Metals define the technological and economic character of the urban era as stone defines the character of the millennia during which Stone Age people first tried to shape tools by hammering or cutting rocks. Ancient metal technology stands as one of the greatest achievements of mankind. The study of metal artefacts to infer the metallurgical techniques used in ancient times forms an important part of the archaeologist’s quest for knowledge about age-old technological practices.

Iron is symbolically designated as “Fe” (derived from the Latin word *Ferrum*). Being one of the widely used metals in the world, it is best known for its physical and chemical properties, use as a high-strength structural material and for steel manufacturing. The discovery and use of iron by man come last in the inventory of the basic metals, as it does after copper, tin, lead and many of their alloys and it marked one of the greatest milestones in his progress (Chakrabarti 1976: 114-124). The juxtaposition of a common commodity whose production and processing often incorporates great technical sophistication to bring out properties far in advance of any other material makes its history, perhaps, most interesting of all metals and is very true in the case of iron (Craddock 1995: 234).

Excavations at Atranjikhera (Gaur 1983) and Hallur (Nagaraja Rao 1971) have brought to light the earliest iron objects in India dated by radiocarbon to 11th and 9th centuries BC respectively. A plethora of iron objects have been unearthed from several other sites in India reflecting its wide spread use from Early Historic period onwards. In northern India, the earliest iron
was reported from Ahicchatra, Atranjikhera (Gaur 1983), Hastinapur (Lal 1955) and Kausambi (Sharma 1960) in association with Painted Grey Ware Culture (PGW), dated between c.1100-700 BC. Chirand, Mahisdal and Pandu Rajar Dhibi (Tripathi 1990) in eastern India have yielded iron in pre-Northern Black Polished Ware (NBPW) context with Black and Red Ware dated to c.700 BC. (Agarwal 1984). A remarkable continuity from Chalcolithic stage to iron producing stage is observed at Nagda, Eran, Prakash, Bahal and Ujjain in Central India and Deccan where iron is found in pre-NBPW layers, suggesting its beginning by around 1100 BC. In northern Deccan, the pre-NBPW sites from where iron is obtained are Prakash (Thapar 1964-65) and Bahal. In southern India, it has been reported from the Neolithic-Megalithic phase at Hallur (Nagaraja Rao 1971) dated to 1000 BC. In western India, the iron working has been traced to Chalcolithic milieu. The scenario here is little confusing as iron is found in quite an early Chalcolithic context at Ahar but its ramifications are not yet archaeologically understood. Jodhpura and Noh in Rajasthan yielded iron in PGW and Black-and-Red Ware level respectively (Agrawala and Kumar 1976). Early iron has been reported from pre-NBPW phase along with Black-and-Red Ware of Somnath-III, Nagar-I and Timbarva-I in Gujarat. NBPW levels of these areas generally belong to a late phase (450-300 BC.). Roy (1986) has placed the iron bearing pre-NBPW levels of these sites between c.700-600 BC. The aforesaid discoveries indicate that at various localities in India occurrence of iron in association with different cultural phases had become fairly common.

The origin of iron in the sub-continent has been variously ascribed by different scholars to Asia Minor (Allchin and Allchin 1968), Aryans (Lallanji Gopal 1960), PGW Culture (Banerjee 1965) and Black-and-Red
Ware Culture (Subrahmanyam 1966). However, these studies were concerned mainly with the antiquity of metal based on the narrow perspective of its archaeological occurrences, conventional categorization and classification. Their works did not deal with the regional characteristics of iron implements in terms of technological, socio-economic implications. In subsequent years, data regarding Iron Age from different regions and periods were subjected to compositional and technological analyses by Hadfield (1912, 1925), Athavale (1967), Prakash and Singh (1968), Bharadwaj (1973), Hegde (1973 a&b), Gaur (1983), Gogte (1982), Rao (1987), Chattopadhyaya and Ghosh (1982), and Chattopadhyaya and De (1989), and socio-economic studies by Sharma (1966), Tripathi (1976, 1990), Lal (1986), Chakrabarti (1985), Ahmed (1991) and Singh (1991). However, these later works concentrated on any one aspect, thus lacking a holistic approach. This thesis is an attempt to overcome the above mentioned lacunae by applying an integrated approach towards a thorough understanding of metallurgical processes and associated socio-economical aspects in the context of Early Historic period of Gujarat. The scope of the study lies in extending such an approach to other regions and periods, which would allow inter-regional and inter-period correlation to provide answers regarding the antiquity and evolution of iron technology in India.

