The Emergence of Iron Use at Hasanlu

VINCENT C. PIGOTT

Artifacts of iron constitute one of the single largest classes excavated at Hasanlu. More than 2000 individual iron objects were recorded during excavation, the majority from the destruction level on the High Mound (ca. 800 B.C.). This collection is important not only because of the broad range of artifact types and technology exhibited, but also because it provides information on a major transition in the developmental sequence of metalworking.

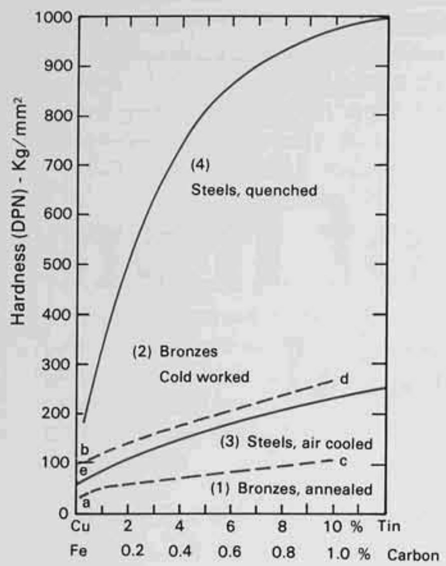
The Appearance of Iron Working in Southwestern Asia

Iron artifacts occur archaeologically in southwestern Asia as early as the 3rd millennium B.C. At that time, bronze was the metal of choice for a variety of artifacts. Iron was rare, a prized material owned by people of high status, as reflected both in the kinds of artifacts manufactured and the contexts in which they occur. In 2nd millennium B.C. Hittite texts, for example, iron artifacts are associated with royalty and religious ceremonies (Košak 1986).

Iron continued to be scarce for more than a thousand years after its initial appearance, and it is not until the latter half of the 2nd millennium that we begin to find significant quantities of the material at sites in the eastern Mediterranean. From this time on, the use of iron spread rapidly, so that by 1000 B.C. it was distributed across southwestern Asia, as far east as the Indian subcontinent.

What factors lay behind the increasing preference for, or dependence on, iron? First, iron has a potential economic advantage based on its availability: iron ores are significantly more common in the earth's crust than are the ores of copper and tin required to make bronze. This advantage is offset to a considerable degree by the significant number of man hours necessary to forge individual iron artifacts. Second, iron can be technologically superior to bronze. In the form of quench-hardened steel, it has a distinct advantage over the best cold-worked 10% tin bronzes (Fig. 2). There is, however, little archaeological evidence that true steels were being consistently and intentionally produced in the Near East during the period when iron first came into common use. Thus, iron artifacts of the early Iron Age were probably no more efficient than the best bronzes of the period, and there is no direct indication that iron was adopted because of its superior mechanical properties. We must, therefore, look elsewhere for reasons behind its wholesale and rapid adoption during this period.

1
Hasanlu iron sword with crescent guard. The hilt is made up of four iron rings wrapped around the tang; inlays were probably fitted between these rings. Technically it is made of a "mild steel," and would be an effective weapon (see also Fig. 15). L. 37.5 cm. (UM 65-31-220; photo courtesy of the Hasanlu Project)

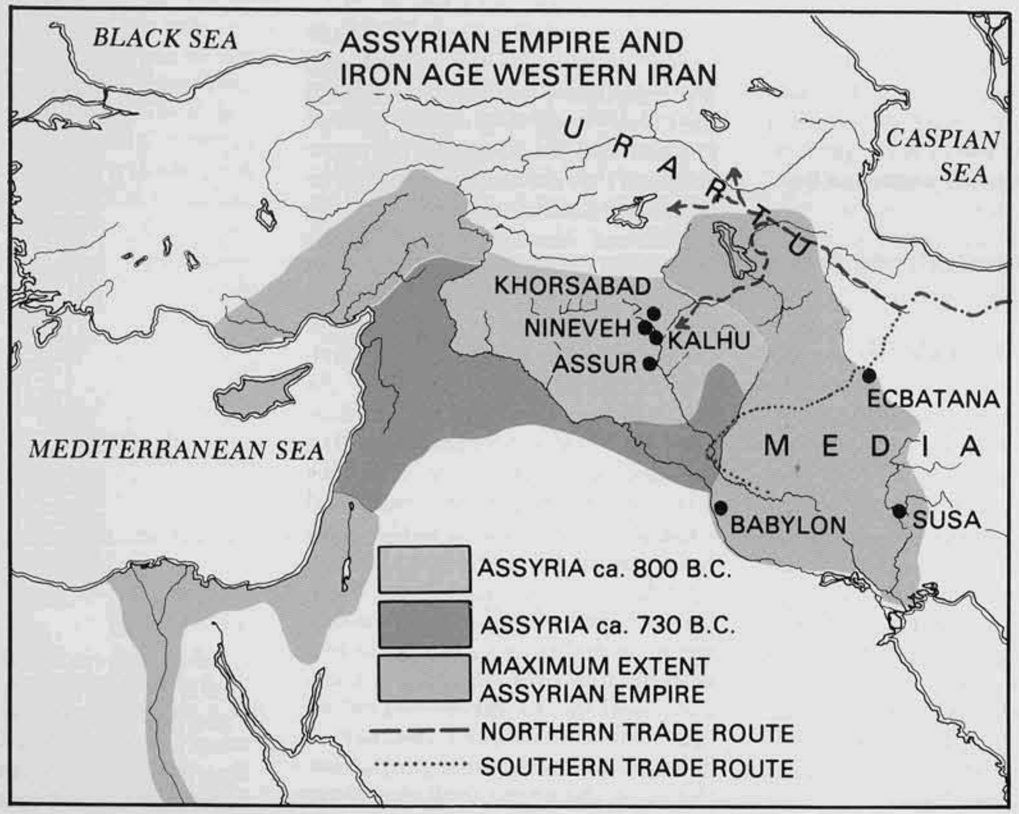


2
Graph comparing the hardness of different forms of iron and copper. Pure copper that has been annealed has the lowest efficiency (point a); it increases in hardness with the addition of tin (up to 10 percent, point c), and with cold-working (point d). Pure iron (point e) is hardened by the addition of carbon, thereby making it into steel. "If steels are heated and allowed to cool naturally, the range of their hardness (curve 3) is slightly below that of worked bronzes, but they become spectacularly superior if quenched (curve 4). The curves are approximate and the hardness varies considerably with impurity content, details of casting technique, prior annealing, and other factors. The brittleness of an alloy generally increases with its hardness" (Smith 1967:40, Fig. 39)

