Volume II

CHAPTER V- CHAPTER VI

APPENDIX I AND II

BIBLIOGRAPHY

MAPS, TABLES, PLATES
CHAPTER V: Pre-Industrial Iron Smelting Activities
It is already mentioned that, in the Indian Subcontinent, human association with iron can most probably be dated back to a remote past of about 2nd millennium BCE. It is generally believed that during man’s earliest attempts of smelting copper/lead, a hard malleable substance was encountered. Perhaps this was the first encounter of man with ‘iron’. One may therefore assume that, the discovery of metallic iron (i.e., Fe) was perhaps an accidental phenomenon. Probably during the post-Chalcolithic phases, metal smiths were not well acquainted with the technical know-how associated with the production of metallic iron. As a result its use was very restricted and its utility in the society was not well understood (as attested by the meagre types of iron objects found from different excavated sites of Gangetic valley, central India, Deccan region, south India etc.). Gradually, with the advancement of technology, varied objects of utilitarian value were produced from iron (Banerjee, 1965; Chakrabarti 1992; Tripathi, 2001). Its remarkable presence in the archaeological assemblages (datable to c. 700/ 600 BCE onwards) suggests that it achieved an independent status in the society. Its evolved status i.e., its presence as wrought iron, cast iron and further steel (as attested by the report of metallurgical analysis of various stratified objects) indicates a steady growth of technological advancement in its production. Such technological innovations nevertheless do not always signify major changes in its methods of production. The conventional methods of production of iron thus had continued for generations without marked changes. However, it is a major drawback that finished objects and some scanty evidence of iron smelting in archaeological assemblages not always provide a complete picture of the smelting activities that had been performed in the ancient days.

The present chapter essentially deals with the database concerning the pre-industrial iron working/ smelting of eastern India. Here, the term pre-industrial iron smelting denotes the traditional method of iron smelting practiced by the indigenous people. Obviously, this indigenous method was in practice throughout the length and breadth of the subcontinent (in various degrees) before the introduction of modern steel making methods as followed in the industries during the British period onwards. This parameter will provide an outline to explain the methodology of iron extraction adopted through various stages, i.e., the processing of ore to the production of iron ingots since the bygone days. Ethnographic data and the reports of the British administrators give insights about the same.

Database: Based on Reports of the British Administrators and the Researchers:
Primary Smelting (production of iron ingots from ores)
The Agarias:
The Agarias of the Palamau regions of Jharkhand and Maikala range of Chhattisgarh practiced iron smelting, the full documentation work of which has been provided by V. Ball in 1880 (Ball, 1880: 120-123; 1881b: 380-381; 1985: 666-669). He noticed that the furnaces of the Agarias are generally erected under some old tamarind or other shady trees, at the outskirts of a village or in a hamlet where Agaraias alone dwell and which is situated in a convenient proximity to the ore bearing areas or to the jungle where the charcoal is prepared. The Sal (*shorea robusta*) trees were generally used for the preparation of charcoal, though in some parts the *Bija* Sal (*pterocarpus marsupium*) is preferred.

Their furnaces are prepared with mud, about 3 feet (0.90m) in height tapering off towards the upper end and having a diameter of about 2 feet (0.60m) at the base to 18 inches (0.45 m) at the top with an internal diameter of 6 inches (0.15m). The magnetic ores are first broken into small fragments by pounding, and are often reduced to a fine powder between a pair of millstones. The haematite ores are not usually subjected to any other preliminary treatment besides pounding. A bed of charcoal having been placed on the hearth, the furnace is filled with charcoal, and then fired. The blast was produced by a pair of kettledrum like bellows which consists of wooden basins loosely covered with leather in the centre. Strings attached to these leather covers are connected with a rude form of strings. These are made by planting bamboos into the ground in a slanting position. The weight of the operator is alternatively thrown from one drum to the other. The blast is conveyed to the furnace by a pair of hollow bamboos, and has to keep up steadily without intermission for six to eight hours. From time to time ore and charcoal are sprinkled on the top of the fire. Subsequently, the slag is tapped off by a hole pierced a few inches from the top of the hearth. Before the conclusion of the process, bellows are worked with extra vigour and the supply of ore and fuel from above is stopped. The clay luting of the hearth is then broken down to take out the smelted materials known as *giri*. It was then immediately hammered by which a considerable proportion of slag is squeezed out. In some cases, the Agarias continue the further process of reheating and hammering to produce pure iron, fit for the market. They at times also made agricultural tools for themselves. However, Ball stated in his report that, in majority of the cases they used to sell them to the *Lohars*.

The works of Elwin (Elwin, 1942) on the Agarias of central India mainly provides detailed information on their iron smelting practices. He recorded that their furnace was a cylindrical clay kiln, called *Kothi* or *Bhatti*, 2 ½ feet high, with a circumference of 8 feet at
the base and 5 feet at the top (Elwin, 1942: 181). In Mandla it did not stand upright, but is tilted backwards on a large stone. At the top the opening was 6” x 6” to receive the charcoal and ore, and at the base there was another mouth 10 inches high and 9 inches broad, to take the blast and to allow the iron to be removed. On the right hand side towards the back was a flue for the slag called Hagan or in Bilaspur loha hagora (aperture for excretion). From the top of the tilted kiln there ran backward a bamboo platform 2 ½ to 4 feet long and 1 ¼ to 1 ½ feet broad, inclining upwards, supported on light poles. This was the machan, the slide, down which ore and charcoal are poured into the furnace. It was plastered with mud, and provided with little walls, 3 inches high. Patharia Agaria used to build this set up, defined as the Mandla model by Elwin (Elwin, 1942: 181).

However, he recorded that in Bilaspur, the Khunta Chokh did not tilt the cylindrical furnace. They used to allow it to stand upright. The hagan is larger and has a deep hole in front of it. The machan has no walls to guide the charcoal to the furnace. The Mahali Asur of Bilaspur made a plain circular furnace without a machan. The ore and charcoal is shaken directly into the mouth of the furnace from a winnowing fan. Similar practice is also used by the Bir, Birjia and Agaria Asur of Palamau and Ranchi. In Kerakhair, the Birjia Asur had built their furnaces near the hillside. These were circular, upright, supported at the back by a stake driven into the ground. These were attached to the kiln by bark, tied round the top. There was no hagan, but from the mouth in front there ran two moulds in opposite directions, one for the iron and the other for the slag.

At Doka, a Bir Asur village, the furnace was 3 feet high, and had a diameter of 2 ½ feet. It was upright, circular, without machan, but with a hagan on the right-hand side (Elwin, 1942: 182).

The Agaria bellows are made of sections of the trunk of the *Trewia nudiflora* (Linn.), a little over a foot in diameter and about 3 ½ inches thick. The wood is chopped out with an axe or sometimes burnt with a red-hot iron. A hole is made on one side to take the bamboo tuyer which used to carry the blast to the fire. Pieces of cow-hide or buffalo-hide (in Mandla) or of sambhar-skin (generally in Bilaspur and Raipur), sometimes of goat-skin, are stretched across the top and tied down. There was a hole in the middle of each cover and a cord (known as the kutidor) is passed through this and held in place by a small twig. The other end is attached to a springe stick (generally of bamboo) called dang, or in Raipur ada-dang, which is fixed in the ground behind the usual place for the bellows. The pair of bellows used to lie side by side before the furnace or forge. Two hollow bamboo poles
called *tonda* or *behngul*, two to three feet long, lead to an earthen tuyer (*nari*) (Elwin, 1942: 182-183).

Before their use, the bellows are soaked in water. When the skin cover of the bellows is sufficiently pliable, any of the Agaria’s family member but rarely the Agaria himself stood with one foot on each of the bellows and depressed them in turn. The holes in the centre acted as valves, and as his foot descended, his heel served as a stopper to the valve and forced the air through the bamboo pipe into the furnace or fire. When he released the bellows, the bamboo stick behind sprang up, lifting the cover and refilling the bellows with air. The bellows-blower used to hold a *kalari* (in Raipur a *kona-dang*) stick in her hand, partly for support, partly to rake down the ore and charcoal from the slide into the furnace (Elwin, 1942: 183-184).

The Patharia Agaria of Mandla, the God-dhuka of Raipur, the Mahali Chokh of Bilaspur and the Bir and Birjha Asur of Bihar used stones, laid across the bamboo poles just in front of the bellows. The Khuntia Chokh, however, used to fix the bellows in place with two bamboo pegs, attached to each by a cord made of *mohlain* creeper tied tightly round the frames. The pegs remain attached to the bellows even when not in use, and are driven into the ground with a hammer when the bellows are to be used. The Khuntia Chokh almost invariably covered their bellows with sambhar-skin, and regarded cow-hide as taboo (Elwin, 1942: 184).

Elwin was informed that the tradition of using leaf-bellows both in Mandla and in Bilaspur persisted till a few years back. However, he failed to document the same during his study. The mythical stories amply testified to the fact that use of such bellows were in vogue among them.

Such bellows are made, for example, by the Dafla of Assam and by the Kharia of Bihar. The latter used a pair of rude bellows, made of a pair of conical caps about a cubit and a half in height. These were made of leaves stitched together with grass and firmly planted upon hollows in the ground. The blast produced by the alternate and sudden swelling and sinking of the caps is conveyed through a pair of bamboo tubes to a heap of ignited charcoal (Elwin, 1942: 184-185). Elwin further referred to the works of S. C. Roy, who suggested that, “these bellows are, or were, used, by the Kharias of Barabhum in Manbhum and Dhalbhum in Singhbhum who live away from villages, occupied by the *Lohar* or *Kamar* blacksmiths” (Elwin, 1942: 185).

The clay tuyer, they used was cylindrical in shape, known as *nari* or *nari-thondi* (in their dialect) It is splayed open at one end, tapering slightly at the other, which is set in the
luting of the furnace or the forge to collect and concentrate the blast upon the fire. The size varied from 7 to 10 inches. One of the specimen measured 9 ½ inches in length, and was 2 inches wide at the broader end and 1 inch at the narrower (Elwin, 1942: 186). After making the tuyer they went to the ore bearing areas and jungle for collecting ore and charcoal. After that, the lumps of ores were broken down into small pieces and crushed into mere earth. They were roasted in an ordinary fire of wood and bark (Elwin, 1942: 187).

