CHAPTER 2

GEOLOGY OF THE RAMAGIRI SCHIST BELT

2.1. PREVIOUS STUDIES

The Ramagiri Schist Belt (RSB) is one of the gold mineralized schist belts in the eastern Dharwar craton (Fig. 1-1). Detailed descriptions of the geology of the area have been given by Krishnamurthy (1960), Ghosh et al. (1970), Chaudhari (1986) and Ramakrishnan and Sundaravanan (1990). The emphasis in most of these studies was towards understanding the gold mineralization.

The Ramagiri gold bearing schist belt is located on the state border between Andhra Pradesh and Karnataka in the Ananthapur district of Andhra Pradesh. The area is accessible by road and by rail from both Bangalore and Hyderabad.

The belt extends for about 50 km in length from Penukonda in the south to north of Kanaganapalle in the north (Fig. 2-1). In the central part of the belt where the present mining activity is concentrated (Fig. 2-2), the belt is about 4-5 km wide. The belt is bifurcated into trident shape with the western arm running to the west of Ramagiri village in the form of a ridge and trends roughly north-northwest. The central arm is wider than the other arms and hosts the gold mineralization. This arm takes a north-northeast trend south of Chennabhavi area. The eastern most
Fig. 2-1 Geological map of Ramagiri schist belt, after Ghosh et al. 1970.
Fig. 2-2  Geological map of Ramagiri area, modified after Ghosh et al. 1970.
arm is less than a kilometer wide and runs north-northeast, and it virtually disappears near Kuntimadi village. The three arms of the belt join together at south-southeast of Ramagiri village and the belt narrows down towards further south. The belt is discontinuous from Mushtikovila to further south to Penukonda.

The belt includes a spectrum of rock types such as intensely folded greenstones, amphibolites, sheared metagabbros, phyllites, chlorite schists and ferruginous quartzites. Ghosh et al. (1970) reported the occurrence of an ultramafic body at the southern end of the belt which is altered to steatite along its contacts with the other rock types. The mineralization is confined to phyllites within the metabasalts along the highly sheared central part of the belt. Pillowed metabasalts, mafic and felsic tuffaceous rocks grading into ferruginous quartzites were also reported by all these previous workers. They implied a subaqueous environment for the emplacement and/or deposition of these rocks. Krishnamurthy (1960) mentioned "the occurrence of two parallel schist belts at Ramagiri, connected to each other in the south..." without detailing the reasons for considering it so.

Krishnamurthy (1960) and Ghosh et al. (1970) considered the western-most arm of the Ramagiri schist belt to be a closed syncline trending N-S and the area occupied by the Ramagiri granite to be the core of a southerly plunging anticline. The steeply dipping foliations and steeply
plunging lineations in the sheared amphibolites and schists on either side of the Ramagiri granite supported their arguments. They also considered the mineralized part of the belt to be the core of a north-south trending syncline. The more open antiform around Cherlapalle area had been recognized by all these workers. Quite pervasive, but non-uniform shearing of all the belt rocks which, at places produces phyllites and shear foliations, also had been reported by these workers. The last geological event in the area appears to be the emplacement of east-west trending dolerite dykes.

Ramakrishnan and Sundaravanan (1990) studied a suite of coarse grained rocks from the eastern part of the belt and considered them to be four differentiated units of a gabbroic sill in association with a quartz-diorite body.

Although some data is available on the chemistry of the belt rocks, no serious effort has been made so far to understand the metavolcanics in a larger perspective. Ghosh et al. (1970) provided geochemical data on metabasalts and phyllites and considered them to be of andesitic affinity. These rocks are thought to overlie pyroclastics and impure calcareous sediments, now metamorphosed to amphibolites. The field evidence for this inferred order of superposition has not been cited. Chaudhari (1986) provided more data on the massive metabasalts and considered the Ramagiri metavolcanics to be a group of iron rich tholeiites, derived from an evolved magma, ranging in composition from basalt to
andesite. The compositional spectrum was attributed to olivine and clinopyroxene fractionation. He pointed out the similarity of Ramagiri volcanics to those of the gold bearing Hutti schist belt, both of which are different from those of the Kolar schist belt.

