CHAPTER 6

TECHNOLOGY OF IRON AND ITS IMPACT ON EARLY HISTORIC GUJARAT

Artefacts are studied as a source of information for understanding socio-cultural phenomena such as technology, economy, settlement pattern, social organisation and religion of various people in antiquity. This chapter reconstructs the salient features of iron technology and various stages of its developments in Early Historic Gujarat. It also attempts to review the socio-economic impact of iron on the Early Historic society.

Based on relative chronology, the Early Historic Period of Gujarat is divided into two phases (refer Chapter IV), namely, Phase I- 400 BC to 100 AD and Phase II- 100 AD to 500 AD. Phase I – indicates the early occurrence of iron in Gujarat in association with Black-and-Red Ware in the pre-NBPW context, followed by the slow and gradual acquisition of mastery over it. The early date of occurrence of iron in this region may be tentatively assigned to 400 BC based on the evidences from Nagara, Nagal, Bharuch and Timbarva. This dating is very tentative as it depends upon the precise context of NBPW levels. The NBPW levels of these peripheral areas (the nuclear region of this ware being the Gangetic Valley) generally belong to the late phase (400-300 BC). Hence, the antecedent iron bearing levels at the sites are dated prior to 400 BC and tentatively 500 BC. Before getting into the Early Historic scenario of Gujarat in which iron occurred at
different periods and its socio-economic impact on Early Historic cultural system, it is pertinent to understand the iron technology on the basis of various results.

To begin with, the typological analysis of iron objects from the aforesaid phases indicate that the iron artefact assemblage comprised of tools for agriculture, hunting, household objects and craft activity. Besides this, a few iron ornaments were also observed. During the initial phase, the number of tools and its variety was less. The lower levels of this phase yielded arrowheads, spearheads and ploughshares (from Timbarva and Dhatva). A gradual increase in number of tools was observed towards the later levels of this phase. The initial levels of Phase II are marked by a variety of tool types in substantial quantity. Towards the middle of this phase, tools of special purpose such as sickles, chisels, daggers and nails along with the types yielded in the earlier levels appear. This probably signals multiple activity during this period, namely, agriculture, hunting and craft (bead making, carpentry etc). The evidence of craft activities is indicated by the presence of large number of beads (of semiprecious stones, glass, crystals, bones, terracotta etc.) and shell bangles. Towards the later levels of this phase, a considerable increase in the number of iron implements of various functions is observed.

On the basis of chemical analysis of iron objects from the chosen Early Historic sites in Gujarat, it is understood that the main impurities present in the iron objects are silica, aluminium, calcium, magnesium, sulphur and phosphorous (Table: 5.4). These impurities are present in the ores and might have passed into the metal while smelting. Silica is present in all the samples in fairly high quantity except in the Devnimori specimens where it
is absent. All the samples reveal the absence of titanium (Table: 5.4). This clearly shows that titaniferrous ores were not used for the extraction of metal.

Nickel is absent in the samples from lower levels of Nagara. The same is observed in all samples from Shamalaji and Devnimori. The iron specimens from later levels of Nagara and Timbarva showed negligible amounts of nickel. The lesser amount of silica present in few samples clearly indicates that these objects were made of iron extracted by the smelting of an ore and not from meteoric iron. The percentage of silica varies from 1.1% to 3.05% (Table: 5.4). The silica content is high (3.05%) in a few samples from Nagara. These samples also had thick siliceous coatings. Even though the samples for analysis were taken by drilling, some amount of silica might have made its way into the sample analysed. Shamalaji samples have relatively low content of silica (1.01% to 1.5%). Devnimori samples are completely devoid of silica. The percentage of alumina in the specimens, as a whole, ranges from 0.01% to 1.73% (Table: 5.4). Few specimens from Nagara showed low concentration of alumina. The amount of Phosphorus in the samples ranges from 0.01% to 0.18%. Sample numbers 1, 4, 7 and 11 (all from Nagara) showed high phosphorus content. The percentage of sulphur was found to be varying from 0.01% to 0.16%. Sample numbers 1, 7 and 8 (all from Nagara) showed low content of sulphur. The amount of calcium is high for samples from Nagara (0.30% to 0.79%) and relatively high in samples from Timbarva (0.41% to 0.58%)(Chart: 6.1). Generally, the amount of calcium is high in most of the objects except few objects from Shamalaji II (Chart: 6.1) (0.01% to 0.02%) and all objects from Devnimori (0.10% to 0.13%) (Chart: 6.2). The high percentage of calcium in the specimens is not enough to propose its use as a flux. Although the
calcium contents in the earlier samples are slightly higher compared to the later period specimens, it is not possible to assume the use of lime as flux. Fluxes are added for lowering the melting point of the slag so that the slag is cleanly removed. The microstructures of the metal specimens analysed from early levels revealed appreciable amount of slag in many of them. This indicates that during the initial phase of settlement in Gujarat the blacksmiths were not familiar with the use of flux to produce good quality objects.