Subsequently, the mouth of the furnace was repaired with clay. Both the top and the waste flue have been plastered. Kodon chaff (which had been burnt the last time the furnace was worked, and is now black and dirty) was cleaned by shaking it up and down in a winnowing-fan, thus removing all the rough fragments. This chaff was then placed into the mouth of the furnace, filling the depression in the ground inside, and pressed it down firmly with a useful little stick known as the tokna-lathi (Elwin, 1942: 187-188). It was smoothened for containing the bloom of the half-molten iron. Now some sand and water is mixed to make a wall about an inch high across the front of the mouth. When this is ready, more chaff is put up to the level of the wall which is again patted and smoothened carefully with the sharp edge of the stick. If there is not enough kodon, charcoal-dust might be used as an alternative. On the little wall, the tuyer was placed in a way so that its wider mouth appeared at the edge of the wall. The clay luting was plastered with wet sand all round it. Some charcoal was then beat by her stick and after putting these broken bits into a winnowing-fan it was poured into the furnace by way of the slide, filling it right up to the top. Some of the charcoal was seen spilled out of the ‘mouth’, but it was pushed back and quickly the mouth was plastered by pressing the wet sand back against the mass of charcoal. In front of the tuyer, a little platform of sand was made, and on this the toknalathi was laid. This provided a shelf for the hollow bamboos that would carry the blast from the bellows (Elwin, 1942: 188-189).

The woman who had to work with the bellows placed them in position, bended down the dang-springes and tied the kutidor-cord, twisting it round twice and knotting it. The bamboo pipes are placed so that they converged at the mouth of the tuyer, and a heavy stone is laid on them to keep them in position. The woman mounted the bellows and another woman put some fire in coals from an old fire in the mouth of the clay tuyer. The first woman, holding her rake in one hand and sometimes a stick in the other, or occasionally supporting herself by holding on to a cord suspended from the roof, began to
work the bellows. The blast quickly forced the fire into the furnace and soon smoke poured out of the top.

The second woman shake a charge of ore out of a winnowing-fan on to the machan-stage, and this is gradually slipped down into the feed-hole and is mixed with the charcoal. Five or ten minutes later, she lighted the smoke with a blazing stick. After about half an hour, the second woman opened the flue with a stick and began to pull out the iron slag with the tongs (Elwin, 1942: 189).

The bellows were worked continuously. As the charcoal and ore were slipped down into the furnace, someone poured more charcoal (from the left) and ore (from the right) on to the stage. The work continued for two to five hours. The ore has been put in ten times during the entire process. Elwin observed that in Nunera the process continued from 5.30 PM. to 10.15 PM whereas in Mandla it was done more expeditiously, from 3.30 AM to 5.15 AM and from 6 AM to 8.45 AM. Thus, he concluded that the duration mostly depends on the kind of ore used, and the amount of iron that is required (Elwin, 1942: 190).

After the completion of the process the bellows are removed. With a stick the sand luting of the hearth was broken down and the tuyer was removed. The blazing coals poured out in a red cascade. The Agaria then adroitly raked the sand into a heap on his right-hand side (where it would be ready for use again) and the coals to the left. Some water was then sprinkled on to the coals. Then the man with sansi-tongs lifted out the rough spongy bloom of glowing semi-molten iron and slag, and carried it to the anvil. Here it is hammered, and most of the included slag, which is still in a state of fusion, is removed (Elwin, 1942: 190).

Elwin noticed one slight variation in Nunera. The Chokh Agaria did not use the tokna-lathi to smooth the chaff (which incidentally was rice chaff, since kodon was not grown in the neighbourhood) and when the hearth was fully plastered, a little cup-like platform was made in front of the dudri, as the mouth of the furnace was called. On this the hollow bamboos rested (Elwin, 1942: 190).

The Asurs/Asuras:

Near the Netarhat plateau the indigenous iron smelting was practiced by the Asura tribe even till the 20th century. K.K.Leuva (Leuva, 1963) made a detailed study on the iron smelting practices of the Asura tribe. He recorded that the Asuras used three varieties of iron ores, magnetite which is called Pola by them, haematite from coal measurers known as Bichi and haematite from laterite known as Gata. These ores are then broken up into small pieces by pounding before they are put in the furnace for smelting. They usually discovered the ore by observing some of it on the surface and then by following the veins
which seem to be nearly horizontal. The veins are from one to five cubits thick, and never seem to extend in one direction. Sometimes they are crooked, but often send off branches (Leuva, 1963: 146-147).

The next important requirement for the smelting is charcoal. In the past, only logs of one size i.e., about 12” to 18” in diameter were employed. Trees of large dimensions cannot be broken up by the tools that the Asuras had. The smaller branches were used for firewood and they were never used for making charcoal. The logs were cut into pieces about 5 or 6 feet long which were filled each one after another in layers crosswise and then the small stocks of logs without any preparation set fire to. When well lighted, water was thrown upon it and the crusts of charcoal thus formed were knocked off each log (Leuva, 1963: 147-148).

The most important apparatus used by the Asuras for the said activities was foot bellows. A pair bellows had three essential parts, a very solid wooden bowl, two bamboo blow-pipes which are fitted to the earthen nozzle in actual contact with the fire place and the raw cowhide covering for the wooden bowl (Leuva, 1963: 148-149).

“The extremities inserted into the nozzle are always knots in the bamboo. This serves a double purpose, it gives additional strength and allows of a bore much smaller than the natural bamboo cavity. The blast forced through this tiny aperture is thus considerably increased. To keep the blow-pipes steady whilst the bellows are working a stone is placed on them. The cow-hide is fastened on the wooden bowl firmly round the outer rim, and yet given free play for an up and down movement. In the centre of this covering there is a round aperture just over one inch in diameter serving as a valve. Through this passes a string tied to a flat piece of wood. This piece is destined to raise the hide again after it has driven the air into the pipe. To the other end of the string a rope is fixed, the string and rope together measuring 27”. The free end of this rope joins a slanting bamboo firmly embedded in the ground so as to have, over the centre of the bowl, a height of 27” plus 5 ½” i.e. 32 ½ “above ground. The bamboo measures 5’ 8” from the issuing point to the rope. Thus the piece of wood always presses against the inner side of the hide cover. Hence, as soon as the operator’s heel, closing the valve and treading the hide, has emptied the bellows, the bamboo springs up again lifting the hide cover. The withdrawal of the heel naturally causes an instant flux of fresh air.” (Leuva, 1963: 149)

Since the heel of the operator must hermetically close the valve it was necessary that string should not impede the heel. Moreover, there should be no loss of air between the heel and the string. The latter is obtained by the constant pressure of the piece of wood against the
air hole. The removal of the string to the rim of the aperture is effected by means as ingenious as it is simple, the bamboo springs instead of being parallel to each other, slightly diverge. Hence the ends to which the strings are attached are not exactly above the two apertures, but far enough on their right and left to keep the strings and obstructors tight against the opening, unoccupied by the operator’s heel. Little amount of water is kept at the bottom of the bowl to keep the covering cow-hide moist and supple (Leuva, 1963: 149-150).

The furnace was erected under an improvised structure near a shady mango tree. It was made of mud with a height of about three feet. It is tapered from below upwards from a diameter of rather more than two feet at the base to eighteen inches at the top, with an internal diameter of about six inches. After preparing the bellows, a bed of charcoal have been placed in the hearth. After that, the furnace was filled with charcoal which was lighted. The draught was produced by the pair of foot bellows. The blast was conveyed to the furnace by a pair of bamboo-tuyers and it was kept up steadily without intermission for more than five hours. From time to time ores and fuel have been added, however, the proportions used not being measured. Ores and fuel were added in this way ten to eleven times during the process. From time to time, the slag was tapped off by a hole pierced a few inches above the base of the hearth. The furnace was lighted at about 7’O clock in the morning and at about 12’O clock it was thought that smelting of the ores were complete. Subsequently, the supply of ores and fuel from the above was stopped and the smelters worked the bellows with extra vigour for ten minutes. The clay luting of the hearth was then broken down and they took out the ball or *giri* consisting of semi-molten iron, slag and charcoal. The ball was quite large and the author suggests that from this two ploughshares could be made. So the smelter cut it into with several vigorous strokes of an axe and then hammered them in order to squeeze out a considerable portion of the included slag which was in a state of fusion (Leuva, 1963: 150-151).

**The Asura-Birjhis:**

The Asuras who chiefly inhabit the districts of Ranchi and Palamau etc. is said to be divided into several sections, of which Birjhia forms the most significant one. They are traditional smelters of iron and practiced, when situations are congenial, shifting cultivation. The study of S.B. Das Gupta (Das Gupta, 1978: 48-52) on the Birjhia tribes of this region revealed that their furnace (*Kuthi*) is a small mud structure almost cylindrical in shape tapering from bottom upwards. These were mostly three feet in height. At the top the diameter was about eighteen inches while at the bottom, about two feet. The wall was
about six inches in thickness, leaving a cavity from top to bottom that gradually widened downwards and constituted the furnace proper. There was an opening on the front side at the bottom, at which two bellows (chapua) were placed and through the mass of melted iron was taken out at the end of the process. The kuthi and its surrounding place were provided with shade by constructing a structure. It is known as kutanri – smelting shop. Charcoal and iron ore (morhen diri) beaten into small pieces called bichi are generally kept at the kuntari. The kuntari was generally at a distance from the habitational areas. A bed by placing dust and ashes was prepared at the bottom of the cavity. An elongated cavity was also made on the bed. An elongated tapering tube (nar) about a foot long and made from clay, was placed at the middle of the opening of the kuthi in such a manner that its narrow end inserted into the cavity and the thicker end of the tube reached the outer edge of the opening. The opening at the bottom of the furnace was closed with dust and ashes. The furnace was filled with charcoal and nozzles of two bellows (chapuas) were placed at the opening of the nar. Pieces of iron ore (bichi) and charcoal were kept on top of the wall of the furnace on the other side opposite the opening. A burning ember was placed at the mouth of nar and bellows were worked by one man by foot. The burning ember was thus forced into the bottom of the hearth by the blast of the bellows and the charcoal inside was lit up. The bellowing was continued throughout the smelting process. The charcoal was burnt and went down in the hearth. From time to time, the dust and ash covering the opening of the kuthi was pierced, by the side of the tube, with a thin piece of twig or bamboo splint when molten slag steamed out. The bellows were worked by several people however the feeding of the hearth as observed by Das Gupta, with charcoal and bichi was done by an adult male. As the molten metal formed on the ‘bed’ the narrow end of the nar gradually melted, acting as a flux in combination with the impurities of molten metal. At the end of the process, the dust and ash covering of the opening was removed along with the remaining part of the nar, and with a pair of big tongs (sanrSI) the red hot semi-solid iron mass was taken out. This was placed on a block of stone and then another person stroked the iron mass with a heavy hammer. The adhering slag pieces were beaten off in this way.

Subsequently, on any other day, the iron mass was again heated in a smithy (pasra) by the smelter and portions of the metal were shaped into ploughshares by beating the same with a smaller hammer (kutasi) on an anvil (nehai) which was a thick block of iron piece. Other implements such as axe (tangi), sickle (datrom) or scythe (matha datrom) were made. Dusts were thrown on the portions of white hot iron in the smithy to ‘cleanse’ the iron thereby and to provide hard and sharp edge.
The said process has been studied and revived by the engineers of SAIL, Ranchi. Here also vertical shaft furnaces with tapering sides were used. The smelting techniques practiced by the Asur-Birjhia tribes are still financially revived by Vikas Bharti, a voluntary action group of Bishunpur. This has been thoroughly documented during my field investigations in the region concerned (see Appendix I).

