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Aspects of Iron Technology in India

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Abstract

India had been at the forefronts of iron production right up to the early decades of the twentieth century as corroborated by archaeological, ethnographical and archival material. Recent ^{14}C dates of the second millennium BCE that are much earlier than dates reported from Afghanistan, neighbouring Iran, and China suggest an indigenous origin of iron in India. Calibrated ^{14}C dates of 1800-1500 BCE from Vindhya –Kaimur region of Uttar Pradesh further reinforce an independent origin of iron technology in India. Iron metallurgy appears to have evolved with trial and error, from simple wrought iron with plenty of slag inclusion to steely iron; from small bits and tiny objects to grand structures like the Delhi Iron pillar over the centuries. The wootz steel swords with beautiful watering pattern on the surface became famous all over the ancient world. The history of iron technology in India has been traced here at three stages of techno-cultural development.

Iron heralded a new era in the history of human civilization. Iron technology has a special place among the ancient technologies that accelerated the pace of progress and brought prosperity in society. In human history Iron Age succeeded Copper-Bronze Age as iron required a different kind of skill and a higher level of metallurgical expertise. The craftsmen who were adept in working with copper and its alloys and other glittering metals like gold, silver etc. that could be used in their native form on a much lower temperature could not smelt iron with the same technique. India has rich iron ore deposit. The ore is not only widely distributed but also easily accessible in the form of nodules scattered on earth's surface. This must have facilitated easy hand picking of rich ore nodules by the early or primitive metal workers. However, richness of mineral and its easy accessibility may not be sufficient conditions for an early and efficient production of metallic iron. The metal workers had to be well conversant with the suitable minerals as well as possess sufficient metallurgical know-how. However, how and under what circumstances the metallurgy of iron evolved has been studied by scholars of other world civilizations. But the history of iron technology in India, its beginning and process of development is yet to be fully studied. Some worthwhile efforts to examine different aspects of iron technology have been made by scholars like, Niyogi (1914), M.N. Banerjee (1927: 432-436; 1932: 364-366), Banerjee 1965; Pleiner (1971:5-36), Sahi 1979: 365-368, 1994; Chakrabarti 1992; Chakrabarti and Lahiri 1994:12-32; Tripathi 1986: 75-79; 1994: 241-251; 2001, 2008; Tewari 2002:99-116, 2003:536-544, 2010: 81-97). On the basis of available information, an attempt is being made to trace a brief history of iron technology in India.

Recent archaeological researches and archival accounts including foreign records by travelers or historians of ancient India, some of them dating back to pre-Christian era bear this out that Indian iron and steel had gained recognition in the ancient world. In 5th century BCE Herodotus, the Greek historian who is also known as father of history stated that in the battle of Thermopylae the Indian soldiers fought with iron-tipped arrowheads (Photius Book VII: 65). Almost at that very time, Ktesias the Greek ambassador to the Persian court and a physician gratefully acknowledged the gift of two swords of Indian steel made to him by the King and the Queen mother (McCrindle 1882, reprint 1973:9). Quintus Curtis reported that the vanquished rulers of North-west India paid a tribute of 100 talents of steel ingots along with bags of gold dust and other precious items to Alexander. This suggests (1) that iron and steel produced in India at that particular age was considered valuable enough to be presented as a tribute to a monarch. (2) It also suggests that by 6th – 5th century BCE Indian iron and steel had become some kind of status symbol and an object of value being exported to different parts of the ancient world. This assumption gets corroborated by facts like accounts of Arrian (c. 92-175 CE) who mentions about import of Indian steel to Abyssinian ports as early as the beginning of the Common Era. These accounts clearly bear this out that iron metallurgy was sufficiently developed in India at quite an early date. A multi-pronged approach incorporating archaeological, anthropological, metallurgical and literary data is required to study ancient Indian iron technology. We now proceed to look into the genesis and development of iron technology on India.

1. Origin of Iron in India

Whether iron metallurgy was indigenous or was learnt through other sources through diffusion is the key issue of beginning of iron in India. We first propose to discuss the diffusionistic theory of origin of iron in India followed by the alternative view points.

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Origin of iron technology in India may be examined by taking into account 1) status of iron at the earliest occupational stratas depicted in archaeological remains and in the literary accounts; 2) chronology of iron on the Indian border-lands to see whether that region had the potential to lend the technological know-how to the neighbouring regions.

1.1 Diffusion of Iron Technology in India

The circumstances and time of introduction of iron has been a much debated issue in Indian archaeology. Gordon (1958) and Wheeler (1958) had ruled out the possibility of use of iron in India prior to 600-500 BCE. It was argued that iron in India was introduced under Achaemenids from the North-western part of the Indian subcontinent around circa 600 BCE. The other set of scholars like Neogi (1914) and M.N. Banerji (1927, 1929, 1932), N.R. Banerjee (1965), Roy (1984) etc. suggested that iron arrived in India through diffusion by the immigrating Aryans (following the disintegration of the Hittite Empire). The Hittites and the Mittannians were known to have possessed the technique of iron production but had secretly guarded this knowledge for centuries. Once the Hittites dispersed to other parts of the world after their defeat in a war with the Mitanni rulers somewhere around 1200 BCE (the date of Hittite movement), the technique of iron working also reached to different parts of the world with them. This assumption gave rise to the theory of diffusion of iron in from a single centre. This also gave rise to association of iron with Aryans. This theory gained further credence by the fact that Rigveda, the earliest text attributed to the Aryans mentions the term *ayas* (that presently stands for iron) several times. Assuming that the Rigvedic Aryans were conversant with iron technology, it was argued that iron was introduced in India by the Rigvedic Aryans who had immigrated through the North-western passes.

The Aryan association of advent of iron in India has been contested by many scholars. Firstly because it is not universally acceptable whether the Rigvedic people came from outside and secondly, whether the word *ayas* that today stands for iron had the same connotation during the Rig Vedic period also. Doubts have been raised on the precise meaning of the word *ayas*. Lallanji Gopal (1961:71-86) closely examined the issue of iron in the Early Vedic period and synthesized the existing evidence on the subject. The word *ayas* in the Rigveda, according to Gopal stood for metal in general, instead of iron as argued by several others like M.N. Banerji (1927, 1929, 1932), N.R. Banerjee (1965), Roy (1984). Lallanji Gopal came to the conclusion that iron was introduced in India during the Later Vedic times. My own examination of the context and usage of the word *ayas* in Rigveda leads to a similar conclusion (for detail see Tripathi 2001:59-65). Even on the ground of metallurgical assessment, the references in Rigveda appear to be applicable more aptly for copper-bronze than iron. During the Later Vedic period (in Vajsaneyi Samhita of Yajur Veda 28.13), the terms *Krishna* or *Shyamaayas* (the black metal) and *lohitayas* (the red metal) denoting iron and copper, respectively were coined (see Tripathi 1994, 1997). It is reasonable to assume thus that Rigvedic *ayas* stood for metal in general and not for iron. With knowledge of iron, a new term had to be coined to describe it during the Later Vedic period. It is also debatable whether the Rigvedic people came from outside to the *sapta sandhava desha* which they refer to as their motherland. Even if we believe that the Rigvedic Aryans were immigrants from outside (from Central Asia or Europe coming through the northwest) there is no definite evidence to suggest that they brought knowledge of iron working with them. In the absence of definite evidence of metallic iron during Rigvedic period, it would be difficult to sustain the argument that the knowledge of iron was acquired from outside by the Aryans of Early Vedic period from the brethren who occupied the distant lands outside the Indian subcontinent.

