Studies on Geology And Mineral Resources of Gandhamardan Area of Keonjhar District, Odisha, India

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Abstract- *The present study is of both basic and applied in nature and aims at generating field characters on iron ore group of rocks and associated ore bodies which have bearing on genesis and industrial utilization. The study area is bounded by latitude 21^0 36'00" to 21^0 42' 02" North and longitude 85^0 29' 00" to 85^0 31' 32" East located in the top sheet numbers 73G/10 and 73G/6 and covers an area of 2209.4 hectares. The main lithological unit mapped out and studied around Gandhamardan are Gritty Quarzite, Dolerite and volcanic, Tuff andIron Formation. On the basis of detailed study of physical and chemical characteristics the iron ore has been classified into Hard Massive Ore (HMO), Hard Laminated Ore (HLO), Soft Laminated Ore (SLO) , Lateritic Ore (LO), Blue Dust (BD) / Friable Ore (FO) / Powdery Ore types.Similarly rocks and iron-containing rocks associated with iron ore have been classified into Laterite,,erruginous Shale And Clay,Banded Hematite Jasper (BHJ)/Banded Hematite Quarzite (BHQ) / Banded Hematite Shale (BHS) types. The Gandhamardan Iron ore deposit occurs as an extensive tabular ore body enriched from Banded Iron Formation. The nature of the ore body is predominantly laminated varying from moderately hard to soft. Gandhamardan Iron ore belongs to the same group of proterozoic rocks (approx. 2500m. yrs old) which host the deposit like Ghiria, Gua , Bolani, Noamundi etc. The competent and resistant Banded Hematite Jasper (BHJ) of Gandhamardan hill form prominent topographic highs.*

Keywords- BHJ, BHJ, Blue Dust, Laterite, Iron ore

I. INTRODUCTION

The study area is bounded by latitude 21^0 36'00" to 21^0 42' 02" North and longitude 85^0 29' 00" to 85^0 31' 32" East located in the top sheet numbers 73G/10 and 73G/6 and covers an area of 2209.4 hectares. The nearest railway head is at Keonjhar situated about 12 km from the Gandhamardhan mine. The place is well connected by an all weather road as the mine is situated in proximity to the National Highway No.6. The place is also connected by National Highway 215 which connects Bhubaneswar with Rajamunda. The Gandhamardhan area is made up of a number of lofty hill ranges spiked with lush green peaks and serpentine valleys situated in the northern part of Odisha state. It is bounded by the Singhbhum thrust in the north and the Sukinda-Bhalukasuni thrust in the south. The area is located at a height of 3477 feet above msl. The area is thickly forested and consists of deep ravines, gorges and waterfalls. The river Baitarani which has its source in the Gonashika hills flows in a northerly direction along the boundary touching Jharkhand and thereafter flows through Anandpur subdivision and through Bhadrak district.The climate of the area is characterized by hot summers, extremely cold winters and rainy season characterized by heavy rainfall and thunder squalls. Summer generally commences in the month of March and lasts up to the month of June. The weather becomes more pleasant with the advent of the monsoon in June and remains as such up to the end of October. The months following the rainy seasons experience extreme cold weather when the mercury falls below 5^0C. The temperature here averages 24.9^0C attaining maximum in the month of May having an average of 31^0C and minimum in the month of December i.e. at an average of 5^0C. The average rainfall witnessed in this region is 1371 mm.

There are many references available as regards to stratigraphy, structure, ore formation and evolution of the Iron Ore Group (IOG) of rocks of north Odisha. The most significant contributions come from Jones (1934), Dunn (1940), Mishra (1961), Prasad Rao et al. (1964), Sarkar and Saha (1962) dealing with regional geology, stratigraphy, geochronology, ore genesis etc. These pioneering workers had provided enough interest and enthusiasm for the subsequent workers like Murthy and Acharya (1975), Sarangi and Acharya (1975). In a way , all their studies state IOG of rocks to comprise of three distinct formations having three broad lithofacies, namely; volcanics, iron bearing sedimentaries and shale which have undergone very little metamorphism. H. Sahoo & S. Acharya (1990) studied lithostratigraphy of the iron ore bearing and associated rocks of Gandhamardan hill and adjoining areas in Keonjhar District. D. Beura, P. Singh, P. K. Nayak and B. Sathpathy have also contributed to the

growth of the knowledge in this area. H. N. Bhattacharya and Kaushik K. Ghosh in the year 2012 reported the Field and Petrographic Aspects of the Iron Ore Mineralizations of Gandhamardan Hill.

