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A study of primary sedimentary structures in banded iron formations (BIFs) of Nagavi area, Gadag schist belt, Karnataka, India

Primary sedimentary structures play a vital role in mineralisation. The banded iron formations (BIF's) are unique rock formations in geological history. The banded iron formations of Gadag schist belt, Karnataka, India, exhibit primary sedimentary structures like meso and micro folds, ripple marks, cross lamination, parting lineation and graded bedding. BIF of Nagavi area is one of the most typical Precambrian formations of the Gadag schist belt (GSB). BIF's outcrops were delineated during field visit. Most of the outcrops were located on top of the hill and Meta-basalts on either side of the hill and trending NW-SE direction. The BIFs of Nagavi study area exhibit prominent primary sedimentary structures and a few pre-consolidation deformation structural features, like folds, faults and brecciation between bands were also observed. The sedimentary structures along with petrographic observations it indicates that the BIFs associated with quartz vein in the form of silica iron oxide.

Keywords: Nagavi area, Gadag schist belt, sedimentary structures, banded iron formations.

1. Introduction

The Dharwar craton in India is host to many of the country's mineral resources, including the famous Hutti, Kolar, Gadag goldfields and these deposits are supported by primary sedimentary structures. The Dharwar craton of the south Indian shield is divided into the western and eastern blocks based on the nature and abundance of greenstone belts and the age of the gneissic basement rocks (Naqvi et al., 1987)]. The Western Dharwar Craton and Eastern Dharwar craton are considered to have different evolutionary histories and metallogenic characteristics.

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(Rajamani et al., 1985). In addition, the craton contains several Archaean greenstone belts, including the well-known Kolar schist belt, Hungund-Kushtagi schist belt, Sandur schist belt, Gadag schist belt, Chitradurga schist belt and Dharwar-Shimogga schist belt. The development of the Gadag schist belt in the 1990s has assisted in a greater understanding of the geology and gold mineralisation. It is composed dominantly of metabasalt in western half of the belt and sediments in eastern half.

BIF hosted gold mineralisation in the Nagavi area, which forms northern part of the central zone of the Gadag schist belt and it has been reported by numerous researchers (Beeraiah et al., 2001). This warrants a detailed study of geochemistry of banded iron formations of the Nagavi area (Sawkar 2010). Hence, this study concentrates on the geochemistry of BIFs of the Nagavi area which have been reported to be important carriers of gold (Fig.1).

2.0 Materials and methods

The geological traverse has been carried out and identified different lithounits like banded iron formations (BIFs), schist,

