CHAPTER 1
INTRODUCTION

The ore of manganese possess a high order of strategic importance. Since no quality steel can be produced without the addition of small amount of manganese, it is aptly called the “Achilles heel” of the iron and steel industries, on the fabric on which the economy of the nation rests.

Towards the end of 18th century the applications of manganese were known to the civilization for medicines, paint, etc (Prasad, 2003). Around the beginning of the 19th century, scientists began exploring the use of manganese in steelmaking. In year 1816, it was noted that iron becomes harder and less brittle by adding manganese to during steel making process.

Manganese, represented as Mn, has atomic number 25 and atomic weight 55. It is the 12th most abundant element constituting about 0.1% of the earth’s crust and 4th most widely consumed metal after iron, aluminum and copper. It is found as a free element in nature (often in combination with iron) in many mineral forms distributed as oxides, carbonates and silicates in earth’s crust. Manganese dioxide has seen wide commercial use as the chief cathodic material for commercial disposable dry cells and dry batteries of the standard, carbon-zinc and alkaline type.

The Central India (Fig. 1.1), which hosts the major chunk of high quality manganese ore deposits, has attracted attention of many internal and overseas manganese ore producers in recent years. An increase in demand of ferro-manganese and alloys has led to higher demands of manganese ores. This led to a severe business competition and enabled launching of many green field projects in this region. In this context, judicious and balanced utilization of these non renewable resources should play a major role. Scientific investigations of these mineral resources, exploration, deposit evaluation, mine planning, balanced and scientific mining, mineral conservation through economic beneficiation of low grade ores and value addition, are some of the important aspects which need to be looked in to for the sustainable growth of manganese and steel industry in the country (Upadhayay, 2009).

In the present competitive scenario of globalization and liberalization combined with the business dynamics in India, these aspects need to be addressed appropriately and strategies formulated accordingly. With a view to address some of these important aspects, the present study, geological aspects of manganese mineralization in Balaghat region, Central India with emphasis on metallogenic controls and exploration have been taken up. This study aims to suggest certain
recommendations to help the explorers this region and to understand the lateral and vertical
extension of the deposit and to locate prospects in the analogous environments.

1.1 STATEMENT OF THE PROBLEM

Production of crude steel is the single most important factor in the demand for manganese. Steel industry accounts for approximately 90% world demand for manganese. Carbon steel is the principal market accounting for 65 to 70% manganese consumption.

The high and medium grade manganese ores is only 15% and beneficiation of rest of low grade ores is indispensable, due to this deficiency introduction of new, economically viable, mineral beneficiation techniques would play a significant role making use of this category of ores through up gradation these low grade ores to obtain high grade or high value products. Balaghat mine had already installed a fully mechanized beneficiation plant to upgrade the low grade ore to high grade. As the domestic steel industry is growing, corresponding rise in the demand for manganese alloys is assured but higher power tariff and poor availability of power has put constraints on manganese alloy producers.

There is a need to increase the availability of manganese ore commensurate with projected steel production in India. For this, exploration efforts to find new or upgrade reserves of high grade, low phosphorus manganese ore is must with a thrust on increasing proven reserves. Extensive exploratory drilling is needed to be undertaken for identifying potential blocks.

The genetic diversity of Mn deposits in general is considerable (Roy 1988, 1992). Genetically manganese deposit can be broadly divided into two categories (i) Primary Mn deposition (ii) Supergene- residual formation. In deposit scale and commercial point of view the primary Mn deposition is most important and it can be further classified in to three sub groups (a) Hydrothermal (b) Hydrogenetic and (c) Diagenetic. Hydrothermal processes also include exhalative or volcanogenic deposits and are products of rapid precipitation from hot (100°- 350° c) mobile metal- enriched fluids, close to the interface between the ocean and the seafloor (Holtstam and Manfeld, 2001). Hydrogenetic deposits are also known as sedimentary deposits formed from slow precipitation at ambient conditions and subsequent sedimentation in relatively stable fresh water or marine environments. The products of these type formations are Fe-Mn crusts and deep sea nodules. Diagenetic processes involve precipitation from pore fluids that have interacted with material at varying levels in sedimentary column. The products may be oxide, hydroxide, carbonate or sulphides and appear in form of cement, fracture infillings etc. The supergene and residual is
secondary formation. However it is very important to know the genetic model of any deposit for find out the suitable exploration method.