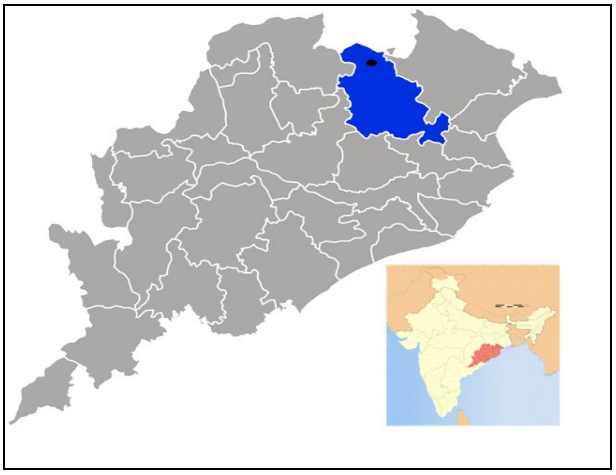

Fig 1. Location map of the study area

II. METHODOLOGY

The present study is of both basic and applied in nature and aims at generating field characters on iron ore group of rocks and associated ore bodies which have bearing on genesis and industrial utilization.

1. Systematic collection of samples from the mine covering a part area of toposheet no 73G/6 and 73G/10 of Survey of India. The area covers a part of Keonjhar district, Odisha.
2. Geological field study of Iron Ore Group of rocks exposed in the above area.

III. RESULTS AND DISSCUSSION

The region under study lies to the west of Keonjhargarh town and covers the area around Gandhamardan hill. Gandhamardan hill is located to the NW of Suakati village at a distance of 15 km from Keonjhar on NH –6. It hosts one of the biggest iron ore deposits of the state (250 million tonnes with average grade of 63% of Fe). Odisha Mining Corporation(OMC), a public sector undertaking and a pioneer body in mining in the state has been operating in this area. The Iron Ore Group of rocks of this region rest unconformably on the Dhanjori Group (Banerji, 1974 ; Acharya, 1976, Sahoo, 1984,) which, in turn, rests nonconformably over the granite that lies to the east and is regarded as a part of the Singhbhum Granitic Complex (Basak, 1962,).These Iron Ore Group of rocks are considered to be an outlier of the Gua- Noamundi- Malangtoli-Khandadhar iron ore belt (Acharya, op cit., Acharya et al., 1982,) which in turn lies due NNW at a distance of abut 25 km and have a basinal configuration.

Regional Geology

The region comprising the Keonjhar and Sundargarh Districts of Odisha and the adjoining Singhbhum District of Jharkhand includes the rocks of volcanic sedimentary belt known as Keonjhar – Singhbhum belt in the iron ore series [Jones , 1934].The area that is to the north of the belt (Bonai – Keonjhar – Singhbhum) was remapped by Dunn (1940). According to him there is a new group of rocks younger than the iron ore group that is included under the Kolhan Group. Once again the area was remapped by Prasad Rao (1956) who put the Gritty Quartzite to be of Kolhan age .The contact between the Kolhan (overlying) group and underlying iron ore group marked by a major unconformity is represented by Kolhan Conglomerate Breccia. The stratigraphic succession is given below.

Kolhan Group
.....unconformity.....
Upper Shale
Banded Hematite Jasper / iron ore
Basic lava

Based on radiometric age data Sarkar, Saha and Miller (1969) concluded that the rocks of the iron ore group evolved in an orogeny (The Iron Ore Orogeny) that culminated with emplacement of Singhbhum granite around 2900 million years ago.Prasad Rao (1964) Murty and Acharya (1975) believed that the rocks of the Bonai-Keonjhar-Sighbhum belt form a part of a discrete basin where basement was marked by the Singhbhum Granite. The area around Gandhamardan was mapped by Prasad Rao and others and later on by Banerjee (1974) who summarized the regional geology of the Keonjhar –Sundargarh- Mayurbhanj and Singhbhum districts

The succession of rocks given by Prasad Rao and Banerjee, 1974 is given below:

Kohlan Group (1584 m yr)
.....Unconformity.....
Singhbhum Granite
Iron Ore Series
Epidiorite (intrusive)
Upper Shale with sandstone and volcanic
Banded Hematite Jasper /iron ore
Lower Shale
Lavas
Older Metamorphic Rocks
{Mica, Sillimanite hornblende, and quartz schist}

