Historicity Research Journal
ISSN : 2393-8900

Impact Factor : 1.4152 (UIF)
Volume - 3 | Issue - 7 | March – 2017

# IRON METALLURGY IN THE AGE OF BUDDHA
## *(Archaeo-literary evidences)*

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## ABSTRACT :

History of metallurgy in the Indian subcontinent began prior to the 3rd millennium BC and continued well into the British Raj. In the recent excavations in Middle Ganges Valley show iron working in India may have begun as early as 1800 BC. Archaeological sites in India, such as Malhar, Dadupur, Raja NalaKaTila and Lahuradewa in the state of Uttar Pradesh show iron implements in the period between 1800 BC-1200 BC.Sahi concluded that by the early 13th century BC, iron smelting was definitely practiced on a bigger scale in India, suggesting that the date the technology's early period may well be placed as early as the 16th century BC. Some of the early iron objects found in India are dated to 1400 BC by employing the method of radio carbon dating. Spikes, knives, arrow heads, bowls, spoons saucepans, axes, chisels, tongs, door fittings etc. ranging from 600 BC—300 BC have been discovered from several archaeological sites.

Iron technology has grown steadily in ancient India and Indian iron product was in great demand. The testimony of the craftsmanship and antiquity of Indian iron and steel industry is visible from the iron objects belonging to the age of Buddha. In the present paper an attempt has been made to reconstruct the iron technology at the age of Buddha on the basis of the archaeo-literary evidences.

**KEYWORDS :** literature, iron technology, iron objects, Buddha, north India, archaeology.

## INTRODUCTION :

The earliest smelted piece of iron belongs to c.5000 BC and has been reported at Samara in modern Northern Iraq. It is 4.30 cm long. Evidence of smelted iron in such an early context is indeed a remarkable discovery. It is followed by the findings of three balls of iron from Tape Sialk in Iran. Which has been discovered from a habitation level of period II dated 4600-4100 B.C(Tripathi,2001:8). Here, in India it is generally believed that the use of iron started first by the people of PGW culture in c.1200-1100 BC. But this theory is no longer tenable today. There is definite evidence of iron from pre-PGW level at Noh in Rajasthan. Sahi(2012:366), traces the beginning of iron smelting in India on the basis of the evidence from Noh in early sixteenth century BC. In other regions, iron is reported from the chalcolithic phase of central India, Bengal, Bihar, southern U.P. and with the megaliths in parts of south India(Tripathi:65).

Iron working as practiced during the period under discussion is not easy to reconstruct. It is even more difficult due to the fact that it requires breaking of furnaces at least partially after acquiring the iron( Tripathi: 132).The fragmentary remains that come to light during the excavation are not very helpful. However, Banerjee(1965: 186-187) on the basis of the archaeological remains identifies three types of furnaces.

The first, commonly found in South India, was conical in shape and circular in plan. They were 2-4 ft. (61-122 cm.) tall, about 10-15 inches (25-38 cm.) across at the base and 6-10 inches (15-25 cm.) at the top. They had two openings at the bottom.

The furnaces of second type, reported mostly from M.P. were cylindrical in shape, which were about, 2 ft. 6 inches (76-20 cm.) tall and 15 to 18 inches (34-45 cm.) in diameter.

The furnaces of third type were tallest among all. They were 8-10 ft. (244-304 cm.) in height and square in plan of about 1 ft. 6 inches (45-75 cm.) across with high-perforated platform at the base. Its front wall was damaged after every complex of operations and re-built again. They were mostly reported from U.P.

In all the three cases, bellows of the skin of goat or sheep were used to ensure the blast of air into furnaces.

In India the earliest furnace used for iron smelting is reported at Atranjikhera(R.C.Gaur,1983: 127) belongs to c.1000 B.C. the pear-shaped furnace appeared here is in some extent similar to Ujjain. At Noh and Jodhpur, furnaces with side hole recovered in which the nozzle or bellows might have been inserted(Tripathi: 144). Two furnaces have been found at Suneri (R.S.Sharma, 1983:59) in district Jhunjhunu of Rajasthan. These are of open type similar to the Ujjain furnaces(N.R.Banerjee: 179). The furnaces recovered at Suneri are provided with bellows. For such bellows Panini uses the word *bhastra*(V.S.Agrawal,1953:57) and the same is probably mentioned as *bhasta (*RhyDavids, T.W and Stede William, 2007) in early Pali text. The Buddhist texts suggest that their bellows made of leather were in use in pre-Mauryan times[13].