The genesis of Balaghat manganese deposit is not clearly established. Most of earlier workers suggest that the deposit is originally sedimentary origin and later on it got metamorphosed, but the source of manganese is not clear. The aim of this research is to find out the actual sources of manganese and to establish the genesis of the Balaghat manganese deposit after a detailed study on its geological, structural, petrological, mineralogical and geochemical data. On the basis of structural and genetic model of the area, suitable and conceptual exploration techniques to identify to enhance the resource base and also to explore the possibility of finding some more new ore deposits in and around the Balaghat manganese deposit.

1.2 SCOPE OF THE WORK

The scope of the present work includes:

a. Review of manganese resource scenario.
b. Review of regional geology and structure of the manganese deposits of the Balaghat area to understand the overall environment of manganese-ore deposit, and geological and structural controls on the mineralization.
c. Detailed study of the ore mineralogical, textural and micro-structural aspects of whole rock and different ore types with a view to understand the genetic concepts so that it can give an idea for future exploration.
d. Geochemical studies of the associated rocks and manganese ores to understand variations of different elements in the deposit.
e. Review of genetic models and controls of mineralisation in the study area.
f. Review of exploration process, and resource evaluation and suggesting norms for manganese exploration in the study area.

1.3 METHODOLOGY

The following methods were used for the investigations mentioned above:

a. Extensive literature survey and data collection on geology, market scenario, structure, genesis, geochemistry, mineralogy, ore characteristics, mining method, exploration techniques and beneficiation processes of manganese ores, specifically from the Balaghat Mine of Central India.
b. Geological mapping and recording structural data in and around the Balaghat Mine.
c. Underground geological mapping of various levels, winze and raises of the Balaghat Mine to understand the structural features.

d. Collection of samples of different rocks and associated manganese ores to study the geological, petrological, mineralogical, textural and chemical characteristics.

e. Analysis and interpretation of data of geochemical data.

f. Establishing the genesis on the basis of geological, geochemical, mineralogical and structural data.

g. Designing optimal exploration procedures, norms and strategies for future exploration.

1.4 AREA UNDER INVESTIGATION

The Balaghat district is situated in the southern part of the Jabalpur division of Madhya Pradesh. It occupies the southeastern slope of the Satpura Mountains and upper Wainganga valley. The district extends from N21°19' to N22°24' latitude and E79°31' to E81°30' longitude. The total area of the district is 9,245 km². The Balaghat district is bound by the Mandla district to the north, Dindori district to the northwest, Seoni district to the west, Gondia and Bhandara districts of Maharashtra to the south, and Rajnandgaon district of Chhattisgarh to the east. The study area is situated between latitudes N21°45' and N21°55', and longitudes E80°00' and E80°15' (Fig.1.1). It is covered by the Survey of India Toposheet No. 64 C/1.

The Wainganga and its tributaries are the important rivers in the district. The town of Balaghat is on the bank of the Wainganga River, which flows from north to south. The Bagh, Nahra and Uskal rivers are tributaries of the Wainganga. The Bawanthadi and Bagh rivers define the boundary of Madhya Pradesh with the state of Maharashtra.

Geographically the district is divided into three distinct parts:

a. The southern lowlands: A slightly undulating plain, comparatively well cultivated and drained by the Wainganga, Bagh, Deo, Ghisri and Son rivers.

b. The Mau Taluka: The long narrow valley lying between the hills and the Wainganga river, and comprising a long, narrow, irregular-shaped low land tract, intersected by hill ranges and peaks covered with dense jungle, and running generally from north to south.

c. The lofty plateau: Comprising irregular ranges of hills, broken into numerous valleys, and generally running from east to west, in which the Raigarh Bichhia tract is situated. The highest points in the hills of the district are as follows: Peaks above Lanji, 2300 or 2500 feet; Tepagarh hill, about 2600 ft.; and Bhainsaghat range, about 3000 ft. above the sea.
Administratively, the district is divided into eight development blocks: Waraseoni, Balaghat, Katangi, Paraswada, Baihar, Khairlanji, Lanji, and Kirnapur.

Fig. 1.1: Map showing location of the study area (a) Outline map of India showing Madhya Pradesh and (b) Location of study area in Madhya Pradesh.
1.5 ACCESSIBILITY

The Jabalpur-Gondia section of South East-Central Railway runs north and south through the district, along the valley of the Wainganga. The section between Balaghat and Gondia was converted to broad gauge in 2005-2006, connecting Balaghat to India's national broad gauge network for the first time. A broad gauge branch train line runs west from Balaghat to Katangi via Waraseoni (Fig 1.2).

Balgahat is directly connected by bus with larger cities such as Bhopal, Nagpur, Gondia, Jabalpur, Raipur, etc. The nearest airport is at Nagpur. Recently a new airport has opened at Birsi village between Balaghat and Gondia.