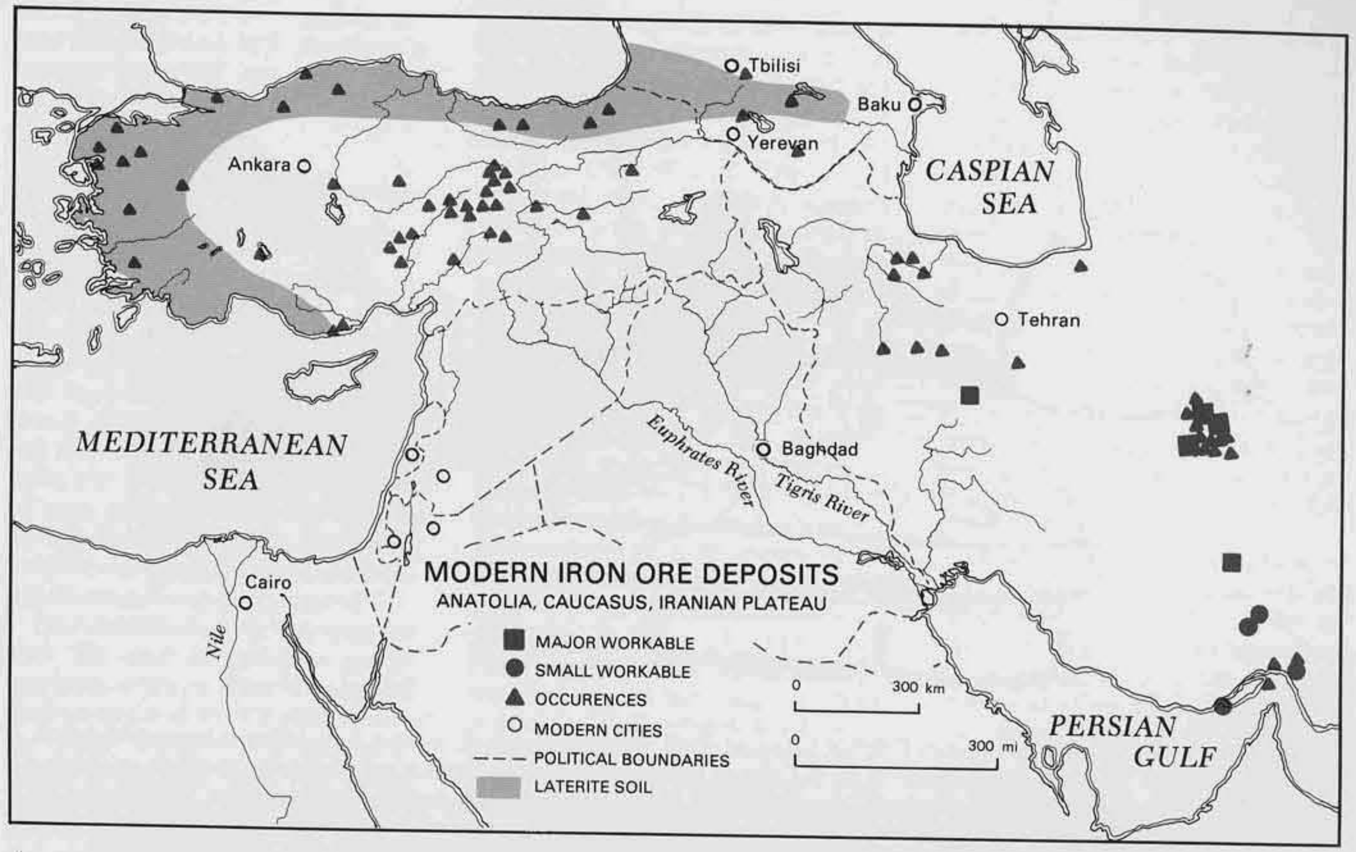
To some extent, this process was part of a general pattern in southwestern Asia, the increasing popularity and availability of metal products. In archaeological sites of the 1st millennium B.C., both iron and bronze occur with greater frequency than in 2nd millennium sites, suggesting that metalworking was expanding as a craft. An increase in the socioeconomic importance of metal and its production would have ensued.

Ethnographic observations of iron production confirm the relative complexity of even the most primitive operations. For production on some scale, mining, ore processing and transport, as well as fuel gathering and charcoal production, are each continuous, labor-intensive activities that are interdependent and must therefore be systematized and coordinated. Of importance here are the number of persons involved, the separateness of the various processes, and the need for overall coordination.

The availability and accessibility of resources would have influenced production and its organization. For example, the general availability of timber for charcoal would have contrasted with the limited distribution of iron ores and/or the limited availability of imported iron in the form of raw metal. Such



3
The changing boundaries of Assyria and Urartu during the early 1st millennium B.C., and the location of major trade routes. (Drawing by Jon Snyder after Pigott 1981:Fig. 6)



4
Locations of modern iron ore deposits in Anatolia, Iran, and the Caucasus. (Drawing by Jon Snyder after Pigott 1981:Fig. 2)

conditions must have led to varying specialized relationships between production centers and their hinterland. Furthermore, the rise of powerful nation-states at this same time, in particular Assyria and its rival to the north, Urartu (Fig. 3), played an important role in the dissemination of iron and its associated technology. These two empires, both with established ironworking traditions, exerted especially strong influence over northwestern Iran during the period of iron's florescence in this region, the 9th century B.C. (see Marcus, Winter, this issue).

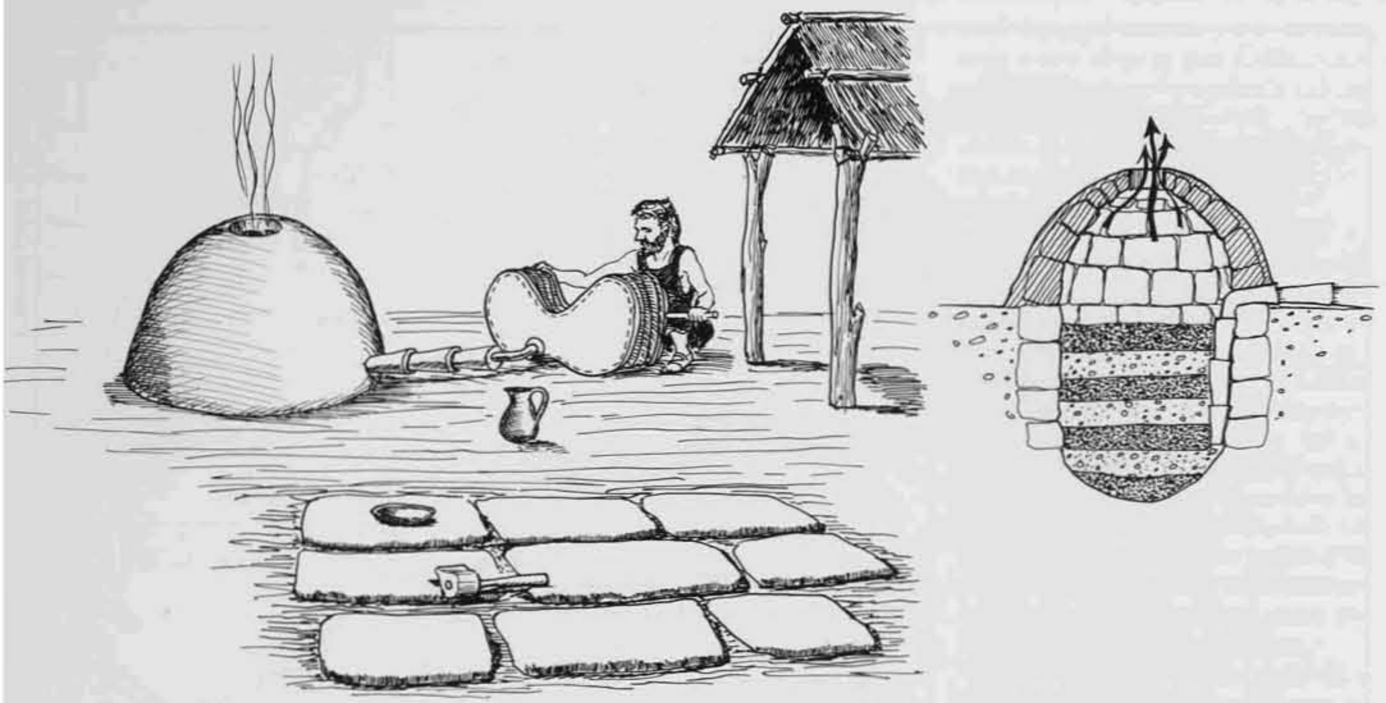
Evidence for Iron Production in Southwestern Asia

