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GENESIS OF MANGANESE ORES OF KORAPUT DISTRICT, ORISSA, INDIA

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ABSTRACT

Manganese ores of Koraput district are typically found in Nishikhal area and occur in association with the khondalite suite of rocks. The manganese ore is high grade in quality with Mn — 59 to 64%. The ores have high phosphorous content, P — 0.30%. The important ore minerals are psilomelane, pyrolusite, braunite, cryptomelane and goethite. Bixbyite, nsutite, hollandite, rhodochrosite and manganite are detected by X-ray. These ores are residual concentration type and suggest enrichment by supergene processes.

INTRODUCTION

The Government of Orissa laid special interest on the exploration of the manganese belt in the Koraput district during its second five year plan period. A number of promising veins of manganese were located in Taldoshi-Upardhoshi, Podkana, Nishikhal, Kinchikhal and Koka areas [MOHAPATRA *et al.*, 1957—58]. Among these Nishikhal is typical having good reserves.

Manganese ores of Nishikhal area (19°13′, 83°13′) is situated 45 kms west of Rayagada town on Rayagada-Kashipur road. The deposit is connected by an unmetalled road of 15 kms to the north of the above mentioned metalled road. Location and geological formations around the deposit are shown in the *Fig. 1.* The area is approachable by foot from Gum village situated about 16 kms from the main

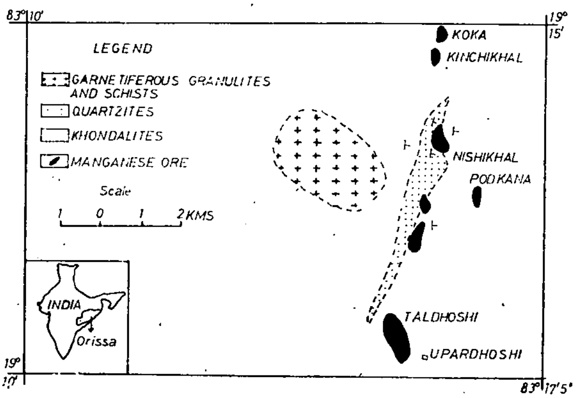

Fig. 1. Geological map of Nishikal area, Koraput

Rayagada-Koraput main road. The area shows extreme climate variations in summer 37,8°C and in winter −1,2°C. The annual rain fall is 100 to 150 cms. The area is thickly forested.

GEOLOGICAL SETTING AND MODE OF OCCURRENCE

Manganese ores are present as irregular veins and lenses in khondalite suite of rocks. The entire manganese belt is found in quartzites and khondalitic gneisses. The ore body is found on the hill slopes, and a few exposures are also seen in the valley region. The general sequence of formations with which the ore is associated intimately is as follows:

Alluvium
Aplites
Quartz-schists, garnetiferous granulites
Khondalitic rocks with manganese ore bodies alternating with the quartzites (quartzites, calc-silicates, garnetiferous and graphite schists)

The manganese deposit is trending N-S and it is 2 to 3 kms long belonging to the upper part of the Khondalite Supergroup of the older Precambrians. The dip of the ore body is 50° to 60° and mostly vertical. The width of the body varies between 1 to 8 metres. The manganese ore is a band, interbedded with garnetiferous quartzite schist or khondalite graphite schist, quartzite and phyllite and the manganese ore has fine intercalations of quartzite.

FIELD CHARACTERISTICS OF THE ORE BAND

Manganese ore occurs in form of lenses, veins, botryoidal and as pockets in khondalites which alternate with quartzites and broadly classified in to three types; 1) brownish black ore, 2) grey massive ore and 3) botryoidal ore. The chemical composition of these types is given an Table 1.

1. *Brown black ore:* Brownish black ore is disconnected from the grey massive ore and botryoidal ore. The ore is hard and compact and in parts brittle. The polished sections show round concentric layers which are colloidal. The structures resemble

TABLE 1

Chemical analyses of the three types of ores

	1 Brownish black ore (average of 3 samples)	*2* Grey massive ore (average of 4 samples)	*3* Botryoidal ore (average of 3 samples)
MnO	34.60	58.50	63.50
Fe_2O_3	31.80	3.20	0.50
Al_2O_3	0.50	1.40	0.50
MgO	4.10	3.00	2.90
CaO	4.50	4.60	4.40
P	0.51	0.26	0.37
V	—	—	—
Ti	0.06	0.31	0.10
Cu	0.0072	0.016	0.011
Ni	0.0032	0.088	0.0088

a nodule. Pyrolusite, bixbyite and goethite are the mineral constituents of such nodular manganese ore.

