CHAPTER 7

MINERALISATION OF THE GREENSTONE BELT
7. MINERALISATION OF THE GREENSTONE BELT.

7.0.0. GOLD MINERALISATION:

7.1.0. GENERAL:

Ramagiri is known for the mineralization of gold since a long time. The ancient workings of the Ramagiri are considered to be 2,800 to 4,000 years old by archeologists. The location of gold mines is also shown on the topographical maps. Extensive mining activity was carried out by different companies including BGML. As the gold appears to have been exhausted the mining activity by BGML also has been stopped. All over the world gold is known to occur in the greenstone belts, with a few exceptions. Though the gold mineralization is not the prime object of the thesis, it is given as the author has looked into the matter deeply.

7.2.0. STUDY OF THE GOLD DEPOSITS:

Gold deposits can be broadly studied under the following heads (Hutchinson 1987).

I. Age Relations
II. Lithological Associations
III. Stratigraphic Relations
IV. Ore and Geochemical Relations.

The gold mineralization in respect of Ramagiri is studied under the above stated heads to the extent possible.

Gold loads are more important in late Archaean belts than in early Archaean belts and much less in similar early Proterozoic belts (Hutchinson 1987)

I. **Age Relations**: The Ramagiri Greenstone Belt is Archaean in age and exhibits all the Kewatian characters.
II. Lithological Association: The mineralization is in the ortho (basic) metamorphic rocks like pillowed, variolitic, tholeiitic and komatiaitic basalt. Further, contact between two lithological units and quartz veins. Ramagiri and the other gold bearing greenstone belts like Kolar, Huttin-Muski and Jonnagiri have similar lithological set up, i.e., ortho - metamorphic rocks, namely, amphibolites, chlorite schists and phyllitic rocks. This set up is similar to Western Australia, where the gold mineralization is associated with the altered lavas. The set up in the Ramagiri gold field is not different.

III. Stratigraphic Relations: Gold is seen in the stratigraphical middle basic horizons in Ramagiri, Jonnagiri. In the Chigarakunta/Bisanattam, it occurs in the middle basic units and stratigraphically acidic upper units. The basic units are considered as the primary hosts and the acidic ones as the secondary hosts.

IV. Ore and Geochemical Relations: Ore occurs in stratiform, discordant and in the form of stockworks. The geochemical aspects are beyond the scope of the present work.

7.2.1. Some views on gold mineralisation

7.2.2. Gold Mineralisation vs Lithologies:

Anhaeusser et al (1969) stated that most of the primary gold deposits of the world are confined to greenstone belts and the mineralization is related to the greenstone themselves. It implies that that the gold was inherent to the basic volcanic rocks and later mobilized within them only.

Gold content in basalts, andesites and diabases is higher than the felsic members (Gottfried et al 1969).

Gottfried et al (1972) did extensive work on the 'Distribution of gold in igneous rocks'. Their work has indicated that
i. The highest gold content normally occurs in the basaltic and andesitic members of the calc-alkaline associations.

ii. Rhyolitic rocks of calc-alkaline series and those of alkali affinity are uniformly low in gold content.

iii. In the alkali provinces all rock types (low CaO and high NaO), irrespective of composition are low in gold content.

Jones (1969) expressed the view that the gold content is inversely proportional to the rock basicity in volcanic rocks but directly proportional in plutonic rocks. In the opinion of the author of the present work, the first part of the statement of Jones (1969) still holds good.

Considering the views expressed by Jones (1969) and Gottfried et al (1972), the paucity of gold occurrence in the greenstone belts of Andhra Pradesh can be explained as documented below.

In respect of gold mineralization the greenstone belts of Andhra Pradesh can be classified as i. Known for the occurrence of gold and ii. Known for non-occurrence of gold (on commercial value). The possible reasons for the non-occurrence of gold in certain belts as viewed by the author of the present work are presented in the table 7.1.