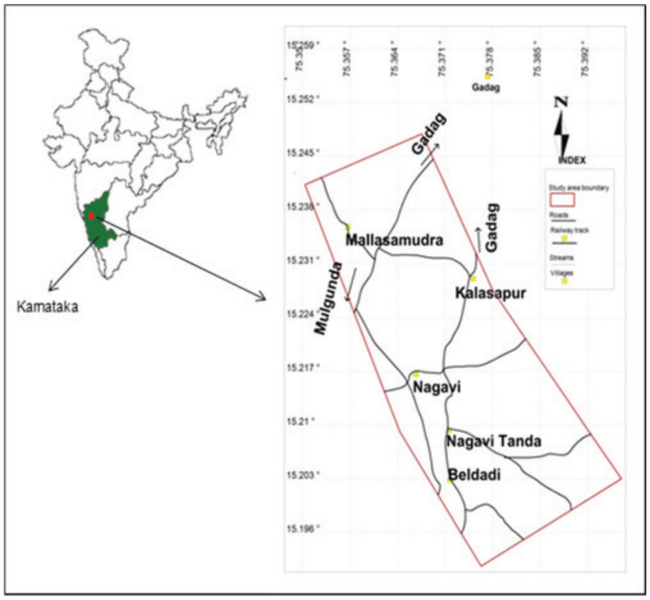

Fig.1: Location map of Nagavi area

metabasalt, shale, argillite, sheared quartz veins and thin bands of carbonates. BIFs occur as dissected bodies occupying the ridge part of the mound and their thickness varies from 1 to 20m. BIFs extend to a length of more than 5 kilometers in study area (Fig.2). Floats of BIFs occupy areas surrounding the ridge portion of the mound. These BIFs exhibit prominent banding with alternate layers of fine to medium grained magnetite/hematite and chert. This compositional layering is usually expressed on several scales in the outcrops from sub-millimeter-scale to feet-scale bands. Hematite and magnetite lead the iron-rich layers, often accompanied by other metal oxides and sulphide such as pyrite and carbonates. The varying amounts of carbonate mineral phases, such as calcite and siderite may or may not be present in both iron rich and chert rich layers. At some places layers of silica may or may not be jasperiferous. Thick inter-beds of shale are also associated with the BIF.

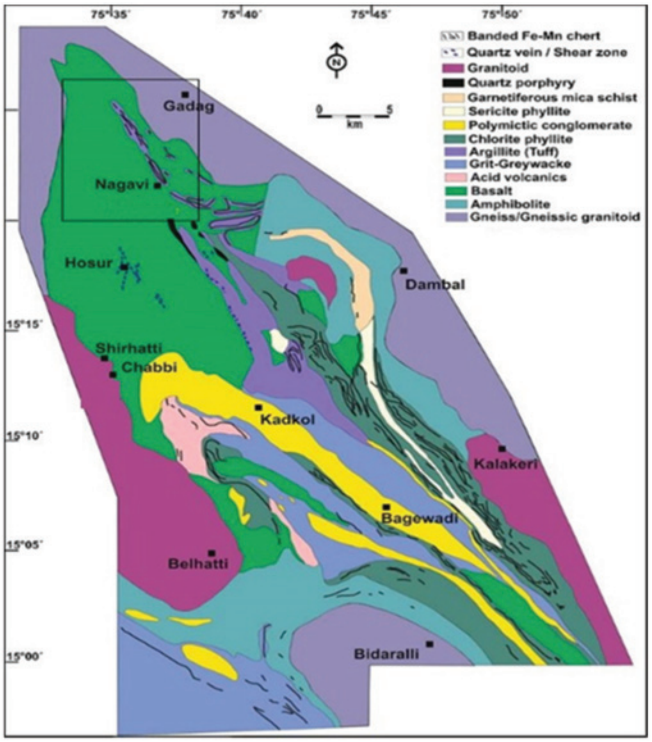

Fig.2: Regional geology of Gadag schist belt (after Ramachandran et al. 2001)

Metabasalts occur on both sides of the mound which are cut across by quartz veins at places. These are dark green, medium to fine grained compact rocks. Pyritiferous metabasalt occur near Mallasamudra village. Greyish green medium gained chlorite schist is occurring in an old working pit near Mallasamudra village. Schistocity is well developed in these schist.

This unit is not much exposed in the study area. Reddish brown coloured shale is observed near Nagavi and Mallasamudra village. It forms very thin bands with medium to fine grain. It occurs as alternating bands within BIFs and quartz veins. Sugary white quartz occurs on top of the ridge and thin quartz veins are observed within the BIFs and metabasalts. The auriferous sheared quartz vein zones occur within the contact of BIF at some places.

Based on semi-detailed gravity investigations (Ramadass Et al., 2002) were carried out over an area of 2750 sq km in the Gadag region in the Dharwar craton. From qualitative analysis, several faults and lineaments were identified. The Gadag schist belt occurs in two discontinuous segments, the main N-S trending segment and its thinner NW-SE trending extension. These two segments are separated by a NE-SW trending deep seated fault. The main segment of the Gadag schist belt is bounded on the east by the NW-SE trending Chitradurga thrust fault and on the west by a major NNW-SSE fault.

