IRON-ORE OCCURRENCES AT TATPAHAR, SOUTH OF SAPEHI, SIDHI DISTRICT, MADHYA PRADESH+

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ABSTRACT

This paper incorporates occurrences of iron-ores in an area situated south of Sapehi at a distance of about 15 Kms east of Sidhi town in Madhya Pradesh. The iron-ore occurrences are associated with the rocks equivalent to Middle Dharwars or the Iron-ore Series of Bihar and are confined to three, more or less, parallel ridges of quartzitic rocks. The largest and the most prominent of the three ridges is locally called as Tatpahar which extends between villages Mynkhari in east and Khoah in west.

A preliminary mineralographic study of the iron-ores of the area reveals the existence mainly of *magnetite*, *martite* and *hematite* with subordinate amount of *specular hematite* and gangue minerals. The iron content in these ores varies between 60 to 65 per cent. The massive iron-ores show both syngenetic and epigenetic features, but the ferruginous quartzite, however, is of metamorphic origin.

INTRODUCTION

The area under study, measuring about 40 sq. Kms, lies between parallels of 24°23'30" and 24°26' north lattitude and meridians 82° and 82°5' east longitude at a distance of about 15 Kms east of Sidhi town in Madhya Pradesh. The area forming a part of Son Valley occupies the land mainly south of Sidhi-Jiawan Road between milestones 69—75 and is confined in topo-sheet No. 63 L/3 (1947) of Survey of India. The area is situated at a distance of nearly 200 Kms south-west of Mirzapur via Hanumana in Uttar Pradesh and south-east of Satna via Rewah in Madhya Pradesh.

The area is mainly occupied by the older crystalline metamorphic rocks in the form of a crystalline complex extensively covered by recent soil with thick vegetation. Their outcrops are scanty and discontinuous in the field due to intense weathering. It is, therefore, very difficult to determine their field relations with satisfaction. Various lithological units of the crystalline complex, which roughly trend NE-SW, occur in banded form. The iron-ore occurrences are confined mainly to three, more or less, parallel ridges comprising highly jointed quartzites with ferruginous material towards their tops. The largest and the most prominent of the three ridges is situated south of Sapehi and is locally known as Tatpahar. It attains a height of about 520 metres and trends ENE-WSW between villages Mynkhari in east and Khoah in the west. Large heaps of slag scattered throughout the area are evidence of an iron industry flourishing, in past, in Sidhi District.

The present area had been neglected by the British geologists as they considered it to be devoid of minerals of particular economic value. The pioneering work, in Son Valley, at and near this area was that of Oldham *et al.* (1901). Later on Auden (1933), Dubey (1950) and Law (1954) also worked at and near this area. The present authors (1976) worked out the preliminary geology of the area. To the best of knowledge of the authors there is no published account of the iron-ores in the area under description.

