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Metals and Metallurgy in the Harappan Civilization

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Abstract

The Indus Valley also referred to as Sindhu-Sarasvati Civilization excelled in variety of technologies, including metallurgy. Over the span of centuries, evolving from Pre/ Early Harappan to the Late Harappan cultural phases, the civilization evolved as an urban civilization. By the mature Harappan period (circa 2700 to 18/1700 BCE) metal technology attained great perfection. Several metallurgical innovations like the intricate *ciré perdue* or lost wax technique, true saw and the eye needle go to the credit of the metal smiths of that period. Exclusive objects of copper, gold, and silver came to be used. For special affects, minor metals like tin, arsenic, lead, antimony etc. came to be used for alloying. Although about 70% of the copper objects of the Harappan period are unalloyed, a judicious alloying pattern as per requirements may be discerned in the metal repertoire. Arsenic was found to be present in several statues probably with a specific reason. The sharp-edged cutting tools like razors, knives or daggers, arrowheads, spearheads, drills etc show a distinct alloying pattern with alloying of tin up to 12-13%. The Harappan bronze tool repertoire comprised typical leaf-shaped arrowheads, spears with bent end, shaft-hole axe, double edged axes, the sword with amid-rib or the bronze female figurines like that of the 'dancing girl'. In fashioning of pots and pans, technique of raising- sinking and drawing was employed. Exquisite gold jewellery and silver ware, though rare, has been found from Harappan sites. We propose to address here issue related to typology, pattern of metal utilization, and the metallurgical processes as well as raw material exploited in the Indus-Saraswati Civilization.

Key words: Alloying, Casting, *Ciré perdue*, Copper-bronze, Gold, Metallurgy, Raw material, Silver, Tin

1. Introduction

Metallurgy was one of the most important and complex technologies invented by humankind. The Harappa or Indus Valley Civilization – now-a-days frequently referred to as Sindhu-Saraswati Civilization in India, has an extensive distribution area extending from Sutkagendor in Makaran and Bhagatrav in south Gujarat in the west, to Alamgirpur in western Uttar Pradesh (in the east) and Gumla and Ropar in the North to Daimabad in Maharastra in the south. There are at least three well defined cultural sub-phases recognized as Pre-and Early-Harappa, Mature Harappa and Late-Harappa. These phases of civilizational growth also demonstrate evolutionary stages through which the civilization grew. There appears to be a gradual transition from a regional– rural set up to an urban Harappan civilization. The Mature Harappan Civilization in its urban phase continued to flourish for several centuries (from BCE 2600 to 2000-1900 BCE, approximately). It declined slowly. The Late -Harappan cultural stage lasted up to circa 17/1600 BCE. The Harappa Civilization had a long span both in time and space. The material remains reflect the changes which took place over the centuries. Any discussions on aspects of the Harappan Civilization must take place with this phenomenon in mind.

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The Mature Harappan Civilization is defined by certain characteristic features which are uniformly spread across the extensive area in time and space. However, there were several regional features noticed in different geographical zones, such as Sind-Baluchistan, Rajasthan, Punjab, Haryana, Kachchh and other adjacent parts of Gujarat. Nevertheless, there were certain common features characteristic of the urban Harappan civilization as noted by Sir Mortimer Wheeler (1968). These were the typical Indus seals, Indus script, and ceramic forms like cylindrical perforated jars, s-profile jars, dish-on-stand and goblets with pointed base. The decoration of intersecting circles, *peepul* leaf, fish scale etc. on the pot-forms is typically Harappan. Other features are triangular terracotta cakes, kidney-shaped shell or faience beads with inlay work, discoid beads with tubular holes across them. The town planning of Harappan settlements with standard bricks size having a proportion of 1:2:4 was another noteworthy feature characteristic of Mature Harappan Civilization. In addition to these features, there were copper artifacts like knives and daggers with bent back, the double-edged razors, barbed arrowheads with holes which were typical of the Mature Harappan period. Some of these features had an earlier beginning during the Pre-Harappan phase attesting to continuity between the stages of cultural growth. The present discussion is focused on the metal technology during the Sindhu-Saraswati Civilization.

The Sindhu - Sarasvati civilization is known for its technological acumen in variety of fields. The field of metal and metallurgy is among the key technologies mastered by the civilization. The earliest evidence of metallurgy in the Indian subcontinent comes forth from the site of Mehrgarh in Baluchistan dated to circa 6500 BCE. It is recovered in the form of a tiny copper bead from grave of a child. Subsequently, other Pre-Early Harappan sites yielded copper objects. With prolific use of copper–bronze artifacts and good understanding of alloying technique, the Harappan Civilization is the only one among the Proto-historic cultures of India which may be designated a Bronze Age Civilization. Over the centuries, during the Mature Harappan period, the metal workers perfected the metallurgical skill. Several metallurgical innovations like the true saw and the eye needle are attributed to the Harappan metal smiths. Variety of metals such as copper, gold, silver was extensively used by the Harappan metal workers. Minor metals like tin, arsenic, lead, antimony etc. were used for alloying. They had also perfected the intricate *ciré perdue* or lost wax technique of metal casting as early as the third millennium BCE. Even a cursory look at the Harappan tool repertoire speaks legions of the mastery achieved by artisans of the Harappan Civilization in metal craft. The commonly occurring metal objects of this civilization include the leaf-shaped arrowheads, spears with bent end, shaft-hole axe, double edged axes, the sword with amid-rib or the bronze female figurines like that of the 'dancing girl' or the exquisite gold jewelry, some of them with intricate inlay work and silver ware.

It may be noted that most minerals and raw materials like ores were not to be found within the proximity of major Harappan settlements. Needless to underline that mechanism had to be evolved to procure the raw material in the form of ores, ingots or half-finished objects from more distant parts of the Indian subcontinent or even from other contemporary civilizations of the world through long distance overland or marine trade. We propose to address here the issue of pattern of metal utilization in the Harappan civilization as well as the metallurgical processes involved in manufacturing of metal objects. An effort will be made to look at metals and the specific tool-typologies in use. Since copper-bronze was extensively used metal, it will receive greater attention in the discussion here. The subject of resource zone exploited by the Harappans may call for an independent subject of inquiry. However, a passing reference to this issue may be necessary here.