On the basis of furnaces recovered at Khairadih, which belong to Mauryan period, Tripathi(2001:148) suggested that the wall of furnaces were made of clay mixed with straw and sand. A bamboo plastered with mud was used as a tuyere at the surface level. The use of furnace for the purpose of iron smelting and tools of ironsmith is clearly documented in literature(K.C.Jain,1974: 287) of the period concerned. The furnace was known as *ayakottha* and the ironsmith handled the process of metallurgy with the help of tongs (*sandasi*) then it was taken out and put on the anvil (*ahikarani*). Objects such as tongs, pincer and anvil having their corresponding names in literatures have been recovered from archaeological sites, namely, Atranjikhera (R.C.Gaur: 223 & 425, XXVII) and Ujjainetc.

The iron bearing levels have generally yielded shadowy looking ash pits and burnt earth with some slags(Tripathi: 144). In most of the cases generally a round shallow pit full of ash is the main reminiscent. The superstructure is consistently missing. In the light of evidences reported at Ujjain, between c.500-200 B.C., Banerjee(1965:179)reconstructed the working of blacksmith in these words "… . the remains of forge with a groove for the introduction of the working end (or nozzle) of a blower or bellows, an improvised stand made from the sturdy and large neck of a broken vessel to support a water jar to store water for quenching, a small or miniature jar to collect small quantities of water according to necessity, and a shallow but large enough bowl to contain water near the hand for quenching".

We have little in common with iron and copper technology. The craft of blacksmith is basically different from that of a copper metallurgist. Unlike copper, iron objects had to be forged stage by stage from a bloom to a bar and then thinning, pointing, folding and forge welding. The operation specially welding would require higher temperature necessitating the use of forced draught(H.C.Bhardwaj,1973:392).

The evidence of smelting is recovered at Ujjain, where huge deposits of iron slags, un-smelted smolten iron ore, lump of crystalline material identified as calcite or aragonite and quantities of a whitish powder probably lime has been reported. The whitish powder perhaps represents the calcium compound resulting from the smelting operation. The calcium compound or whitish powders were used by blacksmith as flux (Banerjee: 178). The calcium as flux is also known to us from Atranjikhera (Tripathi: 145). But at Rajghat, as it is evident through chemical analysis, no flux was added. The alkalis present in the charcoal ash might have played the role of flux. The slag removal by liquation smelting must take place around 1180°C temperature otherwise slag would not drain away. The chemical composition of the metal shows the presence of slag particles, which indicates that it was perhaps difficult to maintain a temperature of 1180°C for long which resulted in the retention of some slag particles in the metal(H.C,Bhardwaj,1979:153). About the actual mode of smelting, according to Banerjee despite that evidence is not clear, certain broad inferences are possible. This he gives as follows: "Alternate deposits of charcoal mixed with the iron slag and whitish powder, possibly lime, as stated above occurring in an exposed section point to a simple method of smelting employed at Ujjain"(Banerjee:178-179). The side of this heaped and simple furnace, which was possibly circular in plan, provided with the passages for intake of air and escape of gases, and outlets for molten iron. The molten liquid, after collection, first cooled by dipping into water and then beaten with hammer to drive out the charcoal, which in the course of the hammering went into the (reduced) iron, giving it, to an extent, the properties of steel, and thus eliminating the slag. Here at Ujjain, we do not have any evidence that charcoal was used as fuel.

Despite the above discussion about technology related with iron, we are not in position to arrive at a concrete conclusion. Since most of the mining zones of iron ores have yielded heaps of slags, therefore it appears that the blacksmiths preferred to complete the making of tools near the mining zones itself(Tripathi:101). Study of these slags is essential to achieve more reliable picture before dealing with iron metallurgy.

The distribution of iron ores in India has a definite bearing on the smelting operations at different times. It gives us an idea about the possible geographical extent of the areas where the iron industry could have developed at early stage. It is very natural that at the earliest stage, only those ores must have been selected for smelting, which was either, easy to work with or were easily accessible. Here one thing is important that all the ores are not uniformly workable or commercially profitable. Now a day hardly any ore that contains less than 50% of iron is considered good for commercial use(Banerjee:189). In the early stages, such consideration certainly did not play any role, but gradually people learnt it through experience.

