Chapter 24
Production and Consumption of Copper-Base Metals in the Indus Civilization

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Introduction

The organizers of this volume have posed an intriguing set of questions regarding the emergence, technological development, and adoption of copper metallurgy. Given the restricted nature of the current data available from the Indus Civilization, we were asked to summarize the approaches taken to date, the nature of production, and the style of Indus metal production and use, both within the Indus domain and beyond its regions of influence. We briefly review the data available for production, pointing readers to the publications available, and consider the case of Indus technological style for all stages of production. We then turn to consumption, reviewing typologies of Indus metal objects and past conclusions about use and distribution of copper-based artifacts. Finally, we discuss the relationships between metal consumption and social values.

There have been several major synthetic reviews of Indus copper metallurgy in the past two decades, including Chakrabarti and Lahiri (1996), Kenoyer and Miller (1999), Agrawal (2000), and Agrawal and Kharakwal (2003). These works provide comprehensive reviews of the nature of the evidence and the current state of interpretation up to the mid- to late 1990s (note that Kenoyer and Miller 1999 was submitted for publication in October 1996). The outline of copper production presented here is essentially the same as that presented in Kenoyer and Miller (1999), with additions and corrections from the few subsequent publications with new information on Indus metal production. Here we also summarize and expand the discussion of typology and the consumption of copper objects, particularly in Indus cities. Through an analysis of the types of forms that are fashioned from copper and the archaeological

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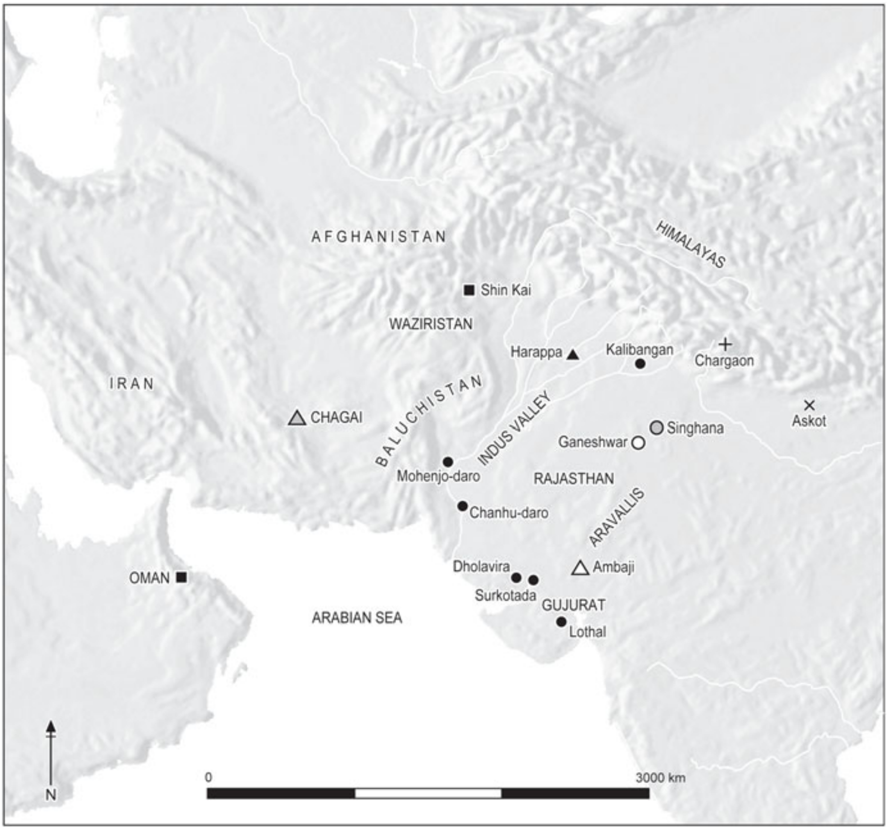

Fig. 24.1 Map of sites and copper ore locations discussed in text

contexts that they are found in, we propose some hypotheses for the role that copper played in the larger economic and social reality of Indus cities.

The Indus Civilization refers to the complex urban tradition that spread across the alluvial plains of northwestern South Asia (Fig. 24.1). Centered on the twin river systems of the Indus and the Ghaggar-Hakra, the Indus Civilization expanded to encompass vast stretches of modern-day Pakistan and northwestern India. During the Regionalization Era of the Indus Valley Tradition (Shaffer 1992), the latter portion of the fourth millennium and early third millennium BC, we can see the beginnings of the growth and development of the major Indus sites (Table 24.1). By 2600 BC, large urban centers, regional towns, and many smaller sites were found within the core area, especially along the river courses. Indus cities, and Indus sites in general, are marked by the presence of several types of diagnostic artifacts. These include chert weights; certain types of terracotta figurines and items of personal ornamentation such as stone beads; seals and tablets inscribed with the Indus script; and distinctive black on red pottery forms (Kenoyer 1998; Possehl 2002). Indus craftspeople produced

Table 24.1 Generalized chronology for the Indus Valley Tradition. (After Shaffer 1992; Kenoyer 1998; Meadow and Kenoyer 2005)

Early Food Producing Era		c. 6500–5000 BC
Regionalization Era		c. 5000–2600 BC
	Early Harappan—Ravi Phase	3300–2800 BC
	Early Harappan—Kot Diji Phase	2800–2600 BC
Integration Era	Harappan Phase	2600–1900 BC
Localization Era	Late Harappan Phase	1900–1300 BC

a variety of items in a diverse array of raw materials, including copper and copper alloys (Kenoyer 1998; Vidale 2000; Vidale and Miller 2000).

Metal objects have been recovered from each of the major excavated Indus cities (Marshall 1931; Mackay 1938, 1943; Vats 1940; Rao 1979; Bisht 1997; Kenoyer 1998; Lal et al. 2003) as well as smaller sites (Shaffer 1982; Agrawal 2000). Perhaps no other raw material besides clay was employed by Indus people to produce such a diversity of forms. Evidence from excavations indicates that copper and bronze were used to make tools, such as knives and saws; weapons, such as spears and arrow points; jewelry, such as beads, rings, and bangles; household materials, such as dishes and other vessels; and items of possible economic control or religious importance, such as scale pans and tablets. Despite the number of copper artifacts that crosscut all aspects of Indus life, the material remains critically understudied (Kenoyer and Miller 1999; Agrawal 2000; Bhan et al. 2002). This is not to say that analyses of copper and bronze objects have not been undertaken. Determining the sources of Indus copper has traditionally been the major focus of Indus metallurgical studies (Desch 1931; Sana Ullah 1931, 1940; Agrawal 1971; Rao 1979; Lal et al. 2003). However, there has been little work done regarding the specific uses of copper at Indus sites, and few detailed typological categorizations of changes over time in the copper and copper alloy assemblages. Notable exceptions to this include Yule's (1985a, b) typologies of copper objects from the major excavations at Mohenjo-daro, Harappa, Lothal, and other Indus sites; work on excavated material from Chanhudaro by Miller (2000); and a discussion of use and consumption at these sites by Mark Kenoyer and Miller (1999), which also includes a summary of catalogues of Indus and related metal objects published before 1996. Work is also ongoing on materials from the urban site of Dholavira (Bourgarit et al. 2005; Srinivasan 2007).

Work being undertaken on copper and copper alloy assemblages in the regions adjacent to the Indus Valley plains is essential for contextualizing the Indus copper metallurgical tradition. Such work includes summaries and typologies of materials from Baluchistan and what is now northwestern India, as well as the Indus Valley, dating from the fifth to second millennia BCE and spanning the range of the Indus Valley Tradition (Yule 1985c; Haquet 1994; Chakrabarti and Lahiri 1996; Agrawal 2000; Sharma 2002; Agrawal and Kharakwal 2003; Mille et al. 2005). The volumes by Chakrabarti and Lahiri, Agrawal, and Agrawal and Kharakwal provide large-scale syntheses of data from numerous excavation reports, covering all of the metallurgical traditions recognized to date within northwestern South Asia. All of this work will allow future examinations of regional variations in metallurgical traditions within the Indus world, as well as comparison of Indus traditions with neighboring traditions.

Overview of Production: Indus Copper Technology and Technological Style

Although there are some new publications on Indus copper, as noted above, the vast majority of these works focus on metal object descriptions, lists of compositional analyses (often reprints from older excavation reports), and discussion of sources of the metal ores. These are all useful, and the major new contributions of our paper also deal with consumption and sourcing. Very little new material on Indus copper production processes is available, partially due to research restrictions and the in-progress nature of current interesting work, but also apparently due to a general lack of interest in production-related questions (other than sourcing) by researchers. The majority of the data presented here is a brief summary of material found in Kenoyer and Miller (1999), updated in Miller (1999, 2005).

Figure 24.2 is a generalized model of the process of production for copper and its alloys. Metal production processes can be divided into raw material procurement, materials preparation, primary production of metal from ore (smelting), and secondary production (melting/casting and fabrication). Table 24.2 shows examples of assemblages characteristic of the most common types of smelting and melting, as well as nonmetallurgical pyrotechnologies (from Miller 1999, Fig. 3.2).