The gold mineralization in Ramagiri schist belt has been known for centuries and the present mining is simply reopening of ancient mined areas. Historically, the most productive mines in this area were Jubital in the south and Chennabhavi in the north (Krishnamurthy 1960) although both of them are now abandoned. The producing mines are situated in the central part of the belt (Fig. 2-2) and are known to produce about 4 gm/ton (Dr. Mayagiri, personal communication).

Krishnamurthy (1960) recognized the main mineralization to be of gold-quartz vein type with highly variable tenor. The veins occur in an en-echelon fashion within the central zone of phyllites, following en-echelon fractures in massive metabasalts. Ghosh et al. (1970) confirmed this geometry and localization pattern for the mineralization. They suggested that chemical reconstitution of metabasalts and associated sediments released enough silica which formed quartz veins in phyllites - the reconstituted basalts. They suggested that the gold also was released and concentrated from the andesitic parent rock rather than from any outside lithologies and suggested a lithogene origin for the gold mineralization. The chemical reconstitution of host
Rao and Srinivasan (1971) in a comment to Ghosh et al. (1970) suggested the source of gold to be hydrothermal solutions rather than the host mafic rocks. Their argument was supported by the high volatile content of the Ramagiri schist belt rocks and the generally low gold content of basaltic rocks. They suggested a magmatic hydrothermal origin for the Ramagiri gold mineralization, which probably had occurred in different pulses as evidenced by several generations of quartz and carbonates.

2.2 PRESENT STUDY

The objectives of the field study were to

1. identify different kinds of metavolcanic rocks in the belt, their field relations, nature and intensity of alteration;
2. to collect rock samples for geochemical studies and,
3. to understand the geological relation between the metavolcanics and granitic rocks.

Field work was carried out and observations were made for about 25 km along the length of the belt from Jubital in the south to north of Balepalem in the north and Kuntimadi in the east to Gangampalle in the West (Fig. 2-2). More detailed field work was done from Jubital to Chennabhavi to understand the relationship between different rock types. Detailed sampling of different textural varieties of well rich in CO₂ and H₂O.
characterized rocks were done for petrogenetic studies.

The belt consists of variably foliated metabasaltic rocks of dominantly fine to medium grain size. Coarse grained amphibolite also occurs without any observed gradational relationship with the massive type. Another variety of very coarse grained amphibolite (Fig. 2-3, plate 1) is found as a linear body along the central part of the belt. A textural variety of this rock type is found to be intruded by a finer grained less mafic rock (Fig. 2-4, plate 1). Highly sheared and foliated granite, chlorite schist and phyllite occur in juxtaposition with the metavolcanics. A less deformed but altered massive ultramafic body is present at the south-western part of the belt. Small but mappable units of less deformed metabasalts with well preserved pillow structures are found surrounded and intruded by granites near Muttavakuntla (Fig. 2-5 and 2-6, plate 2). Banded ferruginous quartzite occurs along the margins of the belt with gneisses. It also occurs as small multiply folded and boudinaged bodies within the belt (Fig. 2-7, plate 3). It is associated with fine grained and layered volcaniclastic material (Fig. 2-8, plate 3), south of Akkampalle. A small body of an intermediate rock with large phenocrysts of plagioclase (Fig. 2-9, plate 4) is found associated with coarse grained amphibolite in the central part of the belt. Quartz veins, aplitic veins and dominantly east-west trending dolerite dykes intrude the belt rocks at several places.
The belt rocks are surrounded on the western and eastern sides by granodioritic gneisses. The gneisses on the east are multiply deformed and sheared and the contact of the belt with the gneisses is highly sheared and mylonitized. The western side of the belt has several varieties of less deformed granodioritic gneisses. The contact between the western gneisses and the belt also is highly sheared. Shearing on the western gneisses is more localized compared to eastern side.

