Chapter I.

Definition of the Chalcolithic culture based on technology; its evolution; an outline of the Chalcolithic culture of India; copper artifacts of the culture; the Chalcolithic sites and the representative copper objects included in this study; the necessity of their metallurgical study; previous work; the methods employed in this study and short summary of the results obtained.

**Definition.**

The term Chalcolithic is derived from the two Greek words, **Chalcos** and **lithos**. When translated, the former word means copper and the latter stone. The term Chalcolithic culture, in archaeological parlance, conveys the idea of a prehistoric culture that possessed, *interalia*, artifacts of copper, as well as, implements of stone, in its cultural equipment. The Chalcolithic culture occupies an important position in Indian archaeology.

**Evolution.**

The development of the metallurgical technique heralded the Chalcolithic culture, which in time covered most of the ancient world. The discovery of metallurgy followed the most important revolutionary change in man's way of life, from that of hunting and food gathering to that of agriculture and domestication of animals. This
settled way of life, which depended upon these two important achievements, together with polished stone tools, pottery making and weaving, is known as the Neolithic culture. The life in the Neolithic period being more leisurely and sedentary than in the preceding period, it favoured the growth of specialisation. Among the outstanding examples of such specialisation are the development of the ceramic industry and the discovery of metallurgy. The Neolithic culture is the basis of the present civilisation.

The knowledge of extraction of copper from its ores and conversion of the metal into useful artifacts, brought the Neolithic culture to an end. This knowledge transformed the Neolithic culture to eometallic culture.

It may be noted that the Neolithic people were acquainted with the use of three metals, gold silver and copper. But they were not in the know of production of these metals from their ores. In the Neolithic period, the use of these metals was therefore, restricted to the availability of naturally occurring, in other words, native metals. The metal objects of this period consisted of, more often than not, tiny objects of personal adornment, small pins or fish hooks. For various other purposes in daily life, the Neolithic people continued to depend upon artifacts made of stone, bone and wood.

Nevertheless, from the shapes of the objects associated with the Neolithic culture, it is quite clear that, these
people were in the know of melting metal, casting it and hammering it to desired shape. The knowledge of melting copper certainly preceded that of extracting the metal by smelting a copper ore.

But melting metal is not metallurgy. Metallurgy is the production of useful metal objects from the ores. Hence its prerequisites are the knowledge of raw materials, technique of transforming them into metals and making useful objects like implements, ornaments, utensils, etc.

The general opinion to-day favours the monogenetic theory of the origin of copper metallurgy. According to this opinion, which is based on the available data, that the region of North Eastern part of Persia was the home land of early copper metallurgy. The Neolithic communities settled there were the first to recognise, in the fourth millennium B.C., the relationship between copper ore, heat and the metal. They were the discoverers of the fact that, certain stones, when fired under charcoal, could be converted into a hard, tough mass, which could be hammered or melted and cast into a desired form, which in its turn could be given by forging, a sharp and enduring cutting edge.

This discovery was of great consequence. It laid the foundation of metallurgy and heralded the Chalcolithic culture. As the metallurgical industry developed, it brought into effect a chain of events.

From the earliest metallurgical centre, the technique of extraction of copper from its ores spread to other parts
of Asia, Africa and Europe in less than a thousand years. The rapid expansion in application of this newly found technology, established new demands and led to the necessity of trade in raw materials and finished artifacts. From the impact of trade, on the small, but fully self-sufficient stone implement using, agricultural communities, settled far apart from one another, it is possible to visualise the breakdown of their self-sufficiency. The knowledge created a bond of relationship between those isolated communities, which led to a comingling of many cultural traits.

