Chapter I

INTRODUCTION

Location and Accessibility

The well-known Singhbhum shear zone of the Indian Geology covers a considerable area in the eastern part of the Singhbhum district, Bihar State. The zone falls in the north-eastern part of the Indian Precambrian Shield, and occurs in the form of a 160 km long arcuate and narrow belt, which is famous in India for its large deposits of copper and uranium and popularly known as Singhbhum copper belt (Fig. 1). The study area includes two sectors, viz., the southeastern sector (A) and the central sector (B) of the Copper belt. The belt extends approximately from Durapuram (lat. 22°46' : long. 85°34') on the northwest of Bharagora (lat. 22°18' : long. 83°34') on the southeast and comprises several copper mining localities. The present investigation was restricted to the copper deposits of Mosaboni (lat. 22°31' : long.86°28'), Badia (lat. 22°29' : long. 86°29'), Moinajharia (lat. 22°28' : long.86°29') and Tamapahar (lat. 22°38' : long. 86°21'), which constitutes a section of Rakha mine (lat. 22°38' : long. 86°22'). All the above localities are included in half-inch Survey of India toposheet nos. 73 J/11 and 73 J/6.
Mosaboni, Badia, Rakha, Tamapahar and Jaduguda which are located on the east of Tatanagar, a well-known steel city of the country, are easily accessible from Tatanagar by motorable roads. The Tatanagar-Howrah section of the South-Eastern Railway passes through the eastern part of the southeastern and central sectors, although these places are not directly connected by railway. Ghatsila, the nearest railway station is 15 km away from the Mosaboni mines whereas Rakha including the adjacent Tamapahar and Jaduguda is 6 km away from its nearest railway station, Rakha mines.

Physiography

The area covering the southeastern and the central sectors of the Singhbhum shear zone is occupied partly by low lands and partly by hilly range of moderate height. The highest elevation in the central sector reaches upto 550 metres above m.s.l. where the quartzite ridges make up the prominent hill features. The low lands including the valley floors in the area are occupied by either mica-schists or by shear zone rocks. The main drainage of the area is represented by the Subanarekha river. It enters the mining district through the northern hill tract, then meanders over the north-eastern part of the mica schist plain. Sankh nadi is the only tributary of the Subarnarekha
river which cuts across the southeastern sector. There are also two minor streams which are called nala in Hindi, viz., Sindurgora nala in the central sector and Badia nala in the southeastern sector. They are mostly fed by mine waste water and occasional rainwater during the rainy season. Among the forest trees Sal (Shorea robusta) is predominant. It generally grows on the hill and their slopes. The area is also covered with some scattered bushes and shrubs.

Climate

May and June are the hottest months when the maximum day temperature goes up to 42°C in the region. In the cooler months of December and January, the minimum temperature recorded is 22°C. The region receives intermittent rain due to the north-eastern monsoon of Bengal from July to September.

History of Mining

The evidence of mining activity in the Singhbhum shear zone is known from the discovery of a copper coin of Kushan period as far back as 440 A.D. in one of the pits in Rakha mine. The presence of old workings and slag heaps along this belt led to the rediscovery of copper during the middle of the last century.
The modern copper mining in Singhbhum was first initiated in 1883 by Singhbhum Copper Company though the mining operation was not regular. In 1905, Geological Survey of India had undertaken boring of the Rakha and Mosaboni area and subsequently Cape Copper Company came forward in 1908 to carry out mining activity and continued it till 1922. Thus, the history of copper mining in this belt from the middle of the last century till the end of 1922 had been a story of adventure. However, Cordoba Copper Company in 1924 purchased the mining rights from Cape Copper Company and found excellent deposits of copper upto a depth of 150 metres at Mosaboni mines. The company was then reconstituted and renamed as Indian Copper Corporation Ltd. (I.C.C.) and started extracting copper. By the end of 1927, the I.C.C. began mining operation at Uadia and Dhobani besides Mosaboni and also took up some of the nearby areas like Pathorgora, Surda and Kendadih for exploration. Detailed exploratory drilling in Rakha-Tamapahar section which began in 1962, was completed in 1965 and since then regular mining operation is in progress in the area. The Indian Copper Corporation was nationalized on 10th March, 1977, and became one of the units functioning under Hindustan Copper Limited (H.C.L.). It was subsequently renamed as 'Indian Copper Complex'. At present the Complex is concerned with mining operation in the following areas, which are included in the Mosaboni group of mines:
1. Mosaboni
2. Rakha
3. Pathergora
4. Surda
5. Kondadih

