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Tectono-Structural Overviews of Iron Formation of North Odisha, India

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Abstract The famous iron formation of north Odisha belongs to the Archaean schist belt comprising of the litho assemblages including the Banded Iron Formation (BIF), Iron Ore and associated rocks. Major iron formations are confined to three different provinces located in the peripheral region encircling the granite complex, which is designated as the North Odisha Iron Ore Craton (NOIOC). These three iron ore belts are intra-cratonic basins that act as depository sites for the BIF, iron ore and associated rocks. The tectonic setting is correlated with the iron ore orogeny and suffered post tectonic deformations. The rocks of all the three belts have undergone multiple phases of deformation including folds and faults. The fold structures in successive phases are superimposed to produce numerous interference patterns.

Keywords: *tectonic setting, structure, iron formation, North Odisha*

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1. Introduction

Odisha is one of the mineral rich states in India endowed with huge quantity of iron ores. Almost all the proven reserve of iron ores are confined to north Odisha. Three horizons of Iron Formations along with associated rocks encircling a cratonic block of granite complex is designated as North Orissa Iron Ore Craton (NOIOC) (Beura and Singh, 2005; Beura et al., 2007 and Beura, 2008) (Figure 1). In the eastern periphery of the craton there occurs Badampahar-Gorumahisani-Suleipat (BGS) belt, which is considered as the oldest BIF and assigned as BIF-I (Acharya, 1984, 2000). The Bonai-Keonjhar (BK) belt lies in the western flank and the Daitari-Tomka (DT) belt remains in the southern periphery of the NOIOC, and have been assigned as BIF-III and BIF-II respectively. The three iron ore belts have been evolved as separate entities without any physical continuity of iron formation although there is some interlinking among associated litho members. The craton encompasses Singhbhum granite complex having enclaves of Older Metamorphic Group (OMG) and Older Metamorphic Tonalite Gneiss (OMTG) (Figure 1).

The BGS belt i.e. the BIF-I has its main stretch in the form of an arcuate shape extends a narrow and discontinuous outgrowth towards south. This iron ore group includes the area extending from Badampahar in the south up to Gorumahisani in the north through Suleipat. The litho assemblages of BGS belt consists of Banded Magnetite Quartzite (BMQ), Banded Hematite Quartzite (BHQ) Banded Magnetite Grunerite Quartzite (BMGQ) and Banded Cherty Quartzite (BCQ) invaded by younger ultrabasics and numerous dolerite dykes. Amphibolites, tremolite-actinolite schist and granite are the older rock types exposed in the area belonging to OMG. The iron formation comprises of dominant minerals such as magnetite, hematite, martite, goethite, specularite and grunerite, and silica minerals. BIF-I is the oldest among the three BIFs encircling NOIOC, which has undergone multiple phases of folding and faulting, and has been suffered medium-grade metamorphism (Amphibolite facies).

The DT belt, as is recalled as BIF-II in the three tire classification comprises of banded magnetite/hematite quartzite, banded magnetite/hematite jasper, quartz sericite/chlorite schist, phyllites, slate, banded chert and few ultrabasics as intrusive. Magnetite, martite, hematite and goethite are the common iron minerals. The rocks of this belt have attained green schist facies of metamorphism. The rocks of DT belt have suffered polyphase deformations. Unlike BGS belt though this belt does not show intricacy in structural geometry, but receives similar deformational episodes. The folds of different periods are co-axial and synchronously cross-folded having mutually perpendicular axial planes (Acharya, 2002). The regional trend of the area is in E-W direction and the plunge is towards west.

The 'U'-shaped BK belt in the south of NOIOC is considered as the youngest Iron Ore Group (BIF-III) comprising of banded hematite jasper, banded hematite quartzite/chert, banded shale, banded manganese formation and ferruginous shale. The iron oxide minerals present in the BIF are hematite, martite, specularite and magnetite. The litho-assemblages of this youngest iron ore belt are un-metamorphosed and lack of any intrusive. The general structural disposition of the rocks of the belt is a synclinorium trending NNE-SSE direction having low plunge towards NNE. The rocks of the area are experienced with three phases of folding.