The principle mineral of iron comprise of greenalite, haematite, ilmenite, limonite, magnetite, pyrite, pyrrholite and siderite. But in India, the ores are broadly divided into three types(Banerjee:189).

The first type consists of the ferruginous formations of Pre-Cambrian Age, which in the unmetamorphosed state comprises of haematite, jaspers and in the metamorphosed state are in the form of magnetite-quartz.

The second type represents the sedimentary iron ores of siderite or limonite composition, known to us from Assam, Bengal, Bihar and parts of Himalayas.

The type three includes the lateritic ores found almost all over India. They are the sub-aerial modification of gneiss, schists and lavas under humid tropical conditions. These occur in the Deccan, Western Ghats and many other places. Because of their low (25 to 35%) contents of iron these are not yet, fully explorable commercially.

In India, we have the evidence of the richest deposits of iron, both in quality as well as in quantity such as Bihar, Karnataka, Maharastra, Madhya Pradesh (Now Chattisgarh), Orissa and Tamil Nadu. Besides it, some ores in Kashmir, Kumaon Hills (Now Uttaranchal), Mandi (Himachal Pradesh) and Patiala (Punjab) are also known to us(see table no.1). The ores of Patiala (Punjab) comprise of both haematite and magnetite, Kumaon ores contain both limonite and haematite, and Mandi ores include both limonite and haematite. The ores of Patiala and Mandi might have played an important role in the development of iron industry in the region.

Due to early acquaintance of man with haematite and magnetite and because of their abundance, it is quite likely that the early iron smelters used these two ores of iron(Bhardwaj,1979:154). Mining is the same as mentioned earlier in the context of copper.

## Result of Chemical and Spectrographic Analysis of Iron Objects from Rajghat and Atranjikhera

From the chemical analysis of iron objects from Rajghat and Atranjikhera silica, alumina, lime and magnesia are present as impurities. According to Usmani "impurities suggests the low temperature reduction (below 1050°C), as the metal would never have liquefied and some of the impurities present in the ore remained entrapped"(Usmani,1992:173). The carbon contents in these objects at Atranjikhera are generally low, and range between 0.18. to 0.33%(see table no.2)and at Rajghat it range between 0.12-0.42%(see table no.3). This in the view of Usmani indicates that "these objects were not hardened by heating and quenching. Only the objects having a high content of carbon can be hardened by heating and quenching".

At present, it is difficult to locate the ores of iron used by smelters. Even the source of technology remains obscure. Bhardwaj points out that "Rajghat iron is often associated with impurities of Ti, Ni, Cu, $P_2O_5$ and S which may indicate that titaniferous ores with apatite complex might have been used. Such ores are found in plenty in Singhbhum and Mayurbhanj."(Bhardwaj,1979:156)However, much earlier Kosambi(1965:115)had suggested that Mirzapur mines produce rich hematite ores which, perhaps, were already explored by the Aryans. As regards the technology Agrawal's(1968:18.) view is that there is a possibility of movement of people of Chirand and Sonpur from east towards the west with their technique which they had for exploiting copper and applied the same to iron.

At Atranjikhera four samples, all belonging to pre 600 B.C., were put to chemical analysis. The result shows that silica, lime, alumina and magnesia are always present as impurities as in the case of Rajghat ores. The carbon content is low and varies between 0.18 to 0.33%. The one tallographic examination of iron objects suggest that it was probably not easy to attain a temperature of about 1180°C for sufficient time during the smelting operations which resulted in the retention of slag particles in the metal. The retained slag particles in the metal have a good chance of escaping during forging process. When the red hot metal is placed on the anvil and beaten with hammer repeatedly. Thus, it is assumed by Usmani that the smelting of iron was done at a lower temperature (below 1050°C) and the forging process was not good enough to remove the slag particles completely.

As it has been suggested that the source of iron, here was probably the hill ranges extending from south of Agra to Gwalior(Gaur:496). The extensive deposits of banded hematite quartzite found in these rocks are considered important and have been worked out on a large scale by indigenous smelter(Usmani:174). In the view of Usmani the general pattern that emerges from the above studies is as follows.