Local Geology

Gandhamardan Iron ore belongs to the same group of proterozoic rocks (approx 2500m. yrs old) which host the deposit like Ghiria, Gua , Bolani, Noamundi etc. The Gandhamardan is detached from main iron ore body by a distance of 30 km for various geological reasons. As in other deposits iron ore of Gandhamardan is associated with rocks like Banded Iron Formation (BIF) and shale. The competent and resistant Banded Hematite Jasper (BHJ) of Gandhamardan hill form prominent topographic highs. Iron ore deposits i.e enriched into the superimposed folding of BIF (in N-S and E-W) directions. The undulating topography being developed where iron ore occupied the crest and lode has been occupied by BIF.Due to geological disturbances and deformations this deposit has become complex and given rise to different types of iron ores.

1. Laterite Ore (LO)
2. Hard Massive Ore (HMO)
3. Hard Laminated Ore (HLO)
4. Soft Laminated Ore (SLO)
5. Friable/Biscuit Ore (Bo) /Blue Dust (Bd)

The general strike of ore body is NSE to SSW and the ore body dips westerly ranging from 5^0 -30^0. The important litho units in the increasing order of antiquity comprises iron formations, tuffs, dolerites and volcanics. Besides the main iron ore deposit 4 patches of hard iron bodies have been exposed in the Gandhamardan hill which is confined between BIF at the hanging wall side and Shale/volcanics at the foot wall side. It occurs in a lower reduced level in comparison with hill top.

Some of the important field and laboratory findings to establish the stratigraphic succession are given below.

a) The quartz-arenites, belonging to the Dhanjori Group lie nonconformably on the eroded top of the granite exposed at a road cuttings on National Highway No.6 (linking Calcutta-Bombay), west of Keonjhargarh town (85^0 35' E : 21^0 37' N). The quartz arenites indicate abnormal stratigraphic sequence as indicated from the current bedding it exhibits.

b) Complete absence of dolerite dykes in the Iron Ore Group of rocks of Gandhamardan hills, and their intrusive relations into the quartz arenite-phyllitic shale that lie south of Ichinda are clearly discernible. So, from this disposition it can be concluded that the quartz-arenites and phyllitic shales are older to the Iron Ore Group. A fault lying to the north-west of Kainsari (Fault F'=F' in Fig.4.1) dislocate the quartz-arenite bodies and abut against the Iron Ore Group of rocks affecting the later rocks (Fault F^2-F^2). This affects the quartz-arenites and phyllitic shales. Hence quartz-arenites and phyllitic shales belong to an age older than the Iron Ore Group i. e. the Dhanjori age.

c) In the western part of Gandhamardan hill, the Banded Iron Formation (BIF) directly overlies the Tuff Formation that rest on the volcanics. To the NNW of Ichinda, the BIF starts with a black chert member at the base followed by banded cherty shale, banded shale, Banded Hematite Jasper and its variants in the ascending order. A massive iron ore horizon is, however, found in between the banded shale and BHJ unit in the western side of Gandhamarden hill (Fig. 4.1). The penecontemporaneous depositional features like intraformational fold, faults, breccias, slump structures, pinch and swell structures etc. in the BIF at different places along different stratigraphic levels of the Gandhamardan hill indicate normal stratigraphy (Sahoo & Acharya, 1990).

d) Geological map indicates two generations of dolerite dykes, thick and long one lying to the east in Fig. 1 and extending further north as of earlier generation and the small and narrow ones as that of the later. This is indicated from the fact that fault affecting the quartz-arenite bodies also dislocate the large dolerite dyke, whereas smaller dykes are found, at times, cross-cutting the fault planes (Fault F'-F') (Sahoo & Acharya, 1990). In the absence of any chilling, cross-cutting or any other effects of intrusion of the large dolerite dyke into the quartz-arenite and phyllitic shales in contrast to the smaller dykes, they can be considered to be of two generations with differing intrusive mechanism. Thus, it can be surmised that quartz-arenites, phyllitic shales along with the older dolerite dyke (representing southern part of the famous Palasponga dyke) were faulted first and was succeeded by intrusion of narrow and small dolerite dykes. The so called Newer Dolerites such as these, have also been found to be of differing ages substantiated by radiometric dates (GSI, 1987).