As mentioned earlier, samples from earlier levels of Nagara and Timbarva revealed high amount of slag inclusions in its microstructure (Plate: 5.14). Those specimen from Nagara III and late levels of Shamalaji and Devnimori showed decrease in slag inclusions (Plate: 5.18). Shamalaji also indicated relatively same amount of slag inclusions like Nagara (Plate : 5.24). When it came to the Devnimori Early Historic levels, the slag content in samples is nearly nullified (Plate: 5.35).

The aforesaid evidences clearly show that in the early stage, the blacksmiths were not in a position to remove or separate out the slag inclusions from the metal to a great extent. Possibly, the blacksmiths could not achieve high temperature for the removal of slag completely from the bloom or did not use a flux for the same during smelting in the initial stages. Due to these reasons, the slag was left out in the bloom, from where it passed into the object. To some extent, the slag inclusions are removed while forging it in red-hot condition. This process of working on iron (hot working) is featured in the microstructures of early specimens (Plate: 5.7). This inference is further supported by the evidence of uniform distribution of the slag inclusion in the early specimens (Plate: 5.1).
The carbon content in the objects of earlier period is less. From the chemical and metallographic analyses, it appears that the objects from early levels of Nagara and Timbarva were made of wrought iron (carbon content less than 0.1%). (Chart: 6.3) The uniform distribution of slag inclusion throughout the ferrite matrix is the distinctive feature of wrought iron (Plate: 5.1).

It can be thus inferred that smelting in the early levels was rudimentary. Also, it implies that the iron technology in the initial phase of Early Historic Period (400 BC-100 AD) was in its incipient stage. Tylecote (1980:209) suggested that the presence of high amount of slag in the metal indicates its direct extraction by bloomery process. The same method could have been adopted by the blacksmiths of Gujarat during this phase.

The percentage of impurities such as sulphur and phosphorus remained almost the same (Table 5.4) throughout the periods. There is a relative reduction in the amount of silica throughout the periods. For example, in the initial period it is 3.02% to 1.81% (Chart: 6.1) and during final stage it became 1.1% (Chart: 6.2). But it is absent in Devnimori samples. This indicates the advanced ore dressing methods adopted prior to smelting in later periods. Almost all the specimens, including those from early and late levels of Nagara, Timbarva, and Shamalaji show relatively low amount of copper ranging from 0.01% to 0.4%. But in the case of Devnimori samples, copper is absent. (Chart: 6.2) This probably suggests that at Devnimori the smiths were either capable of eliminating impurities effectively from passing into the object while smelting as well as in fabrication or used a different ore deposit. The almost complete removal of slag and elimination of impurities from the bloom in Devnimori clearly indicate that the
blacksmiths here had sufficient infrastructure to achieve and maintain high temperature in the furnace so as to enable the removal of impurities and other inclusions.