2. Mining-Metallurgy and Raw Material

The Copper-Bronze Age civilization under scanner was a riverine one which flourished in the fertile plains along the navigable rivers. Apparently, the river plains are devoid of minerals, especially ores needed for metal extraction. Most of the raw materials had to be procured from neighbouring hilly ranges bordering the plains. The main sources of copper exploited by the Harappans are believed to be Baluchistan and Afghanistan, in the region west of Indus. The area extends from highlands of Badakshan to coastal Makaran. Interestingly, this area has also yielded the earliest evidence of copper processing. The other potential region is the mountain range of Oman with which the Harappan civilization, especially the coastal region had close trade relations. The region around Oman has been identified with ancient Magan which was known for rich copper deposits. Presumably, it was a source of copper tapped by the Harappan civilization. The third resource zone was the region east of Indus is the Aravalli range. There are deposits of copper, lead, zinc and silver ores in the Aravalli hills. The copper of this belt is rich in arsenic containing about 4% to 8% in the ore (Hegde, 1969 p. 227). Many copper objects of Harappa and Mohenjodaro have high level of arsenic. This suggests that the region was one of the important sources of copper ore that was tapped by the metal workers of the Harappan Civilization. Stray pieces of copper ore have been recovered from some of the Harappan sites indicating local working, albeit sparingly as there is little evidence to suggest on-site smelting at Harappan sites. Ingots recovered from Lothal and Dholavira hint at the fact that they were brought in from some outside sources to be further refined and fabricated locally.

Hegde (1991, pp.15-16) had examined six copper working sites in the Aravalli copper belt. Evidence of ancient mining was noted there. He observed superficial gouging as well as deep mines in the region. All the deep mines opened into galleries and narrow tunnels following the natural configuration of chalcopyrite ore veins at different levels. These deep galleries were provided with one to one-and-a-half-meter diameter ventilation holes at regular intervals. Hegde (*Op.cit.*) further states,

> We consider the superficial shallow gouging pits as the earliest complete attempt at mining copper ore in the Aravalli Hills. Deep shafts complete with galleries, steps, adits and ventilators may represent later mining activity.

Some of the deep mines must have been used during earlier times too. It is confirmed by the radiocarbon dates recovered from a gallery at a depth of 120 meters at Rajpur Dariba mine in District Udaipur. The date is 3120 ± 160 BP, which is the last quarter of the second millennium BCE. Large heaps of broken stones were found strewn near the mining site. Ore-bearing rock pieces seem to have been carried down to the valley floor where they were roasted, crushed, concentrated and smelted. Regarding their metallurgical skills, it may be pointed out that the Harappans would smelt even sulphide ores, though oxide ores were commonly used. Large quantities of oxide ore were find from a house at Mohenjodaro from a brick lined pit. The similarity in the trace impurity patterns of the Harappan artifacts and the copper minerals of Khetri mines may indicate its exploitation. But so far, the actual copper working in the Khetri belt has not been dated beyond c. 1000 BC. Only future researches may through more light on this subject.

Hegde (1991, pp. 15-25), who has studied copper working sites in the Rajpur Dariba area of Rajasthan, further suggested that ore was roasted to render the smelting process greater efficiency. He feels a high yield would not have been possible if the ore was not well-roasted to convert all copper minerals in the ore into copper oxide and thus render the ore porous and fragile so as to make it easy for crushing. Many grooves of ore-crushing pits were found near the foot of the hills in the Aravalli copper belt. The chalcopyrite ore with its iron content is more complex and difficult to work with due to presence of high percentage of sulphur. For an efficient reduction, a temperature higher than 850°C may be necessary. During this process iron acts as sulphur scavenger helping in conversion of CuS into Cu_2O and CuO. During reduction, FeO reacts with SiO_2 to form 2FeO, $SiCO_2$ (Fayalite) slag with a lower melting point of 1177° C. For an efficient extraction a temperature above 1250°C is required. Therefore, from the cultural stage when the pyro-technology showed sufficient advancement, we come across larger use of copper. The site of Ganneshwar-Jodhpura in Rajasthan is understood to be an important source of copper tools or ingots to the Harappans. Some evidence of copper metallurgy has come forth in course of excavations. Evidence of 'kilns' serving as forging hearth of metal smiths have been reported as will be seen in some detail below.

3. Evidence of Pyrotechnology

Evidence of copper smelting/ forging is rarely found in excavations. Major sites like Mohenjodaro and Harappa, or Rakhigarhi or Dholavira have not yielded evidence of metal working. Kenoyer and Miller (1999) who have made extensive studies on the subject have expressed surprise at the absence of evidence of smelting of metal at the Indus sites. It could be because the excavations are conducted on habitational sites while metal extraction was done near ore deposits located in the more remote areas. Though the habitation sites have occasionally yielded remains suggesting local casting or fabrication of metals as revealed by of kilns or forges.

3.1 Furnaces and Metal working

Vats considered about the possibility of metalworking being done in several furnaces which were discovered in Mound F at Harappa. These furnaces or kilns may be classified under three types. Two cylindrical pits dug in the ground, have been found with evidence of fairly intense firing. One of them is a furnace which is 3 ft. 4 inches in diameter, with a depth of 3 feet 8 inches. There is an evidence of slanting flue, which may have served as an air channel for the furnace. A part of the vaulted roof of the furnace was also found lying inside it, and there were flues in this vaulted roof probably as outlets for smoke of as gaps to be covered when the heat had to be conserved. Thirdly, there are 13 pear shaped pits dug in the ground, often with a column. According to Vats, these were used for metal crafting. Kenoyer and Miller prefer to classify these fire- pits as kilns as there is absence of clear-cut case of smelting at the Harappan sites. Smelting was presumably done closer to the mines as has been suggested by Hegde while discussing evidence recovered from the Aravallis. Miller (1994; 1999) analyzed the pyrotechnological evidence recovered from Harappa. She commented, 'the only claimed metal processing area from the early excavations in Vats' furnace from Mound F, trench 4 the area of workmen's' quarters, stratum II. It was split lengthwise and only half of the kiln was found by the excavators. This kiln was very heavily vitrified, to the point where parts of the surface ran in pencil like formation. The sole item of evidence that this kiln was used for metal processing, however, is a foot note that a crucible fragment with traces indicating that it had been used for bronze casting was found 20 feet south of the kiln. The several pieces and bits of slag found at Harappa are in general contextually associated with post-cremation urns and not with metalworking or furnace remains.