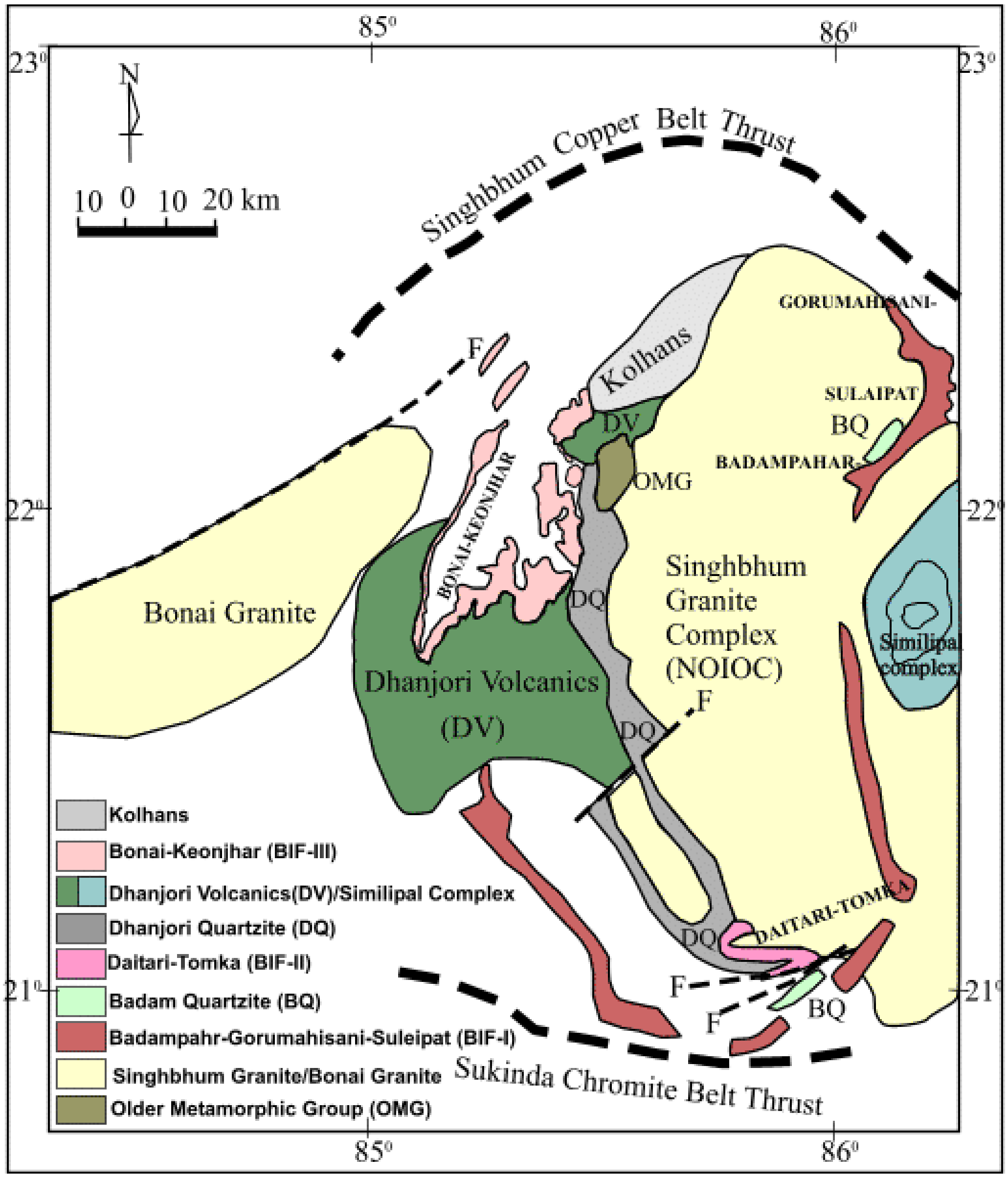

Figure 1. Regional geological setting of NOIOC encircled by three iron formations (Modified after Jones, 1934; Beura et al., 2010)

2. Geological Setting

The iron formations of north-Odisha encircling the cratonic massif form an important part of the Archaean schist belt and is known as NOIOC. To its north there lies Singhbhum copper thrust and in the south Sukinda thrust extends to a limited length. In the north-eastern flank of the NOIOC, the BGS belt trends in NE-SW direction truncating in N-NNW direction towards the northern part. It is underlain by metamorphosed mafic volcanics and clastic sedimentary rocks. The rocks are complexly folded and faulted and have been intruded by ultrabasic and mafic dyke. The Daitari-Tomka belt lying in the southern sector of the NOIOC follows the regional trend of E-W direction and the plunge towards west. The Bonai-Keonjhar belt occupies a distinct 'U'-shaped pattern in the western flank of the NOIOC. The general structural disposition of the rocks of the BK belt shows a synclinorium trending NNE-SSE direction having low plunge towards NNE. The regional stratigraphic succession of the iron formations of north Odisha constituting the Iron Ore Super Group (IOSG) is given in the Table 1.

3. Tectonics and Basin Devlopment

The terrain evolution in the proto-NOIOC was initiated by the progressive tectonic activities, which could originate the depositional basins for the three iron ore belts. During the beginning of the tectonic enforcement, the cratonic massif started undergoing spreading and extension along its margin. The cratonic margin attained the extension activity continuously for quite a long period that led to rifting. All the three i.e. BGS, DT and BK iron ore basins have been formed due to the post rifting grabenisation. Three intracratonic basins so formed along the periphery of NOIOC have been considered as depository of iron ore (Figure 2.A).