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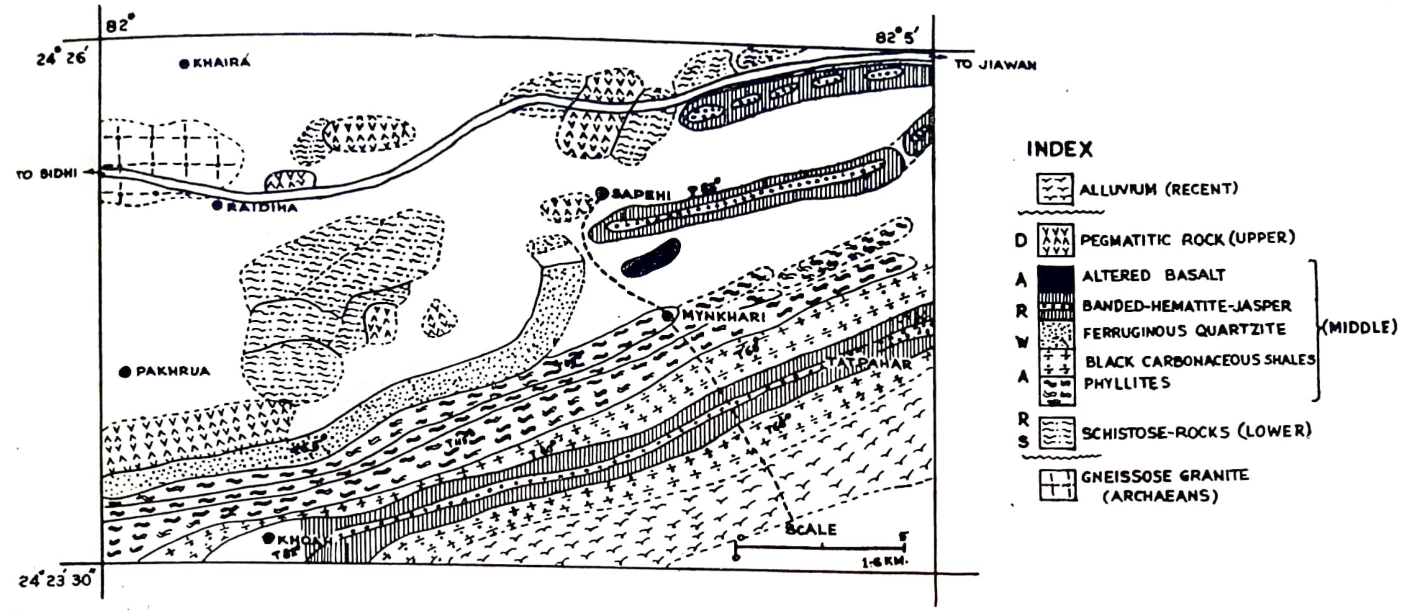

Fig. 1. Geological map of an area near and south of Sapehi, Sidhi District, Madhya Pradesh. Scale 10 cm = 1.6 km × 1/2

GEOLOGY OF THE AREA

The succession of the rock units in the area, modified after Oldham *et al.*, (1901), may be summarised as below :

RECENT		Soil
DHARWARS	Upper	Pegmatitic rock
	Middle	Altered basalt Banded-hematite-Jasper and ferruginous quartzite Black carbonaceous shales Phyllites
	Lower	Schistose rocks intruded by metamorhposed basic and ultra-basic igneous rocks.
UNCOFORMITY		
ARCHAEANS		Gneissose granites

FIELD OCCURRENCES OF THE IRON-ORES

The iron-ores, comprising ferruginous quartzites and the banded-hematite-jasper, are associated with the rocks equivalent to Middle Dharwars or the Iron-ore Series of Singhbhum, Bihar. These rocks occupy a large area near and south of Sapehi. They show high dips. A group of green and calcareous phyllites form the lower most rock unit of the Middle Dharwars. The phyllites are followed by black carbonaceous shales dipping 65° S 55° E. They are exposed on both sides of Tatpahar. Ferruginous quartzites with associated banded-hematite-jasper are the main iron-ore bearing rocks. They follow the black carbonaceous shales and are exposed in three, more or less, parallel ridges near and south of Sapehi. The iron-ores, here, occur mainly as (i) specular *crystalline hematite* in simple filled in pockets in quartz veins and (ii) hill ranges of banded-hematite-jasper and ferruginous quartzitic rocks. Few pockets of the crystalline hematite also occur in a hillock, namely Lakhia-Pahar. (Pl. 1, Fig. 1).

The banded-hematite-jasper and the ferruginous quartzites strike ENE-WSW showing high dips. They are quite hard and resistent rocks standing out prominently in the area. The banded-hematite-jasper often shows minor folds in it. The ferruginous quartzites are coarse to fine grained occurring near the base and top of the ridges.

LABORATORY STUDY

The coarse grained ferruginous quartzite, in hand specimen, appears greyish white becoming reddish with increasing iron content in it. It is generally compact showing a sort of elongation and parallelism of quartz grains comprising the rock. It is shining rock with hardness varying from 5 to 6 and specific gravity 2.5, increaing with the iron content in it. Under the microscope it shows rounded or sub-angular coarse grains of quartz with *specular hematite*. A typical mosaic texture is usually seen (Pl. 1, Fig. 2). It results from secondary growth in the body of the sand grains. The grains are generally arranged in bands that are held together either by silica or the iron-oxide. Talc and epidote in accessory amounts and plagioclase, feldspars and detrital muscovite in subordinate amounts may also be, sometimes, observed. Presence of these minerals indicates that the pure quartz and feldspars have been affected by moderate degree of metamorphism resulting in the formation of the quartzite. The banded arrangement of the grains may be due to formation of the rock under stress.

