CHAPTER I

INTRODUCTION

Prologue

India is the second largest exporter of manganese ore in the world. The manganese ore deposits of India have therefore become very well known. The ore that was being exported till recently was obtained from the deposits occurring in Madhya Pradesh, Maharashtra, Karnataka, Andhra Pradesh, Gujarat, Bihar and Orissa States. Since last fifteen years, the manganese ore deposits of the territory of Goa have been added to these deposits and a considerable quantity of ore is being mined and exported from them.

The manganese ore deposits of Goa, although known from a long time, were not included in the Indian deposits as the territory of Goa was under the Portuguese rule. Therefore, though the Indian deposits were studied in great detail, and considerable information about them is available in the literature, not much was known about the Goa deposits. This is also true about the iron ore deposits and the geology of the Goa region in general. But in 1961, when the territory was liberated from the Portuguese rule and included in the Republic of India, these deposits attracted the attention of the government and private agencies. However, because the iron ore deposits are richer as compared to the manganese ore deposits, most of the mining activity was concentrated
for their exploitation. Considerable information, therefore, is now available about them. The manganese ore deposits on the contrary, being less prominent, have not received due attention from the geologists as well as the commercial firms engaged in their exploitation. Consequently not much information regarding the geological setting, the mode of occurrence, the controls of localization and the genesis of these deposits is available so that it can be used for developing the known deposits and in discovering new ones. The author, therefore, decided to study these deposits in detail.

Previous Work

The earliest reference to the geology of the area is by Foote (1876) who designated the rocks exposed in the area as "the gneissic or metamorphic series". Later he divided his gneissic or metamorphic series into two distinct groups, viz. gneissose and schistose. He proposed the name Bharwar to the latter and recognised three main bands of the Bharwar rocks occurring in the Southern Maharashtra Country and Karnataka. Maclaren (1904, 1905) gave the name "Castle Rock Sand" to one of the three bands described earlier by Foote (1876). He further reported them to consist of dolomitic limestones and quartzites which occasionally graded into quartz schists.

Wetherel (1907) referred to the same rock formations
in some of his papers on iron and manganese ores. Similar references are also found in the publications of Geological Survey of India (Fermor 1907, 1909, 1913 and 1927).

In his classic work on the manganese ores of India Fermor (1909) referred to the manganese ores of Goa as of lateritic type. His study was restricted only to a few mining pits in the northern and central parts of Goa. He did not mention anything about the occurrences of manganese ore deposits in Southern Goa.

Dunn (1942), in his memoir on manganese ores of India, gave a brief description of the manganese ores of Goa and classified them under lateritoid type. All the information available till 1950 has been summarised by Pascoe (1965) as follows:

"The Castle Rock Band is on the same line of strike as the Western Ghat belt and the general type of its rock is sedimentary. The Portuguese Province of Goa consists mainly of Bharvar rocks, very largely obscured by a covering of laterite. The Bharwars are represented by quartzites - magnetite quartzites, hematite quartzites, limonite quartzites, sericite-quartz-schists, fine grained biotite-quartz-schists, phyllites, fine grained grey limestones and basic igneous rocks. The rocks of this belt are generally manganiferous except in the immediate neighbourhood of Deccan Traps where they have been much hardened. Manganese ore has superficially replaced some of the"
decomposed quartzites and has itself originated from the Dharwar rocks especially from the iron ore beds and phyllites."

According to Shepe (1953), the Castle Rock Band begins in North Kanara (Karnataka), runs northwards along the western ghats through Goa until it disappears under the Deccan Traps in Belgaum, while small portions extend in south Ratnagiri district of Maharashtra.

Oertel (1958) made a brief mention of occurrence of some of the iron and manganese ore deposits and their modes of origin in his report on the geology of Goa. Majumdar (1965) briefly described the mineralogy of iron and manganese ores of Goa.

Gokulam (1972) studied the geology of Goa in some details and gave a general stratigraphic sequence of the rock formations. The main emphasis of his work was on the detailed study of the iron ore deposits. He made only passing reference to the manganese ore deposits. Srinivasan and Sreenivas (1972), while discussing the stratigraphy of Dharwar, have referred to the metagreywackes and polymictic conglomerates of Goa and considered them to be of Flysch Facies of geosynclinal stage.

**Purpose of the Present Work**

From the review of previous work, it will be seen that, most of the work of the previous workers was restricted mainly
to the general geological descriptions or to the nature of the iron ore deposits. They have not paid much attention to the manganese ore deposits excepting making a passing reference to their mode of occurrence and type. The different aspects of the manganese ore deposits like the geological setting, the structure, the mode of occurrence, the textures and structures, mineralogy, paragenesis, classification, controls of localisation and the genesis have not been studied in detail by any of the previous workers. Similarly, the petrological characters of the host rocks in which the deposits occur and the environments in which these rocks were formed, have also not been studied in detail so far. The purpose of the present work, therefore, was to study all these aspects.