Modern geological surveys have recorded the location of major iron ore deposits in southwestern Asia, and usable deposits exist on the Iranian and Anatolian plateaus (Fig. 4; Maxwell-Hyslop 1974). Little is known, however, about the specific ore sources that were exploited in the past. Early iron mines have not been found, and evidence for the smelting of iron in the early Iron Age has also proven to be elusive.

The only documented smelting installations that appear to date from this period are located in the Georgian S.S.R., in the region of ancient Colchis along the Black Sea coast (Fig. 5). In Colchis, coastal placer deposits of black sands rich in magnetite (Tylecote 1981), as well as deposits of hematite, may have served as convenient sources of ore for the furnaces that have been excavated (Khakhutaishvili 1976). Such evidence is intriguing, but until the stratigraphy and chronology of these smelting sites (as well as many others known from the Caucasus) are published in detail, their true significance remains obscure.

There may also have been exploitation of iron deposits along the northern Anatolian littoral (Fig. 4), in high rainfall areas where the soil has undergone a process of leaching or laterization. The traveler W.J. Hamilton (1842) recorded iron smelting taking place near Trabzon on the Black Sea coast, where local villagers were grubbing iron ore nodules by hand from the soil. Such nodules could have formed under laterizing conditions and served as a convenient source of iron ore from the Iron Age onward.

The lack of direct evidence for the production of iron may well be a function of the nature of sites excavated thus far, as well as the areas of these sites selected for excavation. Archaeological surveys of metallogenic zones in Iran so far have been concerned with evidence of non-ferrous metal production and mining (Wertime 1968; Berthoud et al. 1982). The location of known iron ore bodies suggests that, with the exception of some deposits in central western Iran, iron users in western Iran would probably have had to foray to the



5
Iron-smelting furnace installation from Colchis, Georgia. Left: reconstruction showing a domed furnace supplied with a forced draft with bellows, being pumped by the seated figure. In the foreground is a paved area, perhaps used for forging. Right: cross-section of the smelting furnace showing the cylindrical clay tuyeres (nozzles) that form a pipe leading air from the bellows to the bottom of the furnace. Black layers represent charcoal, interfaced with layers of iron ore. (Drawing by Jon Snyder, after Khakhutaishvili 1976, and pers. com. Note: The type of bellows shown is conjectural)

south and east along the fringes of the central deserts in search of deposits.

Hasanlu as a Potential Center of Iron Production

As Udy has pointed out, "The nature of any technological process sets limits on the kinds of organization institutionally possible in the society concerned" (1964:115). Iron production on a substantial scale is best supported by an "industrial" organization, one which is continuous and involves various independent activities operating within the proper socio-political environment.

Early iron production on a large scale in western Iran could only have been successful at centers of sufficient size and population density to ensure an adequate labor supply, as well as a demand from elite consumers or patrons. Such a center could have had a centralized administrative organization to coordinate the various production activities.

A settlement of the size and significance of Hasanlu would have provided the necessary conditions for organized production of iron. It is one of the largest Iron Age sites in the Solduz valley, and its location would have permitted it to control local as well as long-distance travel and trade. Hasanlu lies on a route leading from Assyria eastward to central Iran, where it joins the famous silk route to Central Asia and the Far East. The site could have acted as a distribution center for the Solduz and Ushnu valleys, and perhaps controlled access to the surrounding hinterland. That the site had a strategic importance of more than simply local significance during the Iron Age is shown by the fact that following the destruction of Hasanlu IVB, the Urartians chose to garrison the High Mound and erect a major fortification wall (see Dyson, "Architecture," this issue).

Another indication that Hasanlu had the local prominence appropriate to a production center is the presence of a building plausibly interpreted as a temple (BBII; see Dyson, this issue). This monumental structure raises the possibility that the site served as a local religious center for the surrounding population. In addition, the local elite, who resided on the High Mound, constituted an important market. As Winter has pointed out, "it is the upper echelons of society who provide both the entrepreneurs or controllers of the mechanics of exchange and the recipients of the luxury goods" (1977: 380). The same would hold true for the production and receipt of goods produced locally.

Thus Hasanlu by virtue of its size, strategic location, complex material culture, and socio-political organization could have functioned as an important center of production and distribution for the immediately surrounding region. Control over a larger hinterland would have facilitated efficient

metal production by ensuring access to sources of fuel (the Zagros forest), possibly ore, and most importantly, labor.

The Evidence for Local Production at Hasanlu

Bronze-working is well documented at Hasanlu by the presence of stone molds, crucibles, ingots, and associated production debris (Stein 1940; de Schauensee 1988), but the situation for iron is quite different. Despite the large number of iron artifacts from the Iron II period (1100-800 B.C.), no direct evidence of either smelting or smithing this metal was encountered.

One explanation for this absence may be that large-scale metalworking activity was conducted well away from the Citadel, due to the heat, smoke, and industrial debris (especially slag) that would have been produced. The 9th century B.C. plain extending outside the settlement now lies buried under recently deposited alluvial soil, effectively obscuring any traces of prehistoric industrial activity.

There does seem to have been a local source of iron ore. Boulders of the iron ore magnetite were built into wall foundations and used as floor paving in buildings on the Hasanlu High Mound. The jagged edges of these boulders suggest that they were deliberately broken rather than eroded out of the ore body matrix; analyses of two samples showed the presence of titanium in both, suggesting they had come from the same deposit. The use of ore as construction material might indicate that this material occurred near the site in some quantity and was mined. Alternatively these blocks may have come from sources of iron known to lie east of the Solduz valley along the edge of the central Iranian deserts.

In the absence of any direct evidence for production at the site, we must rely on other arguments in support of this activity. First, once iron was available, a continuous demand for it is plausible. The volume of iron found at Hasanlu implies a high level of demand, at least for the military if not for domestic needs. Second, since the low-carbon wrought iron in the Hasanlu artifacts is quite malleable (see below), implements must have bent, dulled, and even broken under heavy use, and blacksmiths would have been needed to repair, resharpen, and reforge them often.