7.2.3. The role of quartz veins in the gold concentration:

Gold mineralization is common along the shear zones that have affected the greenstone belts. Ramagiri is no exception. In addition, the 'carriers' in the form of 'smoky quartz' also have played their role in the concentration of gold mineralization.
Table 7.1: Table showing the gold bearing and non-bearing greenstone belts of Andhra Pradesh

<table>
<thead>
<tr>
<th>Greenstone belt with the known occurrence of gold</th>
<th>The possible reasons</th>
<th>Greenstone belt with the non-occurrence of gold</th>
<th>The possible reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ramagiri-Penakacherla</td>
<td>1. The higher percentage of basic volcanic having the disseminations of sulphide (gold). Acid component is much less. 2. The suitable loci in the form of shear zones, wall rock alteration and abundance of smoky quartz. 3. The carriers of gold have mobilized it at suitable places.</td>
<td>Ramagiri-Penakacherla</td>
<td>1. Though basic and acidic volcanic are present, the original disseminations of gold are of academic interest. 2. Even if suitable loci are present in the form of shears etc, as there was insignificant to nil occurrence of gold, there is no concentration of it.</td>
</tr>
<tr>
<td>Jonagiri</td>
<td>1. The higher percentage of basic volcanic having the disseminations of sulphide (gold). Acid component is also present. 2. The suitable loci in the form of shear zones, wall rock alteration and abundance of smoky quartz. These features extend into the acidic rocks. 3. The carriers of gold have mobilized it at suitable places. 4. The acidic rocks are considered as secondary hosts.</td>
<td>Jonagiri</td>
<td>1. Not even of academic interest</td>
</tr>
<tr>
<td>Chigragunta / Bisanattam</td>
<td>1. The higher percentage of basic volcanic having the disseminations of sulphide (gold). Acid component is also present. 2. The suitable loci in the form of shear zones, wall rock alteration and abundance of smoky quartz. These features extend into the acidic rocks. 3. The carriers of gold have mobilized it at suitable places. 4. The acidic rocks are considered as secondary hosts.</td>
<td>Chigragunta / Bisanattam</td>
<td>1. It is the stratigraphic top of the Kolar Belt. 2. It has extensive acid volcanic and very insignificant basic volcanic. 3. It means there are no suitable rocks hosting gold mineralization. 4. Though shear zones are present gold is of academic (or nil) interest only.</td>
</tr>
</tbody>
</table>
In the Ramagiri area, there are three types of quartz veins, i. Pure white quartz, ii. Brown quartz with carbonate and iii. Smoky quartz. It is mainly the smoky quartz that shows more chemical affinity to the gold. Hence, more concentration of gold is seen with the smoky quartz.

The pure white and the brown quartz are normally noticed at outcrop level easily. But the smoky variety is more abundant at depth in the mines.

The origin of quartz that acts like a host has been a debatable one since long. The white and brown quartz appear to be the products of hydrothermal activity, the smoky quartz, in the opinion of the author may be different. This might have been the result of ‘sweating out’ of silica during metamorphism. Boyle (1961) while describing the gold mineralization in Yellowknife gold belt of Canada stated that the gold present in the greenstone belts was mobilized and migrated to shear zones by diffusion. He, (1961) further advocated that water and CO₂ reacted with meta-basic rocks giving rise to chlorite, chlorite - carbonate - sericite schists. These zones are called altered zones like sericitisation and chloritisation etc. In addition, silica, iron and potassium are released and were mobilized and migrated to different shear zones forming gold-quartz lenses. Similar view was expressed on the carriers of gold in the Ramagiri gold field by Ghosh et al (1970). In the opinion of the author of this work the quartz that is generated by this process will be having the smoky nature and is considered as the best host.

7.2.5. **Primary hosts and secondary hosts:**

The scrutiny of the literature suggests that there are considerable incidence or occurrence of gold in acid volcanic as in the case of Kolar and in Bisanattam. Gottfried et al (1972) has indicated that the gold content decreases from basalt and andesite to dacite and rhyolite. This may indicate that if the alkali content increase the gold content decreases. But the presence of gold in the acidic rocks in Kolar and Bisanattam warrants a critical analysis of the data.

The basic rocks are generally better hosts for sulphides. The high Mg-basalts appear to be the ones that have brought the gold up from deeper levels. If good amounts of gold is present in the acidic rocks also, it indicates that the gold from the basic rocks has been remobilized and redeposited in the acidic rocks, thus qualifying the acidic rocks as secondary hosts (Fig. 7 - 1).