Additionally, to enquire into the diffusion of iron technology through the north-western borders of India, we need to examine the archaeological evidence of use of iron in the subcontinent through which people and commodities had been finding a passage in India from time immemorial. If the evidence of iron on the border lands is comparatively earlier and strong enough to pass on the technological know-how to adjacent regions than the one found in the mainland India, there is a ground to assume that there was a diffusion of technology from there through these passages.

Archaeologically, the areas adjacent to India are the Iranian borderlands, modern Baluchistan (extending over Indo-Iranian plateau). This region has yielded a large number of cairn burials with iron. Stein (1929) has reported as many as 5100 cairns. Many of these cairns have yielded iron objects along with copper-bronze objects and other cultural material along with pottery. Gordon (1950) suggested Iranian connections of Sialk Cementery B and the cairn burials of Baluchistan on the basis of similarities in pottery, burials and the metal objects. However, Lamberg-Karlovsky and Humphries (1968) disapprove of the 'Sialk B connections' or Indo-European movements to east' towards the cairn burials of Baluchistan because of lack of 'convincing parallels'. The ecology also plays a role in isolating this area as the 'natural barriers of mountain desert in Baluchistan and southeast Iran have isolated the inhabitants from the domination of any neighbouring power in the 20^{th} century AD.' 'Thus, it seems likely that the occupants of Baluchistan, separated from both east and west, have always maintained a relatively independent existence.' They further state, "The distinctive painted pottery types could not readily be related to the Iranian Plateau or to the painted pottery tradition further to the east. Talking of the possible areas exerting their influence on the Dashtiari and interior Baluchistan, one must look-first to the Persian Gulf trading areas as an outside source of contact. Secondly, there is a connection among the cultures of the northwest India area. The Iranian plateau is an un-distinguished third" (Lamberg-Karlovsky and Humphries, 1968: 269-276).

A close comparison of chronology, typology and pottery traditions of Baluchi cairns and that of North India tends to lend weight to the contention of Lamberg Karlovsky and Humphries (op.cit.). The burden of archaeological evidence does not favour the hypothesis of diffusion of iron into India from the neighbouring West Asian and Central Asian countries. Firstly, a closer examination of tool typology in Iranian and Afghan sites and those in Sindh and Baluchistan area display little common features with iron objects of mainland India. Secondly, the cultural material corroborates the typological study, i.e. the two areas appear to be culturally distinct. Thirdly, the chronological considerations go against any notion of diffusion. On Iran-Afghan sites as well as Indian North-west, iron emerges more or less simultaneously *recent excavations at Charsaddha, however have yielded c. 1200-900 BCE (McDonnel and Conningham 2007: 151-159).* However, it may be noted that recent ^{14}C dates from the middle Ganga Plain sites are much earlier, going back to 1700/1600 BCE (see Table I).This rule out the possibility of iron technology coming through the bordering lands where occurrence of iron is later than this.

The other ground on which the theory of diffusion rests is the inherent complexity of iron metallurgy. Metallurgists like Forbes (1950) strongly advocated diffusionistic origin of iron. By assuming that iron metallurgy is too complex to be developed independently and had to be learnt or acquired under the guidance of specialist iron worker who possessed it. However, recent studies do not subscribe to this view point. Without going into the details of the arguments put forth by recent archaeo-metallurgical researches, it may safely be stated that iron metallurgy is now proved to be a by-product of copper or lead working (for details see Wertime 1980: 13-14, 16; Charles 1980: 151-82 Tylecote 1980: 183-228).

The following points emerge from the foregoing discussion:

1. An uninterrupted use of iron starts only around 1100-1000 BCE on Indo-Iranian borderlands, that too very sparingly in the graves of a selected few.
2. In the neighbouring regions of the Indian borders, none of the areas appear to be in a position to pass on knowledge of iron metallurgy to India. Chronologically or typologically these regions are distinct and disparate.
3. The Rigvedic society does not seem to possess iron technology, therefore even if they had interactions or relationship with the Avestan or other brethren on the so called Aryan trail, this cannot be taken to be a source of iron technology in India.
4. In Kashmir Valley at Gufkral and in Charsadda there are early ^{14}C dates. But so far no concrete evidence of intrusions has been found in these areas. These were at best early centres of iron production. The earlier phase of megalithic cultural deposit does not have iron. It was evolved in the succeeding phase. Foe all we know today, iron is much earlier at Kashmir Valley and may have passed it to the adjacent regions.
5. The assumption that iron metallurgy had to be learnt from those who had already mastered it is no longer tenable. It is well established now that metallic iron was a by-product of copper or lead working. Therefore, the idea that no independent beginning of iron is possible does not hold good at present state of our knowledge.

On the basis of the foregoing, it may safely be argued that iron in the Indian subcontinent was not an outcome of outside contacts. Therefore, let us explore the prospects of an indigenous origin of iron in India.

1.2. Indigenous Origin of Iron in India

As an alternative view point, let us examine the indigenous theory of beginning of iron in India The circumstances and the chronological framework of occurrence of iron in India needs to be evaluated here.

A. Accidental Production of Iron

Could metallic iron be produced incidentally? Do we have such evidence in archaeological records? Let us examine the archaeological evidence with this angle. A new fact emerged by a close look at the excavated material of Ahar, Rajasthan. Sahi (1979:365-368) noticed presence of iron objects in a horizon labeled as Chalcolithic by the excavators. These objects were present in a mid-phase of the Chalcolothic culture that was dated by the excavators between 16^{th} to 13^{th} centuries BCE. These objects could be a product of smelting of chalcopyrite ore being smelted by the Chalcolithic metal workers at Ahar. (Tripathi 1986:75-79). Attention may also be drawn to the very interesting piece of evidence from Noh, District Bharatpur in Rajasthan which yields tiny bits of iron in a Black and Red Ware (BRW) context in pre-PGW period. A regular use of iron starts at the site from the earliest level of the succeeding PGW period. It is possible to deduce from the evidence that some kind of accidental discovery of iron was made at Noh by early metal workers. Could Iron be accidentally produced at Ahar or Noh, during copper working? What must have followed as a natural corollary was a recognition of iron as a metal in its own right and its deliberate production subsequently.