Third, the presence of iron artifacts unique to Hasanlu strongly suggests that such artifacts were at least forged to shape at the site. Among these unique items are iron shoulder rondels or plaques used as horse gear, and iron sidebar cheekpieces with three holes for attachment (Fig. 6; see also de Schauensee, this issue). These two types of horse trappings are northwest Iranian in style and are unknown on Assyrian reliefs (Dyson and Muscarella 1989).

Finally, the standardization of certain common utilitarian artifact types suggests that they were locally made rather than imported. In the forging of iron only the conscious effort of the blacksmith, combined with certain properties of the metal, results in similarities in the shape of forged artifacts. One particular non-military class of artifact from Hasanlu stands out as mass-produced and deliberately standardized for the performance of specific tasks: a small tanged iron knife with a single cutting edge and an upturned point (Fig. 12). The shape of the implement suggests its use as a flensing knife to skin animals, or perhaps to shear sheep (Egami et al. 1965). Eighty-six such knives were excavated at Hasanlu, and more were found in contemporary burials at Dinkha Tepe (Muscarella 1974).

a b

6a,b
Iron artifacts unique to Hasanlu include two types of horse gear: sidebar cheekpieces with three holes (a) and decorative plaques (b). The plaque or rondel is decorated with a winged horse in relief, made by hammering on the reverse side of the plaque. (a: UM 73-5-369, L. 5.8 cm; b: HAS 60-876, Diam. 19.5 cm, Musée Iran Bastan, Tehran. Photos courtesy of the Hasanlu Project)

Uses of Iron at Hasanlu

During the 9th century at Hasanlu, bronze was being supplanted by iron in a wide variety of uses. One manifestation of this transition is the occurrence of the same artifact type in both iron and bronze. In addition, bronze and iron personal ornaments frequently occur together, suggesting a conscious pairing of the metals for aesthetic reasons.

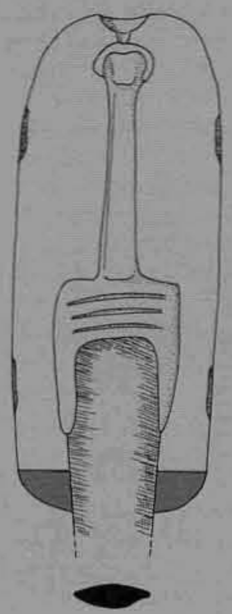
The artifact sample from the site suggests that iron was used mainly for weapons and tools, which far

Casting-On Technology

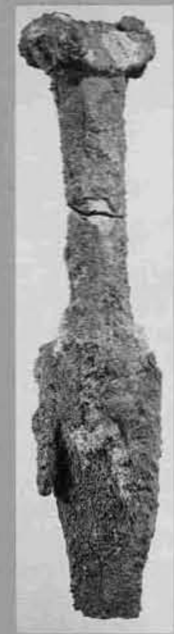
Casting-on, the technique of casting bronze (often decoratively) onto forged iron items, can be described through the following example. A tanged, iron sword blade was first forged in wrought iron. Then, a model in wax of the hilt to be cast-on was fashioned; this model was coated in clay and then fired, melting out the wax (cire perdue) and leaving the impression of the hilt in the clay. The clay mold was then cut into two halves. The iron blade was next sandwiched in position between the two clay mold halves, which were bound tightly together on either side of the blade. Molten bronze was poured into the mold and the bronze cooled in place, heat shrinking into position around the tang of the iron blade (Figs. 7, 8).

As an example of what a cast-on artifact looks like, Figure 9 shows an unprovenanced "ancient" bimetallic spearpoint after sampling. This artifact was given to the author by the late T.A. Wertime in Tehran. For analysis at MASCA the spearpoint was sectioned through the copper collar cast around the area where the socket and blade join. Between the two pieces of the spearpoint note the mounted metallographic sample showing the concentric rings of uncorroded copper (outer ring; Fig. 10) and the uncorroded wrought iron (inner ring; Fig. 11). Perhaps this copper collar was cast-on to reinforce this potentially weak point in the iron weapon.

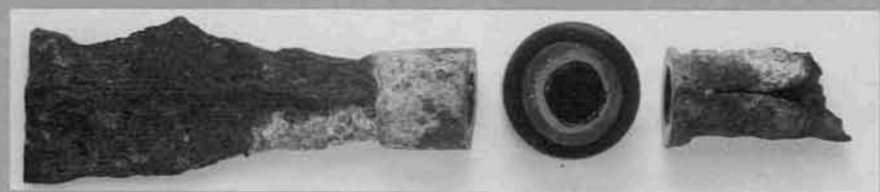
The copper collar was shown by PIXE analysis to have only 0.87 percent tin (Sn), while the blade and socket of the iron spearhead show basically similar compositions, i.e., a low-impurity iron with low levels of various trace elements (see Table 1).



7 (left)
Line drawing showing simulated final stage of the casting-on of a bronze hilt to the tang of a Hasanlu iron sword blade. (HAS 59-566, L. 19.2 cm. Drawing by G. Grentzenberg, courtesy of the Hasanlu Project; mold after Drescher 1958:Taf. 3)



8 (right)
Hasanlu iron sword with cast-on decorative bronze hilt. (UM 60-20-185, L. 19.2 cm. Photo courtesy of the Hasanlu Project)



9
Heavily corroded, socketed iron spearpoint with cast-on copper collar (unprovenanced). In the center is a mounted metallographic sample that was sectioned from the spearpoint at the collar. This sample shows uncorroded copper (outer) and iron (inner) rings. (Photo courtesy of MASCA)

Table 1
PIXE Analysis of Bimetallic Spearpoint*

Blade:				
Fe (99.5%)	Si (0.023%)	P (0.0085%)	S (0.0074%)	Mn (0.058%)
	As (0.019%)	Cu (0.032%)	Ti (≤ 0.0075%)	Mo (0.0052%)
	Ni (≤ 0.014%)	Co (≤ 0.58%)	Cr (≤ 0.016%)	Cl (0.0092%)
Socket:				
Fe (99.4%)	Si (0.051%)	P (0.0098%)	S (0.0136%)	Mn (0.074%)
	As (0.019%)	Cu (0.042%)	Ti (≤ 0.0075%)	Mo (0.0067%)
	Ni (≤ 0.014%)	Co (≤ 0.59%)	Cr (≤ 0.019%)	Cl (0.0092%)
Socket:				
Cu (96.9%)	As (0.47%)	Sn (0.87%)	Fe (0.47%)	S (0.012%)
	Pb (0.36%)	Ag (0.17%)	Sb (0.053%)	Ni (≤ 0.011%)
	Zn (0.28%)	Mn (0.0074%)	Cl (0.012%)	

*PIXE spectrometry data courtesy of Charles P. Swann (Bartol Research Institute, Univ. of Delaware) and Stuart Fleming (MASCA, The University Museum)