The above concept leads to the sequence of events in the mineralization of gold in the secondary hosts.

1. Gold occurs as dissemination and thin stringers in minor quantities in the basic volcanic rocks that can be considered as primary hosts
2. Metamorphism and tectonism might have helped in the development of fluids resulting in the formation of mobilisers.

3. These mobilisers in addition to the deposition of gold in the primary hosts (basic rocks) might have carried them to the acidic rocks where there are suitable loci like shears are present and might have redeposited the gold. Thus, the acidic rocks have become secondary hosts.

Similar view was expressed by Achita Ramaiah (1993) in respect of gold mineralization in the Chigaragunta greenstone belt.
Fig. 7.1. Diagramatic illustration of the above concept
7.3.0. **IRON ORE MINERALISATION:**

7.3.1. **GENERAL:**

Presence of Iron ore in the Greenstone belts is not uncommon, but the quality and intensity may not that much when compared with the association of Iron from the sedimentary rocks.

Iron also occurs in the Precambrian period, i.e., Archaean - Proterozoic. The Iron Formations of this period are divided into two types viz., Algoma and Superior types (*Gross 1970 & 1980)

The Algoma Type is named after the place Algoma of Ontario. The associated rocks are of volcano - sedimentary sequence. This type of Iron formation is associated with gray or red jasper cherts, interbedded with magnetite and hematite rich layers. Further, siderite and pyrite are also common. The association with the volcanic rocks possibly indicates the volcanic nature of the iron formation. The iron formation runs into number of kilometers in length.

The Superior Type, named after the Lake Superior of the United States and Canada and also known to occur in Labrodar trough. The rocks are thinly bedded cherty rocks with granular and oolitic texture. Cherty magnetite and hematite and cherty iron silicates and carbonates rocks form into different stratigraphic units. The associated rocks are quartzites, dolomites, black cherts, black ferruginous shale / slate and volcanic rocks. The beds are few hundred feet thick and extend for reasonably long distances.

7.4.0. **IRON ORES OF ANANTAPUR DISTRICT:**

Iron ore occurs basically at two places, viz., one in the Oblapuram area of Rayadurg taluk and the other at Ramagiri of Ramagiri taluk. In both the cases the ore is with the greenstone belts. The ore at Obulapuram is with the Bellary
greensone belt, i.e., the eastern arm of the Sandur-Bellary greenstone belt. The southern part of it extends into the Anantapur district. The Ramagiri iron ore is with the Ramagiri greenstone belt. This extends towards north into the Karnataka State. Both the greenstone belts run almost parallel to each other.

7.4.1. Similarities and dissimilarities of iron ore at Obulapuram and at Ramagiri:

This can be studied under the following heads;

7.4.1a. Geological Setting:

The iron ore at Obulapuram is associated with the greenstone belt having amphibolites, meta-basalts with bands of phyllite and BIF. The BIF was earlier recognized as ferruginous quartzite. Chert is insignificant. The set up appears to be mainly sedimentary where the iron ore is seen. But higher up in the stratigraphy the above stated metamorphic are observed. This set up is intruded by younger granitoids.

The iron ore at Ramagiri is associated with the greenstone belt having amphibolites, meta-basalts with bands of phyllite and BIF. The BIF was earlier recognized as ferruginous quartzite. This set up is intruded by younger granitoids.

7.4.1b. Nature of the ore:

The iron ore at Obulapuram though associated with the greenstone belt can be considered as ‘Superior’ type as it exhibits more sedimentary association. As stated earlier, the metamorphics of the greenstone are noticed at lower level in the stratigraphy. Evans (1993) describes similar set up and qualifies the ore as
'Superior' type. But the ore at Ramagiri is considered as 'Algoma' type as it is associated with the greenstone belts. The ore at obalapuram is hematite and at Ramagiri it is magnetite. Chert percentage is more at Ramagiri compared to Oblapuram. The thickness at Oblapuram is much more than at Ramagiri. Extensive mining is being done at Oblapuram whereas no mining activity is seen at Ramagiri.

