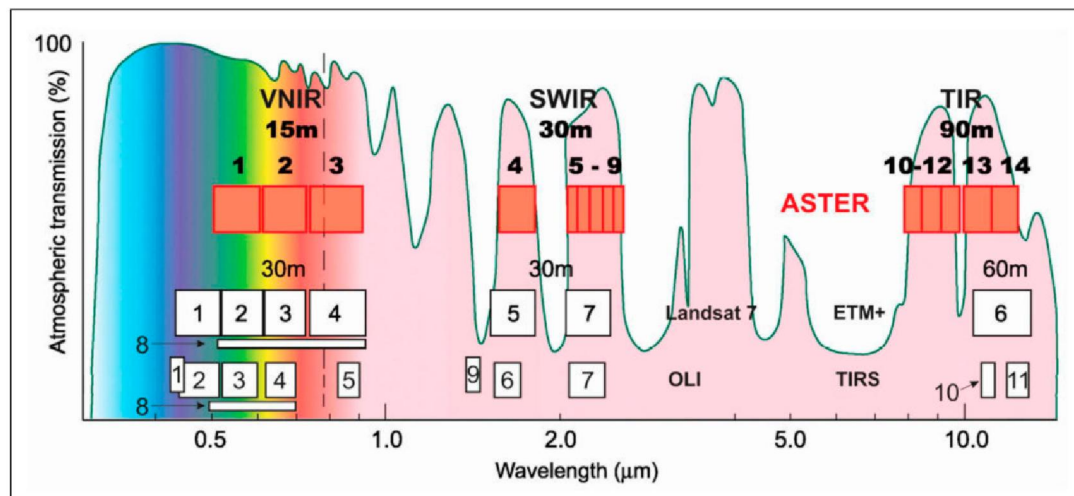


Figure 1: ASTER bands superimposed on model atmosphere

ASTER data are used to create detailed maps of surface temperature of land, emissivity, reflectance, and elevation. The basic tool for geologists in all disciplines is a map depicting the distribution and identity of rock units exposed at the earth's surface. Using these maps, economic geologists search for metal and petroleum deposits; hydro geologists look for ground water; structural geologists classify faults as active or inactive. With its high spatial resolution, and bands covering a wide part of the electromagnetic spectrum, ASTER will provide data that will greatly improve geologists' abilities to produce more accurate geologic maps at a fraction of the cost of conventional ground-based methods.

Table 5: ASTER satellite system: band characteristics

Band	Label	Wavelength (μm)	Resolution (m)	Nadir or Backward	Description
B1	VNIR_Band1	0.520–0.600	15	Nadir	Visible green/yellow
B2	VNIR_Band2	0.630–0.690	15	Nadir	Visible red
B3	VNIR_Band3N	0.760–0.860	15	Nadir	Near infrared
	VNIR_Band3B	0.760–0.860	15	Backward	
B4	SWIR_Band4	1.600–1.700	30	Nadir	Short-wave infrared
B5	SWIR_Band5	2.145–2.185	30	Nadir	
B6	SWIR_Band6	2.185–2.225	30	Nadir	
B7	SWIR_Band7	2.235–2.285	30	Nadir	
B8	SWIR_Band8	2.295–2.365	30	Nadir	
B9	SWIR_Band9	2.360–2.430	30	Nadir	
B10	TIR_Band10	8.125–8.475	90	Nadir	Long-wave infrared or thermal
B11	TIR_Band11	8.475–8.825	90	Nadir	
B12	TIR_Band12	8.925–9.275	90	Nadir	
B13	TIR_Band13	10.250–10.950	90	Nadir	
B14	TIR_Band14	10.950–11.650	90	Nadir	

3.1.3 Image source and specification

ASTER Scene Selection: Jampani-Dulkiburu-Danguaposi block is covered by one ASTER scene and is selected considering cloud free and where possible, from the local dry season such that the effect of vegetation could be reduced. ASTER B1 data is obtained for the study which comprises registered radiance at the sensor, the Level 1A

radiometric and geometric coefficients were applied to the data during pre-processing stage.

Table 6: ASTER Level 1B scene characteristics

Granule ID	Latitude	Longitude	Scene Cloud	Day/Night
ASTB190325050125	North Bounding Rectangle= 22.230329; South Bounding Rectangle= 21.587704	West Bounding Rectangle= 85.207788; East Bounding Rectangle= 85.930319;	0%	Day

3.1.4. Software used:

The ASTER image Pre Processing, processing were conducted using QGIS software.

3.1.5 Pre-processing

Conversion to reflectance: The VNIR and SWIR bands were “stacked” into a single file at 15m resolution. The stacked file was clipped to the required extent. Further atmospheric correction was also attempted.

3.1.6 Enhanced color composite

Color Composite Image of Bands 7-3-1: This image uses both the SWIR and VNIR to produce an emulation of the of the classic Landsat Thematic Mapper “741” stretch,

which combines high-resolution VNIR data with SWIR geologic information (Figure 2). This image is a pseudo-true color image, with green representing vegetation, and shades of white-brown black representing similar lithological variations that the eye would perceive.

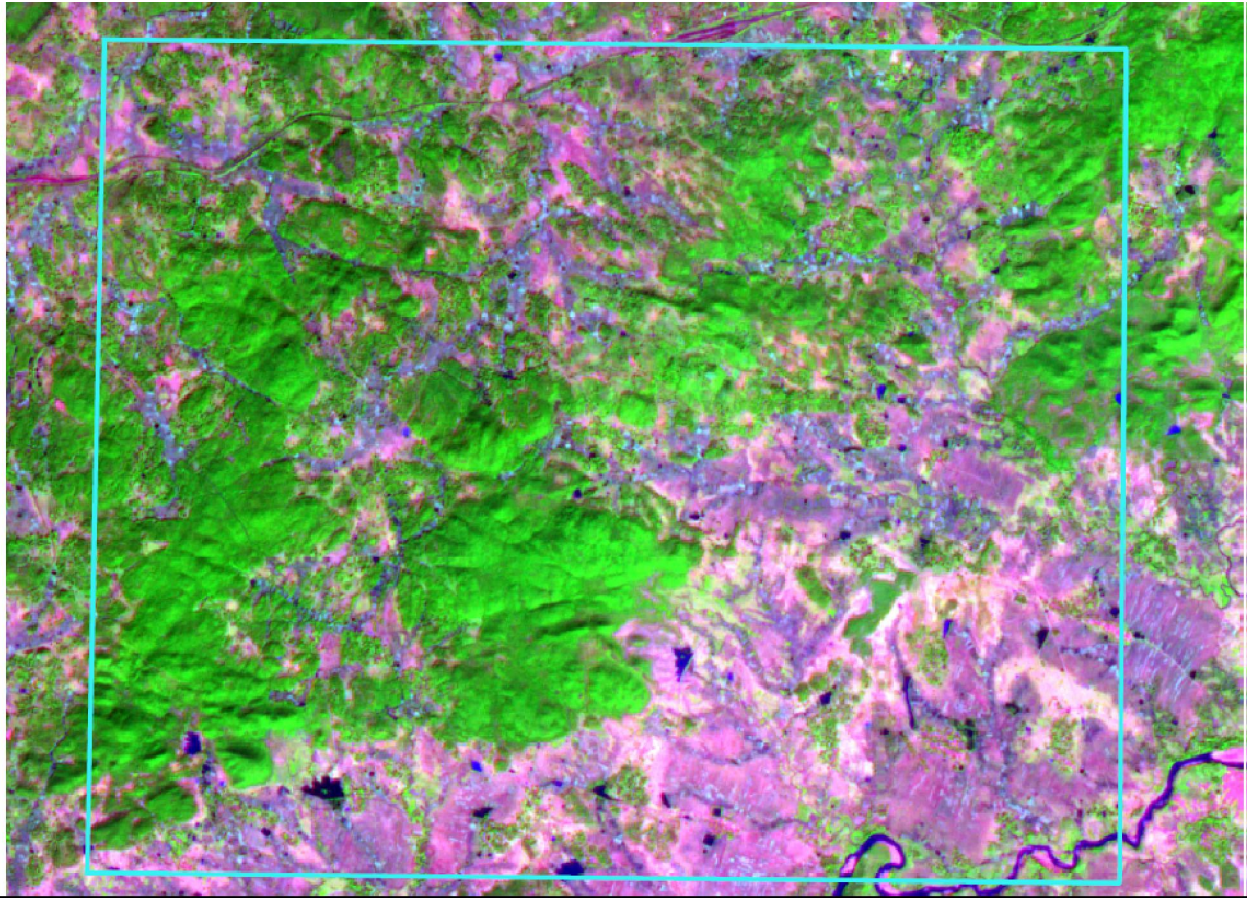


Figure 2: RGB color composite of Bands7, 3, & 1 of the ASTER scene

Color Composite Image of Bands 2-3-1: This image uses data exclusively from ASTER's visual infrared (VNIR) sensor, and therefore has the highest resolution (15m) of the image suite. This image is a true color image, with dark green representing vegetation, and shades of white-brown black representing similar lithological variations that the eye would perceive.