1.6 HISTORICAL BACKGROUND OF THE BALAGHAT MANGANESE DEPOSIT

Balgahat mine mining was started in the year 1903. The Central Provinces Prospecting Syndicate at the herald of twentieth century acquired the manganese mine of Balaghat. This syndicate was converted into a limited liability company in 1908. In April 1924 its name was changed to the Central Provinces Manganese Ore Company Limited. In July 1962 the Government of India took control of the company and it was known as Manganese Ore (India) Limited with its head-office at Nagpur. After 20% disinvestment in year 2010, the company is now known as MOIL Limited. Initially, the deposit was worked by opencast. The first underground level was opened at $3^{rd}$ (320.50 m MRL) level through adit; later on underground was developed by sinking shafts to approach $4^{th}$ level (280.34 m MRL) and below. At present Two shafts are in operation i.e. Holme’s shaft sunk up to $12^{th}$ (40.08 m MRL) level and production shaft up to $15^{th}$ (−49.92. m MRL) level. Total 183.0895 hectors lease area comprises of two leases a) 182.3004 hectors i.e. main lease and b) 0.7891 hectors through which road passes. Out of 182.3004 hectors lease hold area, 7.23 hectors is under protected forest and 31.672 hectors area is under Revenue Forest i.e. total 38.902 hectors area is under forest (Fig.1.3).

1.7 FLORA AND FAUNA

The different types of natural vegetation in this area reflect the topography and underlying lithology. The area around the study area is cultivated, a major part of hills are covered by dense forest. The common trees found to the vicinity of villages are “Neem” (Azadirachata), Tamarind (Tamarindus indica), Pipal, Teak (Shira taberxa) grows along river and in new wide spread planted forests contain mixed growth of Sal (Terminatia sanentora), Bija (Prsocaspus marasupum) Bamboo, Dhawra, Lendia (Lagers troemia paraflora), Trefdu (Diospyros melan

**1.8 MINERAL WEALTH**

The district is rich in its mineral wealth. The important minerals include manganese, copper, and bauxite with minor occurrence of beryl. The area has also good potential for dimension stone. In addition, some lateritic iron ore and marble are also reported. A huge copper (Mo+ Au) mine is situated in Malanjkhand within Balaghat District. Most important deposits of India are located in the Balaghat district. Bharweli, Ukwa and Tirodi are some important manganese mines in the district. A number of other small occurrences of manganese have also been reported from this district. Lensoidal bodies of bauxite occurrences associated with laterite capping over the Deccan Traps are exposed in the northern part of the district. Occurrences of dimension stone have also been reported from Khelwad, Devri, Malanjkhand, Linga, and Lamta area. Reported occurrence of iron (associated with laterite) and limestone are of less importance from economic point of view. Minor occurrences of beryl have been reported from few localities in the western part of the district. Marble occurrences to the south of Lamta can be used as a dimension stone (Fig. 1.4).

**1.9 CLIMATE**

**1.9.2 Rainfall**

The rainy season in this area starts in the month of June and lasts up to the early part of October. The average number of rainy days is 66. July and August are the months of heaviest rainfall. The average rainfall from 1987 to 2010 is 1388.20 mm (Fig. 1.5 a). The annual rainfall of last 24 years is given in Table 1.1.
Fig. 1.2: Map showing accessibility in the study area.
Fig. 1.3: Map of showing various surface structures in and around Balaghat manganese deposit.
Fig. 1.4: Map showing mineral resources of Balaghat district (after District Resource Map, GSI).
Table 1.1: Annual rainfall in Balaghat District

<table>
<thead>
<tr>
<th>Year</th>
<th>Rainfall (in mm)</th>
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<tbody>
<tr>
<td>1987</td>
<td>961.63</td>
</tr>
<tr>
<td>1988</td>
<td>1337.3</td>
</tr>
<tr>
<td>1989</td>
<td>1181.8</td>
</tr>
<tr>
<td>1990</td>
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<td>1141.7</td>
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<td>1993</td>
<td>1526.4</td>
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<td>1994</td>
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<tr>
<td>2008</td>
<td>1131</td>
</tr>
<tr>
<td>2009</td>
<td>973</td>
</tr>
<tr>
<td>2010</td>
<td>1307.2</td>
</tr>
</tbody>
</table>

1.9.1 Temperature

The climate of the district shows variation owing to physiographic conditions. The lowland plains have a hot climate in the month of April, May and June. The Baihar plateau is cooler than the lowlands, and still higher, Raigarh plateau is cooler than Baihar. The uplands are very cold during winter. The climate of the district is moderate with a minimum temperature of 4°C in January and a maximum of 43°C in May (Fig. 1.5 b). The month-wise average minimum and maximum temperature during last ten years of the district is given in Table 1.2.
Fig. 1.5 a: Bar chart showing annual rain fall in the study area during last 24 years.