e) Pandey & Chatterjee (1984) equated the quartzitic sandstones, metagabbros and newer dolerites with the Kolhan Group but the present authors find the so called quartzitic sandstones to be older than the Iron Ore Group of rocks of Gandhamardan hill. The same sandstone, considered as of Kolhan age by them, are traceable over long distance and, in fact, continues further north upto Chamakpur (south of Remuli-Joda road) and south-east upto Daitari region as is mentioned by Prasad Rao *et al.*(1964), Banerji (1974) and this Iron Ore Group based on similarity of lithostratigraphy, mineralogy and structural pattern is correlated with Iron Ore Group is correlated with that of the Jamda-Koira valley (Sahoo, 1984) and thus, are equivalent to Noamundi Group (Banerji 1974) and Noamundi- Malangtoli-Kandadhar-Gua

Group (Acharya, 1976). Thus, the Iron Ore Group of rocks of Gandhamardan hill is younger than dolerites, volcanics, quartz-arenites and phyllitic shales.

A thin layer of ferruginous shale of impersistent thickness has been traced south of the Fault F^2-F^2 and in a number of other places below the laterite and above top laminated ore, which has also been inferred from drilling by Orissa Mining Corporation. This is the youngest shale on top of the BIF, which is preserved only in the core of small synformal structure.

Lithology

The main lithological unit mapped out and studied around Gandhamardan can be grouped as follows-

1. Gritty Quarzite
2. Dolerite and volcanics
3. Tuff
4. Iron Formation

Gritty Quarzite-Gritty Quarzites are confined to Eastern Ghats and southern part of Gandhamardan hill and exhibit normal stratigraphic sequence. They are hard, compact and fine to medium grained.

Volcanics - the volcanic except in one patch in the Eastern sector described earlier are confined only to western and northern part of area. They are hard, compact, fine to medium grained rock with colour varying from mesocratic to melanocratic . the lava exhibit conchoidal fracture, vesicular structure , the vesicle being filled mainly with quartz and ophiolites at places. Under microscope it is fine grained , exhibits granulitic and porphyritic texture and consist of olivine embedded in ground mass composed of lath of plagioclase. Composition is inferred to basaltic.

Tuff - The tuff or tuffaceous shale is mapped in the eastern and southern flank of Gandhamardan. It is a soft fine grained with colour varying from grey, purple, yellowish, greenish to white and occasionally seen to contain zeolite crystal and therefore appears to be a volcanogenic sediment (tuffs) having sedimentary feature like colour banding, bedding planes etc. the trend of bedding in the rock varies from NNE-NNW conformable to that of Iron formation.Under microscope it exhibits porphyritic texture having phenocryst of quartz embedded in fine grained clay minerals. But most of the thin section is semi opaque and X-ray studies may have to be taken to determine the mineralogy.

Iron formation - The banded formation jasper, banded hematite chert, banded hematite shale occurring at the top of the entire Gandhamardan and overlie to the tuff.

Mode Of Occurrence

The Gandhamardan Iron ore deposit occurs as an extensive tabular ore body enriched from Banded Iron Formation. The nature of the ore body is predominantly laminated varying from moderately hard to soft. The laminated nature of the ore body is due to frequent variations in colour and grain size of the constituent hematite grains in alternate lamina. Hard laminated ore, Soft laminated ore, Hard massive ore and lateritic ore occur as intercalated bands with top lateritic capping where as blue dust and powdery ores occur as a persistent horizon between the ore body and the bed rock. The steel grey blue dust and cherry red dust apart from forming a distinct zone at the lower part of the ore body from partings and disseminated pockets in hard and soft ore zone. They are also found as cutting across the lamination of the ore.

Ore Types

On the basis of detailed study of physical and chemical characteristics the iron ore has been classified into Hard Massive Ore (HMO), Hard Laminated Ore (HLO), Soft Laminated Ore (SLO) , Lateritic Ore (LO), Blue Dust (BD) / Friable Ore (FO) / Powdery Ore types.Similarly rocks and iron-containing rocks associated with iron ore have been classified into Laterite,,erruginous Shale And Clay,Banded Hematite Jasper (BHJ)/Banded Hematite Quarzite (BHQ) / Banded Hematite Shale (BHS) types.The general sequence of occurrence of the ore types from surface downwards is as follows.