The fine grained ferruginous quartzite, in hand specimen, is usually compact and massive showing a sort of stratification. It is usually pinkish in colour with vitreous lustre and conchoidal to sub-conchoidal fracture. Its hardness varies between 6 to 6.5 and the specific gravity is 2.6 increasing with iron content in it.

Under the microscope it shows quartz grains with an irregular outline. The individual grains of the quartz are thoroughly cemented together, with generally, no intergranular space resulting in more or less mosaic structure. The elongation of the grains in a particular direction, banded appearance of the rock, overlapping crystals and recrystallisation of siliceous cementing material in continuation with the original crystals again point a metamorphic origin of the rock.

The banded-hematite-jasper, in hand specimen, appears to be made up of alternating bands or layers of ferruginous and siliceous material. Individual bands vary in colour from grey or white to lavender brown or even black. The bands are paper-thick to few centimetres thick with an average thickness around 2.5 mm. These layers are parallel but, at places, also thin out or thicken out laterally. They are often traversed, almost prependicularly, by fine to medium grained quartz veins. In one of the specimens the iron bands containing minute octahedral crystals of the *magnetite* have a rough surface owing to the small shining crystals of the *magnetite* projecting outward from the weathered surface.

In the transmitted light of the microscope the banded-hematite-jasper is seen to consist of alternating bands of iron-oxide and the silica. The silica is chalcedonic as well as microcrystalline. The quartz grains in the siliceous bands show varying degree of fineness; those around iron-oxide are comparatively coarser than those forming rest of the rock. The quartz grains often show undulatory extinction. The red colour of the jasper varies probably due to uneven distribution of iron-oxide in spaces (Pl. 1, Fig. 3).

The quartz grains, in the veins traversing the banded rock, are usually coarser. They grow outward from the cavity wall due to development of small crystals of the quartz towards outer periphery. These veins, however, do not represent infilling along fracture planes.

The ores in hand specimen appear to be massive and purely hematitic with a steel grey colour, cherry red streak, metallic lustre and specific gravity 5.2. At places, the ore has a superficial coating of lustrous greyish black film. The ore is resistant to weathering, though on continued exposure to atmospheric agencies it breaks up into smaller blocks bounded by parallelepiped faces. A microscopic examination of the ore reveals the existence of *magnetite*, *martite* and *hematite*. The *magnetite* content in the massive iron-ore, is 60-80 per cent. Some quartz is also present.

MAGNETITE

It is a dominant constituent among the iron minerals in the iron-ores,but it has generally been martitised to varying degrees. It has a distinctly brownish colour with a slight bluish tint. It generally shows no cleavage but has a very feeble pleochroism and a low power of reflection. It is generally isotropic but, at places, also shows anomalous anisotropism, which may be due to its intimate association with *martite* occurring usually along its octahedral planes. Inclusions of *ilmenite* have also been observed.

MARTITE

It is a variety of *hematite* formed due to alteration of the *magnetite* and is pseudomorphous after the *magnetite*. Martitisation of the *magnetite* has been observed in various stages of development. It shows original shape of the *magnetite* but exhibits such optical characters which are almost similar to those of *hematite*, except a distinctly weaker anisotropism and lesser sharp extinction. The grey colour of the *martite* may be due to incomplete alteration of the *magnetite* into the *martite*. The mineral is non-pleochroic with a sharp deep reddish internal reflection.

HEMATITE

It has a greyish white colour with a distinct blue tone which becomes more pronounced in oil immersion. Two varieties of the *hematite* are distinguished by their reflectivity; one showing lower and the other a higher reflectivity, but both the varieties are slightly pleochroic. Anisotropism is distinct with the colours of anisotropism varying in shades of greyish to greyigh-yellow extinguishing quite sharply twice in a complete rotation. It shows a deep reddish internal reflection.

