CHAPTER II: Distribution of Iron Ores
The second chapter essentially deals with the distribution of iron ores in the present study area. The geological investigations in different resource bearing areas of the Chhotanagpur plateau and its fringes certainly brought forth substantial data on the distribution patterns of iron ore. The presence of the numerous evidence of smelting of iron in this wide distribution zone gives us some understanding about the nature of exploitation of iron ores and obviously the procurement networks involved between the extraction zones and the centres of production. There is no doubt that the concerned metal was extracted by the smelters to produce iron in form of ingots atleast from the 2nd millennium BCE onwards, if not earlier. Here, one may point out that, the investigations on the old mining of eastern India, exhibits a somehow a comprehensive picture about the same and its relationship with ore bearing regions. It is significant to state here that the indigenous smelters (the groups who had acquaintance with the extraction process of the metal particularly iron) used to prefer such iron ores which were easy to extract. Quite obviously, some of these deposits were considered to be of little significance by the present day geologists. Therefore, besides referring to the significant iron ore deposits of eastern India, the present brief discussion also includes some reference to the iron ore deposits, studied by some of the eminent geologists and British administrators of the colonial period (Ball, 1877: 87-94; Oldham, 1852; 1859: 1-32; Sherwill, 1855; Jackson, 1845: 754-756; Buchanan, 1930: 32-33; Mallet, 1875: 1-93). Their works referred to the iron ore deposits which were largely favoured by the indigenous smelters.

It is worth-noting that the mining process for extracting iron is not as strenuous as that of other metals and minerals. These generally occur on exposed surfaces as well as in the admixtural form in the veins of rocks or other metals. The Birbhum region, the Raniganj coalfield area, the old districts of Palamau, Singhbhum, Hazaribagh, the Manbhum area besides the Mayurbhanj, Bonai and Keonjhar areas have significant iron ore deposits which were exploited by the ancient iron smelters. The ethnographic data suggests that during the colonial period, such ore deposits were extensively utilized (Buchanan, 1930: 32-33; Jackson, 1845: 754-756; Ball, 1877: 87-94). The primary iron working areas (in which ore were extracted to produce iron ingots) were definitely situated in close proximity to the ore bearing areas. Archaeological data (slags, broken tuyers, burnt earth) related to the production of iron objects from Mayurbhanj-Keonjhar area, Tel river valleys, Asura sites in the present Ranchi district, Birbhum region also attest to the fact that primary workings were conducted in the vicinity of the ore bearing/ mining areas.
The present discourse is essentially based on the reports of Krishnan (1954), Dunn (1929, 1937), Dunn and Dey (1942), Ball (1877: 87-94, 1880: 1-127, 1881a, 1881b), Hughes (1874: 20-30; 122-124), Oldham (1852; 1859: 1-32), Smith (1856), Mallet (1875: 1-93) etc.

In India, iron ores occur in different geological formations though by far the most important deposits can be pertained to the Pre-Cambrian (Krishnan, 1954: 107).

The iron ores of India can be divided into three major groups according to their origin (Krishnan, 1954: 103-104). The most important group comprises the banded ferruginous formations of the Pre-Cambrian age. In the unmetamorphosed type, which includes the majority of the larger deposits, the ore bodies have been derived from the concentration of the iron contained in the original banded haematite-jasper formation. Where subjected to metamorphism, these ores have been converted into banded quartz-magnetite rocks. In this, the magnetite has been derived from the original haematite. Sometimes the magnetite is associated with amphiboles of the grunerite-cummingtonite group.

The second group consists of sedimentary iron ores of siderite or limonite composition as for example the ores occurring in the Ironstone Shales (Lower Gondwana age) of the eastern coalfields of Bengal and Bihar and the ferruginous beds occurring in the Tertiary formations in parts of the Himalayas and Assam. The siderite ore is often is hydrated and changed to limonite iron-stone near the surface.

The third group consists of lateritic ore derived from the sub-aerial alteration of the iron ore bearing rocks, such as gneisses, schists, basic lavas, etc., under humid tropical conditions, resulting in the concentration of the hydrated oxides of iron often associated with those of aluminium and manganese. Lateritic caps are widespread in India. They cover large stretches of the Deccan traps, the gneisses in the Western Ghats, the schistose rocks of many areas (e.g. Sandur in Madras) the impure limestone formations etc. They, however, of low grade, containing only 25 to 35 percent iron.

The apatite-magnetite rocks of the Singbhum copper-belt constitute another type. They are supposed to have been formed by the magnetite activity associated with a Pre-Cambrian diastrophic cycle, when the rocks of the shear zone were thrust and were intruded by acid and intermediate igneous rocks (Krishnan, 1954: 104).

The titaniferous and vanadiferous magnetites of south-east Singhbhum and Mayurbhanj are genetically connected with the ultrabasic intrusives of the region. The vanadium content is usually small (less than 2 per cent. of V₂O₅) but the titanium is much more.
Similar bodies of magnetites are found also in the ultrabasics of Keonjhar which in some cases are associated with chromite deposits.

Finally, mention may be made of fault and fissure fillings of haematite which are occasionally found.

**Geological Settings:** Iron ores occur in different geological formations in India but by far the most of important deposits belong to the Pre-Cambrian. It contains some ores especially of the Gondwanas and laterites. According to Krishnan, these ores were probably exploited by the indigenous smelters and are of comparatively little importance now (Krishnan, 1954: 107).

The geological formations, the types of ores found in them and the regions in which important deposits are known are the following (Dunn and Dey, 1942; Krishnan, 1954: 107-108).

**Pre-Cambrian:** The most important iron ore deposits of India are those associated with the banded haematite-jaspers of the Dharwarian formations of south India (Mysore, Sandur, Goa) and their equivalents, the Iron-ore series, in northern India (Bihar, Orissa, Central Provinces). The ores are derived from the enrichment of the banded ferruginous rocks by the removal of the silica. The ore bodies generally form the tops of ridges and hillocks and are often of great magnitude. Most of them contain high grade ores near the surface, with an iron content of over 60 percent and are associated with even larger quantities of lower grade ores.

Where metamorphosed regionally or by igneous intrusive, these banded haematite-jaspers have been converted into banded quartz-magnetite rocks which also attain considerable importance in certain areas (Salem-Trichinopoly and in southern Mysore).

In some places, e.g., Mysore, Singhbhum and Mayurbhanj, there are bodies of titaniferous magnetite ores associated with basic and ultrabasic igneous intrusive. They contain some chromium in Mysore and vanadium in Singhbhum-Mayurbhanj. These deposits are considered to be of ortho-magmatic origin. The copper belt of Singhbhum contains apatite-magnetite ores associated with granodiorite.

**Cuddapahs:** The Bijawars of central India and the Pulivendla quartzites of the Cuddapah district contain workable deposits rather small size. They seem to be locally enriched portions of ferruginous formations.
**Vindhyans:** No useful deposits are known in these formations, though some of the sandstone members are to some extent ferruginous. Occasional pockets and concretions of limonite are found in them.

**Gondwanas:** The Barakar formation, in rare instances, contains concretionary masses of limonite. In the Auranga coalfield in Bihar, clay-ironstones are found in some quantity in these formations and they were formerly used extensively by indigenous smelters. Some of these appear to have been derived from the original carbonate ore by oxidation and hydration.