Oro reserves

The copper deposits have been found to continue below the 30th level in Mosaboni mines. The total reserves of the oros up to the 30th level of Mosaboni (including Dadia mine) were estimated at 17.06 million tonnes with an average copper content 1.73 %. The tentative reserves of Rakha mines up to a depth of 600 metres were estimated at 28.9 million tonnes with an average copper content of 1.52 %. In Tamapahar, the reserves up to a depth of 186 metres are estimated to be about 4.6 million tonnes with an average copper content of 1.0 %.

Previous work

Most of the earlier studies on the geology of Singhbhum were carried out by the officers of Geological Survey of India in course of their investigation for the copper deposits in the Singhbhum shear zone. In the last century, Stoehr, E. (1870) reported about the occurrences of copper along the shear zone and briefly discussed the source and origin of copper. He
suggested that the green stone (metabasic rocks) was probably the source of copper mineralization while studying the geology of the area. Dall, V. (1870) suggested that copper was mechanically or chemically deposited contemporaneously with the original sediments resulting in the segregation of copper along fractures and openings in the country rocks. Former, L.L. (1919) regarded the majority of the mineral veins in the area as belonging to the granite phase of igneous activity. The first attempt to classify the rocks of the shear zone systematically was made by Jones, H.C. (1922). Among the earlier workers, Dunn, J.A. (1929) suggested that the copper veins were formed by the hydrothermal solutions emanating from the residual phase of the Singhbhum granite. Later, Dunn (1937) gave a detailed account of copper sulphide mineralization and identified majority of the sulphide minerals. He also abandoned his earlier idea regarding the source of the sulphide minerals and suggested an epigenetic hydrothermal model in which mineralizing solutions were derived from a soda rich magma that consolidated into albite granite (soda granite). He also stated that these liquids were later split into two ore bearing fluids — an earlier oxide fraction from which the apatite-magnetite veins were formed and a later sulphide fraction from which the copper sulphide veins were formed. The investigation carried out in the Singhbhum region by Dunn and Dey, A.K. (1942) was supposed to be one of the most systematic and comprehensive.
The regional geological map prepared by them provided an important frame work for all later investigators. They tried to present the lithology of the major Precambrian rock units and deal with the regional stratigraphy, tectonics and petrology in addition to the genesis of the sulphide ores of this region. Besides, investigating the genesis of the copper ores, Naha, K. (1962, 1963a, 1965) studied the structures and metamorphism of the eastern Singhbhum and suggested that the index minerals formed during this metamorphism indicated a progressive series and the metamorphism was broadly coeval with the folding movements and predated the shearing movement which initiated the retrogressive metamorphism. He also advocated that "thermal disturbance in the upper part of the mantle during the folding of the geosynclinal prism" might be the source of heat for regional metamorphism in Singhbhum.