2. *Grey massive ore:* Grey massive ore occurs as veins and lenses in association with botryoidal manganese ore. The contact between the two types of ore bodies is sharp and sometimes it is not clearly noticeable. The grey massive ore alternates with botryoidal ore and it is discontinuous both in length and widthwise covering about 200 metres in length and 120 metres in width. The essential ore mineral of this type of ore is pyrolusite followed by psilomelane, hollandite, cryptomelane, bixbyite and goethite.

3. *Botryoidal manganese ore:* Botryoidal manganese ore occurs in the area mostly as pockets and lenses sometimes also as veins. It is vug filling type. The botryoidal layers grow towards the centre of the vugs. Botryoidal manganese ore alternates with grey massive ores. The dominating ore mineral is psilomelane followed by hollandite and pyrolusite.

Brownish black ore occurs fareway from the grey massive and botryoidal ore types. Chemical analyses showed low manganese and high iron in the former type of ores and increase of manganese and decrease of the iron content towards the grey massive and botryoidal types of ores. Magnesium content decreases from brownish black type of ore through grey massive ore to botryoidal types, whereas calcium maintains the same throughout. P, Al, Ti, Cu and Ni show some irregularity, however, botryoidal ore types are enriched in these elements. Usually, the dehydrated gels of manganese can adsorb some elements like Cu, Ni and Ca etc. [RAMDOHR, 1969]. Vanadium is found absent in all three types of ores.

The process of formation of manganese ores in the area took place in four stages to reach the high grade ores (type 3) as follows: manganese bearing rocks → brownish black ore → grey massive ore → botryoidal ore. In all the four stages, the manganese is active and enriched. Though the manganese and iron behave geochemically in the same manner they differ sharply in physico-chemical conditions of enrichment.

MINERALOGY

The minerals identified by mineralographic studies of a representative collection of manganese ores are psilomelane, cryptomelane, pyrolusite, hollandite, braunite, nsutite, manganite, bixbyite, rhodochrosite and goethite. Some of these minerals have been identified by X-ray diffraction analyses only. Measured *d* values of individual minerals are given in the Table 2. The values are compared with those of different workers, BERRY and THOMPSON [1962]; SOO JIM KIM [1970]; DESSAI and DESHPANDE [1978]. It may be mentioned that this is the first time that rhodochrosite is identified in the manganese ores of Koraput district.

Psilomelane is the abundant mineral in the manganese ores. It occurs in massive, botryoidal and reniform varieties. Psilomelane is massive and shows colloform textures. It has typical grey colour.

Cryptomelane is found mainly in grey massive ores. It forms colloform bands sometimes with or without alternating pyrolusite layers. The colour is grey and it is fine grained; reflectivity is low, nonpleochroic and isotropic.

Pyrolusite shows metallic lustre and it has a colour varying from iron black to steel grey. Under reflected light, it shows crystalline as well as non-crystalline forms. It is white in colour with yellowish tint; pleochroism is distinct with colour

TABLE 2

X-ray diffraction data of the manganese and iron minerals

Psilomelane		Cryptomelane		Pyrolusite		Hollandite		Braunite	
I	d (Å)	I	d (Å)	I	d (Å)	I	d (Å)	I	d (Å)
6	2.423	28	3.11	47	3.101	31	6.978	22	4.700
20	2.400	21	2.40	31	2.391	25	3.110	34	3.316
17	2.392	17	2.165	18	2.189	6	2.423	20	2.341
5	2.12	8	1.638	19	2.12	17	2.41	16	2.131
6	2.112	10	1.435	10	1.619	9	2.16	17	1.872
11	2.04	18	1.365	13	1.43	26	1.949	14	1.653
15	2.01	16	1.303					21	1.283
10	1.862								
9	1.625								

Goethite		Manganite		Bixbyite		Nsutite		Rhodochrosite	
I	d (Å)	I	d (Å)	I	d (Å)	I	d (Å)	I	d (Å)
13	3.376	27	3.412	32	4.685	17	2.596	40	3.654
23	2.694	32	2.644	20	2.502	13	2.437	28	2.840
17	2.584	41	2.520	13	2.211	27	2.170	13	2.012
21	2.447	33	2.275	10	1.916	19	2.134	17	1.530
15	2.003	24	2.201	18	1.714	9	2.045	15	1.382
17	1.799	16	1.183	15	1.612	44	1.623		
18	1.717			24	1.282	27	1.408		
15	1.688								
16	1.658								
15	1.421								

changing from yellowish white to white. Anisotropism is present in shades of yellowish white.

Braunite is one of the important constituents of the ores. FERMOR [1909] considers braunite as the most important manganese mineral of the Indian manganese ores. Generally, braunite occurs in all manganese ores irrespective of the grade of metamorphism [ROY, 1966]. In the ores, it is fine grained and it has variable colour from dark to grey. The anisotropism is feeble.