Based on satellite imagery and structural studies, (Chadwick at al., 2003) proposed that the rocks are components of a dipping hinterland duplex, which they termed the Gadag duplex. This duplex represents an island arc above a fossil oblique subduction zone. The general trend of lithounits in the Nagavi area is N 50^{o}-55^{o} W to S 50^{o}-55^{o}E and dipping towards north east. The BIF bands are folded into synform and antiform adjacent to the shale.

The general structure of the Gadag schist belt appears to be a doubly plunging, asymmetrical, east–dipping isoclinal syncline. The regional strike of both schistocity and bedding is NW-SE to NNW-SSE, dipping predominantly to NE or ENE from about 50^{o} to 55^{o}. Auriferous lodes occurs mainly in the vicinity of stratigraphic contacts of schistose.

It is well known that the Archaean-Proterozoic Dharwar craton is distinguished by a complex course of geological evolution (Naqvi et al., 2007). The schist belts and numerous enclaves of a wide variety of volcano-sedimentary material (2900 Ma) as well as the younger granites (2600 Ma) seen as extensive exposures in the Dharwar craton lie uncomfortably over the host peninsular gneisses (Naqvi et al., 1997) and form the supra-crustal or cover sequences. The importance of the schist belts in the structural evolution of the craton is well known.

The auriferous Gadag schist belt Ugarkar et al., 2000., is a schist belt of the Dharwar type. To the north of the river Tungabhadra, the Gadag schist belt forms the northern extension of the well-known Chitradurga schist belt and is chronologically equivalent to the Dharwar super group (Narayanaswamy et al., 1963), and is a type area for its study. The Gadag schist belt consists of a 2000m thick pile of meta-volcanics and meta-sediments (Chakrabarthi et al 1993) a banded iron formation. While the geological nature and the inter-relationship of the volcano-sedimentary rocks of the supracrustals sequences help in understanding the tectono-sedimentary environments of deposition, there are no results of detailed geophysical studies reported so far over the schist belts of the craton or determining continental geo-physical

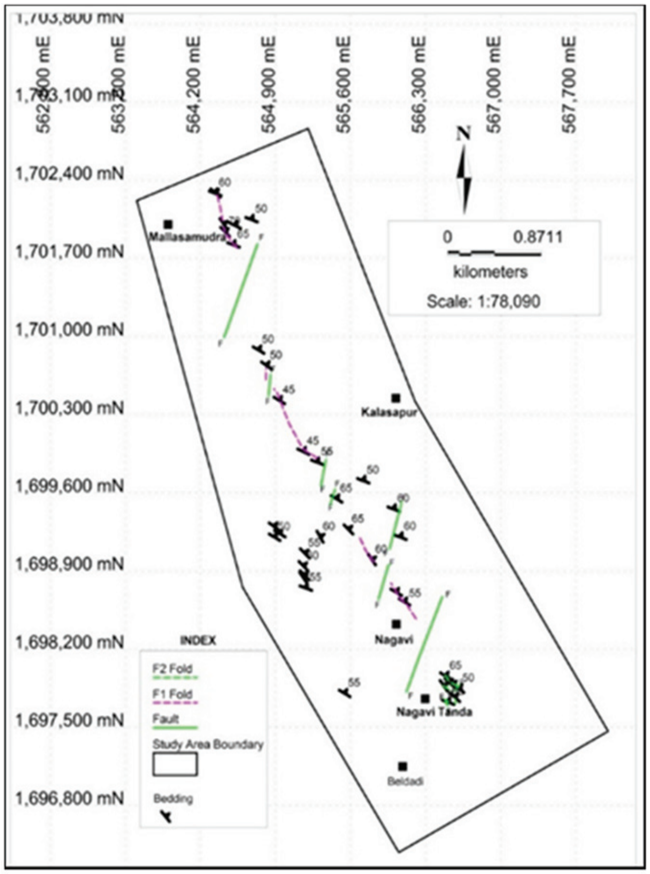

Fig.3: Structural map of Gadag schist field (after Geodata, GSI Bangalore)

