ABSTRACT

India has presented with several gold prospects, like world class examples of Kolar Gold Fields, Hutti Gold Fields and Gadag Gold Fields. Fortunately, all of these gold deposits are located within Karnataka, emphasising the fact that, Karnataka is the prime state for gold production. Apart from these world class gold deposits, several other gold prospects were identified and exploration activities are under progress.

The Dharwar Craton in India is host to many of the country’s mineral resources, including the famous Hutti, Kolar, Gadag Gold Fields etc., 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 and Rogers 1987 and Naqvi 2005). The South Indian Shield forms a coherent unit in which geological activity can be traced continuously over the entire Precambrian. It records more than a billion years of the early history of the Earth, involving several episodes of crustal development. The Dharwar Craton is located in the central part of the South Indian Shield, flanked by the high-grade granulitic terrain to the south and the younger cover of the Deccan flood basalts to the north. All the rocks in the Dharwar Craton are Archaean to Late Proterozoic in age (Radhakrishna and Naqvi, 1986). The structural patterns have been modified by three tectonothermal events that occurred between 3400 and 2500 Ma (Mukhopadhyay, 1986).

The Western Dharwar Craton in peninsular India comprises a typical Meso- to Neo-Archean granite-greenstone terrain. Detrital zircons from two meta-greywackes in a late basin from the Gadag Greenstone Belt preserve at least eight age populations ranging in age from ca 3.34 to 2.55 Ga, and grains as old as ca 3.54 Ga. The zircon provenances for the two samples appear to be the same up to ca 3.25 Ga (D. Srinivasa Sarma, 2012).

The 2.76 Ga to 2.50 Ga old Gadag greenstone belt in Western Dharwar Craton contains a series of volcano-sedimentary assemblages. The assemblage is dominated by acid to basic through intermediate volcanic rock sequences with intercalated high-Mg basalts, ultramafic sills, shallow water clastic and chemical sediments. The associated polymictic conglomerates containing pebbles of gneiss, granites, quartzite, chert, banded iron formation, mafic to felsic volcanics and lithic-greywackes containing fragments of chert, quartzite, vein quartz and metavolcanics reflects a
sialic provenance with an arc and active continental margin type settings. The maturity index of the lithic-greywackes is very low (0.3) compared to the chlorite phyllites and quartz – sericite phyllites which are chemically immature.

The geological setting, associated rock types, their structure coupled with geochemical characteristics indicates through various tectonic discrimination diagrams that the lithic-metagreywackes have continental island arc + active continental margin; chlorite phyllites have continental island arc with oceanic island arc and the quartz sericite phyllites have active continental margin and passive margin tectonic settings, juxtaposed by accretionary processes. The gold mineralisation in the Gadag Gold Field, characterized by hydrothermal wall-rock alteration and quartz vein-sulphide mineralisation indicating greenschist facies mineral assemblages is closely related to shear zone channelized retrograde metamorphism, postdating the amphibolite facies peak regional metamorphism.

The Gadag Gold Field is composed dominantly of metabasalt in the western half of the belt and sediments in the eastern half. The sediments include greywacke, chlorite actinolite schists, BIF and quartz-sericite schists. Gold mineralization within the belt is associated with a number of prominent shear zones, striking NNW-SSE but with some deviations at places. The gold mineralisation is known from the many units of BIF and their contact with tuffaceous rocks. All known mineralisation is in the form of structurally controlled vein systems.

Hematite and magnetite lead the iron-rich layers, often accompanied by other metal oxides and sulphides such as pyrite and carbonates. Thick inter-beds of shale are also associated with the BIF. 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. This warrants a detailed study of Banded Iron Formations with sulphide mineralisation of the Nagavi area. Hence, this study concentrates on geology, geochemistry, Petrography, Mineralogy, Fluid Inclusion, Mineralisation and Remote sensing and GIS technology of BIFs of Nagavi area, which have been reported to be important carriers of sulphide mineralisation. This has created an inspiration to take up research work on the area.

Banded Iron Formations (BIFs) are the economically prominent lithounits of the Nagavi area hosting high grade iron ore deposits alongwith mineralised shear zones
and thickness varies from 0.5m to 2m. In Nagavi area the BIF strike is NW-SE direction and dipping towards NE (45° to 50°) and length is about 5 km in the study area and it continues further. The strata bound ore body is hosted primarily by BIF, which consists of alternating chert and magnetite, chlorite, sulphide, carbonate bands of millimeter to centimetre scale. Metabasalt exposures on both sides of the mound towards hanging wall as well as footwall side and quartz veins cut across the Metabasalts. In Banded iron formations (BIFs), the secondary structures observed are the deformational structures such as folds, faults, oolitic structures shear zones and thrust zones, which are induced by directional stresses. 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.