In the Bhagalpur region, ‘the furnace employed was built of clay and was almost cylindrical having a height of three to four feet with an external diameter of two to two and a half feet at the top and somewhat wider at the bottom, and an internal diameter of only a few inches at the top, increasing to about a foot at the bottom’. A fire-clay pipe was used as a tuyere and the blast was supplied from a couple of bellows of a peculiar pattern which were worked by a man standing with one foot on each of the bellows (Watson, 1907: 20).

Watson reported that approximately 300 tons of irons (per annum) were produced in the Bhagalpur district (Watson, 1907: 20-21). According to his report, the furnaces, employed in the iron smelting activities in the district of Birbhum, were considerably larger than those of Bhagalpur. Each furnace produced a mass of iron weighing 25 maunds, and Oldham estimated the total production of the district as 2,380 tons of crude iron per annum (Oldham, 1852: 7). Some drawings by Oldham of such furnaces used in the Birbhum district have been reproduced in the Memoirs of the Geological Survey of India (Ball, 1877: 87). The furnaces were about 7 or 8 feet high and 5 feet across. Their cross-section was not circular but D-shaped, the flat side being the front and at this side the blast was introduced through the tuyeres. The bellows were of much the same pattern as in the other districts but larger, and several men were required to work them (cited in Watson, 1907: 21).

Buchanan (Buchanan, 1930: 15-17) during his survey in the Bhagalpur district in 1810-11 recorded the iron smelting activities of the Kols near the village of Pahiridihi on the bank of the river Urni. The furnace according to Buchanan was very rude and placed in the open air. It was built entirely of unbaked clay. The top was about a cubit in diameter, perforated with a hole of about two inches wide and concave. Below this was a kind of neck and then the body swelled out. At the bottom of the furnace there was a semi-circular opening. During smelting operation, charcoals were put through this opening, in which was also laid a pipe of baked clay for receiving the muzzles of the bellows. Remaining portion of the opening was then filled up with moist clay. Bellows were then applied. Fire was lit through the pipe. So soon as the fire was kindled, some charcoal was put on the top of the furnace, and as it kindled, some powdered ore was thrown upon it. When slowly both
charcoal and ore went down the process of adding the same was repeated. When the workmen judged that the operation was finished, temporary clay wall from the front opening was removed. Iron ingot was taken out. Interestingly, Buchanan while comparing this smelting operation with that of Mysore, he described the former as less skilful than the latter however, nature of bellows were better than the latter. He described the parts and working of bellows in the following way: “Two are employed, each consisting of a piece of hollow wood, about the shape of a Cheshire cheese, thirteen inches in diameter and six inches deep. A raw hide is stretched loosely over this, and tied round the mouth so as to be air tight. The muzzle is a bamboo, about 4 feet long, passing through the side of the wooden cylinder. In the middle of each skin is a hole about an inch in diameter, through which a cord is passed and tied to a baton of wood which prevents it from passing through the hole which it does not shut. This cord is tied by the other end to a bamboo bent like the spring of a turner’s lathe, which draws the skin lip, so as to be very convex. The two bellows are placed close together, and the workman placing a heel on each hole, stops it, while his weight forces the air through the muzzle. He then alternately presses his weight on one foot, and then on the other, which keeps up a constant blast.” (Buchanan, 1930: 16)

Watson reported that iron smelting process carried out by the Kols of the Dumka region of the Santhal Parganas hardly differed from any of the processes which have been in vogue for the whole of the 19th century in Sambalpur, Orissa, Chota Nagpur and the Rajmahal hills. The furnace was built on a small hill under the shade of a banyan tree. It was made of clay and was carefully dried before use. In form it was almost cylindrical, with a height of 34 inches, outside diameter 26 inches at the bottom, 22 inches at the top, inside diameter at the hearth about 1 foot, at the top 5 inches. On one side a semicircular hole, 1 foot across, was made in the bottom of the wall of the furnace. Into this hole, tuyere was placed resting on a brick. The tuyere was an already baked fire-clay tube 7 inches in length, about 1 inch across at the wider end and slightly conical. The tuyere was then surrounded by a mass of moist sandy clay. The hole in the wall is then entirely filled up with the said material. The bellows were then put in place. Each bellows consists of a short cylindrical piece of wood 16 inches in diameter and 5 inches high, hollowed out from the top to the form of a pill-box, with a goat-skin tied over the mouth. On the side of the cylinder was fitted a bamboo tube, 3 feet in length and fitted at its further end with a small iron tube as a nozzle. Two such bellows were put in place with the iron nozzles pushed into the tuyere of the furnace and the bodies of the bellows close together so that the bamboo tubes were as near in line as possible with the tuyere. In the ground on each side of the furnace a pliant stake 8 or 9 feet in length had been driven (Watson, 1907: 22). These were
now bent over towards the bellows and to the stake on the left-hand side was fastened a string. The string was attached to the goat skin of the left-hand bellows so that the stake, trying to spring back into place, pulled up the skin on the bellows. The stake on the right-hand side was similarly attached to the right-hand bellows. The skins each had a perforation. Then a man standing on the bellows, with one foot on each, depressed the right-hand stake and at the same moment closed the perforation in the skin of the right-hand bellows with his foot. By means of his weight he drove the air from the bellows into the furnace. He then leant over to the left and repeating the operations on the left-hand bellows sent a blast from the left-hand pipe into the furnace and thus alternately he threw his weight from the right to the left in a series of operations. The skins were from time to time sprinkled with water (Watson, 1907: 22).

The furnace was filled with charcoal (the charcoal used was of sal wood, having been burnt in a hemispherical pit in the ground) which was lighted and the blast started. Then the charcoal and ore were supplied from the top of the furnace in the proportion of one skip of charcoal to one measure of ore (the measure consisting of a broken earthen water-pot), the blast was steadily maintained and fresh fuel and ore were added as the previous supply gradually worked down into the furnace. The ore employed was fairly pure haematite in small nodules showing a crystalline fracture. These nodules were crushed to a fine powder before use. Carbon monoxide burnt with a blue flame at the mouth of the furnace and that a white heat was attained within the furnace could be seen by peering down the tuyere. After about half an hour a thin stick was pushed into the moist sandy clay wall surrounding the tuyere, and from the hole thus made a small quantity of slag poured out and solidified. Tapping of slag were made about every half an hour. The slag was almost black and vitreous and on-cooling generally splintered into a thousand pieces. The blast was continued until no more fuel remained, and, in all, probably 1 maund of charcoal and 20 seers of ore were used. This entire process continued for three to four hours. The blast was continued some time after all the material had disappeared from the top of the furnace, then the tuyere was removed, the charcoal raked out from the furnace and quenched, and ultimately the mass of semi-fused iron was dragged out by tongs with long wooden handles, dragged on to the grass and very gently hammered to excrete some of the slag. The iron obtained weighed between 6 and 7 seers. The smelters informed that on being refined this would yield half its weight of *pucca* iron (Watson, 1907: 22-23).

In January 1918, Andrew McWilliam, (a metallurgist of Sheffield), had surveyed the iron smelting operation, practised in the village of Mirjati which is located in the foothills of the Dalma range, near the modern iron steel works in Jamshedpur, Bihar (McWilliam, 1907: 22).
The total iron smelting operation took 5 hours 35 minutes. The ore used was a brown haematite, found in comparatively small masses near the village. Charcoal was made by the family in the adjacent jungle. The ore and the charcoal were first reduced to the size of the beans. Two baskets (14 inches in diameter and 12 inches deep) of beansized ore and four baskets of charcoal of about 8 seers (16 lb.) were required to produce about 5 seers (10 lb.) of iron. The furnace, made of local clay, was 3 feet 10 inches high from the ground level. At the ground level the external diameter was 2 feet 6 inches; at 3 feet 4 inches above it was 1 foot 7 inches, but at the top it was slightly broader- 1foot 9 inches. The top was flat and level to hold a charge of ore and charcoal. The internal diameter varies from 4 ½ inches at the top to 15 inches at the bottom. There was an arched opening in the front from ground level upwards, 15 inches broad by 14 inches high. This was plastered up during the process with a suitable hole at the bottom for the insertion of the nozzle of the bellows. There was another small hole at the side which was generally closed with clay and opened occasionally to remove the slags. The bottom of the furnace inside was in the form of a rounded cavity below the ground level. The bellows were operated by feet. When enough iron was made, the spongy mass was taken out by breaking open the temporary front and was immediately cut in two with an axe. One-half was reheated in a charcoal fire and forged into a piece about 1 ½ inches square.

Traditional iron smelting has been prevalent in several parts of Orissa till the sixties of the 20th century. A note of H.F. Blanford (as cited in Percy, 1864: 261-262; Oldham, 1859: 1-32) clearly explains the nature of iron smelting activities, practiced in the village of Kunkerai of Orissa. The village was inhabited exclusively by the iron smelters, and is distinguished from the nearby agricultural villages by the filth and poverty of the inhabitants. The furnace was built of the highly ferruginous sandy soil which has been previously moistened and kneaded and is generally strengthened by a sort of skeleton of strips of flexible wood. In form, “it varies from a cylinder, more or less circular, to a frustum of a tolerably acute cone, the walls being either of equal thickness (about 3 inches) throughout, or rather thicker towards the base” (cited in Percy, 1864: 261). The height of the furnace is generally about 3 feet, and the mean internal diameter is about 1 foot. There are two openings at the base of the furnace, one in front and the other one is small and placed at one side of the furnace and chiefly below the ground. The front opening is about a foot in height and rather less in width than the internal diameter of the furnace. This is utilized for two purposes, i) through this, resulting mass of spongy iron is extracted at the end of the smelting process, and ii) in the beginning, the opening was well plastered up with a small conical tuyere being inserted at the bottom. This tuyere is usually made of the
same material as the furnace, viz. of a red argillaceous sand, worked by hand into the required form and sundried; but sometimes no other tuyere is employed than a lump of moist clay with a hole in it, into which the bamboo pipes connecting with the bellows are inserted. The other opening forms a communication between the bottom of the furnace chamber and a small trench into which the slag flows, filtering out through a small pile of charcoal. The bed of the furnace is slightly inclined towards this slag hole to allow the slag to flow away freely. The latter solidifies as it leaves the furnace into vesicular cakes, which are removed occasionally with pincers by the workmen.

The inclined tray at the back of the furnace is very locally employed. It is formed of the same material as the furnace, kneaded into shape, and supported on a bed of split bamboos laid on a wooden framework. On it is piled a supply of charcoal which is raked into the furnace as required.