On account of the great demand for the metal, there was a vast expansion in the number and form of copper objects produced in the Chalcolithic Period than in the Neolithic Period. Unlike in the Neolithic Period, when only the native copper metal was available for the production of objects, in the Chalcolithic Period, copper ore deposits were available for extraction of the metal and production of artifacts. Though casting of the metal was known in the preceding Period the availability of large quantities of extracted copper in the Chalcolithic Period brought into vogue more complex forms of copper objects produced in divided and compound moulds. The impact of copper metallurgy was felt in the Indian sub-continent, prior to the Indus Valley Civilisation, early in the 3rd millennium B.C.
An Outline of the Chalcolithic culture of India

The Chalcolithic culture of the Indian sub-continent can be divided into four groups: (1) the peasant communities of Baluchistan, Makran and Sindh; (2) the urban culture of Indus Valley; (3) the Chalcolithic settlements in Western India, Central India and Northern Deccan and (4) the Chalcolithic settlements of Southern Deccan and Andhra-Karnatak region. To these may now be added the recently discovered culture of Pandu-rajah-dhibi in the Ajay Valley in West Bengal, (fig. 1). While the vast hoards of copper implements observed in the Gangetic basin continue to be enigmatic regarding their origin and date, it is possible to put the above Chalcolithic settlements in the third-second millennium B.C. on the basis of archaeological, as well as, C-14 dates.

Sometimes these settlements are classified within the Neolithic complex, mainly on account of their economy, which is mixed farming, which is a Neolithic trait. But the copper objects associated with these settlements, as will be shown below, are of extracted copper metal. Therefore, one cannot deny that these people were acquainted with the use of extracted copper metal objects. To supplement their small number of metal implements they also used a large number of stone tools. If one, therefore, admits that, it is technology rather than economy that should be the diagnostic
Fig. 1

CHALCOLITHIC SITES
OF THE INDIAN
SUB-CONTINENT
trait, the presence of extracted metal objects in the cultural equipment of a stone-implement using culture, will clearly show that, the culture was in contact with metallurgy and therefore, it should be termed as Chalcolithic culture.

If however, the metal objects are made of native copper metal, then the contact of the culture with metallurgy does not arise. But it is easy to determine whether a copper object is made of the native metal or extracted metal. A spectroscopic analysis and a chemical analysis will indicate it. Apart from being free from sulphur, the native metal does not constitute a large number of elements in traces as impurities, as the extracted metal does. Among other things, the native metal is very pure. It constitutes over 99 percent copper. The extracted metal of the Chalcolithic Period, cannot be as pure as the native metal. Among the representative copper objects analysed for the purpose of this study, the best specimen is found to be 98 percent pure; the others, invariably are about 96 percent pure.

In the Indian sub-continent, the impact of metallurgy of copper was felt right from the beginning of 3rd millennium B.C., as noted above. A large number of copper artifacts were recovered from sites like Amri, Nal and Mehi, in Sind and Baluchistan. These sites are dated as pre-Harappan. So far no ancient copper object of the sub-continent has been shown to be that of the native metal. Though no analysis
of the copper objects recovered from excavations at Amri, Nal or Mehi, has been carried out, a fragment of an axe, collected from Nal, near the cemetery, showed on analysis, 93 percent copper.\(^5\) It is therefore, possible to observe that the copper objects recovered from Amri, Nal and Mehi are all made of the extracted metal.

Among these very early copper objects of the sub-continent, are axes, chisels, a tanged knife or spear-head and an outstanding specimen of the metal work, a copper mirror, five inches in diameter, with a handle, also of copper, representing a stylised female figure.\(^6\) These early objects therefore, bring to light not only the early impact of metallurgy in the sub-continent, but also, the advanced craftsmanship, that was in practice in casting the metal.

These artifacts, as well as, the artifacts recovered from the Indus Valley sites like Harappa and Mohenjo-daro are yet to be subjected to a complete metallurgical study. Some of the copper objects recovered from Mohenjo-daro have been analysed to determine their percentage composition.\(^7\) This analytical study was, however, restricted to indicate whether the objects are of unalloyed copper or bronze. Incidentally, the analytical data shows that the purest specimen of copper among them, constitutes only 97 percent copper. That clearly indicates that, these objects were
made of extracted copper and not from the native copper.