There are several bands of highly sheared and foliated granite within the belt. The shearing seem to have been highly intense. The granites are powdered and mylonitized and at places the contact between sheared granite and metavolcanics have been fused giving rise to what appears to be like pseudotachylite (Fig. 2-10, plate 4).

The rocks of the belt are commonly well foliated. Foliation is marked by preferential orientation of minerals, and the foliation planes roughly trend N-S, and dip very steeply. Mineral lineations are observed in the well foliated chlorite schists and are found to plunge steeply. Kink bands and very small folds (Fig. 2-11 and 2-12, plate 5) found in the schistose rocks also are found to plunge very steeply. Metabasalts when sheared are found to develop two sets of fracture cleavages intersecting at small angles, and are sub-parallel to the general foliation of the belt rocks. (Fig. 2-13, plate 6).
The presence of felsic veins, intimately associated banded ferruginous quartzites and volcaniclastics are of enormous help in deciphering the tectonic history of the Ramagiri belt. The closure of a southerly plunging (approximately 30° due south) tight overturned fold is observed in hornblende schist in the eastern-most arm of the belt, east of Polepalli village. But the folds of this generation are not represented in the associated ferruginous quartzites. Another generation of open southerly plunging (approximately 50° due south) antiformal folds are found south of Akkampalli village. In the closure area of this generation of folds, the foliation trends roughly east-west. These folded foliation planes could be layering of the iron formation or the axial plane foliation of a previous generation of folds mentioned above. In the latter case, F₁ and F₂ are coaxial folds. The second generation of folds probably were formed in response to some shearing movements. This is supported by the presence of sheath folds in banded iron formation (Fig. 2-14, plate 6) and sheared, folded and boudinaged felsic veins in hornblende schist (Fig. 2-15 and 2-16, plate 7). The last generation of folds are broad folds with east-west trending axial planes (Fig. 2-17, plate 8) and they refold the whole eastern part of the belt, west of Cherlapalle (Fig. 2-2). The third generation of folds refolds the second generation and produces interference patterns (Fig. 2-18, plate 8).
The Ramagiri granite occupying the gap between two arms of the Ramagiri schist belt appear to be made up of composite intrusions and have several textural varieties. Near Muttavakuntla, the coarse grained Ramagiri granite is found to have elongated bodies of basaltic rocks with well preserved pillow structures (Fig. 2-5 plate 2). The granite is found to intrude these well preserved pillows (Fig. 2-6 plate 2). Compositionally, these pillowed metabasalts are similar to other basaltic rocks of the belt, which occasionally have relict pillow structures preserved in them. Thus, the shearing which affected the whole belt probably was syn- to post-granite intrusion.

The intensity of shearing appear to be localized, and is exhibited by highly schistose rocks within the belt. The metabasalt when highly sheared, are found to transform into chlorite schist and to phyllite. Although this conversion is textural and mineralogical, it appears to be a manifestation of the intensity of shearing and closeness of shear fractures too. There are more than one set of fractures, probably related to shearing which intersect the dominant foliation at small angles (Fig. 2-13 plate 6), and are therefore, sub-parallel to the dominant foliation. When these shear fractures are widely spaced, lozenge shaped, relatively undeformed massive metabasalts are found interleaved, within highly sheared, schistose and chloritised rocks (Fig. 2-13 plate 6). This brittle-ductile deformation is quite pervasive and is found in all scales. This could be responsible for
the large diamond shaped bodies of massive basaltic units surrounded by schistose rocks near Jubital area. They also provide excellent opportunities for geochemical sampling.