The petrography and mineralogical assemblages have played very important role in sulphide mineralisation in the Nagavi area. Thin section studies showing that the mineralogical assemblages of Quartz (40%), Opaque-iron oxide (50%), Carbonates (5%) and minor minerals Chlorite (5%). BIF is a very fine grained, banded with alternating Iron and silica rich bands. The rock is proportionately chertier and highly carbonated. These bands are mostly boudinaged and one band shows intrafolial folds. Pyrite is major mineral and it occurs as individual or aggregates of subhedral. It shows strong yellowish to greyish anisotropism and brownish cream to reddish brown bi-reflectance. The metabasalt one of the major lithounit in the study area and exposed few kilometers along both the hanging wall and foot wall side of the hill. The appearance of chlorite in the metabasalts and sericite in the greywackes / argillites implies the indication of regional grade of metamorphism or the green schist facies metamorphism. Large crystals of disseminated pyrite contain small inclusion of arsenopyrite observed in the metabasalt and also show mutual boundary texture with arsenopyrite which suggests simultaneous growth of these minerals. Pyrite occurs as characteristics cubic crystals and as clusters of small grains.

Geochemistry has played vital role in BIFs origin, especially Silica (SiO$_2$), Alumina (Al$_2$O$_3$) and Iron oxide (Fe$_2$O$_3$) along with MnO and P$_2$O$_5$. Based on the results of BIF samples (Wt. %) of SiO$_2$, Al$_2$O$_3$ and Fe$_2$O$_3$ content, the samples were analysed and grouped as Banded Hematite Quartzite and Banded Magnetite Quartzite. The silica content varies from 50.01% to 71.97%, alumina varies from 0.28 % to 1.64 % and Iron content varies from 24.63 % to 47.26%. The MgO varies from 0.06 % to
0.42%. The correlation of Al₂O₃ and CaO and alkalies suggests little input of feldspar in the BIF. The K₂O contents in BIF are highly variable depending on the degree of oxidation, ranging from about 0.03% to 0.06%. The distribution of aluminum fluctuates little with respect to alteration and the depletion in samples that have been chloritised and silicified-hematised is likely a reflection of the absence of alumina silicates and it is varying from 0.28% to 1.64%. These variations indicate that the extensive Fe exchange for Mg with increasing alteration.

The primary gold mineralisation of the Nagavi area consists mainly of quartz sulphide gold veins. The gold mineralisation is seems to be epigenetic because 1) it occurs in a zone of deformed rock associated with a large regional shear-zone structure, 2) it is restricted to zones of intense fracturing with discordant quartz sulphide veins, 3) textural evidence indicates that the replacement of primary magnetite by pyrite. The Au-bearing veins crosscut ferruginous quartzite which is interpreted as banded iron formations (BIFs).

Fluid Inclusion studies have played vital role in sulphide mineralisation in Nagavi area. Textural and microthermometric studies indicate that the heterogeneous trapping of a low-salinity (~3.6 wt. % eq. NaCl) aqueous fluid co-existing with a carbonic fluid. They are most likely heterogeneously trapped inclusions. These fluid inclusions are syngenetic, liquid bicarbonate aqueous salt and vapor-rich fluid formed due to immiscibility of H₂O –CO₂ – NaCl ±CH₄ ±N₂ proto fluid with a temperature and pressure drop. The homogenization temperatures of CO₂ range from 8.3⁰C to 30.0⁰C. Fracturing is greatly enhanced fluid circulation through the BIFs, allowing reaction of the sulphide-bearing fluids with the iron oxides. The petrographic study of wafers indicated the presence of primary and secondary mono-phase/bi-phase inclusions in the samples. The size of the vapour phase in the form of bubble ranging in size from 0.036 µm to 2.036 µm. In Micro thermometry method especially carbonic inclusion, the characters of the bubble indicate heterogeneous nature of the parent fluid. The inclusions are generally irregular and facetted and few are small and rounded. The size of inclusions varies from 1.43 µm to 60.9 µm. The Mono-phase carbonic (CO₂) fluid inclusions are transparent to dark. Carbonic fluid inclusions are more abundant than aqueous fluid inclusions in these samples.
The Remote Sensing and GIS technology played major role in analyzing data especially satellite imageries like Landsat ETM, LISS III and Cartosat DEM. The field data also correlating and super imposed on imageries. The Landuse Landcover map has been prepared through ERDAS software. The lineaments and auriferous sheared zones were identified through satellite imageries.