B. Chronological Evidence of Early Iron Production

Early radiometric dates from a large number of sites in the Vindhya-Ganga plain away from the borderlands of India have added new dimension to emergence of iron in India (see Table1). Sites in the eastern parts of the Vindhyas like, Raja Nal-Ka-Tila and Malhar near Varanasi have yielded ^{14}C dates going back to the 2nd millennium BCE (Tewari 2003, Table III.2 & III.3; 2010: Tables 1-4: 81-97). Dadupur in Lucknow, Jhusi near Allahabad and Aktha in Varanasi have also yielded early dates from iron bearing layers. The iron objects coming from Raja Nal-Ka-Tila are of different types. These are: a nail, an arrowhead, a knife and a chisel. Radiocarbon dates from this iron bearing period range between 1400-800 BCE. Nearby, there is the site of Malhar on river Karamnasa, a tributary of Ganga. Malhar is situated in the hematite rich zone of the eastern Vindhyas. Period I of the site is iron free. Period II succeeds the preceding period without any break in culture. Iron appears during the period II. The iron artifacts are nail, spearhead, arrowhead, awl, knife, bangle, sickle and ploughshare (Tewari 2003, Fig. 4). Slag and tuyeres were also found in abundance at the site and in the nearby ore-rich area. One may easily conclude, seeing the massiveness of the slag heaps and other associated remains that it was an iron production centre. The activity seems to have continued unabated for centuries. Till recently this region had been occupied by the Agaria community showing evidence of pre-industrial working and a possible survival of traditional Indian iron technology in the region. The ^{14}C dates from the iron bearing period II are 1993 cal. BC (3390 ± 160 BP), (3430 ± 90 BP), 1679-1442 cal. BC. At Dadupur, iron has been reported right from the earliest cultural deposit of period I. The strata have been ^{14}C dated between 1900-1700 BCE. The iron objects like arrowheads found in this period are in a highly corroded state. Likewise, there are two ^{14}C dates from Aktha (Varanasi) going back to 17th century BCE (Table-1). In the nearby area early ^{14}C dates of 1107-844 BCE have recently been reported from the site of Jhusi at the confluence of Ganga and Yamuna in Allahabad. Lahuradeva in district Sant Kabir Nagar (Basti) has yielded iron in period III dated to 1300-1200 BCE. Outside contacts with this region are indeed a remote possibility as this is a land locked area in the heartland of India in the Vindhya-Ganga Plain.

Another context in which we come across an early evidence of iron are megalithic burials. Megaliths have been found from Kashmir in the North to the peninsular India in the South. But maximum concentration of megaliths has been noted in the southern part of India. At Gufkral in Kashmir, as noted above, iron has been reported from the megalithic phase II. The phase I of megalith is iron free dated by ^{14}C determinations to 3790±110 and 3570±100 BP. The excavator Sharma (1992: 67) proposes a date of 1550-1300 BCE for the iron bearing deposit. The ^{14}C dates for the period are c 1888- 1674 cal BC. In Deccan and south India iron first appears with the megalithic culture. At the settlement site of megalithic culture at Takalghat (Deo 1982) iron appears in the earliest levels, with a few indeterminate objects but its use becomes more common in the subsequent levels. The typology of these megalithic burials shows a distinct character. It had been dated to 750 BCE by Deo on the basis of the cultural material as was assignable to such remains during that period. However, the recent ^{14}C dates of 1400 BCE from Vidarbha region of Maharashtra are 2940±160 BP, 3080±120 BP and 2820±100 BP (Tewari 2003, table 1). The calibrated dates will fall in the range of 1393 to 834 BCE which is much earlier than the date suggested by Deo. These dates push back the antiquity of iron bearing levels in Vidarbh region to 1300 BCE. The recent analysis of iron objects from Mahurjhari show knowledge of steel making in this region in ninth century BCE (Deshpande 2010: 636-639). This could have been achieved only with a long experience in iron metallurgy. There are ^{14}C and AMS dates from sites like Hallur (11/1200 BCE), TL dates Tadkanhalli and Komaranhalli etc. that take back the antiquity of iron in peninsular India to1400 BCE. Thus we come across radiocarbon dates ranging from first half to middle of the second millennium BCE from several parts of the Indian subcontinent.

On the basis of such early chronology of use of iron in India, it may safely be argued that iron technology in India had a much earlier beginning than in the neighbouring countries. These early dates therefore point at an earlier and thus independent and indigenous origin of iron in India. If it was discovered by early metal workers who experimented and subsequently perfected the metallurgy, this must have been a gradual process. Whether it is discerniable in iron tool typology brought forth in excavations needs to be looked into at this stage.

II. Stages of Iron Technology

As the archaeological data suggest there was an evolutionary trend in iron metallurgy. We find a development in metallurgy from simple wrought iron to steely iron. The number and quality of iron objects shows improvement over the period that actually spans over thousands of years. Therefore the Iron Age should be studied accordingly. Here the Age of Iron has been classified under three stages, namely, Early, Middle and Late Iron Age.

II.1. Early Iron Age (From the earliest times to 700/600 BCE)

We have hardly come across ornamental or bi-metallic objects of iron as reported from several Old World sites. Nor there are clear-cut evidences to demonstrate experimental stages in iron metallurgy. However, we may cite the case of Noh. There is indeterminate tiny

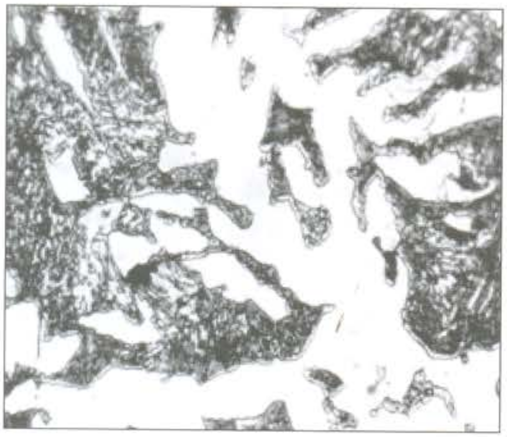

Plate 1a: Photomicrograph of iron implement showing Widmanstatten pattern, Hatigara, West Bengal, India.

piece of iron at a period dominated by Black-and-Red Ware (BRW) though a regular use of iron starts from the succeeding Painted Grey Ware (PGW) period at Noh. Earlier, the PGW culture was supposed to be the first iron using culture (Tripathi, 1976) but in recent decades there are several sites like Noh and Jodhpura (Rajasthan), Jakhera, (district Etah), Abhaipur (district Pilibhit), Dadupur (district Lucknow, Uttar Pradesh) which have yielded iron in a pre-PGW

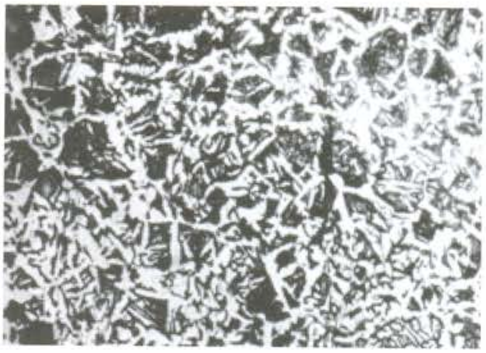

Plate 1b: Photomicrograph of iron implement showing carburization, Hatigara, West Bengal, 500x.

context. The associated potteries are BRW and Red Ware. Jakhera has notably yielded an indeterminate object and an arrowhead with a long tang from the Pre-PGW period from its BRW pottery using cultural period assigned by the excavator to middle of the second millennium BCE. From the succeeding Period III.A (Proto-PGW period) 19 iron objects like hoe, sickle, and arrowheads along with lump and slag were found. A furnace base was also recovered from the proto-PGW phase at Jakhera indicating local smelting of iron (Sahi 1994: 144). From Period III B - the Painted Grey Ware period - hoe, sickle, spearhead, arrow-head, dagger, chopper, chisel, axe, nails, rods etc have been reported. (Sahi 1994: 142, Figs. 14, 15). But generally other sites in the region yield iron from the PGW period. The site of Atranjikhera, situated nearby has no iron in its pre-PGW period. Iron appears there for the first time from the PGW period. The 2.50m thick PGW deposit divided into three sub-periods yields iron from the earliest strata. The lowermost phase has yielded only seven indeterminate bits and some lumps of iron; regular tools appear from mid-PGW phase (46 objects); and the upper phase yields 81 objects (Gaur 1983; see Plate 2a). This indicates a gradual but consistent rise in iron objects between BCE 1100/1000 and 600. Significantly enough, all these sites mentioned above, are located near the Agra-Gwalior iron ore deposit.