Smelting and Sourcing

There has been considerable confusion in the literature about evidence for the presence of copper smelting versus melting stages at Indus sites. In the hopes of preventing its spread farther through the secondary literature, we emphasize that, based on all information to date, only melting of copper took place at sites within the main Indus region, as might be expected for a floodplain region with no metal mineral deposits or much stone at all (see Law (2008) for the distribution of mineral deposits around the Indus Valley). To date, there is no evidence for the import and smelting of quantities of metalliferous ores at any of the Indus sites. In particular, only a small number of actual mineral fragments have been reported, and there is a significant lack of smelting slags. (We use the usual definition of an ore as a mineral with economic value for the production of metals, with the knowledge that copper-bearing minerals also had other values, especially as pigments for cosmetics and paintings. Therefore, we carefully reserve the use of the term “ore” to quantities of metallic minerals probably intended for metal production.) Mineral fragments that might possibly relate to metal working found at Indus sites include various cuprous minerals, hematite (iron), löllingite (arsenic and iron), antimony, cinnabar (sulfide of mercury), and several types of lead minerals, including cerussite, galena, and orpiment (see Miller 1999, pp. 192, 204–217 for full discussion). However, since the

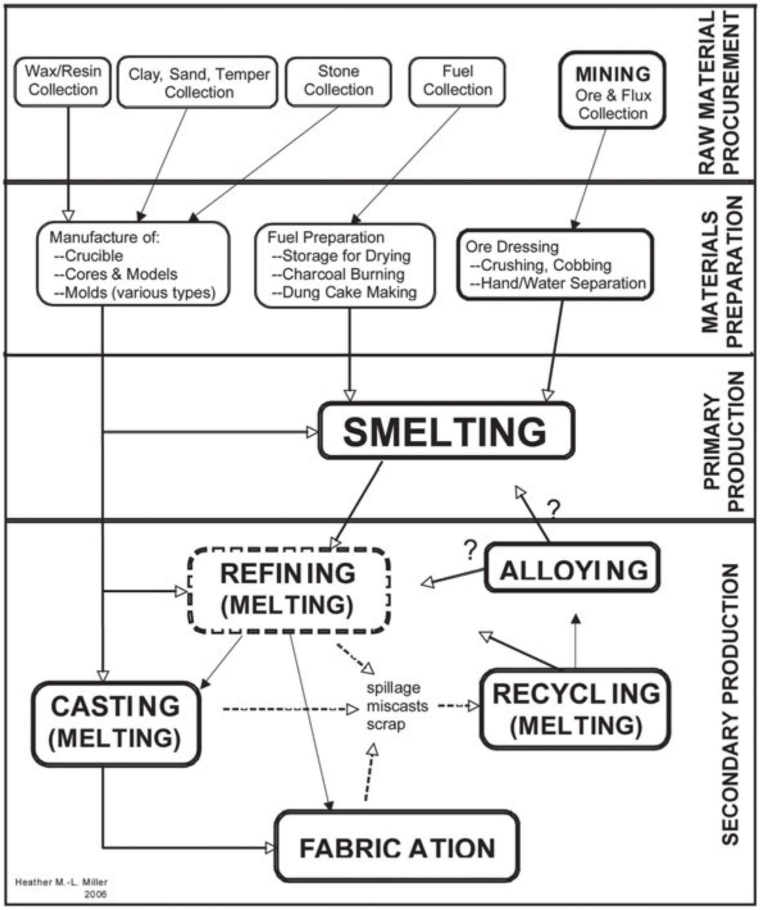

Fig. 24.2 Generalized diagram of copper production

great majority of these minerals were not found in association with metal processing debris, it is more likely that most of them were imported not for metal production or alloying, but for other purposes—as cosmetics, medicines, poisons, or pigments. An interesting contextual exception is a fragment of löllingite found at Harappa that was the only noncopper object in a copper vessel containing a hoard of more than 90 copper/alloy objects and scrap (Vats 1940, p. 90), which might be suggestive evidence for deliberate arsenical alloying; analytical testing might be interesting.

Furthermore, smelting of metal ore usually results in fairly conspicuous accumulations of manufacturing debris and broken firing structures, especially the weather-resistant vitrified masses of silica and other fused minerals that generally accumulate in conspicuous mounds near the smelting furnaces. On the basis of quantity and type of slag, the small amounts of copper metal slag found at Indus Civilization sites seem to be more representative of melting than of smelting (Miller

Table 24.2 Assemblage characteristics for nonferrous metal processing. (Compiled from Craddock 1989, p. 193, Fig. 8.2; Bayley 1985; Cooke and Nielsen 1978)

Material type	Smelting	Melting	Nonmetallurgical
Ore/Flux	Fragments usually found in association	Fragments rare/none	No associated ore/flux
	Proximity to ore source	Proximity to markets	
Installations (kilns/furnaces)	No Ash	Ash possible	Ash possible
	Diameter usually < 60 cm	Heavily vitrified, some slagging	Diameter may be large (> 60 cm possible)
	Heavily vitrified & slagged	Usually less poorly preserved (not destroyed to remove melt)	Tend to be unvitrified, but may be ash-glazed
	Usually poorly preserved (destroyed to remove smelt)		Usually better preserved
Kiln tools/furniture (crucibles, molds, tuyeres, *etc*.)	Heavily vitrified and slagged; crucibles possible; molds unlikely	Some vitrification and slagging or ash-glazing; crucibles and a variety of mold types possible	(Different types of kiln tools/furniture)
Other Slags (especially scoria/dross)	*Large quantities (many kg) of hard, dense scoria, dark in color with relatively uniform structure and fewer, larger bubbles*; includes both furnace bottoms and tap slags)	*Slags much more vesicular/porous; lighter weight; less homogeneous but inclusions distributed very heterogeneously; macroscopic metal inclusions possible/likely*	*Usually much lighter in color and density; also unhomogeneous*. (Glass slags more obviously glassy than most other slags.)

1994, 1999). Metal ingots must therefore have been imported into the Indus region, and a number of copper ingots have been found at several sites, as well as a possible lead ingot at Mohenjo-daro (detailed in Kenoyer and Miller 1999 and in Miller 1999, Fig. 3.4, 220–222; the latter includes a correction to the erroneous citation that an ingot was found by Sir Aurel Stein at a site in Cholistan).

In addition, if there were Indus settlements engaged in large-scale extraction of copper (smelting) at any of the source areas surrounding the Indus region in Rajasthan, Baluchistan, Afghanistan, or Oman, they have yet to be identified. It seems more likely that the Indus people were engaged in trade for copper ingots with local groups in one or more of these source areas. As this must have been an extremely important trade item, considering the apparent abundance of copper used by Indus people, it is not surprising that sourcing has been such a focus of interest, particularly given the possible Indus use of several source areas. It is noteworthy that there are mineralogical resources on all sides of the Indus region, making alternate sources of supply possible, and so sourcing gives us some idea about **actual** trading connections as opposed to simply **possible** connections. The inability to clearly distinguish between actual and possible connections has been another long-term problem with discussions of Indus copper, and indeed many Indus raw materials.

Law's (2008) current excellent work on many types of stone provides a model of how much such research might tell us about the direction and nature of such connections, and how they change over time.

The systematic pursuit of Indus ore sources has been difficult, due to a number of factors. The complexity of sourcing studies in general is compounded by the fact that the Indus Civilization had numerous likely source areas for metals, particularly for copper. Each of these source areas has their own geologically complex mineral deposits. Preservation of metals is extremely poor at most Indus sites. There are also potential problems with what appears to be a high degree of metal recycling at some Indus sites (Kenoyer and Miller 1999), which might be addressed if studies could be focused on copper slags ingots, and prills from remelting sites as well as finished objects. The location of some of the potential ore/ingot sources in border areas or tribal regions that are not easily accessible to modern researchers (e.g., Baluchistan and Afghanistan) is a major issue that has been a problem for several decades now. However, lead isotope analysis is slowly being carried out on Indus samples and regional ore sources by several projects; we present initial, preliminary work by Hoffman and law below.

Lead Isotope Case Study

The application of lead isotope analysis (LIA) is extremely complex for copper materials from the Indus Civilization. A primary obstacle is that, at present, there is no comparative database of geological isotopic values from the many potential sources surrounding the Indus, and there are potential logistical difficulties in obtaining the samples from several of these possible source areas. Additionally, the often highly corroded condition of the Indus archaeological materials may present difficulties for any analytical procedure. While these challenges may preclude the ready establishment of the specific source-provenance correlations that have traditionally been the result of LIA research programs in other regions, there are several broad statements regarding copper metals and the Indus that have been made and can be immediately tested through the application of LIA. While it may not be possible to identify the specific sources utilized by individual Indus sites, it is possible to discuss the likely and unlikely sources of copper metals present at sites during a given time period. This would provide important evidence for issues related to metal consumption, resource availability and access, and the operation of Indus metal acquisition. At present it is possible to make some tentative evaluations of the preliminary data emerging from ongoing research at the site of Harappa.