3.1.1 Crucibles

A shallow earthenware crucible, oval at the base with straight sides and a fragmentary earthenware crucible found in Mound F, near a furnace "whose contents show that it was used for melting bronze." Chakrabarti & Lahiri (1996, p.50), state "Only the presence of arsenic / arsenic-rich minerals is attested to and includes a piece of yellow arsenic (hartal) in Sq K 12/14, Mound F (Vats, 1940, p. 80) and a small lump of lollingite found in 'jar 277'. This attests to some activity related to metallurgy of copper or bronze. Unfinished and unworked objects have been mentioned. The most important examples are from 'jar 277', with contents suggesting metal related activity. In addition, attention may be drawn to the numerous pieces weighing 2 pounds approximately 1 kg.

Ingots have been reported from several Harappan sites. Mackay refers to occurrence of 'quite a number of ingots and castings' which throw considerable light on the methods adopted by the metallurgists of Mohenjodaro. The plano-convex shape ingots with uneven looking top had characteristic puckering due to the contraction of metal when cooling. It is reported from Lothal and several other sites. This suggests that 'the ore was smelted in an open hearth'. But we cannot say at present state of our knowledge that it was produced locally. Dholavira has also yielded similar copper ingots.

4. Copper -Bronze Metallurgy in the Indus-Saraswati Civilization

Historically speaking, copper is one of the earliest utilitarian metals exploited by man. Even in its natural or native form some copper ores like pyrite shine like gold (therefore, also called 'fools' gold'). It is only too natural that man was drawn towards the shining metallic material. Being a ductile and soft material, the shining ore pieces could be beaten to desirable shapes by the early metal workers. Even in its native form copper can be worked on low temperature. Technically it is possible to hammer or 'cold work' copper to shape small objects out of it by bending, grinding or polishing it. For smelting of copper, shallow furnaces as noted in excavations of some early cultures attaining temperature up to 400°C or a little higher could be used. These furnaces were capable of producing regulus that could be further worked in clay crucibles to procure the metal for shaping into desirable objects.

The melting point of copper is 1080°C. A little later, the furnaces provided with bellows could generate temperature capable of producing adequate heat to bring the ore to a melting point. The molten metal was procured as ingots by pouring into stone, clay or sand moulds. This can be achieved by using cuprous ores like malachite [$CuCO_3$.Cu $(OH)_2$] cuprites or (Cu_2O) azurite $2CuCO_3Cu\ (OH)_2$. By adding flux, the melting temperature could be reduced further. However, in India the most frequently found ore is chalcopyrite. It occurs at Khetri (Rajasthan), Surda, Mosabani and Rakha in Singhbhum region (Jharkhand), at several places in Madhya Pradesh, such as Balaghat, Bhind, Jabalpur, Gwalior, Sagar etc. Copper also occurs in Kumaon- Garhwal at places like Almora (Uttarakhand), and in Sikkim and Nepal in the neighborhood. Other deposits closely accessible to the Harappan metal workers were in parts of Baluchistan and Afghanistan and regions further west to it.

In the Indian subcontinent, as noted above, we find the earliest use of copper in the form of a small bead in a child burial from period I (Neolithic) at Mehrgarh dated to 6500 BCE. Objects like beads and rings also occur in the next period that is, Period II. These objects could be of native copper. But from the succeeding Chalcolithic period, terracotta crucibles have been found indicating smelting of copper in Baluchistan region by 5^{th} - 4^{th} millennium BCE. Among the metals used during the Sindhu-Saraswati civilization, copper was most common playing an important role in economy. The fact is fully borne out by large number of copper objects found at Harappan settlements. The Harappans had mastered the most complicated metal forging techniques in copper as will be discussed below.

The tool typology may be classified under the broad category of hunting tools or war weapons'; implements utilized in various sectors like agriculture, masonry, carpentry and craftsmen's implements were found. A fairly large number of house-hold objects like pots –pans and domestic appliances, toys, figurines or ritualistic objects are common. Besides copper or bronzes, gold and silver have generally been used for fashioning objects like jewelry, including a tiara (found at Kunal in Haryana), other ornamental objects or decorative pieces, containers etc. It is worth underlining here that each category of metal object manufactured by metal smiths was distinct in its own way so far as the technique and composition of the metal was concerned. Almost 70% of the copper objects of the Harappan civilization are seemingly unalloyed. Others have been alloyed judiciously to suit the purpose for which they were fabricated or for adding to the design and finish of the object concerned. For instance, the sharp-edged cutting tools like razors, knives or daggers, arrowheads, spearheads; drills etc. show a distinct alloying pattern with up to 12-13% tin in the matrix of finished metal object. For instance, for casting of mirrors the composition of tin had to be much higher. On the other hand, the pots and pans required different kind of composition for convenience of forging and hammering into desirable form. Therefore, higher malleability and ductility was required for hammering the pots into shape. Percentage of tin in pots or pans is generally found to be smaller. The technique of raising- sinking and drawing was employed there. Arsenic was found to be present in several statues probable with a specific reason of adding special effect and hue to the finished product. Thus, different fabrication techniques appeared to be employed for fashioning different types of metal artifacts. For casting and moulding of objects, a more suitable composition of metal was required. The alloying percentage of minor metals was adjusted suitably. For shaping objects, a variety of moulds – single or double–had been utilized by the Harappan metal smiths. The moulds were made of clay or sand and occasionally of stone. For welding together different metal pieces, technique of riveting or pouring or running of molten metal over the desired part was in vogue. The fabrication of artifacts had to pass through several stages as shown below.

4.1 Techniques in Metal Craft

Without entering into further discussion on the metallurgical traits, we now proceed to narrate the key stages seemingly prevalent in copper metallurgy in the past. The copper smelting process consists of several stages that may be summarized as under (Agrawal 1971, pp. 156-57; 2000, pp. 33-53; 2009)

Stage I: The first step in shaping native copper involves hammering, cutting, bending, grinding, and polishing.

Stage II: Annealing native copper by heating and hammering is the next step.

Stage III: It is a stage of smelting oxide and carbonate ores; smelting ore in wood or charcoal fire over a clay lined pit with air. It gave away (1) regulus and (2) slag to be discarded.

Stage IV: Melting and casting copper: melting native copper or regulus over furnace or fire in a crucible and casting into stone, clay or sand moulds. This is the stage of fashioning objects by cold work, annealing, finishing by grinding and polishing.