A complete metallurgical study of these objects can bring to light, interalia, the provenance of the raw materials from which the metal was extracted, merits of the smelting process employed for extraction of the metal and the techniques employed in the production of these useful objects from the solid metal. According to Marshall, the Indus Valley copper objects, might have been produced from the raw materials available in the region of Baluchistan, Afghanistan or the Aravalli ranges. He has however, emphasised the probability of the use of raw materials of the Western region, rather than that of India, on the basis, that the daggers and knives recovered in the Indus Valley site Mohenjo-daro, resembled some of the weapons recovered at Susa and Anau. Spectroscopic analyses of the ore samples collected from these three regions and a spectroscopic analysis of the specimens are quite likely to throw more light on the sources of the raw material.

The Chalcolithic culture of Western and Central India and Northern Deccan is chronologically a continuation in time of the Indus Valley Civilisation. C-14 dates for Lothal and Kalibangan, the two famous sites of Indus Valley Civilisation in India to-day, indicate that the Indus Civilisation was on the decline both in Rajasthan, as well as, in Saurashtra, by Circa 1800 B.C.
Coinciding with the decline of the Indus Valley Civilisation, we perceive the emergence of the Chalcolithic culture of Central and Western India. The earliest phases of Navdatoli and Ahar go back to a period circa 1800 B.C. The Chalcolithic culture in Central and Western India and Northern Deccan is observed to continue up to circa 1000 B.C. Chronologically, the Chalcolithic culture of the region precedes the next important culture of the country, the Painted Grey Ware culture, dated to circa 1100 B.C. at Atiranji Khera, by C-14 method.

The cultural outfit of the Chalcolithic communities, recovered from Western and Central India and Northern Deccan, indicates that the people lived essentially as small peasant communities. Though they were contemporary with one another, their cultural assemblage was not entirely similar. Instead of homogeneity, one can observe marked local variations in the materials recovered. This is to be expected in a culture so widely distributed as to cover Western India, Central India and Northern Deccan - an area extending over 1,50,000 square miles. The materials which indicate a broad uniformity among the various equipments of the culture recovered from different sites are (1) the use of wheel made Painted Pottery; (2) blade tools, particularly the ribbon flakes; (3) Steatite and faunae ornamental beads and (4) copper artifacts.

So far no evidence has come to light to indicate the source of the Indian Chalcolithic culture, either of the
Indus Valley or of the subsequent period. It is not known yet, whether the culture was evolved within the Indian sub-continent or came from without. Nevertheless, the West Asian contacts of the Indus Valley Civilisation is too wellknown to be described here. Suffice it to say that there was authenticated commercial traffic between the Indus Valley cities and Elam and Mesopotamia. The influence of the Indus Valley Civilisation in the subsequent Chalcolithic culture of Central and Western India, particularly in the patterns and some of the recurrent forms of pottery cannot be mistaken. But these do not clearly link up the post Indus Valley culture, with the Indus Valley Civilisation. What happened to the Indus script and to the fully developed urban Civilisation, are questions yet to be solved.

During the last decade and a half, more than a dozen sites belonging to the Chalcolithic culture in Central India, Western India and Northern Deccan have been excavated. These excavations have brought to light three principal variants in this culture in the region. They are, (1) Banas culture; (2) the Central Indian Chalcolithic culture and (3) the Northern Deccan Chalcolithic culture. All these variants differ in their ceramic traditions. Technologically and in food economy, they are all in the same level.

