Chapter I

INTRODUCTION

GENERAL STATEMENT

The mining and extraction of iron has been practised in India from the time immemorial. India's assessment of total iron ore reserves is about 210,000 million tons i.e., about 25 °/o of the total world reserves. But so far as her output is concerned she is the sixth iron ore-producing country of the world.

Some of the well-known Indian iron ore deposits and workings are located in the states of Bihar, Orissa, Madhya Pradesh, Mysore and Goa. These deposits have been drawing special attention of the Indian as well as many of the world's consumers and natural resources investigators since independence.

Iron ore deposits in the present Indian Union territory of Goa are also known for a very long time. But they were of little interest to India till the territory was freed from the Portuguese in 1961.

The earlier Portuguese government did not take any interest to carry out systematic geological surveying and mineral prospecting in Goa so long as it remained under their occupation. As a result, neither any previous geological map nor any official useful information regarding the geology and mineral resources of the territory was available. About a year after the liberation

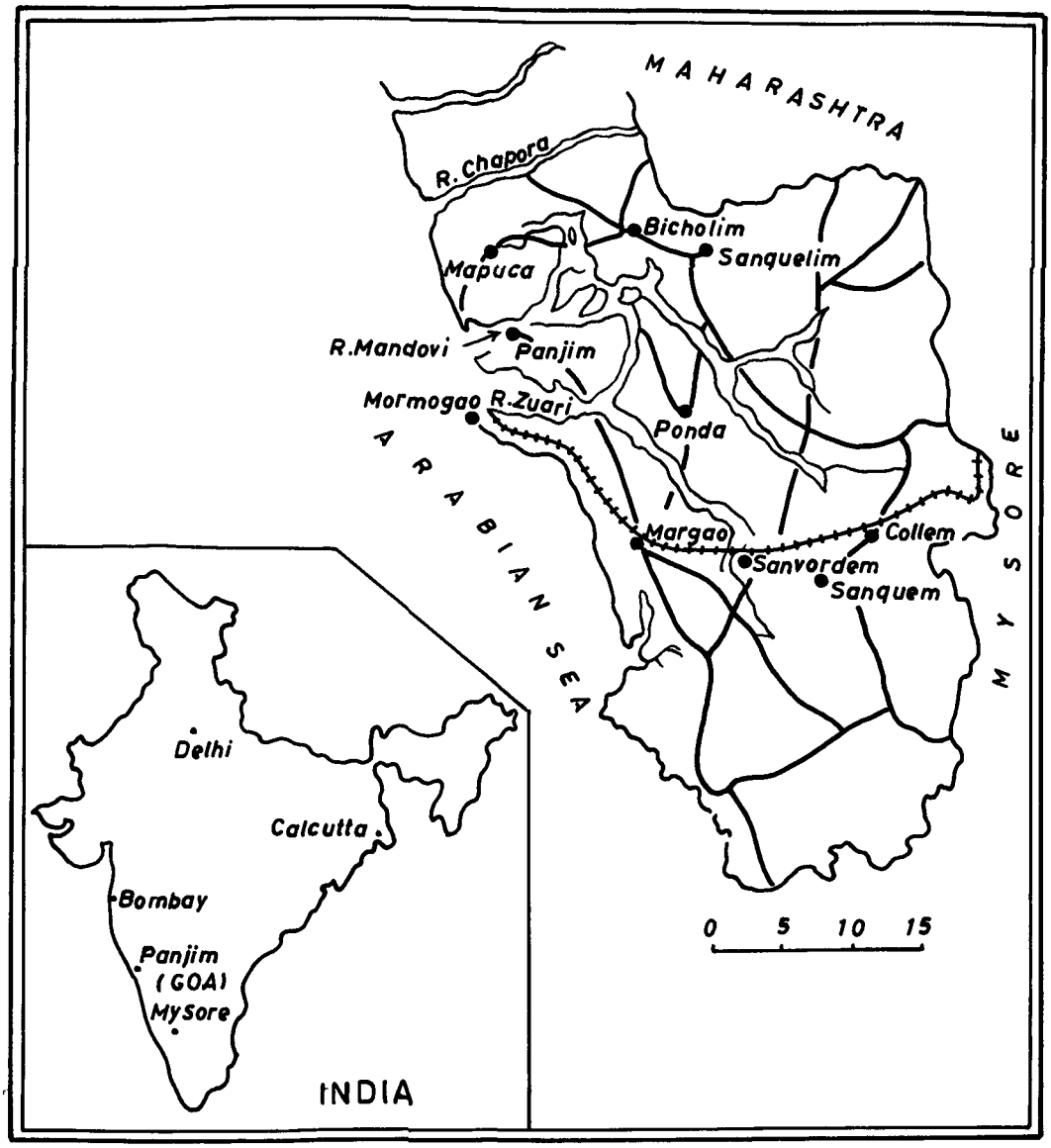

FIG. 1 LOCATION MAP

of Goa, both the Geological Survey of India and Indian Bureau of Mines extended their activities in the territory in order to survey and assess for the first time its mineral resources. As soon as the administration became normal after the liberation movement, the present worker availed of the first opportunity to enter Goa with the purpose of investigating one of its largest and important deposits of iron ore.

The present work includes the study of geology, structure, mineralogy and genesis of the two well-known iron ore deposits viz., Bicholim ($15^{\circ}35'15''$; $73^{\circ}57'$) and Sanquelim ($15^{\circ}34'$: $74^{\circ}30''$) of Bicholim taluka (= subdivision) , Goa. It is hoped that this study might be useful to compare the iron formations of Goa with similar other formations occurring elsewhere in the country. It may even be of great help to the future workers particularly, those who may wish to work on the structure, mineralogy and genesis of similar other Precambrian iron ore deposits of Goa and also of the adjacent state of Mysore.

LOCATION AND ACCESSIBILITY

Goa is situated on the west coast of India, about 350 Km south of Bombay, between latitudes $14^{\circ}53'$: $15^{\circ}48'$ north and longitudes $73^{\circ}45'$: $74^{\circ}24'$ east. It has an area of about 3,600 sq.km. The territory is partly bounded by the states of Maharashtra on its north and northeast and Mysore on its south and southeast, the Arabian sea demarcates its entire western boundary (Fig.1).