The Ironstone Shale stage, particularly of the Raniganj coalfield, contains considerable amounts of clay-ironstone derived from siderite which is irregularly distributed as thin lenses in the formation. At some places the iron ore lenses and concretions are said to form 5 to 7 percent of the volume of the strata.

In the succeeding Raniganj-Kamthi group there is much disseminated iron to produce the prevailing red tints of the sandstones, but there is nowhere sufficient concentration of the material to constitute workable ore.

**Jurassics:** The inter-trappean beds of the Rajmahal hills contain thin beds and concretions of ironstone which were formerly worked for smelting in small indigenous furnaces.

**Deccan Trap:** The tropical weathering of the Deccan trap, at and near the surface, has given rise to massive beds of laterite which is in many places fairly rich in iron, perhaps averaging 25 to 30 percent of the metal. The laterites also contain deposits of titaniferous bauxite.

Laterite also occurs over gneissic rocks as in Malabar and Travancore and over the Rajmahal traps in Bihar. The limonitic material from laterite, often forming rich concretions, has been smelted by the indigenous artisans for many centuries.

**Tertiary:** The Nahan series of the Siwaliks in the Uttar Pradesh and Assam Himalayas, the Tipam series of upper Assam and the Rajamahendri, Cuddalore and Varkala (Warkilli) sandstones contain fairly rich concretions of ironstone which were formerly used as ore in the respective regions named above. They are all of Miocene age. The ores used in the Beypore works in Malabar in the 19th century was of this type.

In West Bengal, the district of Birbhum has the largest concentration of iron ore deposits and this can be found from different formations. In the report of Thomas Oldham one can get detailed information about the same. Magnetite ore are found near Namgulia from the
Metamorphics. Veins of limonite occur in the sandstones of the Damuda and Mahadeva series belonging to the Gondwana system and, according to Krishnan, these ores have been used to some extent by the indigenous smelters (Krishnan, 1954: 113). Layers of Pisolitic iron ore and pockets and thin beds of limonite and haematite are found in laterite amidst flows of Rajmahal traps.

Oldham (Oldham, 1852) reported that the ore is an oxide of iron, partly earthy, partly magnetic. This occurs in thin seams, spreading in an entangled manner through the soapy trappean clay stone. The bed of layer in which it occurs is on an average 5 feet thick. However, iron ore is not uniformly disseminated but occurs in irregular bunches or nests. There is no vein, though only thin disseminated threads or strings of ore passing in every direction across and among the clay matrix, and filling up every fissure in the mass. The ‘soapy trappean claystone’ referred to by Oldham is probably Laterite (Oldham, 1852: 8; Krishnan, 1954: 113). The laterite itself is in some places rich enough to be worked as ore. According to Hughes, there were two or three seams of limonitic ore in the laterite, but much of the ore worked at the time was derived from one bed, which occurred near the base of the laterite (cited in Ball, 1877: 89-93). Analysis of the ores showed that they contained 28 to 59 percent iron, the average of 29 samples showing 43 percent iron and 1.5 percent P₂O₅.

Ball suggested that in Birbhum, ore occurred in beds near the base of the laterite (Ball, 1877: 87). These were possibly not constant in thickness for long distance. However, the ores were abundant and it contained a high percentage of iron, occasionally nearly 60 percent and averaging over 40.

Another area which has large ore concentrations is **Raniganj Coalfield of the Burdwan district.** The earliest official reference to iron ore of the Raniganj coalfield is found in a report by Motte and Farquhar in 1777 (Cited (in details) in Heatly, 1843: 542-563). Here, iron ores occur in form of thin beds of ironstone in the Ironstone Shale group of the Damuda series. It stretches over a distance of some 25 miles in east west direction in this coalfield and has a width of 1 to 2 miles. The individual bands of ironstone are thin and of variable thickness and frequency. At a depth of some 20 or 30 feet, the ore which is brown in colour near the surface, is grey and of the nature of iron carbonate. This suggests that at and near the surface the original grey carbonate has been converted into brown hydrated oxide.
During the course of survey by Smith (Smith, 1856) in the Raniganj area, he observed that the southern boundary of the village of Rajpore delimited by Chhoroolia on the north, Jamsol on the east and Sottoor on the west and south is distinctly defined by a sudden and abrupt alteration of the angle of inclination in the strata.

Traversing the tract in question and going northward, the first indication of iron ore observed is from the surface being thickly strewn with lumps of it. A section, not a deep one, of the iron bearing strata is exposed in a stream or rivulet less than half a mile to the west of the village of Barool. Here are shown two seams of ore, the upper 8 inches and the lower 9 inches thick, with a course of nodular ore averaging 3 inches. Similar occurrence has also been recorded at Jamsol.

The site fixed for the shaft is on the bank of the small stream already referred to about half a mile to the west of the Barrool village. It was sunk to a depth of 32 feet, yielding four seams of iron ore of the aggregate thickness of 18 inches. In addition to these, a vein of carboniferous iron ore was passed through 3 feet 6 inches thick.

Regarding the Taldangra iron ore field, observations made by Smith is worth noting:

“The tract of country of most, indeed the only one of importance in this neighbourhood as iron ore bearing, lies on the east of the Barakar River. Between the 146th and 148th mile-stones on the Grand Trunk Road, three or four seams of ore are exposed; the section being presented in the water-courses, running southerly to the Barakar. Through these I traced the ore to near the river, where they are lost by a depression…. The lowermost bed of ore at the Grand Trunk Road continues the lowest all the way down the bed of the brook…In extent to the north of the Grand Trunk Road it reaches about two miles, when it is interrupted by very disturbed ground. In width from east to west it is rather more than a mile.” (Smith, 1856: 8)

On the western side of the Barakar, about 1 ½ mile from the river, is another small field of iron stone, but so limited in extent, and surrounded by disturbed and broken strata, as to be unworthy of notice. Smith observed that the native smelters on the banks of the Barakar about 4 miles distant used to obtain their supply of ore from this spot, a thin seam being found at a depth of about 3 feet.

During the course of his survey, Blanford found that the Ironstone Shale outcrops spread over a length of 33 miles, with an average thickness of 1400 feet and also noted the irregular mode of occurrence of the ironstone bands in them. Near Jamsol (23° 43’ N and 87° 09’ E) he recorded 26 bands, varying in thickness from 2 inches to 12 inches, within a
total thickness of 150 feet of the Ironstone Shales (Blanford, 1865: 76). From measurements made by D. Smith (Smith, 1856) in shaft sunk near Barool (23° 44’ N and 87° 08’ E) about 8 miles north of Raniganj, Blanford calculated that the Ironstone represents about 1/17th of the thickness of the strata and thought this would be an average for only the upper part of the Ironstone Shales, where the ore is more abundant than in the lower part. The content of iron in the bands exposed at the surface was found to vary between 18 to 54 percent (Blanford, 1865: 77).

In 1872, the report of Bauerman confirmed the observations of the previous researchers that the Raniganj field was at that time the most promising for the establishment of iron smelting industry. However, there is no doubt that indigenous smelters must have also exploited the said ore deposits of immense significance (cited in Krishnan, 1954: 114). T.W.H. Hughes (Hughes, 1874: 20-30) published a comprehensive report in which he incorporated his estimation on the aggregate thickness of the ore. According to him, ironstone occurred in the proportion of 1 foot to 10 or 12 feet of shale and taking the group as 1000 feet he calculated that every square mile would contain approximately 200 million tons of ore (Hughes, 1874: 25). He has also analyzed the chemical composition of ores collected from the western part of the Raniganj coal field at Begunia, Kulti, Boldih, Chalbalpur, Malakola, Sibpur etc (Hughes, 1874: 122-124).