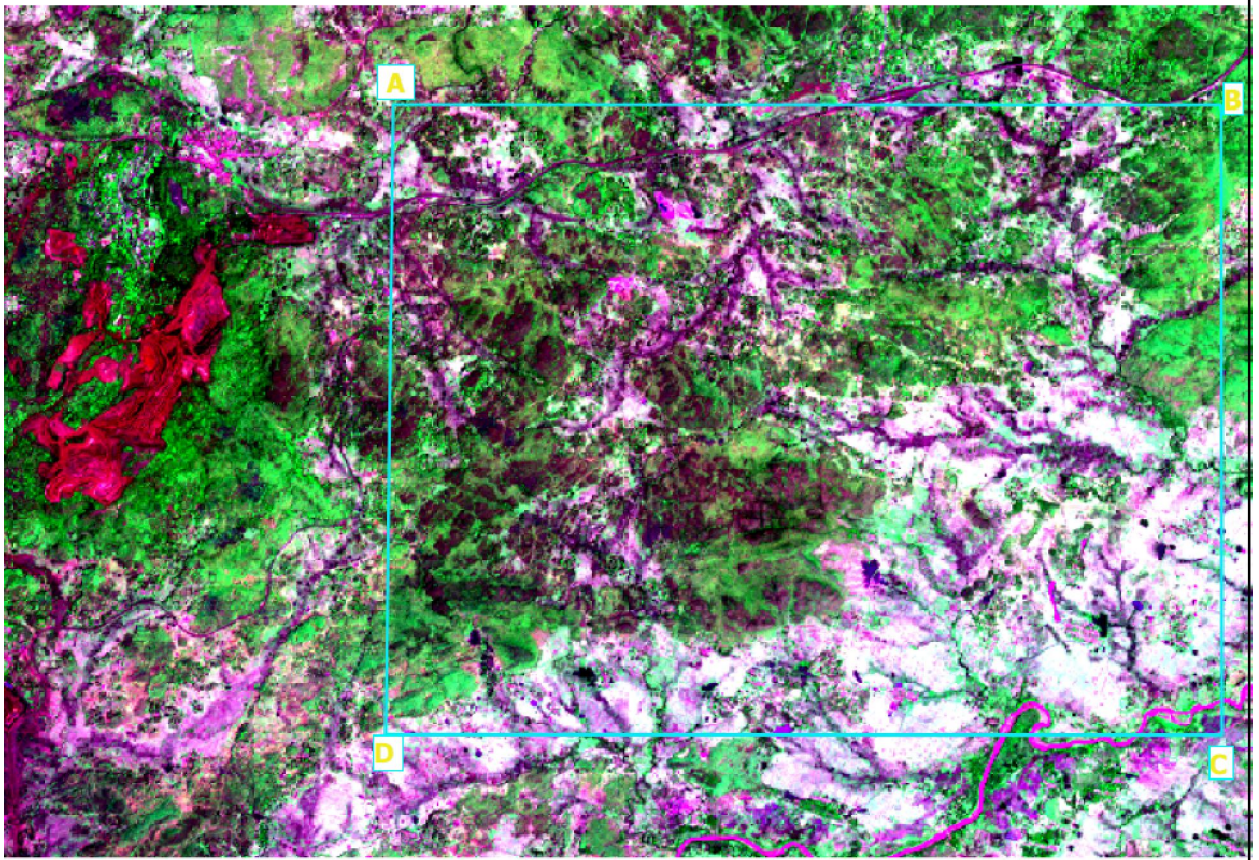


Figure 3: RGB color composite of Bands 2, 3, & 1 of the ASTER scene

Color Composite Image of Bands 3-2-1: This image uses data exclusively from ASTER's visual and near-infrared (VNIR) sensor, and therefore has the highest resolution (15m) of the image suite. This image is a false color image, with red representing vegetation, and shades of dark gray to black representing volcanic rocks and white representing clay mineral zones (Figure 3).

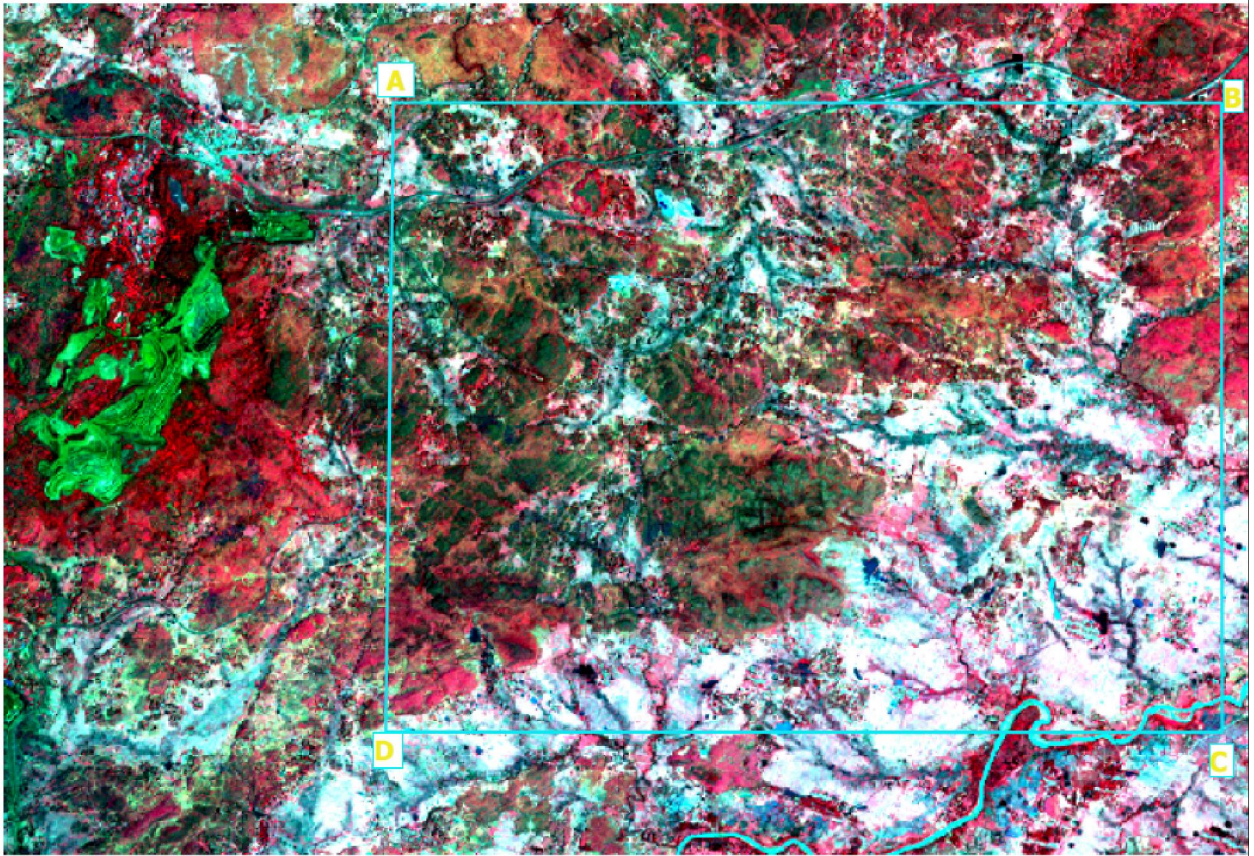


Figure 4: False color composite of Bands 3, 2, & 1 of the study area

3.1.7 Digital Elevation Model (DEM):

Digital elevation model (DEM) is a digital representation of the topographical surface. Ministry of Economy, Trade, and Industry (METI) of Japan and the United States National Aeronautics and Space Administration (NASA) have launched Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model Version 2 (GDEM V2) on October 17, 2011. Aster DEM has been used in current study for visual interpretation. In order to investigate the geological and structural feature of the study area from ASTER GDEM 30 meter resolution data, thematic map includes elevation, aspect, slope and shaded relief have been used. The illustration of DEM image has given in Figure No.-5

Remote Sensing Image of Jampani-Dulkiburu-Danguaposi (Digital Elevation)