“The blowing apparatus…… consists of a circular segment of hard wood, usually mango-wood, rudely hollowed, and with a piece of buffalo hide with a small hole in its centre tied over the top. Into this hole a strong cord is passed, having a small piece of wood attached to the end to keep it inside the bellows, while the other end is attached to a bent bamboo firmly fixed into the ground close by. The bamboo acts as a spring, drawing up the string and consequently the leather cover of the bellows to its utmost stretch, while air enters through the central hole. When thus filled, a man places his foot on the hide, closing the central hole with his heel, and then throwing the whole weight of his body on to that foot he depresses the hide and drives the air out through a bamboo tube inserted in the side and communicating with the furnace. At the same time he pulls down the bamboo with the arm of that side. Two such bellows are placed side by side, thing bamboo tubes priming to the same tuyer; and so, by jumping on each bellows alternately, the workman keeps up a nearly continuous blast” (cited in Percy, 1864: 262).

In 1839, Kittoe observed the iron smelting activities, practised in several localities of the districts of Talcher and the adjacent states of Ungool and Dhenkanal. However, his did not record the entire process (Kittoe, 1839: 137-144).

In 1875, Ball observed that along the frontiers of the Hingir highlands in Sambalpur, there were few Lohar villages. At many of the large villages there were furnaces, however, they were worked by the temporary settlers. They used to settle at the place where timber was abundant. They shifted to new localities when they have exhausted the supply in their vicinity. Although Sal was the wood most commonly used for making charcoal, he found that the Bijasal (Dipterocarpus marsupium) seemed to be preferred by some. The wood
was cut into logs about 3 ½ feet long, or rather more, and was burnt in holes which were about 4 feet square and 18 inches deep. He observed that the furnaces were somewhat smaller than the largest which were in use in Bengal. They were furnished with a tray above, in which a quantity of mixed ore and charcoal was kept, which can be raked into the top of the furnace by the person working the bellows. This, according to Ball, of course, was a great saving of labour as compared to the usual system which involved the presence of a second person to feed the furnace. Differing from the practice in Hazaribagh, the same individuals made the giri (bloom) and also worked it up into iron for the market. The giri were much smaller than in Hazaribagh, in one case at Jodiboga not exceeding 6 or 7 seers, generally, perhaps, they were about 10 seers. The Mahajans got 16 to 20 seers of iron for a rupee from the Lohars, but owing to system of transactions being chiefly in kind, this could not be accurately ascertained. (Ball, 1875: 120-121)

In a village near Baipariguda in Jeypore subdivision of Koraput district a demonstration of primitive iron smelting was organized in 1960 by a team of the Birla Industrial and Technological Museum, Calcutta under the supervision of S.K. Bagchi (cited in Srinivasan, 1998: 229, 239-240). Srinivasan in 1990 recorded information regarding iron smelting practice at Bangurkela, a village located about 20 km from Rourkela. The smelters had migrated from Ranchi. During his survey, the smelting was no longer in operation. Significantly, the group used limestone or local Kankar as fluxing agent (Srinivasan, 1998: 229). Mohanta et al. recently surveyed the Mayurbhanj and Keonjhar districts extensively and discovered ancient remnants of iron objects, iron smelting furnaces, ingots etc. The use of wood in charcoal furnace at the site of Badampahar has been recorded. Besides, Auski at the foothill was found scattered with slags and tuyeres (Mohanta et al., 2003: 81-90).

M.K. Ghosh (Ghosh, 1964: 132-135), National Metallurgical Laboratory, Jamshedpur studied the process of traditional iron workings and types of furnaces being operated in the villages of Kamarjoda (Bihar), Singlebecha and Jiragora in Orissa. Three furnaces, which represent almost three stages of evolution in furnace design, have been described by Ghosh.

The Kamarjoda furnace was a shallow bowl of about 1 foot in diameter and 6 inches in depth. This clay lined bowl was excavated in the ground. A shaft of 3-4 inches in diameter and 18 inches in height was erected above this. A thick clay wall has covered the back portion of the furnace area up to another 2 feet. Clay with a mixture of straw that had been kneaded thoroughly with water was used to construct the furnace. It was allowed to dry
and the whole structure was smeared with clay once again to smoothen and fill up the cracks and crevices, if they appeared. The furnace was then operated by charging it with small (1-1.50 in) charcoal pieces (processed from Sal tree) and crushed haematite ore. On either side of the aperture, on the clay wall additional charcoal and ore were piled up for feeding into the furnace. The front portion of the furnace was sealed with a mixture of damp sand and clay after the tuyere had been inserted through it. Twin foot operated bellows were used.

About 15-16 kg of ore (which contains 45-50 percent Fe content) and equal amount of charcoal were charged. It took about 4 hours to complete the smelting process. In this type of furnace, temperature did not exceed approximately 1100°C and the metal was never molten during this process. There was almost no accretion of carbon at the low temperatures encountered, and the charcoal used as fuel did not introduce sulphur or phosphorous in the metal. So the result was a very pure iron. An ingot of 2 kg approximately was obtained from 30 kg of ore. The Kamarjoda furnace had been described as a furnace of the most primitive type, because it had no provision for tapping of slag. The metal tended therefore, to scatter in small discrete particles throughout the slag matrix, which had to be broken open to obtain the metal.

**Singlebecha furnace** was a 4 feet square by 3 feet deep chamber that was dug with steps leading into it. A bowl shaped pit of 1 foot diameter and is about 9 inches in depth was dug into the floor of the chamber beneath one of the walls. A shaft of 3-4 inches in diameter was raised above the centre of the bowl. Here, the pit was provided to allow the slag to run from the bowl. There was a slope towards the pit to facilitate an easy flow into it. The slag pit-chamber lay into the main pit and did not undercut the side wall. The status of smelting was investigated by inserting a rod through the tuyere. When molten slag was stick to the inserted rod, the sand wall was broken in order to allow the molten slag to run out and collect in the pit. The slag wall built again and blowing resumed till more slag was collected. After several such attempts of raking the slag when the final tapping was done, the entire wall was broken and the bloom was removed with tongs and quenched with water. The adhering slag was hammered off.

**Jiragora furnace** was of shaft type having 2 feet 6 inches to 3 feet in height with an internal section tapering from 1 foot at the base to 3-4 inches at the top. A platform supported by a bamboo stick was built near the furnace which was used to store the additional charge for feeding into the same. A pit was dug to collect the slag. The furnace was mostly above the ground while the Singlebecha furnace was an underground variant of
this one. Its efficiency had been calculated to 36.2% with 24 kg ore and 30 kg of charcoal reduced over a period of six hours.

It is quite interesting that three different types of furnaces i) bowl type, ii) underground and iii) shaft furnace were found in close proximity to each other.

Small furnaces variously known as *Bhati* (in Sambalpur), built above the ground and *Gana* (in Koraput), built underground were in operation in Orissa. Low grade iron ore was charged in layers with wooden charcoal. Each charge was called *Bhadi*. Entire operation required 12 charges of ore and 9 of charcoal. Srinivasan in his work identified 50 villages in Koraput district and 15 villages in Sambalpur district which were engaged in traditional iron smelting.

In 1991, Rourkela Steel Plant embarks on a project on the ‘Revival of Rural Ironmaking’ with active collaboration of Lohars who were employed at the plant (during 1991) and revived the process of melting, as practiced in the past (Srinivasan, 1998: 228-240). “A typical furnace based on the design of the one reported to be used in Orissa, was constructed. Total height of the furnace was, 1050 mm, of which about 20mm is below the ground. A significant modification made is that the furnace wall is in two layers with an annular space, filled with sand for better heat conservation. A fluted tuyere is placed at an angle of 15-20° to the horizontal. Preheating of the charge is done. The furnace is started by charging charcoal from the top and lighting it. The burden consists of 10 charges of 15 kg sized ore and 25 kg charcoal each with some limestone. Air blast is maintained continuously by a hand blower… Normally, 4-5 deslagging operations are done. The blowing stopped when the charge has descended to the critical level. The sponge iron lump is pulled out with a pair of tongs. It is subjected to hammer blows to consolidate it and remove slag inclusions. Then, it is transferred to the forge for shaping into implements” (Srinivasan 1998: 234-236).

The *Birbhum district* of West Bengal remarkably portrays the evidence of pre industrial iron working as does the other parts of Eastern India. According to Sherwill’s report, the iron mines of Birbhum were situated in the western and north-eastern parts of the district, particularly in Tappeh Sarhet-Deoghar, Parganas Nooni, Mallarpur and Mayureswar (Sherwill 1855: 25, 26, 30).

In 1852, there were about seventy furnaces in operation at four sites. At Deocha, there were thirty furnaces, about thirty at Ballia-Narayanpur, at Damra four, at Ganpur, about six (Oldham, 1852: 7). In a note on a specimen of iron object from Ballia-Narayanpur, Torrens gives an explicit description of the site and the methodology for performing iron working.
activities. According to him, the region is covered with an interminable Sal forest which furnishes them with good quality charcoal. He observed that small shafts were sunk throughout the region in order to obtain iron ore. The furnace or Chula is of clay, about 3 to 3 ½ feet broad and each is served with three large bellows worked by the feet (Torrens, 1850: 77-78).

**Secondary workings (the production of finished objects from ingots):**

The secondary iron smelting works (i.e., the production of finished objects from ingots) of the Agarias were taken place at the little forge or dukan (shop) (Elwin, 1942: 195). After making iron ingots the bellows were shifted to the other end of the hut, and placed so that the bamboo poles converged on a small clay nozzle. It was fixed by mud in the ground and pointing slightly downwards towards a small hole filled with charcoal. On the right-hand side and at right angles to the line of this nozzle there was a small earthen wall about two feet high and three feet long (but often considerably smaller than this) which was pierced by a hole leading to a still deeper depression in the ground. This acted as a flue and an escape for any slag that was still further forced from the iron on its refining.

An anvil and a couple of welding hammers or ghana were in the collection as significant tools for such refining works. The ghana was of two types. One (generally used in Dindori) was a solid block of rounded iron, with a hole through the centre to hold the wooden shaft. Both the ends were the same, blunt and round. It measured five inches in length, with a diameter of three inches and weighed, without its shaft, 2 seers 14 chattaks (Elwin, 1942: 195-196).

The other type of ghana was a long piece of iron with its haft at one-third of its length, blunt at one end and pointed at the other. A typical hammer of this kind from Lapha Zamindari, weighed 4 ½ seers (without handle). The handle was 2 ½ feet long, the head of the hammer being exactly a foot long, 1 ¾ inches wide at its broad end and ¾ of an inch wide at the narrow point.

Besides, sansi or tongs were also kept at the forge. These were again of two types, straight-lip tongs, with straight pointed ends, and gad tongs (called koki-sansi) with the ends bent over to ensure a firmer grip. A normal length was 1 foot 8 inches and the weight was ½ to ¾ seers (Elwin, 1942: 196).

There were also a number of small, but very necessary, tools which the Agaria had in their collection. First among these was the iron matorna, a small anvil flat on one side and slightly hollowed on the reverse to make a sort of swage-block when turned upside down. These were 3 ½ inches long and 2 ¼ inches broad. The tussa, a punch of iron 2 inches
long, was used to cut the iron or to make deep indentations. It had a sharp edge at one end. The *suja pawari* was a round iron bar 3 ½ inches long, and was used to cut holes in the iron. Handles also were hammered round it. The *paslor* was similar to the former, but it was thicker (Elwin, 1942: 197).