Gee presumed that, (Gee, 1932: 292) the thickness of the Ironstone Shales is known to be about 1,200 feet. The total area covered by this formation including that with a thin capping of alluvium (the main outcrops between Barakar and Ajai rivers) is about 44 square miles. Krishnan based on old report, estimates the total reserves not exceeding 500 million tons.

The iron stone shales were the source of iron ore for the Barakar Iron Works and the Bengal Iron and Steel Co. which had their blast furnaces at Kulti in the Raniganj coalfield. After 1906, the iron stone used to be mixed with magnetite, obtained from the apatite-magnetite rocks from Turamdih, south of Tatanagar in the Singhbhum district, though from 1914 these ores were completely replaced by the haematite ores mined in the Pansira and Buda hills near Manoharpur in the Singhbhum district. It is stated that in 1913 about 7000 tons of iron ore were mined from the ironstone shales and used in the furnaces at Kulti (Krishnan, 1954: 115).

Haematitic clay-ironstone occurs in small quantities in the shales of the middle and upper Barakar strata as also to some extent in the Raniganj strata in the eastern part of the
Raniganj field. These are not of importance at the present day, though used formerly by the indigenous smelters (Krishnan, 1954: 116).

Ferruginous laterite containing about 25 percent iron covers an appreciable area in the same field but it can scarcely be considered as iron ore at present (Krishnan, 1954: 116).

Some rich deposits of magnetic iron ore are described by Blanford as associated with the metamorphic quartzites just beyond the boundary of the field near the village of Tituri, about two miles west of Biharinath hill. Hughes observed that the ore occurs interlaminated with the quartzite and gneiss in bands varying in thickness from 3 inches to 2 feet. They were very pure containing 60 to 70 percent of metallic iron (Hughes, 1874: 27).

In a manuscript report submitted in 1888, E.J. Jones (cited in Krishnan, 1954: 116-117) stated that a small excavation was made in the outcrop of these ores. They dip slightly west of north at 45°. A band of ore can be traced at intervals from Brindabanpur towards Lallgarh for about a mile, the band varying in thickness from a few inches to three feet. From the debris found on the surface it was deduced that the length of the band was about 15 miles. Taking an average of 1 foot thickness over this distance, Jones calculated that 55,000 tons of the ore would be available within a depth of 5 feet from the surface. The deposit was of enough significance for the indigenous smelters.

According to Ball, throughout Manbhum, in those parts where metamorphic rocks prevailed, greater or less quantities of magnetic ores sand were found in the beds of rivers. These were found scattered throughout the superficial deposits. Occasionally, titaniferous ore was found associated with the magnetic sand. In a small hill near Teludi (Tiluri) close to Biharinath (Biharinath), some magnetic ores had also been recorded. In the sub-metamorphic rocks, far to the south, there were some apparently bedded magnetites, seen in the section of the Kasai river. Ball opined that these at first sight, on the weathered surface, resembled the interbedded or meta-diorites, thus their true character as massive bright ore was difficult to ascertain. These according to him, would probably yield a large supply of ore. At various places along the line of disturbed junction between the metamorphic and sub-metamorphic rocks of Manbhum, which ran nearly due east and west across the district, Ball observed veins or lodes of red and brown haematite. The latter especially were found in great abundance (Ball, 1881a: 46-47).

In Purulia district, titaniferous iron-ore occurs in a number of localities viz. Manbazar (23° 03’ N and 86° 40’ E), Supur (23° 01’ N and 85° 52’ E), Gaurangdih (23° 26’ N and
86° 46’ E), Jhalda (23° 22’ N and 86° 00’ E) Baraojora (23° 12’ N and 86° 05’ E) areas (Hunday and Banerjee, 1967: 176-177). At Bauch (22° 59’ N and 86° 40’ E), lodes of haematite are reported from the hills, situated in close proximity to it. The ore is said to be rich and abundant. Lumps of ironstone ranging in size of a pea to huge boulders occur in the Panchet hill (23° 37’ N and 86° 27’ E). Small deposits of iron ore are found within Tamakhan (22° 59’ N and 86° 35’ E) and Asanpani (22° 46’ N and 86° 27’ E). Besides, magnetite iron sands occur along many stream courses in the Archaean terrain, and these were formerly smelted for iron (Hunday and Banerjee, 1967: 176-177).

In **Bankura district**, near Biharinath hill, deposits of magnetite ore occur intercalated with quartzite and gneiss, in bands varying from 7 cm to 1m in thickness. The debris found on the surface indicates that the length of the band is about 24 km (Krishnan, 1954: 115-116; Hunday and Banerjee, 1967: 177). In Porapahar (22° 57’ N and 86° 49’ E) zone, sporadic occurrences of haematite are noted along and near the major fault zone extending from Sabubad (22° 57’ 40” N and 86° 55’ 30” E) to the west near Bauch (22° 59’ N and 86° 40’ E). The deposits are found near Ambikanagar (22° 57’ N and 86° 49’ E), Barga (22° 57’ N and 86° 46’ E), Mukutmanipur (22° 57’ N and 86° 47’ E), Pura (22° 57’ N and 86° 48’ E), Bagjabra (22° 57’ N and 86° 48’ E), Kharidungri (22° 57’ N and 86° 48’ E), Ruparhir (22° 57’ N and 86° 49’ E), Dedu (22° 57’ N and 86° 51’ E), Salua Jamda (22° 58’ N and 86° 52’ E) and Dhargram (22° 57’ N and 86° 54’ E). Ferruginous bands in the quartz veins and quartz debris occur near Purnapani (22° 46’ N and 86° 47’ E), Kuchaipal (22° 45’ N and 86° 50’ E), Maula (22° 51’ N and 86° 45’ E), Pukuria (22° 49’ N and 86° 50’ E) and Bishanpur (22° 52’ N and 86° 54’ E). Laterite iron ore is reported near Bagjobra and Dahala. Magnetite in association with vanadium and titanium is reported from Saltora (23° 33’ N and 86° 56’ E) area (Hunday and Banerjee 1967: 177-178).

In the **Midnapur district**, haematite and magnetite ores similar to those found in the Bankura and Purulia districts have been found in the Archaean terrain whereas, the lateritic iron ore were reported from the eastern and southern parts of the district. The phyllites and quartzites in the north-western part of the district grade into haematite phyllite and banded haematite quartzite which contain low grade iron ores. The crystals of magnetite have been found in surface detritus near Jarma (22° 35’ N and 86° 41’ E) and Dublakona (22° 36’ N and 86° 45’ E). Several small laterite patches are found in the north-western corner of the district on Archaean terrain near Patpinira pahar, north of
Talaibani, Dhangi Kusum, north and north east of Bhankhabhanga and near Sarisabasa. Extensive and thick laterite covers are found near Jhargram, Gidni, Kharagpur and also on the south-western part of the district (Hunday and Banerjee, 1967: 179).