In recent years, on the basis of Co, Ni values obtained from pyrite Sarkar, S. C. (1966a) suggested a magmatogenic hydrothermal source of the ore solution. Further, he (op. cit., 1966b) suggested that much of the soda granitic rocks in the shear zone were not magmatic in the usual sense and the ore bearing hydrotherms came from an obscure source below. Mukherji, B. (1968) emphasized the probability of genetic relation between the soda granite and sulphide mineralization in the shear zone on the basis of their studies on certain trace elements like S, Cu, Ni and Co, which are common in both.
Based on their observation on the geological and geochemical investigation, Bhattacharjee, S.B. et al., (1968) supported the idea of hydrothermal origin of the copper ore. Acharyya, S.K. (1968) suggested that the hydrothermal solution, which was produced during the granitization of the country rocks, was responsible for sulphide mineralization after granitization. Talapatra, A.K. (1968) suggested a close association of migmatization (feldspathisation) and sulphide mineralization and stated that a considerable amount of copper might have been added to the migmatitic solution when it moved up through the country rocks, as the highly sodic migmatitic solutions probably did not have sufficient copper to give rise to the extensive copper deposits along the entire shear zone. Further, he added that copper along with such elements as Co, Ni, V were probably added to the migmatitic solution in addition to those it already had, by mobilization of those elements originally present in the country rocks (mostly in schists and epidiorite) and that the mobilization of these elements was favoured by the prevailing temperature gradients within the shear zone. Schenellman, G.A. (1968) in his short comment stated that the ore bodies in the shear zone are 'stratabound'. Sarkar, et al. (1971) considered the deposit to be of exhalative-volcanogenic layered type and suggested that the copper sulphide deposits originated as a result of their concentration within the volcanic rocks of the shear zone and were thereafter simply metamorphosed.
with little or no migration or later concentration. Ghosh, A.K. (1972), after examining some of the trace elements data of a part of the copper belt suggested that the ores were formed by the diffusion of ore elements from the country rocks into the structural trap of the shear zone and that there was an initial mobilization of the elements that might have taken place during the early periods of regional metamorphism and attendant deformation. Further, he stated that mobilization of the ores constituents could only take place during intense shearing. Banerji, A.K. (1962, 1974) suggested that the ore deposits in the shear zone originated as a result of their mobilization from the pre-existing volcanogenic rocks of the zone by albite-rich metasomatic fluids that percolated through the country rocks and transformed them partly into albite-schists and gneisses. According to him, the fluids that became enriched in some of the basic elements like Fe, Mg, Ca, Co, Ni, Cr, V, Mn and Ti and water were responsible for the alteration of the country rocks into different zones of biotitization, chloritization, and sericitization. While commenting on the views regarding the origin of the copper deposits expressed by other workers, Banerji (1981) stated that the copper deposits of the belt could not be categorically ascribed either to epigenetic hydrothermal or syngenetic metamorphic process. However, he admitted that the genetic history of these deposits is complex and suggested that the deposits were derived from some syngenetic
volcanic rock by the way of concentration through tectonic, granitic and metasomatic processes that are supposed to be indicative of their epigenetic hydrothermal relationship with the country rocks. In the light of above consideration, he expressed that the deposits might be regarded as remobilization syngentic.

**Purpose of work**

The present investigation has been planned after reviewing carefully the previous work and certain existing problems of the copper deposits in the Singhbhum shear zone. An attempt has been made by the present author to study the lithostratigraphy, petrography and geochemistry of the host rocks of copper in the shear zone and also the associated Dhanjori volcanics. The purpose of the present work is also to investigate in some detail the mode of occurrence, mineralogy and geochemistry of the sulphide ores of the study area and suggest their probable source and origin.

**Methods and presentation of the work**

I. **Field investigations**

Investigations were carried out broadly on the following lines:
1. **Geological mapping**

The field investigation which included the construction of geological map was conducted in the two sectors of the study area, viz., Mosaboni-Badia-Moinajharia and Rakha-Tamapahar-Jaduguda covering about seven sq. km and five sq. km on a scale 1:16660 and 1:12500 respectively. The minor structures such as joints, puckering slickensides and pebble elongation were recorded in details and the contacts of the different litho-units were plotted carefully.

2. **Collection of surface rock samples**

A survey of various outcropping rock types of the study area was conducted; several traverses were taken to collect the desired samples along as well as across the general strike of the different litho-units encountered. About 230 relatively fresh and unweathered samples of rocks were collected systematically on a grid except in the southeastern sector where they were collected randomly due to scarcity of fresh rock exposures.

3. **Collection of underground samples**

About 150 ore samples were collected from the cross-cuts, winzes, raises and levels of the 23rd, 24th, 25th and 26th of Mosaboni mines and from the 3rd level of Tamapahar section of Rakha mine at certain measured distances. Following the same procedure, about 160 samples of the host rock were also
collected from the underground workings of the two sectors. The mineralized portions of the host rock were avoided as far as possible.

II. Laboratory investigations

1. Petrographic and mineragraphic studies

Petrographic and mineragraphic studies of the thin section of rocks and polished blocks were carried out under transmitted and reflected light respectively.

2. Chemical analysis

Systematic analysis of rock and ore samples for the determination of major and minor oxides and the trace elements were determined by the Atomic Absorption Spectrophotometer.

