ABSTRACT

Most of the world's primary gold production comes from the Precambrian rocks and many of the major gold deposits are associated with various rock components of Archean greenstone belts. Although this association is clear, the reasons for this association are not, unlike Ni-sulfide deposits which are reasonably well understood. An understanding of this aspect is fundamental both to exploration of these ores and to our knowledge of Archean supracrustal geology.

Gold mineralization in the Archean Kolar Schist Belt of the Dharwar Craton is very well known. However, the origin of this important deposit in terms of source, transport and depositional mechanisms of gold is not known. As a part of our major research on the relationship between petrogenesis and ore genesis in Archean greenstone belts, we have chosen the Kolar Schist Belt for our study. One of the objectives of our research on the Kolar gold deposits is to characterise the mineralogy and geochemistry of individual ore lodes and to evaluate the geological and geochemical processes responsible for this important gold deposits in India. The result of
this may potentially be very useful to evaluate other greenstone belts in India for their gold mineralization.

The Kolar Schist Belt is one of the eastern-most, Archean, volcanic-dominated belts of the Dharwar Craton of South India. Although sporadic occurrences of gold is reported in all the greenstone belts of the Dharwar Craton, economic concentrations of gold is particularly confined to the eastern belts such as the Kolar, Ramagiri and Huti, of which Kolar is by far the most significant. The Kolar belt is a N-S striking, linear (80 x 4 km), multiply folded synform with a northerly plunge and is sliced by three sets of major fault systems. The belt is dominated by several units of mafic volcanics of which some could have been derived by partial melting of an incompatible element enriched mantle sources (Rajamani et al. 1985). Banded iron formation occurs as continuous ridges along the western margin of the belt and also occurs as discontinuous patches on the eastern margin and within the belt. A felsic volcanic unit called the 'Champion Gneiss', which is believed to be derived from low per cent melting of komatiitic rocks occurs
along the eastern margin of the belt. The belt is surrounded by granitic gneisses and all the rock units in and around the belt have undergone a middle amphibolite facies of metamorphism. Gold occurs here as gold-sulfide lodes and as gold-quartz-carbonate veins associated virtually with all the rock components of the belt. The belt can be divided into three parts along the strike namely, northern, central and southern parts. Dominant mineralization and extensive mining is confined to the central part. New lodes with economic concentrations of gold have been discovered in the southern part, whereas in the northern part mineralization appears to be rather poor and uneconomic.

In the central part of the belt (the Kolar Gold Fields) there are several gold lodes occurring both as gold-quartz-sulfide lodes associated with banded iron formation which are interlayered with amphibolites and as gold-quartz-carbonate lodes associated with amphibolites. There are several sulfide lodes which are commonly confined to the stratigraphic contacts. They grade into unmineralised sulfide iron formation towards west, which are associated with several bands of graphitic-sulfidic schists.
In the southern part of the belt gold occurs as sulfide lodes associated with the banded iron formation within amphibolites and as gold-quartz-lode associated with felsic volcanics. In northern part gold occurs as auriferous carbonaceous sulfidic chert associated with amphibolites.

In the central part of the belt (KGF area) several stratiform gold sulfide lodes occur on the western side of the belt. These lodes have a maximum of 10 m in width and extended for a few kilometers along the strike. These lodes are parallel to each other and in turn parallel to the schistosity of the host rocks. These lodes consist bands/layers of sulfide, oxide and cherty-quartz and the width of these bands decreases towards the western margin of the belt. The proportion of magnetite decreases and that of sulfides increases towards the western margin. Pyrrhotite and arsenopyrite are the dominant sulfide minerals in all the lodes. Loellingite, sphalerite and chalcopryrite occurs as minor phases. The westernmost lode has relatively higher amounts of sphalerite and chalcopryrite and lower amounts of arsenopyrite. Arsenopyrite occurs as euhedral crystals and are highly deformed. Gold commonly occurs as patchy inclusions
mostly in deformed arsenopyrite crystals. Gold also occurs as large subrounded inclusions in silicates. In addition to these minerals, many samples contain discrete ilmenite grains. The sulfide lodes in general have lower gold than quartz-carbonate lodes. Among the sulfide lodes in the central Kolar Schist Belt, there seems to be some positive correlation among arsenopyrite, magnetite and gold. For example, the westernmost lode has lower arsenopyrite and magnetite and much lower gold. This lode has higher abundances of Ni, Cr and base-metals. This lode also has higher TiO₂, Al₂O₃, and K₂O compared to eastern sulfide lodes.