7.4.1c. Chemistry / Grade of the ore:

The ore at Oblapuram has indicated the grade as 56.63% – 63.88% as Fe%. The ore at Ramagiri has 37.10% to 64.96% as Fe% in the western band and 23.24% to 34.72% as Fe% in the eastern band. As the ore at Ramagiri is mainly magnetite, pellitisation may be helpful in using the ore in different industries.

7.4.2. Ironstone and Iron Formation:

7.4.2a. Ironstone: Iron ore occurs in the form of Ironstones in the Phanerozoic Era. These ironstones are classified as Minette Type, named after the Minette beds of Jurassic age in the eastern France and the Clinton Type, called after the Clinton iron ores of Silurian age in the area south of Alabama, in the region of Newyork.

The Minette Type of ironstones are mainly constituted by the chamosite and siderite. These are oolitic ores but oxides are less important.

The Clinton Type are deep red to purple, massive hematite – chamosite-siderite with oolitic textures. These ores contain 50% of iron. They also contain fairly high content of clastics including quartz.
7.4.2b. Iron Formation: Iron formation has alternating layers of chert and iron. Hence it called Banded Iron Formation (BIF). It occurs in four different facies, (Evans 1993) viz.,

i. Oxide facies - This is the most important facies and it can be divided into hematite and magnetite sub-facies. Carbonates may be present. Chert varies in percentage in sub-facies. The magnetite sub-facies show more of alternate banding of magnetite and chert.

ii. Carbonate facies - This is interbanded with chert and siderite in equal proportions. If magnetite is also present in the bands it grades into oxide facies. If pyrite is present it may grade in to the sulphide facies.

iii. Silicate facies - If the bands of magnetite- siderite- chert are associated with iron silicate, it forms silicate facies. It is difficult to study this facies because of the complexity of the iron silicates. This has very low economic interest.

iv. Sulphide facies - This will have pyritic carbonaceous argillites. It is thinly banded. The carbon content will be 7-8% and the pyrite will be 37%. This will be normally mined for its sulphur content.

The differences between Ironstone and Iron Formation, (James, 1966) are documented as table number 7-2 for better understanding.

The examples of Iron Formation from Andhra Pradesh are that the Iron Formation of the Ramagiri area is of Algoma Type (Fig.7.2) and the one from Pendlimarri Mandal of the Kadapa district is of the Superior Type. (Fig. 7.3)

Fig. 7.2. Algoma Type - Ramgiri Area (Anantapur District). The dark colored bands are magnetite and the light colored bands are that of chert.
## DIFFERENCES BETWEEN IRONSTONE AND IRON FORMATION (After James, 1966.)

<table>
<thead>
<tr>
<th></th>
<th>IRON-STONE</th>
<th>IRON-FORMATION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age</strong></td>
<td>Pliocene to middle Precambrian. Principal beds are from the lower Paleozoic and the Jurassic</td>
<td>Cambrian to early Precambrian. The principal formations are approximately 2000Ma. The youngest is Cambrian</td>
</tr>
<tr>
<td><strong>Thickness</strong></td>
<td>Major units are a few meters to a few tens of meters</td>
<td>Major units are 50m to 600m</td>
</tr>
<tr>
<td><strong>Original areal extent</strong></td>
<td>Individual depositional basins are rarely more than 100 miles (160km) in maximum dimension</td>
<td>Difficult to determine. Some deposits have continuity over many hundreds of miles (kilometers)</td>
</tr>
<tr>
<td><strong>Physical characters</strong></td>
<td>Massive to poorly banded, silicate and oxide facies are oolitic</td>
<td>Thinly bedded and has layers of dominantly haematite, magnetite, siderite or silica alternating with chert, which makes up approximately half of the rock. Oolites are rare.</td>
</tr>
<tr>
<td><strong>Mineralogy</strong></td>
<td>Dominant oxide is goethite, haematite is very common, magnetite is relatively rare, chamosite is the primary silicate, calcite and dolomite are common constituents.</td>
<td>No goethite, magnetite and hematite are about equally abundant, primary silicate is greenalite, chert is a major constituent, dolomite is present in some units but calcite is rare or absent.</td>
</tr>
<tr>
<td><strong>Chemistry</strong></td>
<td>Except for high iron content, no distinctive aspects</td>
<td>Remarkably low content of Na, K and Al.</td>
</tr>
</tbody>
</table>

**Associated Rocks:** Both are typically inter bedded with shale, sandstone, or greywacke; yet the iron formation has little or no clastics as compared to the iron stone.