Coal was placed in the tuyer of the forge. Subsequently, charcoal was ignited with a few short sharp blasts of the bellows and then the blowing process was continued. The first step was to remove the slag and charcoal that was adhering to the extracted iron ingot. It was hammered off on the stone anvil, known as *dhidha*. Sometimes it was cut in half with an axe, and the two pieces were put in the refining fire of the forge. After two hours or so, it became *pajar* iron and it was fit for the most exacting and important work (Elwin, 1942: 197).

The Agaria then pulled out of the fire the ball of *dhidha* iron with the help of tong that he had put there an hour ago. He held it on the anvil with his left hand while with his right he hammered it with the welding hammer. His son grasped the second hammer, raised it above his head and brought it down heavily on the iron. For several minutes they hammered in perfect unison. After removing some slag they put the ball back into the fire. Elwin observed such tradition of hammering at Mandla. However, in Bilaspur and Raipur he recorded that the hammer was heavier, two men did not hammer together, but only one used the hammer while an assistant used to hold the iron with the tongs (Elwin, 1942: 198-199).

The ball of iron was again removed from the fire and beaten. It was then ready as *pajar* iron. The Agaria decided to make a *tabla* axe from it. With heavy hammers both father and son beat it into a rough square and returned it to the fire. The Agaria then dipped it in a pile of cow-dung ashes ‘to stop it peeling too much’ and again beat it out with the heavy hammer till it was flatter and longer. He took some lumps of *nari mati* and crumbled them, and when the iron was in the fire he threw pinches of the dust on to it. Gradually he beat the block of iron into shape, making a broad head and a long narrow tail. He constantly had to dip the tongs into the *kotna*-trough to cool them. Then he hammered out the two ends of the tail, put it on the anvil and beat the tail over and back to make a handle. The *paslor* – pin then inserted and the handle beaten on to it, and gradually the two side wings were also beaten into the handle. Now he made with the *tussa*-punch some deep indentations in the ‘waist’ of the axe between the handle and the blade. He made the axe blade downwards, and gently tapped it until the blade became broader. This process took half an hour to complete. An anvil was made for this by driving the welding hammer point downwards.
into the ground and beating on the broad end. At last the axe was tempered by being put very slowly into water. It took just two hours to make (Elwin, 1942: 200-201).

**Making of an arrowhead:** Previously-made a strip of iron firstly put in the fire. When it was ready, the smelter hammered out the tip of the iron-strip into a blade. Then with the sharp end of a chisel (*cheni*) he made indentations in the blade about an inch from the tip. After heating the iron twice, he was able to cut it right through. He bended the two wings over and hammered out the shaft of the arrow till it was long and thin. He cut from the rest of the strip a sufficient length, and hammered this out till it was round and straight. Then he hammered the two wings back and pushed them out a little till they form the two wings of the arrow in the familiar form. He made the point very sharp, and twirled it round on the anvil to see if it was true. The whole process had taken three-quarters of an hour (Elwin, 1942: 198-199).

**Nails:** The Agaria beated a small lump of *kuari loha* into a thin strip, concentrating on one end. When the end became thin enough and achieved a good point, he placed it across the *matorna*-anvil and, bending the end to the length of $\frac{3}{4}$ inch over the edge, broke it off (Elwin, 1942: 201).

**A ring:** A small lump of iron was beated out into a thin strip. The Agaria caught one end with the gad tongs, and with the straight-lip tongs twisted it round and round. Then he bent it into a ring round the handle of the rake (which was thinner than his paslor), carefully hammered the two ends together, and dipped it for a moment in water.

To temper and strengthen the iron, little pinches of *chirona mati* were thrown at it while it was in the fire. Sometimes it was dipped into a pile of cow-dung ash. If the iron was not amenable to working, the lemon and salt was rubbed on it and was also put in the water of the *kotna*-trough. A type of clay, locally called *mitti ka sohaga* was also used ‘to make the iron soft and help the bits to stick together’. Implements were always dipped in the *kotna* after they had been fully processed (Elwin, 1942: 201-202).

**A sandi,** three-pronged fork used by cow-herds was useful also for catching snakes. A ball of iron was beated into a bar broad at one end and tapering almost to a point, about eighteen inches long and half an inch thick. Then the Agaria broke off six inches of the thinner end and put it aside near the fire. He placed the broad end in the hollow of the swage-block and hammered a slight indentation in the middle, laid the *suja pawari* across it and beated it over, so that now there was a handle capable of taking a stick. Now, squatting the while on an old inverted bellows-frame, he hammered out a thin bit of iron to a point, bent it over so that it made a small hook, but then hammered the hook into the
original rod. He did the same for the other end, placed it in the hollow of the swage block and bent it over into a horseshoe, and then hammered the two points of the horseshoe close together. Now he placed this over the handle and very carefully placing them together put them in the fire and then hammered them so that there was now a prong with three points. He straightened the middle point with the tongs and pushed the two side points out a little with the file, and the sandi was made (Elwin, 1942: 202-203).

A razor: Out of a strip of thin iron, not more than an eighth of an inch thick, the Agaria broke off a small piece four inches long, and hammered it to a very fine edge. He cold-worked this for a long while, then heated it, dipped it for a moment into the tempering water, and then pushed the red-hot spike into a small handle of katai wood (Elwin, 1942: 203).

Other objects made in Agaria workshop:

Apart from the making of objects which have some religious significance such as rings of three kinds (Aitvar mundri i.e., ring of twisted iron, Surahi mundri, ordinary ring of plain iron, Chulmundri), Chhura, anklet of plain or twisted iron, objects of magicians etc. the most significant tools made by Agaria was ploughshares. In Mandla, Elwin documented three varieties of ploughshares: The olaha was the largest and heaviest, and was not used when the soil was very hard or muddy. The kurra and bataraha only differed from the olaha in being smaller and lighter. The first was used in the hot weather, the latter in the rains. The kurra weighted 9 chattaks to the olaha's 1 seer, 1 chattak, or almost exactly half. The share was fixed into its trough in the sole of the plough by a clamp, the jaru. Also used in ploughing was the painari which had an iron point called kaluha fixed in place by a small nail (arhai). This was used to drive the bullocks forward, to cut grass and thorn bushes, to break off earth.

The bakkhar was the paring harrow. It was fitted with a share (pans). It was used for rooting up stubble and breaking the clods of earth that the plough had turned up.

The kanta or spud was used to dig up roots or to make holes in the ground. It was a favourite implement of the Baiga, who used it for making holes in their bewar-clearings for sowing pulse.

The hassia, or ‘rude reaping hook’, was the sickle used to reap rice or kodon, to cut grass, to weed, to cut meat.

The gaend was a large iron ring which is fixed round the pole in the centre of the threshing floor, and to which the rope controlling the bullocks was attached. Besides, several kinds
of digging implements, such as bars, mattocks, adze etc, axes, chisels, different varieties of
arrowheads, knives etc. were made from iron (Elwin, 1942: 203-210).

The reference to the secondary smelting activities is also available in the works of Watson.
He has recorded the said activities at several localities of the then **Bengal Provinces**.

Besides the bellows, anvil, a few pairs of tongs, a few hammers and a cold chisel were the
important implements by using which the blacksmiths used to perform the refining
activities (Watson, 1907: 30). His work entirely carried on in a small shanty not more than
10 feet by 10 feet. The hearth (*hafar*) was generally on a level with the floor of the shanty.

At the back of it there was built a small wall of mud, generally from 6 inches to 1 foot high
and from 1 to 11 feet long. Through this wall or slightly sunk in the ground below it, an
iron pipe was placed for carrying the blast from the bellows. The bellows (*bhathi, bhanti*)
according to Watson were like magnified English kitchen-bellows. The upper board was
fixed whereas, the lower board was moved up and down by means of a wire, chain or rope
which was fixed to one end of a lever. The fulcrum of the lever was provided by a
horizontal bar either supported by two upright posts or by one post on the one side and the
wall of the shanty on the other. The other end of the lever was also placed almost over the
hearth and to it is attached a chain. The blacksmith squatting near the hearth and handling
the piece of iron in the fire with a pair of tongs (*saursi saneso*) with the one hand, with the
other pulled the chain and worked the bellows. When the piece of iron had been
sufficiently heated it was withdrawn by the tongs from the fire and hammered into shape at
the anvil (*nihay, lehai, lehi*). The hammers used were of various shapes and known as
*martol, hathauri* or *hathuli*.

Watson observed that the hearths hardly varied within the limits of the province (Watson,
1907: 29-30). Sometimes besides the wall of mud already mentioned at the back of the
hearth, there might also be built another small wall running parallel to this at the front.
These walls were built of loosely piled bricks (as at Burdwan) and were as much as 1 ½ or
2 feet high. The whole hearth might also be raised to a height of 1 or 2 feet and the raised
hearth might or might not be bounded by higher walls. In the small blacksmith’s shop, a
few loose bricks were piled on either side of the hearth. According to Watson, the neatest
arrangement which he had documented in Bengal was at Dubrajpur in the Birbhum district.
Here a considerable part of the floor of the smithy was raised to a height of 1 or 1 ½ feet,
the raised platform being made of mud, supported at the sides by stakes. The hearth was
built on this platform and was surrounded by four mud walls rising as a furnace 2 ½ or 3
feet high with a base 18 inches square. The front wall had a small hole in it, whilst the side
wall was almost cut away by an arched opening through which the work was manipulated in the fire. This rectangular structure, according to him, was furnished at the top with an arrangement which could best be likened to the upper part of a large earthenware jala. “Alongside of the hearth on the platform was a seat for the smith, several anvils and several hemispherical bowls sunk in the platform containing water for quenching and tempering, and all arranged on the platform within the most convenient reach of the smith. This was in marked contrast to the ordinary smithy which is grimy, littered with all kinds of odds and ends, and apparently with no order or arrangement whatever”. (Watson, 1907: 30).

The smith for making bullock wagons needed a little more space and had generally a kind of yard adjoining the smithy. He also required a space for storing a considerable quantity of iron bar for the tyres of the wheels and he needed a circular pit for tying the wheels. This was done in the usual way by heating the tyre until it fitted easily on to the wheel and then quenching it in position (Watson, 1907: 30).