In the late levels of Phase I, specimens, especially those from Shamalaji, reveal an increase in carbon content 0.41 to 0.61% (Chart: 6.3). The microstructures (Plate: 5.4) indicated that the surface area of the nails and the working edge of knife and spearhead are carburised. The inner area shows less carbon content. This indicates preferential carburisation of the object. It can be noted that the blacksmith was aware of the properties that can add strength to an object through carburisation.

But at the same time, it may be noted that the later specimens from Devnimori showed low carbon content (0.14 to 0.16%), which implies that they were made of mild steel. (Chart: 6.5). The nails and sickle analysed from Devnimori showed 0.15% to 0.16% of carbon. Etched sections of the nails and sickle (Plate: 5.4) revealed features of case hardening.

Coming to iron content, it was observed that the Nagara samples contained less iron and its amount varied from 54.3 % to 67.57%. The samples from Devnimori (Chart: 6.4 and Chart: 6.6) showed higher amount of iron (98 % to 99.01 %). However, the high purity of iron at Devnimori specimens indicate that the metal extraction technique employed at the same place was more efficient than the other places.

Ferrite is the major constituent of all the samples. Due to the heavy corrosive state, samples from Nagara and Timbarva were completely mineralised and revealed relic carbide structures (Plate: 5.6). But from the
chemical analysis, it became clear that the object is made of steel. Objects belonging to late levels show a structure, which is mixture of ferrite and pearlite (Plate: 5.34). The pitting due to corrosion is very severe in Nagara I, II and Timbarva II and III level samples. The pitting and corrosion products remain a common feature in all the later samples, though in a comparatively lesser percentage (Plate: 5.3). In the case of Devnimori specimens, the corrosion is not observable to any great degree (Plate: 5.38). As mentioned earlier, Devnimori samples are relatively purer having high iron content and are completely devoid of slag inclusions. Samples from late levels of Shamalaji and those from Devnimori show equiaxed pearlite structure with ferrite grain boundaries (Plate: 5.35).

Samples from Nagara, Timbarva and Shamalaji show irregular flow-like patterns (Plate: 5.7). They are due to cold working. There are bands of relic carbide along with slag and corrosion products and are visible in Nagara II samples. The alternative metal and slag rich areas are visible in few samples from Nagara, Timbarva and Shamalaji (Plate: 5.8) and is due to hot working. Most of the samples from Nagara (except those from early layers), few from Timbarva II, and those from Shamalaji revealed surface carburisation (Plate: 5.4). The surface, as in the case of nails or the working edges in case of sickle, spear head, dagger etc. were hardened either by carburisation or case hardening. Few of the Nagara II objects are made of wrought iron and later on to enhance their property, they were case hardened. These samples highlight deliberate introduction of carbon into the object (deliberate steeling) to strengthen it and increase its properties. Blacksmiths would have had no reason to make such objects unless they understood the properties, which such processes can impart to the object. Most of the samples from Nagara III and Shamalaji II showed strips of
alternate ferrite and cementite areas (Plate: 5.11). High and low carbon strips are seen arranged alternately. One sheet is carburised whereas the other is not. These strips of iron were piled alternately and forge-welded together to slabs having requisite ductility (of wrought iron) and hardness (of carburised iron). Later on, these piles could be heated, hammered and folded during the fabrication of the artefacts (Agrawal et.al. 1980-81: 99). This type of strengthening of the object is known as lamination technique. Microstructure of the aforesaid laminated specimens clearly showed visible welding joints, continuous strips of slag inclusion and sudden change in carbon content.

The microstructural studies of contemporary blacksmith’s and tribal samples revealed some interesting features. The microstructures of traditional blacksmithy and tribal samples show similarity with microstructural features of Devnimori samples. The equiaxed ferrite structures (which develop under normal cooling conditions) with Widmanstatten features (which develop due to quenching) in contemporary ladle, pure ferrite areas in the tribal arrowhead and the elongated forged features in contemporary Angle are similar to those seen in Devinimori samples. This can be taken as an indication of similarity in fabrication technique and implies that Devnimori smiths may have achieved similar working practices as those practiced by present day traditional blacksmiths. Hegde (1973) had proposed a continuity in the techniques of smelting iron-ore practiced by ancient iron smelters and those prevalent among present iron working communities such as Loharias. In the present case, no conclusions regarding smelting can be drawn as the communities studied do not smelt iron at all. However, the similarities in the microstructure which
results due to the fabrication techniques is significant as it validates inferences drawn regarding the early historic production techniques (Chapter V).