Fig. 1.5 b: Bar chart showing month-wise average temperature in the study area during last 10 years (in °C).

**Table 1.2:** Month-wise average temperature in °C of Balaghat district (Last 10 Years)

<table>
<thead>
<tr>
<th>Month</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>4.4</td>
<td>28.4</td>
</tr>
<tr>
<td>February</td>
<td>8.8</td>
<td>28.8</td>
</tr>
<tr>
<td>March</td>
<td>12.3</td>
<td>32.1</td>
</tr>
<tr>
<td>April</td>
<td>18.6</td>
<td>38.6</td>
</tr>
<tr>
<td>May</td>
<td>20.5</td>
<td>43.0</td>
</tr>
<tr>
<td>June</td>
<td>23.4</td>
<td>40.4</td>
</tr>
<tr>
<td>July</td>
<td>21.5</td>
<td>30.8</td>
</tr>
<tr>
<td>August</td>
<td>22.6</td>
<td>28.0</td>
</tr>
<tr>
<td>September</td>
<td>21.6</td>
<td>30.4</td>
</tr>
<tr>
<td>October</td>
<td>18.0</td>
<td>31.5</td>
</tr>
<tr>
<td>November</td>
<td>16.6</td>
<td>30.5</td>
</tr>
<tr>
<td>December</td>
<td>12.6</td>
<td>28.5</td>
</tr>
</tbody>
</table>
1.10 DEMOGRAPHY

As per Directorate of Census Operations in 2011, Balaghat had population of 1,701,156 of which male and female were 841,794 and 859,362 respectively. There were total 206,815 children under age of 0-6. The density of population is 184 in 2011. Average literacy rate of Balaghat in 2011 is 78.29 compared to 68.72 of 2001. Balaghat District population constituted 2.34 percent of total Madhya Pradesh population.

1.11 PEOPLE AND THEIR OCCUPATIONS

The area is thinly populated. Most of the people are farmers and villages are generally situated on plain cultivated areas. The production of rice plays an important role in the economy of the area. Some parts of study area are under forest land. The bamboo cutting is one of the seasonal incomes for local people.

The Balaghat district is second highest producer of sericulture in the state. The environment of Balaghat is quite suitable for sericulture. Sericulture having an agro forestry base is a small scale industry in rural areas, which help villagers for generating revenues of self-employment. Around the Bharweli village, most of the peoples are connected with the mine work and others are farmers (Fig. 1.6).

1.12 PHYSIOGRAPHY

The study area is at a general elevation of 303 m. above mean sea level (Fig. 1.7), having the highest elevation of 620 m and the lowest at 300 m (Fig. 1.8). A hill range is in the north eastern border of the study area. The ridge slopes towards southwest (Fig. 1.9).

The Balaghat mine lease area is located near the southern side of Baihar plateau and is hilly. There are two parallel ridges striking NNE to SSW. The distance between the crests of two ridges is about 400 meters (Fig. 1.10).

1.13 SOILS

The district has alluvial soil in the lowlands, and black and brown clay loam soil in the plateau and tablelands. The most fertile soils in the district are the alluvial lands on the banks of Sone and Deo rivers in the plain areas of Waraseoni and Balaghat tahsils. The quality of soil in the lowland is generally superior to the soils in Baihar and Raigarh tablelands where mica particles tend to reduce soil fertility. In the lowlands, the depth of soil is more.

Next to the Sone and Deo alluvium, the most fertile soils lie to the east of Wainganga in the lowlands extending to the south from Dhansua hills to the Bagh River. It is rich in black and brown
soil of superior quality. Apart from the Dhansua and Hatta tract, brown soil of good quality is found in the north Karaola tract to the west of Wainganga and Bhandara in the extreme south east. Good amount of rice soil, though of medium quality, occurs in the Katangi and south Karola tract in Waraseoni tehsil (west of Wainganga) and Lanji and Kirnapur in Balaghat tahsil (east of Wainganga). In the low lands, poor soils are found at the base of the hills. In the plateau region of Baihar Tahsil and eastern part of Balaghat Tahsil, the soil is of medium to poor quality.