As we move further east in the Ganga plain, there are several early Iron Age sites such as Chirand, Sonpur, Panr etc. in Bihar and Hatigra, Pandu-Rajar-Dhibi, Mangalkot etc. in Bengal (see Tripathi 2001). The latter has yielded iron objects from the earliest phases of occupation with 8 objects, like arrow-head, spearhead, nail and rod besides the 8 indeterminate pieces. A furnace along with 16 iron objects was found in a trench of 6x6 m. at Mangalkot from the lowest

Plate 1c: Electron photomicrograph of iron implements, Hatigara, West Bengal, 3000x.

level datable to 1200 BCE. The succeeding period has yielded more evolved shapes like sickle, chisel, peg, and a knife or sickle blade (?) from mid-phase of the culture (Datta 1992: 293-308).

By and large, the metallurgy of iron at this stage was quite elementary. Bloomery iron that could be produced at much lower temperature was the norm, slag inclusions are found in the matrix of iron (see Plate 2a showing composition of a celt from Tadkanhalli).

Plate 2a: Microstructure of a celt, Tadkanhalli, India.

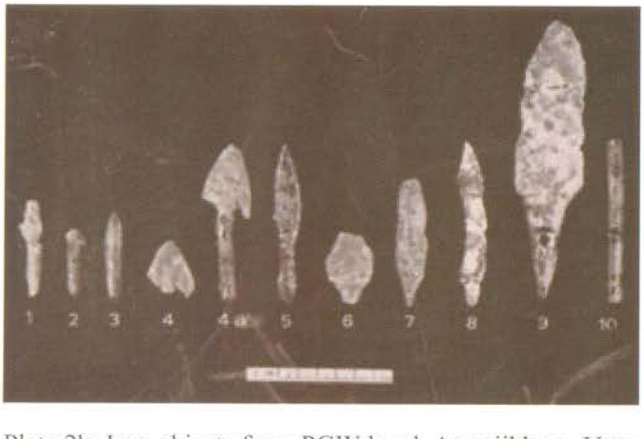

Plate 2b: Iron objects from PGW level, Atranjikhera, Uttar Pradesh, India.

A dagger dated to 1100-1000 BCE was analysed from Hatigra (Ghosh and Chattopadhyay 1987: 21-27; see Plate 1a, b and c) had widmanstatten structure due to prolonged exposure at a temperature of about 1200^{0}C followed by a slow cooling. It is said to be a 'low carbon hypoeutectoid steel'. The above mentioned specimen shows carbon indicating carburization (see Plate 1b). Objects from Pandurajar Dhibi and Mangalkot have a high percentage of silica in them (De and Chattopadhyay 1989; Datta 1992: 303). It shows the elementary nature of metallurgy and low efficiency furnaces in use at this stage. But samples analysed from the megalithic site of Mahurjhari in Deccan as noted earlier, shows steeling (Despande 2010). This may indicate existence of regional centres that experimented with metallurgy and developed the technology of crucible steel that later comes to be known as crucible steel or wootz steel.

II.2. Middle Iron Age (8th - 7th Century BCE to 1st to 2nd AD)

The Northern Black Polished Ware (NBPW) succeeds PGW culture in North India in *circa* 800/700 BCE. It is contemporaneous with late phase of Painted Grey Ware culture as the two cultures overlap at most of the sites. This was a period of consolidation of iron technology with traces of steeling, case hardening and

Plate 3a: Electron photomicrograph of Sickle showing tempered martensitic structure, Pandurajardhbi, West Bengal, 3000x.

Plate 3b: Iron objects, Agiabir, Uttar Pradesh, India (No.8 from Stage III).

carburization. A relative increase is recorded in the number and types of iron objects (Table 2). There is a qualitative and quantitative improvement in iron objects (see Plate 3b, iron objects from Agiabir). We come across more sophisticated weapons like javelins, lances, daggers, blades, elephant goads, which occur together with the earlier types that become more prolific. Agricultural implements rarely reported from Early Iron Age, with a few exceptions like the site of Jakhera yielding iron sickle and ploughshare became relatively frequent during this period.

Six iron samples from Rajghat (Varanasi) belonging to 600-400 BCE were analysed. All of them are found to be of wrought iron having slag inclusion. Evidence of carburization has been attested in sample No. 6 at Rajghat. It has 1.10% carbon. However, it is difficult to ascertain whether carburization was deliberate (Bharadwaj 1979:148).

An iron sickle of Pandurajar Dhibi (Period III, NBPW phase) shows the presence of martensite and a non-uniform structure. It also exhibits retained acicularity at certain places, especially around large patches of ferrite areas. Electron micrographs obtained at a magnification of 1000x and 3000x clearly represent its tempered martensitic structure (Chattopadhyay 2004: 98 plates 51, 52; see Plate 3a). It may be said that the iron of the sickle blade had been forged at a significantly high temperature to extricate the slag particles giving the metal a more homogenized structure. Carburization was done during manufacturing of the tool by subsequent heating and forging. Inside the core, the carbon content that is retained is only 0.22%. But the high level of corrosion that took place over the time must have caused depletion of carbon. There is also an uneven distribution of carbon concentration. It indicates that carbon was more than 0.4% initially.' There are also indications of quenching and tempering (De and Chattopdhyay, 1989: 37).

II.3. Late Iron Age (2nd AD to 5th - 6th Century AD)

In the opening centuries of Christian era there is not only a proliferation in tool types (Table 2), but iron metallurgy seem to improve significantly. The iron objects from the site of Khairadih, district Ballia in Uttar Pradesh show a rich variety and good skill of the artisans (see Fig. 1b). Techniques like lamination and quenching are evidenced (Plate 4a, bent knife from Sringaverpur, Uttar Pradesh). In 200 A.D. Taxila has yielded rich iron tool repertoire, including some armour grade weapons (see Fig. 1.a). Hadfield (1913-14) found many of these to be high carbon steel that compares closely with iron production by ethnic

Fig. 1a: Iron objects, Stage III, Taxila, Pakistan.

Fig. 1b. Iron objects, Stage III, Khairadih, Uttar Pradesh, India.

smelters. Sisupalgarh in Odisha (datable to 5th-6th A.D., Lal1949: 95, Fig.10.32) yielded a caltrop, a weapon to be used in the battlefield. It is well attested that ancient Indian smiths at this stage had a thorough knowledge

Plate 4a: Microstructure of a bent knife showing laminated structure, Sringaverpur, Uttar Pradesh, India.

of the importance of carbon alloying, case hardening and tempering. However, these techniques seem to have been used judiciously wherever necessary. For

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instance, a nail differs in composition from a knife or a dagger showing a selective use of carburization or quenching by the ancient iron workers. These technical skills must have been acquired over a long period before the craftsmen could have ventured to take up challenging jobs of manufacturing a 7-8 ton iron pillar that must have required skill of high order especially with its corrosion resistant property.