**Relative abundance of facies:** No gross differences apparent; probable order of abundance for ironstone; oxide, silicate, siderite sulfide: for iron formation; the order is similar but, siderite facies may be more abundant than silicate facies.
7.5.0. THE RAMAGIRI IRON ORE:

7.5.1. Nature of occurrence:

Iron formation occurs in two independent blocks in the Ramagiri area. One is in the western limit of the greenstone belt in the Reserved Forest and the other in the eastern limit of the greenstone belt.

7.5.2. Ramagiri West Reserved Forest.

The iron formation or BIF occurs as a thick band running for nearly 8km and crowning the schistose hills of the Ramagiri West Reserved Forest. (Fig. 7.4). It has alternating magnetite and chert bands (Fig. 7.2)
7.5.3. Structure:

The strike of the Banded Iron Formation is NW – SSE that is in conformity with the schistosity of the associated schists. It dips westerly and occasionally easterly at a steep angle of 80° to 85°. The formation being a steep dipping, the width can be considered as thickness. In the present situation the thickness can be considered as 9 meters on average. The depth persistence of the Banded Iron Formation appears to be considerable. In one of the exposed section, it was found that the ore body was extending beyond 10 meters. (Fig.7.5). It is assumed that it will extend beyond 20 meters depth.

Fig.7.5. Reflection of the depth persistence and steep dip.
The iron formation extends northwards beyond the reserve forest area, occurring on top of a small mound. It runs for a distance of 2.75 km along the strike. The terrain from the reserve forest boundary up to a distance of 1 km is covered. A trench has been excavated in the covered and the continuity of the BIF is found.

In fact, the continuity of the iron formation can be established even without digging a trench, as the iron formation is steeply dipping, it will definitely continue in the strike direction unless affected by faulting.

7.5.4. On the eastern side:

In the area around Cherloppalle, (57F/11), the iron ore occurs like a neck-lace around a gneissic elongated dome called Cherloppalle Dome. (Fig.7.7). This makes the iron formation desirable into two, the western band (Fig.7.7) and eastern band (Fig. 7.7). Both the bands are similar in nature. The eastern band is more quarzitic. It has two bands within it.

Fig. 7.7 Cherloppalle dome with the western & eastern iron bands
The western one runs for nearly 12 km and the eastern one extends for about 6.5 km. The iron ore formation reflects minor warps, (Fig. 7.7), as observed in the eastern band.

7.6.0. Chemistry of the iron ore:

Table: 7.3. Analysis of the Iron ore

<table>
<thead>
<tr>
<th>S.No</th>
<th>Iron as Fe₂O₃ %</th>
<th>Iron as Fe %</th>
<th>S.No</th>
<th>Iron as Fe₂O₃ %</th>
<th>Iron as Fe %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>52.80</td>
<td>36.96</td>
<td>1</td>
<td>40.70</td>
<td>28.49</td>
</tr>
<tr>
<td>2</td>
<td>82.60</td>
<td>57.82</td>
<td>2</td>
<td>33.20</td>
<td>23.24</td>
</tr>
<tr>
<td>3</td>
<td>55.80</td>
<td>39.06</td>
<td>3</td>
<td>49.60</td>
<td>34.72</td>
</tr>
<tr>
<td>4</td>
<td>92.80</td>
<td>64.96</td>
<td>4</td>
<td>48.80</td>
<td>34.16</td>
</tr>
<tr>
<td>5</td>
<td>55.20</td>
<td>38.64</td>
<td>5</td>
<td>47.00</td>
<td>32.90</td>
</tr>
<tr>
<td>6</td>
<td>66.60</td>
<td>46.62</td>
<td>6</td>
<td>35.60</td>
<td>24.92</td>
</tr>
<tr>
<td>7</td>
<td>57.80</td>
<td>40.46</td>
<td>7</td>
<td>42.40</td>
<td>29.68</td>
</tr>
<tr>
<td>8</td>
<td>53.00</td>
<td>37.10</td>
<td>8</td>
<td>40.00</td>
<td>28.00</td>
</tr>
</tbody>
</table>
The study of the above table indicates that the western band has more Fe% than the eastern band. The scrutiny of literature suggests that there are number of hypothesis for the origin of Proterozoic iron formation. These are presented in the following table number 7.4.

