



BRONZE I. IN PRE-ISLAMIC IRAN

BRONZE

i. In Pre-Islamic Iran

When tin is alloyed with copper, it decreases the temperature at which the two metals will melt, increases fluidity during casting, and acts as a deoxidant (Berthoud et al., 1982, pp. 48-49). Although the amount of tin that must be present for bronze to be considered an intentional alloy is still much debated (e.g. Heskell, 1982, pp. 318-19; Moorey, 1985, p. 18), a low tin content does little to enhance the mechanical properties of an artifact. For example, copper becomes noticeably harder when the tin content is above a few percent, and a bronze with 10 percent tin is the optimum composition for implements like chisels or daggers, when cold hammered during final working. When tin content is above about 15 percent, the bronze becomes brittle and between 20 and 30 percent it can take on a silvery hue. In order to shape high-tin bronzes (the “white bronzes” of the early Islamic period; see below) containing 22-24 percent tin, they must be forged at high temperature, followed by quenching (plunging into a liquid for rapid cooling), for a functional finished product (Goodway and Conklin).

Although copper deposits occur with reasonable frequency throughout the highland zones of southwestern Asia (defined here as the entire portion of



Asia west of the Indian subcontinent; Figure 27), sources of tin are far less common. The only traces of tin that have been geologically documented within the modern political boundaries of Iran are in the southeast, at several locations in the Dašt-e Lūt near Sīstān (Stöcklin et al., p. 58). Strabo mentions in his *Geography* (15.2. 10) that tin was present in Drangiana (modern Sīstān). Large deposits of tin were, however, identified elsewhere in neighboring Afghanistan (Figure 28) during joint Afghan-Soviet geological surveys sponsored by the United Nations Economic, Social and Cultural Organization (UNESCO; Chmyriov; Shareq et al.) and by a French archeometallurgical survey (Cleuziou and Berthoud; Berthoud et al., 1982). Two primary zones of occurrence are known, the first extending from south of Qandahār to Badakṣān province in the northeast, the second running north from Sīstān to the vicinity of Herat (Shareq et al., pp. 165-90; summary and map in Stech and Pigott, pp. 40, 44-45; cf. Muhly, 1987, p. 101, contra Penhallurick, p. 31). These tin deposits are the most extensive so far documented in southwestern Asia and constitute the most likely source of the earliest tin used in the region.

At least twelve major copper-rich zones encompassing more than 200 deposits have been documented in Iran by G. Ladame and by the Geological Survey of Iran (Bazin and Hübner). In Afghanistan a total of 241 copper deposits have been recorded (Shareq et al., 1977, pp. 101-35, map 6; see also Berthoud et al., 1977; Heskell, 1982, pp. 340-81). The abundance of copper on the Iranian plateau and in Afghanistan, together with the availability of tin, has led to speculation that this entire region may have been a “heartland” of the early development of bronze metallurgy (Stech and Pigott, p. 48).

Current understanding of early developments in copper-base metallurgy on the Iranian plateau is based largely on archeological excavations, archeometallurgical field surveys conducted by Theodore A. Wertime and colleagues (1964; 1968; 1973; Caldwell, 1967, pp. 318-405; Tylecote, 1970) and a team led by Thierry Berthoud (Berthoud et al., 1975; 1976; 1978; 1979; 1990a-b; 1982), and from independent research by such scholars as D. L. Heskell (1982), P. R. S. Moorey (1969; 1982; 1985), J. D. Muhly (1973; 1976; 1983; 1985), and A. R. Vatandoost-Haghighi (for a bibliography of the archaeology and art history of metals in ancient Iran, arranged by periods, see relevant sections in Vanden Berghe, 1979; Vanden Berghe and Haerinck, 1981; idem, 1987).

The Neolithic (ca. 7500-5500 B.C.) and Chalcolithic eras (ca. 5500-3300 B.C.). The term “bronze” has frequently been applied to copper-base metals, regardless of composition. For that reason, though the alloy did not appear on the Iranian



plateau until the 4th millennium B.C., discussion begins with the earliest occurrences of copper. Current evidence suggests that native copper was first used in the Neolithic and continued in use through the Chalcolithic (Heskel, 1982, pp. 384-88). A 9th-millennium B.C. mineral-copper pendant from Zawi Chem Shanidar (Zevī Ćemī Šānedār) in the Iraqi Zagros mountains (Solecki, 1969, p. 361) indicates early familiarity with copper ore. Among the earliest excavated metal artifacts that are arguably composed of native copper are a tolled bead (ca. mid-7th millennium) from the site of Ali Kosh (‘*Alikoš*’) in the Deh Luran (*Dehlorān*) plain of northern Kūzestān (Smith, 1969); several awls (ca. mid-6th millennium) from Tepe Zagheh (Zāgā) on the Qazvīn plain (Shahmirzadi; ca. 5th millennium); copper fragments from Chogha Sefid (*Čogā Safid*; Hole, 1977, p. 245); and pins, projectile points, awls, and spiral coils (ca. mid-5th millennium) from Tepe Sialk (Sīalk) near Kāšān (Halm, 1939; Coghlan, 1942, pp. 22-34; Lamberg-Karlovsky 1967, pp. 145-46). Analyses of the Ali Kosh bead and a Sialk pin indicate that they are of cold-worked native copper (Smith, 1968, pp. 239-40; 1965, pp. 28-30; Wertime, 1964, p. 1260; Knauth, p. 40). The earliest metal found at Tepe Yahya (Yaḥyā; mid-5th millennium) consisted of two copper awls, one of which was shown by analysis to have been shaped from native copper (Heskel and Lamberg-Karlovsky, 1980, p. 232; see Heskel, 1983, p. 364, table 1, for the earliest metal artifacts in southwestern Asia). It can be argued that in the Neolithic experimentation with native copper (and other raw materials as well) was stimulated throughout southwestern Asia by the desire to achieve decorative effects. Such experimentation could have led to inadvertent technological innovation (Smith, 1976).