Impure wrought iron was used.
Flux was not used for the smelting of iron.

Presence of large amount of slag particles in iron objects indicate that the ancient people were not well acquainted with its reduction process and the role of temperature during smelting. They were not in position to attain temperature of about 1180°C for a long period at the time of smelting.
In conclusion, it can be argued that no sufficient work has been done on iron technology because of two reasons. First, non-availability of the early iron implements in good condition, which is a necessary requirement for chemical and metallographic study. Most of the times the objects

unearthed from excavations are in a high state of corrosion with no metallic core left. For such type of specimen no chemical and metallographic analysis is possible. Secondly, the less-corroded objects are kept in the museum as the important finds from the excavated sites and hence not available for the above mentioned scientific study. From the technological point of view in pre. 600 B.C. iron technology was in a primitive age. The wasteful rich metalliferrous slags show that iron metallurgy was in an elementary stage(Bhardwaj,1979:158). Even though the Mesopotamians in 5th millennium B.C. succeeded in exploiting iron ores and shaping them to form, but the real breakthrough could not be achieved till 1500 B.C. In India, as well, though iron metallurgy has its origin quite early but the full scale use of iron is quite late. In the opinion of Tripathi(Tripathi:100), iron age in the true sense started around c.500 B.C. in India, when the technology was ripe to take over and to utilize the commonly accessible and available iron ores.

The period under consideration witnessed a revolutionary change in metal technology. Iron replaced copper as the household objects for making tools and implements which have been found in sufficient quantity. Added to this, presence of slags throughout the country during this period also proves the prolific use of iron. The dissemination of knowledge and techniques of smelting iron, which was hitherto not known, gave a tremendous boost to the dependability and serviceability of iron. The discoveries of sources of iron ores found by deliberate exploration and its extensive use for making a large variety of objects had a great impact on socio-economic life of the people. It became possible for the people to clear the forest, to lay roads for easy moveability, and to enrich their life style. Man's technological advances and the utility of iron helped the developmental process to grow rapidly. Thus, the use of this metal may have helped forge a common techno-cultural bond between people of different regions.

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## PERCENTAGE COMPOSITION OF IRON ORES FROM DIFFERENT AREAS, WHICH WERE EXPLOITED BY THE PEOPLE DURING THE PERIOD UNDER STUDY

| S.No. | Location of Ore | Insoluble | SiO2 | Fe2O3 | FeO | AI2O3 | CaO | MgO | P2O5 | TiO | MaO | V2O5 | SO2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Raniganj, Jharkhand | 10.6 | 8.5 | 53.2 | 13.48 | 4.07 | 1.00 | 0.85 | 0.57 | ---- | ---- | ---- | 0.55 |
| 2. | Palamau, Jharkhan | ---- | 5.54 | 69.23 | 21.60 | 0.50 | 0.62 | 0.11 | 0.02 | 0.16 | ---- | ---- | ---- |
| 3. | Singhbhum, Jharkhand | ---- | 2.42 | 85.87 | 2.45 | 4.31 | 0.35 | 0.17 | 0.18 | 0.34 | 0.11 | ---- | 0.02 |
| 4. | Singhbhum, Jharkhand | ---- | 0.57 | 72.12 | 8.07 | 2.83 | Tr | 0.20 | 0.97 | 13.84 | 0.14 | 0.59 | ---- |
| 5. | Mandi, Himachal Pradesh | ---- | 9.22 | 63.72 | 24.79 | 1.28 | 0.33 | 0.29 | 0.003 | ---- | 0.11 | ---- | 0.25 |
| 6. | Patiala, Punjab | ---- | 9.38 | 57.4 | 57.4 | 14.8 | 1.3 | ---- | 0.42 | ---- | ---- | ---- | 0.15 |
| 7. | Kaladhughi, Orissa | ---- | 36.62 | 49.91 | ---- | 5.27 | 1.10 | ---- | 0.66 | ---- | ---- | ---- | ---- |

**Table No.1**

**Krishnan,M.S.,1955, *Iron Ores in India,* Calcutta, p.85**

SiO2: Silicon dioxide
Fe203: Ferric oxide FeO: Ferrous oxide AI2O3:Aluminium oxide
CaO: Calcium oxide MgO:Manganese oxideP2O5:Phosphorus pentoxideTiO:Titanium oxide
MaO:Manganese dioxideV2O5:Vanadium pentoxideSO2:Sulphur oxide