The preparation of knives, scissors and razors was rather a specialized branch of the blacksmith's works. Watson preferred to call the blacksmith employed in this work a cutler (Watson, 1907: 30). He recorded that such works required the usual hearth, bellows, anvils, hammers, tongs and chisels and in addition water for quenching blades (pan, pahin-halno), vice (bice, paksawasi), file (ret, ooga), drills (bhumar), grindstone and polishing wheels (san). The blacksmiths used to store the water for quenching or tempering the blades in a trough sunk in the floor of the shop or in any handy vessel, such as an old tin canister. In the Darjeeling district a vessel for holding the water was made of bamboo. Some of the smiths recognized the delicacy of the operation of tempering. Watson believed that the best Darjeeling kukris were made of that steel which excelled in quality any other steel goods produced in Bengal. He said that “…kami recognises something of the delicacy of his operations. For the best work he uses only charcoal as fuel for his hearth and he considers the tempering of his blades an operation requiring care and skill”. (Watson, 1907: 30). The grindstones and polishing wheels were the other significant tools of the cutler's shop. They were made of sand and lakh or fine grit and lakh, and as generally seen were discs about half an inch thick and about 1 foot or 1 ½ feet in diameter mounted on a wooden axle or spindle 3 to 4 inches in diameter. The spindle was mounted horizontally in a shallow pit and a deeper pit is cut to accommodate the disc. The disc was made to revolve by a cord passing over the spindle.
He also cited an interesting account of such secondary smelting work from the then district report of Burdwan and according to him this work was carried out in probably the best cutlery shop of Bengal:

“The blade of a knife, or scissors, is first of all fashioned by the blacksmith. His implements are an anvil, bellows, a hammer, chisel, and a pair of pincers. He heats the iron or steel in the furnace and beats it to the required shape and size on the anvil. A skilful blacksmith can thus fashion 72 knives/blades during the course of the day, two inches to three inches in length, by a quarter of an inch in breadth. The blacksmith hands the rough blades to the grinders and polishers.

There are two kinds of hones for grinding and polishing and sharpening blades. The first is of ordinary sand found on the banks of rivers and is used for rough work. The second is of very fine grit, obtained by crushing what appears to be very coarse grained sandstone, called locally ‘kruich pathar’. As all the specimens were grimy and discoloured, I was unable to identify them satisfactorily. The sand is mixed with lakh, the proportion being one seer of sand to a quarter of a seer of lakh. The ingredients are placed over fire and mixed. The artisan then shapes his wheel on a board with his hands. The solid wheel is about 15 inches in diameter, and its polishing edge is about a quarter of inch in breadth. The polishing wheel of stone grit is made in practically the same way. The ‘kruich pathar’ is first of all crushed very fine; it is then carefully strained through a cloth, and only the finest grit is mixed with the lakh, in the proportions already indicated. The wheels are then fixed to a wooden pole about 12 inches in girth and about 2 feet in length. This pole passes through the centre of the wheel, and when force is applied, revolves with the pole. A hole is dug in the floor of the workshop, and the pole and wheel are fixed horizontally so as to allow them to revolve easily. The wheel is of course vertical to the pole. The driving power is applied by another wheel 3 or 4 feet in diameter fixed about 10 feet away. A belt of thin rope passes over the indented rim of the driving wheel and round the pole of the polishing wheel. The driving wheel is worked, as a rule, after the manner of a tread mill, and enables the operator to revolve the polishing wheel with considerable force and rapidity. The cutler squats on his hams over the revolving polishing wheel. He takes the knife or scissor blade in both hands and applies it to the revolving edge of the polishing and sharpening wheel, dipping the blade in cold water, whenever it becomes too hot to hold. The skilled artisan does the preliminary polishing and grinding on the sand wheel. He then makes over the blade to a confere who proceeds to apply it to the ‘kruich pathar’ polishing and sharpening wheel. When the blade is sufficiently sharp and polished, it is handed over to another artisan, who fixes it in a vice, drills the necessary holes, shapes the brass, horn, or ivory for the handle, and fixes the blade thereto. The brass is in thin sheets, and is readily cut with a pair of steel shears made in the workshop. The horn, or ivory, is cut with a saw made locally or imported. It is shaped with a file and fixed to the blade. The horn or ivory is also highly polished by rubbing it in a mixture of brick dust, charcoal and oil. Finally, the knife is again polished on the ‘kruich pathar’ hone. Inaccuracies of the handle and springs at the
back are also ground away, and the article is now bright and beautiful, and ready for sale. In the case of a highly skilled artisan the polish is mirror-like, and equal to that of the imported article; the edge is also equally keen and fine. The operation in the case of a scissor blade is somewhat different. The blade and thumb-ring are polished and rounded on the revolving hones. The blade is then fixed in a vice, and the operator proceeds to polish the ring, and the lower parts, with an instrument called a ‘maskolla’. This is a somewhat flat blade of steel rounded at the edges and point and fixed to a wooden handle.

It is made locally. This instrument is rubbed forcibly against and all round the ring and lower parts of the scissor. It gives the finished article a very high degree of polish, making it smooth and easy to the fingers.

The holes for screws and nails are drilled with an instrument called a ‘bhumar’. This is a steel drill made in the workshop; it is 2 or 3 inches in length and is fixed to a round wooden handle about 8 or 10 inches in length. It is a pointed instrument, and when worked with a bow rapidly bores its way through brass, horn, ivory, iron and steel.

In the case of the razor blade the process is identical. The blacksmith gives it birth on the anvil; it is then passed over to the polisher and the driller. But very few artizans make razors, and only one or two cutlers lay claim to be able to fashion razor blades of superfine quality. The brittle nature of the steel, and the delicacy of the blades, demand an exquisite judgment and gentleness of touch on the revolving hone. A good razor blade has also to be manipulated with great patience; the skilled artisan working from morning till evening cannot turn out more than two such blades a day: and his profit is not more than 4 annas per rupee….

It may be observed that horn and ivory are scraped with an instrument called a rendar. This is a four-cornered piece of steel, 3 inches in height, fixed to a wooden handle. The final polishing is done with brick-dust, charcoal and oil.

The revolving hones last a month and-a-half in the case of the sand wheel and 3 months in the case of the ‘kruich pathar’ wheel. In large workshops half-a-dozen such wheels may be seen spinning, so that the blacksmith is frequently under the necessity of making fresh ones.

"Dies for stamping the artisan's name on the heel of the blade are made of steel locally…” (Watson, 1907: 30-32).

Watson also gave the details of gun powder manufacturing at Monghyr which have little scope to be included in the present study. However, his documentation on the making of iron vessel is worth noting.

This vessel was made up of several zone-like strips of sheet-iron riveted together. The sheet-iron was marked out by a compass and cut out by a chisel, and the various zones were hammered until they had assumed their proper curvature by means of a wooden mallet on an anvil with a concave surface. The various zones were put together temporarily
and the position of the rivets decided upon and marked. The various pieces were then punched separately and riveted together in the cold by small rivets made from a thin rod of soft iron. The edges of the various segments were well hammered before they were put together, and after riveting, the line of junction of two pieces was very vigorously hammered to make a tight joint. For riveting frequent use was made of the iron clubs. These were firmly fixed in the floor of the shop. “The ghara, even when nearly complete, can be put over one of these clubs, the head of which formed a hard smooth round surface against which the rivet may be driven home. An awkward rivet just in the last stages may be some-times driven home by the small club (12) or (13) held in the hand inside the ghara whilst the outside is pressed against the concave anvil. By way of ornament circles are drawn round the ghara by a compass with a chisel-like point (11). The neck is put on last and consists of two sheet-iron collars and a forged iron ring”. (Watson, 1907: 34).

Besides, he also referred to several types of objects, which were indigenously made. Of these, mention may be made of agricultural implements, cooking utensils and articles of domestic use, tools and other articles used in various handicrafts and weapons.

**Ore Selection/ Mining:** A brief discussion on the nature of ore selection and mining by the indigenous smelters should be incorporated here to have a comprehensive picture on the entire process of the production of iron objects. There is no doubt that iron nodules were handpicked from the surface by them and in most of the cases, low grade ores of inferior quality had been selected by them (La Touche, 1918: 233). Thus the deposits considered to be of little significance by the present day geologists were greatly favoured by the indigenous smelters. This is due to a variety of reasons, such as easy accessibility or close geographical proximity. The ores were hand-picked in form of nodules from exposed surfaces near nullahs or rain gullies. Shallow digging was also done. In areas where iron was present in form of veins in the parent rock, it was retrieved by fire setting and chiseling out the desired minerals.

The Agarias (Elwin, 1942: 173-177) recognized the occurrence of ore by the colour of the soil. They also found the occurrence in a pit. The pits are small, generally not deeper than the height of a man. After getting into the pit, the Agaria began to dig with his mattock. A basket is handed down to him and he filled it with earth and stones and heaved it up to the others. They emptied it and sorted the contents. After cleaning it was carefully packed in the dadu and tukna basket. Regarding the selection of ores, Elwin pointed out that “In many cases, the ore is a partially de-hydrated limonite, but not quite a true haematite. It is a remarkable fact that massive steel-grey haematite which occurs in immense deposits in
some places is not used although limonitic pockets in them might have been scraped out and this inferior material smelted” (Elwin, 1942: 176)

Jackson in his report mentions about the use of argillaceous iron ore in the smelting activities at Birbhum. It was in fact an iron-ore matrix with brown haematite and small crystalline nodules of magnetite iron ore (Jackson, 1845: 754-756). In Birbhum, Torrens documented that small shafts were sunk throughout the ground for extracting iron ore.

Ore extraction process at Pokharia, about 7 ½ miles north-west of Nunihat was also documented by Buchanan during his survey in the district of Bhagalpur in 1810-11. He was informed that the Kols used to discover the ore by observing some of it on the surface, and then used to follow the veins or beds which seemed to be nearly horizontal. The veins were from one to five cubits thick, and never seemed to extend far in one direction. It had never been known to extend more than a bigha in length. They were often interrupted by water and below the ore they usually found masses of rotten rocks, mostly quartzose, and clay. The veins were from 1 to 1 ½ cubits wide, and were crooked, but often sent off branches. It was always found under clay generally red or yellow in colour and, never on the hills nor very near rocks. *Mogormati* or white schistose mica in decay was also found in the iron mines, which were treated as one of signifiers of iron mines. Buchanan recorded that ores were mainly of two types: *Asula* (meaning ‘original’, pure) *Bel* in large concretions and *Dusra* (second) *Bel*, a blackish granular matter containing much clay. The *Asula* is most commonly intermixed with stiff clay and *Mogormati*. The *Dusra* is mixed with stiff clay alone. Buchanan observed that the men used to take out the ore and make the charcoal whereas the women used to prepare the ore. The *Asula* was much easier to clean (Buchanan, 1930: 32-33).

In the Dumka region, Buchanan saw the occurrence of iron mines which had been opened at the south-eastern side of the cultivated lands. He observed that, “the people have there evidently dug among the fragments of quartz, and say, that it was without success; but the mine is immediately adjacent under the soil of yellow clay, which there, is not above two feet thick. In this, for about a space of forty feet square, they have made small excavations, and taken out the ore to the depth of about a cubit. On the upper surface it forms angular nodules from the size of the first to that of the head, which are composed together, and the interstices filled with soil. This renders it easily wrought and pieces are taken out with the miserable stick pointed with iron used as a pickaxe or spade. Below this depth the mine becomes more solid, and the natives neglect it as too expensive”. (Buchanan, 1930: 45). The extension of the veins, both vertically and horizontally was difficult to ascertain. After
extracting the ore, it was washed to separate the clay. It is then powdered by the pickaxes and a stick, and then it was winnowed to separate the earthy matter.