The Banas culture, distinguished by its White-Painted-black-and-red Ware, is dated to, as stated above, Circa
1800-1200 B.C. The excavations at Ahar, have brought to light the pedestalled gray ware bowl, the unique Chandelier-like dish-on-stand and animal handled lids, which show affinities with similar vessels recovered from Hissar, Shah Tepe and Geoy Tepe in Iran.\(^{13}\)

The Central Indian Chalcolithic culture dated to Circa 1700 B.C. to 1000 B.C. also shows contacts with Western Asia. At Navdatoli, the principal site of the region, channel-spouted bowls and pedestelled bowls have been recovered which can be compared to similar pottery forms recovered at Sialk, Tepe Giyan and Hissar.\(^{14}\)

The above references indicate that there is a high possibility of the contact between the Chalcolithic culture of Western and Central India on the one hand and the Chalcolithic culture of Western Asia, on the other. The presence of the ribbon flake stone tools, with crested guiding ridge, in almost all the sites except those in the Banas Valley, further indicates this contact. It is wellknown that the technique of making ribbon flakes seem to have originated in the Jericho region and it was transmitted to the Indian Chalcolithic communities through the settlements in the Fertile Crescent and the Iranian Plateau.\(^{15}\) But, to bring out the origin of the Indian Chalcolithic culture, further spade work will have to be carried out not only in India, but also in Pakistan, Afghanistan and Iran.
Copper artifacts of the Chalcolithic culture

The copper artifacts of the Chalcolithic culture are predominantly cutting and piercing implements such as axes, chisels, knives and spear-heads. However, the metal was also used in the production of ornamental objects like beads, bangles and rings. Among the copper objects of Indus Valley Civilisation, there were also a few utensils made from the metal. The copper objects of the culture are normally of unalloyed metal. But the production of bronze alloy by the fusion of tin in copper was also known in this period. Pure copper is comparatively a soft metal and therefore not quite suitable for producing cutting tools with keen, hard and enduring edge. The use of bronze tools indicates that the property of softness of copper, as well as, the improvement effected in the metal by fusing it with tin, was realised during the Chalcolithic Period. With the available evidence, it is not, however, possible to say, whether the production of the alloy was evolved within the Indian sub-continent independently or it was learnt from a foreign source. But it is certain that the Chalcolithic communities in India were acquainted with this important alloy. The chemical composition of the bronze specimens given in Chapter IV will leave one in no doubt that the metal tin was deliberately fused with copper to produce this alloy. The production of the alloy, during the Chalcolithic Period, was not accidental.
However, the knowledge of production of bronze and cognizance of the superiority of the alloy over the unalloyed metal, not withstanding, the implements of the unalloyed metal predominate in number over the implements made of the alloy during the Chalcolithic Period. This can be attributed to paucity of tin ore in India.

Artifacts of bronze, along with copper implements, were also recovered from the Chalcolithic culture sites of Western Asia. In that region also, copper objects predominated over the bronze objects. In Mesopotamia, copper and bronze artifacts were in use before 3000 B.C., but subsequently, it was observed, that the alloy was employed sparingly even in the production of tools. The small number of bronze objects in Mesopotamia is also attributed to paucity of tin. Marshall has quoted documentary evidence in support of this view.

The Chalcolithic Sites and the copper objects included in this study

In this metallurgical study, the representative copper objects of the Chalcolithic culture distributed in Western India, Central India and Northern Deccan are studied. From among the three principal variants of the culture in the region, namely, the Banas culture, the Western and Central Indian Chalcolithic culture and the Northern Deccan Chalcolithic culture, five important sites were available.
for the study of their copper artifacts. Geographically this region can be divided into four parts: (1) The Aravalli region; (2) the Central Indian region; (3) the Northern Deccan region and (4) the Western Indian region.

From the Aravalli region, the metal artifacts recovered from Period I of Ahar were available. From the Central Indian region, the copper objects recovered from the Chalcolithic levels at Navdatoli were obtained. From the Northern Deccan region copper implements recovered from Chandoli were secured. From the Western Indian region, the copper objects recovered from Somnath and Langhāraj were procured.