In the central part of the belt, where there is gold mineralization, the basaltic rocks are highly sheared and have been converted to highly fissile rocks which hosts the auriferous quartz veins. With respect to this sheared central part of the belt, the metavolcanic rocks towards the western side are generally of one type. They are massive except where sheared and are fine grained. A coarser grained spotted variety is also found at places. As will be discussed later, rocks of this western side are similar in composition too. This part has a serpentinized ultramafic body with cross-cutting serpentine veins. Thin bands of carbonated ultramafic rocks are found to occur along the strike of the main ultramafic body. There are two major, probably tectonically interleaved, sheared granite units separating the metavolcanics of the western part.

The eastern side of the mineralized central part of the belt consists of a variety of rock types. Different textural varieties of amphibolites, several bands of varying dimensions of sheared granites, phyllites, felsic dykes, plagioclase porphyritic rocks and volcanoclastics associated with banded ferruginous chert are found in this part of the belt. Compositionally, as well as in lithological association and disposition, the east-central part of the belt appears to be different from the western block. Further
to the east of the east-central block, the rocks are essentially fine to medium grained hornblende schist with intercalated ferruginous quartzites. This rock is finely layered or laminated giving the appearance of metamorphosed volcanioclastics with which it is associated at places.

Our observations suggest that phyllites of the Ramagiri schist belt do not belong to any single rock type and probably were derived from different rock types. One variety of dark grey phyllite has gradational contact with metabasalts and compositionally also, they are similar to a great extent. The other variety of light grey phyllites are highly sheared granite. They are distinctly different from the mafic rocks of the belt and are similar to granites in major-, trace- and rare-earth element compositions. They do have less altered felspar grains at places. But it is not clear which type of phyllite hosts the gold mineralization, since the phyllites of the belt were treated as one single rock type by the previous workers.

Amphibolites or their retrograded equivalents are the dominant rock types of Ramagiri schist belt. Wide spread post-metamorphic alteration characteristic of ancient mafic-ultramafic rocks in the form of serpentinization, carbonization, chloritization and epidotization (Condie 1981) are observed in Ramagiri schist belt. The ultramafic body especially sheared portions of it occurring as thin bands are found to have undergone intense serpentinization, carbonization and chloritization whereas, the metatholeiites
show limited carbonization and epidotization locally in areas of intense shearing. The sheared and mylonitised granitic rocks present at several places within the belt are to be seriously considered to understand the geological evolution of the 'Ramagiri schist belt'.

Another better studied auriferous belt, the Kolar schist belt, occurring about 200 km south-southeast of Ramagiri in the eastern Dharwar craton is different from the Ramagiri belt in this aspect. Whereas Ramagiri schist belt has a spectrum of rock types, phyllites, chlorite schists and amphibolites with intercalated sheared granite units, Kolar belt has only different textural varieties of amphibolites, and rocks are of amphibolite facies. The presence of several bands of highly sheared granitic bodies separating the basic rocks, highly sheared tectonic contact with the surrounding gneisses and an assemblage of rocks of diverse origin and characters in the Ramagiri area poses a serious question as to whether it can be called a schist belt sensu stricto. The present Ramagiri belt appears more like a tectonic melange put together constituting rocks of diverse origin and characters by tectonic processes.

For the purpose of petrogenetic study we will consider only the dominant mafic rock types of belt; namely, massive amphibolites of the western part, coarse grained amphibolites of the east-central part, hornblende schists of the eastern side and the ultramafic unit. Other lithological units such as ferruginous quartzite, sheared granite and felsic dykes
are not discussed here.

2.3 PETROGRAPHY

Ultramafic Rocks

There are 3 varieties of ultramafic rocks occurring along the south-western part of the belt. The first one is a medium grained massive rock without any preferential orientation of minerals. This rock is made up essentially of low relief low birefringent serpentinite, occupying well preserved polygonal, relict, olivine crystal outlines (Fig. 2-19, 2-20 and 2-21, plates 9 and 10). The olivine crystal outlines are marked by very fine grained opaques, which may be magnetite similar to what was reported from Komati formation of south Africa (e.g. Condie 1981). There are veins of fibrous serpentine criss-crossing, mainly along relict crystal outlines. There is no other major mineral constituent, except for opaque minerals which could be magnetite or chromite.