Stage V: Smelting of sulphide ores requires special care. The following process is observed:

(i) Roasting the ore to remove bulk of sulphur.

(ii) Smelting roasted ore (with charcoal in low shaft furnace)

(iii) Roasted ore yields copper matte (copper and iron sulphide) and slag

(iv) Smelting of roasted matte with charcoal and silica flux in low shaft furnace yields: (a) Blue metal which is rich in copper, and (b) slag that is rich in copper and iron,

(v) The above process leads to roasting blue metal.

(vi) Blue metal smelted with charcoal yields (a) black copper, (b) rich copper matte (c) slag rich in copper.

(vii) Melting black copper (with blast air in charcoal fire or with charcoal in crucible) leads to (a) refined copper, (b) slag rich in copper.

(viii) Finally, refined copper is fashioned by casting, etc; copper thus produced is 99.5% pure.

5. Casting and Fabrication

The smelting of ores yields ingots or semi-refined lump of copper which requires further refining. These are easy to transport. Incidentally, several ingots have been reported from sites of the Sindhu-Sarasvati civilization. For fashioning copper artifacts two basic techniques are in vogue. (1) Casting and (2) fabrication are two major steps perceptible in ancient copper metallurgy.

5.1. Casting

This involves pouring of molten metal in moulds to achieve desired shapes. Different types of practices of copper casting have been described by metallurgists studying ancient copper technology. Mention may be made here of Forbes (1964), Tylecote (1962; 1992), Agrawal (2000) who have described different aspects of ancient copper metallurgy, especially the casting technique in the ancient cultures. Copper casting is categorize into three broad classes: (i)open casts, (ii)part moulds or closed moulds, (iii) lost wax process (*ciré perdue*). The lost-wax process or "*ciré perdue*" is a developed technique. It is generally used for casting complex shapes. A wax model is prepared over a clay core. The wax layer is of the thickness of the desired object. An outer mould of clay is built over this "incorporating the spruce cup, runner, riser and vents." Two holes-were left as the inlet and outlet for the molten metal. The wax was heated to melting point. It was followed by pouring of molten metal into the inlet and the wax could run off through the other hole. Along with the wax, surplus metal also flowed out. It was then allowed to cool. The mould had to be broken to retrieve the object. Obviously, it could not be reused. This also explains near absence of occurrence of moulds at ancient metal working sites.

It can be done by pouring liquified metal into moulds as ingots after smelting of copper or for fabrication of artifacts. Though Rao reported stone mould from Lothal (Rao 1979, p. 557, 568; Fig. 121 nos.3,4) for casting pins or rods but Agrawal expresses doubts over the identification (Agrawal 2000, p. 46). Open cast terracotta moulds or sand moulds were also said to have been in use during the Harappan times. It is possible that perishable material like wood or sandy clay might have been in use. This also explains the absence of moulds at the sites (Agrawal 2000, p. 47).

Open moulds consist of hollow shapes carved out to receive the molten metal. Such moulds are generally made with stone. A flat piece of wood or some other material is used to cover it. Flat moulds are reported from Chanhudaro (Mackay 1943, pp.40-41). Closed moulds are fashioned out of two or, at times, more fitting pieces of stone, clay or bronze. Small holes into the opposite pieces of moulds helped ensure a straight line (by thrusting dowels into these holes). Ridges are formed on the sides of copper objects produced with this method. Agrawal (1971, p. 181) reports to have examined and found such ridges on harpoons found in the Copper Hoards. Ridges are found on objects, such as on two barbs in the Shahjahanpur specimen and three in the Shahabad specimen. Gungeria axe too had ridges of this type due to the use of double mould.

5.2. Fabrication

At this stage copper must be alloyed to improve its hardness and tensile strength. During smelting, copper absorbs gases and thus becomes porous. This necessitates alloying with tin or arsenic, without which complex castings are impossible.

The metal forging techniques popular in the antiquity may be described as under:

I. Hammering: Ingots were beaten to the desired shape to produce vessels, wires and other artifacts.

II. Spinning and Turning: It was done by turning a pot on a lathe. Lathe, according to Mackay (1931) was not a common method used in the Indus Valley Civilization as it has not been supported by evidence from excavations. However, sinking and turning must have been used in shaping utensils–pots or pans.

III. Drawing: Copper wire and silver wire has been found in excavations from Proto-historic sites, including from the Harappan sites. Such wires must have been made by a technique known as drawing used for ornaments etc. is not clear whether the wires were drawn or forged (Agrawal, op.cit.)

IV. Cutting: The metal smiths of the Harappan civilization could use this technique rather efficiently. Mackay (1938, pp. 368, 452, 475) reports finding of several double edged chisels which might have been used for cutting metal sheets. On analysis these are graded as tin bronze or arsenical bronze. Thus they had higher level of hardness. Therefore these could be aptly utilized for cutting purposes.

V. Cold Work/Hammering: This is done on cold metal. Pure copper is, as a rule, soft but by hammering it can be made much harder. However, too much hammering makes it brittle.

VI. Joining: Two separate pieces could be joined to complete the shape of an object. This was commonly practiced in joining handles or rims on pots or pans. A specimen from Harappa testifies to pouring of molten metal to join a handle on the body of the pot, (Mackay1931, p. 489). It was also common method used in gold and silver objects.

VII. Hot Work: This refines the coarse grain found in cast copper. It increases the density of the metal by closing up small pores and gas holes. The highest tempera-ture required is 1050°C and the lowest 400°C.

VIII. Annealing: It is a process of heating cold worked brittle metal to regain its malleability. It has been a popular method during antiquity

5.3 Alloying

The Harappan specimens, on the other hand, display a high percentage of alloying, though unalloyed specimens have also been found. According to the following table given by - Agrawal (1971, p. 168) the percentage of alloys in Harappan objects greatly varies.The Chalcolithic copper objects analyzed by Hegde were found to be made of either more than 98 per cent pure copper or a small percentage could be classified as low tin bronze (Hegde 1965). In post-Harappan Chalcolithic objects percentage of tin varied from 3.12 to 12.82. Bronze tools have keener and more enduring cutting edges than copper tools. Alloying copper with tin facilitated casting and hot forging operations.