Hoffman and Law (see this article and Law 2008) conducted lead isotope analysis (LIA) at the Laboratory for Archaeological Chemistry (LARCH) at the University of Wisconsin-Madison to analyze the isotopic characteristics of seven archaeological copper mineral specimens from Harappa, and compared them to samples from potential source areas within and adjacent to northwestern South Asia (Tables 24.3 and 24.4). Wherever possible, minerals were obtained, but slags were also analyzed

Table 24.3 Regional ore deposits

Deposit	Location	Sample type
Ambaji	Northern Gujarat	Ore
Ganeshwar	Northern Rajasthan	Slag
Singhana	Northern Rajasthan	Slag
Chagai Hils	Baluchistan	Ore
Shin Kai	Waziristan	Ore
Chargaon	Himachal Pradesh	Ore
Askot	Uttaranchal	Ore
Various	Oman	Published Ore Data

Table 24.4 Copper minerals from Harappa

Sample	Mineral type	Location	Period
H94/4999–529	chalcocite	misc. surface find	Unknown
H90/3008–13	chalcocite	Mound E—survey	Harappan or Later
H90/2070–12	chalcocite	Mound E—survey	Harappan or Later
H90/3008–14	chalcocite	Mound E—survey	Harappan or Later
H90/3022–98	malachite	Mound E—Tr. 58	Harappan or Later
H95/4943–8	malachite	Mound ET—Tr. 28	Harappan or Later
H90/3126–1	malachite	Mound E—Tr. 56	Harappan

for some sites. Additionally the data from South Asia were compared to published LIA values for copper deposits in Oman (Calvez and Lescuyer 1991; Weeks 2003).

Lead isotope analysis was first developed to date geological deposits (Faure 1986; Dickin 1995). Three of the isotopes of lead (^{206}Pb,^{207}Pb, and ^{208}Pb) are the products of the decay of uranium and thorium, while the fourth (^{204}Pb) is taken to be a stable reference isotope (Faure 1986). Since there are only four isotopes of lead, three distinct ratios exist. Based on the principles of radiogenic decay and the known half-lives of the daughter products, geologists have used lead isotope abundance ratios to develop models for extrapolating the age of geological samples (Faure 1986; Dickin 1995). Over the past 30 years, archaeologists have adopted and applied this technique to the study of archaeological metal remains (Gale and Stos-Gale 2000). This is because Pb isotopes do not undergo fractionation during smelting or any subsequent manufacturing processes (Gale and Stos-Gale 2000). Therefore an artifact containing lead will retain the original isotopic composition of its parent deposit. As a result, lead isotopes have demonstrated a high degree of utility in establishing source provenance correlations for archaeological metals. Of course for copper artifacts this is a best-case scenario. It is always a problematic possibility that copper from two or more sources could be mixed and other metals or materials could be added during the manufacturing process, either of which could alter the isotopic characteristics of the finished object.

Some initial conclusions can be drawn from this research on the Harappa materials, through the analysis of a bivariate plot of the LIA results (Fig. 24.3a). The samples from both of the Himalayan sources are clearly distinct not only from each other, but also from all of the other sample regions as well. All seven of the archaeological copper minerals from Harappa that were analyzed clearly do not exhibit an isotopic

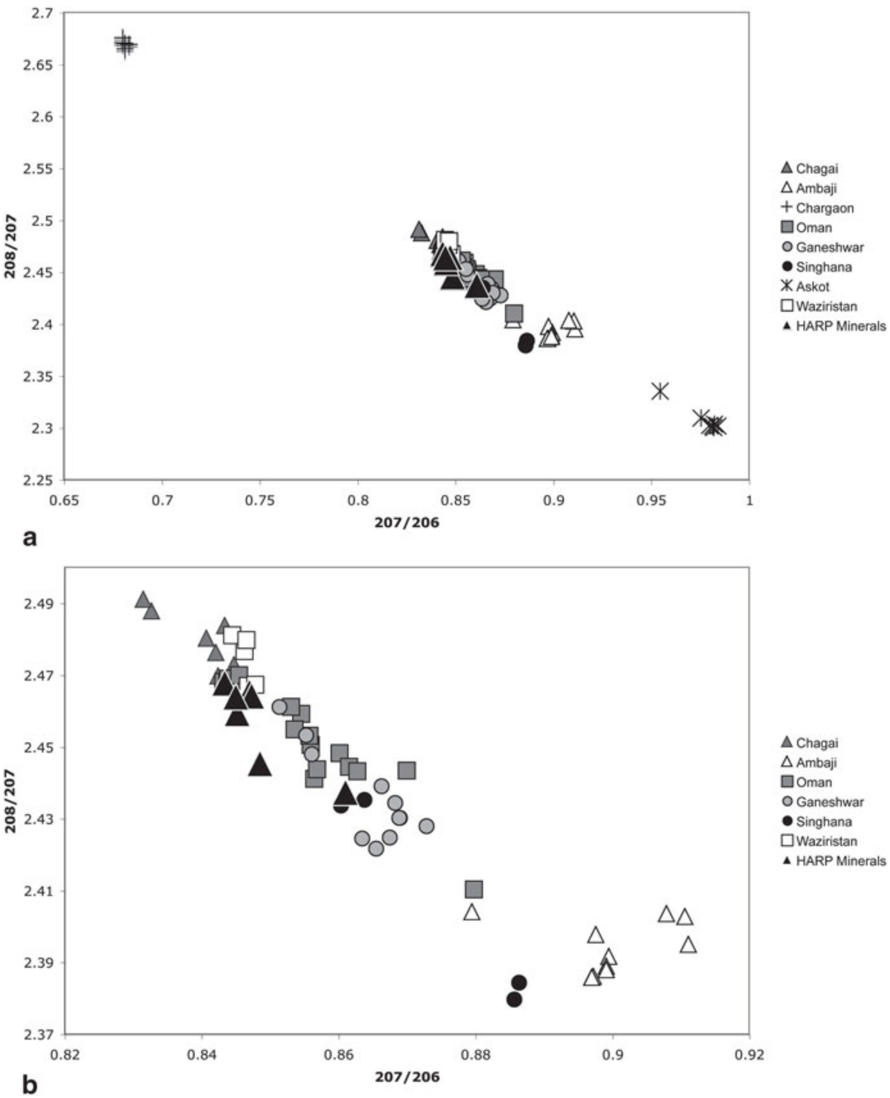

Fig. 24.3 **a** LIA results for regional ores sources and mineral fragments from Harappa. **b** The same in detail

relationship to the Himalayan sources. These samples can be eliminated from further analysis of this data set and the other samples can be examined in greater detail (Fig. 24.3b). None of the samples from Harappa are isotopically related to the modern ore samples from Amabaji. Five, or perhaps, six of the Harappan minerals do appear to be related to one of the sources to the west or south of Harappa, that is, Baluchistan, Waziristan, and Oman. Many of the copper mineral samples from the site fall in the area where the isotopic values for these three sources overlap. The overlap exhibited

Table 24.5 Copper or copper alloy artifacts from Harappa

Year	Lot	Rec.	Type	Feature	Trench	Mound	Phase
H2000	2102	1447	Sheet/Blade	1	54	E	Harappan
H2000	2226	40	Sheet/Blade	1	54	E	Harappan
H2000	2357	3	Bead	475	54	E	Harappan
H2001	2394	3	Bead	534	54	E	Harappan
H1996	6913	45	Bangle	686	11	E	Harappan
H1996	6958	61	Rod	730	11	E	Harappan
H1994	4343	3	Sheet/Blade	283	11	E	Harappan
H1995	4638	1	Bangle	538	10	ET	Harappan
H1995	4968	12	Bangle	174	28	ET	Harappan
H1996	7227	32	Rod	30	37	F	Harappan
H1996	7248	1	Rod	56	37	F	Harappan
H1998	8627	18	Rod	37	43	F	Harappan

by these sources is likely the result of the similarity in geologic age of these three ophiolitic metallogenic zones. One of the seven copper mineral samples from Harappa *may be* isotopically analogous to the slag samples from northern Rajasthan, specifically those from Ganeshwar (Fig. 24.3b). Based on these seven archaeological copper mineral samples from Harappa, the following conclusions can be advanced. It is unlikely that either Ambaji or the central Himalayan sources were supplying Harappa with copper minerals. Harappa *may have procured a small portion* of its copper minerals from sources in northern Rajasthan. However, at present, the data indicate that the majority of Harappa's copper minerals were obtained from sources to the west or south of the site. If mineral procurement parallels copper ingot procurement, sources to the west or south likely supplied the majority of Harappa's needs.

LIA has also been conducted on 12 copper or copper alloy artifacts from Harappa, although the compositional analysis of these artifacts has not yet been done, as discussed below. Examples of beads, bangles, rods, and sheets were analyzed. All artifacts were from the Harappan Phase (Integration Era) and from either mound E, ET, or F (Table 24.5). This analysis was conducted at the University of Michigan, Department of Geosciences on a Thermal Ionization Mass Spectrometer (TIMS). Recent archaeological applications of LIA have demonstrated the utility of using the technique to determine the number of potential source areas present even in the absence of geologic comparisons (see Weeks 2003 for further references). In order to determine if the results of these initial analyses indicated the potential for different source areas for the copper artifacts, cluster analysis was run on the data. The results strongly indicated the presence of three possible groups, or source areas, with perhaps two of the groups indicative of closely geologically related source areas (Hoffman 2007). It must also be noted that these objects may contain alloyed lead or other metals that might affect these results; compositional analysis has not yet been done, but given the compositional work to date at Harappa, it would be surprising if all of these samples were made only from unalloyed copper metal (see Kenoyer and Miller 1999 for tables of compositional analysis published up to 1995). As noted above, it is important to be aware that lead isotope ratios can be affected by mixing together lead from different sources, both the mixing of lead from two different

