Metal Craft of Harappan Culture: A Case Study at Binjor

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Abstract

The Harappan culture is highly sophisticated and unique in world context. The techno-culture has presented the world saws- both plain and circular, drills and needles. Several archaeological sites related to this culture have revealed copper bronze along with other artifacts manufacturing in a vast area in this sub-continent. Several furnaces, ingots, metal artifacts and pyro-technology have been revealed in Harappa, Mohenjodaro, Kalibangan, Banawali, Dholavira, Lothal and a few other sites, yet no complete industrial area has been discovered. Three sessions of excavations (2014-15, 2015-16 and 2016-17) have revealed a single centre for metal craft at Binjor (4MSR) (29°12'87 2"N, 73°9'421"E & 159m. MSL), which lies about 500 m from dried bed of the Ghaggar/ Hakra (ancient *Saraswati*), 6 km west from the district head quarter Anupgarh, Rajasthan. We shall discuss here the pyrometallurgical remains including furnaces, ore-minrals, slag and a metal supported with the newly known Nantokite, a very rare mineral and is usually found as the alteration product of Cu-minerals in archaeological sites in arid climate.

Introduction

The excavations have revealed three distinct cultural stages comprising of Pre/Early Harappan, Transitional phase (Early to Mature Harappan) and Mature Harappan. The antiquities comprise of varieties of metal artifacts including tools, ornaments, fishhook, spearheads, arrow head, slag and raw materials, several varieties of furnaces, mould, anvil and other objects. In addition to these, beads made of gold, steatite, paste, terracotta and semi-precious stones, stone weights; gold objects have also been found. These evidences clearly identify a continuous copper manufacturing centre. Present paper includes the beginning of intensive analyses to establish the techno-cultural parameters of the site. The site is shown in the centre of Harappan sites (Fig. 1).

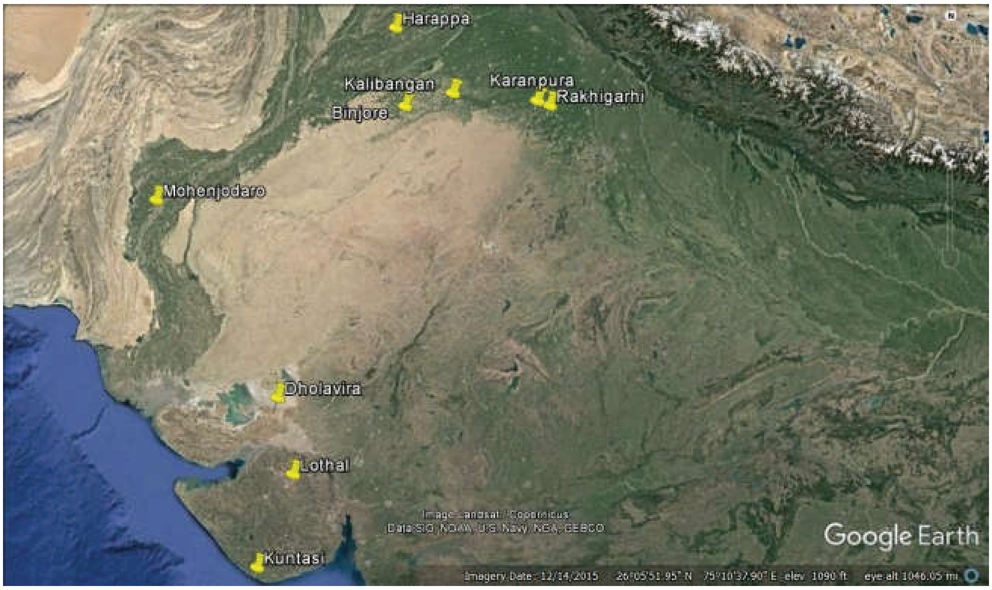

Fig. 1: Location of Binjor in the centre of Harappan sites of India and Pakistan.

The two major techniques were practiced in Harappan sites revealed casting and forging. The fabrications of artifacts were basically with the application of different processes used in forging. With these basic practices, Harappans presented the world with needle, flat and circular saws and drills.