Mallet recorded that the Kamis (Nepali iron workers of Darjeeling) opted for magnetite, the black coloured and hard to smelt ore because it was more suitable for production of sharp-edged weapons like khukri (dagger) or ban (arrow) (Mallet, 1875: 67).

However, there is no doubt that the indigenous smelters used to meticulously prepare the ore. The ore was handpicked in substantial amounts. After extracting, it was washed, crushed into pea-sized pieces, winnowed, sifted and finally roasted for removal of further impurities (La Touche, 1918: 233).

**Important sites:**

**Birbhum district:**

By following the reports of the British administrators, survey was conducted in the northwestern parts of the district.

Recent survey at the site Ballia- Narayanpur, on the right bank of the river Brahmani, led to the discovery of iron working evidence in form of the remains of furnaces, slags, brick bats and burnt earth. The extant furnace is about 250 cm in height and 130 cm in breadth. The thickness of the wall is about 36 cm. Here the furnaces are found exposed in a linear form along the river bank. Slags were seen scattered all around the site.

At the site of Deocha, the iron smelting furnaces have been found in a cluster having an area of 1 sq. km. This site lies on the right bank of Dwarka. At least 20 units (each unit in form of mound has broken pieces of furnace, burnt earth, brick bats, iron slags) have been documented during the present survey at the site.

Altogether 10 units containing large chunks of slags have been recorded at the site of Ganpur (about 3 km from Sibpahari). Burnt bricks have also been recorded with the coatings of smelted materials.

Slags in considerable amount have also been found from the mound of Jatadharitala at the site of Damra.

Another cluster of sites was found in the southern parts of the district along the Illambazar road.

**Jashpur** is located about 1km east of Dubrajpur. The site is known for its painted BRW, red ware and microlithic findings recorded during early sixties (IAR, 1962-63: 43). Chakrabarti and his associates (Chakrabarti, Sengupta, Chattopadhyay and Lahiri, 1993: 126) have found red slipped ware, pieces of greenish stone bowl, microlithic flakes, iron slags. That the area was extensively used for pre-industrial smelting activity is evident.
Dabarpara at the site of Krishna Nagar has also the remains of pre-industrial iron smelting activities. Over an area of 300 x 300 sq m, 10 such units (each unit in form of mound has broken pieces of furnace, burnt earth, brick bat, iron slags) have been recorded with iron slags, bricks with the coatings of metal wastes and burnt bricks. The ruins mainly portray a continuous practice of iron working at the site.

Lohagram of Pochiara is a nearby locality which also has the remains of iron smelting. A large mound of the site has yielded substantial number of iron slags and burnt bricks, probably the remains of furnace.

By following anthropological approach, Hitesranjan Sanyal (based on administrators’ accounts) has identified two types of iron manufacture in Birbhum, I) the first type of manufacture was practiced in the western part of Birbhum by the tribals who has been identified as Santhals by Torrens whereas, Ball identified them as a local branch of Munda-Kols. In the first type, the furnaces were small. In search of ores and timber, this metal working group used to migrate from one area to other. As a result, the furnaces were not used for long periods. II) The second type of manufacturing activity was carried out by the ‘Bengali-speaking people in the north-western part of the district’. Here, ore and timber for the preparation of charcoal fuel were easily obtainable. Technically, such enterprise is not superior to the earlier one though it functioned on a much large scale (Sanyal, 1968:101-108). However, Gupta assumes that the available reports of the British administrators do not substantially suggest such patterns of geographical distribution of the workgroups as suggested by Sanyal. According to Gupta during the pre-British/ British period, there were three stages in the process of manufacture of iron objects (Gupta, 1980:94-106; 1984, 203-204; Sarkar, 1997: 142). In the first stage, some semi-aboriginal groups/low caste groups used to dig the ore (Bhattacharyya, 1972: 136). They brought it to the Salois or Lohars (blacksmiths). The Salois at the Kotsal extracted iron in its raw state by smelting and this pig iron was then passed on to the Dukisal where it was again smelted and pure iron was extracted. For reducing the ore into pig iron these Salois used to employ workmen, known as Shasa. It is worth mentioning that those who reduced the ore into pig iron were invariably Muslims and the refiners were essentially Hindus.

Profusion of slags in the form of a mound ranging in height between 1m and 2m have also been reported from the area presently in the Jhargram subdivision of West Midnapur. Here, broken furnaces (mostly cylindrical in shape), broken tuyers and slags are found.
scattered in plenty at the sites of Laljal, Jamtholgara, Joram, Dhuliapur, Dangardihi, Benghuta, Akhuldoba, Agnibil etc. These areas in the fringes of the Chhotanagpur plateau with the access of raw materials, plentiful availability of water and demand from the plains must have played crucial roles in iron smelting of eastern India.

The site of Maliara (near Pakhanna) in the Bankura district has yielded the remains of pre-industrial iron smelting activities in form of broken furnaces, iron slags, ashy layers etc which must have been operated as an organized workshop in the concerned period.

The area in and around Susunia has also yielded substantial evidence of pre-industrial iron smelting activities. Explorations in and around the sites like Suabasa, Pachasimulia, Siulibana, Bagdiha, Jamthol, Paharbeda, Kamarshol, Jhatipahari etc. revealed broken furnaces, slags, broken tuyers etc.

Churulia near Asansol in the Burdwan district, on the bank of the river Ajay, is another pre-industrial iron smelting site. However, the site has a late-medieval fort complex and other earlier structures which are said to have been constructed by a local chief named Raja Narottam. The site is notable for the occurrence of a large mound with a good concentration of the metal wastes. In all probability, this place was utilized for iron smelting as confirmed by the occurrence of slags, tuyers, remains of furnaces etc.

Chandan Katuriya in the Bhagalpur district has yielded the evidence of pre-industrial iron smelting (Hunter, 1877/ 1976 (reprint) b): 241). Evidence in form slags and burnt bricks has been documented along the bank of the Chandan river. There is no doubt that the said activities must have been performed along the river bank. Shikaripara, Jarmundi and Basukinath in the district of Dumka have ample evidence of such smelting activities (Mishra, 2003: 103). The centres had been working on haematite and limonite. Mahesh Mundi and Barki Saraiya in the Giridih district have also bore the traces of such smelting activities. Survey at the site of Mahesh Mundi has exposed the remains of atleast two furnaces. Probably haematite was used as raw materials (Mishra, 2003: 103). In the Hazaribagh district, Chauparan and Bermo are two important centres of pre-industrial iron smelting. The sites are found scattered with the burnt bricks probably of broken furnaces and considerable number of iron slags. Besides, Hunter in 1877 documented large scale iron smelting activities from the sites of Kharakdiha and Ramgarh. He also stated that in 1863, Tandawa, 10 miles north of the Damodar in the Pargana Karanpura, was the chief seat of iron smelting activities. As many as twenty-three Bhatis or foundries were at work during six months (Hunter, 1877/ 1976 (reprint) a: 158). Mallet in 1890 reported that furnaces using the ironstone shale groups were numerous in the vicinity of the Bokaro and
Karapura coalfield (in Watt, 1890: 512). Besides, haematite of the Barakar group was also profusely used by the smelters. The major iron producing centres of the Palamau district are Hussainbad and Deori Kalan (Mishra, 2003: 103). In Lohardaga district, a variety of iron ore occurs, viz. magnetite, haematite, limonite and lateritic ores. In Sehna block of the district, evidence of pre-industrial iron smelting has recently been documented. Vemo, Basia and Sindega are three important places in the district of Gumla from where evidence of pre-industrial iron smelting has been detected. Magnetite occurred in nearby areas were used for the said activities (Mishra, 2003: 104). In the Ranchi district, Churi, Bundu, Topra etc. has yielded such evidence of iron smelting. In all probability, lateritic ores were used for the said purpose (Mishra, 2003: 104). As per the record of Ball in 1881, ores extracted by the indigenous smelters of the East Singhbhum district were ferruginous schists and laterites (Ball, 1881b: 375). The significant smelting centres were Murhu, Patamada, Bagbera and Sarjamda etc. However, Chirla, Manjhari etc. were similar important centres of the West Singhbhum district.

In Orissa, preindustrial iron smelting sites have been recorded throughout its length and breadth. In Jajpur district, the most significant sites are Chandikhole and Nadangipenth (Satapathy, 2011: 225-231). Chandikhole is situated on the flat laterite bearing areas on the western fringe of deltaic plains. The site is found scattered with slags, burnt bricks, broken tuyers and brick nodules etc. Nadangipenth, situated about 10 km from Daitari hills has also yielded such evidence. In Mayurbhanj district, important pre-industrial iron smelting sites are Begdega, Badampahar and Auski (Mohanta, Basa, Chattopadhyay and Das, 2003: 81-90). The sites have yielded the remains of charcoal making furnaces, iron smelting furnaces, broken tuyers, slags, ores, ingots and anvils. The study at the site of Badampahar also revealed that, for the preparation of charcoal, the indigenous iron smelters used a specific type of dome shaped furnace. Six such furnaces were recorded along with three specimens of iron smelting furnaces at the site. The study also unfolded the fact that the iron smelters of the region used to make small furnaces by locally available clay and grit. They used three to five vertical layers for the furnace wall. The maximum diameter of the furnace at its outer side is 0.44 m and 0.18 m at its inner side. The thickness of the furnace wall varies from 0.12 m to 0.19 m. Besides the above sites, mention may also be made of Kulgi, Balitangri, Baghia, Bijatala, Tirilipi, Bhatchatra, Padhia, Kendumundi I, Kendumundi II, Dudhibari, Rengalbera, Telkoi etc. Chemical and mineralogical studies carried out on the slag samples indicate that the specimen is feebly magnetic, dense, and porous and the surface suggests that the slag was uniformly well fused. Singida river valley (Satapathy, 2011: 225-231) of Angul district has proved
to be the most potential area for pre-industrial smelting. The region has so far yielded at least 12 sites having the remains of pre-industrial smelting. Of these, the Asurbahal site alone has yielded the remains of 30 such furnaces. During survey iron ore, slags, burnt clay, broken furnaces, fragments of tuyers etc have been documented from the site. Other significant sites from the region include Belparha, Durgapur, Kandha Sahi, Tangrisahi, Kisinda, Kuskila, Nuapada, Pandukata, Pitachari, Putagaria, Srirampur, Sunakhani etc. which have also yielded the remains of pre-industrial iron smelting. Besides, field survey in the Karandi river valley in the districts of Angul and Sambalpur has also resulted in the recording of pre-industrial iron smelting evidence from Guapada 2 and Betgarh locality. The evidences of pre-industrial smelting activities have also been documented from Dangala and Gothapada in the Gopalpur area of Nayagarh district. Apart from the above, iron slags and traces of iron smelting activities were also reported from the Tel river valley (Mishra, 2008: 10-30) in the Kalahandi and Bolangir districts.