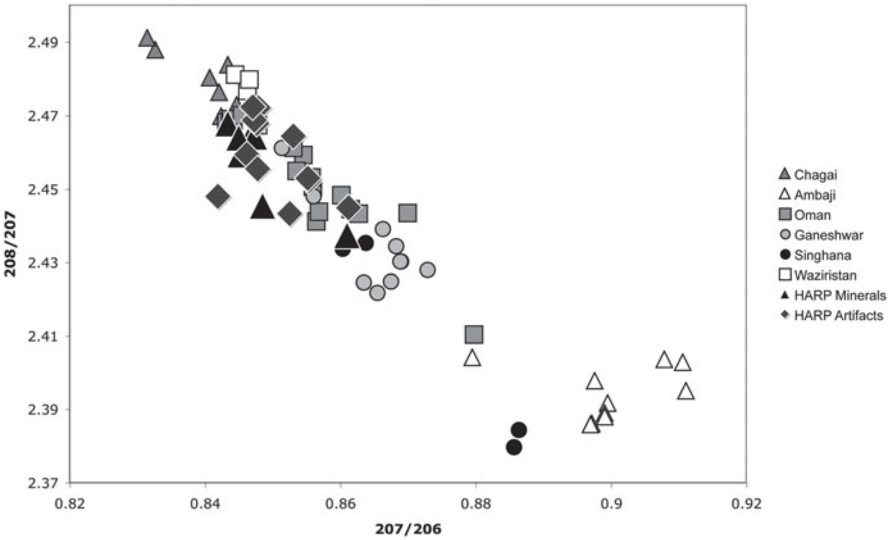

Fig. 24.4 LIA results for regional ore sources, mineral fragments, and artifacts from Harappa

copper ore sources, and the mixing of other metals containing lead impurities with copper. However, the match to patterning with mineral fragments is very interesting and bodes well for further research.

A final bivariate plot compares the results of the LIA on archaeological mineral samples and geological ores and slags with the results from LIA on these initial dozen artifacts (Fig. 24.4). Comparing the results from the analysis of the archaeological mineral samples to the artifacts, some preliminary conclusions can be drawn. The first is that the same broad pattern seen in the archaeological minerals, that of being primarily related to copper ore sources west or south of Harappa, is also evident in the data from the artifacts. Further, just as in the minerals, there is a potential isotopic correlation with slag samples from northern Rajasthan. However, this connection does appear to be very weak based on the data presently available. It is also important to note that the groups defined through cluster analysis on the archaeological data continue to correlate with one another when plotted alongside the data from geological ores/slags and archaeological minerals. The results from the beginning stages of analysis of the copper assemblage from Harappa indicate that during the Harappan Phase, the city was obtaining copper raw material primarily from sources to the west or south of the site in Oman, Baluchistan, and Waziristan. The artifacts from Harappa also demonstrate this pattern. While there is some evidence for the possible utilization of copper from northern Rajasthan at Harappa, it is neither firm nor indicative of a high degree of use, contrary to previous hypotheses regarding the source of Indus period copper (Agrawal 2000).

Recently some of the data and conclusions outlined above have been used to argue that the Indus city of Harappa obtained significant amounts of copper raw material and finished artifacts from sources and/or locations in the Aravalli Hills of Rajasthan

(Rizvi 2007). We cannot support such statements; in fact, our conclusions to date are quite different. While it is not possible to rule out sources in the Aravallis for either copper minerals or artifacts found at Harappa, it is also not possible to conclusively support this hypothesis. Even if supported, only a small proportion of objects and minerals could come from this source. The lead isotope work conducted to date is only on a sample set of nineteen archaeological objects and mineral fragments, and only a few dozen geologic samples. It is critical to note that due to the limitations regarding access to geologic samples from the Aravalli region, particularly critical areas in northern Rajasthan, slag samples were used as proxy data. Only future laboratory analysis will confirm the validity of these proxy data in regards to the actual isotopic signature of the region.

Again, as stressed in previous presentations by Hoffman, preliminary data from ongoing research conducted by Hoffman and others have demonstrated that there may be a limited degree of isotopic overlap of a single copper mineral and two, perhaps three artifacts from the site of Harappa with copper sources in northern Rajasthan. It must be stressed that this association is far weaker and more limited than the more definitive conclusion that the vast majority of copper (analyzed to date) has its source in regions to the west or south of Harappa in either Waziristan, Oman, or Baluchistan, and likely some combination of all three.

Melting and Alloying

As noted above, all of the data published for Indus sites to date are indicative of melting rather than smelting assemblages. The melting of original smelting ingots to produce secondary or refined ingots is a common intermediary stage between the production of the original smelting ingot and the final fabricated or cast object. This secondary ingot production is undertaken for one or more reasons: to remove slags or other undesired elements left in the original smelting ingots; to break up large smelting ingots into more workable or transportable ingots; to melt down metal scrap; and/or to form metal alloys. The production of alloys can take place at any one of a number of stages during the production process. For the Indus, not only is the place of alloying in the production sequence unknown, but also the very question of what alloys exist is difficult to answer. What constitutes an alloy and what a single metal with impurities? As detailed in Kenoyer and Miller (1999) and Miller (1999), different researchers have used different standards to define alloying, and in the lower percentages (less than 5 %) it is often not possible to determine if the "alloy" is the result of the intentional mixture of two separate metals or metal ores, or due to the natural metallic impurities in particular copper ores (Stech 1999). Thus, for the analyses of Indus copper objects to date, only tin is unequivocally an "alloy" with copper. Lead and arsenic are strong possibilities as deliberate "alloys", at least for some objects, but involve some complications as discussed in Miller (1999, pp. 222–228).

At this point it appears that Indus metalsmiths did not follow a rigid system of alloying related to specific artifact categories for copper and its alloys. For example, morphologically similar objects found at Indus sites are made from relatively pure copper, from arsenical copper, and from tin-alloyed copper (Kenoyer and Miller 1999). As detailed in Miller (1999, pp. 195–196), possible patterns of alloying are obscured by sampling and excavations problems, as well as the prevalence of Indus recycling as seen in the numerous caches of metal objects and scraps recovered from all of the major sites. Furthermore, patterns of alloying are likely obscured in these analyses because the Indus metalsmiths used alloying for a variety of purposes—functional, aesthetic, ritual, and/or simply expedient. Tin could be added to copper to increase strength and hardness for some objects, or used to produce particular colors or fulfill ritual requirements in others. Alternatively, the only material available for a smith to use may have been a mixture of alloyed scrap metals; expediency is too common ethnographically to ignore. (See Lahiri (1993, 1995) and Chakrabarti and Lahiri (1996) for excellent discussions of the variety of reasons for alloying in modern and historic South Asia.) When faced with the choice of desired characteristics, including hardness and color, the Indus metalsmiths may have chosen from a number of alternative means of producing a given result; in some cases they may have used physical modifications such as forging to harden metal, while in other situations they may have produced a harder metal by modifying the composition of the metal through alloying. These choices would depend on the manufacturing techniques used, the types of copper and alloys available, and the stage of metal production (smelting, melting, casting of blanks, *etc.*) at which the end product was first visualized (Miller 1999, pp. 196).

Casting and Fabrication

Production techniques for metal objects can be classified depending on the state of the metal during working. *Casting* refers to the manipulation of molten metal, while *fabrication* is the treatment of nonmolten metal, whether cold or hot. Fabrication involves the direct shaping of metal, while casting begins with the shaping of other materials into which the molten metal is poured. The tools and techniques of the two categories overlap to some degree, and ancient metalworking ateliers may have been involved in both fabrication and casting. Some objects, however, may have been cast by one group of artisans and finished or fabricated by another group in a separate workshop. The possible division of manufacturing stages into discrete and often exclusive activities practiced by different artisans is an important part of metal working that has not been investigated for the Indus Civilization, primarily because few metal production areas have been conclusively identified. At this point, in spite of Miller's excavations in the year 2000 in the most promising area of Harappa for metal workshops, we can say little about the nature of copper metal production organization. It was noteworthy that almost no inscribed material was found in this area, so that there is no evidence to date for any sort of centralized control of metal production, at least for Harappa (Miller 2005).

For all of the metals, all of the evidence to date for both casting and fabrication techniques has come from the examination of finished objects. Casting of copper objects appears to include both open face and bivalve casting, as well as lost wax techniques. Mille et al. (2005) discuss early casting methods at the Baluchistan sites of Mehrgarh and Shahi Tump; the latter case might be more related to eastern Iranian traditions than Indus traditions. Fabrication techniques include shaping by forging to manufacture both sheets and vessels, cutting, cold and hot joining, and finishing methods such as polishing, engraving, and inlay (see Miller 1999, pp. 228–241 for more details). The preserved Indus corpus of copper and copper alloy objects appears to be well made with a good standard of workmanship, but fabrication and casting techniques do not appear to be particularly complex or intricate, in contrast to contemporaneous metal traditions in eastern Iran or Central Asia (e.g., the repoussé work from Shadad (Hakemi 2000)). Although remelting for scrap was common, as indicated by both finds of hoards and (possibly) patterns of artifact composition, there is every reason to think that the work preserved is representative of the overall production abilities. However, more precise information on finishing, and on manufacturing techniques in general, might benefit greatly from the restudy of all objects in a standardized fashion, including radiography of the objects and selected metallography, particularly given the generally better preservation of those objects kept from the older, large-scale excavations. (This is optimistically assuming better research conditions than those that currently exist in many areas.)

Technological Style

Style of objects has been a major focus of archaeological thought for decades. Hegmon (1992, 1998) summarizes the three main archaeological approaches to style as: (1) choices made between functional equivalents that reflect particular time periods or regions, as in Sackett's work on isocrestic style; (2) active and passive communication of information, as exemplified by Wobst's and Wiessner's writings; and (3) encoding of cognitive processes, as examined by Hodder and others.