The site of Ahar is the type site of the culture, in the Banas Valley, in the Aravalli region. The site was excavated in two seasons, in 1954-55 and 1961-62. During both these seasons, surprisingly no stone tools were recovered. In view of the absence of the stone tools, the culture of Ahar of Period I, dated to 1800 B.C. to 1200 B.C. cannot be termed as Chalcolithic, in accordance with the definition. However, from this study, it has been possible to bring to light that, Ahar was a copper producing centre of the Chalcolithic Period. Probably, this was one of the many such centres of the Period. But so far this has been the only site that had yielded remains of Chalcolithic Period copper smelting, in the form of slags. Ahar is therefore, the key site of this metallurgical study.
Ahar, situated in the Banas Valley, in the South Eastern Part of Rajasthan, is within the city limits of Udaipur. The excavation of the remains of the Chalcolithic Period, Period I, of this site, has brought to light a characteristic pottery known as the "Painted-Black-and-Red" or "Painted-Cream" Ware. To-day this Ware is also referred to as the Ahar Ware, after the type site. The earliest and the latest phases of the Period I levels, are dated to 1800 B.C. and 1200 B.C. respectively by C-14. The site was first excavated by R.C. Agrawal in 1954-55. The site was trenchcd more extensively by H.D. Sankalia, et al., in 1961-62.

Food economy and the pottery traditions of Period I of Ahar are similar to the other Chalcolithic sites, excavated in Western and Central India. It is also contemporary with the Chalcolithic Period, in this part of the country. That apart, the site has also yielded copper implements along with copper metallurgical slags. But no stone implements, figure in Ahar culture.

The total absence of stone tools in the two seasons excavation of the site, may be attributed to: (1) that the inhabitants of ancient Ahar, must have relied upon copper or its alloys, or (2) that the excavation of the site was restricted and further extensive excavation of the site may provide an answer to this problem.

Since 1954, quite a large number of sites with the 'Ahar ware' pottery, have been observed, but the spread of
the culture was noted to be restricted to the South Eastern part of Rajasthan comprising the districts of Udaipur, Chitorgarh and Bhilwara.21

During second season's excavation of the levels of Period I at Ahar, four flat socketless copper axes, a sheet of copper metal and a few fragments of copper bangle were recovered, along with a slag-like material. Among these specimens one axe, the metal sheet piece and the slag like material were available for this study.

Axes are the most common cutting implements of the Chalcolithic Period. Flat axes with pointed butts were common in the Early Dynastic Period in Egypt.22 Copper axes with rounded butts were recovered from Jamdet Nasr in Mesopotamia.23 Axes of varied shapes were also recovered from the Indus Valley sites. But as a rule, the axes recovered from the Indus Valley sites possessed almost parallel sides with slightly splayed edges.24 At Harappa, Macky25 could distinguish five different types of flat axes. These axes were probably used, during the Chalcolithic Period for cutting wood. It is probable, that they were also used as weapons. For the purpose of this metallurgical study, four axes from the four different sites, Ahar, Navdatoli, Chandoli and Somnath which were available were studied. From Langhnaj, only one copper artifact, in the form of a knife was recovered and that was included in this study, along with the other specimens.
Navdatoli is situated on the south bank of the Narmada river, in the Nimar district of the State of Madhya Pradesh. The present small hamlet of Navdatoli is occupied by boatmen. Deposits of the remains of Chalcolithic culture in Navdatoli was fairly extensive. There were four mounds covering an area of about half a square mile. The site was excavated from 1952 to 1959, jointly by The Deccan College Post-Graduate Research Institute, Poona and the M.S. University of Baroda. The extensive excavations have brought to light a rich collection of cultural equipment of the Central Indian Chalcolithic culture. The Chalcolithic Period at Navdatoli is dated from 1800 B.C. to 1000 B.C. by C-14. Among the cultural equipments, were the tools, made of copper, as well as, stone. Among the copper objects recovered from this site an axe, a chisel and a bangle piece were available for their metallurgical study. The bangle, though highly corroded, was specially included in the study to know, whether during the Chalcolithic Period, the metallurgist had any special composition for the metal, meant for the production of ornaments.

