Copper occurs native as well as in combined state. The minerals of copper possess distinctive crystalline structure. Among these minerals, the native metal, that is, the naturally occurring copper is also included.

Copper ores are natural mixtures of copper minerals and a host of other minerals. For the purpose of exploitation of a copper ore deposit at a profit, the proportion of copper mineral in the ore deposit should be sufficiently high.

Concentration of copper ore in the earth's crust constitutes an ore deposit. Such deposits range in size from a few thousand tons to several million tons. These ore deposits may at times be found confined to very near the earth's surface or extend to several thousand feet underneath.

Copper ore deposits of India

Copper ore deposits are very widely distributed in India. They are observed in a number of host rocks under a variety of structural conditions. But they are not observed anywhere in the country in great concentration.
The following places may be mentioned as the centres of copper ore deposits in the country: the Aravalli region in Rajasthan and Northern Gujarat, the Chhota-Nagpur region in Bihar, Garhwal and Almora in Uttar Pradesh, Jabalpur district in Madhya Pradesh, Kurnool and Agnigundala in Andhra Pradesh and Chitaldurg in Mysore. (fig. 2)

Although, as many as one hundred and sixty-five copper minerals are known, the number of copper minerals commonly observed in the country is only seven. They are the following:

(1) Chalcopyrite or Copper pyrite, Cu$_2$S Fe$_2$S. It is crystalline in the tetragonal system, possesses brass yellow colour and metallic luster.

(2) Chalcocite, Cu$_2$S. It is crystalline in the orthorhombic system and has grayish black colour.

(3) Bornite, Cu$_3$FeS$_4$. It is crystalline in the cubic system and possesses pinkish brown colour.

(4) Tetrahedrite, $4 \text{Cu}_2\text{S Sb}_2\text{S}_3$. This mineral is otherwise known as sulphantimonite of copper. It is crystalline in the cubic system and possesses steel gray colour.

(5) Covellite, CuS. It is crystalline in the hexagonal system and possesses indigo blue colour.

(6) Malachite, CuCo$_3$Cu(OH)$_2$. It is crystalline in the mono-clinic system and possesses bright green colour.
Azurite, \(2\text{CuCo}_3\text{Cu(OH)}_2\). It is also crystalline in the mono-clinic system, but possesses azure blue colour.

Among these seven commonly observed copper minerals, the most important mineral of the country is chalcopyrite. When pure chalcopyrite contains 30.5% copper, 30.6% of iron and 39% of sulphur.

Among the copper ore deposits of India, the deposits observed in the Aravalli region and the Chhota-Nagpur region are outstanding for their extension and abundance. At both these places chalcopyrite mineral predominates.

In the Aravalli region chalcopyrite are deposits are observed near Khetri, Babai, Singhana, Akhwali, Daribo, Dev Bari, Delwara, Kotri and a number of other sites. Khetri, Babai, Daribo and Singhana are situated near Jaipur. The chalcopyrite belt here is continuous for over fifteen miles. The belt is located in the upper part of a zone of slates and schists of Ajabgarh age. It is not without interest to note here that all these copper ore deposits are delineated with ancient mining. Dev Bari, Delwara and Kotri chalcopyrite copper ore deposits are observed near Ahar.

In the Chhota-Nagpur region the copper ore belt is observed to extend over eighty miles in the districts of Singhbhum and Hazaribagh. In this region also the ore occurs predominantly as chalcopyrite. The mineral is observed in lenticular strangers in schists and quartzites.
The ore deposits in this region are also delineated with ancient metal workings. According to Marshall the region of Chhota-Nagpur was isolated by deep forests until the historic times. Access to these ore deposits, for the purpose of their exploitation, during the Chalcolithic Period was not easy. That apart, these ore deposits are situated too far away from the Chalcolithic sites of Northern, Western and Central India.

Probable Sources of the Raw material for Smelting Copper During the Chalcolithic Period.

Among the above two extensive copper ore deposits in the country, the ore deposits of the Aravalli region are the nearest to the Chalcolithic communities settled in Western India, Central India and Northern Deccan.