Goethite is usually found in association with colloform cryptomelane and pyrolusite. In many cases, it forms the core around which concentric layers of cryptomelane and pyrolusite are deposited and also vice versa. Occassionally, stalactitic forms of manganese oxides are formed around a central core of goethite. Under reflected light, goethite is observed as layered and needle like forms or more often, it forms the nucleus around which manganese oxides form concentric layers. Needle-like crystals are often replaced by cryptomelane.

The minerals like nsutite, manganite, hollandite, bixbyite and rhodochrosite are identified only by X-ray studies.

TEXTURES

Colloform texture: The term 'colloform' is in other words called as colloidal or gel texture [EDWARDS, 1954]. The ores showing colloform textures are composed of layers of cryptomelane, pyrolusite and rarely nsutite *(Figs 2—4)*. Colloform layers

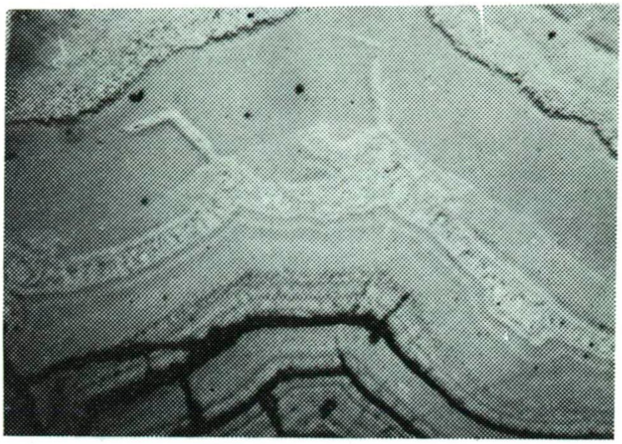

Fig. 2. Colloform bands of pyrolusite (white) alternating with cryptomelane (dark grey), psilomelane (grey) and gangue (black). Pyrolusite (white) is replacing the psilomelane (grey) ×70.

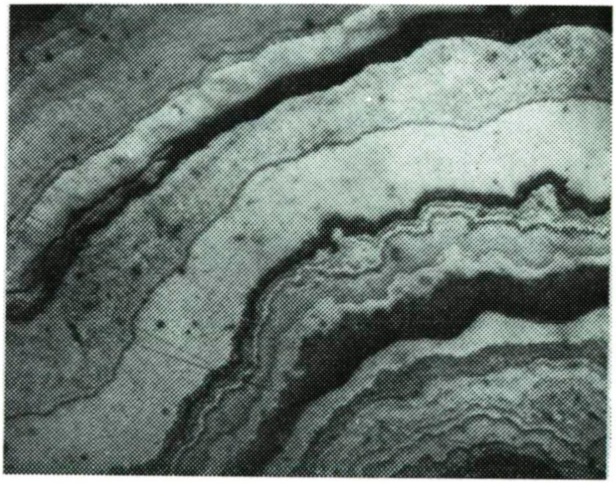

Fig. 3. Colloform texture. Alternating bands of gangue (black), cryptomelane (grey) and pyrolusite (white) ×90.

may be monomineralic or may consist of more than one mineral. Concentric layers of different mineral composition often enclose small nuclei of the ore or gangue at the centre *(Fig. 5)*.

Fracture fillings: Fractures generally develop in the brittle minerals like quartz and later these fractures are filled with one or several minerals. The fractures may localize later deposited ores or serve as channel ways to initiate the replacement of the fractures mineral by younger minerals [EDWARDS, 1954]. The fractures may form a net work or may show bifurcations *(Fig. 6)*. Some of the segmented veins found at different parts of fracturing may filled with crystals of pyrolusite, psilomelane or gangue.

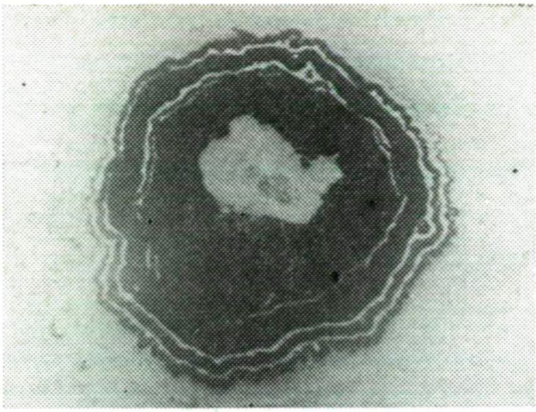

Fig. 4. Pyrolusite (white) at the centre surrounded by layers of goethite (dark grey) and pyrolusite (white) ×70.