Technological style is essentially the application of all of these aspects of style to the process of production, as opposed to simply the form and material of the end product. Like style of object, technological style also includes culturally specific choices made between functionally equivalent production techniques, which can actively or passively communicate social information, and which can be manifestations of cognitive processes (Miller 2007, pp. 193–194). While achieving renewed popularity in the 1990s, many of the original formulations of the concept of technological style date to the late 1970s, when it was especially applied to metal technology (Lechtman 1977; Steinberg 1977; Lechtman and Steinberg 1979). Technological style includes both technological style of production, focusing on choices about production techniques and materials, as well as investigations of the technological style of organization of production, focusing on the order and number of stages in a particular *chaîne opératoire*, or the organization of workers themselves. (Miller 2007,

p. 194) For example, Killick's discussion (this volume) of changes in the values of different metal types in sub-Saharan Africa, based primarily on color characteristics, illustrates how cultural style can substantially guide the raw material choices made by metal workers, which then affect all other stages of production (see Miller 2007, pp. 191–201 for more discussion and examples).

For the Indus Civilization, we see a number of broad aspects of technological style in the way metal production is both carried out and organized. One characteristic is an apparent focus on *procurement* of metal, including via recycling, rather than *production* of metal from ore via smelting. Another characteristic seems to be a lack of interest in elaborate forming methods, and possibly a greater focus on alloying.

The Indus people seem to have had no trouble in reliably procuring sufficient quantities of copper and alloys in metallic form, both as primary ingots and through recycling, as described above. There is no evidence that they carried out or controlled production of the metal from ores found in the surrounding regions, and so trade for ingots produced by others is the most parsimonious explanation at this time. This situation may reflect the need for further exploration of the mineral source areas in Baluchistan and Afghanistan, but certainly there is no evidence of any significant Indus mining or settlement presence in Oman or the Aravallis. There is, however, plenty of evidence for Indus trade in various materials with at least the first three regions, Baluchistan, Afghanistan, and Oman (Mery and Blackman 2005; Law 2008). It would be of great interest to examine the Indus presence at Nausharo (near Mehrgarh) in the Bolan Pass in southern Baluchistan as possibly a settlement relating to the (metals?) trade with Iran, in the same way that the team from M.S. University-Baroda (Bhan et al. 2004 Chase 2007) has examined the role of the Indus and non-Indus settlement of Gola Dhoro (Bagasra) as possibly a settlement relating to the trade in shell and semi-precious stone ornaments. What was the nature of the Indus period occupation at Nausharo? Work done in many other areas on cultural contact and the varying nature of interactions, from colonization to resistance to conversion, could be usefully applied to the French team's long-term work at this site. Comparative examples include the possible effects (or not) of Egyptian demand for copper metal on the social and political situation in the Levant referenced by Thornton in this volume; Hanks and Doonan's (this volume) discussion of interaction models for the societies of Central Asia; the culture contact models developed by Yao (2008) for indigenous Yunnan interactions with the Han Empire; and Stein and others' work on the nature of the Uruk expansion (Rothman 2001; Stein 2001).

It must be emphasized that trade for ingots is only one method of metal procurement. Recycling of existing metal objects is often referenced in the literature, but seldom seriously incorporated into models of metal production as a significant source of metal. Studies of North American metal use during the European contact period form an important exception (Latta et al. 1998; Ehrhardt 2005). As also discussed by Ehrhardt in this volume, the native people of the Eastern Woodlands of North America were able to procure the metal they needed for fabrication of objects, in the form of traded European metal objects or sheet. They did not develop or adopt techniques of smelting or even melting. This may partially relate to their prior focus on native copper sources, but then such a focus emphasizes again the need to consider other methods of metal procurement besides smelting.

The main effect on an Indus technological style of production of a focus on procurement of metals rather than production of metals from ore is that the emphasis shifts from producing metal ingots with desired qualities at the smelting stage to producing metals with desired qualities at the melting and fabrication stages. If recycling was an important source of Indus raw material, as hypothesized, this implies that Indus metalsmiths developed a repertoire of techniques for working with various (even random) alloys to produce desired attributes. Such techniques would likely include methods for recognizing different types of alloys, flexibility of working methods to deal with different alloy responses within a relatively wide range, and a variety of methods of adjusting desired characteristics such as color or hardness. Smiths would have to be innovative and flexible. Archaeologists studying such smiths will need to focus on different skills and emphases than those relating to smelting, which have tended to dominate Old World metallurgical studies, as is not surprising given the obviously remarkable transformation involved in the smelting of mineral to metal. Hence our strong interest in other stages of production, and especially in consumption, an interest that would have been shared by Indus smiths.

In terms of forming methods, if anything the Indus is remarkable for simplicity of technique—production of cast and fabricated objects is generally very competent but by no means exceptional in technique or intricacy of design. Based on analogies with other Indus technologies, which seem to show an Indus preference for complexity of material over complexity of shape Miller has previously suggested that Indus alloying techniques might have been more complex than their generally simple forming techniques (Miller 1999; Miller 2007; Vidale and Miller 2000). This suggestion has never been tested, due to difficulties with export of materials over the past decade as well as generally very poor preservation of metals at Indus sites, and so remains to be confirmed, overturned, or modified.

Comparable data about methods of manufacture from numerous sites would give us more information on the diffusion and independent invention of metal processing techniques within the Indus Civilization. Such data would also allow investigation of possible regional styles of production within the Indus Civilization, e.g., Indus plains versus Gujarati versus Baluchi techniques. More broadly, Indus production data could also be used to contrast a general "Indus technological style" with other contemporaneous traditions, such as the Chalcolithic cultures of northwestern India, or Iranian, Central Asian, or Mesopotamian traditions (e.g., Thornton in this volume). It will be particularly interesting in this regard to see if the technological traditions from Baluchistan are more similar to the Indus style(s) or the eastern Iranian style(s) of production, or perhaps vary between technological affiliations over time. Similar questions might be posed of the northwestern Indian materials, with additional archaeological work, particularly for the late third millennium and early second millennium. Until such work, it is difficult to say too much about regional production styles from the published photos and tables, although even those might be put to better use for the investigation of the consumption of copper objects, as discussed below.

Consumption: Typologies and the Use of Indus Copper Objects

Previous Typological Studies of Indus Copper Artifacts

The initial excavation reports from Mohenjo-daro (Marshall 1931; Mackay 1938) delineated several broad types for Indus copper tools, weapons, vessels, and personal ornaments. The immediately succeeding excavations (Vats 1940; Mackay 1943) used these types, as did the majority of later excavations at Indus sites (Rao 1979; Joshi 1990; Lal et al. 2003). It is important to note that the typological categories developed, largely by Mackay, were not based on metric data but rather on macroscopic morphological characteristics of forms from Mohenjo-daro. It appears that assumptions were made regarding the use of individual forms and uncritically accepted. Each successive excavation applied this categorization scheme with the addition of new types to the schema as the need arose. As a result, the typology of Indus copper materials has been largely unrevised since the earliest days of archaeological excavation of Indus sites.

The work of Paul Yule (1985a, b) and Miller (2000) has attempted to address this need for a formalized typology of Indus copper artifacts. While both researchers have published updated categorizations, neither has been widely adopted. Both systems have limitations that prevent them from being applied as a fully functional typology for Indus copper and bronze artifacts, although both provided helpful background for the system employed here by Hoffman. The system proposed by Yule provides a detailed and thorough classification scheme for both vessels (Yule 1985b) and ornaments (Yule 1985a); however it does not provide categories for tool forms. The work does represent a solid foundation for future study. Heidi J. Miller's system, for designed to characterize the metal objects from the site of Chanhu-daro exclusively, is much more specific in its definition of typological categories, and is by intention a combination of a morphological and a functional typology. The typology in its published form suffers from three major drawbacks that prevent it from being used as a comparative tool. The first is that it is only able to deal with complete or mostly complete objects. The vast majority of copper artifacts recovered in modern excavations are fragmentary and lacking many of the critical diagnostic elements of Heidi J. Miller's system. This is typically due to either corrosion or breakage from a variety of pre- and post-depositional processes. The second drawback is that, by design, the typology does not incorporate forms absent in the material from Chanhu-daro. While Heidi J. Miller (2000) does provide for the expansion and modification of the system, it is not specifically clear how other investigators would incorporate their definitions into the existing scheme. Finally, the system developed for Chanhu-daro, as a typology partly resting on the functions of objects, relies heavily on inferences relating to function such as the nature of working surfaces and hafting techniques for each tool form. While many of the inferences are likely correct, at this point they cannot be substantiated from the available evidence. This makes it difficult to assign objects confidently to a particular type.

In spite of these difficulties, in reviewing the published images of copper objects from Indus sites Hoffman felt that a typology *broadly* based on function would be best suited for the investigation of the use of copper objects at individual sites, particularly in the light of the need to allow comparison with the extensive work that has been done for Chanhu-daro. In this categorization scheme, function was inferred primarily from the morphological characteristics of the artifact. Definitions based on specific metrical data and any other types of information not readily available from an inspection of published photos and line drawings were avoided. Through the application of this classification system it is possible to make comparisons between the individual sites in order to understand how metal was being used in the Indus Civilization. The classification scheme applied by Hoffman also draws much of its inspiration and format from the system first outlined by Kenoyer in Kenoyer and Miller (1999).