The colossal Delhi Iron Pillar (see Plate 4b) produced with approximately 7000 kg of wrought iron of fairly homogenized structure of over 98% purity. It shows an

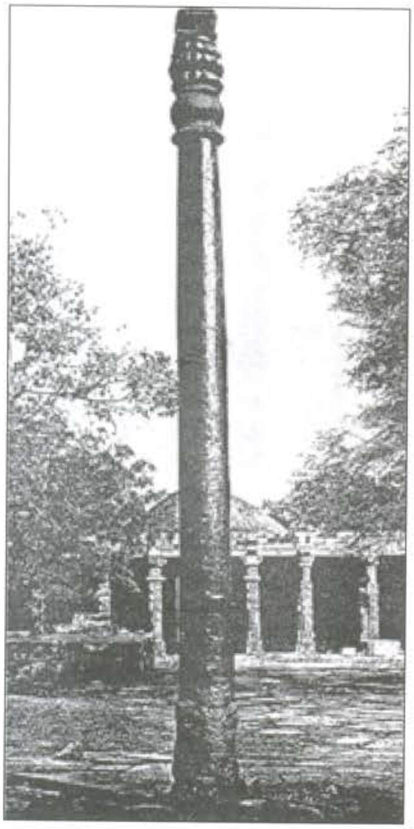

Plate 4b: Iron Pillar, Delhi, India.

expertise of high order and a capability of mass production of iron by 5th - 6th AD. As per published records, the largest iron making furnace of Nagpur (17th century pre-industrial furnace) could produce about 40 kg of iron per heat, (Prakash and Tripathi, 1986). The precise logistics have not been worked out but at least 200 furnaces of that size should have operated simultaneously or the same furnace operated repeatedly to produce that much iron of consistent quality to manufacture such a pillar (Balasubramaniam, 2008).

It appears that the artisans during the successive periods mastered the technique of forge-welding to manufacture colossal structures like pillars and beams. An examination of the fractured surface of the beams used in the Sun Temple at Konark in Orissa (see Plate 5a) clearly indicates that it was manufactured by

Plate 5a: Iron beams, Sun temple, Konark, India.

forge-welding square rods. Jena (cited by Prakash 1997) found traces of lead between rods, where the forging joint was not perfect. Large lead bath was said to be used for uniform heating of a bundle of wrought iron bars to the correct temperature and then forging them together. Since the iron surface is non-wettable by lead, normally it will flow out when the wrought iron bundle is taken out but some molten lead might get trapped in the crevices. Incidentally, some lead has been noticed also in Delhi Iron Pillar, (Balasubramaniam 2008).

Wootz or Damascus steel was famous and was in demand in the ancient world market. Generally this type of steely iron was being produced in the southern part of India. Beautiful swords with watering pattern on the surface were famous all over the world. The steel was being exported to Middle East from the ports of southern India. Pliny in Natural History, The encyclopedia of the Roman Empire mentions about import of iron and steel from Seres which has been identified with the ancient Cheras of south India. The Sangam literature also refers to a brisk trade with the Yavanas in the early centuries of the Common Era. Excavations like Arikamedu have shown presence of Roman artifacts. The Periplus of Erythrian Sea has also mentioned the Seres (Cheras?) shipped variety of commodities from the western coast like Muziri on the Malabar coast (Schoff 1912). We also hear about Seric iron that is significant in the present context. These references suggest trade in the famous wootz steel. There appear to be several sword making centers in other parts of India as well in the early centuries of Christian era as will be clear from the literary accounts (Tripathi, 2007: 403-426).

During the Early Medieval Age there must have been pressure on the artisan class to produce iron objects in a large number, especially to assist in the agricultural and war sectors. Though the archaeology of early medieval times is not very well documented, the rich literary evidence of the period does provide valuable data on the socio-economic life. We have already discussed the masterpieces like the Delhi iron pillars that belong to this age (4^{th} – 6^{th} century CE).

Victory pillars and monuments were erected to reiterate superiority and power of rulers of the age. Under these circumstances the industries capable of providing the tools, equipment, and weapons must have been much sought after. During this period, the demand for better, efficient and effective weapons for winning wars, tools and implements of masonry, building material, agricultural implements must have multiplied manifold.

Large sized structures of iron like pillars, beams etc. used in monumental buildings are found in several parts of the country. The frequently mentioned examples are the Delhi iron pillar of 5th century AD weighing over 6096 kg (nearly 7 tons) and the iron beams at Konark temple datable to 9th-10th century AD, which lie in several pieces in the temple complex. Its longest piece is 11,000 mm in length and 175 x 197 mm in cross section and weighs approximately 3000 kg (see plate 5a). Another noteworthy example is the victory pillar at Dhar that is said to be the biggest iron pillar in the country and perhaps anywhere in the world. It is broken in three parts during its transportation to a mosque by Dilawar Khan the governor of Allauddin Khilji in 1399 CE who tried to move it to another place.

What happened to such a developed iron industry during the succeeding period? This needs to be investigated closely. When the British arrived, their engineers systematically studied Indian iron working as they found a unique evidence of iron production in small workshops flourishing in several parts of India. It will be worthwhile throwing light on status of traditional Indian iron technology during this period.

III. Tradition of Iron Working and Its Survival in India

Both literary and ethnological evidences throw light on the status of iron till nearly pre-British period. There are Sanskrit texts composed up to 1400-1500 CE that speak of iron production and its trade.

In addition to this, the British period accounts and records give us a fair idea about the indigenous iron production that we plan to touch upon here. Some insight on this subject may be gained by literary accounts and ethnographic material brought to light from time to time.

III.1. Literary Accounts on Iron Working

The accounts of an Egyptian-Greek merchant in his book 'Periplus of Erythrian Sea' (Schoff 1912) testifies to the export of Indian iron to Abyssinia in the 1st half of the early centuries of the Christian era. Periplus gives a detailed account of the voyages undertaken by its author and the ports he had visited. The most important harbour was Barygaza, a corrupted Greek form of Bhrigukachchha (modern Broach or Bharoch) on the mouth of the river Narmada.

The technique of steel making was mastered as is evident from the textual data. As mentioned earlier, Varahmihir (550 AD) gives an elaborate description of carburization of sword blades. Such references bear this out that the artisan communities of 5th – 6th century AD had developed very complex processes of carburization and tempering. These processes must have already been in practice and were well established to find mention in important texts like the above one. Once perfected, the technique led to production of exclusive pieces that must have been in great demand in the contemporary world.