The Chalcolithic site of Chandoli is situated on the right bank of the river Ghod, in the district of Poona, in the State of Maharashtra. The site was excavated in March 1961 by the Deccan College Post-Graduate Research Institute, Poona. Among the copper objects recovered from the site
are an axe and a spear-head. Both these specimens were available for this study. The axe was subjected to a complete metallurgical study consisting of quantitative chemical analysis, spectroscopic analysis and metallographic examination. In view of the fact that, the spear-head is an unique find in the Deccan, only a very small fragment of the specimen could be had from its thin antennae portion, for its analytical study. The sample was sufficient enough for its analytical and quantitative chemical analysis. The specimen could not be subjected to spectroscopic analysis to determine its minor constituents or for metallographic examination to determine the technique employed in its production, as sufficient sample from the specimen could not be removed without causing serious deformation to the implement.

Somnath is situated in the Saurashtra region of the Gujarat State. The site was excavated jointly by the Department of Archaeology of the then Government of Saurashtra and the M.S. University of Baroda, in the year 1956. Among the four copper artifacts recovered from the site, there is only one cutting implement, an axe. The other three objects are fragmentary. The axe was available for the purpose of this study.

Langhnaj, situated in the Mehsana district of the Gujarat State, is essentially a microlithic site. Excavations of the site from 1941 to 1963 by H.D. Sankalia, et al, has resulted in the discovery of a large number of
microliths, animal remains, human skeletons, crude, hand-made, ill-fired pottery, wheel made pottery and a copper knife. The knife was recovered in 1963. It was available for this study. Attempts were made to obtain many more representative specimens of copper objects, excavated from the other sites of the Chalcolithic Period, in the region of Western India, Central India and Northern Deccan. But these efforts have not been successful up to this time. Fortunately, however, the representative specimens of the above five sites were easily available.

In view of the fact that these five sites fully represent the entire Chalcolithic culture complex of the post Indus Period in the region of Western India, Central India and Northern Deccan, it was considered that a complete metallurgical study of the representative objects of these sites, should be sufficient enough to draw basic inferences regarding the important aspects of the Chalcolithic Period copper metallurgy.

The necessity of metallurgical study

The problem of identification and correct interpretation of the metallic objects, that are recovered from the excavation of the archaeological sites, in India, has not been thoroughly tackled so far. But this study is essential. Undoubtedly, the metal objects are one of the most important items in the material culture of a people, prehistoric or otherwise. In order to truly understand and assess their cultural level, we cannot afford to neglect their advance.
or degeneration in the metallurgical field. A detailed metallurgical study of a number of stratified metal objects of a particular region and period can provide us with such important information as, (1) the probable source of the raw materials from which the metal was extracted; (2) a comparative study of the composition of such contemporary objects of a region, can result in establishing groups of objects, with relative agreement in the composition. Such agreement is usually derived from the use of similar sources of raw materials for extracting the metal. More than not, the raw materials with similar composition belong to one region. Therefore, such a study can, not only provide with clues to the original source of the raw materials, but also, the distribution pattern of the metal extracted from the raw materials of a particular region; (3) if it is observed that, the metal extracted from the raw materials of a region was distributed far and wide, that will demonstrate the direct or indirect contacts that were prevalent among the contemporary communities, settled far apart from one another; (4) the study will also bring to light the important features of the metallurgical techniques employed in the extraction of the metal; (5) the determination of the percentage composition of the objects will indicate the quality of the metal and whether the objects were made of a comparatively pure metal or an alloy; (6) the metallographic examination of the objects will reveal the techniques employed for producing the objects from the solid metal,
whether the object was wrought or cast, and what thermal
treatment it was subjected to in antiquity; (7) among other
things, the metallographic examination can also bring to
light the physical conditions of the metal, such as, porosity,
brritleness and the presence of metallic or non-metallic
inclusions in the metal.