Towards a Working Typology

The following is a provisional typology for understanding the nature of the variation in Indus copper assemblages both within individual sites and between sites. Within each major category, there is a possibility for a number of individual distinct subcategories and the proposed classification system is by no means comprehensive or exhaustive. The primary advantage in the proposed system is its ease of use, flexibility, and ready adaptability to use in both the field and in archival research as well. This system could be modified in order to better understand specific aspects of Indus copper metallurgy, such as manufacturing techniques, alloying patterns, or other specific interpretive questions, without altering the essential overall structure.

Vessels Vessels are a functional category of copper and bronze objects from Indus sites. Roughly one half of the forms have parallels to known ceramic vessel types, but the others appear to be only found as metal forms (Yule 1985a, b). The reason(s) for unique metal shapes are still unclear (see Kenoyer and Miller 1999, pp. 133 for discussion). Typical Indus copper and bronze vessel forms include jars, pots, bowls, dishes, pans, and scale pans. Vessel forms are manufactured from sheet copper using a variety of fabrication techniques. All vessel forms will be considered as a single category here, as it can be argued that their uses as containers were similar. The one exception, the relatively rare subtype of scale pans, will be considered further below. Scale pans come in various sizes and seem to have been used to weigh a variety of substances at Indus sites rather than simply as containers.

Tools Another functional category of Indus copper and bronze forms are those objects that were used as tools. Here a tool is taken to be any object that is used to accomplish a mechanical or manual task. Indus tools take a variety of forms. These forms can be grouped into three broad subcategories; blade tools, rod tools, and axes/adzes. In turn, each of these subcategories of tools may contain specific types. Blade tools are manufactured from sheet copper and distinguishable types include triangular barbed arrowheads, saws, knives, spears, and razors. Blade tool types are morphologically distinctive and further research is needed to determine if additional types and subtypes can be defined. However, all of these tools would have been used as blades; that is, to cut some material. Rod tools are those manufactured by casting and include two distinct types: chisels and pointed tools. Chisels are rectilinear rods with wedge-shaped working ends (Miller 2000, p. 315). Pointed tools are also rods, but can range in cross section from rectilinear to round and have a variety of working ends. At present, this type comprises a variety of morphologically similar objects that may have been used for a range of purposes and tasks. Hooks are another category of rod tools. It is inferred from their shape that these tools would have been used for fishing. A final category of Indus copper and bronze tool forms is that of axes and adzes. All of the objects in the axe/adze category are morphologically similar and would have been used in comparable ways. They are easily differentiated from blade tools even in fragmentary form, since they are not made from sheets and are considerably more massive.

Ornaments Items of personal ornamentation are another major functional category of Indus copper and bronze forms. Four subcategories can be defined based on object morphology. The first is bangles. Bangles are any circlets made of a continually homogenous material (Kenoyer 1992; Miller 2000). There appears to be two major subtypes of Harappan bangles, one that is solid with a round cross section and one hollow with a crescent–shaped cross section (Yule 1985a; Miller 2000). Each of these may also have additional subtypes, continuous and noncontinuous. Rings are similar in appearance to bangles and are always solid. They may consist of a single coil of metal or multiple overlapping coils. A third major subtype is beads, pendants, and discs. All of these objects have been perforated for attachment or hanging. As indicated in Heidi J. Miller's work, there may be five distinct subtypes of beads: round, barrel-shaped, cylindrical, tube, and spacer (Miller 2000, p. 309). Pendants are objects that are perforated at one end (Kenoyer 1992). Discs are objects that are round, with a concavity. They are usually perforated and it is hypothesized that they may have been sewn into clothing or other fabrics as sequin-like decorations. A final subcategory of ornaments is decorative-headed pins. It is unclear specifically how these objects were used, but they appear to be morphologically similar and are typically topped by either a decorative motif or an animal figure.

Other At the present stage of analysis, all remaining metal objects have been grouped into the category of "Other". This is due to the low frequency and/or uncertain status of these objects. Three of the five categories are relatively clear types but are not yet fully studied: mirrors, figurines, and tablet/tokens. Mirrors are round to oval in shape and have a small tang that would have likely been attached to a handle, and represent a clear functional category but are very rare finds. Two morphological types of figurines have been published from excavations so far, human and animal, but it is not yet clear how these objects were used; for example, how many were free-standing objects versus decorative elements of pins. The relatively rare category of tablets/tokens, only found at Harappa and Mohenjo-daro, is also based solely on morphology, with distinctive subtypes apparently present at each site. Tablets from Harappa have Indus script and other symbols molded onto them, while the objects from Mohenjo-daro are inscribed (Fentress 1976). The remaining two categories, miscellaneous objects and manufacturing debris, are currently umbrella groups that require further analysis for more exact characterization.

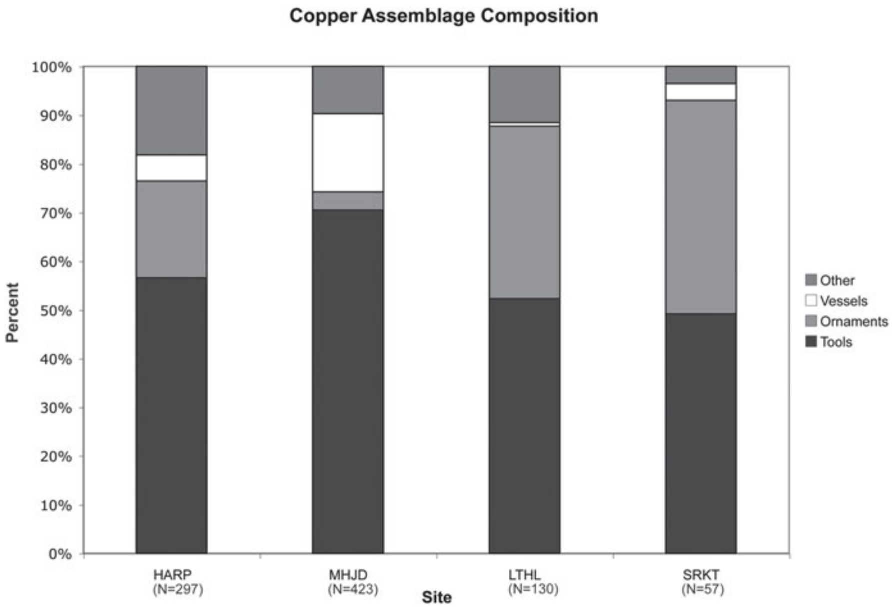

Fig. 24.5 Distribution of copper types at individual sites

Individual Site Breakdowns

Hoffman reviewed the copper objects that were published as either photographs or line drawings from the excavation reports of Mohenjo-daro, Harappa, Lothal, and Surkotada, and categorized them according to the scheme outlined above (references for each site below). In addition, Hoffman reviewed the site report for Kalibangan and the published breakdown for Chanu-daro from Miller's work (2000). Finally, digital photographs of objects recovered by the Harappa Archaeological Research Project (HARP) team at Harappa were also reviewed. The breakdown for the distribution of types for each site is shown in Figs. 24.5, 24.6, 24.7, 24.8, and 24.9, using the categories discussed above.

Mohenjo-daro Mohenjo-daro was first excavated by the Archaeological Survey of India from 1922–1927 and then again from 1927–1931 (Marshall 1931; Mackay 1938). The two reports describing these excavation programs published images, both line drawings and photographs, of approximately 420 copper objects. The published assemblage is comprised largely of tools (see Fig. 24.5). Within the tools category, blade tools are the dominant subcategory (48 %), with rod tools comprising 38 % of the tool assemblage and axes/adzes making up 13 %. Additionally, a large number of copper vessels were recovered from the site. This is likely skewed due to the three large hoards found in DK Area (Mackay 1938). Each of these hoards contained a large number of axes/adzes, blade tools, and vessels. The excavations at Mohenjo-daro published a very small number of personal ornaments made from copper, especially