Observation:

In all probability, ancient iron smelting process was thus fulfilled by the following criteria: i) easy availability of water, ii) access to the raw material bearing zones. iii) Charcoal for fuel besides iv) having proper technical know-how to make furnace, tuyere and bellows.

Evolution of iron smelting activities over generations is well documented in European history. There the primitive furnaces were constructed either against a hillock or as bowl in the ground with the help of clay and stones. The sizes of the primitive furnaces were very small (30-60 cm in diameter and nearly 50-60 cm deep). The technology of iron production during such early stage was known as bloomery process. Later it was felt that the time of contact of carbon monoxide with the ore was not sufficient in bloomery process, which led to poor yield of the bloom. Thus, construction of shaft over bowl furnaces which addressed this problem was made.

Realizing that proper aeration is the main factor for efficient reduction of iron ore into metallic iron the furnaces were upgraded by force air blast, generated by the use of crude bellows, made from animal hides. This particular design of the furnaces continued till 13th century C E.

Subsequently, new smelting unit (known as Catalan Forge, derived its name from the province of Catalonia in the north of Spain, where probably it was first introduced) was developed. The main purpose was to increase the production rate and to reduce the fuel consumption. In this unit, the air bellow was replaced by falling water device known as Trompe (2 nos.) to force air blast into the furnace.
As the demand for iron grew, the size of Catalan furnace progressively increased and resulted into stuckofen (the term was used in Germany). This was considered to be progenitor of the Blast Furnace. The furnace was 3.0-4.0 m in height made of clay and stone and having round or a rectangular cross section. Blast was supplied through two numbers of tuyers by water driven bellows and a false door was provided for extraction of metals. Though evolutionary development of iron smelting furnaces have taken place in this order, as above stated, simultaneous use of Catalan Furnace and Stuckofen has been reported from various parts of Europe till the 18th century CE (please see Percy: 1864: 278-347).

However, reconstructing such history in Indian context is rather difficult due to dearth of sufficient evidence. The nature of primary iron extraction/smelting units (primary iron extraction/smelting unit refers to the furnaces, bellows and the other smelting apparatus involved in the process of reduction of iron ore into iron ingots) have definitely evolved in India though it is difficult to trace the course of such evolution based on available data. However, it is attested by a few British administrative records that such development was confined to some particular areas. For example the use of Catalan forge was in vogue in Central India (Tendukera) during 17th / 18th century (Percy, 1864: 255-259). In sharp contrast to the above, the process was very much in stagnation for generations in some parts of the country. Therefore the evidences point towards simultaneous use of these different categories of smelting units in different parts of India rather than one type of furnace giving rise to the next one. The continuation of the use of wooden bellows at least till the British period is a significant feature of iron smelting activity of eastern India as well as some other parts. The use of bowl furnace and shaft furnace are also simultaneous as mentioned earlier (in the Orissan context). This Dichotomy was guided by regional factors, like nature of raw materials, clay etc., conventional / unconventional perception of the smelters, local demand and above all the nature of royal patronage.

The primary smelting/extraction methods of iron production perhaps continued unmodified over the ages as evidenced by the chemical composition of slag found from the both stratified layers of archaeological sites of the Iron Age and subsequent phases as well as those yielded from preindustrial iron smelting sites datable to the pre-British period. Chemical analysis of the slag found from the site of Senuwar (datable to 700-300 BCE) suggests the loss of iron in slags, probably due to inefficient reduction of iron. The slag contains 47% FeO and 24.36 % Fe₂O₃ (Chattopadhyay and Singh 1994-95: 61-63; Chattopadhyay 2004: 100). The picture is similar at the site of Khairadih as its two slag specimens found from the NBPW cultural phase shows the presence of 40.60 % FeO and
15.40 % $\text{Fe}_2\text{O}_3$ and 44.60% $\text{FeO}$ and 24.40 % $\text{Fe}_2\text{O}_3$ respectively (Chattopadhyay 2004: 93). The slag specimens from three successive cultural phases viz. Chalcolithic, Iron Age and Early Historical phases of the site of Mangalkote have 48.59%, 53.67% and 56.39% $\text{FeO}$ respectively (Datta, 1998: 38). 28.53% $\text{FeO}$ and 43.35 % $\text{Fe}_2\text{O}_3$ are present in the stratified slag specimen from Dhuliapur (De and Chattopadhyay, 1989-90: 116). In 1963 M.K. Ghosh, National Metallurgical Laboratory, Jamshedpur studied the process of traditional iron workings still practiced in the villages of Kamarjoda (Bihar), Chinglebecha and Jiragora in Orissa. During his study, he also analyzed the chemical composition of ore used in these smelting operations as well as the resultant slag and ingots. Quite interestingly, the slags from the site of Jiragora contains 46% of total Fe, whereas, those from Kamarjoda contains 16% Fe, 55.34% $\text{FeO}$ and 1.14 % $\text{Fe}_2\text{O}_3$. Slag that flowed out from the furnaces of the site of Chinglebecha contains 1% metallic Fe, 58.43 % of $\text{FeO}$ and 8.72 % of $\text{Fe}_2\text{O}_3$ while those remained in the furnace has 2.10% metallic Fe, 12.27 % $\text{FeO}$ and 1.86 % $\text{Fe}_2\text{O}_3$ (Ghosh, 1964: 132-135) (see Table 26). Interestingly, the resultant slags recorded (by Watson in 1907) during the course of indigenous smelting activities at Birbhum have been analysed by Mc Namara. He found that these two samples had nearly 55.45 % and 54.00 % of iron. While describing the nature of iron ingot found from this smelting activities, Watson reported that “As to the quality of the iron produced, the mass of iron on being cut with a cold chisel was seen to consist of a very considerable crust of brittle material, apparently almost entirely slag with an exceedingly slender mesh-work of iron, and an inner portion of tough, malleable iron” (Watson 1907: 24). This probably indicates that much of the iron was lost in the slag due to unsuccessful reduction of iron at Birbhum in spite of producing at least 2380 tons of iron per annum. Therefore, the picture of inefficient primary smelting is also replicable during the pre-British/ British period. The labour intensive iron smelting process based on same old furnaces operated through foot bellows continued without marked changes.

However, it is beyond any doubt that secondary refining is the crucial factor for the final production of finished objects which was done by repeated heating and forging. It is well attested by the evidence from different sites, that since the 7th-6th century BCE onwards this refining technology started achieving its excellence. Since the time, carburization was done by repeated heating and forging. Subsequent knowledge of quenching, tempering and steeling was also attained by the metal smiths (Tripathi 2008). It is well tested that finished objects from the NBPW period onwards from different sites contains at least 95- 99% pure iron. The nature of the concerned artefacts found from different stratified contexts of sites suggests their utility in multifarious activities predominantly related to warfare/plundering.
several non-farming activities viz. fishing, hunting, fowling, wood/timber working and other types of craft works besides some farming tools. The analysis of these implements not only shows their significant roles in a particular settlement but also the involvement of different metallurgical skill to obtain particular metallic properties of these implements (some are hard, some brittle, some are not so hard) effective for certain jobs. One of the marvels of Indian metallurgy i.e., the Delhi Iron Pillar with its 6069 kg weight still maintains its anticorrosive property (Balasubramaniam, 2001). The evidence of iron tools that extensively used during the post-Gupta cultural period, especially in the monumental architectures such as monasteries and temples, fort, fortifications besides other secular and religious structural activities suggests the continuity of iron working traditions and large scale consumption of the same. The vast repertoire of such tools found from the monastic sites of Orissa substantiates the above statement. Other colossal structures like the iron pillars at Dhar (Smith, 1898: 143-146), Mount Abu (Neogi, 1914) and Kodachadri (Anantharaman, 1999: 1428-1430) and iron beams of Konark temple, belonging to relatively later centuries are the metallurgical masterpieces and bear testimony to a well-developed and organized iron industry. Literary data also attests to the same. For example, one of the Pali texts, Udanapali (Khuddhaka Nikaya) makes a clear cut reference to forging a bloom with an iron hammer- ayoghana hatasseva jalato jatavedasa (cited in Tripathi, 2008). Quenching has been referred to in Samyuktanikaya. The iron plough here that has been heated for the whole day makes a sound as soon as it is dipped in water (Kashyapa, 1959). Milinda Panho also refers to quenching of an iron pierce (ayosulani) into a stream. Varahamihira in his Khadgalakshanam assignable to 550 CE gives an elaborate description of carburization of sword blades. “There are suggestions of plunging the red hot sword into the solution of plantain ashes and whey, and keeping it for twenty-four hours followed by grinding the blade on lathe. It could also be quenched by thrusting it directly into the trunk of a plantain tree and allowing it to cool overnight. This would first convert the austenite into martensite and transform it into tempered martensite due to reheating of the sharp edge of the blade by the flow of the heat from the thick back edge.” (Prakash, 2002: 29) Agni Purana (CCXLV. 21) mentions about the sword making centres of which Anga and Vanga must belonged to the present study area. Besides others, Rasa Ratna Samuchchaya, a tenth-twelfth century text on alchemy categorically gives the description of the saliency of Indian iron (Biswas, 1987: 29-46). Three basic types of iron with different sub-types (according to their properties and nature) have been precisely classified here. Kanta loha is a soft wrought iron with five sub varieties of different magnetic properties. Munda loha, probably named after the metal smith tribes of central India with its three sub-varieties
mridu, (soft which is drutadava ‘melting and softening quickly’ and could have been a low melting point grey cast iron), Kuntha (it expanded with great difficulty on hammering, could be a mottled grey iron) and the Kadara (it ‘breaks on hammering’ could be white cast iron) forms the major variety. Tiksna loha with its six sub-varieties was carburized iron that could be hypo-eutectoid (less than 0.83 percent carbon) or hyper-eutectoid (more than 0.83 percent carbon) steel. In the medieval period Ain-e-Akbari provides an exhaustive list of weapons, cannons and guns, made of iron in the Moghul arsenal (Moreland, 1923). All these data substantially corroborate the fact that the metallurgical skills attained its zenith gradually with the growing demands of iron tools and weapons. Unfortunately, this growing need was met with by introducing larger sizes of furnaces with larger bellows at some places in the Moghul Empire though such introduction hardly changed the basic design of the existing furnace.

However, it will be unwise if we ignore to study the presence of other constituents of a particular slag/ finished objects apart from metallic iron or iron oxides as they are the signifier to trace the nature of ore as well as fuel used in those smelting activities. These will help in locating the probable sources of raw materials as well as the primary smelting centres (as it is generally believed that in some cases iron ingots were produced in primary smelting centres, situated in close proximity to the raw material bearing zones and later on transferred to the secondary refining centres). In the present chapter which is preliminary in nature/deliberation, attention has been given to understand the nature of already survived living traditions (at least till the pre-British period) which had its root in the remote past and served as a backbone to the Indian societies in general and eastern India in particular.