The scanty information revealed from the excavation at Harappan sites could not reveal the availability of metal for Harappa and Mohenjodaro. The furnaces discovered in that sites revealed only the presence of copper smiths furnace.

SanaUllahas contributions (1931, 1940) as quotted in Agrawal [1] have revealed the chemical analyses of copper- bronze artifacts of Mohenjodaro and Harappa. His analyses clearly identified only 30% of those were alloyed. Compositionally, the alloy comprises 1% to 11% tin in copper, 1% to 7% As, 1% to 9% Ni, and 1% 32% Pb.

Furnaces discovered at Harappan Sites

Before the excavation at Binjor, Agrawal (2009:296-98) [2] summarized the two types of kilns and furnaces from Harappan sites, as intermittent and continuous. Those are oval, oblong, circular and pear- shaped. The oval shaped furnaces are common. A fine paste of clay is applied for smoothness along the walls of pit. From Harappa sixteen furnaces were reported (Vats 1940) [3]. Those are of three types: part of round pottery jar, cylindrical pits dug in the ground; with or without brick lining. The third types include pear shaped pits – with or without brick linings. A remarkable observation made by Kenoyer and Miller, that there was no metal processing slag excavated from Harappa and Mohenjodaro [4].

Analyses of Furnaces and hearths of Binjor

Several hearths are exposed in three sessions of excavations, in circular, oval and yoni shaped. In some of the hearths, broken earthen pots were also discovered. Basically three varieties of furnaces were discovered in the site along with sub variant.

1. Kiln for smelting purpose.
2. Smaller kiln mostly rounded or oval for secondary melting.
3. Rounded shape mostly like basin in which lower part of pottery jar is fitted for heating and forging artifacts associated with stone anvil, tools, polisher and shallow water tank probably for quenching and other purpose. Interestingly small rounded heath filled with powdery ash or gypsum was also used in floors and that might be used for final polishing. In the same complex stone weights of different denominations have also been recovered besides finished artifacts like chisel, spearhead, arrowheads, needle, copper points, razor, knife, fish hook, beads and others.

Furnaces excavated at Binjor

Several types of furnaces were discovered at Binjor. There were definitely similarities of Binjor furnaces with the furnaces observed in Harappan sites as summarized earlier. Amongst the furnaces examples may be cited for the oval shaped furnace lined with mud bricks (Fig. 2), oval shaped furnace for smelting copper ore. Those were connected with tuyers through which air drafts are blown (Fig. 3). Furnaces and hearths of different shapes are shown in Fig. 4.

Fig. 2: An oval Furnace, the centre indicates the location of the ingots indicates the location of the ingots a crucible for forging into the artifacts.

Terracotta moulds of various size and shapes, terracotta crucibles and slag have also been recovered. Apart from that, huge deposit of industrial wastes like ash, burnt charcoal and vitrified terracotta cakes, potteries, bones, broken piece of copper fragments are also yielded. The hearth share contained the terracotta cakes of different shapes of *mushtika, idly* and triangular ones. In matured Harappan stage several hearths were exposed.

Fig. 3: Oval shaped furnace for smelting copper ore. Those were connected with tuyers through which air drafts are blown.

The three types of terracotta cakes as mentioned earlier, were used for different purposes. For example *mustika* cakes were perhaps used to control the temperature of furnaces, *idly* shaped cakes were possibly used to retain heat in domestic hearths and *chulas* for keeping milk and water warm. The triangular cakes might be used as decorative pieces on the walls of building. The terracotta cakes are shown in Fig. 5 and Fig. 6 indicates the location of the terracotta cakes by the side of the furnace.

Fig. 4: Furnaces and hearths of different shapes.

Fig. 5: The terracotta cakes are shown.

Analyses of Minerals, Slag and Metal

Samples for this study have been collected from the ore-slag interface, metal, slag, chips of burnt bricks, and soil from the center of the kiln. Amongst these, one sample from the ore-slag interface (Fig. 7) and one sample of the metal artifact (Fig. 8) were mounted on synthetic resin and were polished. The polished mounted samples were first studied in reflected light using

Fig. 6: Location of the terracotta cakes by the side of the furnace.

optical petrographic microscope. This was followed by studying the samples using Scanning Electron Microscope to generate back-scattered electron images (BSE) and to have preliminary semi-quantitative idea about the compositions of different phases present in the samples using energy dispersive X-ray scanning (EDS). In the ore part of the ore-slag interface the identified minerals include mainly copper oxide and copper chloride. In the copper oxide phase the Cu:O atomic ratio varies between 1:1 to 2:1, which suggest that the mineral may actually be tenorite (CuO) or cuprite (Cu_2O). However, we cannot negate the presence of malachite in the sample.