Lateritic/float ore /Soil
Lateritic ore /Hard laminated ore/Hard massive ore
Soft laminated ore.
Blue dust/Friable ore/ Powdery ore (FO)
Inter gradation of one ore type with other is a very common feature.

Massive Ore - Massive ore is usually fine grained, dense and compact. It often exhibits fine laminations parallel to the bedding plane. The thickness of the lamina ranges from microscopic dimension to as thick as 0.7cm. Perpendicular set of joints is well developed in massive ore. The massive ore does not exhibit much evidence of slumping. It is seen in the topographic highs and show gradational relation with the underlying laminated ore. It is very hard and compact in nature rarely showing laminations. It is jointed sometimes. Its hardness varies from 6.0 to 6.5. It is very hard and compact in

nature rarely showing laminations. It is jointed sometimes. Its hardness varies from 6.0 to 6.5. It is compact, jointed, steel grey in colour having specific gravity 4.30 and bulk density 3.75 t/m3. The massive ore may be of hematitic (Fig.2A) or goethetic (Fig.2B). The Fig. 2C shows the association of massive goethite with ochre.

Fig 2A.Field photograph of iron ore

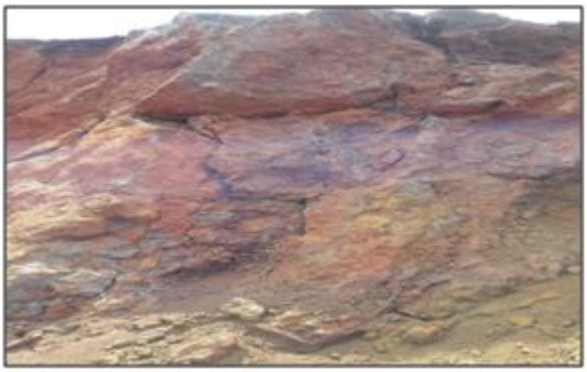

Fig 2B.Field photograph of iron ore

Fig 2C.Field photograph of iron ore

Fig 2D.Field photograph of iron ore

A. Massive hematitic ore associated with SLO
B. Massive goethtic ore
C. Massive goethtic ore associated with yellow ochre, the red colur is due to limonite coating
D. Soft laminated ore (SLO) associated with shale

Laminated Ore - The laminated ore exhibits well developed layering due to alternate iron rich and clay rich bands (Fig.2D). This type can be grouped into hard laminated ore (HLO) and soft laminated ore (SLO) depending on its compactness. The HLO exhibits large-scale open folds in mine faces while small scale puckers and tight folds are generally seen in SLO/shaly iron ores. The laminated ore of this region is observed to be associated and/or interlayer with thin bands of ferruginous shale. The shaly iron ore is termed when shale bands are relatively thicker than iron bands. Based on its compactness it is classified in to two: hard laminated & soft laminated.

Hard Laminated Ore (HLO): It is comparatively hard with lamina of varying thickness from 0.5mm. it is steel grey and cherry red in colour. It shows effects of alteration or limonitisation particularly at or near the surface. Its hardness varies from 5.5 to 6.0.

Soft Laminated Ore (SLO): This ore types are closely laminated and soft in nature. It varies in colour from cherry red to steel grey, very often it grades into powdery ore. This ore type is very important because of its predominant occurrence and grade. Its hardness varies from 5.0-6.0.

Biscuity/Friable Ore- The friable ore, also known as biscuity ores are usually seen between BHJ/BHQ and laminated ore . With a little pressure this ore converts to powdery form.

Blue Dusts (BD)- The fine-grained iron ore powder with characteristic metallic blue colour is well known as blue dusts

(BD). This ore occurs as pockets passing laterally or vertically into one of the primary ore types. Occurrence of blue dusts is neither related to topography nor confined to any stratigraphic sequence. Usually BD is of very good grade, need no beneficiation and is generally processed without passing through the washing plant and hence termed locally as 'Direct Ore' (Mohanty and Wadhwani, 1986). Distinct gradation between primary litho types to biscuity bands to fragile zone containing blue coloured powder is recorded in different bench levels of the study area.

Lateritic Ore: Laterite/Lateritic ore in the region occurs as blankets over almost all the members of iron formations. When it is developed in contact with some ore bodies, its grade is proved to be relatively high (Fe: Av. 59%), while with contact of shaly horizon, it is of low grade (Fe: Av. 56%) nature and contain more alumina (6-7% - Al_2O_3).When it is of commercial/economic grade it is termed as lateritic ore.. Occasionally, large profile of yellow ochre adjacent to iron ore/ BHJ/BHC is seen. (Fig. 3A).