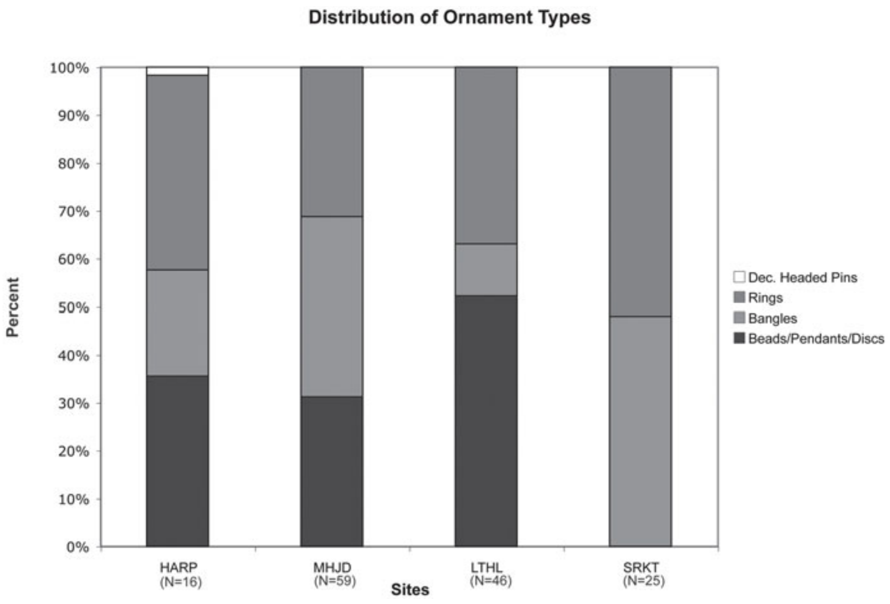

Fig. 24.6 Distribution of ornament types at individual sites

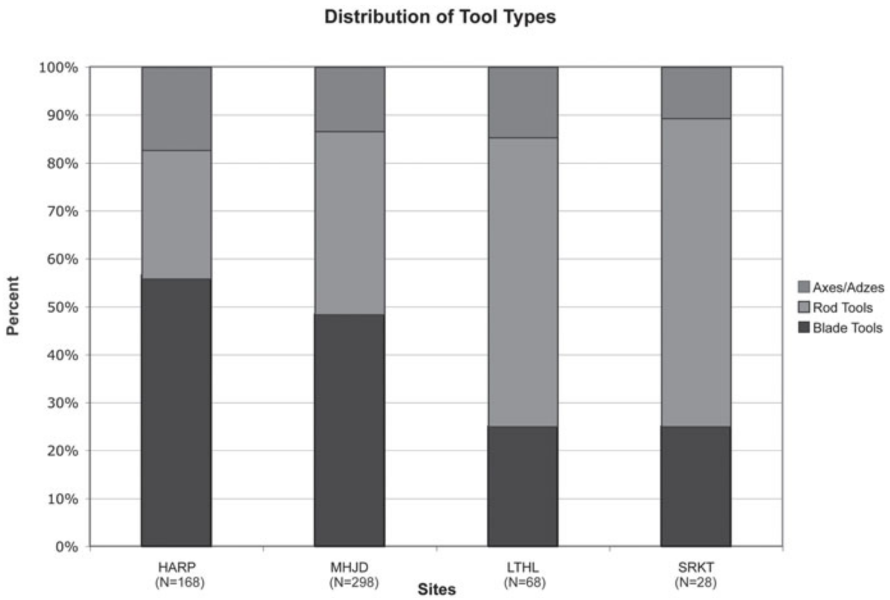

Fig. 24.7 Distribution of tool types at individual sites

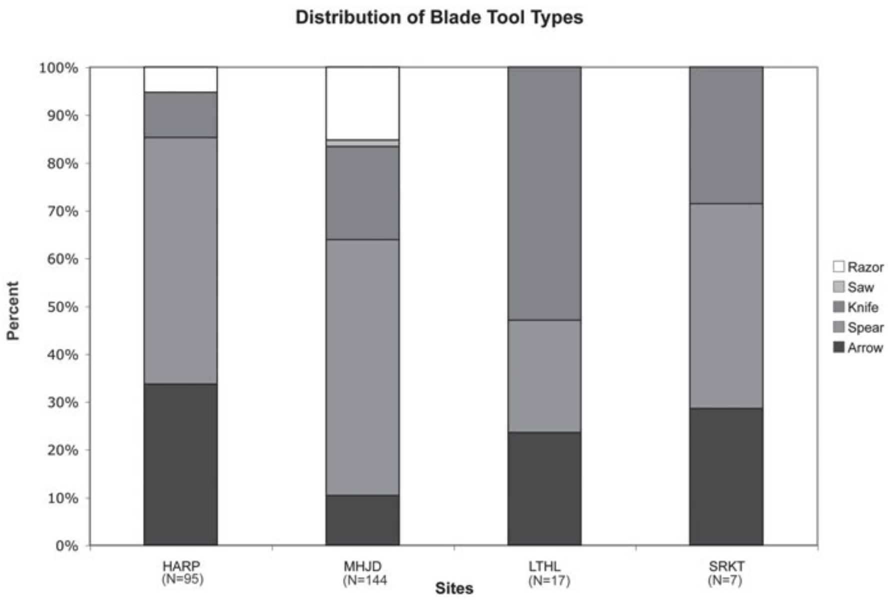

Fig. 24.8 Distribution of blade tool types at individual sites

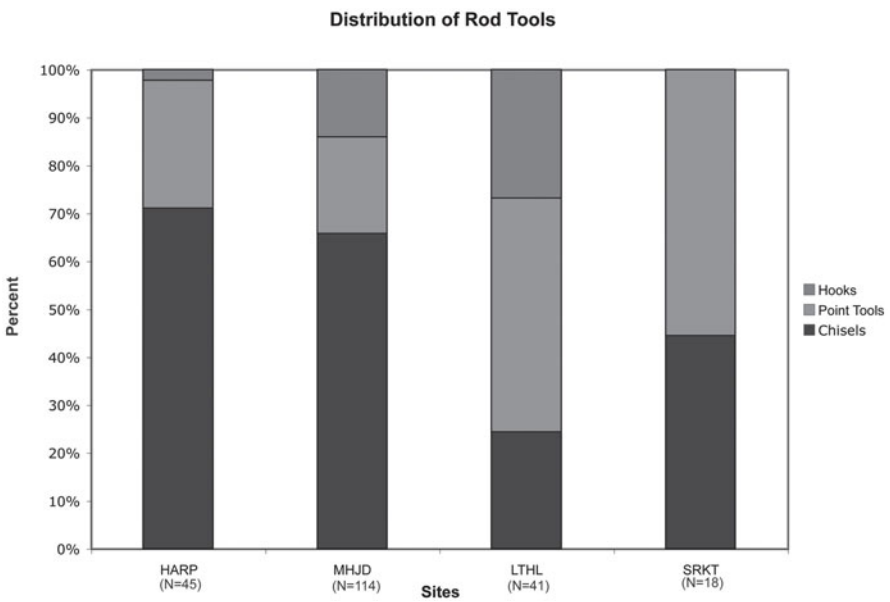

Fig. 24.9 Distribution of rod tool types at individual sites

as most ornaments found in hoards were made from gold, silver, and stone. It is likely that this is a result of a combination of the high amount of post-despositional corrosion of copper at the site and the excavation methods employed in these older excavations, especially the lack of screening.

Harappa The Archaeological Survey of India first excavated the site of Harappa from 1920–1921 through 1933–1934 (Vats 1940). During these excavations a number of copper objects were recovered. Of these, approximately 190 are published in photographs; of these, over 90 came from a single hoard (Vats 1940). Since the assemblage for this portion of excavations at Harappa is dominated by a single hoard find, the distribution of copper types is slightly different from the patterns seen at the rest of the sites. Tools comprise the majority of the assemblage, with only a few dozen items of personal ornamentation being published. Blade tools dominate the tool types, not surprising since the hoard was comprised almost totally of copper vessels, axes, and blades. Rod tools are also well represented, but not in the typically even manner seen at the other sites. The early assemblage from Harappa is also noteworthy for having three tablets and two scale beams. Overall, this group of copper artifacts is overwhelmingly made up of large tools.

In contrast, the excavations by HARP over the past two decades have revealed a slightly different pattern of types and distributions than the previous excavations at the site. An assemblage of 110 complete copper objects so far recorded by the HARP team is comprised mainly of arrow points and ornaments. Tools are less numerous, but are relatively evenly split between the categories rod tools and blade tools. It is important to note that the HARP assemblage includes five examples of scale pans of various sizes and nine copper tablets so far recovered from the site. The types of objects and their proportions recovered during the HARP excavations differ slightly from those of the other sites, likely due to two factors. The first is excavation methods, in this case the screening of fill by HARP in order to recover small objects. The second factor is that the HARP excavations have been primarily focused on tracing the margins of the mounded occupation areas at Harappa and locating the course of the city walls. Investigation of these types of contexts rather than the dense room and house blocks that were the focus of the majority of the earlier excavations should result in the recovery of different types of objects. In addition, Hoffman had access to records of all of the objects found by HARP, rather than only published examples.

Lothal Excavations at Lothal have uncovered 1,500 copper artifacts, of which 130 images are published (Rao 1979). The illustrated assemblage is split relatively evenly between tools and ornaments. In terms of tools, rod tool types dominate the assemblage at Lothal, specifically the category of pointed tools. Typical Indus arrow points have also been found. Stylistically Indus personal ornaments, such as beads, bangles, and rings are also found at Lothal, as well as animal figurines. Unfortunately, no specific find locations are provided for the majority of the objects, so any discussion of context or spatial distribution is not possible. The excavators do report the presence of copper objects of all types throughout the sequence at the site (Rao 1979).

Surkotada The excavators of Surkotada, a small site in Kutch, reported a total of 129 copper objects plus one hoard of beads and bangles (Joshi 1990, p. 266).

They provide illustrations for 57 of these items. The distribution of illustrated types follows a similar pattern to Lothal, as the assemblage is almost evenly split between tools and ornaments. Rod tool types, specifically pointed tools, dominate the tool assemblage. Joshi (1990) indicates that the overall assemblage has similarities with those of Kalibangan, Chanhu-daro, Harappa, Mohenjo-daro, and Lothal. This does appear to be the case. It is also important to note that copper of all types appears from the earliest excavated levels through to the end of the Indus sequence (Joshi 1990). Unfortunately, no specific find locations are provided for the objects, so any discussion of context or spatial distribution is not possible.