In Jharkhand, the districts of Palamau and Singbhum have remarkable concentration of iron ores:

**Palamau district**: Investigations of Ball (Ball, 1880: 112; 1881b: 376) in the region led to the discovery of three types of ores- i) magnetite occurring as bands in metamorphic rocks; ii) siderite and haematite occurring as beds in shales or as concretionary masses in sandstones of Barakar formations.; iii) lateritic ore in laterite beds on the plateaux.

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<th>Magnetite:</th>
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<td></td>
<td>b) More or less decomposed</td>
<td>or in veins, in hornblendic rocks or as disseminated crystals in granite</td>
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<td>and altered</td>
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<td>Siderite and</td>
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<td></td>
<td>b) Limonite or brown</td>
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Magnetite occurred in the concerned region at a considerable number of localities both in nests or in bands in hornblendeic rocks, and occasionally crystals, which were thinly disseminated through granite veins. Ball reported that the indigenous smelters used to ground the small partially decomposed crystals into a fine powder before using in smelting. In one case, an altered massive magnetite near Kuruchi was used, however, the pure ores was not known to be used in any case by the concerned smelters. He stated in his report that ‘it is not suited for their works’. Ball also referred to the ore deposits occurring in beds in the Barakar rocks at the eastern end of the Auranga field, near Rajbar (Table 1). It occurred in a well-defined zone of ferruginous shales, about 200 feet thick,
of which perhaps 10 percent consist of iron ore. A sample of the richest band contained 49.2 percent of metallic iron. The zone extended for 2 to 3 miles with 5° dip. Another abundant source of ore was also recorded by Ball in a detached area of Barakar rocks to the north of Balunagar (Ball, 1881b: 377-378). Here, the iron-stones occurred in abundance over an area of about 4 square miles. Some of them can be identified with the ironstone group, however they were overlaid by sandstones of Barakar character. The iron ore formed 10 percent of the concerned geological section at the site. The best bands generally had a lenticular shape. These were largely used for indigenous smelting and Ball observed that in several places at the outcrops there were shallow pits for extracting the same. One sample of the ordinary ore yielded 45.3 percent of metallic iron whereas one of the black band contained 39.4 percent metallic iron (Ball, 1881b: 378).

Fragments and lumps of magnetite are found at several villages, especially near Rajhara, Lunkha, Kopah, Hosir, Kurahi etc. They all appear to be comparatively small occurrences though none of them have been examined in any great detail (Ball, 1881a: 113-117).

Rajhara: In a stream about 2/3rds of a mile northwest of the village for a distance of about 50 yards, flat, though weathered fragments of magnetite occur abundantly. On the bank of the stream there is an imperfect section of rocks which consist of hornblendic and granite gneisses with granite and quartz veins.

Lunkha: In a small ridge north of the village of Lunkha there is a considerable abundance of fragments of magnetite. One irregular block measured upwards half a cubic foot in content.

Kopeh, South-West: One mile to the south-west of Kopeh, in the ravines, a large rounded fragment of magnetite was found. This had probably been derived from a nest in the hornblendic rocks. None was found in situ.

Kopeh, South-East: The iron-workers at Kopeh, though living close to Lunkha ore did not make any use of it. The ore they used consists of small semi-decomposed crystals of magnetite derived from disintegrated granite veins, and laboriously sifted from the sand accumulated in ravines near the Ledee stream south of the Aurunga. The ore has to be smashed into fine powder before being smelted.

Satbarwah: To the south-west of Satbarwah, near Rubdan, on the slope of a small hill, there are traces of ore. They are mostly of decomposed and altered magnetite.

Hosir: The ore used at Hosir seemed to be similar in character and origin to that of the south-east of Kopeh.
Monodag: In the stream south-west of Monodag, which is to the north north-east of Mooroop, there were some bands of Magnetite seen in the gneiss.

Hirhun/Hurhunj: In a stream near this village, when marching up to the Daltonganj field, Ball found a few fragments of magnetite.

Kurahi: It is situated in the centre of the extensive group of hills south of Cheinpur, being about four miles south of Chandoo. The ore was used by the smelters of Chorhut.

Adur: Smith described some ore which he recorded at about two miles north of Chorhut in the vicinity of Adur in the following words, It is “a very partial deposit of Magnetic ore of the very richest quality, but so limited in quantity as to be of no importance”.

Morwaie: On the faulted boundary of the Hutar coalfield south of Morwaie there was, in conjunction with some fault rock, an outcrop of magnetite much altered and decomposed, principally into red haematite.

Kotam: Near the junction of the Kaliburna river with the Koel and also close to Kotam, small fragments of Magnetite, some superficially altered to brown and some to red haematite are found scattered about with fragments of vein quartz.

As a result of field survey by Krishnan the following ore deposits have been investigated (Krishnan, 1954: 117-118). 1. Clay-ironstone and haematite of Rajbar (23° 47’ N and 84° 39’ E) in the Auranga coalfield which occur as strings of nodules of Barakar rocks. Here, the occurrences are restricted to a zone of ferruginous shales over 2 miles long and about 200 feet thick. The average iron content of the analyzed samples was 44.8 percent. Similar ores have also been reported from the detached area of Barakar rocks to the north of Balunagar (23° 50’ N and 84° 41’ E) where ironstones are seen over an area of about 4 sq miles. The bands are more or less lenticular in shape and pinch out after some distance. Similar ironstones also occur near Morwai (23° 46’ N and 84° 07’ E) in the Hutar coal-field.

2. Magnetite ores occur in the Ladi Estate near Daltonganj of the district. There are two groups of deposits known from the district- i) Gore and ii) Biwabathan.

i) Gore deposits: Iron ore deposits occur in the hills and have an extension of 1000 yards in north/north west- south/ south- west direction. The geological sequence of the formations noted here (from top to below) is 5. Dolerite; 4. Granite; 3. Beds of Magnetite and magnetite-schists; 2. tremolite-schists with or without magnetite; 1. Calciphyre and limestone.
Beds of magnetite associated with certain amount of haematite are seen well exposed on the top of four out of five hillocks. The magnetite beds are underlain by tremolite-schists, some of the bands of which also contain some magnetite. The base and the central part of the hills are generally made of granite. Masses of intrusive dolerite, presumably of a later age than the granite are seen on the north-western side of the Gore hill. Limestone and Calciphyre are exposed on the south-eastern side of the Gore hill below the tremolite-schist, and these are generally underlain by granite.

The average height of the hillocks is about 200-350 feet above the general level of the country. The structure appears to be synclinal, with the iron occurring on the top of the hills. The main ore body is more or less massive magnetite which passes below into magnetite-schists.

The area occupied by the richer and more massive ore is about 180,000 sq.ft though that occupied by the magnetite-schists is much larger. The length of the main ore body is about 2000 ft and the average width about 90 feet. Specimens of the typical richer ore have a specific gravity between 4.3 and 4.63. It has been estimated by Auden that the reserves would amount between 300,000 and 400,000 tons. This, however, is based only on surface observation.

Messrs. K.K. Sen Gupta and J. Sen Gupta have stated in their paper (1939) that the ore body has a length of about 2640 feet, a width of 75 feet, and a depth of 200 feet. On this assumption they have calculated a cubic content of 39.6 million c. feet which would amount to about 5 million tons of ore (Sengupta and Sengupta, 1939: 143-148). These figures are considered by Auden to be a great exaggeration, as the extent of the ore body both in area and in depth appears to be definitely much smaller than that assumed by the Sen Guptas (cited in Krishnan, 1954: 119).