In the Man-valley to the northeast, hardly any black soil is found, while the better quality brown soil is found occasionally in scattered plots and in the depressions or shallow valleys, which form an important feature of the tableland. The proportion of good brown soil is considerable in the Raigarh plateau to the extreme northeast of the district (Fig. 1.11).

1.14 DRAINAGE

The principal rivers, which flow through the district, are Banjar, Halon, Jamunia, Tannar Kanhan and Wainganga. Banjar enters the district from Raipur district in the east and flows in the north and west direction through the main plateau into the Mandla district. The only river of any significance to the east of Wainganga is its tributary Sarathi. Bagh drains the country to the east of the Wainganga, with its tributaries (Deo, Son and Ghisri).

All these rivers have their sources in the hilly country to the south of Baihar tableland. Bagh enters the district from Bhandara, forms the southwestern boundary of the district from Bhadra hills to Wainganga, till it joins it at Borinda. Nahara and Uskal rivers start from the Dhansua forest and the open country southwest of Tipagarh and ultimately join Wainganga near Chacheri. The drainage pattern in general is dendritic to subdendritic. In study area Waingangā is the main river, which flows north–east to south–east. Another river Chandan flows in the southwestern corner of study area. Tondia Nala flows from western corner and join with the Chandan River.

In the Mines area, Mangardoh nala receives maximum water from the upper reaches of the ridge. Although there are slopes in the western direction, the water draining from this slope is absorbed by the plain area and does not reach the nala. On the contrary, prominent drainage is observed in the eastern part of the ridge. Here, the water flows in the southeastern direction and the three streams meet the nala in the southeastern corner of the mines area (Fig. 1.12).

Some of the GIS generated maps on these above aspects are given below
Fig. 1.6: Map showing land use and land cover status of the study area.
Fig. 1.7: Contour map of the study area.
Fig. 1.8: Map showing physiography of the study area in 3D.
Fig. 1.9: Map showing slope amount and direction of the study area in 3D.
Fig. 1.10: Map showing physiography in and around Balaghat manganese deposit in 3D.
Fig. 1.11: Map showing various types of soils of the study area.
Hydrogeologically the study area can be broadly divided into two types (i) poor to moderately good (ii) very good to excellent. The adjoining parts of the Wainganga River shows very good to excellent hydrogeological conditions (Fig. 1.13).

1.15 GEOMORPHOLOGY

1.15.1 Introduction

The compound landscapes of the Balaghat area have developed by a number of geomorphic processes of more than one cycle of erosion in which some exhumed or resurrected landforms are also observed. There are some exceptions to the otherwise youthful nature of topography, which is presumed to date back to Early Tertiary (Oligocene) period. There were many influencing factors governing the development of landforms. Lithology and structures appear to have played a much more dominant role than any other factor. The multi-cycle erosional activities indicated by the plantation surfaces at various level and changes in relief in the present part are also indicated by many anomalous situations in the fluvial region.

1.15.2 Morphogenetic units

Four distinct morphogenetic units have been worked out in this area. These are:

a. *Summit surfaces*: This unit is in the form of an elongated ridge in the northeast southwest direction. The maximum height of the ridge is 620 m. above M.S.L. The ridge constitutes the water divide for the nalas.

b. *Hill side slopes*: This unit ranges from 460 m. to 330 m. in height and consists of moderate to steep slopes at few places. The slope varies from 30 to 65 degrees with colluvial deposits. The weathered rock fragments slide down the slope and rest at an angle of repose. Steep slopes are towards northwest and southeast. In the southwestern side, the slope angle reduces gradually. The high slopes in all the three directions convert into moderate slope gradually, which is followed by medium plain and low plain areas.

c. *Plain land*: This unit is mainly found in southern and western part of the study area. This plain land is utilized for agriculture, though it has undulating slope conditions.

d. *Valley Surface*: Wainganga River flowing northeast to southeast forms the main water body of the study area. This area is cultivated and very good in ground water condition.
Fig. 1.12: Map showing drainage system in the study area.
Fig. 1.13: Map showing hydrogeology of the study area.
1.16. SUMMARY

GIS is a very reliable technique, which is used to generate different types of information. When the field data are used in GIS studies, the scope of the subject increases many fold. In the present study the maps of lithology, geology, geomorphology, drainage etc. are prepared by using Survey of India toposheets No. 64 C/1 in GIS software. The toposheet was georeferenced and digitised in GIS software and different thematic maps were generated. These maps were superimposed for GIS studies to understand the structure and geology of the area with the help of drainage pattern, physiography and hydrogeology. This chapter deals with the interpretation of these terrain elements.