Scholar - kings like Bhoja of Dhar (1010-1053) had composed a text on iron metallurgy entitled Yuttkalpataru. Bhoja also acknowledges a presence of three earlier texts with the title Lauharnaua and Lauhadsp and Lauha Pradeepa. Agni Purana deals with weapons - types and techniques of manufacture of various weapons and centres famous for sword making. It also namesof port towns like from where commodities including swords were being exported. The ports mentioned there are: Surparak (Sopara) Vanga (Bengal) and Anga (Bhagalpur with its capital at Champa in Bihar). Ibn Haukal (HEID 1.37) mentioned the city of Debal in Sind as a famous sword making centre. Kurij in Kutch is said to be another such centre. However during the political turmoil that the Indian subcontinent faced during the medieval period took its toll on the preservation of such texts. With changing socio-political configurations iron technology receded into background from the centre stage. It was simply relegated to a low status and the metallurgy became a craft being possessed by the ethnic communities living close to the ore deposits in the forests. Over the period they were cut off from the mainstream of the Indian society. Nevertheless the metallurgical skill continued to be the prerogative of these communities till the British period as will be demonstrated in the statements of the British engineers and administrators who were surprised by the high quality iron and steel being produced by them.

Propagation
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The Geniza records of the eleventh and twelfth centuries bear testimony to the export of Deccan iron and steel to the Middle East, (Goitein 1966, 339). Fakhr-I-Mudabbir (11th Century AD) thought that the Indian swords were the best. The Damascene sword or Maujdarya was considered exclusive, even by the Arab world. It is said that these swords could fetch the highest price in the world market.

Plate 5b: Agaria furnace, Singaruli, Madhya Pradesh, India.

Special mention may be made here of *Ras Ratna Samuchchaya* (RRS), a 10th -12th century text on alchemy. A very fine classification of different types of iron has been attempted in *Ras Ratna Samuchchaya* showing a deep understanding of behaviour of iron in the smelting-refining process. Three basic types of iron with different sub-types (according to their properties, appearance and nature) have been categorised in RRS. There are three major types of iron, namely *Kant Lauha, Tikshna Lauha, Munda Lauha*. Each of these types of iron has several sub varieties. There is a list of fourteen (sub) types. Prakash (1991) and Biswas (2001) have tried to translate the terms of *RRS* in modern terms. These types of iron and steel were meant for different specific functions and usages. This shows the remarkable expertise mastered during the early mesievalmetal workers in India. It stands to reason to assume that a well-developed scientific basis existed in the ancient times as evident from some of these textual references.

Abhidhānaratnamālā, a text of this period, makes a list of metals that includes copper, bell metal, iron and steel, lead, tin, silver and gold. Different parts of the country were famous for different metals. *Agni Purana* (CCXLV. 21) describes five centres that were famous for sword making. They are *Khatīkhattara* and *Rishika* (not identified so far), Surpāraka (Sopara), Vanga (Bengal) and Anga (Bhagalpur, Mungher districts of Bihar). Ibn Hauka[12], (HIED –1.37) mentions the city of Debal in Sind as a famous sword-making centre. Good quality swords were being produced also from iron or steel from Kurij in Kutch. These centres must have catered both to the local needs as well as to exports.

A fourteenth century AD work, *Sarangadhara Paddhati* (referred to by Joshi 1970: 82) by the alchemist *Sarangadhara* describes the technique of manufacturing swords.

The Asur and the Agaria tribes carried out this tradition of iron production. The ethnic societies have carried this legacy till the fifties in the 20th century. On investigation the British engineers found, as mentioned earlier, that the pieces produced by the Agaria, the traditional ironworkers were far superior to the British or Swedish iron.

"----bar iron…of most excellent quality, possessing all the desirable properties of malleability, ductility at different temperatures and of tenacity for all of which I think it cannot be surpassed by the best Swedish iron; ... the Agaria piece when brought to the bend it showed itself possessed of the power of elongating and stood the bend better than the general run of English iron purchased in the Bazar" (J. Franklin, 1829, quoted by Dharmpal 1971: 289).

Another instance worth mentioning here is the one mentioned by La Touché (1918),"...its (iron's) superiority is so marked, that at the time when the Britannia Tubular Bridge across the Menai Straits was under construction preference was given to use of iron produced in India". A good amount of iron was imported from India in construction of the above bridge.

Sir George Braidwood (1878 cited by Krishnan 1954: 70) recorded in the notebook of the British Indian section: "Indian steel was with such properties celebrated from the earliest antiquity and the blades of Damascus which maintain their pre-eminence even after the blades of Toledo became celebrated, were in fact made of Indian iron.....The Ondanique of Marco Polo's travels refers originally, as Col. Yule has shown, to Indian steel, the word being a corruption of the Persian Hindwany i.e. Indian steel. ---- the swords of Kirman were eagerly sought after in the 15th and 16th countries AD by the Turks who gave great prices for them. Arrian mentions Indian steel 'Sideros indicos' (that) was imported into Abyssinian ports"

After 'the Great Indian mutiny' in 1857, the British Government confiscated all the sharp edged weapons like swords, daggers and knives etc. kept by people. These weapons of the Moplas of Malabar made with native iron in the Indian blast furnaces are said to be of such high strength that it could not be shredded. It is said, "---and wonderful material they (iron objects) were. To break them was impossible, so a pair of strong hand-shears was made to cut them up. But the remarkable point was this, that if put into the shears with the thin cutting edge first, they could not be cut at all, but notched the shear blades immediately", Charles Wood (1894: 179). The above statements are self sufficient to prove the saliency of Indian iron being produced by the indigenous iron workers in their clay furnaces till the British period. It may be construed from the above accounts spanning over several centuries that India had a rich tradition of iron working from the early centuries before Common Era that lasted right up to the pre-modern times.

III.2

The ethnic communities still reside in the remote parts of Vindhyan and Chota Nagpur plateau passing through several states from Uttar Pradesh to Chhattishgarh, Jharkhand and Odisha. Studies conducted by Elwin (1942), Leuva (1963) in Jharkhand, Chattisgarh, Ghosh et al. (1964) in Bihar and Orissa, Prakash and Igaki (1984: 172-185) at Bastar in Madhya Pradesh, Vikash Bharati, Jharkhand (Sharma, 1998) and our own work in Wadruffnagar and Sonbhadra, Sidhi region, revealed an adherence to rituals related to iron working processes. Ghosh (op. cit.) studied the ancient iron making sites of Chiglabecha and Kamarjoda in Orissa and at Jiragora in Bihar. Our own observations of the iron working in Sonbhadra-Sidhi region in UP-MP border in Vindhya-Kaimur hills is quite revealing (see Plate 5b: Tripathi 2001 for details). The metallurgical expertise was preserved by the ethnic communities who had traditionally pursued it as a profession till the British times but due to a variety of reasons like several other Indian crafts metallurgy also succumbed to the adverse socio-political condition.

It should now be our duty to save our heritage in the field of metallurgy by trying to document the surviving tradition and if possible to save our cultural heritage by providing them the basic facility to produce iron in their age old way with the raw material that is rated economically un-viable by the modern industries.