MASSIVE IRON-ORE

The massive iron-ore, in a polished section, shows big remnants of brownish *magnetite* swimming in the *hematite*. (Pl. 1, Fig. 4). The *magnetite* remnants with sutured borders suggest a replacement origin. In many other sections silicate gangue minerals are also present in association of the *magnetite-hematite*. Some amount of *limonite*, showing deep red internal reflection and polygonal or cellular structure, is also present. The *hematite* shows octahedral cleavage. A deep red to light pinkish reflection is seen in the *magnetite* grains due to their extensive limonitisation.

SPECULAR IRON-ORE

The specular iron-ore, in hand specimen, is steel grey or iron black in colour showing conchoidal fracture. It has a specific gravity 5.3. It is faintly magnetic. The fresh surface of the ore shines with radiating acicular crystals.

Under low magnification of a microscope a thin section of the specular iron-ore shows an intimate admixture of acicular to pleaty gangue and ore minerals. Sometimes a radial divergent structure is resulted due to the intergrowth. The ore mineral is predominantly *martite* in which pale brownish relicts of the *magnetite* are found embeded in a slightly brighter pale bluish *hematite*.

Under higher magnification of the microscope the *magnetite-hematite* intergrowth is very well seen. The gangue minerals are greatly replaced by the *martite*. The replaced relicts of *specularite* occur as rhomb-shaped highly anisotropic crystals embeded in a dark gangue. A slightly lesser dark and massive gangue appears to be quartz with polygonal cracks, filled with limonite which shows brownish internal reflection.

SPECTROGRAPHIC STUDY OF IRON-ORE POWDER

The powdered sample of the massive iron-ore was spectrographically studied to gather some idea about the concentration of important elements in it. The study was done by means of Hilger's large quartz spectrograph run with 200 Volts D.C. at 56 ampere. The sample was excited in a carbon electrode which was also made the positive electrode. The copper arc was superimposed as a standard to measure the lines by Hartmann's formula ($\lambda = \frac{\lambda O}{\lambda - \lambda S}$) and wave lengths of different lines were calculated. Prominent and persistent lines of different elements were identified from the standard wave length chart given in chemical spectroscopy by BRODE. The following wave-lengths of the prominent lines of the respective elements present in the spectrograph have been observed :

PRISM SPECTRUM OBSERVATION OF THE MASSIVE IRON-ORE

Element	*Wave length*
Cu 1	3247.5 A°
Cu 2	3274.0 A°
Cu 3	3332.0 A°
Cu 4	5218.2 A°
Fe 1	4872.3 A°
Fe 2	4891.6 A°
Fe 3	4919.5 A°
Fe 4	4959.6 A°
Mg 1	5172.6 A°
Mg 2	5185.6 A°

The spectrographic study of the massive iron-ore of the area reveals that the strong lines of important trace elements present are for copper and magnesium.

CHEMICAL STUDY OF THE IRON-ORES OF THE AREA

Ten samples each of the massive iron-ore and the specular iron-ore were chemically analysed. The results of the chemical analysis are given below in Tables 1 & 2.

Table 1—Chemical analysis of the Massive Iron-ore

Sample No.	S.I. 1	2	3	4	5	6	7	8	9	10
	%	%	%	%	%	%	%	%	%	%
Fe.	64.58	63.05	65.2	65.3	64.92	65.12	63.5	60.57	64.62	61.03
SiO_2	11.45	12.25	10.2	11.8	10.50	10.02	11.7	10.25	11.42	9.95
Al_2O_3	5.05	6.52	2.50	5.2	4.75	3.60	5.03	6.33	4.80	3.88
MgO	0.72	0.15	0.38	0.66	0.45	0.35	0.66	1.85	0.67	1.02
Ca	0.66	0.8	0.5	0.73	0.65	0.67	0.72	0.91	0.67	0.28
P	Traces									

Table 2—Chemical analysis of Specular Iron-ore

Sample No.	Sp. 1	2	3	4	5	6	7	8	9	10
	%	%	%	%	%	%	%	%	%	%
Fe	62.95	64.05	64.17	61.90	65.08	61.84	63.25	62.89	64.88	60.97
SiO2	8.87	10.75	10.55	9.44	11.35	8.73	9.15	10.08	11.05	11.65
Al_2O_3	5.09	5.38	6.82	4.98	7.8	7.77	6.06	7.78	6.89	8.02
MgO, Ca and P	Traces									