In north Goa there is a small town at Bicholim where the present head quarter of Bicholim taluka is located. The town is about 35 Km northeast of Panjim, the capital of Goa. In the Londa-Vasco-de-Gama section of Southern Railway, Colem Sanvordem and Margao are the railway heads of Bicholim. The other possible approach to the area is by sea from Bombay to Panjim and then the remaining distance by road.

TOPOGRAPHY AND DRAINAGE

Physiographically, Goa can be divided into three well-defined regions viz., 1) the hilly coastal belt with a few sandy stretches facing the Arabian sea, 2) the hilly sub-Ghat, which occupies a greater part of the country and 3) the mountaneous region of Western Ghats along its northern and eastern boundaries. The area under consideration falls within the sub-Ghat region. It has a varied topography consisting mainly of highlands and low hills. The hills are generally woody and rugged, more or less flat-topped and scattered. In contrast to these low hills there are a few well-defined hilly tracts of which Sirigao (161.54 m) is the one whose northern side rises abruptly from the plains while its southern side gradually slopes into small, flat-topped and isolated hills (Fig.2). The Sanquelim hill (97.03 m) also shows similar topographic features with the exception that its southern slope abruptly merges into a wide plane which extends upto the main drainage basin of the area beyond Virdi ($15^{o}33'$: $73^{o}54'30''$). Other significant higher

topographic features in the vicinity are Mulgao (136.70 m), Dudonem (147.68 m), Sanquelim (135.42 m), Maulinguem (131.57 m), Porlem (121.68 m). Rest of the area is low-lying. The relief of the area is approximately 130 meters.

The drainage network in northern Goa is considerably dense (Fig.2) due to the fact that it lies on the windward side of the Western Ghat escrapment and hence a suitable site for heavy monsoonic precipitation. In the greater part of the area, however, there are two distinct directions of drainage, some flow more or less at right angles to NW-SE, the general strike of the hill ranges and others, more or less parallel to them. The third order meandering streams of the area viz., Bicholim, Valvota and Arvalem are sluggish and flow more or less across the ranges. All these three streams join together on the southern boundary of the area, near Mati ($15^{\circ}33'$: $73^{\circ}58'30''$) and flow southwards for about a distance of one Kilometer before joining the main river, Madei. The smaller streams and nalas (= brooklet) are mostly seasonal and more or less follow the regional strike of the hill ranges. Accordingly, the stream courses have developed a trellis pattern in the topographically uneven portions of the area. In the flat-lying coastal belt the dominant stream pattern is dendritic.