These detailed informations are invaluable for
determining the technical stage attained by the community to
which the objects in question belonged. The metallurgical
study of ancient objects, therefore, not only provides one
with the necessary information for their correct identifica-
tion and precise interpretation, but also, helps to complete
the archaeological record of a people. Archaeologists to-day
aim to know, the past communities of human beings, as
completely as possible. The metallurgical study helps to
achieve this aim.

However, not all archaeologists in India are greatly
moved by this new idea. Cutting samples from the ancient
metal objects, for their metallurgical study, is still met
with considerable resistance from certain quarters. It is
done under the guise of keeping the typological forms of the
specimens intact. This attitude of dilettanteism is difficult
to be appreciated in this age, where every effort is made to
study the ancient objects, as completely as possible, all
over the world.

In this metallurgical study, from the available specimens,
only the minimum necessary quantity of the samples were cut. The cut portions in the specimens were subsequently made good, with suitably tinted plaster of Paris, so as to see, that the photogenic quality of the antiquities is not impaired. It is earnestly hoped that, the advanced analytical techniques like the $\gamma$-ray spectroscopy, will soon be available in India for this kind of archaeological research. $\gamma$-ray spectroscopy can provide, with the chemical analysis of a specimen without causing any damage.

Nevertheless, the metallurgical study of the representative excavated metal objects should be encouraged in India. Such a study will form an essential complement to the archaeological record. In the United Kingdom, West Germany and Austria, vast progress is being made in this study. In a vast country like India, with such an abundance of material available, the metallurgical study of the representative objects has been a desideratum.

In this study, therefore, an attempt is made to examine the available metal objects of the post-Indus Period Chalcolithic culture of India, excavated in the region of Western and Central India and Northern Deccan. Copper objects of the Chalcolithic Period are the earliest objects of the extracted metal. It is therefore in fitness of things, that the first attempt in metallurgical study of ancient Indian metal objects, is carried out on the stratified copper objects of the Chalcolithic Period.
Previous Work

As has been pointed above, so far, there has been no complete metallurgical study in ancient Indian metal objects, which consisted of spectroscopic analysis, quantitative chemical analysis and metallographic examination, with their interpretation. This work is the first of its kind. However, some excavation reports have enclosed percentage composition of the metal objects excavated. Notable among these reports are, Marshall's *Mohenjodaro and the Indus Civilisation*, Sankalia's *From History to Prehistory at Nevasa*, and Rao's "Excavation at Rangpur". Analytical data included in these works are noted in this study.

Methods employed in this study

This is a detailed metallurgical study. It has been aimed to reconstruct the important features of the Chalcolithic Period copper metallurgy in India. The following methods were employed in this study:

1. Spectroscopic analysis of the artifacts and the sample of copper ore obtained from Khetri was carried out to determine the constituent elements present in the specimens. This analysis has brought to light the impurity patterns of the artifacts and the sample of copper ore. Hilger Glass Spectrograph was used in this study.
2. Systematic quantitative chemical analysis of the artifacts, samples of the metallurgical slags and the
copper ore sample, was carried out to determine the percentage composition of the specimens. Gravimetric and Colorimetric methods were employed in the analysis. Unicam SP 1400 was used in the colorimetric analysis.

(3) Metallographic examination was carried out on the samples cut from the artifacts, so as to elucidate the internal micro-structure of the specimens. Universal Karmera Mikroskop of Röchert Optesch Werke, Austria, was used for observing and photographically recording the micro-structures of the metal specimens.

A short summary of the results obtained:

The metallurgical study has fulfilled the main purpose for which it was undertaken. It has given enough data to reconstruct the important features of the Chalcolithic Period copper metallurgy.