Percentage of tools	70%	10%	14%	6%
Tin content	1%	8%	8-12%	12%

6. Copper- Bronze Objects from Harappan Civilization

Discussing the nature of Harappan tools repertoire, Wheeler (1968, p.73) observed, “In considering the possible elements of war, we may reject the simple chert blades which occur abundantly on all Harappan sites, as on many others of the same general period. But alongside these are found metal implements of which a majority may have been used equally by the soldier, the huntsman, the craftsman, or even by the ordinary householder and are included in the section without prejudice. They are of copper or bronze generally poor in tin and include spears knives, short swords, arrowheads and axes. Spears are invariably tanged and cannot clearly be distinguished by knives (see figs. 6, 7). Most of them are thin, flat, leaf-shaped blades which will buckle on impact and must have been stiffened by being set back between the split ends of the shaft, which would thus serve as a mid-ribbed. Sometimes two small holes near the base of the blade suggest a former binding for such a device rarely the blade has a slight median thickening, the section being diamond-shaped. Such reinforced blades are upto 18.5 inches in length and may rather represent short swords or dirks, a type of weapon for which there is no other evidence. They are from late levels, and have parallels of c.2200-1750 BCE in Syria and Palestine. The lead shaped spearhead is universal; no barbed blade has been found, although there is a clear illustration of a barbed spear on a Mohanjodaro seal, and a barbed spear head from Ur has been sighted in this connection……leaf shaped knives may sometimes be differentiated from spears by having a slightly sinuous recurved point, a Harappan peculiarity hardly ever found outside the Indus civilization.

> Arrow-heads are fairly numerous and are almost invariably of copper or bronze. They are thin and flat, with long, narrow barbs and no tang, resembling the swallow-tailed flint arrow-heads of Egypt and northern Iran. Copper or bronze axes are flat without the shaft-hole, which had early developed elsewhere in western Asia. Some of the axe blades are long narrow, with nearly parallel sides and may sometimes have been used in prolongation of the haft: others are short and relatively wide, with boldly expanded edge.

In-depth study of metals and metallurgy during the Indus Sarasvati Civiliaztion has been made by Agrawal (1071; 2000; Kenoyer and Miller, 1999). The discussion here borrows heavily from these works. The important tool typology of this civilization may be classified as under.

6.1. Ornaments and Mirrors

The use of copper as a form of ornament has a long history in the greater Indus region and can be traced back to the early levels at the site of Mehrgah, where there is evidence for a single copper bead from Neolithic levels (Period 1B) at c. 6000 BCE (Jarrige, 1979). Several Copper ornaments have been reported from subsequent layers (Jarrige 1983), but these objects have not been analyzed, so details of composition and manufacture are still unknown.

The presence of mirrors, remarks Agrawal (2000, p. 73) in the burials is intriguing, as they were made of a considerable amount of metal that could have been recycled. Metal mirrors are a new object during the Harappan phase, as mirrors were not previously made in any material, either polished stone or metal. Bronze mirrors have been recovered from sites like Rakhigarhi, Lothal, Dholavira and Mohenjodaro (Figs. 3 and 5) illustrated here have more or less similar design. The composition of the same is not known due to lack of analytical study of the same.

Talking of Harappan Jewelry, the human figurines – terracotta or metal– demonstrates a love for ornaments. Copper beads and spacers are also included in some of the hoards (for example at Allahdino; Agrawal 2000), but copper ornaments have primarily been recovered in non-hoard contexts, such as in the debris accumulating in the streets or habitation areas, or in some of the burials. Out of total 168 copper / bronze ornaments reported, 130 were found in non-hoard context and only 38 were found in hoards, generally in association with gold and silver or gold foil

Fig. 1. Carnelian belt and gold jewelry from Mohanjodaro

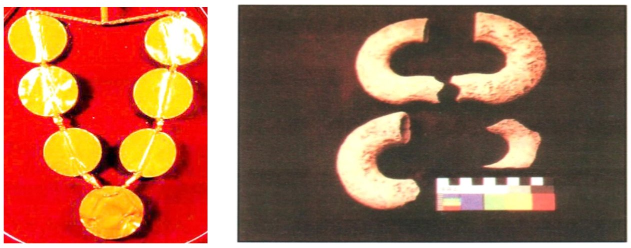


Fig. 2. A. Gold jewelry from Lothal, B. Jewelry from Mandi, Bagpat

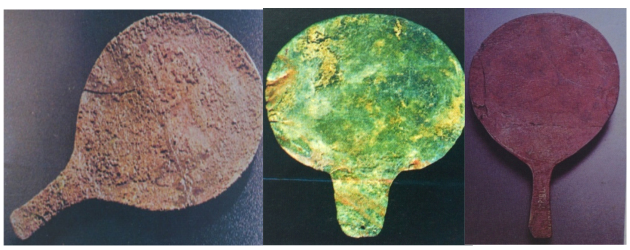


Fig. 3. Copper mirror from Dholaveria, Rakhigarhi & Mohenjo-Daro Photo by D.P. Sharma

fragments that were probably lost in the muddy streets or courtyards. Although very little metal was buried with the dead, burials, like hoards, provide a context in which metal ornaments were intentionally placed by the Indus peoples. Metal objects found in burials are almost all of copper / bronze. This includes mirrors, finger rings, bangles, and occasional beads. In one instance three gold beads were found, strung together with three stone beads. While the mirrors are invariably placed with female burials, the other metal ornaments have been found with both male and female individuals. It should be noted that no utilitarian copper/bronze tools have been found in the burials.

About the Harappan ornaments, Lal (1997, pp. 167-68) notes "Of gold, no vessels, even tiny ones, were made, evidently because of its rarity and cost, however, ornaments were frequent. These included a variety of beads – micro beads, barrel shaped ones, some flat and discular with axial holes, amulets, pendants, rings, broaches, etc. (Fig.1 & 2).One of the spacers found at Lothal has ten holes, indicating the same number of strings in the necklace concerned. Thin, elongated, conical pieces with a hole near the thinner end may have been ear pendant of the type used even now in India, However, no less interesting is a hollow conical ornament which is even today worn by rural womenfolk in Rajasthan and Haryana, in the middle of the upper part of the forehead, where the hair parts sideways. It is known as *chauk*. Attention may also be drawn to the circumstantial evidence regarding the occurrence of a small, thin, discular plate with two perforations on a margin. It was found at Lothal, on an altar where an animal had been sacrificed and may thus have had some ritualistic significance. In this context, the excavator (Rao 1985, p. 634) reminds us of the ornament wore on the forehead by "priest" from Mohenjodaro. Bangles (seen in Fig.1) were fashioned by bending rods into slightly open circles while some were made with silver or from hammered gold. Rings of silver and copper were equally popular during the mature Harappan period. Variety of copper objects was recovered from the sites of the Indus Valley; it is being described briefly here:

There is close similarity among artifacts recovered from different sites including from Harappa and Mohenjodaro. Therefore, these objects are being discussed together (see Figs. 7 and 9).Vessels, adze (one socketed), dagger knife, spear head, chisel, scrapper, razor, nail pearer (surgical or toilet set), cobbles awl needle, pin, antimony rod, mirror, fish hook, arrow head, hasp or a typical Indian *Kundi* made with rounded copper bar; latches and hooks have been reported from Harappa.