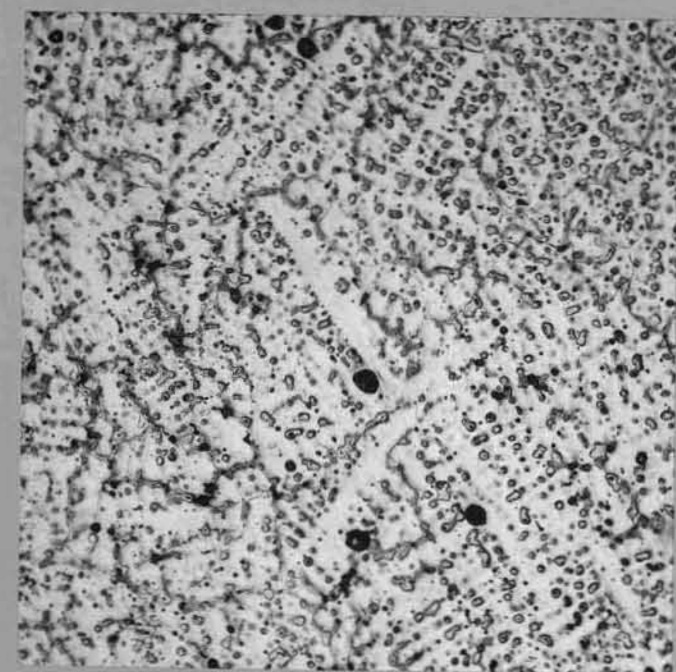
outnumber personal ornaments and other non-utilitarian types of iron objects. Excavation has yielded some 700 arrowpoints, 500 spearpoints, and 70 swords. Tools follow weaponry in quantity, with some 90 sickle blades and 90 small knives. Personal ornaments include some 140 pins, 40 bracelets, 15 rings, and 115 decorative studs and bosses. With the addition of various other categories of artifacts, there is a total of over 2000 iron objects from the site. Although artifacts used to wage war predominate in the assemblage, it is the variety of iron tools and equipment that is of special interest, for it would appear that as smiths became better versed in the manipulation of iron, they began to make more items for use in daily life.

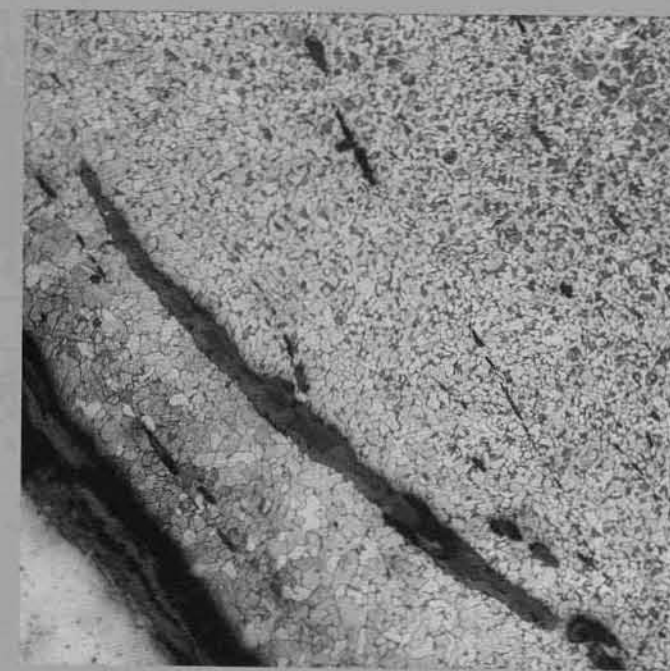
A Climate for Experimentation

Artifacts within the burned settlement indicate wealth both in the great variety of materials used and in the high quality of craftsmanship. The kinds of materials include:
- *metal*—copper, tin-bronze, iron, antimony, silver, gold
- *glass and related materials*—frit, paste, Egyptian blue
- *rocks and minerals*—carnelian, agate, meerschaum
- *organic materials*—ivory, amber, wood.

In fact, one of the distinguishing characteristics of this period at Hasanlu is the wide array of materials employed by local craftsmen. The settlement may have provided what Cyril Stanley Smith has characterized as "an aesthetically sensitive environment" (1970: 501). Such an environment, Smith contends, often encourages experimentation; moreover, "thoughtful intimate awareness of the properties of matter first occurred in the minds of people seeking effects to be used decoratively" (1976:3).

Experimentation and creativity would have been fostered by elite patrons seeking craft products as status markers. Bimetallic artifacts, which use two rather different metals to complement each other, may be the best representation of innovative technological craftsmanship. Such pieces are of particular interest technologically, since they are characteristic of transitional metal industries.





10,11
(10, left) Photomicrograph (100x magnification, ammonium hydroxide:hydrogen peroxide etch) of as-cast dendritic structure of the cast-on copper collar shown in Figure 9. This structure is indicative of simply molten metal that has cooled in place after casting. (11, right) Photomicrograph (100x magnification, Nital etch) of sample sectioned from spearpoint. In the lower left corner can be seen the join between the copper (left) and the iron (right). Oxidation along the seam suggests that the iron had been attacked by surface corrosion prior to the casting-on of the copper collar. In the iron, note the absence of any pearlite in the zone to the right of the seam and to the left of the large, elongated slag stringer that dominates the lower left side of the photo. It is possible that the iron spearpoint was decarburized and the microstructure recrystallized along its surface at the point where and when the high-temperature, molten copper was cast-on. In the zone to the right of the large stringer one begins to detect the increasing presence of pearlite colonies as one moves deeper into the core of iron and away from the surface. The frequency of the pearlite, however, is still low, and this artifact is best described as a low-carbon wrought iron. The flattened and elongated slag stringers (several can be seen across the field) reflect the direction of forging of the metal. (Photos courtesy of MASCA)

12
Small iron knives with a single cutting edge and upturned point were apparently mass-produced at Hasanlu. L. 10.8 cm. (HAS 74-286, Musée Iran Bastan, Tehran. Photo courtesy of the Hasanlu Project)

Bimetallic artifacts often consist of a forged iron artifact that has had a decorative bronze portion "cast-on" (see box; see also Maxwell-Hyslop 1964). Bimetallic objects fall within 13 of 76 metal classes represented at Hasanlu. Two classes are of interest here. The first consists of lion pins, each constructed of a stylized couchant bronze lion with an attached bronze chain (Fig. 13). The body of the lion has been "cast-on" to a pointed iron shaft. About 40 of these pins, in various sizes and styles, have been found. Two rested on the shoulders of a young adult who died in the collapse of Burned Building II (Muscarella, this issue). A second class of bimetallic artifacts consists of spearpoints. Seven of these points have bronze blades riveted onto an iron haft/socket, and one has the reverse composition with an iron blade in a bronze haft/socket (see Muscarella Fig. 2b and de Schauensee, Fig. 22). Because of their riveted and hence relatively weak construction, they may be ceremonial rather than true weapons.

