CHAPTER VI
CONCLUSIONS

Among the metal artefacts, by far the greatest amount of work has been done on copper and its alloys. In the Indian subcontinent the interest of archaeometallurgists have concentrated mainly on Harappan metal artefacts, while the copper objects belonging to the Copper Hoard Culture has been one of the less attempted areas of research. Barring a few isolated analysis carried out in the late sixties and early seventies, there has been no serious attempts to understand the metal technology of the Copper Hoard Culture. Even the scientific studies on the Harappan objects have used the traditional wet chemical analysis and spectroscopy for the quantitative determination.

With the introduction of new physio-chemical methods and nuclear methods of analysis and the increasing number of metal objects from archaeological excavations, analysts have continued their efforts to fill the lacunae in our understanding of the ancient technology. This study also seeks to throw more light on our existing knowledge of the Harappan and Copper Hoard metal technology. It is for the first time that an attempt has been made to understand and compare the salient features of the metal technology of the two Cultures.
The material used in this venture has been obtained from the excavated sites of Harappan and late Harappan affiliation, namely Nagwada, Kuntasi, Somnath, and Pithad in Gujarat and Mitathal in Harayana. The Copper Hoard samples are mainly from the Patna Museum collection and are unstratified chance finds from district Mayurbhanj in Orissa, Palamau and Ranchi districts of Bihar and Madnapur district of Uttar Pradesh.

The representative samples were subjected to chemical analysis and metallographic examinations. The conclusions regarding the alloy designs, impurity pattern and smelting technology are based on the results of the EDXRF studies, while the comparison of the smithery techniques are based on the microscopic examination.

It has been observed during the course of this study that the Copper Hoard smiths used only copper for the manufacture of all their objects, which mainly consisted of tools and weapons. They did not try to produce any type of alloy using different combinations of metals and non metals. On the other hand the Harappan period has shown two types of alloys: copper - tin and copper - arsenic alloy. By compiling the analytical data of almost all the Harappan metal samples analysed so far by various analysts, it was possible to infer that only tin bronzes were a result of conscious choice while arsenical bronzes were still in the experimental stages and
the few examples encountered were merely incidental, as discussed in detail in chapter V. Presumably, it was apparent to the Harappan metal workers that particular combinations of ore minerals and furnace conditions produce a metal that is more suitable than pure copper, while the Copper Hoard smiths were ignorant of this fact.

The composition of the alloys produced by the Harappan craftsmen varied according to the utility of the object. Tools like axes and chisels, which require a tough working edge contained tin between 1-11 %. It is at this range, that the bronze formed is harder and sturdier than copper. The alloys used in the objects of art and ornamentation, like the fragments of jewelry from Kuntasi, contain very high percentage of tin and lead. Such bronzes are soft and have a shiny silver like appearance which makes it more suitable for ornaments.

The purity of the metal used for the manufacture of artefacts largely depends on the smelting technique employed by the smiths for the extraction of copper from the ore. The iron content in the extracted metal plays an important role in assessing the smelting technology. The lesser the quantity of iron in the extracted metal, the better the technology. The EDXRF studies have revealed that the iron content in all Copper Hoard samples was quite high, while it is negligible in the Harappan artefacts.
This indicates that the smelting technology of the Harappans was superior to that of the Copper Hoard Culture.

Although the Harappan smiths were more advanced in alloy designs and smelting techniques than the authors of the Copper Hoard Culture, the smithery techniques employed by both is very similar. From the microscopic examination of the representative samples, it is clear that the craftsmen of both the Cultures produced finely cast objects which were free from casting fins and porosity holes. The metal was homogeneous and compact. They employed smooth well-ventilated moulds, with vents for the escape of gases trapped inside when the hot molten metal is poured. The cast objects were cooled either rapidly by exposing it to the atmosphere; or slowly by covering under hot ash.

As mentioned earlier (chapter V, unit II) it was believed that the Copper Hoard people did not anneal the cast objects and were unaware of the advantages of heating a cold worked brittle metal to regain its malleability. The microstructure of several Copper Hoard objects in the study, has revealed annealing twins and recrystallized grains. The fact that even the Copper Hoard smiths were familiar with the process of annealing and employed this technique in the fabrication of the objects is a significant feature of their metal forging techniques brought to light by besides dendritic structures, recrystallized grains and annealing twins, the Harap
Pan samples also show slip lines and grain deformation. Such features are formed in the crystal structure when the metal is subjected to cold work. Plastic deformations occur when the metal is work hardened by the smiths in order to give it a keen cutting edge or when the object is in use.

Evidences of cold work by the smiths can be obliterated by heating the metal above the recrystallization temperature. However, the slipping of grains when the object is in use, remain in the microstructure. It is interesting to note that none of the Copper Hoard samples examined show any slip lines and cross slip lines. Thus, it may not be wrong to say that these objects were not used at all after their manufacture.

From the current study it was observed that the impurity pattern of the artefacts from Nagwada, Pithad, Somnath and Kuntasi, all in Gujarat are in relative agreement. This may be an indication of common source of raw material for the extraction of the metal. The presence of zirconium in traces in the samples of Nagwada, Somnath and Kuntasi may further support this assumption.
However, the study has not revealed any conclusive evidence regarding the sources of raw material. Provenance determination requires a detailed survey on ore artefact correlation and ancient mining technology as well as analysis of as many ore samples and artefacts as possible. This will require an all India sampling campaign and a sample library. The methodology adopted by Pittioni, the Sumerian committee and Lead isotope assay will have to be tried and these may give conclusive results.