The Area

In order to study all the aspects of the manganese ore deposits mentioned above an area, in which the deposits are concentrated, was selected. From the Location map (Fig. 1.1) it will be seen that the east-west railway divides the territory of Goa in almost two equal parts. The iron ore deposits are mostly confined to the northern part whereas the manganese ore deposits occur in the southern part. In the southern part the deposits are confined to the eastern region which is included in the Sanguem district. Therefore, this work is concerned with the geology of the manganese ore deposits of Sanguem district of Goa.
Fig. 1.1 Location map.
The area under study lies in the Survey of India topographic sheets 43 I/3 and I/4 and is bounded by longitudes 74°, 4', 10" and 74°, 15' East and latitudes 15°, 0' and 15°, 20', 16" North. Towards the east, the area is bounded by the western ghats while towards the west and southwest the boundary is marked by the Camacona district of Goa. The southeastern boundary is marked by the State of Karnataka, while the south-central railway line which passes through the heart of Goa in an East-West direction is along the northern boundary. The nearest railway station is Sanvorde which is about 60 kms. by road from the southernmost part of the area.

The national highway No. 14 runs through the area and most of the manganese mining centres are located to the south of the national highway. This highway also passes through Sanvorde which is the major town in the area. The nearest mining centre, which is the Rivona group of mines, is about 30 kms. from Sanvorde to the south, while Vilyena group of mines is about 35 kms to the south-east. The farthest mining centres are the Netravli group of mines, and the Verlem-Salgini group of mines which are about 55 kms and 60 kms respectively from Sanvorde in southeast direction.

The town of Sanvorde in the north is connected with Salgini in the south by a road which is metalled upto Netravli while further south i.e. from Netravli to Salgini, it is an unmetalled road suitable only for mining machinery and jeeps.
Physiography

Generally speaking, the area is a strip of low land between the western ghats and the Arabian sea. The western ghats are represented by hill ranges in north-south direction. The western ranges are made of low lying hills with an altitude of about 500 m, whereas the eastern ranges are made of higher hills with a maximum height of 1500 m. In the southwest portion of the area the hill ranges trend in east-west direction. The east-west running ranges constitute the main water divide in the southern part of the area, while towards the eastern part the divide becomes north-south.

The streams rising from these divides empty their waters into two small rivers, the Guloli river which flows through the eastern part of the area passing by the villages Netravali, Kurdi, Sanguem and Sanvorde and the Kushavati river which flows through the western part passing by the villages Rivona and Quepoa. In the central portion of the area, there is a separate divide which runs east-west and the streams arising from it empty their waters either into Kushavati or Guloli river. Most of the area is drained by these two rivers, while a small portion of the area, the north-eastern corner, is drained by a tributary of Guloli river called Uguem river. The two main rivers, the Kushavati and the Guloli, meet each other at Panchwadi which is to the west of Sanvorde and beyond this, the river is named as Zuari. The river Zuari in turn meets the Arabian sea at Marmagoa, which
is one of the best natural harbours of India. The rivers Kuari, Guloli and Kushavati, apart from their value as source of water, also serve as channels of communication and transport, since they are navigable several miles in their lower sections and thus provide a cheap means of transport for the manganese and iron ores that are mined in this area.

Methods of Study

The present study was undertaken to investigate all the aspects of the manganese mineralisation occurring in the area. For the purpose, an area of about 350 square kms. was selected. It was divided into four sectors and about twenty mining pits from each sector were carefully studied and representative samples of manganese ore were collected.

Simultaneously, while studying the pits, the lithological units were also mapped on 1:50,000 scale and representative samples of the rocks were also collected. Similarly, structural elements such as foliations, lineations, joints and faults were also noted. The field work was carried out in six trips of about 20 days duration each between 1973 and 1975. The structure of the area was also studied by aerial photographs on 1:60,000 scale.

The samples of the rock types were subjected to laboratory investigations. Modal analysis of the rocks was carried out by Rosiwal method on the lines suggested by Chayes (1954 and 1956). Rock samples were chemically analysed by
the rapid method technique of Shapiro and Brannock (1956), using U.S.G.S. silicate rock standards (Flanagan, 1957). Twenty-five such analyses of the different rock types are included in this work. Optical properties of the minerals were determined with the help of Four Axes Universal Stage. The anorthite content of the plagioclases was determined with the help of Universal Stage by using Slemmons' (1962) Curves. About forty polished sections of opaque manganese minerals were studied under the ore microscope. The manganese ore samples were also subjected to the gravimetric thermal analysis, differential thermal analysis, and X-ray analysis for identifying the different manganese minerals. Chemical analysis of the manganese ores was also carried out and forty-two such chemical analyses are included in this work.