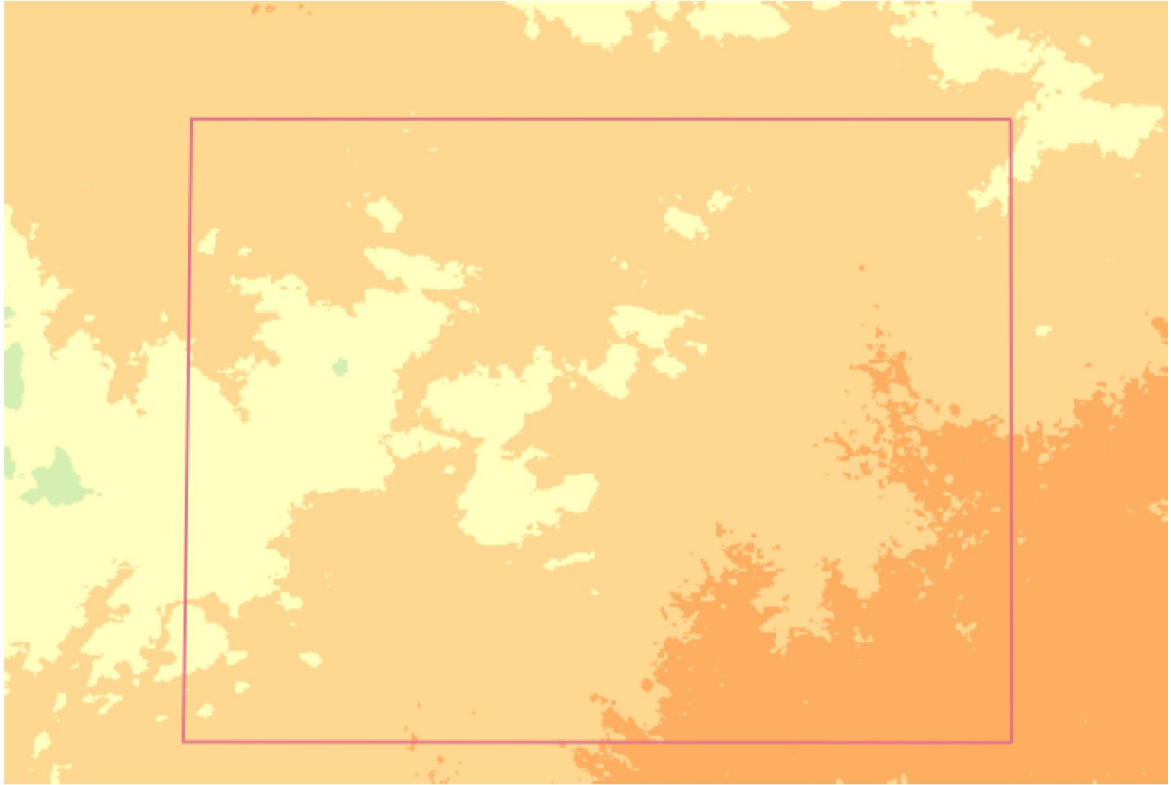


Figure 5: DEM Map of the Block

3.1.8 Principal Component Analysis – PCA

Principal components transformation is an image enhancement technique for displaying the maximum contrast from several spectral bands with just three primary display colors, (Vincent, 1997). Multispectral images often have similar visual appearance for different bands, thus causing data redundancy (high correlation of spectral bands). PCA is a multivariate statistical technique used to reduce this data redundancy by transforming the original data onto new orthogonal principal component axes producing an uncorrelated image, which has much higher contrast than the original bands. In this study, PCA was performed on ASTER data covering the 9 wavelength bands (VNIR and SWIR). For lithologic discrimination and the color composite created from the PC images gives valuable geological information. PC 1, with high variance and positive loading from all ASTER bands, contains significant albedo and topographic information and that accounts for high correlation between the input bands. PC2, PC3 PC4 and PC-6 display

fair lithologic contrast and the rest of the PC (PC1, PC5 PC7 to PC9) show strips and noisy images and appear to be less informative Eigen Value of the PCA also states supports the same. The details of the Eigen Vectors are as bellow:

Table 7: Eigen Vectors

Eigen vectors									
Bands	Vector_1	Vector_2	Vector_3	Vector_4	Vector_5	Vector_6	Vector_7	Vector_8	Vector_9
1	-0.13514	0.598719	0.075368	-0.78587	5.62E-17	5.73E-33	-1.46E-49	1.47E-33	-3.95E-17
2	-0.10599	0.694008	0.404929	0.585792	-9.92E-17	3.25E-17	4.78E-51	-3.25E-17	9.87E-17
3	-0.12603	0.344757	-0.90906	0.197143	2.40E-16	4.33E-18	-5.86E-18	-8.25E-18	-4.81E-17
4	-0.39888	-0.0827	0.025682	0.008051	-0.8789	6.97E-17	1.19E-16	6.83E-17	-0.24673
5	-0.39888	-0.0827	0.025682	0.008051	0.077088	0.816452	-7.53E-17	-0.00858	0.400904
6	-0.39888	-0.0827	0.025682	0.008051	0.077088	-0.41565	1.23E-16	-0.70278	0.400904
7	-0.39888	-0.0827	0.025682	0.008051	0.077088	-0.4008	-4.32E-17	0.711357	0.400904
8	-0.39888	-0.0827	0.025682	0.008051	0.323816	-2.82E-17	-0.70711	8.41E-17	-0.47799
9	-0.39888	-0.0827	0.025682	0.008051	0.323816	-2.82E-17	0.707107	-2.69E-17	-0.47799

Table 8: PCA Eigen Cumulative Details

	Eigen values	Accounted variance	Cumulative variance
1	15647.56834	97.57217	97.57217
2	313.5270258	1.955033	99.5272
3	68.21750259	0.425378	99.95258
4	7.604949291	0.047422	100
5	1.66E-14	1.04E-16	100
6	1.22E-30	7.59E-33	100
7	3.13E-48	1.95E-50	100
8	-1.17E-31	-7.30E-34	100
9	-1.68E-15	-1.05E-17	100

From the above it can be appreciated that vector PC- 1 is albedo effect, 4, 3, 2 are having more prominence over the other Eigen vectors. Hence the same has been utilized and analysed.

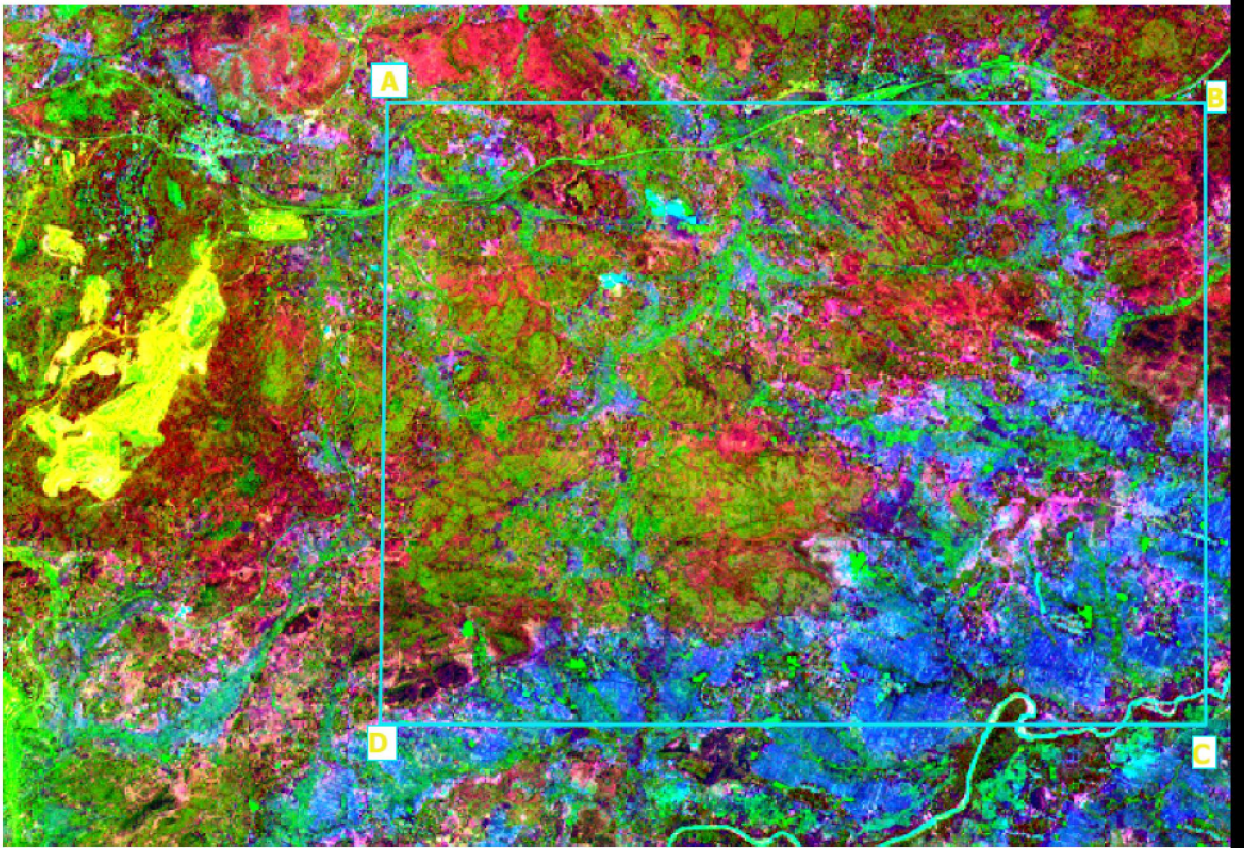


Figure 6: RGB color composite of PCA 4, 3 & 2 of the study area

As per the Interpretation it can be appreciated that, yellow color implies Iron ore, Sky blue implies the hydrous mineral, green implies vegetation, deep Red & dark purple with pink implies Iron ore group of rock & light red color implies basaltic rock.