## CHEMICAL AND SPECTROGRAPHIC ANALYSIS OF IRON OBJECTS OF ATRANJIKHERA

| S.No | Date & Objects | Fe2O3 | SiO2 | AI2O3 | CaO | MgO | Cu | Ni | TiO2 | P2O5 | S | C | MnO2 | Co | Zn | As |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Upper Phase of PGW, Iron | 89.36 | 0.53 | 1.33 | 0.60 | 0.12 | - | - | Tr | 0.33 | 0.08 | 0.33 | Tr | - | - | - |
| 2 | Middle Phase of PGW, Rod | - | 1.80 | 0.82 | 1.31 | 0.19 | - | - | Tr | 0.21 | 0.10 | 0.18 | Tr | - | - | - |
| 3 | Middle Phase of PGW,Bangle | - | 1.51 | 0.96 | 0.82 | 0.71 | - | - | - | 0.18 | 0.09 | 0.26 | Tr | - | - | - |
| 4 | Middle Phase of PGW, Piece | - | 1.32 | 1.25 | 0.73 | 0.62 | - | - | Tr | 0.21 | 0.12 | 0.31 | Tr | - | - | - |

**Table no.2**

**Gaur, R.C.,1983, *Excavations at Atranjekhera,* Delhi,pp.489 and 495**

Fe2O3: Ferric oxideSiO2: Silicon dioxideAI2O3: Aluminium oxideCaO: Calcium oxide
MgO: Manganese oxide Cu: CopperNi: NickelTiO2: Titanium oxide
P2O5: Phosphorus pentoxideS: SulphurC:CarbonMnO2: Manganese dioxide
Co:CobaltZn:ZincAs: Arsenic

## PERCENTAGE COMPOSITION AND IMPURITY PATTERN OF IRON OBJECTS FROM RAJGHAT BASED ON CHEMICAL AND SPECTROGRAPHIC ANALYSIS

| S.No. | Objects | Date | Fe | SiO2 | AI2O3 | TiO2 | CaO | MgO | Cu | Ni | Cr | P2O5 | S | C | Mn | B | Co | Zn | As | Sb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Blade | 600-400 B.C | 91.21 | 0.88 | 0.5 | Tr | 0.32 | 0.15 | - | Tr | - | 0.24 | 0.19 | 0.15 | - | - | - | - | - | - |
| 2. | Arrow head | - | 85.7 | 3.8 | 2.01 | Tr | 1.20 | 0.24 | - | Tr | - | 0.15 | 0.12 | 0.20 | - | - | - | - | - | - |
| 3. | Broken nail | - | 92.3 | 2.8 | 1.7 | Tr | 0.82 | 0.80 | 0.1 | Tr | - | 0.22 | 0.08 | 0.42 | - | - | - | - | - | - |
| 4. | Piece of rod | - | 89.5 | 1.5 | 2.01 | Tr | 0.52 | 0.34 | Tr | Tr | - | 0.21 | 0.09 | 0.12 | - | - | - | - | - | - |
| 5. | Fragmentary piece | - | 91.4 | 1.8 | 0.98 | Tr | 0.82 | 0.25 | Tr | Tr | - | 0.25 | 0.10 | 0.28 | Tr | - | - | - | - | - |
| 6. | Bent nail | - | 92.50 | 0.42 | 0.52 | Tr | Tr | 0.08 | 0.20 | Tr | - | 0.08 | 0.08 | 1.1 | - | - | - | - | - | - |

**Table no.3**

**Bhardwaz, H.C., 1973, *'Aspects of Early Iron technology in India'*, Agrawal D.P & A. Ghosh,(Eds.), *Radio Carbon and Indian Archaeology*, Bombay,p.394**

Fe:IronSiO2: Silicon dioxideAI2O3: Aluminium oxide TiO2: Titanium dioxide
CaO: Calcium oxideMgO: Manganese oxideCu: CopperNi: Nickel
Cr: ChromiumP2O5: Phosphorus pentoxideS: SulphurC: Carbon
Mn:ManganeseB:BoronCo: CobaltZn:Zinc
As: ArsenicSb:Antimony