Table 1. Stratigraphic succession of iron formations of north Odisha

IRON ORE SUPER GROUP (NOIOC)	Kolhan Group		Kolhan sediments (Sandstone, Limestone, Shale)
	-----------------Unconformity--------------------------		
	Bonai-Keonjhar Group (BIF-III)	Upper Shale	Fe-shale Banded shales
		BIF-III	Banded Hematite Chert/Jasper and banded hematite shale
		Shale	Lower Banded shale Banded Manganese Formations (BMnF) Variegated shales Tuffs & Tuffaceous shale
	------------------Unconformity ---------------------------------------		
	Dhanjori Group		Dhanjori Volcanics Dhanjori Quartzite
	------------------ Unconformity----------------------------------- ---		
	Daitari-Tomka Group	Upper Metapelites	Phyllites Slate Fe-Phyllites
		BIF-II	Banded Chert Banded Magnetite/Hematite Chert/Jasper and Banded Magnetite/Hematite Quartzite
		Lower Metapelites	Banded Phyllites Quartz Schist Chlorite schist
	---------------------- Unconformity -----------------------------------		
	Badamphar-Gorumahisani-Suleipat Group	Upper Quartzite	Badam Quartzite Micaceous Quartzite
		BIF-I	Banded Magnetite/Martite Quartzite Banded Magnetite/Grunerite Quartzite
		Lower Quartzite	Banded black and green chert Tremolite-actinolite schist Fuchsite Quartzite
	-------------------Non- conformity-------------------------------------		
PRE-IOSG PRE-CAMBRIAN			Singhbhum Granite≅Keonjhar granite ≅Bonai granite) (older to BIF-I) Tonalite gneiss (OMTG) OMG (Mica schist, fuchsite quartzite, Para-amphibolite, Hornblende-schist etc.)

Supracrustal rocks along with BIF were mostly deposited in the early Proterozoic rift basins. The sialic crust, on stretching, gave rise to thinning and fracturing near the margins of the proto continental block, which led to subsidence troughs and on further spreading led to volcanism accompanied by deposition of chemical precipitates (Mukhopadhyay, 1989). Archaean continental crust experienced tectonic- magmatic reactivation in disruption and fragmentation in early Proterozoic time (Gaal, 1989). The Iron ore basins of Karnataka are intra-cratonic in nature and they are fringed by volcanics that erupt along fracture zones. Ultimately those basins led to block-rifting causing zone of depression and subsequent deposition of sediments (Radhakrishna, 1983). The sedimentary setting of Proterozoic iron formation of Hamersley Group (Morris and Horwitz, 1983) and Transval Super Group (Beukes, 1984) has also undergone tectonic system of basin development. Sawkin (1990) while discussing the spectrum of rift-related metal deposits stated that the iron deposits along with volcaniclastic were formed in the rift –related environments.

Materials from various sources comprising volcanics of mafic to acid-intermediate composition, volcaniclastics and chemical precipitates were accumulated in the tectonically evolved basins through different processes. The basin architect and external dynamic events could regulate the material inflow and deposition. Looking at the present-day configurational and compositional setting of the basins, it can be suggested that the intra- cratonic basins have received sediments from terrestrial source through continental denudation, sea water through transgression and regression, deep circulation of marine or meteoric water and from volcanic exhalation inside the basin (Figure 2.A).