3.1.9 Band Ratio

This procedure involves the division of two bands, where the band with high reflectance features of the given material is assigned as numerator, while the other band with high absorption feature for the same material is assigned as denominator. Rationing can be thought as a method of enhancing minor difference between materials by defining the slope of the spectral curve between two bands. The resultant gray-scale band ratio image is not a direct measurement for the material's contents, rather it mark the area with highest possibilities for the presence of the given material. The combination of three-band ratio image as red-green-blue (RGB) image is useful

for the interpretation of the result. Ratio images have been used in many geological investigations to recognize and map areas of Iron ore mineral (Aref Shirazi 2018).

In this study a ratio image is mainly prepared for iron oxide mapping where iron oxide in pink, green to pale blue indicates vegetation, and greenish Orange indicates Clay minerals.

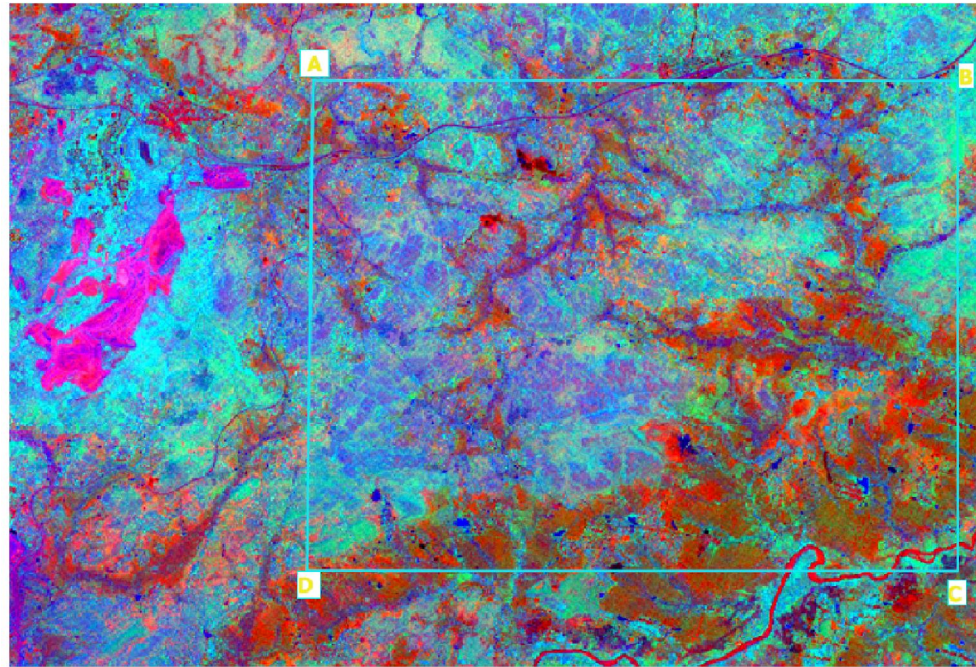


Figure 7: Map of iron ratio image of the study area

3.1.10 Conclusion:

To appreciate the lithological difference, compared to Band Ratio map Principle Component Analysis is better suited and with the help of the same.

The principle component Analysis as well as Band Ratio map also corroborates that three major lithology available they are viz.

- Basalt in the NW & Central Part of the block,
- Clayey mineral in Southern & South Eastern Part of the block and
- Iron ore group of rocks in South West Side & North Eastern part of the block

There is no major Iron ore occurrence is observable in the block.

Chapter-IV

4.1 Geology of the Block:

The Jampani-Dulkiburu-Danguaposi block is located to the East of Bonai synclitorium's Eastern limb (in the extreme North Eastern part of the limb). Systematic Geological mapping in 1:12500 Scale was carried out in the block during Financial Year 2018-19. The aim has of detailed mapping is to identify iron/ Manganese ore body (BHJ/BHQ) (if any) in the block.

Systematic Geological mapping in 1:12500 Scale was carried out in the block during Financial Year 2018-19. The aim of geological mapping was to undertake regional mapping of the block to identify iron/ Manganese ore body (BHJ/BHQ) (if any) in the block.

During mapping following lithologies were demarcated

- I. The block is mostly covered by (basaltic lava) Danguaposi lava corelatable with Jagannathpur lava excepting Southern & South Eastern part of the block.
- II. In Southern & South Eastern part of the block is covered by metapelite & the Quartzo feldspathic gneiss is occurring as patches within the metapelite. Metapelite & Gneiss is corelatable with Older Metamorphic. The metapelite is unconformably overlain by basalt.

Both basalt and metapelite are the most dominant lithology observed in the block apart from these two lithologies following lithologies are also observed in the block:

- III. Ferruginous Shale/banded chert (sometimes grades to BIF) corelatable to the iron Ore Group of rocks is occurring either 'as sandwich between Metapelite and basalt' or 'as outliers within the basalt'. The iron ore group is unconformably overlain by basalt and unconformably underlain by metapelite.

- IV. All the 3 major lithologies, basalt, Metapelite and Iron ore group have been intruded by Quartz.
- V. Apart from the quartz reef, Dolerite dyke is the other intrusion observable in the block. Dolerite has intruded in Metapelite and Basalt only. It is inferred that, dolerite dyke intrusion may be post to the quartz reef.
- VI. Unconformable to the basalt, Metapelite and quartz reef, Iron clast/ground mass bearing conglomerate/sandstone has been deposited.
- VII. With weathering of ferruginous sandstone of Iron ore group and basalt, lateritic soil has formed. And with weathering of basalt & metapelite clay has formed.

Stratigraphic succession of the block, West Singhbhum District, Jharkhand.

Laterite

Dolerite

Conglomerate (with hematite clast/matrix)

Quartz Reef??

-----Unconformity-----

Jagannathpur lava (Danguaposi lava)

-----Unconformity-----

Iron Ore Group

(Tuff (ferruginous Shale), banded ferruginous chert, Banded Iron Formation, Ferruginous quartzite, sandstone.)

-----Unconformity-----

Older Metamorphic

(Schists, quartzite)

The Geological map of the block is attached in the **Plate-04**

4.2 Detailed description of Lithologies:

4.2.1 Older metamorphic Rocks:

Older metamorphic rocks in this block comprises of Metapelite & quartzofeldspathic gneiss.

4.2.1.1 Metapelites:

In the southern & South Eastern part of the mapped area identified metapelitic Schist lithology comprising of minerals quartz, muscovite, garnet & biotite. The metapelitic schist has with intermittent quartz veins parallel to the foliation plane. Folding in metapelite could be inferred from the rolling of strike. The Metapelite is highly weathered and are converted to clay. The impression of metapelite converting to clay has been observed in the all over the Southern and South Eastern part of the Block.



Figure 8: Surface exposure of Metapelites

4.2.1.2 Quartzo Feldspathic Gneiss:

Gneissic rock exposures are observed as pockets in the metapellitic rock zones. Such gneissic rock did not show any greater continuity. The Gneissic layers are having segregation of quartz and feldspathic layers only. In certain gneissic outcrop mineral lineation are also observed.



Figure 9: Sectional View of Quartzo Feldspathic Gneiss

4.2.2 Iron Ore Group of Rock:

Iron Ore Group of Rock comprises of Ferruginous Sandstone, Ferruginous Shale, Banded Chert, and BIF among these rocks, Ferruginous Sandstone is only mappable as individual lithology. All the other lithologies Ferruginous Shale, Banded chert, BIF occur in such a fashion that they cannot be mapped separately.

4.2.2.1 Ferruginous Sandstone

Ferruginous sandstone, the subhedral to anhedral quartz mineral grains are an important detrital constituent and its typical granularity can be easily recognized by the naked eye. These are dirty yellow to buff colored, hard, indurated rock. This lithounit

has been found in the North Western part the mapped area near Rangarbera reserve Forest. The trend of the rock unit is NNW-SSE with moderate dip. The Ferruginous Sandstone at places show a cross bedding pattern.

Under thin section studies the rock shows the abundance of subhedral to anhedral detrital quartz minerals (95%). The sandstone as a whole is moderate to well sorted, mature rock bounded by siliceous as well as ferruginous cement. Petrographically, the rock shows quartz as the most abundant detrital silicate. Quartz grains are subangular, subrounded to rounded in shape and shows undulose extinction and monocrystalline grains showing irregular fractures and concave grain boundary. However, the presence to a few chert grains have been noticed but there is complete absence of platy minerals like muscovite, chlorite.



Figure 10: Surface exposure of (old quarry exposure) of Ferruginous Sandstone



Figure 11: Ferruginous Sandstone with Cross bedding

4.2.2.2 Ferruginous Shale/ Banded Chert / Banded Iron Jasper (BIF group of rocks)

Among Ferruginous shales, Banded Cherty Quartzite, Banded Iron Jasper Ferruginous shale forms major portion compared to jasper rich quartzite. Banded iron jasper occurrence is very less concentration as pockets only. BIF group of rocks are mostly observed in the contact zone of Metapelite and basalt as sandwich apart from them, the BIF group of rocks are observed as outlier in Basalt and inliers in metapelitic area.

The, banded iron jasper bands consist of Jasper and hematite. The thickness of the jasper bands varies from a few mm to a few cm where as the thickness of the hematite bands is in few mm only and is steel grey in colour with cherry red to brownish streak and metallic luster. The jasper bands are fine grained and vermilion red in colour. In the entire mapped area there is no mappable BHJ is observed.