The ore consists mainly of magnetite, replaced to a varying extent by haematite as analyzed by J.A. Dunn and J.B. Auden. Haematite is seen as thin flakes along the octahedral planes of the magnetite. Some quartz and amphibole are also seen in the sections. The magnetite-schists consist mainly of magnetite and quartz but the iron content is generally below 30 percent. The quantity of magnetite in these schists has not been taken into account by Auden in the said estimate (cited in Krishnan, 1954: 119-120). According to Auden, the tremolite schists was composed mostly of tremolite showing polysynthetic twinning, with interactive index ranging between 1.63 and 1.65.
According to a few analysis made by Messrs. R. V. Briggs and Co. of Calcutta, the average ore contains, in general, 55 to 60 percent iron (cited in Krishnan, 1954: 120).

**Biwabathan:** This ore deposits occur about half a mile south-east of the Biwabathan village. It comprises a small elliptical outcrop which is (65 x 55) sq. feet in area. The outcrop is strewn over and surrounded by a substantial amount of iron ore debris. The associated rock in the elliptical outcrop is probably a lamprophyre of the type commonly found in the coal-bearing Barakar formations of the Jharia coalfield. The rock is seen to contain a considerable amount of mica associated with magnetite and haematite. It is also probable that the haematite is a crust formed on the weathered lamprophyre.

Small exposures of magnetite-tremolite schists are seen over a distance of 320 yards just to the south of the railway line near telegraph pole 362/2 on the Daltonganj Branch line. Here tremolite-schists are associated with dolomitic limestone. Similar occurrences of magnetite-schists have been recorded north of Sua (24\(^0\) 00’ N and 84\(^0\) 06’ E), about 4 miles southeast of Daltonganj (Krishnan, 1954: 120-121).

**Singhbhum district:**

In the Singhbhum district, Ball reported that the ores used in the furnaces of the indigenous smelters were derived from the ferruginous schists (Ball, 1881a: 86). Besides, haematite also occurred in association with the trap. In the eastern parts of the district, some deposits of lateritic ores have also been documented by Ball. However, according to him, the most promising sources of iron ore in Singhbhum were found in a number of lodes or veins which occurred in the neighbourhood and to the west of ‘Chaibassa’ (Ball, 1881a: 86-87). He further reported that some of the ores were manganiferous in their nature. In the Hazaribagh district, magnetites were also found in abundance in the area occupied by the crystalline or metamorphic rocks. These deposits were examined by H. Bauerman. In the valley of the Damuda, the supplies of ore used by the indigenous smelters were chiefly drawn from the weathered outcrops of the ironstone group of the Damuda series which was represented in the both the Bokaro and the Karanpura fields.

The apatite- magnetite ore is found closely associated with the copper belt of Singhbhum, especially between Dhadkidih (22\(^0\) 45’ N and 86\(^0\) 06’ E) of Seraikhela on the west to Khejurdari (22\(^0\) 24’ N and 86\(^0\) 34’ E) of the south east Singhbhum (Krishnan, 1954: 121). The rock is usually a mixture of apatite and magnetite with some biotite, chlorite and very subordinate quartz. This is generally found on the hanging wall side of the copper lodes. It forms lenses of varying sizes in the enclosing ancient schists of the Archaean
age. The largest lens is 900 ft long and 60 ft thick in the middle portion. The lenses are usually arranged en echelon. They are sometimes bordered by granite. They are confined to the shear zone which afforded suitable conditions for the formation of veins and lenses derived from the soda-granite. This granite is responsible for the copper mineralisation along the same zone. After formation, the rocks have again been folded and sheared in the Pre-Cambrian times and penetrated by the later Singhbhum granite.

Apatite is generally the dominant mineral in the apatite-magnetite rocks, but the proportion of the two minerals varies considerably from place to place. Magnetite is abundant in these rocks near Patharghora (22° 32’ N and 86° 27’ E). Large lenses are found near Kumharia, Ramchandrapahar, Khariatola, Kanyaluka, Badia, Sungri etc.

**In south eastern Singhbhum and the adjacent parts of Mayurbhanj**, a few deposits of magnetite containing titanium have been found. In 1908, Fermor reported the iron ore deposits of this region which he named as Turmadih deposits. These occurred in some foothills of the north base of the Dhoba Hills in the villages of Talra, Turamdih and Kudada. The ore is magnetite. It was found in a series of schistose magnesian rocks. This also contains steatite as an important constituent. According to Fermor, here, magnetite occurs in four ways i) as scattered grains, ii) as large patches of irregular shape, iii) as definite veins traversing the magnesian rocks, iv) as veins up to 3 feet thick, composed of magnetite with vein quartz, secondary limonite and chert (cited in Holland 1909: 41-42).

In 1910-11, J.A. Page observed the existence of titaniferous magnetite in Pora Pahar and Kotwar Pahar. During the re-survey of the Singhbhum district by J.A. Dunn and A.K. Dey (Dunn, 1937: 214-223) between the years 1929 and 1933, the boulders of magnetite were found at places like Dublabera (22° 29’ N and 86° 17’ E) and Sindurpur (22° 28’ N and 86° 15’ E) in Singhbhum and near Kumhardubi (22° 17’ N and 86° 19’ E), Bet Jharan (22° 16’ N and 86° 19’ E) and Kuduni (22° 17’ N and 86° 21’ E) in Mayurbhanj. The ores occur as thin veins, lenses and pockets in gabbroid and ultra-basic igneous rocks. Their presence is usually shown by abundant debris scattered over the surface.

The gabbroid and ultra-basic rocks are often altered to serpentine and steatite or to epidote. They generally show coarse grained augite and basic feldspar, in other cases the rocks are of the composition of peridotite or anorthosite. The augite is extensively uralitised. Some apatite is generally found as an accessory mineral (Dunn, 1937: 215-216).
The specific gravity of the magnetite ore ranges from 3.8 to 4.8. Both magnetite and ilmenite are present, and in many cases appreciable amounts of haematite are also seen. The minerals seen under the reflecting microscope are magnetite, ilmenite, coulsonite (iron-vanadium oxide), haematite, rutile and goethite. Some silicate minerals are also found. Magnetite and ilmenite are inter-grown, the latter occupying the octahedral planes of the former. Graphic intergrowths are also seen which are due to ilmenite and magnetite separating out from a solid solution of the two. Haematite is found to replace magnetite in varying degrees, though this may partly be due to weathering and partly to ex-solution. According to Dunn (Dunn, 1937: 219) at high temperatures the ore consisted of a solid solution of $\text{Fe}_3\text{O}_4$ and $\text{FeTiO}_3$ with some amount of $\text{Fe}_2\text{O}_3$. When the temperature was lowered by cooling, the ilmenite began to segregate along the octahedral planes of magnetite and at still lower temperature the haematite are also separated out.

The ores are related genetically to the gabbroid rocks. It is interesting to note that there is an abundance of magnetite veins in the gabbroid rocks in the neighbourhood of the haematite deposits near Kumhardubi. This association according to Krishnan may possibly suggest the absorption of a considerable amount of haematite by the basic magma and re-crystallization of magnetite on cooling. The magnetite is found to be the last mineral to crystallize out of the basic rock, but it often contains a certain amount of ilmenite which originally must have existed in it in solution but later crystallized out as a fine intergrowth.