Banded Hematite chert / Jasper: This litho-unit consists of alternating thin laminae of silica (in various forms) and iron minerals (with very occasional dispersion of clastics). Because of its hardness and relative resistance to erosion, it forms high ridges and attained a maximum thickness of 150 m. in this area. As the name connotes, they are generally banded though irregular lenses are also noticed. These bands, conspicuous by their colour contrast (composition), range in thickness from paper-thin up to a maximum of 25 cm (Fig. 3B).

Fig. 3A Field photograph of rocks associated with iron ore

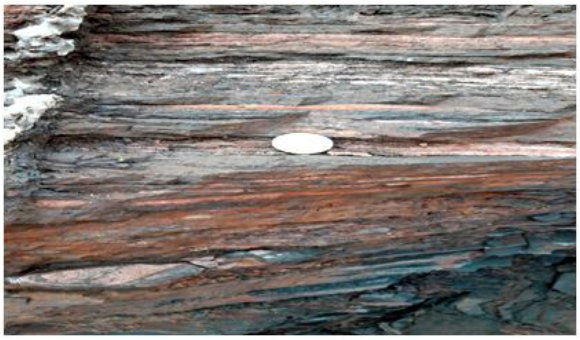

Fig. 3B Field photograph of rocks associated with iron ore

Banded hematite shale: Alternate bands of hematite and shale are seen associated with iron ore. The banding may be regular or irregular (Fig.3C). When the iron content of such rock is high, it is called transitional ore. Because of its soft nature it easily gets weathered at the surface.

Shale: Shale in different colour shed are found to be associated with iron ore and iron-containing rocks. It may show regular or irregular banding or layering (Fig. 3D).

Fig. 3C Field photograph of rocks associated with iron ore

Fig. 3D Field photograph of rocks associated with iron ore

IV. SUMMARY AND CONCLUSIONS

A thick pile of marginally metamorphosed sedimentary and volcanic group of rocks of Precambrian age, well known as ‘Iron Ore Group’, constitutes the principal

geologic formation of the area in Gandhamardan Hill region of Keonjhar district, Odisha, India. The base of the stratigraphic column is occupied by lower volcanic formation. It is succeeded by Lower Shale Formation (LSF) comprising weathered tuffaceous rocks. The LSF is overlain by various members of Iron Formations (BIF/Iron Ores) principally consisting of chemical sediments. These were intruded by two generations of dolerite dykes, which become feeder for the outpouring of lavas in the western part followed by deposition of tuffaceous shales. The different members of BIF are chert, banded shale, massive iron ores, irregular and regular banded hematite jasper and upper shale, which were deposited on the tuffaceous shales in a narrow north-south basin bordered by peripheral north-south faults at the eastern and western sides. The BHJ due to leaching and/or enrichment by iron solutions gave rise to iron ores that lie in the upper part of BHJ. The belt consists of commercially exploitable deposits of iron in the form of hematite and goethite mostly having massive or hard laminated types of ores. The main lithological unit mapped out and studied around Gandhamardan are Gritty Quarzite, Dolerite and volcanic, Tuff andIron Formation. On the basis of detailed study of physical and chemical characteristics the iron ore has been classified into Hard Massive Ore (HMO), Hard Laminated Ore (HLO), Soft Laminated Ore (SLO) , Lateritic Ore (LO), Blue Dust (BD) / Friable Ore (FO) / Powdery Ore types.Similarly rocks and iron-containing rocks associated with iron ore have been classified into Laterite,,erruginous Shale And Clay,Banded Hematite Jasper (BHJ)/Banded Hematite Quarzite (BHQ) / Banded Hematite Shale (BHS) types. The Gandhamardan Iron ore deposit occurs as an extensive tabular ore body enriched from Banded Iron Formation. The nature of the ore body is predominantly laminated varying from moderately hard to soft. Gandhamardan Iron ore belongs to the same group of proterozoic rocks (approx. 2500m. yrs old) which host the deposit like Ghiria, Gua , Bolani, Noamundi etc. The competent and resistant Banded Hematite Jasper (BHJ) of Gandhamardan hill form prominent topographic highs.

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