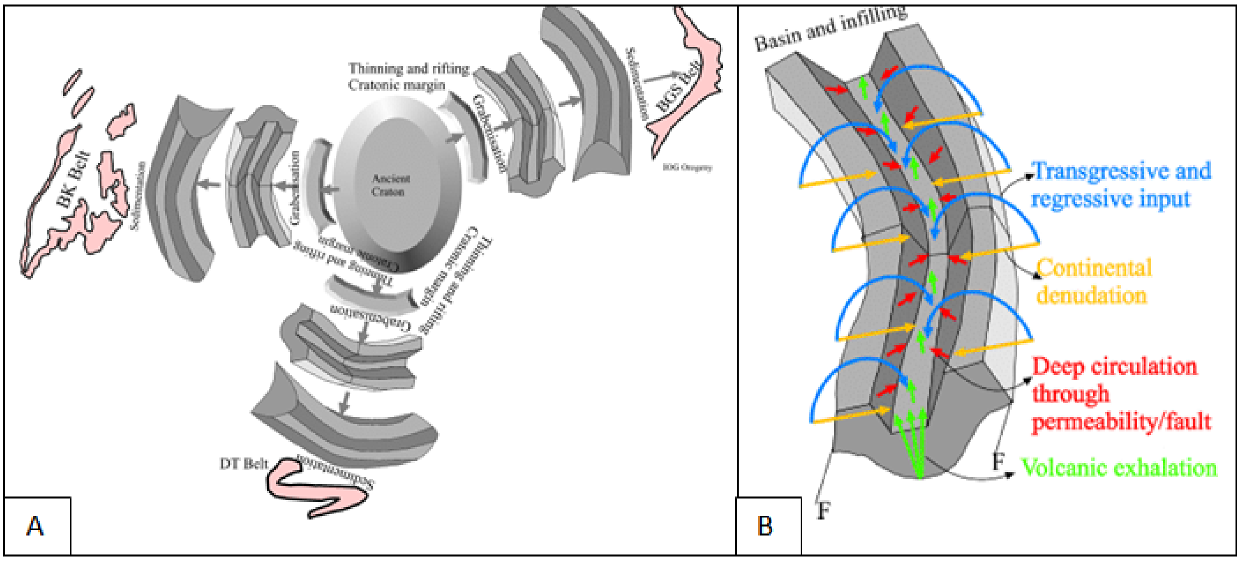

Figure 2. Schematic diagram showing: A. Tectonic model of iron ore basins that constitutes the IOSG of north Odisha, B. Various sources supplying materials to basin

4. Structural Setting

The iron formation of north Odisha has actively been undergone range of deformational episodes. The Structural dispositions of the litho units of the three iron ore basins exhibit varying structural patterns from simple to intricate that may indicate probable chronology. Even though the three provinces have suffered multiple phases of deformations BGS belt, the oldest one has undergone the most complex type structural geometry. Up to three phases of fold episodes have been retained in the supracrustals in the BIF-I of BGS belt, which have been clearly manifested in the litho-units. At best three phases of deformation are observed producing co-axial and synchronous cross folds in the BIF-II of DT belt. The BIF-III of the BK belt has undergone at least three phases of deformation, which results in more open type cross folding. Successive phases of folding lead to plunge reversal that results in series of antiform and synform, and canoes and inverted canoe-shaped folds.

In BGS belt the tight and isoclinal first folds (F_1) are overprinted by nearly co-axial, upright and tight to open second phase fold (F_2). Both the folds plunge in NE-SW direction and the plunging axes are parallel to the general trend (NE-SW) of the belt. The last phase of folding (F_3) is developed as gentle and broad warps and is much localized in nature. The F_3 fold has steep northeasterly dipping axial plane and plunging axis is towards NW direction. The relationship among the three phases of folding is established by geometrical analysis as $F_1 // F_2 \wedge F_3$ (Beura and Singh, 2009). Such type of pattern and trend is observed in DT belt with less pervasiveness of the second phase fold. First episode of folding of BK belt has axial plane trends in N-S and dips either in north or south. The folds are double plunging towards east and west. The second fold movement striking in E-W direction has axial plane dips towards east and west directions. The third episode of folding is traced locally having N-S trend with high plunge either in north or south ward. In BK belt the geometrical relationship of three phases of folds are established as $F_1 // F_3 \wedge F_2$.

In both BGS and BK belt three phases of folding have been superposed to give rise interference patterns such as dome and basin structures, hook shaped fold patterns, eyed fold and mesoscopic folds of S, Z and M shape. Interference patterns are less prominent in the DT belt. Regional faults have been traced along the periphery of the basins as evidenced by differential altitude and displacement between the adjoining litho-units exhibiting escarpment and vein quartzes. The NE-SW trending major faults remain parallel to the regional structural disposition of the BGS belt. Besides, a number of E-W faults have also been noted across the regional trend.

5. Discussion and Conclusion

The iron formation of north Odisha comprising three separate basins reveals features related to tectonic setting and structural disposition of litho types. The three iron ore provinces encircling the NOIOC are developed as the intracratonic basins due to rifting and grabenisation, which might have been supported by iron ore orogeny. These intracratonic basins have been considered as depository of iron ore that receive materials from various sources comprising volcanics of mafic to acid-intermediate composition, volcaniclastics and chemical precipitates. The probable sources of material suppliers might be continental denudation, sea water transgression and regression, deep circulation of marine or meteoric water and volcanic exhalation inside the basin. The north Odisha iron formation is experienced with polyphase deformational episodes, which are well documented in all the three iron ore provinces. The BGS belt is seemed to be suffered from intricate deformational episodes suggesting it to be the oldest formation among the three. This has resulted in superposition of fold structures that exhibit abundant structures of interference patterns. Although the DT belt and the BK belt have experienced similar type of deformation, complex geometry in fold as well as interference pattern is hardly noticed. Co-axial and synchronous cross folds are prominently found in the BIF-II of DT belt. Open types cross folding geometry are resulted in the BIF-III of the BK belt.

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