Analytical procedure

On the basis of thin section study, a total number of 70 rock samples were finally selected for chemical analysis. For the determination of major and minor oxides and some trace elements, 26 samples of feldspatic rock, 15 of chlorite-quartz schist, five each from chlorite-biotite and biotite-quartz schists, four of biotite schist and 15 of Dhanjori volcanics were selected (Figs. 2 and 3). Out of eighty-five fairly
enriched mineralized ore samples, 28 samples (20 from north-Badia section of Mosaboni mines and 8 from Rakha-Tamapahar section of Rakha mine) were analysed for their trace element determination.

Rock samples having small veins of quartz, magnetite and tourmaline were, however, rejected. The selected samples of rock and ore have been crushed and ground in automatic grinder to -200 mesh size and small quantities of each sample were taken after conning and quartering for chemical analysis. The powder was dried in the oven at 100°C in order to eliminate the hygroscopic moisture for determining the major and minor oxides, a slightly modified procedure of analysis, suggested by Shapiro, L. and Brannock, W. J. (1962) has been followed.

SiO₂ : Determined by molybdenum blue method.

Al₂O₃: Determined by calcium aluminium alizarin red-S complex method.

Fe₂O₃: Determined on the orange colour developed with Orthophenanthroline.

TiO₂ : Determine on a yellow colour produced with Tiron.

MnO : Determined on the pink colour of permanganate complex developed by oxidation with potassium peridate.

P₂O₅ : Determined by yellow molybdovanadophosphoric (vanadomolybdate) acid complex.
All the above mentioned oxides were determined at different wave lengths on the UV-spectrophotometer (Hungarian Model: Spectromon 202). CaO and MgO were determined by titration with disodiumethylene-diamine tetra-acetate (EDTA). FeO was determined by titration with a standard dichromate solution using diphenylamine sulfonic acid as the indicator.

Na₂O and K₂O were determined by Atomic Absorption Spectrophotometer. Loss of ignition (LOI) of the samples was determined by the heating of sample powder in a glass tube at about 800°C.

The solution for the determination of trace of Cu, Ni, Pb, Zn, Co, Cr, Rb, Sr was prepared by dissolving two grams of rock sample powder in 20 ml 1:1 HNO₃ and diluting it to 100 ml with distilled water. The trace elements were determined using Atomic Absorption Spectrophotometer (Model: Varian AA-6, D).

Preparation of solution of ores

Some important elements of the sulphide ore samples, viz., Cu, Pb, Zn, Ni, Co, Cr, Rb, Sr, In, Ti, were also determined by using Atomic Absorption Spectrophotometer (Model: Varian AA-6, D) by the procedure suggested by Ward, F. M. et al. (1969) and Angino, E. E. and Billings, G. K. (1967) whereas
total iron Fe was estimated colorimetrically by UV-spectrophotometry. The solution was prepared by taking one gram of sample powder in a platinum crucible adding it with five ml of perchloric acid and 20 ml hydrofluoric acid in addition to a few drops of distilled water. It was kept on a hot plate at low temperature for slow evaporation for at least six hours. Then it was removed from the hot plate and allowed to cool. Two ml of perchloric acid and five to eight ml of hydrofluoric acid were added again.

The crucible was again kept on the hot plate at moderate temperature for about four hours and cooled. Five ml of perchloric acid was added and heated till perchloric acid fumes were completely removed. The solution was filtered and distilled water was added to make it 100 ml in a volumetric flask. The elements (specially copper), which are present in abnormally higher concentration were determined after diluting the solution to 20, 30, 50 times of the prepared solutions.

From 21 ore samples, pyrite, pyrrhotite and chalcopyrite were separated by using the Franz-Isodynamic Magnetic Separator. Following the same procedure mentioned earlier the trace elements were determined using Atomic Absorption Spectrophotometer.
Presentation of the results

After the chemical analyses, the data were fed to I.B.M. Computer (No. VAXDIGITAL 170) for calculation of the element ratio of petrogenetic significance, correlation coefficient between major, minor and trace elements and also the mean values. The element analyses, normative compositions and other petrochemical calculations are presented in different tables. All the available data were standardized against U.S.G.S. standard; BCR-1, W-1 and SY-1. To avoid any error in the determinations double and triple runs were made taking different samples from the same specimen powders. Rock standard was also analysed to check the probable error. The relevant details of accuracy, precision and lower detection limit of elements for the rock and the ore samples are given in tables 1, 2 and 3.

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