These then, are the salient features of the iron technology of the Early Historic period as revealed from the metallurgical and chemical analyses and ethnographic study. With this background of iron technology, it would be interesting to relate the findings with the material and artefactual assemblage of the sites to draw some inferences about the effect of iron technology on the socio-economic condition of the time and vice versa.

There is a lot of uncertainty with regard to the archaeological and historical data during the Early Historic Phase I, which shows the introduction and gradual conquest of iron. As mentioned in Chapter V, the Early Historic period of Gujarat is authentically recorded after 300 BC. Archaeological scenario of the pre-Mauryan period of Gujarat is not yet clear. We have literary records mentioning Kutch and Saurashtra. Even though legends and traditions talk about the existence of Yadavas in Gujarat, no archaeological or historical evidence is available to support this (Bhowmik 1980:17). Panini in his *Astadhyayi* mentions that Kachcha represents waterlogged portions in south against the dry desert area in the north (Agrawala 1953: 51). Kachcha was historically connected with Sindh as its province during Hsuan Tsang’s visit to India in the 7th century BC (Majumdar 1960: 25). While discussing corporations of guilds of warriors, Kautilya mentions that corporations of warriors of Kamboja and Saurashtra lived by agriculture, trade and wielding of iron weapons. He further mentions ‘Surashtriyas’ as a Republic and the people of Saurashtra as mostly known as group of agriculturists, traders and warriors The aforesaid references clearly point to
the fact that during pre-Mauryan period, Saurashtra was a Republic. Rajgor (1996: 95) believes that a large number of silver punch-marked coins reported from Junagadh perhaps throws light on the existence of a pre-Mauryan Republic (Janapada) in Saurashtra. He further postulated its date to around 450-300 BC.

The early levels of Early Historic phase from Dhatva (Mehta et.al. 1957), Nagal (IAR 1957-58), Bharuch (IAR 1958-59), Timbarva (Mehta 1955), Nagara (Mehta and Shah 1968), Vadnagar (IAR 1953-53), Prabhas Patan (IAR 1971-72) and Dwaraka (IAR 1979-80) are assigned a date from 500 BC to 300 BC. Hence, these levels may be considered as pre-Mauryan levels. However, the paucity of archaeological evidences makes it difficult to comment on the society of this period. But the occurrence of punch-marked coins (Rajgor 1996: 95) postulates the prevalence of money economy during the pre-Mauryan period. The iron objects from Early Historic Phase I (400 BC- 100 AD) comprise of arrowhead from Nagal; blades (broken part of knife), Ploughshare from Dhatva; fishhook from Prabhas Patan and chisel, arrowhead and spearhead from Nagara. Analysis of these early phase tools shows that technology was in its incipient stage. But the late levels of Phase I indicate the beginning of shell industry at Prabhas Patan, Nagara and Vadnagar; bead industry at Bharuch, and iron smelting at Dhatva and Prabhas Patan. The significant features of early phase in association with NBPW context are the ring wells from Bharuch and mud walls from Timbarva. Late levels of Phase I showed occurrence of a rampart at Nagara and fortification at Prabhas Patan. The occurrence of crystal beads, carnelian beads punch-marked coins, lead ornaments, shell bangles, bone points and variety of terracotta objects indicate craft diversification. The occurrence of specialized tools such as chisels indicate
lapidary work whereas arrowheads and spearheads indicate hunting and defense. Iron is found in all the layers, except the lowest two layers of Phase I. Bone points, arrowheads, and beads of carnelian and semi-precious stones are found throughout.