The Fe% in BIF group of varies from 8.39 % to 46.22%. However, Hematite floats (rolled pieces) occurring within BIF group shows high Fe% of 64%, 54% & 52.14%.

In Banded Hematite Jasper only have Fe% more than 45% (threshold value), this lithology is not in mappable scale (Annexure-I)

In the BIF Group of Rocks, Manganese (pyrolusite) is noted as vein intrusion, possibly as replacement minerals in vugs formed in Ferruginous Shale. In 5 samples Mn% is noted to be positive in nature & the same varies from 15.56 % to 44.37%. Of the 5 samples, only one sample is collected from insitu rock, whose value is 15.56%. All the remaining samples are collected as floats whose source rock could not be traced.



Figure 12: Ferruginous Shale with limonitisation



Figure 13: Banded Chert



Figure 14: Banded Hematite Jasper



Figure 15: Occurrence of Manganese as vug filling in shale

4.2.3 Amygdaloidal Basalt (Danguaposi Lava):

Amygdaloidal basalt occupies a major part of area mapped in the Northern/central/north western part of the mapped area and is correlated as Jagannathpur lava. The rock is massive, fine grained and is characterised by absence of foliation. Fine-grained rock show conchoidal fracture. Amygdules in the volcanic rocks are found to be of various shapes and sizes. The sub-spherical to spherical shaped amygdules commonly range in size from 2 mm to 2.5 cm in diameter. Occasionally, they are as small as 0.5 mm in diameter and very rarely as large as 4 cm in diameter.

These amygdales are mainly filled with secondary quartz and chert, Two distinct sets of joints ($N20^{\circ}-30^{\circ}E$ -- $S20^{\circ}-30^{\circ}W$ & $N70^{\circ}-80^{\circ}W$ — $S70^{\circ}-80^{\circ}E$) with vertical dips have been identified. In this unit, laterite capping is found to be developed and occur at certain places where the elevation is less. The color of the litho unit varies from yellowish earthy brown, greenish. At certain places columnar basalt are also preserved.

Basaltic rock is being mined in this block near Padapahar and Kuidasai Villages (South of Rail Line)



Figure 16: Amygdaloidal basalt



Figure 17: Stone Quarry for Road metal in Amygdaloidal basalt

4.2.4 Quartz Reef:

Quartz reef is observed in the basaltic rock, Metapelite and Banded Iron Ore Group. These quartz reefs are located in the Daubera PF, neighbourhood of Gutusai, Gitilipi, kurasai, Grdiasai, Jhorpai, Baliyagora villages. Most of the quartz reefs mapped are having 30 m thick, at places; these are upto 500 meters long and 100 meters wide. These reefs are composed of white, brown to grey vitreous quartz. At places, quartz occurs as crystalline aggregates. In Dubera RF, quartz reef formed veridical cliff having elevation difference of 80m and in Bongaburu there is difference in elevation of more than 100m.



Figure 18: Quartz reef with other secondary/syn deformational veins



Figure 19: Milky white Quartz reef, near Durita village



Figure 20: Milky white Quartz reef, near Durita village

4.2.5 Dolerite Dyke:

A few dolerite dykes have been noticed at places in the eastern & South Eastern portion of the mapped area i.e. at south east near Ram Tirath, Sialjora, Gitilipi, and Kurasi. villages. These dykes trending NW-SE are found to be intrusive into the Metapelite. These are dark green in colour, very hard, compact massive rock and show the presence of stout prismatic ferromagnesian crystals. Strike lengths of the bodies vary from tens of meters to 500 meters with width ranging from 25 meters to 100 meters.

4.2.6 Conglomerate:

Conglomeratic rock is formed unconformably over the Basalt, Quartzite & Older metamorphic group of rocks. These sedimentary rocks are observed in NW & Southern part of the block and are in mappable scale only in 2 places they are viz over the basalt and Older Metamorphic/basalt contact. Conglomerate occurring in quartz reef it is not in mappable scale.

Conglomerate clast in general comprises of two mineral viz. Hematite/BIF, Quartz, hence can be coined as polymictic Conglomerate. Clasts are mostly round edged in nature, matrix supported & are having cross bedding was also observable implying that the conglomerate might have formed in fluvial environment.

Due to presence of clasts of Hematite/BIF, two samples of the conglomerate was analysed for Iron ore whose Fe% is 61.12% & 35.95%. The high Fe% of 61.12% sample was collected from conglomerate occurring in Quartz reef.



Figure 21: Conglomerate in Quartz reef



Figure 22: Conglomerate with bedding and cross bedding



Figure 23: Conglomerate in Southern part of the block

4.2.7 Lateritic Soil:

Lateritic soil is observed on the top and slopes of the small hillocks of Jagannathpur lava & ferruginous sand stone. The colour of the lithounit varies from reddish to earthy brown. The fragments of haematite are rare and in areas it is randomly oriented and size varies from pebble to silt size. At places it also shows massive character.



Figure 24: Lateritic Soil near Padampahar Station

Chapter-V

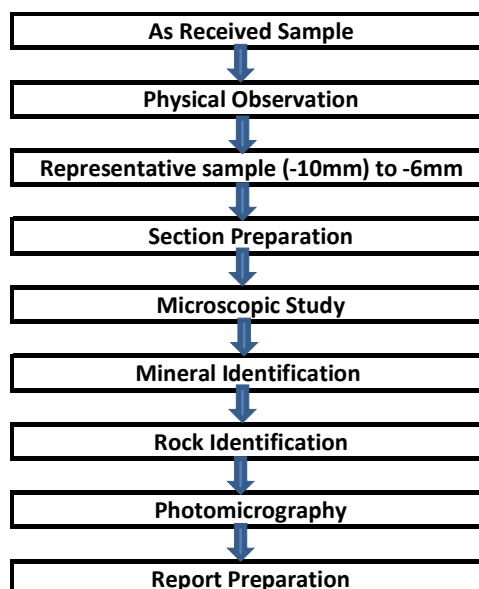
5.1 Petrographic Study of Rock Samples

5.1.1 Introduction

Mineralogy Lab. Of NMDC Hyderabad had received 06 number of rock samples from Investigation division (HO) for Petrological studies, mainly for rock identification. These samples were collected from Jampani, Jharkhand. These samples needed to be prepared proper petrological thin sections and to be studied under the polarizing microscope. Based on the samples received, representative sub samples have been taken and thin sections have been prepared by using STRUERS make complete sample preparation unit and these sections were studied under the LEICA petrological microscope, MEIJI Stereo Zoom Microscope and few samples were also studied under the TESCAN make SCANNING ELECTRON MICROSCOPE. These samples were studied as per following test plan-

5.1.2 Test Plan

The plan for above mentioned samples for petrological studies is as follows-



5.1.3 Microscopic Observation and Rock Identification Based On Minerals Observed

The 'as received' samples were studied as per above mentioned test plan. The physical studies were done on all samples and were crosschecked with the Microscopic Observation's Outcome as well.

a) Basalt [Jampani-P9]

This sample shows minerals Augite, Plagioclase (mainly Labradorite) and Olivine with variable shapes and sizes of particles with porphyritic texture. Mineral grains are as coarse as 800 microns to as small as 50 microns (Sample no. Jampani-P9, Fig. 25) but most of the grains variable sizes. Based on the physical and microscopic observation, the rock identified as Basalt.

b) Quartzite [Jampani-P10]

This sample shows only one mineral i.e. Quartz. This quartz also shows highly compactness in nature as compared to Quartz and sand stone with deformational effect under the microscope. Based on the physical and optical properties of mineral observed, the rock identified as Quartzite. The grain size and shape vary from coarse to fine as 2000 microns to 200 microns with granulose texture (Sample no. Jampani-P10, Fig. 26).

c) Dolerite [Jam-72]

This sample shows minerals Augite, Plagioclase and Olivine with variable shapes and sizes of particles with ophitic texture. Mineral grains are as coarse as 1000 microns but majority of grains are in 350 to as small as 50 microns (Sample no.-Jam-72, Fig.27,) but most of the grains are variable in sizes. Jam-72 shows coarse to medium shapes grains with ophitic texture. Based on the minerals and texture observed in the sample, the rocks identified as Dolerite.

d) Gabbro [Jam Dc-43]

The sample received was physically shows mesocratic appearance, coarse to fine grain particles with some mesobands of leucocratic minerals which was confirmed as Bytownite microscopically. Apart from these, dominant dark colored minerals observed which were confirmed as Pyroxenes (Augite) and olivine. Most of the grains are in less than 500 micron and shows phaneritic texture. Based on the minerals and texture observed in the sample, the rock identified as Gabbro (Fig. 29).