Working iron and bronze concurrently, blacksmiths would have become more familiar with the malleability and versatility of the newer metal. Analyses of iron artifacts from Hasanlu IV suggest that a malleable low-carbon wrought iron, at times a mild steel, was in use. Such a material lent itself well to the skills of craftsmen previously schooled in fashioning luxury goods in other malleable materials such as gold and silver (and to a lesser extent copper and bronze): "when reasonably pure, [iron is] beautifully responsive to cold working, to raising and repoussé, to punching, tracing and chasing and similar techniques that are seen perhaps at their best in gold and silver" (Smith 1972:119-120). Examples of the use of these techniques on iron have been found at Hasanlu (Fig. 14). Thus, smiths whose traditions of metalworking probably included a certain familiarity with iron from numerous previous generations may have finally, under the stimulation of the cultural conditions of the Iron II period, begun to investigate iron's potential as a significant new material.

Interaction with Assyria

The most intriguing question concerning iron at Hasanlu is the source of the metal itself, which at present remains unclear. As stated above, neither iron smelting nor blacksmithing has been archaeologically documented anywhere in Iran. If iron was not in fact produced at or near Hasanlu as suggested above, the most likely source for this material was Assyria.

In view of the heavily military nature of the iron assemblage, we can propose several ways in which Assyrian iron might have arrived in Solduz. One scenario would place an Assyrian garrison at Hasanlu during the Iron II period (Hasanlu period IVB). In this situation, a number (if not most) of the iron artifacts found at the site probably would have been of Assyrian origin. They could have been imported as finished objects, or perhaps forged at Hasanlu from iron that had been imported in bloom form by blacksmiths accompanying the troops. Local workers might have been enlisted to produce artifacts according to Assyrian specifications.

Another possibility is that military aid in the form of iron and/or iron weapons might have been sent as gifts or perhaps traded from Assyria to allies at Hasanlu in return for their allegiance. Quantities of iron could even have been taken as tribute or booty by the rulers of Hasanlu, who may have conducted their own raids on smaller settlements to the south or west. Even if locally produced, the influence of Assyria on the Hasanlu iron industry was obvious and pervasive. Local smiths would have depended on technological knowledge gained from Assyria, and used Assyrian weapons as prototypes.

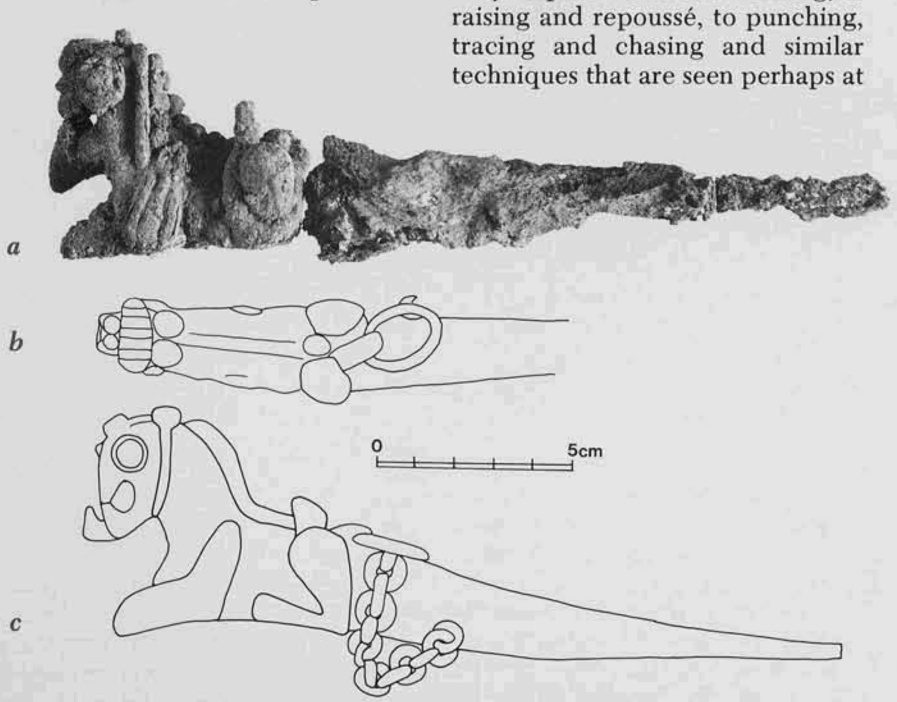
Interaction between the occupants of the Ushnu-Solduz valley and those of northern Mesopotamia—perhaps in the form of trade or the exchange of gifts—probably began at the time of the consolidation of the Assyrian empire, around 1200 B.C. (Levine 1977). At Hasanlu two inscribed artifacts suggest direct contact with Mesopotamia prior to the 9th century B.C. The name "Kadashman-Enlil" on a fragmentary stone vessel probably refers to Kadashman-Enlil II, who ruled Babylonia from 1279 to 1265 B.C. (Fig. 16). A fragmentary stone macehead bears the words "Palace of Ashur-Uballit," referring to an Assyrian king who reigned from 1365 to 1330 B.C. There are also a few distinctive early imports: fragments of two mosaic glass beakers found at Hasanlu are of a type known in Assyria prior to the 10th century B.C. (see Dyson, "Architecture," Fig. 8; von Saldern 1966).

Many non-iron artifacts apparently of local manufacture also show clear affinities with Assyria. For example, the potters at Hasanlu during Iron II were apparently glazing their pottery in imitation of Assyrian types (see Introduction, Fig. 10a); they also made glazed wall tiles and wall cones that followed Assyrian models. It is possible that not only the forms, but the entire technology of glazing was derived from the Assyrians, who were accomplished at this art.

Contact was intensified during the 9th century. The first military campaigns into western Iran documented in the Assyrian annals occurred during the reign of Aššurnasirpal II (883-859 B.C.; Levine 1977). It is quite likely that Assyrian craftsmen including blacksmiths traveled with the campaigning troops, repairing and resharpening military equipment. Travel of a peaceful nature between the two regions may have been more frequent. Aššurnasirpal II records the invitation of 50,000 foreign guests to the dedication ceremonies of his new capital at Nimrud (see Schneider, this issue). Polities from the Zagros Mountains of western Iran such as Gilzanu, possibly identified with the Ushnu-Solduz valley, were represented (Brown 1960; Winter 1977:378).

The cultural changes occurring at Hasanlu during this period—emerging wealth, social stratification, and military organization—must have encouraged "emulation" of the Assyrians. Within the context of material culture, emulation is a term used by Winter to describe the "acceptance of a visual theme along with its contextual significance and the integration of it into the fabric of the embracing culture"; such emulation is often undertaken "with a specific desire to identify with the original culture or meaning of the motif" (1977:379). In Assyria, iron had been a metal of special status associated with persons of high prestige and/or a metal of some religious significance. It is not surprising, therefore, that the inception of the widespread use of iron should correspond with the period of wealth and innovation at Hasanlu.