ORIGIN OF THE IRON-ORES

There has been a long controversy regarding the origin of iron bearing rocks. A primary origin of *hematite* in banded iron formations has now been unanimously accepted. Dunn (1937, 1941b) noticed occurence of *magnetite,* replaced by *martite,* in Iron-ores of Singhbhum, Bihar, but he is of opinion that the *magnetite* is a product of metamorphism. The quartz-magnetite rocks have been found associated with rocks showing various grades of metamorphism from nearly unmetamorphosed rock in the Biwabik Iron Formation of Mesabi range (Gruner, 1923) to rocks showing highest grade metamorphism in South India (Krishnan, 1953, 1954). According to James (1954) *hematite* remains a major constituent in association with the *magnetite* in areas of intense metamorphism such as in Republic District of Michigan.

Edwards (1936) and Miles (1941) from Western Australia ; Hallimond (1925) from Britain ; Gruner (1922), White (1954) and Huber (1959) from U.S.A. ; Dunn (1941 a, b), Spencer and Percival (1952) and Krishnan (1954) from India worked on sedimentary iron-ores and many of them suggested a primary origin for both the *hematite* and the *magnetite.*

In the present area main occurrence of the *hematite,* associated with the banded-hematite-jasper and the ferruginous quartzites, equivalent in age to Middle Dharwars or the Iron-ore Series of Singhbhum, Bihar, is confined in southern region. The origin of the main ore body is related to the origin of the banded-hematite-jasper. It is mostly believed that the rhythmic banding in the associated jasper quartzites is of sedimentary origin. Thus the *hematite* deposits of the area are originally of sedimentary origin although they have subsequently undergone much alteration. In the Lake Superior region *hematite* is rhythmically interbedded with jasper or the red chert. JAMES (1954) considers it a primary sedimentary deposit but according to DUNN (1941 a) a sedimentary origin, which accounts for the formation of the banded jaspilites in the Lake Superior region, can not be made applicable to all the banded hematite quartzites merely on the basis of their lithological similarity. The ferruginous quartzites may have different modes of origin at different places. The field and the microscopic evidences are completely in favour of a metamorphic origin for the ferruginous quartzites of this area. Majority of the workers on the iron-ores unanimously accept that all the ferruginous bands are of the sedimentary origin but the problem of the origin of the siliceous layers in them remains unsettled. DUNN (1937) believes that these siliceous layers have been formed due to secondary silicification of older shales and phyllites. This silicification had been contemporaneous with the deposition of these beds with numerous evidences of alteration. JAMES (1954) and WHITE (1954) during their work on Biwabik Iron Formation of Mesabi range established that the major part of the chert is primary in origin having been formed as an original constituent of the iron formations rather than as later replacement. The original silicification and enrichment of the iron ores of the present area were probably brought about to large extent by iron rich circulating waters at a temperature of about 100°C and to lesser extent by addition of meteoric water. This enrichment has probably been brought about by replacement of the silica by iron and recementation of the grains.

The petrographic, mineralographic and the field study of the massive iron-ores of the area led authors to conclude that the massive iron-ores of the area have been formed by replacement and later enrichment, but the ferruginous quartzites are the product of metamorphism. The field evidences and microscopic study of the *crystalline hematite*, however, point to a primary origin for it.

PROBABLE FUTURE PROSPECTS OF THE AREA

With the large amount of wood charcoal locally available the massive iron-ores of the area can be utilised in small scale blast furnaces. The cottage iron industry of the district can be revived by improving the old indigenous methods and employing cheap power and local labour. The *specular crystalline hematite* can be used economically by applying advanced methods of ore beneficiation.