CLIMATE AND RAINFALL

Goa enjoyes a tropical climate with an average temperature of $27^{\circ}C$ and an annual rainfall of about 3,500 mm. About 60 $^{\circ}/o$

of the precipitation is received from June to August. The climate is very much influenced by the moisture-laden wind. The monsoon breaks in early June and withdraws by early October. During this period humidity varies from 90 °/o to 95 °/o. In rest of the year humidity varies from 80 °/o to 95 °/o. The summer season lasts from March to May when murcury column touches nearly 32°C. The period between December to February is rather cool and dry.

AREAL EXTENT AND ROCK EXPOSURE

Most of the important workable iron ore deposits of Goa occur in the northern part of the river Madei (Fig.2). These deposits constitute the iron ranges of Sirigao-Sanquelim, the Onda-Valguem-Pale and the Onda-Pissurlem-Vantem. The present study is confined to the iron ore deposit of Sirigao-Sanquelim range.

The investigated area extends lengthwise from Sanquelim on the southeast to Sirigao (15°36'15" : 73°54') on the northwest. Its northern and southern boundaries are roughly demarcated by the localities, Nanora (15°38' : 73°55'30"), Curchirem(15°36' : 74°0') and north of Poriem (15°35'15" : 74°1'30") on one side and Dudonem (15°33'15" : 73°56'30") and Gauntana (15°32'45" : 74°1') on the other. The total area covered is of about 50 sq.km. The Bicholim township is more or less centrally situated in the area.

The Sirigao-Bicholim deposit forms a prominent hill-range

which extends northwestwards from south of Bicholim town through Langao (15°35'30" : 73°56') and Redeval (15°36' : 73°56') upto Sirigao village. In the southeastern end of the area, near Sanquelim town, there is another rich deposit of iron ore, locally known as Sanquelim deposit. In addition, there are also some minor iron ore workings at Sarvon (15°34'30" : 73°56'), Nanora and a few abandoned pits which were also visited but not considered worthwhile to include in this work. The deposit generally contributes three different types of iron ores viz., hard, friable and powdery. Occasionally, they have minor association of manganese ores.

Unfortunately, widespread and deep lateritization in the area has affected the rock exposures to such an extent that it is difficult to recognise the original character and structure of the exposed rocks. Only in the deeply cut mine workings comparatively fresh rocks and ores provided more useful geological data for this investigation. Road and nala cuttings with but a few exceptions are also not so deep as to expose fresh rocks. In general, good natural rock exposures in the area are so scanty that they thwarted systematic collection of geological informations.

TECHNIQUES OF INVESTIGATION AND PRESENTATION OF THE WORK

The techniques adopted for field as well as laboratory investigations were all guided by the demand of the problem.

Broadly, the present study was based on the following methods of investigation and techniques :

1. Field techniques :
   (a) Reconnaisance survey followed by the preparation of a gelogical map of about 50 sq.km around the area on a scale 1 : 25,000.
   (b) Preparation of a detailed surface geological map of Sirigao mines on a scale 1 : 2,4000 with the help of telescopic alidade and plane table.
   (c) Examination of field characteristics of the country rocks and systematic collection of rock samples for thin section study.
   (d) Close examination of the iron ores in different mine sections and selection of ore samples for ore-microscopic study and chemical analysis.
2. Laboratory techniques :
   (a) Thin section study of phyllites, banded ferruginous quartzites, quartzites, and some basic instrusives.
   (b) Examination under ore-microscope of about 60 selected samples of polished ores.
   (c) Friable and powdery ores were run through an Isodynamic magnetic seperator to seperate the more magnetically susceptible minerals from the ores.
   (d) Sieve analysis of a few samples of powdery ore.
   (e) The hard, friable and powdery iron ores and a few ferro-manganese ores were analysed by the Geo-Chem

laboratories of Bombay. The results obtained from them are used in this work.