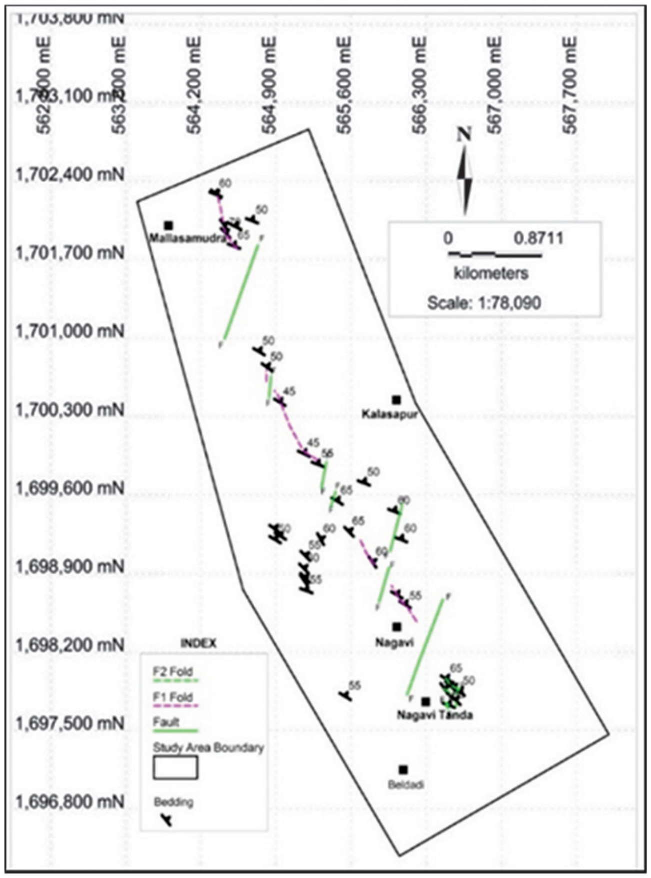

Fig.4 Structural setting map of Nagavi area

signatures. At places quartz veins are intruded into the BIFs and metabasalts. The primary and secondary structures are observed in the deformational structures such as ripple marks, vesicular structures and folds, faults, shear zones, thrust zones respectively, which are induced by directional stresses (Ugarkar et al., 1994).

The study area forms a part of regional fold whose anticlinal closure lies at the North of Nagavi area. The fold is defined clearly by the hard compact rocks of BIF with the relatively softer rocks [1]. Along with BIF the lithounits viz metabasalt, quartz veins, argillites, chlorite schist's, quartz sericite phyllite, carbonates and Iron also are found to occur conformably (Fig.3).

3.0 Nagavi structures (Sedimentary structures in Nagavi area)

In banded iron formations (BIFs), the secondary structures observed are the deformational structures such as folds, faults, shear zones and thrust zones, which are induced by directional stresses (Fig.4). The study area forms a part of regional fold whose anticlinal closure lies at the Nagavi area. The fold is defined clearly by the hard compact rocks of BIF with the relatively softer rocks (S.C. Puranik, et al., 2011).

The structure and tectonic aspects of the BIF were studied and most of these banded iron formation horizons belong to the oxide facies banded iron-formations as defined by (Kaila et al, 1989) but silicate facies banded iron-formations are also locally developed. Studies on various aspects of BIFs and the resultant iron ores especially the high grade hematite ores are attracting the attention of different researchers in recent times. Along with BIF the litho units viz metabasalt, quartz veins, argillites, chlorite schists, quartz sericite phyllite, carbonates and iron are found to occur conformably. Numerous basic and acidic intrusive intersect these rock formations.

3.1 Ripple Marks

These ripple marks are wave shaped structures formed by fluid movement over sediments and are syndepositional modifications. In Nagavi area the ripple marks are observed in few places (Fig.5). These are symmetrical in nature. These ripple marks indicate that the shallow water deposition of these banded iron formations (BIF's).