6.2 Vessels

Many copper vessels were made from single sheets of metal by hammering. In some cases, as testified at Mohenjodaro they were made in two parts and joined together. As seen in projection the bases were "lapped on" to the upper parts. In other cases, knobbed handles of lids were secured by rivets with the help of molten metal. The heavy bronze vessels appear to be cast. In some cases, the final finish seems to be given by hammering aided by frequent annealing and carful rubbing or by turning them on a lathe.

A special shape reported from Harappa by Vats is a carinated jar from Mound AB. It is 7.8 inches in height and 7.7 inches in diameter (at the mouth) and 11.5 inches (across the body). It has been made in two parts which are joined together by hammering. Such vessels have been found from other sites as well (Fig.4, 5).

Among the other shapes mention may be made of jar covers, scale pan and beams (Chanhudaro).Chanhudaro has yielded copper canister shaped container which is fitted with wire-loop handle. (Mackay 1943, pl. LXXIII, 37)

Another remarkable finding is a fluted cosmetic jar (Mackay 1943: pl. LXXIII, 39) with a very narrow (0.22 inches diameter) mouth and long neck. It might have been used for keeping kohl. This is a unique example among Harappan vessels.

Fig. 4. Pots and pans Mohenjo-Daro, after J Marshall

Fig. 5. Pots, pans, mirror etc from Mohenjo- Daro after Mackay

6.3. War and Hunting tools

It has generally been stated that there is a relative scarcity of weapon grade tools in the Harappan civilization. Only exception to this is the evidence coming forth from Ganeshwar-Jodhpura site. Though it is labeled as a Chalcolithic site, but it has a unique position of being almost contemporaneous to the Mature Harappan sites and is located in the copper ore rich area of Khetri in Rajasthan. Occurrence of hundreds of inverted v-shaped arrowheads from this site is noteworthy. Similar shapes along with copper celts have been found at Kalibangan in Rajasthan suggesting its supply from the Ganeshwar - Jodhpura complex. Similar arrowheads have been reported from sites like Lothal, Dholavira, (Figs. 8, 9), Harappa, Mohenjodaro and Chanhudaro (Marshall 1939, Pl.CXLII No.13; Mackay1938, Pls CXXI, CXXVII etc.). The subject needs a detailed and independent treatment which may not be taken up at this juncture.Nevertheless, the evidence is significant from the point of view of metal technology of the Harappan period. The important war and hunting tool-types (Figs.6-8) may be enumerated as under:

6.3.1 Blade Axe: Mackay points out that there is 'no skimping' of metal in the manufacture of blade axe, which was first cast in open moulds and then hammered for requisite hardness. There are traces of polishing or rubbing after they were hammered. Long and Narrow Axes are found in long and short types as revealed by Mahenjodaro excavations. Lothal has yielded several types of axes. Flat axe with a long narrow blade or a broad blade is most common type. There is thick rectangular type axe. Shaft-hole axes are reported though rarely. One specimen has been reported from Chanhudaro from a relatively late phase (Agrawal 2000, pp. 71). More noteworthy is the shaft-hole axe (Rao 1985, Fig.107).

Leaf shaped blades are typically Harappan tool. They are provided with tang with pointed end. Theseare reported from Lothal (Rao *op.cit.*).

6.3.2 Spear or Lance: These types have thinner and longer blades. They could have been mounted on a bamboo Shaft. Possibly they were made from rods of metals, which were 'little thicker than the tangs'. Their edges were possibly sharpened by honing and hammering (Figs. 6,7).

6.3.3 Knives and Dagger, Arrow head, Spear lance-heads and Sword or Dirk: The latter has double edge.A specimen recovered from the Mohenjodaro (1930-31) is heavy for its size and is well made and thick.

Fig. 6. Copper & Bronze arrow heads and spear heads from Mohenjo-daro, after J. Marshall

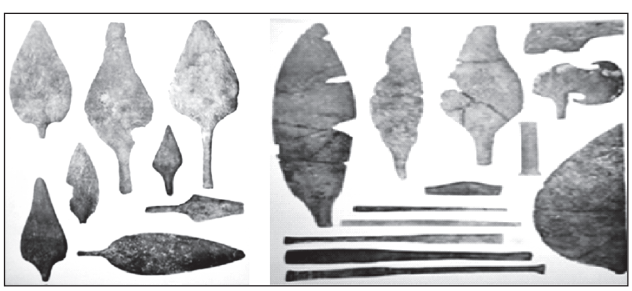


Fig. 7. Copper & Bronze Leaf shaped spear heads and arrowheads, Mohenjo-daro, after J. Marshall

6.3.4 Razor: Razors were classified into double blade which is the most common type. The blades are very thin. Their tangs are oval in section. They seem to be roughly cut out of metal sheets and hammered into shape. Generally, razors are not very large in size (Mackay 1937-38, p. 468)

6.4. Fish Hooks: Which are found frequently at Harappan sites including Mohenjodaro

6.5. Chisel: Chisels have either rectangular or square sections;there are ones with tangs having flattened section orrounded sections. Some specimens are illustrated in the Fig.7 here. The size is rather small. According to Marshall (1931, p. 502) these were used for wood work or may be for some soft stones such as steatite which are common at Indus sites.

7. Miscellaneous tools and implements

Variety of implements used for different functions have been found during at Harappan sites. Fig. 9 shows miscellaneous objects recovered from Dholavira. True saw with teeth like the modern ones was a Harappan invention. Sickle, plumb bob (lead), chisel, awl, reamer, drill, bolt etc. have been reported from Mohenjodaro (Mackay, 1937-38, p. 476). Eye needle, as pointed earlier was another Harappan contribution.