The entire work is presented in the following order :

i) Introduction
ii) Geology of the area
iii) Petrography and metamorphism
iv) Ore deposits
v) Structure
vi) Mineragraphy and paragenesis
vii) Genesis
Summary and Conclusion

MINING

The mining of iron ores in Goa was initiated on a small scale in 1908 by a group of French mining engineers. They also carried some prospecting work, as could be seen even today in a number of prospecting tunnels in Bicholim mines. The mining activity ceased soon after 1908 and revived again in 1949. Since then the mining industry in Goa has been progressing (see Varma et al., 1967). The enterprise enjoyed a boom in 1957 and onwards with increasing demand of Goa's iron ores by the Japanese steel industry. With the help of Japanese mining engineers, Chowgule and Co., a local mining concern, mechanised their Sirigao mines in 1963.

Both the Sirigao-Bicholim and Sanquelim deposits occur along

the ridge slopes facing northeast or southwest. Initial open cast mining requires the opening of the faces of the ridge from which the laterite overburden is removed first. In a systematic mining operation, faces are progressively cut backwards in the form of successive benches to reach the ore zone. The height of each bench varies from mine to mine. In the highly mechanized Sirigao mines benches are vertically five meters apart with correspondingly greater bench width to allow laying of mine roads. On the contrary, in unsystematic prospecting and inadequate information on the extent and reserve of ore deposit resulted irregular mining at many places in the area. A portion of the Sirigao-Bicholim lease belonging to Bandekar and Co., may be cited as an example of above fact. All the present major workings in the area are open-cast.

PREVIOUS INVESTIGATIONS

A review of the few available previous geological literature on Goa revealed that the region had failed to receive due attention of the earlier workers, probably because the Portuguese government did not encourage any traditional geological study. The Geological Survey of India has not yet published any report of the work done by its officers since about 1963.

Fermor (1909, p.980-985) first referred to the nature and mode of occurrence of manganese ores of Goa but mentioned nothing about the iron ores. In his account on the correlation of the

ancient schistose formation of Peninsular India, Fermor (1936, p.104) stated that

> The Portuguese territory of Goa has never been systematically surveyed geologically so that it is not known whether the Dharwar rocks of that track belong to the Castle Rock band or to an additional band ...

Krishnan (1952, 1955), while dealing with the iron ores of India, mentioned only about the occurrence of iron ore deposits at Bicholim, Goa. But he did not enter into the details of the subject.

Dhepe (1953) in his paper outlined the geology of Goa giving some information regarding the mode of occurrence, grade, mining, etc. of the iron and manganese ores.

D'cruz (1963) described briefly the geology, mining and marketing of the iron and manganese ores of Goa. He further referred to the occurrence of Dharwar schists, in addition to the pre-Dharwar granite and some post-Dharwar basic intrusives, laterite, etc., in Goa.

Souza (163) discussed in two seperate papers the mining of iron ores in Goa and the geomorphology of the territory.

Recently, Varma et al., (1967) have given an outline of the geology, in addition to the physical and chemical nature of the iron ores of Goa.

The publications, referred to above, obviously show that the geological investigations done so far on the iron ore deposits of Goa and particularly, of Bicholim and its adjacent

areas are not only incomprehensive but also have little bearing on the structure, mineralogy and genesis of the ore deposits under study.

ACKNOWLEDGEMENTS

The author wishes to express his sense of gratitude and appreciation to Dr. S.H.Rasul, B.Sc.(Hons), M.Sc.(Cal.), Ph.D.Tech. (Sauger), F.G.S.I., F.A.A.Sc.,(U.S.A.), certified Professional Geologist (U.S.A.) , of the Department of Geology, Aligarh Muslim University, Aligarh, for his valuable guidance, constant encouragement and constructive criticism all through the accomplishment of this work.

The author is also grateful to Professor P.Ahmad, Head of the Department of Geology, Aligarh Muslim University, Aligarh, for providing necessary laboratory facilities and taking keen interest in the work.

Many thanks are due to all his research colleagues of the department for stimulating discussion and rendering help in every possible way.

The author avails of this opportunity to acknowledge the kind co-operation, including permission provided by the mine-owners viz., Messrs Chowgule and Co.(P) Ltd., Messrs V.S.Dempo and Co. (P) Ltd., Messrs Sesa Goa (P) Ltd., and Messrs Bandakar and Co. (P) Ltd., of Goa, to examine their

mining properties in the area.

The grant of a Junior Research Scholarship by the Ministry of Education, Government of India, New Delhi, is gratefully acknowledged.

Thanks are due to Messrs Allen R. Shaw and Salimuddin Ahmad, for typing the text and drafting work respectively.