The massive serpentinite is variably weathered. Where there are patches of carbonates the rock becomes very light in weight. Alteration gives rise to another variety of ultramafic rocks, which has approximately equal amounts of medium relief, low birefringent, medium grained crystals of well crystallised carbonate and finer grained fibrous talc (Fig. 2-22, plate 10). This talc-carbonate rock at places have bands of opaque mineral(s), and has somewhat well developed foliation marked by fibrous talc(Fig.2-22 plate 10)
The other variety of ultramafic rock from this area is also a monomineralic rock. This rock is made up essentially of greyish green coloured, low relief, low birefringent, medium grained chlorite. This rock is highly weathered and sheared at places and thus, development of foliation is highly variable. Opaques are present and are found to be concentrated at places. The massive serpentinite definitely has some original igneous texture still preserved in it in the form of relict crystal outlines. The absence of any other crystal form, other than that of olivine would suggest that this was a monomineralic rock to begin with, which later got sheared and altered to different degrees to give rise to different varieties. The talc-carbonate rock probably was derived from the precursor to serpentinite by alteration where CO$_2$ was freely available. But the chlorite rocks do not have any igneous textures preserved in it and probably was formed in response to metamorphic and alteration processes, commonly found in ancient mafic-ultramafic rock associations(Condie 1981).

**Massive metabasalt**

Massive metabasalt is a fine grained rock although medium grained varieties are also found. Generally, the grain size is so low (Fig. 2-23, plate 11) that the rock is nearly aphanitic. When the grain size is large enough to recognize the minerals, amphiboles, chiefly pale green slightly pleochroic actinolite is found to make up major part of the rock. Plagioclase content is variable but
generally do not exceed 30 per cent. Quartz is present in small amounts only.

This rock type has undergone considerable deformation. The fine grained texture is probably, an original igneous texture, but it is equally possible that some granulation occurred during shearing also. Minerals, wherever can be recognized, lack definite crystal habit. There is development of preferred orientation of minerals, at places of stronger shearing (Fig. 2-24, plate 11). Plagioclase is found altered at places, to sericite. Chlorite, carbonate and epidote are common post metamorphic alteration minerals in this rock, which are common in ancient mafic rocks (Condie 1981). When the shearing and associated alteration are extreme, the amphibolite becomes chlorite schist and phyllite, consisting essentially of chlorite, carbonate and quartz as described above. Other accessory minerals and opaques are not common.

The rock type is generally fine grained and it may be the effect of shearing undergone as well. There was not much of recrystallisation during deformation, as exhibited by the lack of preferred orientation of minerals with definite crystal habit. But reconstitution of original basalt mineralogy as shown by the presence of epidote, chlorite and carbonates is found in areas of intense deformation.

The basaltic rocks exhibiting well preserved pillow structures, found near Muttavakuntla are essentially made up
of randomly oriented amphiboles and fine to medium grained plagioclase (Fig. 2-25, plate 12). This rock type also shows alteration at places. Opaques and other accessory minerals are rare.

Coarse Grained Amphibolite:

The east-central part of the mineralized area of the Ramagiri schist belt has narrow but mappable elongated bodies of coarse grained amphibolite. As one moves to the eastern part of this body, the degree of deformation increases, but the general mineralogy and grain size remains more or less the same.