The only other copper ore deposits that may be considered in this connection, particularly on account of their proximity to the Chalcolithic communities settled in Central India and Northern Deccan, are the ore deposits observed in the State of Madhya Pradesh, in the District of Jabalpur. These ore deposits are very limited in their extension. They are located near the railway station of Niwar and near the railway station of Sleemanabad and at Narsinghpur, eighty miles north of Sleemanabad. These ore deposits are observed in dolomitic lime stone. The veins of copper minerals in these sites are found to be only six inches to three feet in width.
The copper minerals of these ore deposits are found to consist of Chalcopyrite and tetrahedrite. These minerals are also indicated to be associated with among other things, galena, pyrite, magnetite, and traces of gold and silver. However, at none of these three sites the ore deposits are indicated to be delineated with ancient metal-work.

On the basis of proximity in location, to the Chalcolithic Period communities in Western and Central India and Northern Deccan, it is possible to observe that both the copper ore deposits, observed in the Aravalli region as well as in the Jabalpur district may have been exploited for the purpose of extracting copper metal during the Chalcolithic Period. However the presence of evidence of ancient metal-workings around the ore deposits of the Aravalli region and the absence of such evidence in the Jabalpur district, will restrict the probability to the ore deposits in the Aravalli region.

During the last decade and a half, more than a dozen Chalcolithic culture sites were trenched in the region of Central and Western India and Northern Deccan. In all these sites the copper objects recovered were very few in number. In all these sites, except at Ahar, the scanty supply of copper implements was complemented by stone-tools.

Eventhough most of these sites have yielded copper tools only Ahar, located in the Aravalli region, has yielded evidence of Chalcolithic Period copper metallurgy in the
form of metallurgical slags. From the quantitative chemical analysis of the slag like material excavated from the layers belonging to Period I at Ahar, it has been possible to indicate, in this study (Chapter III) that, Ahar was a Chalcolithic Period copper metallurgical centre.

Though the number of copper metal artifacts so far recovered from Ahar is only five, the absence of stone tools in the Chalcolithic Period of the site, does indicate that there must be many more copper implements buried in the site. Further excavation of the site is bound to throw light on this point.

Recent explorations in the Banas Valley, around Ahar has brought to light, the probability that there might be many more copper smelting centres of the Chalcolithic Period in the Aravalli region. Since Agrawal¹⁰ discovered Ahar with its peculiar 'Painted-black-and-red or cream' ware, a number of 'Ahar ware' sites have been brought to light.¹¹ Excavations in these sites, alongwith the further excavation of the type site, Ahar, may bring to light further evidence of copper metallurgy of the Chalcolithic Period in the Aravalli region.

As the evidence of copper metallurgy is totally absent in the other Chalcolithic culture sites of Western India, Central India and Northern Deccan, it is possible to observe, that the copper smelting industry was not carried out at any of these sites.
Under the conditions that prevailed in the Chalcolithic Period, it is obvious, that the metallurgy of copper was restricted to the region where the ore was available alongwith an abundance of fuel. The ore could not have been transported over long distances in that period.

Ahar and the other Ahar ware sites are located in the Aravalli region. Ahar is surrounded by Chalcopyrite copper ore deposits of Dev Bari, Delwara and Kotri. All these sites are within the radius of twenty miles from Ahar. There is abundance of fuel in the region to-day. It is quite probable, that the availability of fuel was equally abundant, in the region, during the Chalcolithic Period.

The availability of copper ore and the necessary fuel, may have provided the necessary impetus for the early metal working communities of India to settle in the Aravalli region. The great demand for the metal sustained their metallurgical industry for centuries. In this connection, it is worth emphasising that a number of the copper ore deposits of the Aravalli region are marked by the evidence of ancient copper-metal-workings.

From the foregoing, it is possible to observe that from among the two copper ore deposits located in the region of Western India and Central India, the Aravalli copper ore deposits and the Jabalpur district copper ore deposits, quite likely, the Aravalli copper ore deposits
were exploited for the purpose of extraction of the metal, during the Chalcolithic Period.

In order to further prove this observation, the representative copper artifacts from Ahar, Navdatoli, Chandoli, Somnath and Langhnaj were subjected to Spectroscopic analysis.