References

1. Agrawala, R.C. & Vijay Kumar 1976. The Problem of PGW and Iron in north-eastern Rajasthan. Mahabharat Myth and Reality Differing Views S. P. Gupta and K.S. Ramchandran (Eds.) Delhi: Agam Prakashan, pp.241-244.
2. Balasubramaniam, R. 2008. Marvels of Indian Iron through the Ages. New Delhi: Rupa & Co. and Infinity Foundation Series.
3. Banerjee, M.N. 1927. On metals and metallurgy in ancient India – metallurgy in Rigveda. Indian Historical Quarterly 3(1-2): 121-33.
4. Banerjee, M.N. 1929. Iron and steel in Rigvedic age. Indian Historical Quarterly 5: 432-36.
5. Banerjee, M.N. 1932. A note on iron in Rigvedic age. Indian Historical Quarterly 8: 364-66.
6. Banerjee, N.R. 1965. The Iron Age in India. Delhi: Munshiram Manoharlal.
7. Bhardwaj, H.C. 1979. Aspects of Ancient Indian Technology. Varanasi: Motilal Banarasidass.
8. Biswas, A.K. 2001. Minerals and Metals in Pre-Modern India. New Delhi: D.K. Printworld.
9. Chakrabarti, D.K. and N. Lahiri 1994. The Iron Age in India: the beginning and consequence. Puratattva 24, pp. 12-23.
10. Chakrabarti, D.K. 1992. The Early Use of Iron in India. Delhi: Oxford University Press.
11. Charles, J.A. 1980. The coming of copper-base alloys and iron: a metallurgical sequence. In *The Coming of the Age of Iron* (Eds.) T.A. Wertime and J.D. Muhlly. New Haven, London: Yale University Press. Pp. 151-182.
12. Datta, A. 1992. Early stages of iron technology and the development of regional pattern in India. In *Man and his Culture: A Resurgence* (Ed.) Peter S. Bellwood, New Delhi: Books & Books, pp. 293-308.
13. De, S. and P.K. Chattopadhyay 1989. Iron objects from Pandurajar Dhibi: Archaeo-metallurgical studies. *Steel India*, A Biannual Technical Journal for the Iron and Steel Industry, 2(1): 33-41.
14. Deo, S.B. and A.P. Jamkhedkar 1982. *Excavations at Naikund*. Bombay: Department of Archaeology and Museums. Government of Maharashtra.
15. Deshpande, P.P., R.K. Mohanty and V.S. Shinde 2010. Metallographical Studies of a Steel Chisel found at Mahurajhari, Vidarbha, Maharashtra. *Current Science* 99(5): 636-639.
16. Dharampal 1971. *Indian Science and Technology in the 18th Century*. Hyderabad: Academy of Gandhian Studies.
17. Elwin, V. 1942. *The Agaria*. London: Oxford University Press.
18. Forbes, R. J. 1950. *Metallurgy in Antiquity*. Leiden: E.J. Brill.
19. Gaur, R.C. 1983. *Excavations at Atranjikhera*. New Delhi: Motilal Banarasidass.
20. Ghosh, M. K. 1964. 'Primitive Iron Making in Contemporary India', *Technical Journal*, Jamshedpur, Tata Iron and Steel Co. No. 2(3).
21. Ghosh, N. C. and P. K. Chattopadhyay 1987-88. The archaeological background and an iron sample from Hatigra. *Puratattva* 18: 21-27.
22. Goitein, S.D. 1966. *Studies in Islamic History and Institutions*. Leiden: E. J. Brill.
23. Gordon, D. H. 1950. The early use of metals in India and Pakistan. *Journal of the Royal Anthropological Institute* 80: 50-78.
24. Jayaswal, Vidula 2009. Antiquity of Varanasi as Revealed by Excavation at Aktha (2008-09), *Puratattva*, No. 39: 141-146.

25. Joshi, S. D. 1970. *History of Metal Founding on the Indian Subcontinent since Ancient Times*. Ranchi: Mrs. Sushila S. Joshi.
26. Krishnan, M. S. 1954. *Iron Ore, Iron and Steel*. Bulletins of the Geological Survey of India No. 9. Series A - Economic Geology, Delhi: Geological Survey of India.
27. Leuva, K. K. 1963. *The Asur*. New Delhi: Bhartiya Adimjati Sevak Sangh.
28. Lamberg-Karlovsky, C. C. and J. Humphries 1968. The cairn burials of South-eastern Iran. *East and West, New Series* 18(3-4): 269-76.
29. McCrindle, J. W. 1973. *Ancient India as Described by Ktesias The Knidian*. Delhi: Manohar Reprints.
30. Mc Donnel G. and R. Conningham 2007. The Metal objects and Metal Working Residues in Charsadda: The Brithish Pakistani Excavations at Bala Hisar, R. Conningham and Hasan Ali (eds.) : 151-159, BAR International Series 1709.
31. Niogi, P. 1914. *Iron in Ancient India*. Calcutta: Indian Association for Cultivation of Science.
32. Pleiner, R. 1971. The Problem of the Beginning Iron Age in India. *Acta Praehistoricaet Archaeologica* 2 : 5 –36.
33. Prakash, B. and K. Igaki 1984. Ancient iron making in Bastar district. *Indian Journal of History of Science* 19(2): 172-185.
34. Prakash, B. and V. Tripathi 1986. Iron technology in ancient India. *Metals and Materials*.(Sept. Issue):568-579.
35. Prakash, B. 1991. Metallurgy of iron and steel making and black smithy in ancient India. *Indian Journal of History of Science* 26(4): 351.
36. Prakash, B. 1997. Metals and metallurgy. *History of Science and Technology.* Vol. I. (Ed.) A.K. Bag. New Delhi: INSA. Pp. 80-174.
37. Roy, S.N. 1984. Early literary data on the use of iron in India. Paper presented in *World Archaeological Congress*. Southampton. U.K (typed copy).
38. Sahi, M. D. N. 1994. Excavation at Jakhera (Distt. Etah) – 1986-87, A Brief Report. *Aspects of Indian Archaeology*. Jaipur : Publications Scheme 139-153.
39. Sahi, M. D. N. 1979. Iron at Ahar. In *Essay in Indian Protohistory* (Eds.) D.P. Agrawal and D.K Chakrabarti. New Delhi: B.R. Publishing Company. Pp. 365-68.
40. Schoff, W. H. 1912. *The Periplus of the Erythrean Sea* (Translation). New York, London: Longman's Green & Co.
41. Sharma, A. K. 1992. Early iron users of Gufkral. In *New TrendsinIndianArtandArchaeology*I,(Eds.)B.U.Nayakand N.C.Ghose. New Delhi: Aditya Prakashan.Pp.63-68.
42. Sharma, Mahesh 1998. Report on Rural Iron Making Practiceat Bishunpur, SAIL, Ranchi.
43. Stein, A. 1929. *Archaeological Tour of Waziristan and Northern Baluchistan*. Delhi: Memoirs of ArchaeologicalSurvey of India No.37.
44. Tewari, Rakesh 2003. 'The Origin of Iron Working in India: New Evidence from the Central Ganga Plain and the Eastern Vindhyas' *Antiquity* 77, pp. 536 - 544.
45. Tewari, Rakesh 2010. Updates on the Antiquity of Iron in South Asia, Man and Environment, XXXV (2), 2010, pp.81-97.
46. Tewari, Rakesh, R.K. Shrivastava and K.K. Singh 2002. Excavations at Dadupur,: District Lucknow 1999-2000, Pragdhara12:99-116.
47. Tripathi, V. 1986. From copper to iron – a transition. *Puratattva* 15:75-79.
48. Tripathi, V.2001.*TheAgeofIron in SouthAsia: Legacy and Tradition*. New Delhi: Aryan Books International.
49. Tripathi, V. and A. Tripathi. 1994. Iron working in ancient India: an ethno-archaeological study. In *From Sumer to Meluhha*. Wisconsin Archaeological Report, Vol. 3, (Ed.) J.M.Kenoyer.Wisconsin.Madison.Pp.241-251.
50. Tripathi, V. 2008. *History of Iron Technology in India (From Beginning to Pre-modern Time)*. New Delhi: Rupa & Co. and Infinity Foundation Series.
51. Tylecote, R.F. 1980. Furnaces, crucibles and slag. In *The Coming of the Age of Iron*. (Eds.) T.A. Wertime and James D. Muhly. New Haven, London Yale University Press. pp. 183-228.
52. Wertime, T. A. 1980. The pyrotechnologic background. In *The Coming of the Age of Iron*. (Eds.) T. A. Wertime and JamesD.Muhly.NewHaven,London:YaleUniversityPress. Pp.1-24.
53. Wood, C. 1894. 'Discussion' *Journal of the Iron and Steel Institute*. XLIV:179.