8. Inscribed Metal Objects Seals/Tablets

Kenoyer and Miller (1999) have made exhaustive study of metal objects with inscription. At Mohenjodaro hundreds of inscribed tablets have been recovered (Marshall, 1931; Mackey, 1937-38; Yule, 1985). A rare variety of copper tablet with raised script was found at Harappa (Vats, 1940). Lothal and Dholavira also yielded a good number of copper tablets (Fig. 10). These rectangular or square tablets have inscriptions in Indus characters as well as motifs on both the

Fig. 8. Copper & Bronze arrow head's, from Dholavira, after R.S. Bisht

Fig. 9. Copper & Bronze objects from Dholavira, after R.S. Bisht

faces. Kenoyer and Miller (1999:134) assume that the inscription might have been carved with stone burins or bronze graver.

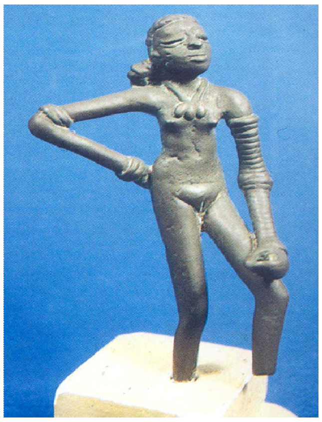
8.1. Figurines

Among the most talked about metal objects from the Indus Valley Civilization is the bronze image of the 'dancing girl'(Fig.11. A,B). It is an excellent example of lost wax technique or ciré *perdue*. It is also remarkable for its execution and artistic expression. Noteworthy is the fact that it is richly adorned with ornaments. There is a prominent necklace with a pendant hanging almost up to her chest; nearly 20-25 bangles are worn on the wrist and fore-arms of the left hand; the right hand which rests on the waist has a wrist band or bangles and an armlet. In addition to this female figure, there are animal figurines of dog, swan, elephant; bull and goat were also cast in miniature in copper-bronze(Fig. 12-15). Large sized animal figures are reported from a relatively later phase of the Harappan Civilization from Daimabad as discussed below in some detail.

Fig. 10. Rectangular Copper bifacial tablets, Mohenjo-daro, after Marshall

8.2 Daimabad Bronzes

The site of Daimabad is located in Ahmadnagar district of Maharashstra. It has been placed in the relatively later phase of the Harappan Civilization and also long distance away from the main Harappan zone. Excavations at Daimabad (Sali, 1986) yielded a variety of copper objects along with evidence of copper working. Mention of kind of copper smelting furnace and a 'lump of copper' ore at the site may suggest smelting at the site. Chalcopyrite ore is available in the locality therefore there is a possibility that it was used for copper extraction at the site. A hoard containing four large sized animal figurines, viz, elephant, rhinoceros, bison or a buffalo and a chariot with a rider is the most significant finding of the



Figs. 11(A & B). Bronze Dancing Girl, Mohenjo-daro, National Museum New Delhi & Karachi Museums

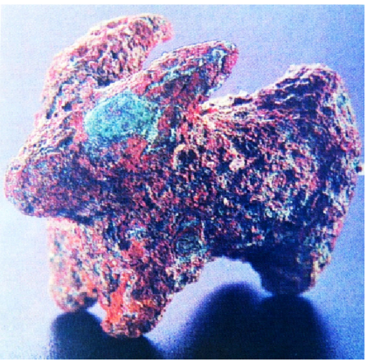


Fig. 12. Miniature rabbit bronze, Dholavira, after R S Bisht

Fig. 13. Unhumped Bronze bull from Kalibanga

Fig. 14. Miniature Dog, Lothal, after Rao

Fig. 15. Model of bronze chariot, Mohenjo-Daro

excavation. Dhavalikar (1993, pp.421-426) discusses the contents of this hoard in detail. There is a chariot with a man which is driven by two bulls. Its total length is 45 cm and a width is 16 cms. The other figure is that of an elephant which is standing on a platform (27 cm. long and 14cm. broad). The trunk is curved upwards. The rhino figure is standing on two horizontal bars resting over two sets of solid wheels. The buffalo is quite naturalistic in execution. Its height including the wheels is 31 cm and length is 25 cm. It resembles a bison. It stands on a platform similar to the elephant figure. The front wheels are smaller than the rear ones (8 and 10, cm respectively). Chemical analysis reveals varying percentage of alloying in these objects. Tin alloying ranging from 0.85 percent to 6.51 percent has been reported in these objects (Shinde et al., 2016, p. 114).

Summing up the discussion on copper technology, we can say that the Harappans had mastered the technology and had made a judicious use of metal alloying to suit the nature of the object. For instance, the bronze mirrors had much higher percentage of tin content than other artifacts. Of the 177 copper objects analysed from Harappa and Mohenjodaro only 30% were alloyed (Agrawal, 2000, p.72). Tin alloying ranges from1-12%; arsenic alloying, 1-7%; nickel alloying, 1-9%; and lead alloying are 1-32%. Tin bronze is most frequent compared to other alloys. As discussed earlier different techniques of fabrication were known to the Harappan metal smiths.

9. Gold and Silver

Precious metal objects from the Harappan phase sites have been recovered from hoards rather than from burials. Gold and silver ornaments and silver vessels have been found almost exclusively in hoards. It is interesting that copper / bronze vessels have been found almost equally in hoard and non-hoards contexts. Gold and Silver ornaments have been found stored in ceramic, copper, or silver vessels that appear to have been stone beads made from agate carnelian, jasper, turquoise, and other varieties of coloured stones, deliberately hidden away. Some of these hoards include broken ornaments and melted lumps of gold and silver that would undoubtedly have been re-melted and made into new ornaments. The hoards often contain numerous gold objects like beads, leaf perhaps fragments of ornaments. The metallurgy of gold and silver was fairly evolved as is fully manifest in the exquisite jewelry found in excavations. Gold and silver have generally been used for fashioning objects like jewelry, including a tiara (found at Kunal in Haryana), other ornamental objects or decorative pieces and even containers. Amulets, pendants, armlets, beads, brooches, pendants and earrings of precious metals were found from Harappan sites. The gold ornaments a mastery of metal craftsmanship (Fig.1,2).The gold smithy was highly evolved as evident from the jewelry from the Harappan sites. Silver was rather scarce in this part of the world. Therefore, the number of silver objects is rather small. It comprised beads, bangles, buckles and other ornamental pieces. Though few household objects like cups or containers are not altogether missing (Fig. 16, 17).