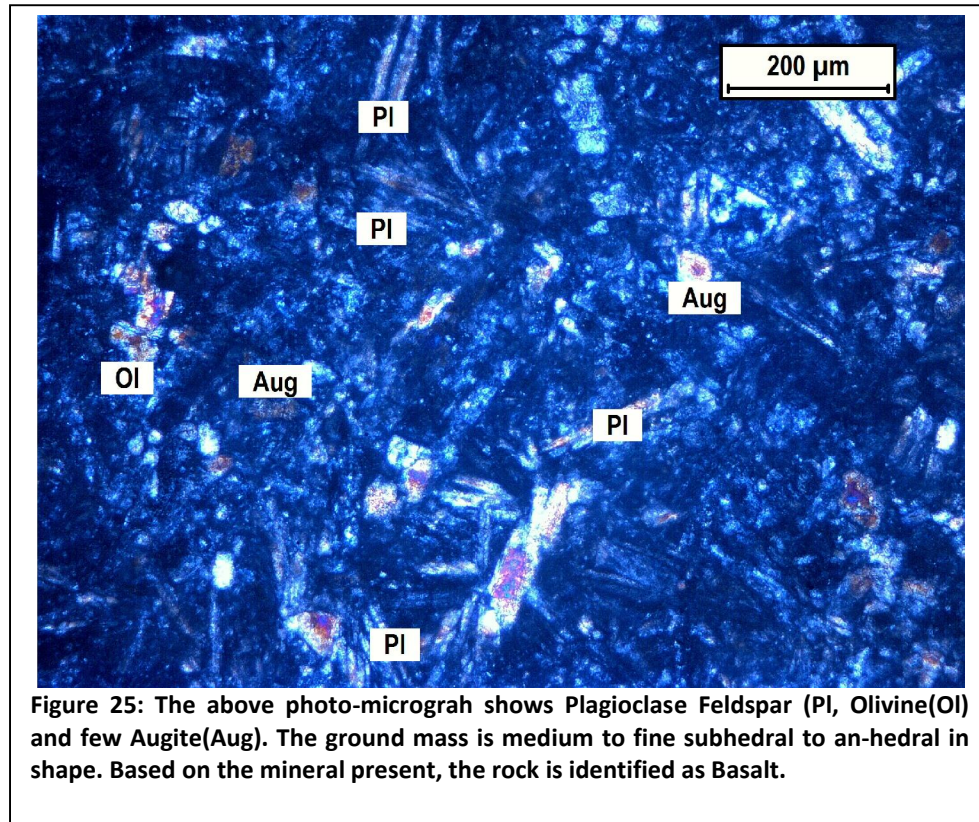
e) Quartzo Feldspathic Gneiss [Jam-209]

This sample shows presence of mainly Biotite, Feldspar (Anorthite) & Quartz. Apart from these, few opaque grains of iron oxides also observed. Detailed microscopic study reveals that the grain size varies from medium to small in size with gneissose texture in size where coarser particles are as big as 500 micron and small particles are as small as 50 microns in size. Based on the minerals and texture observed in the sample, the rock identified as Quartzo Feldspathic Gneiss (Fig. 28).

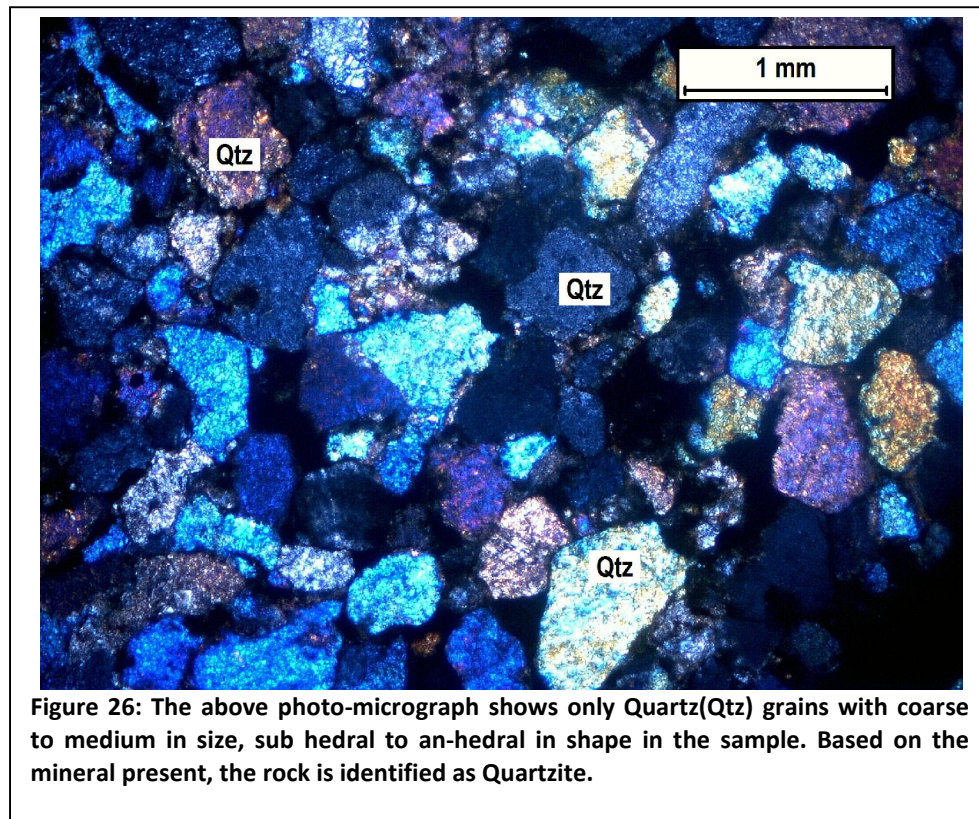
f) Quartzite [Jam-451]

This sample shows only minerals present is Quartz without any foliation. Grain size varying from 2mm to 500 micron with granulose. Some part of the sample also indicates about pink quartz grains presence. Owing to which, microscopically sample looks as pink Quartz. Based on the mineral present in the sample, the rock identified as Quartzite (Fig. 30).