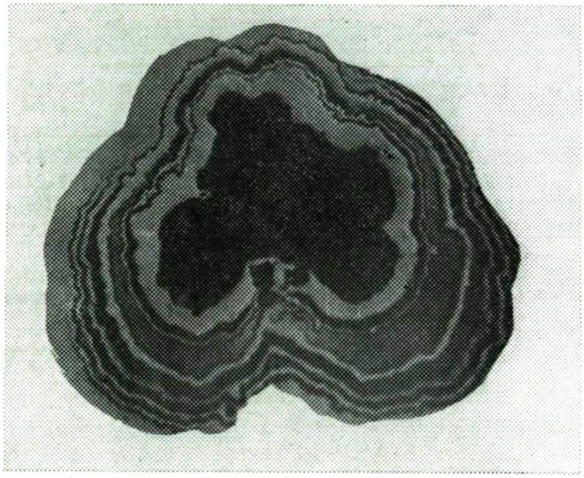

Fig. 5. Gangue (black) surrounded by layers of pyrolusite (white) and goethite (grey) ×100.

Replacement texture: Replacement texture is the dominant mechanism in the process of downward enrichment of ores, which is of major economic importance [Bastin, 1950]. The replacement is mainly confined to fractures, mineral cleavages, contacts between mineral grains etc. Many replacements have taken place at ordinary temperatures equal to the waters of surface origin. Some replacements also occur at high temperatures ranging up to 500° and even more. In the present ores the replacement is mainly seen between pyrolusite — braunite, cryptomelane — gangue, and pyrolusite — psilomelane. The replacement of braunite and pyrolusite is common *(Fig. 7)*. Cryptomelane is seen as patches in a ground mass composed of braunite and gangue, the gangue is mostly quartz and sometimes the ore replaces the gangue.

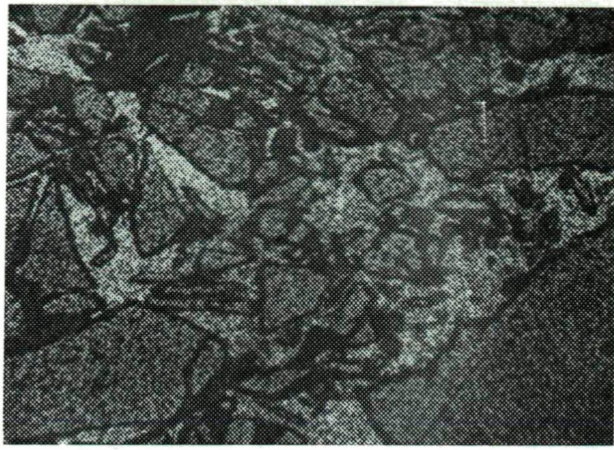

Fig. 6. The fractured veins showing the pyrolusite (white) in quartz (grey) ×70.

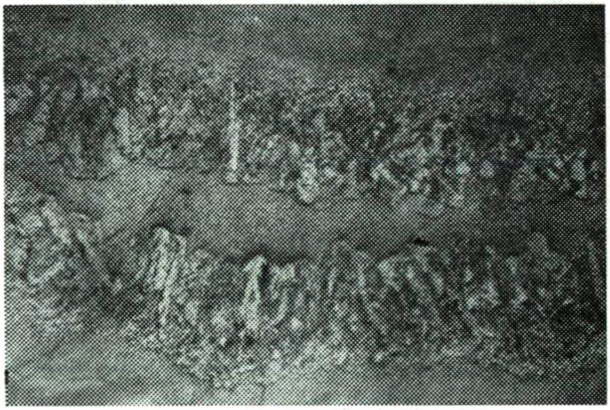

Fig. 7. Scaly forms of pyrolusite (white) replacing braunite (grey) ×70.

GENESIS

The primary minerals are rare, the reasons may be topographic relief. The deposit mainly consists of supergene enriched secondary oxides derived from primary syngenetically metamorphosed oxide and silicate assemblages. Most of the primary minerals have undergone supergene alteration.

The ore consitutes both the higher and lower oxide minerals that indicate the change of oxygen during deposition. SOKOLOVA [1964] applied the physico-chemical methods on the formation of ore minerals. According to her, higher oxide minerals like pyrolusite, psilomelane, cryptomelane have the highest Eh and considerably low pH values. The lower oxides like manganite have low Eh and pH values and intermediate minerals like hollandite, braunite have intermediate values between two above. Thus, the change of oxygen and acidity varies from low-intermediate-high, then the formation of minerals in the area may be written as follows:

1. Manganite → Nsutite → Pyrolusite
Psilomelane
Cryptomelane

2. Manganite → Nsutite → Hollandite → Pyrolusite
Braunite   Psilomelane
Cryptomelane

Thus, the manganese ores form by chemical reshuffling of the manganese bearing rocks in sediments under suitable conditions of temperature, pressure, Eh and pH. The manganese ores of Nishikhal area are essentially originally syngenetic sedimentary resulted from a set of systematically metamorphosed oxide and silicate assemblages by supergene enrichment.

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