The neckpieces recovered from Mohenjodaro and kept in the National Museum bear testimony to the art of gold smithy. Lal, the archaeological chemist of Archaeological Survey of India had analyzed two gold objects from Lothal. They contain 33.45% and 41.48% silver but no copper, nickel, lead or zinc. On this basis

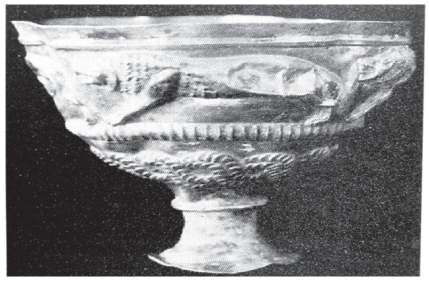


Fig. 16. Pedestalled Gold cup with Lion decoration, Quetta

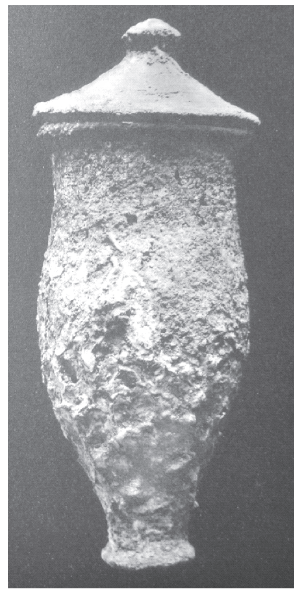


Fig. 17. Silver Jar with knobbed lid, Mohenjo-Daro

he concludes that it is electrum rather than an artificial mixture of silver (derived from galena) and gold (Lal, 1985, pp. 664-665). Special mention may be made here of a gold pedestalled cup from Chanhudaro. It has a lion motif on it (Fig.16). Harappans seem to have accessed silver from different sources. One of the likely sources of gold according to Kenoyer and Miller (1999, p. 120) could be streams and rivers in Afghanistan as well as upper reaches of the Indus Valley.

Silver objects in the Harappan Civilization are relatively numerous. According to Marshall (1931) silver was more common compared to gold. Besides ornaments like beads, bangles, rings, fillets brooches, seals etc. there are a few vessels of silver as well. Special mention may be made of a silver jar with pointed base;it also has a knobbed lid (Fig 17). These objects also contain some copper as revealed by analysis (Sana Ullah in Mackay 1938, p. 599). There are silver deposits in Baluchistan, Afghanistan and Aravalli hills in Rajasthan. Correlation studies, however, have not yet been sufficiently conducted to suggest the exact source of silver. As observed by Sana Ullah (1938, p. 589) argentiferous galena was probable source of silver.

10. Conclusion

In this brief survey of metals and metallurgy during in the Sindhu- Sarasvati Civilization, we observe mastery in metal crafts and a systematic utilization of resources by a well–organized socio-political system. The affluence of the Harappan civilization is reflected in the metal repertoire. The impression that the people of this civilization were peace loving is reflected in the tool-typology of the civilization. There is a relative scarcity of weapons or tools of offence. Large numbers of stone tools were utilized.

It is particularly sophisticated due to its simplicity. As observed by Agrawal (op. cit.) ‘The metal craft of this civilization has neither the complicated mouldings of Mesopotamia nor the ornate design of Chinese metal ware’. The Harappan smiths had achieved a sophistication which is manifest in its simplicity. Most of the artifacts appear utilitarian. Except for two specimens of the dancing girls no human images are available in metal. But the animal figure examples do show their competence in the lost wax method of casting. The Harappan sites have been rich in copper-bronze compared to the Chalcolithic and the Copper Hoard-OCP culture which were partially contemporary with the former. However, unlike the other Chalcolithic culture of India, one comes across plenty of pots and pans in metal here. The main tool types may be classified as razors; leaf shaped knives with incurved end; sickle blades with externally sharpened edge; chisels; spear heads; thin barbed arrow-heads; straight and circular saws; blade-axes; mid-ribbed daggers; drills; eyed needles. It may be pointed out that needles with eyes on the pointed ends, true saws, circular saws, and drills are Harappan contribution to the world of instruments. Shaft-holed axes are rather a rarity and must depict imports. One of the razors from Mohenjodaro was found wrapped in cloth. Mohenjo-Daro yielded a hoard below 4.8 feet with 40 objects including a goat figurine. The Hoards numbered 2 and 3 came from the same room in DK area containing utensils, tools, celts, figurines etc. This indicates that the metal objects were valuable and special care was taken towards maintenance and safety of objects.

There is a judicious use of metals and the metallurgical skill which is in keeping with the general temper of the Harappan civilization. While fabricating artifacts, different techniques were employed by artisans for different types of objects. Vessels, for instance were shaped with technique of raising, sinking and forging together two pieces with an exemplary expertise. Lost wax technique was known though used for moulding figurines. Wires have been drawn using another technique. Alloying was done suitably in accordance with the nature and function of artifacts. As noted earlier, mirrors for instance, have higher tin content than other objects. Tools with sharp edges like saw and chisels seem to have been hardened by alloying with arsenic. A small percentage of tin alloying may add golden hue to the finished artifacts. Unfortunately, the number of metal samples which have been analyzed so far is rather small. The compositions and techniques could be better understood had greater attention was paid to study this aspect of Harappan Civilization.

Since copper-bronze artifacts played a key role in shaping the techno-cultural personality of this civilization, greater attention should be paid to study of metals and metallurgy and raw material procurement mechanism of Harappans.

For procurement of raw material, not only the smallest deposits were tapped, even pacer deposits seem to have been exploited, especially for gold. The sites closer to the mineral deposits appear to have gained special status. The palatial structure at Mundigak in Afghanistan may be an example in the case. Likewise, the expansion of Harappan 'empire' up to Daimabad in Maharashtra could be consequence of some such mechanism. The marine trade with contemporary civilization in Persian Gulf might have been major asset in procurement of precious commodities including metals. Despite these facts, it may be pointed out in the end that much work needs to be done in the field of metals and metallurgy of the Harappan times. Further analytical researches from different archaeo-metallurgical is needed. Our knowledge about the metallurgical technique is still far from satisfactory. Further researches are expected to shed more light on aspects of metals and metallurgy of the Harappan civilization.

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