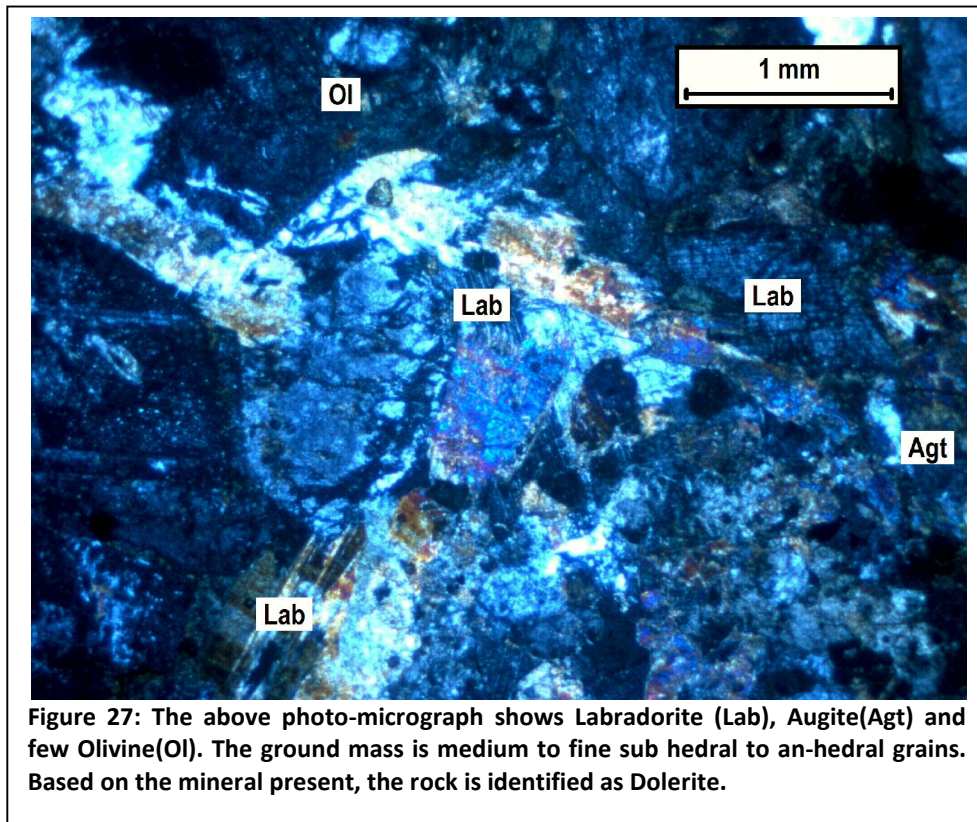
1. Sample No.-JAMPANI-P9



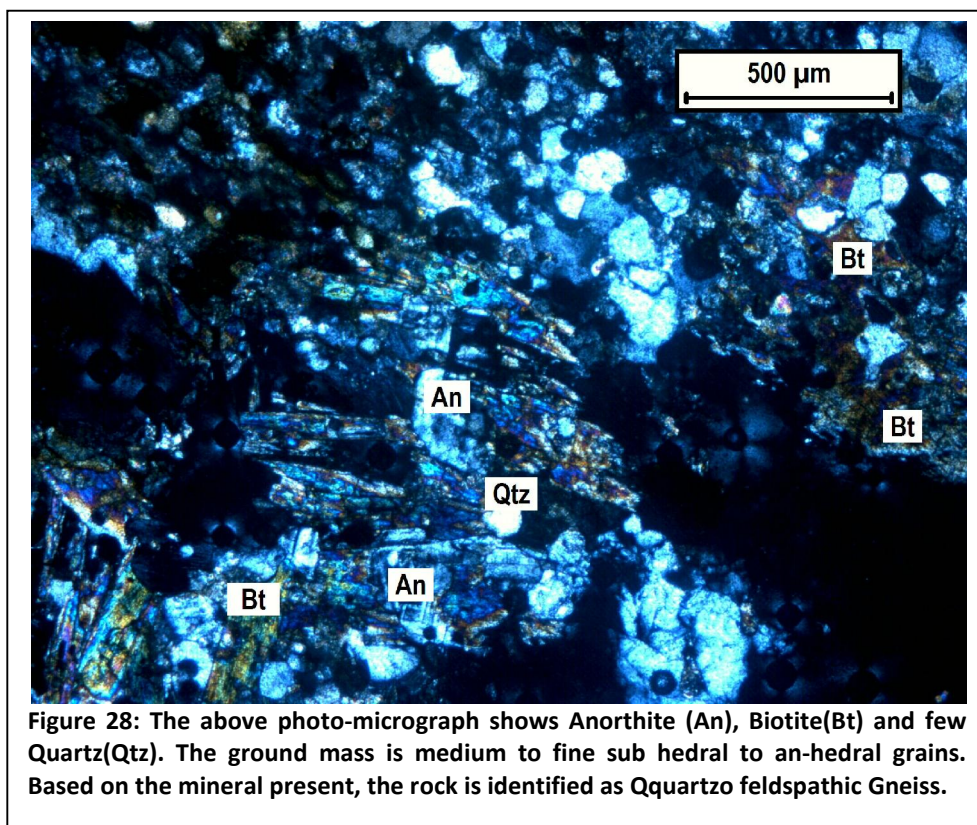
2. Sample No.JAMPANI-P10



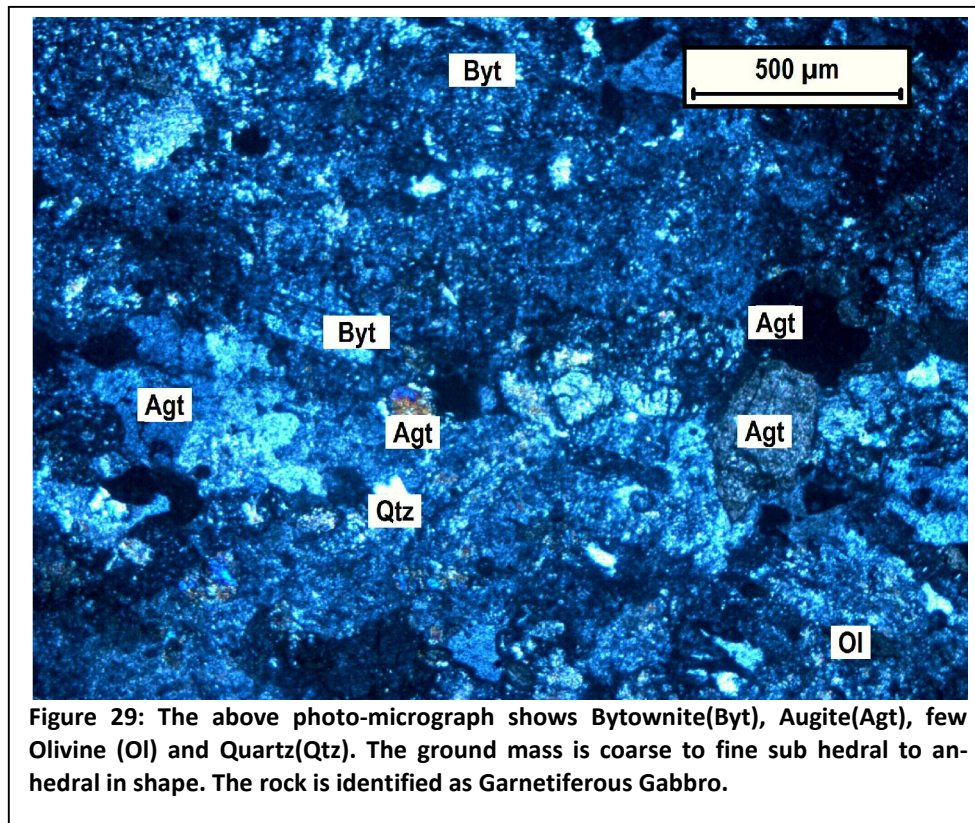
3. Sample No.-JAM-72



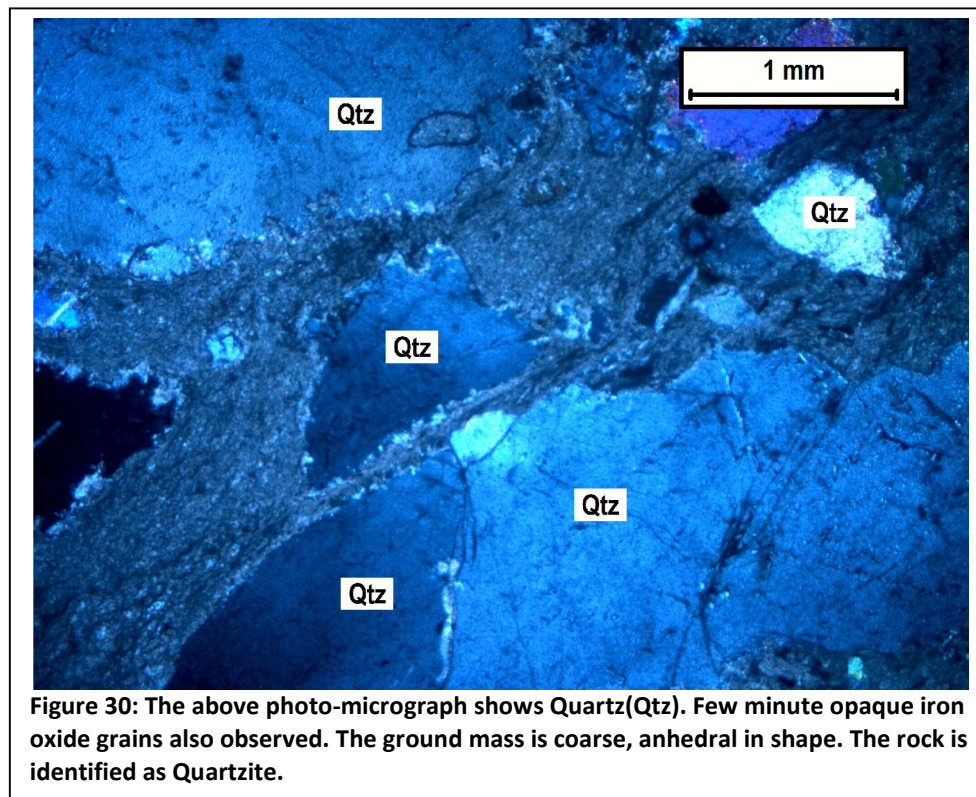
4. Sample No. JAM-209



5. Sample No.-JAM-DC-43



6. Sample No.JAM-451



Chapter-VI

6.1 Quantum of work

Table 9 Details and nature and quantum of work proposed vs. achievement

Sl. No.	Item of work	Unit	Proposed Quantum of Work	Achieved
1	Literature survey	lump sum	Undertaken	
2	Remote Sensing for Mineral Targeting & Structural Mapping	Scene	1 scene study in 100 Sq. km area	Undertaken using Aster Data
	LISS IV- (5.8 mtrs resolution)	Scene	1 scene	
	Cartosat-2 (1 mtr resolution)	Scene	3 Scene	
3	Topographical Survey (on 1: 12,500 Scale)	Sq. Km	100	Not Undertaken
	Fixation of Four Coordinate Points by DGPS	Nos.	4 nos	NA
	Bore Hole Fixation (Scout Boreholes)	Nos	5 Nos	NA
	RL & Coordinate Determination	Nos	5 N0s	NA
4	Geological Mapping (on 1:12,500 Scale)	Sq. Km	100 sq.km	100 Sq. Km.
5	Geophysical Survey			
	a)Magnetic	Line Km	30	Not advised
6	Surface Sampling			
	a) Grab/ Chip samples	N0s.	80Nos	39
	b) Pit samples	Nos.	10Nos.	Not advised
	c) Trenching samples	Nos.	10Nos.	Not advised
7	Test hole Drilling: (if required)	m	250 (5 Bhs)	Not under taken
	Geological work			
	a) Geological Core Logging & Supervision charges	m	250	Not undertaken
8	Laboratory Studies			
	i) Surface Sampling (Primary samples)	Nos.	100	33

Sl. No.	Item of work	Unit	Proposed Quantum of Work	Achieved
	ii) Drill Core Primary & Check Samples	Nos.	250	NU
	* For 6 radicals viz FeO, Al ₂ O ₃ , SiO ₂ , LoI, P, S			Undertaken for Mn also
	a) Preparation of Thin Section	Nos	10	6
9	b) Study of Thin Section & Mineralogical studies	Nos	10	6

Chapter-VII

7.1 Exploration Methodology

7.1.1 Geological Mapping:

7.1.1.1 Procedure:

The geological mapping was carried out by close traversing in scale of 1:12,500 with the help of GPS and Brunton Compass. The surfaces out crops were measured along the vertical exposed sections and their lateral extension. Dip and strike of different plane in the out crop of different lithologies measured

7.1.1.2 Equipment:

G.P.S. (Global positioning system), Brunton compass, Geological Hammer, pocket lens

7.1.2 Sampling/Chemical Analysis:

During geological mapping, 41 grab samples were collected. Out of 41 nos of samples, 35 nos of samples have been analyzed at R&D centre, NMDC Hyderabad for chemical analysis and remaining for thin section for petrographic studies. Samples for chemical analysis are labeled as Jampani- P 23 and 06/JP/24/1018. All samples were analyzed in such radicals Fe%, SiO₂, Al₂O₃, LOI, P, S, MnO. 33 nos of samples are showing Fe% is varying from 4.56%.to 54.00% Fe, except two sample which were analyzed 61.12% and 64 00% Fe respectively. For Microscopic study samples are labeled as Jampani- -P 9 ,P 10, 01/JP/29/10/18 to 04/JP/29/10/18. The Microscopic study has been carried out in 6 nos of rock samples.