Chanhu-daro and Kalibangan Two additional sites with significant metal assemblages from early excavations are not included in these figures, but will be incorporated in future research. Heidi J. Miller (2000) examined 521 tools from and found the assemblage to be dominated by different types of tools (64 %). Of this group, no single type of tool dominated. Overall, the tools were relatively evenly split between blade tools and rod tools (Miller 2000, p. 318). Mackay (1943) reports that four hoards were recovered during excavations at Chanhu-daro, but all were much smaller than the hoards found at Harappa and Mohenjo-daro. The excavations from Kalibangan are only partially published at this point (Lal et al. 2003). While the report concentrates on the Early Harappan (Regionalization Era) component of the site, the volume does include the results of compositional analyses on 19 objects. Two are from the late Early Harappan period and 17 are from the Mature Harappan (Integration Era) period. Unfortunately, no photographs are published. The excavators do list some descriptive information for each object, but these are not specific and do not provide the basis for confident comparison. However, the museum at the site displays a number of copper objects recovered from the excavations. All of these items conform to forms and types seen in the published reports from other Indus sites. Hopefully, with the fuller publication of the excavations, it will be possible to compare the material from this site to the others.

Metal Object Use in the Indus Civilization

The use of copper in Indus cities has traditionally been interpreted through two main lenses. The first is that the forms and artifact types fashioned from copper are largely unchanging over the course of the Indus Civilization (Mackay 1938; Piggott 1950). The second is that copper was widely available and used by all segments of society at sites of all sizes (Shaffer 1992). An extreme form of this line of argument is that copper tools and utensils eventually almost totally replaced lithic implements (Cleland 1977, p. 175); however, more recent evidence makes it unlikely that this is the case. For instance, the HARP excavations at Harappa have unearthed over 12,000 lithic blade tools alone. In addition to more detailed studies on Indus copper production, it is also important to begin to test these traditional interpretations about the consumption of metal in the Indus Civilization.

In examining the six assemblages reviewed above, some trends appear to be emerging from the data. Tool types dominate the assemblages from the two large urban centers, Harappa and Mohenjo-daro; however, it is unclear if this pattern is related specifically to patterns of metal usage and consumption. The techniques of excavation used by the early excavators of Indus sites, combined with the poor preservation conditions of the soil at the sites, would have privileged the recovery of large forms over smaller more fragile metal objects such as beads, bangles, and rings. The massive quantities of material recovered from these very large excavations would also have meant that excavators discarded or ignored fragmentary, unidentifiable, or poorly preserved objects. It is relevant to note that in excavations that have practiced more modern methods of recovery (Lothal, Surkotada, and HARP), the proportional representation of ornament types increases (Fig. 24.5). At Lothal, Chanhu-daro and Surkotada, there is a more even distribution of forms between tools and ornaments.

Furthermore, the existence of large hoards of tool types aides in explaining the shift in distributions. The evidence from excavations indicates that large Indus copper hoards, such as those recovered at Mohenjo-daro and Harappa, were dominated by vessels and caches of axes/adzes and blade type tools (Marshall 1931; Mackay 1938; Vats 1940). The recovery of such hoards has a significant effect on the proportions of tools to ornaments. At Mohenjo-daro and Harappa, the blade tool forms constitute the majority of the tool assemblage (Fig. 24.7). In contrast, at Lothal and Surkotada, where either no hoards only small caches of ornaments were found, rod tools form the majority of the tool assemblage at just over 60 % for both sites (Fig. 24.7). Chanhu-daro exhibits an even split between the two categories of tools (Miller 2000). Note that four small hoards were uncovered at Chanu-daro (Mackay 1943). These results point to very careful collection and storage of large or massive metal objects by the Indus people, with the great majority of metal mass found in hoard situations. This also supports the comments made by Kenoyer and Miller (1999) and Miller (1994, 1999) about the likelihood of recycled scrap as a major source of Indus metal.

The patterns exhibited by the data also appear to validate the idea that Indus sites of all sizes, and from every region, had relatively equal access to copper tools and ornaments. While the presence of hoards at the larger urban centers likely increases the proportional representation of larger or more massive objects such as vessels, axes/adzes, and blade tools, these categories are not significantly absent from any of the other sites. There are two artifact types, however, that do exhibit a degree of difference related strictly to site size: scale pans and copper tablets. Scale pans would have been used to weigh a variety of substances, likely in exchange situations, and may also have had a role in taxation or other aspects of economic control (Kenoyer 1998). Scale pans are present at all sites except Chanhu-daro and Surkotada, two of the smaller sites in the sample. Weights are found in great numbers at Chanhu-daro, though, so the absence of scale pans may simply represent lack of preservation in the areas excavated. Copper tablets, like other tablets and as opposed to seals, have recently been interpreted as having religious meaning, particularly the molded types of tablets (Parpola 1992). Copper tablets are present only at the sites of Harappa and Mohenjo-daro. The presence of these copper tablets may therefore represent the location of pilgrimage centers at these sites, or may represent some economic or social meaning for these objects that was restricted to some type of elite or special interest group. Overall, though, it does seem that Indus sites both large and small were consuming copper metal of all types and in broadly similar proportions.

In sum, the distribution of the various types of copper objects combined with their archaeological contexts does allow for some tentative conclusions about how the metal was used by the residents of Indus sites. The first point is that it does not appear, at present, that copper was a material to which access was restricted. Copper tools and ornaments are typically found from all contexts at Indus sites, but tend to come mainly from inside house and room blocks (Marshall 1931; Mackay 1938; 1943; Vats 1940; Rao 1979; Joshi 1990). There is often little copper in larger more public spaces, from whence it might be scavenged, and all hoards have been recovered from just underneath what are considered to be house floors. It is also noteworthy that there is little copper recovered from Indus burial contexts. Unlike many other third millennium Civilizations, metal was not being interred with the dead in appreciable quantities. This may indicate either that copper objects were not high status or wealth items in the hierarchy of Indus craft products, or that wealth items were not interred with the dead but kept in circulation, as discussed in Rissman (1988, Kenoyer and Miller (1999), and Miller (2007)). (Also compare situation in Iron Age South India, as presented by Gullapalli in this volume.)

The evidence also indicates that one of the primary uses of copper was to help in the production of other components of the Indus material assemblage. It is likely that copper was used in bead production, to carve seals, for carpentry, in food production, and for daily household use as well. While there exists an overall similarity in the copper tool assemblages at Indus sites, some contrasting patterns exist between the larger and smaller sites. At the sites of Lothal and Surkotada, knives are the dominant subtype of blade tool (Fig. 24.8) and point tools are the majority subtype of rod tools (Fig. 24.9). This is in contrast with Harappa and Mohenjo-daro where the larger more robust subtypes of both categories dominate. At both of these large sites, chisels are the overwhelming majority of the rod tool types (Fig. 24.9) and spears are the major subtype of blade tools (Fig. 24.8). While such a contrasting pattern of copper tool type distributions is intriguing, at present it cannot be explained without first resolving possible issues of differential archaeological collection methods or preservation conditions, as discussed above. It is hoped that further research into the use of copper implements and the addition of new information from previously unpublished sites, as well as ongoing research, will provide the necessary data needed to further explore the initial patterning.

One of the major interpretative questions for studies of Indus copper assemblages is how types may or may not have developed and changed over time. At present, the chronological data for excavated copper objects are not sufficient to make any interpretations about this question. The majority opinion remains with Piggott (1950) that Harappan copper forms are remarkably static and consistent over time (Marshall 1931; Mackay 1938; Rao 1979; Joshi 1990; Agrawal 2000). It is hoped that further study of the material recovered from the Harappa Archaeological Research Project will allow for the development of copper production and consumption to be investigated against the precise radiocarbon chronology from the site. But for the moment, the question of the changes in copper metal forms over time in the Indus Civilization remains unresolved.

Future Directions

The present study is an effort to delineate the manner in which copper was used as a resource in the Indus Civilization. The brief review undertaken here is perhaps best viewed as a first step. While some interesting patterns do appear to be present in the data, much more detailed study is required before they can be substantiated. It is critical that the material from excavated Indus Civilization sites that has not been published be brought to press as soon as possible. Information from these sites, particularly those of Dholavira, Rakhighari, and Kalibangan, would provide important comparisons to the presently available evidence. Further, it is necessary to examine the existing copper materials from Indus sites for any changes over time. Unfortunately, for a number of the sites the chronological information is either not available or not published. In order to further refine our understanding of the types of objects that were made from copper and the trajectory of development for Indus copper working, it is necessary to understand how the technology changed and developed over time.

In the absence of secure archaeological contexts and definitive chronological sequences, methods for tracking changes in Indus copper assemblages must be expanded beyond typological examinations. Laboratory-based analytical approaches may provide the most direct approach for understanding the growth and development of this technological tradition. One avenue for investigation would be to expand the existing tradition of compositional research on Indus copper metals. A program of compositional analyses, directed at tracking the composition of artifact types, would assist in answering important questions regarding alloying practices in Indus copper metallurgy. The first of these is whether or not the use of alloys is restricted to certain types or production techniques. Also, it is critical to understand how alloying patterns may have changed. The use of differing alloys over time could result from choices related to changing cultural fashions, or changes in the availability of raw materials, or from technological refinement. Besides data from compositional analyses, an instrumentation-based analytical program can provide data on the types and availability of copper raw material sources over time. Through the application of lead isotope studies to Indus archaeological copper materials, as described in the production section above, a picture of how individual sites were supplied with copper raw materials, and perhaps even finished products, may be developed. Hoffman has begun work along these lines with material from Harappa, as part of his dissertation research on Indus metals.

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