The coarse grained amphibolites in general, have 60-65 per cent of the rock constituted by very large (more than a centimeter across) actinolite porphyroblasts (Fig. 2-26, plate 12) characterised by slightly pleochroic, pale green crystals with well developed cleavage and an extinction angle of 11°-12°. Hornblende phenocrysts are also observed. The ground mass is constituted by approximately equal amounts of amphiboles and felspars. Plagioclase phenocrysts also are observed occasionally. Myrmekitic intergrowth is observed in several sections. Opaques are generally rare, but are found to form patches at places. There are several varieties of this coarse grained amphibolite. Although present, undeformed variety of this rock is rarely observed. As the degree of deformation increases, the rock gives a totally crushed appearance under the microscope (Fig. 2-27, plate
with truncated and granulated amphibole grains set in a matrix of fine grained amphiboles and felspars. As the degree of recrystallization also increases, the matrix is found to recrystallize into fibrous amphiboles, chlorite and elongated crystals of felspars, and they swerve around sub-rounded porphyroblasts (Fig. 2-28, plate 13). Although preferred orientation is generally absent to crude in this rock type, when the degree of deformation and recrystallization increases, they exhibit pronounced preferred orientation and the foliation planes are marked by recrystallized matrix separated by stretched and elongated porphyroblasts (Fig. 2.28, plate 13).

In more deformed and recrystallised varieties, the crushed and altered amphiboles are found to have patches of some alteration product. There are instances where, the whole amphibole grain has been transformed, while retaining the original crystal outline. Carbonate grains are found at places especially, where there is intense deformation and granulation. Epidote grains, although few, are also observed.

Hornblende Schist:

The eastern part of the mineralization and the eastern-most arm of the belt (Fig. 2-2) have fine grained thinly laminated rocks. These rocks are closely associated with the bordering banded iron formations and fine grained, thinly laminated volcaniclastics.
Under the microscope, this rock type shows alternating layers of mafic and felsic minerals. The mafic layers are made up of fine grained, preferentially oriented grains of slightly pleochroic, pale greenish hornblende. It constitutes about 50 per cent of the rock. The felsic layers are made up of fine grained felspars and quartz (Fig. 2-29 and 2-30, plate 14). There are occasional thicker bands of quartzo-felspathic material too.

The deformation undergone by this rock is well exhibited by the extreme laminated nature. The grains are well recrystallised and the cleavage of hornblende grains mark the foliation, which is parallel to the alternating layers of mafic and felsic minerals. This rock probably is a more recrystallised variety of the associated volcanioclastics, but in chemical characteristics, they are similar to the massive metabasalts of the neighbouring parts of the belt.

Carbonates and epidote grains are occasionally found and opaques are generally rare.

**Chlorite Schist:**

This is a medium grained rock with well developed schistosity marked by sheared and elongated minerals. Approximately 50 per cent of the rock is made up of yellowish green low birefringent fibrous laths of chlorite. Approximately 30 per cent is made up of subrounded and elongated, medium to coarse grained quartz and plagioclase.
Fine grained felspar is also present. Chlorite fibres are found to swerve around sub-rounded felspar grains. At places, there are bands of well crystallized and twinned coarse grained carbonates. The carbonate content is quite variable and it reaches even 30-35 per cent of the rock in some thin sections. Amphiboles are totally absent.

There are mineralogical and textural varieties of this schistose rock, where carbonates (Fig. 2-31, plate 15), sericite or felspars (Fig. 2-32, plate 15) dominate. Quartz is generally not found but there are pods of deformed and fine grained quartz at places. Irrespective of the dominant mineral present, this rock type is invariably highly sheared and altered.

**Phyllites**

As mentioned earlier, there appears to have two different types of phyllites, not only in terms of colour but compositionally and texturally also. The light grey coloured variety has subangular to subrounded phenocrysts of quartz and felspar set in a matrix of fine grained quartz and felspar. Occasionally, thin bands of fibrous chlorite are also observed. The deformation undergone by this rock type is well exhibited by the subrounded nature of the phenocrysts and the developed foliation (Fig. 2-33, plate 16).

The other variety of dark grey phyllite is nearly aphanitic and well foliated (Fig. 2-34, plate 16). This has textural as well as compositional similarities to some of the
metabasalts of the area. The foliation is marked by the compositional layering of light grey and dark grey bands. Fine grained opaque minerals occur as thin bands in microscopic scale.