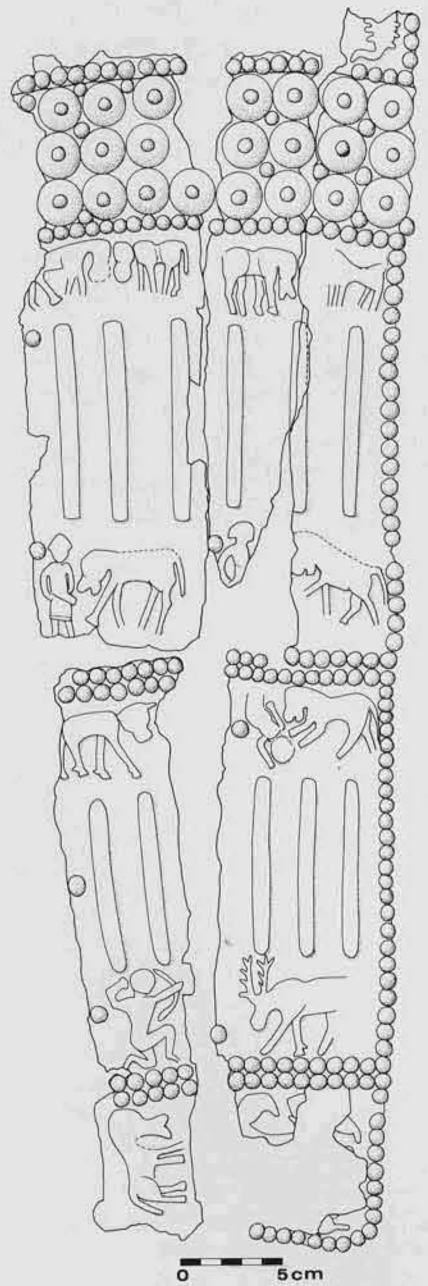
Another result of Assyrian influence appears to be the association of iron with military status. Military paraphernalia in iron far outnumber other classes of iron artifacts found in the burned Citadel of Hasanlu IVB. In light of the military nature of the incursions of Assyrians into western Iran during this period, it



13a-c
Lion pins consist of a bronze body cast onto an iron shaft. Such pins were worn on the upper body, with the iron shaft inserted through a loosely woven garment. The heavy bronze body was kept upright by a bronze chain attached to the lion's back and clipped to the cloth. (a: HAS 62-523, L. 16.3 cm, Musée Iran Bastan, Tehran; b, c: UM 73-5-541, L. 19.3 cm. Drawings by Maude de Schauensee; photo and drawings courtesy of the Hasanlu Project)

Table 2
PIXE Analysis of Lion on Bimetallic Pin, HAS 62-523 (Fig. 13a)°

Cu	85.3%
As	0.220%
Sn	12.7%
Fe	0.250%
S	0.104%
Pb	0.785%
Ag	0.140%
Sb	0.124%
Ni	0.041%
Zn	0.091%
Cl	0.21%



14
The iron panels on this quiver from Hasanlu IVB were decorated by cold working to form raised figures of people and animals. Easily recognizable near the bottom is the figure of an archer shooting a stag. The round bosses and studs are of bronze. (UM 71-23-324, L. 58.3 cm. Drawing by Denise Hoffman, courtesy of the Hasanlu Project)

Iron Metallography

Over a century of archaeological excavation in southwest Asia has yielded thousands of iron artifacts, but it is only over the last 20 years that these artifacts have begun to be studied by archaeometallurgists. The primary technique of analysis has been metallography (see Glossary). Through the microscopic analysis of polished and etched sections of ancient iron artifacts, scholars have sought to provide an understanding of their process of manufacture. A "memory" of how such artifacts were smelted and forged is contained within the crystalline microstructure of the metal of each artifact (Smith 1976). Tapping this memory can prove to be particularly informative.

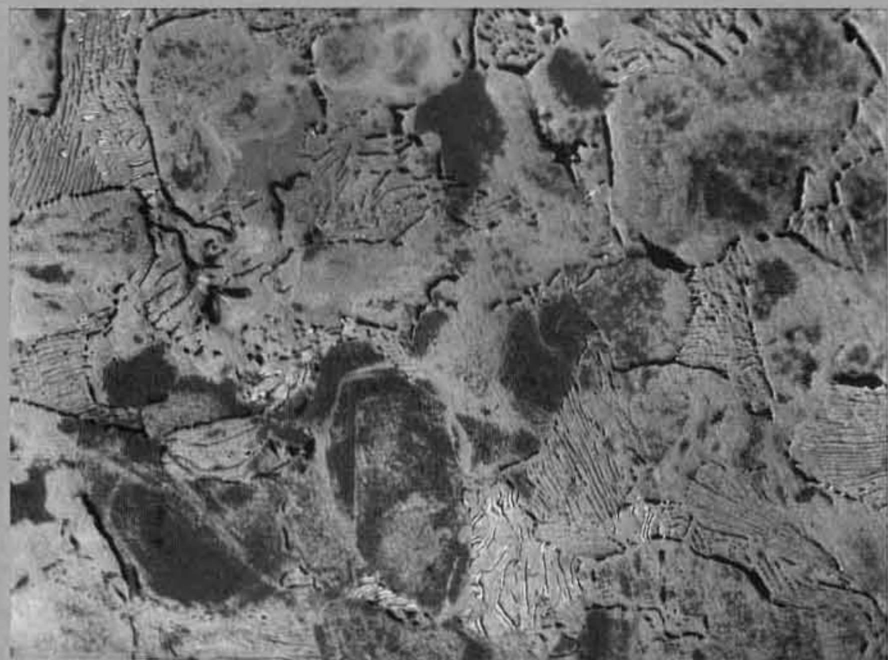
Analysis and interpretation of the Hasanlu material is complicated by the fact that most of the artifacts are heavily oxidized. The presence of so much corrosion makes metallographic observations of the microstructure difficult to achieve. Pioneering work on the iron from Hasanlu by Reed Knox (1963) at the University of Pennsylvania established that a certain level of observation could be achieved even from oxidized iron. Figure 15 is a photomicrograph of a polished section of an oxidized Hasanlu iron sword (Fig. 1). Magnified 1250 times, what we see microstructurally are rather evenly distributed, pseudomorphic pearlite colonies—the lamellar structures—entrapped in a matrix of iron oxide.

Knox's work indicated that original microstructures are often preserved pseudomorphically as "ghosts" in the oxidized metal and can be useful in interpretations. Pearlite has a characteristic lamellar structure consisting of alternate parallel plates of iron and iron carbide. It occurs in carbon steels that have been cooled in air from temperatures above approximately 725° C. The presence of the pearlite colonies suggests that this particular region of the sword had a microstructure and carbon content indicative of steel; while it is possible to suggest that this artifact may have actually consisted of steel, a number of analyses from various points on the sword would have to be conducted to determine the evenness and distribution of carbon-bearing structures.

Analyses of iron artifacts from Hasanlu suggest that the pieces at the site are, in most cases, intermediate between wrought iron (with virtually no carbon content) and steel (i.e., iron with an appreciable carbon content; see Glossary). As a result of the smelting process used to produce Hasanlu iron, the distribution of carbon in the iron was markedly heterogeneous. This fact makes it difficult to categorize iron at Hasanlu, but in general it can be described as a low-carbon, heterogeneously carburized "steel."

Thus the metallography of Hasanlu iron artifacts indicates that the microstructures are frequently quite variable in carbon distribution across the sampled sections, which in turn suggests that the metalworkers responsible for producing the iron and forging the artifacts had no special knowledge of how to produce steel consciously and consistently.