From the spectroscopic study of the artifacts and the sample of copper ore obtained from Khetri, it has been possible to show that, probably the Chalcopyrite ore deposits of the Aravalli region were employed as the raw material, for extracting copper, during the Chalcolithic Period. As pointed above, there is relative agreement in the impurity patterns of the artifacts and the ore sample.

Among the many copper ore deposits of India, only two are observed within the region of Western India, Central India and Northern Deccan. They are, (1) The Chalcopyrite ore
deposits of the Aravalli region and (2) the Chalcopyrite and tetrahedrite ore deposits of the Jabalpur district.

The Aravalli region ore deposits, though poor in copper content, are observed to be extensive and abundant in the region. At a number of places they are also observed to be delineated with ancient mining and metallurgical slags.\(^33\)

The Jabalpur district ore deposits are observed to be very limited in extension and are not indicated to be worked in early times. That apart, they are also found to contain, among other impurities, gold.\(^34\)

In any normal smelting process of the Chalcopyrite ore, among the various elements present in the ore as impurities, gold, silver, tin, lead, nickel and dismuth, pass on into the constitution of the extracted metal, without much loss in quantity, during the smelting process.

In this connection, the absence of gold in any of the artifacts analysed, is not without interest. The Aravalli region copper ore deposits are found to be associated with Cobalt, Nickel and Silver, among other impurities. But they are nowhere indicated to be associated with gold.\(^35\) The spectroscopic analysis of the Chalcopyrite ore, obtained from the ancient mine of Khetri, has indicated the presence of a number of elements as impurities, but it has not indicated the presence of gold in it. (fig.\(^{10}\))
It is, therefore, possible to observe that, the metal of the Chalcolithic Period copper artifacts was probably extracted from the Chalcopryite ore deposits of the Aravalli region. The evidence of ancient ore mining and metal work in the Aravalli region at Khetri, Singhana, Daribo and other places,36 and absence of such evidence in the region of the ore deposits of the Jabalpur district, lends support to this observation.

Among the various Chalcolithic sites excavated in the region, only Ahar has yielded the remains of Chalcolithic Period copper metallurgy, in the form of metallurgical slags. The quantitative chemical analysis of the samples of the slags has proved that Ahar was a copper smelting centre of the Period, in the Aravalli region.

The study has indicated that the smelting process practiced during the period was quite advanced. There are evidences to show that, the ore was thoroughly roasted to eradicate the volatile elements like sulphur and Arsenic, which are highly harmful, if allowed to be present in the extracted metal and in the smelting process, the ore was fluxed with silica, so as to bring down the temperature of fusion of the ore and also facilitate the separation of the extracted metal from the impurities in the ore.

The study has also indicated the presence of bronze objects alongwith the copper objects. The Chalcolithic Period metal workers were therefore cognizant of softness of
unalloyed copper and that copper-tin alloy, bronze, was not only harder, but also, produced a better cutting implement.

However, the analysis of the bangle fragment, from Navdatoli has indicated that the metallurgist of the Chalcolithic Period did not have a special composition in the metal, meant for an ornament.

The metallographic study of the artifacts has brought to light, among other things, that among the four techniques that are available for the purpose of fashioning out useful objects from the solid metal, such as, (1) forging, that is, hammering in either hot or cold; (2) melting the metal and casting it to the required shape; (3) fabrication, that is, building up the object using thin metal plates secured by rivets and (4) sheet metal working, by which the object is fashioned from a single metal plate, either through sinking or raising, only the first two techniques were employed in the production of the artifacts.

To sum up, the study has brought to light important features of the technical skill and metallurgical knowledge possessed by the Chalcolithic Period metal workers in India.
References

5. Ibid.
8. Ibid.
32 Rao, "Excavations at Rangpur and Other Explorations in Gujarat", *Ancient India*, Nos. 18 and 19, 1963, pp. 5-207.


34 Ibid.

35 Ibid.

36 Ibid.