These magnetites generally contain a variable but small amount of vanadium. In many cases the vanadium oxide content is less than 2 percent, though occasionally some specimens have yielded up to 7%. Several specimens found from Dublabera show a vanadium oxide content of 1.8 to 3 percent. The titanium content, on the other hand varies from 10 to 25 percent.

Dunn and Dey (Dunn, 1937: 217) analyzed the chemical composition of the ores found from Kumhardubi, Dublabera, Baludungri etc.

Mayurbhanj district: Haematite deposits occur in the following areas (Bose, 1904: 167-173)

i) Gorumahisani hill; ii) Near Bandgaon in Sarandapir; iii) Sulaipat- Badampahar range; iv) Simlipahar range and the tract to the east; v) Several localities from Kamdabedi to Thakurmunda, over a distance of 25 miles.
These deposits were subsequently examined by Perin and Weld and a summary of their findings is given by Holland and others (cited in Krishnan, 1954: 125).

The Gorumahisani pahar (22° 19’ N and 86° 18’ E) which rises to a height of about 2964 feet, is made of banded haematite-quartzites associated with quartzites, epidiorites and grunerite bearing rocks. The epidiorite appears to underlie the grunerite-schists and quartzites. So far as the quartzites are concerned, the most common type appears to be of sedimentary in origin and others are of secondary origin. The latter include fine cherty banded rocks. Of these, the banded-haematite-quartzites are the most common. The quartzite of sedimentary origin is seen spread over the eastern and north-eastern parts of the hill. The quartz grains are all highly strained and many are granulated. The rock in places is faintly banded. Near its base it contains lines of fine amphibole. The banded haematite-quartzite consists of alternating thin layers of haematite, haematite and quartz and quartz which may be of considerably varying widths, from several inches down to a minute fraction of an inch. The layers are of different colours, from black through dark red, light red to white. The quartz in some bands is cherty, in others it is relatively coarse-grained. The coarser quartz is usually considerably strained. The banding is usually finely jointed and faulted, and minute veinlets of quartz, quartz and haematite, or of haematite alone, commonly cut across the banding. It occupies the eastern part of the hill, which is capped on the north and east by ore bodies. The top of the hill shows a lateritic capping, while a patch of solid ore occurs in the south-western parts of the hill. On the western and north-western sides the hill shows granite which is traversed in a few places by dolerite dykes.

The ore is of two types, one being a massive hard haematite and the other a lateritic haematite. The hard ore is bedded and appears to grade into banded grunerite rock which is often rich enough in iron to be considered as ore. The grunerite bearing rock is considered to be a product of metamorphism of the haematite-jasper. There is much detrital ore on the hill, the patch of lateritic ore also occurs on the top of the hill (Krishnan, 1954: 125-126).

The Sulaipat or Okampad (22° 09’ N and 86° 15’ E) deposits forming a peak in the Sulaipat range, 12 miles south/ south-west of Gorumahisani, are small. The ore from these deposits is of very high grade showing 86 percent iron, 0.90 percent silica, 0.09 percent manganese and 0.016 percent phosphorous (Krishnan, 1954: 127).
The third important deposits occur in the Badampahar peak, on the range of the same name, 8 ½ miles south-west of Okampad. The average ore contains 55 percent iron, 7.5 percent silica and 2.8 percent alumina. Some yellow coloured ore contains 66.6 percent iron, 0.72 percent silica, 0.42 percent alumina, 0.062 percent phosphorous, 0.15 percent sulphur (Krishnan, 1954: 127).

The most important groups of deposits of iron ore occur in south Singhbhum and the adjoining districts of Bonai and Keonjhar within the area bounded by latitudes of 21° 40’ N and 22° 20’ N and longitudes of 85° 05’ E and 85° 32’ E (Krishnan, 1954: 128). The rocks exposed in this region consist of a series of the Pre-Cambrian sedimentary formations known as the Iron ore series. This part of Singhbhum is marked by a zone of shear along which rocks have been thrust towards the south and metamorphosed. The shear zone shows intrusions of soda-granophyre with which are associated deposits of copper, apatite and magnetite. North of the shear zone the rocks consist of phyllites and tuffs with basic intrusive at the bottom, which are overlain by ferruginous quartzites and phyllites.

The Iron ore series recorded to the south of the shear zone consists mainly of banded haematite-quartzites and shales with intercalations of lava flows and tuffs. This banded haematite-jaspers consists of alternating bands of jasper or chalcedony and haematite containing varying proportions of iron oxide and silica. Dunn (Dunn and Dey, 1942: 367) believed that certain phyllites and shales in eastern and southern Singhbhum were originally volcanic tuffs and that they have been either silicified or replaced by iron to some extent, the latter in contact with banded ferruginous rocks. In some places the phyllites are manganiferous and have been partly replaced by manganese ores. Such manganese ore bodies are of small dimensions and are seen in several places in Keonjhar and Bonai.

A.K. Sen (Sen, 1982-83: 111-119) suggests that the iron rich sediments of the Iron Ore Group represent the transitional member between the volcanic and the sedimentary clastic facies. According to him, the iron formation is composed of two distinct rock types.

i) Jaspilite: This is a banded rock (banded haematite jasper/ quartzite) consisting of alternate bands of jasper (chert/silica) and oxidic minerals of iron (haematite/ magnetite).

ii) Haematite rock: This consists mainly of oxidic minerals of iron, with subordinate but variable quantities of iron rich clays and practically no free silica. The haematitic rock as
good as the jaspalite, occurs in the form of regular and continuous bedded entity, extending from one end of the area to the other.

There are two jaspilite horizons alternating with two other beds of haematite rock to attribute a variable thickness of 100 to 350 m to the entire iron formation. These rocks occupy the high ridges in the area, such as the Gua-Kiriburu hill range on the west and the Noamundi-Thakurani Pahar hill range on the east. The trends of rocks in these areas are nearly parallel, being north north-easterly with local variations. Actual vertical sections exposing bedded bodies of haematite rocks, are observed in the Baljori-Merelgara area, Dudubila and Chhota Baljori areas (Sen, 1982-83: 114).

Some older rocks viz. quartzites, hornblende- schists and mica-schists are found amidst the Iron-ore series in south Singhbhum. These were originally considered to belong to an older metamorphic series of the Archaean age, but are regarded by Dunn as forming part of the Iron-ore series (Krishnan, 1954: 119).

The Iron-ore series in south Singhbhum is overlain by the Kolhan series. This can be dated to the Cuddapah age (Algonkian). This Kolhan series consists of basal conglomerates and sandstones which are overlain by some limestones and shales. This series overlaps with the various stages of the Iron-ore series and the intrusive granites. The quarries have been excavated in some of the outcrops of iron ore group occurring as isolated inliers within the overlying Kolhan group of rocks. These inliers occur as discrete hillocks, composed entirely of jaspilite. On excavation the following section has been exposed (Sen 1982-83: 114).

4. Shale
3. Basal sandstone-conglomerate

........................................Unconformity......................