Spectroscopic analysis provides one of the specific methods of qualitative analysis. It is direct, rapid and simple. Unlike the qualitative chemical analysis, the spectroscopic analysis requires very small quantities in samples. For the purpose of this study linear pieces of 2 cms./0.2 cm./0.2 cm. measurement, were cut from the specimens for their spectroscopic study. The technique of emission spectroscopy using a Hilger Glass Spectrograph was employed. As this spectroscopic method is not accurate for determining the elements quantitatively, the method was not used for determining the percentage composition of the specimens. However, the method was effective for indicating the presence of various elements in the specimens, though some of them were very minor constituents, being present only in very minute traces.

Minute traces of various elements present in the copper artifacts of the Chalcolithic Period are impurities or chance inclusions. Obviously, they could not have been deliberately added by the ancient metallurgist. These impurities are drawn into the constitution of the metal from the raw material from which the metal was extracted.
Therefore, from the impurity pattern of the Chalcolithic Period copper artifacts, it is possible to trace the raw material from which their metal was extracted.

When copper is smelted from an ore, normally elements like gold, silver, tin, nickel, lead, cobalt and bismuth will pass on to the constitution of the extracted metal, if these elements are present in the copper ore smelted, without much loss in their quantity, during the smelting process. Elements like iron, manganese, zinc, aluminium, chromium, molybdenum, vanadium, gadolinium, zirconium, tungsten, titanium and manganese, will also pass on to the constitution of the extracted metal, if they are present in the ore smelted.

The difference in the former set of elements and the latter, is that, while the elements in the former set pass on to the extracted metal, quantitatively without any loss during the smelting process, the elements of the latter set, pass on to the extracted metal with great loss in their quantity. Often they are present in the extracted metal only in minute traces.

Apart from these two sets of elements, elements like phosphorus, silicon, calcium, arsenic, sulphur and antimony also at times pass on to the extracted metal, if they are present in the copper ore smelted.

In the spectroscopic study of the representative Chalcolithic Period copper artifacts, all these twenty-four elements were sought for in their respective spectrographs.
Sulphur is omitted as it is not spectroscopically recorded. Presence or absence of each of these elements in the specimens studied is indicated in the Table of Results - 1.

Alongwith the copper artifacts, the sample of chalcopyrite copper ore obtained from the ancient mine of Khetri in the Aravalli region, was also subjected to spectroscopic analysis. Elements present in the ore sample are also recorded in the table showing the results of spectroscopic analysis.

(Vide Table of Results-1 on the following page)
<table>
<thead>
<tr>
<th>Name of the site</th>
<th>Description of the specimen</th>
<th>Cu</th>
<th>Sn</th>
<th>Au</th>
<th>Ag</th>
<th>Pb</th>
<th>Ni</th>
<th>Co</th>
<th>Bi</th>
<th>Fe</th>
<th>Mn</th>
<th>Zn</th>
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<tr>
<td>Ahar</td>
<td>Axe</td>
<td>+</td>
<td>nd</td>
<td>nd</td>
<td>nd</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>nd</td>
<td>+</td>
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<tr>
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<td>nd</td>
<td>nd</td>
<td>nd</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
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<td>+</td>
<td>+</td>
<td>+</td>
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</tr>
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<td>+</td>
<td>+</td>
<td>nd</td>
<td>+</td>
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<td>+</td>
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<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>nd</td>
<td>+</td>
</tr>
<tr>
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<td>+</td>
<td>+</td>
<td>nd</td>
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<td>nd</td>
<td>nd</td>
<td>nd</td>
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<td>+</td>
<td>+</td>
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<td>+</td>
<td>+</td>
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<td>+</td>
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<tr>
<td>Langhnaj</td>
<td>Knife</td>
<td>+</td>
<td>nd</td>
<td>nd</td>
<td>nd</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>nd</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Khetri</td>
<td>Chalcopyrite</td>
<td>+</td>
<td>nd</td>
<td>nd</td>
<td>nd</td>
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</tr>
</tbody>
</table>

nd = not detected
Fig. 3

Spectrograph of the axe from Ahar
Spectrograph of the metal sheet from Ahar
Fig. 5

Spectrograph of the axe from Navdatoli
Spectrograph of the chisel from Navdatoli
Fig. 7

Spectrograph of the axe from Chandoli
Spectrograph of the axe from Somnath
Spectrograph of the knife from Langhnaj
Spectrograph of the sample of copper ore from Khetri
Discussion of the Analytical Data Collected from the Spectroscopic Analysis.