The objectives of this present work are:

1. To assess the geological setting, chronology and material testimony of the Early Historic sites yielding iron in Gujarat.

2. To classify iron objects from these sites on the basis of their morphology and probable function.
3. To analyse the typology of the iron objects to know the major types and their distribution in different sites.

4. To undertake chemical and metallographic analyses of iron implements with a view
   a) To know chemical composition of the object to understand the nature of the iron in terms of its purity and percentage of alloying element.
   b) To understand the microstructure of the objects to know technology that is, methods of production, heat treatment etc.
   c) To infer the changes in production technology with regard to its Typology.

5. To assess how reliable these metal types are for establishing cultural and economic aspects of this region.

6. To study the traditional iron working practices and observe the resultant microstructure.

7. Finally to appreciate the role-played by iron technology in the development of Early Historic communities in Gujarat.

General Outline of the Thesis

Chapter 1 - Introduction: This chapter begins with a discussion on the importance of iron as a metal, its advent in the Indian sub-continent, its cultural affiliation both in space and time. It includes a brief literature survey pertaining to theories of antiquity of iron in India and various type of work done in the field earlier. This is followed by the problem of the
thesis, its nature and enumerating the aims and objectives and the methodology adopted for the study.

Chapter 2 - Understanding “Iron”: This chapter introduces iron as a metal, types of its ores, their distribution in the Indian sub-continent, its properties, Iron-Carbon equilibrium, alloys of iron, present day extraction of iron, pre-industrial iron working in India and special reference to Gujarat and practices of contemporary blacksmithery.

Chapter 3 - Materials and Methods: This chapter deals with the classification of iron artefacts found from Early Historic sites in Gujarat based on the morphological and functional aspects. This is followed by a detailed discussion on various analytical methods, namely; metallography, wet chemical analysis and spectroscopy of both the archaeological artefacts and samples from contemporary blacksmiths.

Chapter 4 - Archaeology of Early Historic Gujarat: This chapter presents physiography of the region, archaeological and chronological background of Early Historic period, brief summery of excavated sites Early Historic sites in Gujarat followed by their material testimony. It also includes reconstruction of a relative chronology for Early Historic sites in Gujarat.

Chapter 5 - Results: The results obtained from various analytical methods mentioned in Chapter 3 are outlined here. This includes the results of typological, compositional and metallographic (microstructural features) analyses. It also elucidates the results of ethnographic survey done on contemporary blacksmiths.
Chapter 6 - Technology of Iron and Its Impact on Early Historic Gujarat: This chapter reconstructs the salient features of iron technology and its development in Early Historic period. An attempt is also made to throw to light on the possible socio-economic impact of iron on Early Historic society.

Chapter 7 - Conclusion: A gist of the major aims and objectives of the study, the methods adopted for the same and the major results are discussed in this part of the thesis.
Statement I

(Statement showing the particulars on which the work is based, the discovery of new facts and of new relationships between the facts observed by others and how the work tends to help the general advancement of knowledge).

Various scholars have studied iron objects from Early Historic and Megalithic periods. Athavale (1967), Bharadwaj (1973), Hegde (1973 a&b), Gogte (1982), Chattopadhyaya and De (1989) emphasized on the analytical and metallographie studies while socio-economic aspects have been investigated by Sharma (1974), Tripathi (1976, 1990), Lal (1986), Chakrabarti (1985) Ahmed (1991) and Singh (1991). These studies have tended to concentrate on either one or the other aspect, thus, lacking a holistic approach. In addition to this, it appeared that no detailed investigation was carried out on iron objects from Early Historic Gujarat, though this region had yielded substantial amount of the same.

This thesis is an attempt to overcome the above discrepancies by adopting an integrated approach towards thorough understanding of metallurgical processes and associated cultural aspects in the limited context of Early Historic period of Gujarat. This study deals with the analytical and metallographie aspects of iron objects recovered from sites of Early Historic period of Gujarat emphasizing on typology, functionality, metallurgy, technology and socio-economic significance of the metal. The
study has been carried out using materials recovered from various sites excavated by M.S. University of Baroda.