3.2 Bedding

The bedding represents the presence of beds more or less well separated from its adjacent lithounits on either side. The bedding planes of BIF are sharp and linear and can be traced for kilometer and their thickness varies from a few millimeters to centimeters were observed in the Nagavi area (Fig.6).

Fig.5: Ripple marks in BIF
(Hill top area near old Adit of Nagavi Area)

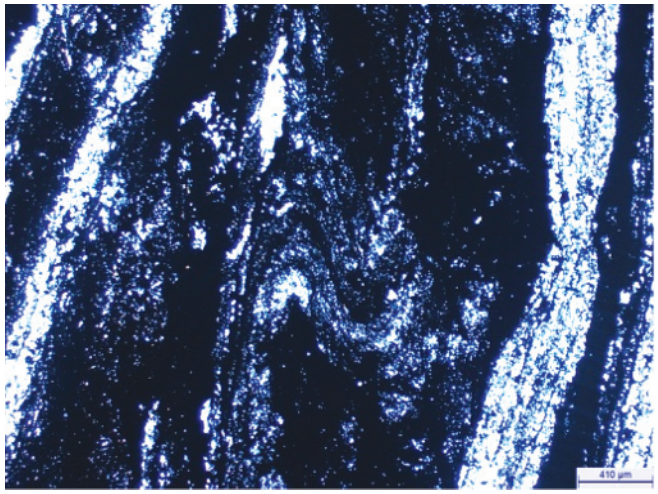

Fig.7: Thin section showing fold structures within BIF

Fig.6: Bedding with anticlinal fold in BIF (Hill top area near Nagavi)

Fig.8: Tight fold in BIF (Hill top area near Nagavi)

3.3 Folds

The compositional banding in the BIF defines the F1 folds and intersection lineation also defines the F1 fold axis. It is prominently seen as grove lineations on BIF surfaces in Nagavi area. The F1 folds show a northerly plunge of 40^{o} to 45^{o}. Several folds are seen at the anticlinal closure near Nagavi. Each minor fold has its axial portion intensely sheared and thus there are seven parallel shears and the corresponding quartz veins forming auriferous lodes. These shear zones are confined only to the hinge portion of F1 fold whereas the main axial shear continues further north Mallasamudra. Near Mallasamudra village due to dilation of the shear zone and multiple faulting, auriferous quartz veins are emplaced.

These folds are of small scale in nature and are confined to either iron oxide or silica micro/meso bands. Such localized folds were produced by intra layer gliding when the sediments are in the hydroplastic stage

(Narayanaswamy, 2003). In Nagavi area milky-white quartz veins along the main sheared zone are observed. A minor fault trending in NNW-SSE direction has affected the western limb of the syncline (Figs.7 and 8).

3.4 Faults

In the study area, the major and minor faults (Fig.9) have been identified in different parts of the area. The major faults occur near Nagavi and Mallasamudra village across the strike (NE-SW) and minor faults occur in top and either side of the hill in BIF as well as Metabasalts. The faulting confined to a stratum lying between undeformed bands is called intraformational fault (Gross et al., 1972) Such faults are of small scale in nature and are confined to micro/meso bands of silica or iron oxide. Such faults can be attributed to the deformation due to jerking during consolidation during hydroplastic stage.