Table 1: Radiocarbon Dates from Iron Age Level

Sl. No.	Sites	Radiocarbon dates in BP/BC on the basis of half life 5730 ± 40 years	Calibrated
Raja Nal - Ka –Tila			
1.	BS-1378 1996-97 Trench No. U - 19 (6) 1.95-2.00#m with iron	2626±110 BP 676±110 BC	822 (773) 486 BC
2.	PRL - 2047 1996-97 Trench No. U-20 (6) 2.08-2.10#m with iron	2980±90 BP 1030±90 BC	1196 BC-1188 BC -1164 BC-1143 BC -1132 BC-976 BC -970 BC-930 BC

Continued to next page

3.	BS – 1299 1995-96 Trench No. A-l Pit sealed by layer No. (6) with iron	2914 ± 100 BP 960 ± 100 BC	1118 (963) 859 BC
4.	BS – 1300 1995-96 Trench No. A-l (6) 2.00#m with iron	3150 ± 110 BP 1200 ± 110 BC	1423 (1307) 1144 BC
5.	PRL-2049 1996-97 Trench No. T-19 (6) 2.00#m with iron	3150 ± 90 BP 1200± 90 BC	1406 BC -1198 BC 1186 BC-1164 BC 1143 BC-1132 BC

Malhar

6.	BS - 1623, MLR II Trench No. XAl, Layer No. (3) Depth 0.55 cm	3550 ± 90	1886, 1664 1649, 1643 BC
7.	BS - 1593, MLR II Trench No. Al, Layer No. (3) Depth 90-100 cm	3650 ± 90	2010, 2001, 1977, 1750 BC
8.	BS-1590 MLR II Layer No. (4) 80 cm	3850 ± 80	2283, 2248, 2233, 2030 BC

Dadupur

9.	BS-1822 Trench No. DDR-3, A -1	3368 ± 80 BP 1420 ± 80 BC	1679 (1522) 1422 BC
10.	BS-1759 Trench No. DDR-3, A-1	3480 ± 160 BP 1530 ± 160 BC	1882 (1685) 1465 BC
11.	BS-1825 (Pit sealed by (12)	3532 ± 90 BP 1580 ± 90 BC	1739, 1706, 1695 BC

Lhuradewa

12.	BS-1939	2940 ± 100 BP	1205, 1205, 1188

Jhunsi

13.	AU/JHS/ 9 2075C-15 (46) 1210	2730 ± 90	897 (806) 789 BC
14.	AU/JHS/ 12 2077C-15 (49) 1240	2900 ± 90	1107 (973, 956, 941) 844 BC
15.	AU/JHS/ 16 2081C-15 (53) 1325	2780 ± 90	966 (830) 799 BC
16.	AU/JHS/ 18 2083C-15 (62) 1520	3290 ± 90	1597 (1490, 480, 1450) 1400 BC

Continued to next page

Aktha

17.	S - 3580	3350 ± 160 1660 ± 218	Un calibrated
18.	S - 3849	3460 ± 180 1771 ± 248	Un calibrated

Komaranhalli, Karnataka

19.	PRL - 46 (TL)	1320 ± 400	----------------
20.	PRL - 47 (TL)	1380 ± 300	----------------
21.	PRL - 47 (TL)	1200 ± 280	----------------
22.	PRL - 49 (TL)	1130 ± 500	----------------
23.	PRL - 50 (TL)	1440 ± 290	----------------

Hallur, Karnataka

24.	TF - 570 (14C)	2970 + 105 BP 1385 - 1050 BC	----------------
25.	TF - 573 (14C)	2820 + 100 BP 1125 - 825 BC	----------------

Veerapuram, Andhra Pradesh

26.	PRL - 729 (^{14}C)	----------------	1374 (1186, 1183, 1128) 921
27.	PRL - 729 (^{14}C)	----------------	1293 (1047) 899
28.	PRL - 730 (^{14}C)	----------------	1679 (1493, 1476, 1458) 1319

Vidarbha, Maharashtra

29.	PRL - 1361 (^{14}C)	2940 ± 160	1393 (1205, 1205, 1188, 1181, 1149, 1144, 1129) 917
30.	PRL - 1452 (^{14}C)	3080 ± 120	1490 (1381, 1334, 1321) 1131
31.	PRL - 1456 (^{14}C)	2820 ± 100	1185 (973, 956, 941) 834

Gufkral, Jammu & Kashmir

32.	----------------	----------------	1888 -1674
33.	----------------	----------------	2195 -1900

Charsadda, Pakistan

34.	----------------	----------------	1200 - 900

Table 2: Iron Objects at Different Cultural Stages

TOOL TYPES	NAME OF TOOLS	EARLY STAGE	MIDDILE STAGE	LATE STAGE
Hunting Tools	Spear heads	*	*	*
	Arrow heads	*	*	*
	Points	*	o	o
	Socketed tangs	*	o	o
	Blades	*	*	o
	Spear lances	o	*	o
	Dagger	o	*	*
	Sword	o	*	*
	Elephant goad	o	*	*
	Lances	×	×	*
	Armour	×	×	*
	Helmet	×	×	*
	Horse bits	×	×	*
	Caltrop	o	o	*
Agricultural Tools	Axes	*	*	*
	Sickles	*	*	*
	Spade	×	*	o
	Ploughshare	×	*	o
	Hoe	×	*	*
	Pick	o	o	*
Household objects	Knives	*	*	*
	Tongs	*	o	o
	Discs	×	*	o
	Rings	×	*	o
	Spoons	×	*	*
	Sieve	×	×	*
	Cauldron	×	×	*
	Bowls	×	×	*
	Dishes	×	×	*
Structural and craft tools	Rods	*	o	o
	Pins	*	o	o
	Nails	*	*	*
	Clamps	*	*	*
	Chisel	×	*	*
	Pipes	×	*	o
	Sockets	×	*	o
	Plump bob	×	*	o
	Chains	×	*	*
	Door hooks	×	*	*
	Door handle	×	×	*
	Hinges	×	×	*
	Spikes	×	×	*
	Tweezers	×	×	*
	Anvils	×	×	*
	Hammers	×	×	*
	Scissors	×	×	*
	Saw	×	×	*

Definite existence – * Confirmed data not available – o Non-existence – ×

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