In order to reconstruct the various stages involved in the extraction and fabrication techniques involved production of iron objects, a detailed investigation of representative iron specimen from excavated sites of Timbarva, Dhatva, Nagara, Shamalaji and Devnimori is attempted in this thesis.

The thesis, thus, adds a detailed information to our existing knowledge on the following aspects:

1. Typological studies elucidate different types of iron objects and their probable function. The objects from Early Historic sites fall under the categories of arrowheads, knives, chisels, axes, sockets, nails and rings. Few sickles and daggers were also present.

2. The varying typology of artefacts signals a wider range of activities. Apart from hunting, objects representing utilitarian activities such as carpentry, building and warfare are also present. The types of iron objects in the earlier phases were mostly meant for agricultural and household activities. During the course of time, along with these objects serving above purposes, objects of warfare and building activities also appeared.

3. A comparative study of the composition of Early Historic objects of this region resulted in identifying slow decrease in the percentage of
4. The composition analyses further revealed that cobalt and nickel were absent in the objects, thus, ruling out the possibility of using meteoritic iron as a source of raw material.

5. The study revealed the percentage composition of metal objects and their purity. Out of these, while the objects of the earlier phase showed less amount of carbon. In the later stage of phase I showed high carbon content which continued in the phase II indicates advancement in technology.

6. The microstructure of the objects belonging to the earlier phase revealed mostly ferritic features and at times, together with relic pearlite. The later phase objects revealed pearlite and ferrite structure.

7. The presence of slag in the objects indicates that iron must have been extracted by the bloomery process and not from the pig iron. Specimens from the early levels of the excavated sites revealed large amount of slag inclusions. The earlier level specimens showed comparatively high impurity concentration to that of later phase. This indicates the infant stage of technology.

8. The study has brought to light the different smithery techniques such as lamination and carburisation that helps to understand the fabrication techniques of ancient iron objects. The objects of later period, which
might have been used for agriculture and warfare are produced by these advanced methods so as to get the proper sharpness and hardness.

9. It was observed that microstructure of some objects showed rolled features, which clearly explains the tool making activities, such as forging and hammering.

10. The ethnographic work helped to understand the forging technique, heat treatment and other fabrication techniques carried out during tool production. Ethnographic survey formed the base to understand the ancient metal working techniques in a better manner.

11. The ethnographic work throw light on the Lohar community and the Bhil tribal community which still depends on black smithy for their livelihood, types of objects they produce and mode of marketing.
Statement II

(Statement indicating the sources of information and extent to which the thesis is based on the works of the others and portion of the thesis claimed as original)

The chief sources of information for this study are the published reports of excavation of sites, namely, Dwaraka, Somnath, Amreli, Nagara, Shamalaji, Devnimori, Vadnagar, Dhatva and Timbarva. The reports of other sites are unpublished and hence, information pertaining to those is based on personal communication with the excavators. Published data on the chemical analyses of various sites have also been cited in the thesis.

The major references for the study is:

Agrawal, D.P. 1984 Archaeology of India. Select Book Services Syndicate, New Delhi.


In addition to these, research articles by various scholars namely, R.N. Mehta, M.D.N. Sahi, S.B. Deo, K.T.M. Hegde, V.D. Gogte, A. Sundara, Harinarayan, O.P. Agrawal, T.N. Roy, R.S. Sharma, P. Singh, D.K. Chakrabarti, V. Tripathi, M. Lal, P.K. Chattopadhyay, many monographs and gazetteer of all the districts of Gujarat were also referred for the thesis.
The portion of the thesis claimed as original are the chemical and metallographic analysis of samples their interpretation and results. Wet chemical analysis, Carbon analysis, Atomic absorption spectroscopy, Preparation of specimen for metallographic study by developing microstructure and the detailed metallurgical study of 26 representative samples various excavated Early Historic sites of Gujarat and one slag specimen from Nagara is also an original contribution of the thesis. The reconstruction of the salient features of the iron metallurgy during Early Historic period by studying impurity pattern, smithery techniques, proposing probable impact of iron on early historic period and ethnographic study of contemporary traditional blacksmithery also form the original part of the thesis.