The results of analysis indicate that the pattern of impurities in the artifacts mainly constitutes the following elements: lead, nickel, cobalt, bismuth, iron, manganese, zinc, aluminium, chromium, molybdenum, zirconium, titanium, gadolinium and arsenic. Vanadium is observed to be present in some and magnesium is observed to be present in some others. In a few specimens tungsten was also present. But the main impurities are the first fourteen elements. They constitute the impurity pattern of the ancient metal. It is not without interest to indicate that this impurity pattern is in full agreement with the elements present in the chalcopyrite ore sample obtained from the ancient mine of Khetri.

From analytical data above, it is interesting to note the absence of gold in all the specimens. This is highly interesting. It may also be noted that only one of specimens, the axe from Navdatoli, has indicated the presence of silver in it as an impurity.

While silver is noted as an impurity in some of the copper ore deposits of the Aravalli region, particularly those observed at Daribo and Akhwali, gold is nowhere indicated as an impurity in any of them. But in the copper ore deposits of the Jabalpur district both gold and silver are noted as impurities.
Had gold been present in the copper ore smelted for the extraction of copper during the Chalcolithic Period, it would have been brought to light in this spectroscopic analysis of the artifacts of the period. Absence of gold in all the specimens indicates that the copper ore smelted, probably did not constitute gold as one of its impurities. The sample of chalcopyrite from Khetri has also indicated the absence of gold in its spectroscopic analysis. Therefore it is possible to observe, that during the Chalcolithic Period, copper ore deposits of the Aravalli region was exploited for the purpose of extraction of the metal. The ore deposits observed in the Jabalpur district were not exploited.

The above observation can be further supported by the absence of calcium in the impurity pattern of the artifacts studied above. The Jabalpur district copper ore deposits are observed, as pointed above, in dolomitic lime stone. If the metal of the above objects was extracted from any of these ore deposits, at least some of the objects would have indicated the presence of calcium as an impurity in the metal.

Limitations of the Spectroscopic Study.

However, much cannot be read into the comparative study of impurity patterns of the ore samples and the ancient metal specimens. The process of metallurgy is a chain of events, such as ore dressing, roasting, smelting and finally purification of the metal. In this chain of
events, it is but natural to expect many variables that may hinder the direct linking of the ore with the metal. Though the metal is a reflection of the ore in more ways than one, the reflection cannot be expected to be complete. It is bound to be partial.

As has been indicated above, the copper ore is never entirely the copper-bearing mineral. It is mixed with various other compounds. Eventhough the ore deposits of a region are similar, it is not necessary that they should completely agree in their impurity pattern with one another. Even the samples from the same mine coming from different positions are found to disagree in this respect. Thomson has pointed out that the impurities may vary even within a few feet. This variability aspect, that has been observed in the basic raw material itself is quite unhelpful to draw a useful conclusion in our study. Nevertheless, in view of the fact that only two ore deposits are involved in this connection, it is possible to pool together the archaeological evidence and the analytical data collected in this study to arrive at a conclusion.

The archaeological evidence has shown the absence of copper metallurgical industry in any of the Chalcolithic sites except at Ahar which is situated in the Aravalli region. The analytical study of the slag-like material recovered from the Chalcolithic Period levels has proved that Ahar was a copper smelting site of the Period.
The spectroscopic study of the Chalcolithic Period artifacts has brought to light, among other things, the absence of gold in any of them, even in traces as an impurity. Gold is associated as impurity with the Jabalpur district copper ore deposits. The spectroscopic analysis of the Chalcopryrite ore sample from the ancient copper ore mine of Khetri has also indicated the absence of gold in it. The absence of Calcium in the impurity pattern of the objects is also noted above.

The impurity pattern of the artifacts shows a relative agreement in the composition of the specimens studied. Such an agreement is derived from the similar sources of the raw material employed in the extraction of their metal. The impurity pattern of the artifacts, by and large also agrees with the impurity pattern of the Khetri Chalcopryrite ore sample.

From the foregoing it is possible to observe that during the Chalcolithic Period, the copper ore deposits of the Aravalli region were exploited and it is probable that the industry of copper metallurgy was restricted to that region only during the period.

Wide distribution of the metal smelted in one region brings to light, not only the contacts that were prevalent among the Chalcolithic communities settled so far apart from one another, but also the prevalence of a sound system of trade in this useful metal during the Period.
References:


4. Ibid.