3.5 Sheared Zones

The axial shear zones as described previously, a

Fig.9: Minor faults across and along the strike in BIF

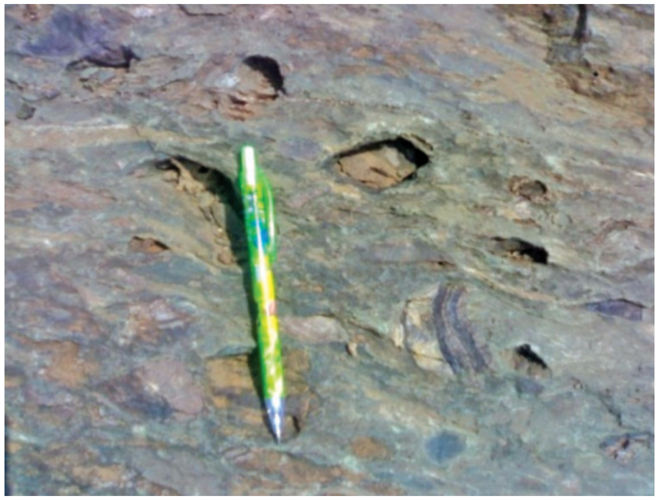

Fig.10: Vesicular structures within Quartz of BIF in metabasalt

mineralized shear zone trending in N20ºW- S20ºE direction for nearly 500m is seen in the old working mines near Nagavi Several N-S trending shear zones (parallel to F1) are noticed in Nagavi and Mallasamudra area. Syntectonic auriferous quartz veins are emplaced into the sheared BIFs in F1 axial direction.

3.6 Vesicular Structures

The vesicular structures were discovered in the study area and these are usually formed in warm, supersaturated, shallow, highly agitated marine water intertidal environments. The vesicular structures observed within metabasalts and BIF contact near southern part of Nagavi area (Fig.10). The vesicular textures extrusive rock containing voids left by gas bubbles that escapes as lava solidifies.

4.0 Results and discussion

The general structure of the Nagavi area appears to be asymmetrical, east –dipping isoclinal syncline. The regional strike of both schistocity and bedding is NW-SE to NNW-SSE, dipping predominantly to NE or ENE from about 50º to 55º degree. Auriferous lodes occurs mainly in the vicinity of stratigraphic contacts of schistose, BIFs and chloritic phyllite and also the sheared fault zones. It clearly indicates that the folds and faults are formed due to high pressure. The vesicular structures within quartz of BIF in metabasalt shows. The faults are of small scale in nature and are confined to micro/meso bands of silica or iron oxide. Such faults can be attributed to the deformation due to jerking during consolidation during hydroplastic stage. In Nagavi area a few milky-white quartz veins along the main sheared zone are observed. The F1 synclinal closure at Nagavi shows a multiple shearing due to the absence of digitization. There are also numerous small barren quartz veins having much the same strike, a few of which cut across the metabasalt at various angles, usually small, and consisting of disconnected lenticular patches of quartz on either side of hill. Sheared and fractured quartz veins along with contact of BIFs outcrop at top of the hill. The vesicular textures extrusive rock containing voids left by gas bubbles that escapes as lava solidifies.

5.0 Conclusions

In the Nagavi area the primary and secondary structures are observed in the deformational structures such as folds, faults, shear zones, thrust zones and vesicular structures, which are induced by directional stresses. The general trend of lithounits is N 50º-55º W to S 50º-55ºE and dipping towards North East. The BIF bands are folded into synform and antiform adjacent to the shale. At places quartz veins are intruded into the BIFs and Metabasalts. The fold is defined clearly by the hard compact rocks of BIF with the relatively softer rocks. BIF with other formations which are clearly indicating banding between micro and meso bands of iron oxide and silica reveal that they are of sedimentary origin. The presence of ripple marks indicates the shallow water deposition. The cross lamination suggests the inclined depositional character. Intermittent turbidity environment of sedimentation supports the presence of graded bedding. The parting lineation suggests the time gap before the deposition of other laminae. The presence of pinch and swell structure, convolute lamination and devolvement structure advocate the micro environmental variation or differential compaction before final consolidation. The scour and tool marks suggest the unidirectional flow of fluids or oscillatory movement of fluid with sharp edged sand grams. The shrinkage cracks (seneresis cracks) might have developed due to dehydration. Thus, it could be said that the BIF were deposited in the form of silica iron oxide gel in shallow water conditions.

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