Statement I

(Statement showing the particulars in which the work is based on the discovery of new facts or of new relations of facts observed by others and how the work tends to the general advancement of knowledge.)

A detailed metallurgical study of the representative copper objects of the Chalcolithic Period in India, has been a desideratum. The few Quantitative chemical analyses, notably carried out by Md. Sannaullah Khan and Dr. B. B. Lal, are restricted to indicate the percentage composition of the artifacts studied. A detailed metallurgical study, consisting of Spectroscopic analysis, Quantitative chemical analysis and metallographic examination of the artifacts, has not been so far attempted.

In order to fill in this lacuna, a detailed metallurgical study of the representative copper objects of the Chalcolithic Period, excavated from Ahar, Navdatoli, Chandoli, Somnath and Langhnaj, is attempted in this thesis. From the data collected, from the metallurgical study of the artifacts and the data collected, from the Quantitative chemical analysis and Spectroscopic analysis of the Chalcopyrite copper ore sample, obtained from the ancient mine of Khetri, and the Quantitative chemical analysis of
the samples of metallurgical slags recovered from Period I levels at Ahar, the important features of the Chalcolithic Period Copper metallurgy is reconstructed in this thesis. The thesis, therefore, adds detailed information to our existing knowledge on the following aspects:

1. It indicates the probable sources of the raw materials from which copper was extracted during the Chalcolithic Period. From among the two copper ore deposits observed in the region of Western and Central India, namely the ore deposits of the Aravalli region and Jabalpur district, this study has indicated that it was probably the ore deposits of the Aravalli region that were exploited for extracting copper during the Chalcolithic Period.

2. The study has brought to light that the impurity pattern of the artifacts recovered from Ahar, Navdatoli, Chandoli, Somnath and Langhnaj are in relative agreement. Such an agreement is usually derived from the use of similar sources of raw materials for the extraction of the metal. As has been pointed out above, in this case, the raw materials were probably the Chalcopyrite ore deposits of the Aravalli region.

3. The wide distribution of the metal derived from
the raw materials of a region, during the Chalcolithic Period, indicates that there were contacts prevalent among the isolated communities settled far apart from one another.

(4) The distribution pattern of the metal also brings to light that, there was some system of trade in this useful metal, during the Chalcolithic Period.

(5) It is pointed out in this thesis that the probable mode of movement of the metal, during the period, was through a nomadic, peripatetic, tribe like the present day Loharias of Western India, whose specialised vocation was copper metal work, such as casting and forging of useful objects from the solid metal.

(6) The Quantitative chemical analysis of the slag like material recovered from the Period I levels at Ahar, has proved that it is a copper metallurgical slag. Therefore, the site of Ahar was a Chalcolithic Period copper smelting centre.

(7) It is pointed out in this thesis that, during the Chalcolithic Period, the industry of copper metallurgy was certainly not as wide spread as the metal artifacts. The industry was restricted to the region where copper ore and fuel were available in abundance. Ahar was probably one of the many copper smelting centres of the Chalcolithic Period, in the Aravalli region.
(8) The study has brought to light the important features of the Chalcolithic Period copper metallurgy and the technical knowledge possessed by the metal working communities of the period. *Interalia*, the following important aspects of the metallurgy of the period are revealed:

(a) the crushed copper ore was subjected to a prolonged period of roasting at a high temperature, in order to get rid of harmful volatile elements like sulphur and arsenic;

(b) the roasted ore was fluxed with silica so as to reduce the fusion temperature of the ore and facilitate the separation of the metal from the unwanted elements in the ore;

(c) the high purity of the extracted metal indicates that the smelted metal was further reduced in an attempt to purify it as far as possible; and

(d) among the artifacts studied some were made of bronze. In these bronze specimens, the percentage of tin is so considerable as to clearly indicate that tin was deliberately fused with copper to produce the alloy. 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 implement with keener and more enduring cutting edge, than copper.

The metallographic study of the selected artifacts has clearly brought out, that among the four techniques available for the purpose of producing these useful objects from the solid metal, namely: (a) forging, either hot or cold, (b) melting the metal and casting it to required shape, (c) fabrication, that is, building up the object using thin metal sheets and (d) sheet metal work, that is, fashioning the object from a single metal sheet, either by sinking it or raising it to the desired shape, that only the first two techniques were employed. It is probable, that they were the only two techniques known and practiced by the metal workers of the Period.

The metallographic examination has also brought to light that, while some implements were possibly cast in crude unventilated sand moulds, some others were probably cast in smooth, properly ventilated clay moulds.

The study has also indicated the mechanical qualities of the metal of the Chalcolithic Period artifacts, whether it is porous or brittle and what non-metallic inclusions it contains.
The thesis has emphasised the need for horizontal excavation of the key site of Ahar and vertical excavation of at least a few 'Ahar Ware' sites in the Banas Valley.
Statement II

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

The chief sources of information for this study are the published reports of excavations of the Chalcolithic sites in India. Published analytical data of the Chalcolithic copper objects are also noted in this study. For Quantitative chemical analysis, Spectroscopic analysis and Metallographic examinations, the following standard reference books were consulted:

1. A Text Book of Quantitative Inorganic Analysis, by A.I.Vogel,
2. Standard Methods of Chemical Analysis by W.W.Scott,
3. The Colorimetric Method of Analysis by F.D.Snell and C.T.Snell,
4. Colorimetric Estimation Method Sheets by Unicam Laboratories,
5. The Spectro-chemical Analysis of Metals and Alloys by F.Twyman,
6. Chemical Spectroscopy by W.R.Brode,
7. A Text Book of Metallurgy by A.R.Bailey,
8. The Principles of Metallographic Laboratory Practice, by G.L.Kehl and
The original portion of the thesis is claimed in the detailed metallurgical study of the representative Chalcolithic Period copper objects and the reconstruction of the important features of the Chalcolithic Period Copper Metallurgy. Linking the metal of the Chalcolithic Period copper objects studied, with the copper ore deposits of the Aravalli region is a contribution of this thesis. The study has also brought to light that Ahar was a Chalcolithic Period copper smelting centre.

Vast scope for further research in the metallurgical study of various metal objects of different periods of Indian history, excavated from the archaeological sites, has been clearly brought out by this thesis.