Fig. 7: Copper ore partially reduced possibly malachite or other mixed copper ore.

Fig.8: Some of the copper artifacts found in excavation.

The exact phase can be identified using Electron Probe Micro Analyzer (EPMA), which will be the next target of this study. The Cu:Cl ratio in the copper chloride is 1:1, which suggests that the mineral is most likely nantokite (CuCl). In reflected light nantokite appears greenish in color, and therefore may be confused with malachite. Consequently detailed geochemical analysis is required to identify the actual phases. It is uncertain, whether tenorite/cuprite actually represents the original ore mineral or is oxidized/corroded product of the ore mineral, which was originally used. A detailed textural (relation between different minerals) study in this regard is warranted. Nantokite is a very rare mineral and is usually found as the alteration product of Cu-minerals in archaeological sites in arid climate. It may be noted that nantokite is secondary in nature and is found to replace existing copper mineral, for example Cu-oxide, in the studied samples. The interface between the ore and the slag contains euhedral cassiterite (SnO_2) crystals. It is quite likely that cassiterite was used for the production of the metal. The slag part commonly contains quartz (SiO_2), plagioclase feldspar (solid solution between $NaAlSi_3O_8$ - $CaAl_2Si_2O_8$), alkali feldspar ($(K,Na)AlSi_3O_8$)) and some unidentified ferro-magnesian minerals. The plagioclase feldspar is compositionally albitic ($NaAlSi_3O_8$) in nature.

The metal sample contains the metal, copper oxide (cuprite/tenorite) and nantokite. In addition, it also contains some unidentified Pb-As±Sn±Cu±Cl bearing alloy/ mineral. The metal comprises predominantly of Cu and Sn with or without As. This suggests that the studied metal is not typical copper artifacts. It is rather bronze or arsenical bronze. The concentrations of different metals are variable. The Cu, Sn and As contents range between 65-70 wt.%, 20-25 wt.% and 7-10 wt. % respectively. The presence of cassiterite (SnO_2) at the interface between the ore and the slag suggest that the Binjor site was an important site for the production of bronze and arsenical bronze in which Cu and Sn-ore minerals were used. The important question that needs to be answered is that what was/were the possible source (s) of Cu- and Sn-ore or ore mineral.

Sources of metal/mineral

From the beginning of the excavation at Harappan sites, excavators were rather concerned with the composition of metallic specimens found in excavation of Harappa, Mohenjodaro, Kalibangan, Lothal and other Harappan sites, discovered in the present geographical areas of India and Pakistan. From the very beginning archaeologists were much eager to identify the origin of the copper- bronze metal objects. They tried to locate the mineral sources. Any discussion on the possible source of metal or mineral requires knowledge about the availability of metal resources or ore deposits in the surrounding areas or in areas accessible from the site of industrial manufacturing of metal objects.

Agrawal (1971: 152, 2009: 173) [5] referred to the source of copper ore from Rajasthan, quoting the report of the Indian Bureau on the composition of Pb upto 0.18, Zn 0.18, As 0.06, Co 0.01, Ni 0.05 and Fe around 15-20%. The result of his researches based on trace elements possibly highlights the use of Khetri ores being used by Harappans. Kenoyer and Miller (1999) commented 'At this point there is no direct evidence for Harappan Phase mines or smelting sites in the Aravalli copper resource areas, even though these areas have been explored by numerous scholars' [6].