2. Jaspilite
1. Haematite rock bed (iron ore)

In **Eastern Singhbhum**, the Iron-ore series consists of lenticular beds of conglomerates, basic igneous rocks, phyllites and banded ferruginous rocks which are overlain by arkose, quartzites and tuffs. Over this lies the Dhanjori stage which also contains conglomerates, quartzites and lavas (Dunn and Dey, 1942: 327).

The pre-Cambrian formations have been intruded by masses of granites. This is known as the Singhbhum Granite which is seen in south Singhbhum and in the adjoining parts of Keonjhar.
The rocks of the Iron-ore series in south Singhbhum, Keonjhar and Bonai give rise to a rugged topography. The beds of banded haematite-jasper form a prominent ridges rising to about 2500-3000 feet in altitude. The lower ground contains phyllites, lavas and shales. The whole succession of rocks is folded into a series of asymmetrical or slightly overturned anticlines and synclines (Krishnan, 1954: 123).

The banded haematite-jaspers consist of alternating bands of jasper or chalcedony and haematite containing varying proportions of iron oxide and silica. Due to their greater hardness they stand up as prominent ridges and cliffs. On weathered surfaces, the haematite bands often stand up while the jasper bands form depressions. These vary in colour from grey or white to lavender, red and brown to black. They might show intense crumpling and contortion and minute faulting and dislocation. The silica in the jasper bands is sometimes chalcedonic and sometimes microcrystalline. The individual layers as well as the banding are not always regular and they vary considerably in thickness. The maximum thickness of the haematite-jasper formation is stated by Jones (Jones, 1934: 198) to be about 3000 feet in Bonai and about 1000 feet in the main iron ore range on the border of Keonjhar and Singhbhum (see Table 2). As a result of microscopic analysis, it has been observed that the siliceous bands consist of very fine grained quartz which often shows undulatory extinction. Amidst the grains of silica are found small crystals and flakes of haematite. Some of the bands display elongated streaks of magnetite or maritime arranged parallel to the banding. The jasper bands vary in colour from red to brown due to the presence of abundant minute flakes of blood-red haematite. Rhomb-shaped crystals of silica are also seen occasionally and they apparently represent pseudomorphs after iron-carbonate. Some of these rhomb-shaped crystals have actually been proved to be colourless siderite for, on heating, they were converted into black powdery iron oxide (Jones, 1934: 198-199). This indicates that part of the iron was deposited originally in the form of iron carbonate.

This significant Precambrian Banded Iron Formation (BIF) of the Bonai-Keonjhar belt forms a U shaped synclinorium. Thakurani Pahar deposit (22° 06’ N and 85° 26’ E) is situated in the north-eastern corner of the eastern limb of the synclinorium. Besides, the eastern limb of the synclinorium constitutes from NE to SW a number of detached iron bodies in and around Noamundi (22° 09’ N and 85° 26’ E), Joda (22° 01’ N and 85° 25’ E) and Malangtoli (21° 49’ N and 85° 19’ E). The western limb is almost continuous from
Gua (22° 11’ N and 85° 25’ E) to Rongtha (21° 46’ N and 85° 08’ E) (Chakrabarti and Saha, 1984: 14-25).

The haematite-quartzite is often folded, contorted and faulted. These structures are attributable to compression during the course of compaction and partly to the result of slumping of the material during the process of leaching of the silica and enrichment by ferric hydroxide.

Spencer and Percival have noticed the common occurrence of micro-spherulitic structures in these rocks. These are apparently due to the shrinkage of the original colloidal material after deposition. They also pointed out the fact that there is almost absence of detrital material in the haematite-jasper. This indicates that deposition took place in clear water (Krishnan, 1954: 131).

The banded haematite-jasper is frequently seen to transform into hard massive iron ore when followed laterally. It occasionally passes also into laminated ore with a shaly appearance or into lenses or pockets of powdery ore. This powdery ore is seen to contain aggregates of maritime and granular or flaky haematite. This powder is apparently the residue of iron ore left after the complete leaching away of the silica from the original banded haematite-jasper.

The following analyses are typical of the composition of haematite-jasper which is high in silica and low in iron (Percival, 1931: 193).

Krishnan (Krishnan, 1954: 132-133) has analyzed the nature of iron ore that can be derived from the banded haematite-jasper. These are of different physical types-

Massive ore: This ore are generally exposed at the surface of these deposits. It is a massive, dark brown to steel grey compact ore. It generally weathers into large blocks. The massive ore may also show regular bedding without much evidence of slumping. However, some amount of micro-folding, slumpage patterns, flow and flowage features are present in the haematite bands as well as in the clay bands. The exposed surface of such ore has generally a dark brown to black polished appearance owing probably to the presence of a film of hydroxide which has been dehydrated. It is mostly characterized by alternating lamination of dull lustured reddish haematite and the steel grey haematite. The dull lustured bands are made of haematite needles embedded in a ferruginous clayey matrix and the segregated haematite needles without clayey materials from the steel grey bands. This type of ore has a specific gravity of about 5.0 and contains 68 to 70 percent iron. Such float ore found in association with the larger outcrops.
Laminated ore: The bedding planes are well portrayed in this type of ore though there may be small open spaces between the laminae. These open spaces sometimes are filled up by the powdery ore or more often by a shaly substance. The ore is generally compact but may often be appreciably porous. The content of iron is less in porous type of ore and it may contain only 55 to 60 percent iron. When broken up and screened the interstitial powdery material is eliminated and the ore thereby becomes richer.

It is of little doubt that the laminated ore has resulted from the leaching out of silica from the banded haematite-jasper. The specific gravity of the material shows much variation, from 3.5 in the more porous varieties to nearly 5 in the solid types. The iron percent also varies considerably.

Shaly ore: This type of ore which is generally met with at some depth has a shaly texture with silky or satiny lustre. Sometimes these are quite rich but others may be as low as 50 percent in iron with a substantial amount of siliceous and aluminous matter intercalated between the layers. This type may also be derived partly from the enrichment of the shales of the Iron-ore series by infiltrating solutions containing iron.

Powdery ore: The powdery variety is found in all deposits which have been exposed. It occurs as fairly large pockets and lenses, passing laterally into one of the other types. When *in situ* it displays bedding and may contain lumps of laminated ore within it. Sometimes it has a micaceous appearance due to the presence of minute flat flakes of specular haematite. The colour of powdery ore varies from dark blue-grey to black and it consists largely of haematite with some quantity of martite. It also contains occasionally thin layers of white kaolin-like materials. It is generally quite rich in iron content with 66 to 69 percent. It is fairly hard and has very dark brown or cherry red colour on grinding it to fine powder.

On hill slopes and on outcrops a kind of breccias can be observed. These are generally formed by the binding together of pieces of ore by secondary limonite. It is thus due to the re-cementation of pieces and lumps of ore at the surface. This type of material is usually of high grade, having an iron content of over 60 percent.

Hard and massive ore is generally confined to the surface but may extend to a depth of 50 to 100 feet. Compact and laminated ores may extend to various depths from the surface. Sometimes they also contain intercalations and masses of unreplaced haematite-jasper and powdery ores.
Besides the extensive deposits, discussed above, in the **Kalahandi district**, the occurrence of concretionary limonite has been recorded from alluvial deposits. Bands of haematite was also used to a small extent near Olatura (20⁰ 20’ N and 83⁰ 26’ E) (Walker, 1902: 19-20). In **Cuttack district**, important iron ore deposits include concretions of haematite, weathered out from the sandstones of the upper Damuda and to a lesser extent, pisolitic nodules occurring in the lateritic deposits. Analysis of two specimens of concretionary ores collected from Kankeri (20⁰ 58’ N and 85⁰ 03’ 30” E) and Pal Lahara (21⁰ 26’ N and 85⁰ 15’ E) yielded 46.8 and 47 percent of iron respectively (La Touche, 1918: 243).