Table – 7.4. Hypothesis for Origin of Early Proterozoic Iron – Formation

<table>
<thead>
<tr>
<th>Model</th>
<th>Suggested cause of IFM deposition</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lacustrine</td>
<td>Deposition in deep stratified or ephemeral saline lakes</td>
<td>Cowell, (1966) &amp; Fugster &amp; Chou, (1973)</td>
</tr>
<tr>
<td>Continental</td>
<td>Iron released during normal weathering under anoxic atmosphere precipitated in restricted marine basins</td>
<td>Garells &amp; others, (1973)</td>
</tr>
<tr>
<td>Weathering</td>
<td>Iron and silica precipitated from sea water as a result of evaporative concentration</td>
<td>Trendall, (1973), Button, (1976)</td>
</tr>
<tr>
<td>Evaporative</td>
<td></td>
<td>Cloud, (1973)</td>
</tr>
<tr>
<td>Biological</td>
<td>Iron and silica precipitated from sea water as a by product of metabolic activity</td>
<td>LaBerg, (1973)</td>
</tr>
<tr>
<td>Upwelling</td>
<td>Iron and silica precipitated from marine bottom waters as a result upwelling</td>
<td>Holland, (1973), Drever, (1974)</td>
</tr>
<tr>
<td>Hydrothermal</td>
<td>Sea water enriched in iron and silica by sea floor hot spring to point of precipitation</td>
<td>Gross, (1980), Simonson, (1982a)</td>
</tr>
</tbody>
</table>

IFM = Iron Formation
The exhalative origin of numerous Archaean iron formations have been convincingly established, (Gross, 1980). But number of other theories have gained momentum. Hydrothermal model is supposed to be the modern one.

7.6.0. Origin of the Ramagiri Iron Ore:

The origin of the Precambrian iron ore is highly debatable. The knowledge of the origin of the iron ore helps in planning mining and will also yield considerable useful information on the grade of the deposit.

The Ramagiri Iron ore is associated with the green schist grade of metamorphic rocks. The parentage for these schistose rocks is the basic volcanics. Hence, there is an opinion in respect of origin, is that, it (iron) is volcanic in origin. The differentiation of basic magma rich in magnesium starts with komatitic basalt and gradually goes to iron rich tholeiites. If this is considered as a clue, then volcanic origin can be acceptable. In fact, there are volcanic cherts also. Hence, both the iron and chert of Ramagiri can be volcanic. However, these iron formations are banded giving a sedimentary look to the rock.

The Banded Iron Formation, (BIF), as it is popularly called, is an indicative of one cycle of magma eruption. In certain schist belts number of Banded Iron Formation are observed. This type of set up reflects that there are number of volcanic cycles in the schist belt. This can also be verified by calculating the Mg. No (beyond the scope of the present work) of the volcanics lying immediately above any BIF. If the Mg. No, crosses 60, it indicates that the magma is primary and a new volcanic cycle has started. This concept is valid and proved. However, in the present situation, there are two locations of the bands of BIF. The extensive extension of the iron – formation of Ramagiri, indicates that it is possibly related to the volcanic activity.
7.7.0. Use of the Mineral:

The analysis when compared with the standards (Table. 7 - 4), the ores of Ramagir, Nossannakota have the Fe range "between" 30% - 60% have higher percentage of silica. The fines can be used in the Sintering industry where the Fe required is 56% minimum. Beneficiation and pelletisation may increase the chance of its utility. Higher percentage of SiO₂, i.e., up to 6% is used in the Durgapur Steel Plant.