Complementary evidence comes from analyses of unprovenanced iron swords thought to be from Luristan and dated to Iron III (e.g., Pleiner 1969a,b: Smith 1971; see also Muscarella 1989), as well as from analyses conducted on Assyrian iron artifacts (Pleiner and Bjorkman 1974; Pleiner 1979; Curtis et al. 1979). These studies suggest that iron of comparable quality was being produced and used in these two regions neighboring northwestern Iran.



15
Photomicrograph of iron sword UM 65-31-220 (see Fig. 1; 1250x magnification: Nital etch) showing pseudomorphic pearlite colonies (note their lamellar structure) preserved in the oxidized matrix of the sword. The light colored, elongate lamellae are probably uncorroded carbides. This artifact had evidence of evenly distributed carburization (in the form of pearlite colonies) in the central portion of the blade, as well as at the blade's edge. Thus it would qualify as a "mild" steel and most probably was an effective weapon of war. Along one edge of the blade distorted structures in the oxide suggest some evidence of cold-working deformation of the metal. Grain size, when apparent, is seen to be coarse, and there is some indication of the artifact having been cooled fairly slowly. (Metallographic analyses were conducted on this weapon by Reed Knox and the author, in consultation with Robert Maddin; see Pigott 1981. Photo courtesy of MASCA)

16
A stone vessel from Burned Building II at Hasanlu bears a partially preserved cuneiform inscription. In the top register, above alternating figures of goats and trees (once inlaid), is the phrase "of Kadashman-Enlil...." This kind of brief inscription designated items as either the property of, or a gift from, the monarch named. The inscription refers to the Babylonian king Kadashman-Enlil I (early 14th century B.C) or II (ca. 1275 B.C.). (HAS 64-656, Dia. 7.8 cm, Musée Iran Bastan, Tehran. Photo courtesy of the Hasanlu Project)

could be expected that the indigenous use of iron would concentrate on weaponry. Of the iron artifacts excavated at Hasanlu, roughly 65 percent can be classified as weapons.

The military might and political power of Assyria would have provided status indirectly and symbolically to those who owned Assyrian or imitation Assyrian goods. Ownership of such goods would have lessened the "power gap" between these elites and their Assyrian counterparts. More specifically, at Hasanlu these goods would have served to increase the prestige and political power base of the local elite, "strengthening the existing social hierarchy while at the same time manipulating the local population by allowing them to identify with the added prestige of the elite" (Winter 1977:381).

Thus by the 9th century B.C., trade, travel, military campaigns, and even semi-permanent garrisons in western Iran were all sources of frequent and significant interaction with the Assyrians. The impact of this interaction on the Ushnu-Solduz valley must have ranged from a

Glossary

bloom: the spongy iron mass produced in the solid state directly as a result of the reduction or smelting of iron ore. It is combined with large amounts of slag which must be extruded by sequential heating and hammering. The distribution of carbon in the metal is normally quite heterogeneous and low. However, bloomery smelting can, under certain circumstances, produce steel

carburization: the process of heating bloomery iron in contact with charcoal, resulting in the absorption of carbon into the surface layers of the iron, converting them to steel. The process can also occur during bloomery smelting, resulting in steel

cold working: the hardening of pure copper through hammering the cold metal. This technique strengthens the metal and was often used in shaping an object or sharpening edges after casting

metallogenic zones: those areas in the earth's crust where geological conditions resulted in the emplacement of a high density of ore deposits

metallography: the study and analysis of the microstructure of metals by means of optical microscopy. A sample of metal is cut from an artifact, mounted, polished, etched, and then observed and photographed under the microscope. Information concerning the methods of the artifact's manufacture is revealed in its microstructure

quenching: to cool steel very rapidly, for example by plunging it into water or some other liquid. It can produce substantial hardening of steel under specific circumstances

steel: "iron that has been combined with carbon atoms....Through this, it changes its physical properties to become an alloy...and often a 'solid solution' which is extremely hard, tough and strong, and quite unlike iron except in appearance and density. Unlike (wrought) iron, it can take and retain a sharp edge but cannot be easily worked. Steel can be made to assume different degrees of hardness, brittleness, toughness, etc., depending on the temperature control and rapidity of cooling in its manufacture....Carbon steel, the earliest and commonest type, has carbon as its chief alloying element" (Congdon 1971:18)

wrought iron: "a tough, malleable, gray-white metal with (usually) a fibrous structure and a melting point of 2750-2800°F [1510-1535°C] ....[W]rought iron contains at most only a few tenths per cent of carbon" (Congdon 1971:18). This term is commonly used to refer to low-carbon iron which has been forged by a blacksmith following smelting direct transmission of technology (for example, ceramic glazes) to that of less tangible ideas, such as the nature of elite status and the symbols proper to this status.

Iron as a Marker of Social Change

The circumstances that led to the adoption of iron at Hasanlu also existed in other areas of western Iran. A general pattern of political and economic centralization is suggested throughout the region (Dyson 1965; Young 1967). For example, at Marlik, near the Caspian Sea, wealth and social stratification are documented by a cemetery containing grave goods that are comparable to the Hasanlu assemblage in skill and artistry, as well as in the variety of materials used (see Winter, Fig. 8, this issue). Eighth to 7th century B.C. cemeteries from western Luristan have also provided ornate grave goods as well as indications of standardized production in the form of classic Luristan iron swords (Fig. 18; Muscarella 1988:184-189; 1989). Architecture in the form of manor houses/forts has been excavated at Tepe Kordlar to the north of Hasanlu, at Godin Tepe and Nush-i Jan in the central western region, and at Baba Jan in Luristan. These too are suggestive of wealth and stratification.

At all of these sites, the indications of wealth and advanced social stratification coincide with the widespread occurrence of iron, as well as with a period of intensified Assyrian presence in each region. Sites such as Godin, Baba Jan, and Tepe Sialk lie directly along the southern route linking Assryia with the Iranian plateau, and Assyrian stelae and rock sculptures document the importance of the route to Assyrians (Fig. 17). Thus Assyrian interest and influence, perhaps stimulated by economic factors such as trade and the acquisition of raw materials, appear to be the critical variables in the process of the adoption of iron in western Iran (Pigott 1981).

18
Iron sword from Luristan. (UM 30-38-18, L. 41.9 cm)

17
This stele of King Sargon II, found in 1965 near the modern city of Kangavar in Iran, marks an important route leading between Assyria and Iran. An inscription on the opposite side (dated 716 B.C.) includes a description of the king's campaign against the Manneans. (Photo courtesy of the Royal Ontario Museum, Ontario)

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Vincent C. Pigott trained in Anthropology at the University of Pennsylvania and joined The University Museum's Applied Science Center for Archaeology in 1979. Since that time, his research in the field and in MASCA's laboratory has focused on issues in the development of metalworking and metal use ranging across Southwest, South, and, recently, Southeast Asia. He did field work at Hasanlu from 1970-74 and was Assistant Director of excavations in 1974; his dissertation was based on his work at the site. Since 1984 he has directed the Thailand Archaeometallurgy Project, and is currently excavating a group of prehistoric copper smelting settlements in central Thailand.

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