However, in India there are evidences of very old mining and metallurgical activities, particularly in the now-recognized states of Gujarat-Rajasthan- Haryana in western India. The Proterozoic rocks of this region occur along a prominent linear zone known as Aravalli-Delhi Fold Belt (ADFB). In recent times several in-depth studies on the geology and mineralogy has been made on the Aravalli copper belt. Several base metal sulphide deposits occur in this fold belt (Sarkar and Gupta, 2012) [7]. Majority of these deposits, however, are well known for their Zn-Pb content. For example, some important Zn-Pb deposits occur at Zawar, Sawar, Rajpura-Dariba-Bethumni, Ghugra-Kayar (these deposits are hosted by carbonate rocks), Rampura-Agucha, Pur-Banera, Jahazpur (these deposits are hosted by clastic sedimentary rocks) and Ambaji-Deri (hosted by volcanic rocks). Amongst these dominantly Zn-Pb deposits, Rajpura-Dariba-Bethumni mineralized belt is also known for Cu-mineralization. Sphalerite (ZnS) and galena (PbS) are two major sulphide minerals of the Zn-Pb ores. In Rajpura-Dariba area the main Cu-mineral is chalcopyrite ($CuFeS_2$).

Major Cu-deposits in the ADFB occur at Madan Kudan-Kolihan- Chandmari (hosted by garnetiferous chlorite schist and albitic quartzite with amphibole) in the Khetri copper belt and Kho-Dariba (hosted by quartzite) in the Alwar copper belt. The important and abundant primary sulphide ore minerals in the Cu deposits of Khetri copper belt include chalcopyrite ($CuFeS_2$), pyrrhotite ($Fe_{1-x}S$) and pyrite (FeS_2). In addition, Co-rich pentlandite ((Co, Ni,

$Fe)_9S_8$) sulphide), cobaltian mackinawite ($(Fe,Co,Ni)_9S_8$), cobaltite (CoAsS), arsenopyrite (FeAsS), sphalerite (ZnS), magnetite (Fe_3O_4), and ilmenite ($FeTiO_3$) also occur in the ores in minor quantity. Secondary minerals, for example, cuprite (Cu_2O), malachite (($Cu_2(CO_3)(OH)_2$) and tenorite (CuO) are also reported from the deposits. The principal ore minerals in the Kho-Dariba deposit are chalcopyrite, pyrite and pyrrhotite. Additionally, minor cubanite, sphalerite, mackinawite and pentlandite occur in the ores of Kho-Dariba. The copper ores, therefore, likely was derived from the copper deposits of the ADFB.

Amongst the Cu-deposits the best known Cu deposits occur in Khetri Cu belt. The ore mineralization is hosted by albitic amphibole-bearing quartzite and garnetiferous chlorite schist. However, the origin of copper belt is controversial. Sarkar and Dasgupta (1980) proposed that the ores were initially deposited by the sedimentary- diagenetic process and were subsequently modified during deformation and metamorphism [8]. They did not entirely reject involvement of an exhaustive component. More recent studies (Baidya et al., 2016, b; 2017a, b) [9, 10] in Chandmari-Koliham and Madan Kudan areas suggest that copper was likely transported as Cu-chloride complexes and precipitated as Cu-sulfide due to destabilization of chloride complexes during precipitation of Cl-rich amphibole and Cl-rich marialitic scapolite. Cobalt pentlandite and cobaltian mackinawite are the two important Co sinks (Baidya et al 2016b) [9]. Detailed compositional study of copper ore will be beneficial to pinpoint the origin of copper for Harappans.

An unique polymetallic deposit of Cu (-Au)- Ag-Sn-W-Bi occur in Tosham area, Haryana. The ore mineral of Sn is cassiterite (SnO_2) occurring in quartz veins. The other ore minerals are galena, pyrite, sphalerite, arsenopyrite, pyrrhotite etc.

From the above discussion it is evident that the western part of India had required Cu and Sn deposits which could have supplied the ores for the Binjor site. It has been mentioned that the ores of Khetri Cu belt occur in albitic schist, which also contains Fe-Mg-Ca-Na silicate minerals, commonly amphibole. Presence of albite and Fe-Mg minerals in the ore-slag sample may indicate that the ores of Khetri copper belt was used for metallurgy purpose. It needs to be mentioned that a very prominent feature of the ADFB is the presence of a long linear zone occupied by albite-rich rocks and the belt is therefore, known as albitite line. It is possible that this or similar rock was used as fluxing material.

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