In the central Kolar Schist Belt, the dominant gold mineralization is associated with quartz-carbonate lodes on the eastern side of the belt. These lodes are essentially fissure-veins and have sharp contact with the host rock. The lode system is generally parallel to the strike of the belt extending for several kms. Individual veins are usually less than 1 m in width and cut the schistosity in many places. These lodes appear to be in en echelon branching sets, terminate abruptly and pick up after some interval. The lodes consist of predominantly
of quartz with significant quantities of carbonate and minor amounts of tourmaline, biotite. They also have trace amounts of sulfides mostly galena, pyrite, sphalerite, pyrrhotite and chalcopyrite along with gold and scheelite. These lodes have anomalously higher concentrations of Cr and Ni.

In the southern part of the belt gold mineralization is present in association with sulfide facies of banded iron formation, amphibolites and with felsic volcanics. Here sulfide lodes seem to be more prominent, although gold-quartz lodes are also known to occur within the Champion Gneiss. The gold-sulfide lodes have higher proportions of sulfides, and are well crystallised. The lode associated with banded iron formation at Mallappakonda is well banded. It includes monomineralic layers of large crystals of arsenopyrite and has the highest arsenopyrite content among the sulfide lodes in the belt. However, this lode does not have the highest concentration of gold. Here gold occurs as inclusions in deformed arsenopyrites and also in silicates. The sulfide lodes associated with amphibolites are massive and net-textured sulfidic-chert. The dominant sulfide mineral is pyrrhotite with minor amounts of pyrite,
chalcopyrite, galena and sphalerite. Gold occurs as inclusions in chalcopyrite and also in silicates. Arsenopyrite occurs in trace amounts. However, these lodes have higher concentrations of gold relative to the arsenopyrite-rich lodes of the belt. They also have relatively higher concentrations of base metals.

The temperatures of final equilibration of the mineral assemblages in various lodes were estimated from the arsenic content of arsenopyrite (Kretschmar and Scott, 1976). The estimated temperatures are 540°C and 480°C for southern arsenopyrite dominated lodes and the central sulfide lodes respectively. These estimated temperatures are in agreement with the middle amphibolite facies of metamorphism of the host rocks inferred from the mineral chemistry of calcic-amphiboles (Rajamani et al. 1981).

The disposition of gold-sulfide lodes parallel to each other and to the general schistosity of the multiply-folded amphibolites, their intimate association with banded iron formation which in turn are associated with amphibolites, the interbanding of sulfides and oxides in the ore lodes and their textural features all seem to suggest a syngenetic origin for the sulfide lodes. The deposition of banded iron
formation and auriferous sulfides seem to be contemporaneous, the latter probably deposited from convective hydrothermal solutions reaching the sea-floor. The topography of the sea floor and the depth of the seawater seem to have controlled the amount of the sulfide and their associated gold. Deep water facies seem to have lower gold, arsenic and higher concentration of sulfides and base metals as suggested by Fripp (1976).

There seems to be no correlation between arsenopyrite contents, gold and base metal concentrations among the various sulfide lodes of the entire Kolar belt, perhaps suggesting that all the lodes are not related to a single geothermal system. However, the uniformity in the mineralogical and chemical composition of all the sulfide lodes suggests that the ore solutions responsible for the deposition of these lodes could be broadly similar in their chemical composition. The minor variations in their mineralogy and chemistry are probably due to local variation in the physico-chemical nature of ore solutions and/or in the environment of deposition. The general paucity of base metals, and the preponderence of silica and
Fe, lower concentration of gold, in all the sulfide lodes of the belt probably implies the involvement of relatively low-temperature, high-pH hydrothermal solution related to a low water/rock ratio geothermal systems, in the transportation and deposition of gold.

The gold-quartz-carbonate lodes in the central part of the belt differ in their field disposition, geometry, structural features and in their mineralogical makeup from that of gold-sulfide lodes. In contrast to the gold sulfide lodes, the gold-quartz-carbonate lodes have unusually higher concentrations of Ni and Cr. The association of high Ni and Cr values with that of high gold values and low abundances of galena-dominated sulfides suggest that the chemical nature of the fluids involved in their transport were probably different and were enriched only in H$_2$O and CO$_2$, containing some carbonyl complexes which are potential carriers of Au, Cr, W, Si with little sulfur (Hutchinson and Burlington, 1984). This hydrothermal system may have been related to post-metamorphic processes and perhaps genetically related to the intrusion of sub-volcanic equivalent of the Champion Gneiss. Precipitation of gold occurred when the gold-rich, uniform, fluid-reservoir
reached gold saturation perhaps by reaction with country rock amphibolites.

Thus, there are at least two contrasting types of gold mineralization in the Kolar belt. Sulfide lodes could be relatively older than the quartz-carbonate veins. It is possible that these two types of gold deposits may not have any spatial relations at the time of their formation.