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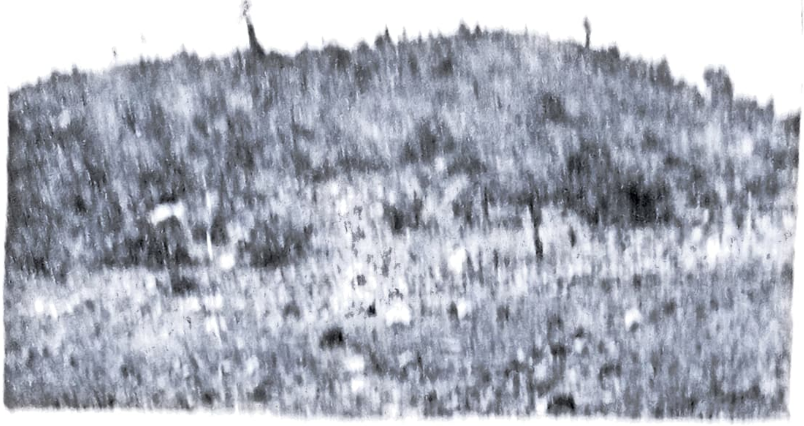

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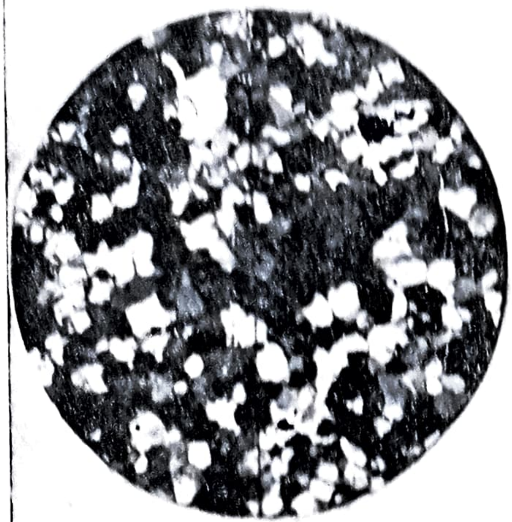

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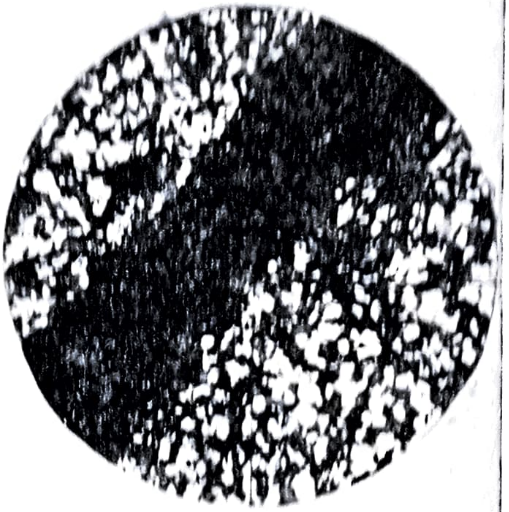

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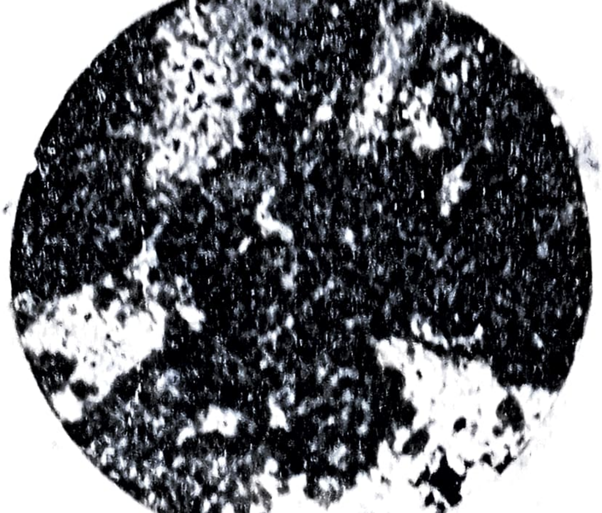

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EXPLANATION OF PLATE 1

1. Lakhia Pahar, south of Sidhi-Jiawan Road near milestone 73.
2. Thin section under × nicols of the ferruginous quartzite showing mosaic texture. × 90.
3. Thin section under × nicols of the banded-hematite-jasper showing hematite band at the centre surrounded by the fine grained silica. × 90.
4. Thin section under × nicols of the specular hematite with big relicts of the magnetite. × 90.