W.W. Hunter in 1877 referred to the iron ore deposits of the then **Hazaribagh** district (Hunter, 1877/ 1976 (reprint): 150). According to him, in this region iron ores occurred in abundance. There were two varieties of ore deposits, the clay iron ores of the ironstone shales and haematite of the Barakar group. In the metamorphic area, surrounding the fields, magnetic iron ores had also been met with in several places. Hunter opined that this particular variety of ores would be of great advantage to the iron manufacturers. The most widespread ore deposit in the field is the clay ironstone of the middle group. He had no doubt it has similar composition as that from the Raniganj area. However, no analysis was made of the ores from the concerned region. He further informed that the richest ores came from the Barakar group containing approximately 50 to 60 percent iron. He also provided with a list of sites and percentage of iron content of the ores found from the said sites. These are i) Chepo Jugra 56.8; ii) Arahara (stream) 42.12; iii) Gondalpura (2 feet seam) 37.3; iv) Mandu 33.8; v) Belhargada 30.6; vi) Damodar river (12 feet seam) 25.6; vii) Mairan Kalan 18.4; and viii) Arahara 11.2. His report was based on the study made by Donaldson who was deputed to report on the iron and coal deposits near Hazaribagh. According to Hunter, the magnetite iron ore must be looked for in the metamorphic rocks. He also informed that the iron manufacture is one of the ‘chief industrial features of Hazaribagh’. During his time of visit, about 200 furnaces were at work in the district.

In spite of the rich iron ore deposits of the Singhbhum district, the indigenous smelters preferred to use those which were obtainable in a nodular form in most of the hill ranges. The nodules were small of dull red colour with a glassy surface. Ores also occurred in form of black earth, which were usually found in stratified masses. For extracting the ores, these were dug out by the smelters.
In the **Darjeeling district**, a ferruginous band, in the Tertiary sand-stones of Lohargarh had been recorded by Mallet (Mallet, 1875: 65). The outcrops ran along the southern brow of the hill, with a thickness near the centre of perhaps 40 yards. The length of the outcrop was about a mile from east to west, or between the points where the band disappeared below the alluvium. There was clearly an almost unlimited supply of ore. However, Mallet (Mallet, 1875: 66) suggested that the ore is of poor quality and portions, containing only about 30 percent, of iron, as shown by Mr. Tween's assays:

<table>
<thead>
<tr>
<th>No. of assay</th>
<th>Percentage of iron</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30.8</td>
</tr>
<tr>
<td>2</td>
<td>28.7</td>
</tr>
<tr>
<td>3</td>
<td>32.3</td>
</tr>
</tbody>
</table>

The ore varies from ferruginous clay to an impure brown haematite, and has frequently a ‘pseudo-brecciated aspect’. It is not smelted by the indigenous smelters. The Chenga naddi also carries a considerable amount of ore, an assay of one of which gave 39.6 percent of iron. Mallet assumed that the lumps which stand such water transport are the tougher and purer, or less clayey, portions of ore.’

A bed of iron-ore was also reported from a mile east-south-east of Sikbhar (Mallet, 1875: 66-67). It is two or three hundred feet above the bed of the Rer, and some three thousand feet above the sea. It has, as yet, only been worked at two spots, about two hundred yards apart. The section at the eastern digging includes actinolite rock, with some quartz and talc-schist containing octahedrons of magnetite. This is covered by the band of ore, which seems to be about 20 feet thick. Above it, is more actinolite rock with crystals of magnetite, and then fine-grained gneiss dipping north-east at 30°. The magnetite of the main band occurs as an aggregation of irregular crystals about the size of peas. These cohere but slightly to each other, so that the rock is easily crumbled. In places the ore is pure magnetite, but more usually it includes a varying proportion of actinolite. At the other spot where the ore has been worked, it is schist, composed of magnetite, micaceous haematite, actinolite, and talc, irregularly interbanded. Specimens of both the kinds of ore have been assayed by Mr. Tween with the following results:

<table>
<thead>
<tr>
<th>Variety of ores</th>
<th>Percentage of iron</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnetite</td>
<td>71.50</td>
</tr>
<tr>
<td>Micaceous haematite</td>
<td>59.89</td>
</tr>
</tbody>
</table>

Neither contain any phosphorus or sulphur.
Rangu naddi: The actinolite rock, which accompanies the magnetite, is a peculiar variety of rock which according to Mallet have not been found elsewhere in situ. Pieces of similar stone are, however, brought down by the Rangu, a stream which joins the Tista south-west of Kalimpong. The bed it comes from may be the same as that at Sikbhar, and Mallet (Mallet, 1875: 68) suggests that a close search towards the head of the Rangu might be rewarded by the discovery of accompanying magnetite.

Sakkau-Chu: Blocks of magnetic iron schist are washed down by the Sakkam river south of Dalingkot. The rock is composed of magnetite and quartz, the grains of each being sometimes distinct, but more usually intimately blended, so that the rock becomes almost compact.

The Ma-Chu brought down large lumps of micaceous haematite. The hills through which these streams flow are uninhabited, and covered by dense forest.

The above discourse on the distribution of iron ores may not precisely help in reconstructing the history of the extraction process of iron. Significantly, the mining process of iron is quite different from that of copper and its alloys. As previously mentioned, with rich iron deposits spread over a substantial part of the subcontinent in general and the present study area in particular, not much mining was involved. They were mostly gathered from the surface or dug out from shallow pits and trenches, or when available, are collected in form of iron sand from the beds of streams. Therefore, the remains of mining activities are not so visually prominent as that of copper, its alloys and gold. It is quite obvious that most of the research works on mining specifically dealt with copper and its alloys, rather than iron. However, it will be unwise to ignore that fact that copper bearing veins or ores also contains qualitative iron component. Hence, in a few cases the course of mining may not be singularly dedicated to the procurement of copper but some amount of iron. Unfortunately, the study, so far carried out on old mining activities failed to record the evidence of the extraction of copper along with iron from a same area.

It may also be pointed out here, that the distribution of iron ore in the present study area has a close association with the pre-industrial smelting traditions, recorded from the undulating uplands of the eastern Indian plateau including its fringe areas. There is no doubt that ore-bearing areas of Singhbhum were one of the richest centres of pre-industrial mining of iron in eastern India. However, the indigenous metal workers hardly applied the so called mining technique to collect iron ore. The occurrence of slag in the
near-by ore-bearing areas and the reports of the British officials and geologists (who have documented the occurrence of pits and trenches, dug out by the indigenous smelters for extracting ores) suggest that the extraction and production of iron had a long tradition in this part of the eastern Indian plateau.

The above database has enough merit/ scope to explain the connections maintained between the resources bearing areas and the archaeological settlements which has apparently exploited such resources. In absence of specific information related to the analysis of ores and artefacts, the observations rendered here are essentially hypothetical. A logistic approach has been taken in the reconstruction of the history of the use of iron and obviously the exploitation of such resources.