The presence of ploughshare in Phase I, at Timbarva and Dhatva (both village settlements), indicate agriculture. The absence of iron plough of Early Historic contexts from other parts of Gujarat till date indicates that wooden plough might have been used for ploughing (Dhavalikar and Possehl 1974: 34-46). Aiyer (1966: 337-338) observes the use of wooden plough as a tillage implement in black cotton soil tracts (Aiyer 1966: 337-338). Agriculture was the mainstay of life and the main crop harvested was rice. This is substantiated by the presence of rice sticking to the potsherds and bricks evidenced from Dhatva (Mehta et.al. 1975) and rice, kodra and math recorded from Nagara. Faunal remains from Dhatva, further substantiate that the economy of the people of this region depended heavily upon farming and cattle breeding/animal husbandry (Mehta and Shah 1968).

Structural evidence helps to rate the degree of economic prosperity. The main categories of structural evidences are: a) mud flooring, b) wattle and daub structures (Mehta 1955: 27) c) houses built of stone (Rao 1966: 30-34), burnt/baked bricks (Mehta and Shah 1968: 20-33), d) earthen embankments; e) mud walls and f) monastic complex settlement (Mehta et.al. 1966: 32-66). To draw a complete picture of Early Historic habitations on the basis of scanty data provided by limited excavated remains is difficult. Hence, the interpretation of Early Historic settlements and their functional aspects poses serious limitations.
Period III of Nagara indicated diversification of craft activities represented by bead industry of semiprecious stones, glass, terracotta; chank industry, glass industry etc. The diversification of craft activities clearly indicates the role played by iron technology for craft diversity. The usage of iron implements for the craft production accentuated various occupational groups such as smiths, carpenters, makers of bone objects, workers of semi-precious stones and agriculturists.

In the earlier days barter system preceded punch marked coins for transaction. At a later stage large number of Kshatrap and Gupta coins made of silver as well indicate a stable economy. To assess the socio-economic status of the respective sites, the civic features proposed by Soundararajan (1984: 59) such as rampart, stone and burnt brick structure, drain, kiln, roads, public structure, trade elements, coinage, reservoirs, exotic objects, craft expertise, horse/cart, script were looked for. Based on these parameters and the material testimony of each excavated site, (refer Chapter IV) Nagara, Amreli, Prabhas Patan, Dwaraka, Vadnagar, Shamalaji, Devnimori, Bharuch, Nagal and Karvan arbitrarily suggest to have been urban centres.

Phase II at these sites on the whole indicates profuse use of iron along with diversification of craft activities, elements of foreign trade such as Roman Amphorae, Red Polished Ware, development of urban settlements, fortification, brick structural remains, monumental buildings and development of religion. The iron objects in this phase, comprise of spearhead, arrowhead, sickle, nails, daggers, fish hooks, rings, trowel, knife, chisels, horse bit and rod. In all the excavated sites, iron
encompassed a wider range of activity. Apart from hunting, crafts of smith, carpenter and the house builder are indicated in the cultural assemblage. The tools of specialized nature, namely, sickle (Plate: 5.32) and dagger (Plate: 5.10) started appearing in this phase. It may be observed that, iron was also used for making working tools. Small amounts of copper objects, namely, kohlstick, bangles, wire, rings etc are also encountered in this phase. The large amount of slag deposits at different sites indicates the local manufacture of iron objects. Thus, the impact of iron on different spheres of activities might have also contributed to the urbanization in this region. The diversification of craft activities, glass manufacture etc. might have become possible and easy by the use of various iron tools and objects.
Chart: 6.1 Content of Other Elements in Iron Objects of Early Historic Phase I

Chart: 6.2 Content of Other Elements in Iron Objects of Early Historic Phase II
Chart: 6.3 Carbon Content of Iron Objects from Early Historic Phase I

Chart: 6.4 Fe Content of Iron Objects of Early Historic Phase I
Chart: 6.5 Carbon Content of Iron Objects of Early Historic Phase II

Chart: 6.6 Fe Content of Iron Objects of Early Historic Phase II