7.1.3 Sample preparation and analysis:

All samples are grounded to -100# size and will be made into two parts and one representative samples were sent to Chemical Lab of NMDC R & D Centre, Hyderabad for chemical analysis for determine the Fe, SiO₂, Al₂O₃, P, LOI & Mn. In these samples, Iron is determined by edox titration method, using potassium dichromate as primary

standard, Si using gravimetric method, LOI using thermo gravimetric Analyzer, Al₂O₃, P & Mn using Inductive Coupled plasma Spectrometer. Result of the the chemical analysis are attached as Annexure.

For Microscopic study, thin sections of all samples were prepared by using STRUERS make and these sections were studied under the LEICA petrological microscope, MEIJI Stereo Zoom Microscope and few samples were also studied under the TESCAN make SCANNING ELECTRON MICROSCOPE. A detail chemical analysis study report is enclosed as **Annexure-I**

Chapter-VIII

8.1 Conclusion & Recommendations:

8.1.1 Conclusion:

- Based on the remote sensing studies, Principle Component Analysis and Band Ratio Imaging, Could segregate 3 major lithologies viz, basalt, ferruginous Shale/chert band/BIF and the Metapellitic terrain.
- During the course of mapping, No Iron/Manganese ore enrichment areas have been noticed in the block.
- The chemical analysis of rock samples show Fe % ranging from 8.39% to 54% with majority of the samples falling less than 45%. The rock samples where the Fe% are higher than 45% is of BIF rock, but the BIF are not in the mappable scale.
- In conglomerate rocks, either 'the chemical analysis values of Fe% & Mn % are not encouraging' or 'the continuity of conglomerate is not there'. Further the hematite % in conglomeritic Clast is less. Hence, conglomerate could not be considered for exploration.
- Laterite soil due to its association with basalt and ferruginous sandstone and Basalt, it is inferred that the laterite would be below the sub-grade ore category.
- The persistence of ore & chemical analytical data of Manganese data are also not encouraging

8.1.2 Recommendation:

The G-4 stage exploration have been carried out in Jampani-Dulkiburu-Danguaposi block West Singhbhum District, Jharkhand employing large scale mapping (1:12,500) and rocks/ ore sampling and analysis have not given any encouraging results for Iron as well as manganese.

In view of the absence of any promising mineralization of iron ore and manganese ore, the chances of encountering large scale mineralization are poor in the block. Most of the area is covered by Danguaposi lava.

No potential Iron/Manganese Ore body is found for further exploration.

Hence, **no further exploration work for Iron Ore & manganese ore is recommended in the Jampani-Dulkiburu-Danguaposi Block.**

Chapter-IX

9.1 Expenditure:

Table 10: Details of Expenditure for G4 level exploration in Jampani-Dulkiburu-Danguaposi block

Sl. No.	Item of work	Unit	Proposed Quantum of Work	Amount Claimed (In Rs.)
1	Literature survey	lump sum		243,600
2	Remote Sensing for Mineral Targeting & Structural Mapping	Scene	1 scene study in 100 Sq. km area	2,250,000
	LISS IV- (5.8 mtrs resolution)	Scene	1 scene	
	Cartosat-2 (1 mtr resolution)	Scene	3 Scene	
3	Topographical Survey (on 1: 12,500 Scale)	Sq. Km	100 sq.km	-
	Fixation of Four Coordinate Points by DGPS	Nos.	4 nos	
	Bore Hole Fixation (Scout Boreholes)	Nos	5 Nos	
	RL & Coordinate Determination	Nos	5 N0s	
4	Geological Mapping (on 1:12,500 Scale)	Sq. Km	100 sq.km	1,937,000
5	Geophysical Survey			-
	a)Magnetic	Line Km	30 Line Km	
6	Surface Sampling			-
	a) Grab/ Chip samples	N0s.	80Nos	
	b) Pit samples	Nos.	10Nos.	
	c) Trenching samples	Nos.	10Nos.	
7	Test hole Drilling: (if required)	m	250m (5 Bhs)	-
	Geological work			
	a) Geological Core Logging & Supervision charges	m	250	-
8	Laboratory Studies			
	i) Surface Sampling (Primary samples)	Nos.	33	298,782

Sl. No.	Item of work	Unit	Proposed Quantum of Work	Amount Claimed (In Rs.)
	ii) Drill Core Primary & Check Samples	Nos.	250	-
	* For 6 radicals viz Fe, Al ₂ O ₃ , SiO ₂ , LoI, P, S			
9	a) Preparation of Thin Section	Nos	6	300,000
	b) Study of Thin Section & Mineralogical studies	Nos	0	
10	Vehicle expenses	Nos.	1	182,650
11	Camp charges	Nos.	1	360,000
12	Map generation & Compilation of data			490,000
13	Report Preparation [As per Mineral (Evidence of Mineral Contents) Rule-2015]	N0s	1	246,700
14	Miscellaneous expenses including core cutter	Lump sum		60,237
Total				6,368,969

Reference:

- Aref Shirazi, Ardeshir Hezarkhani, Adel Shirazy, 2018, Remote Sensing Studies for Mapping of Iron Oxide Regions, South of Kerman, IRAN Volume 7–Issue 04, 45-51
- ASTER Reference Guide Version 1.0. 2003. Earth Remote Sensing Data Analysis Center.
- Ball, V. 1881. The geology of Manbhum and Singhbhum. Geo. Surv. India, Rec., 18, Pt.2.
- Dunn, J.A. and Dey, A.K. (1942) The geology and petrology of eastern Singhbhum and surrounding areas. Mem. Geol. Surv. India, v.69(2), pp.281–450.
- Dunn, J. A. “The Geology of North Singhbhum including Parts of Ranchi and Manbhum Districts,” Memoir Geological Survey of India, Vol. 54, No. 2, 1929, pp. 1166.
- Interim report on regional geochemical mapping in and around Sonua-Goilkera areas covering toposheet nos. 73F/6, 73F/12 and in 73E/6 in parts of West Singhbhum, Ranchi and Hazaribagh districts of Jharkhand.
- Jones, H.C. (1934) The iron ore deposits of Bihar and Orissa. Mem. Geol. Surv. India, v.71, pp.105–120.
- Pushpesh Narayan, D.C. Jangid & H.M. Kundu: Appraisal for Iron Ore around Silpunji Kantoria Block, West Singhbhum dist., Jharkhand (G4 stage); Unpubl. Report of Geol. Suv. of India (F.S. 2010-2012)
- Rajendran S and Nasir S., 2013, Mapping of manganese potential areas using ASTER satellite data in parts of Sultanate of Oman Int. Journal of Geosciences and Geomatics ISSN: 2052-5591, May 2013, 92-101
- Rowan, L., Mars, J., 2002. Lithologic mapping in the Mountain Pass, California area using Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) data. Remote Sensing of Environment 84, 350–366.

- Saha, A.K., Ray, S.L. and Sarkar, S.N. (1988) Early history of the Earth: Evidence from eastern Indian Shield. *In*: Mukhopadhyay, D. (Ed.), Precambrian of the Eastern Indian Shield. Mem. Geol. Soc. India, v.8, pp.13–37.
- Saha, A.K. (1994) Crustal Evolution of Singhbhum-North Orissa, Eastern India. Mem. Geol. Soc. India, v.27, 342p.
- Sarkar, S.N., Saha, A.K., 1983. Structure and tectonics of theSinghbhum– Orissa Iron Ore Craton, eastern India. *In*: Saha,A.K. (Ed.), Recent Researches in Geology: Structure and Tectonics of Precambrian Rocks. Hindustan Publ. Corp., NewDelhi, pp. 1–25.
- W. P. Loughlin, “Principal Component Analysis for Alteration Mapping,” Photogrammetric Engineering and Remote Sensing, Vol. 57, No. 9, 1991, pp. 1163-1169.