During the Chalcolithic the use of copper expanded dramatically. In the early phases the repertoire of copper artifacts was modestly diversified, including needles, pins, tanged dagger blades, chisels, and both shaft-hole and flat axes. By the end of the era it had been expanded to include seals, midribbed daggers, shaft-hole maceheads, spiral-headed pins, coiled bracelets, earrings, and finger rings. Similar objects were made of lead, silver, and gold (Moorey, 1982, p. 86). Analysis of artifacts from this period reveals the presence of varying amounts of arsenic. It is likely that native copper and ore were being drawn from sources on the Iranian plateau that contained arsenic naturally, for there are no indications that arsenical copper was being produced by intentional alloying. Unfortunately, the microstructure of copper produced by simple melting is indistinguishable from that of an artifact produced from smelted copper (Maddin et al.). The presence of arsenic in copper, regardless



of whether the latter has been melted or smelted, improves mechanical properties in much the same way that tin does (Maréchal: cf. Coghlan, 1975, p. 83).

Smelting furnaces from the prehistoric periods on the Iranian plateau have so far been excavated only at the Bronze Age site of Shahdad (Šahdād) in Kermān province (Vatandoost-Haghighi), but regrettably detailed information on them is unavailable. While furnaces may eventually be excavated at other prehistoric sites, we must also recognize that the technologically simple process of smelting in a crucible could well have dominated the production of copper and copper alloys from early prehistory well into the Bronze Age. Crucible smelting would have required no permanent installation. Archeometallurgical remains from Neolithic, Chalcolithic, and Bronze Age sites on the Iranian plateau support this observation. At Chalcolithic: Tal-i Iblis (Tall-e Eblīs) near Kermān large quantities of crucible fragments occurred with slag, ore, and copper-base artifacts (Caldwell, 1967; 1968; Caldwell and Shahmirzadi; Dougherty and Caldwell). At Seh Gabi (Segābī) between the Kangāvar and Asadābād valleys (7 km northeast of Godin/Gowdīn Tepe) both fragmentary crucibles and possible ingot molds were excavated (Levine and Hamlin, p. 212). The earliest strong evidence for smelting, possibly in a crucible, comes from late 5th-millennium Tepe Ghabristan (Qabrestān) near Qazvīn, where 20 kg of malachite, what may have been a clay tuyère (a tentative identification of the only prehistoric example of such an artifact from the Iranian plateau), and a crucible and molds encrusted with slag, including molds for shaft-hole implements, were excavated (Majidzadeh). It is significant that, though the crucible itself can be used not only for melting native copper but also for smelting oxide ores like malachite (Tylecote, 1974) and mixtures of oxide and sulfide ores (Rostoker et al.), when malachite is smelted in crucibles or bowl furnaces, it produces little slag as residue (Tylecote, 1974). At Ghabristan slag in any quantity was not encountered, and the slagged molds probably resulted from the pouring of molten copper that had been smelted in the crucible directly into them (cf. Muhly, 1983, p. 352).

Current research supports the idea that copper deposits on the Iranian plateau were being mined for their arsenic-rich minerals and ores, and it is in these deposits that evidence of early workings must be sought. Unfortunately, very little archaeological research has been conducted on ancient mining. Deposits of copper including mineralized arsenic are not common on the plateau. Although most ore deposits show indications of “old workings” (see Berthoud



et al., 1976, 1977, 1978; Bazin and Hübner), only the copper mine at Veshnoveh (Vešnova) near Qom has yielded any indication of possible prehistoric exploitation (Holzer and Momenzadeh). A single ceramic vessel of the Sialk IV type (ca. later 4th millennium) was found in one of the many galleries, but no arsenical copper ores were reported at this deposit.

In the deposit at Taknar in northern Khorasan (Bazin and Hübner, p. 90), on the other hand, the arsenic-bearing copper ores enargite and tetrahedrite are present but only in small amounts. It is possible that such a source could have supplied prehistoric sites on the northern plateau, including Tepe Hissar (Hešār), where Chalcolithic and later levels yielded artifacts almost exclusively of arsenical copper (Pigott et al.).

The single mining region on the plateau with arsenical copper ores present in sufficient proportions to have been exploited in the Neolithic period and later is the Anārak district (10,000 km²) about 200 km northeast of Isfahan on the southern border of the Dašt-e Kavīr (Bazin and Hübner, pp. 61-63). Over twenty occurrences of polymetallic mineralizations occur there, including copper, lead, zinc, silver, gold, bismuth, cobalt, iron, manganese, molybdenum, antimony, and uranium. Two adjacent deposits, Talmessi (Talmesī) and Meskānī are considered the primary sources. The richness of the former has been emphasized by Maczek and his colleagues (p. 65), who reported that in 1314 Š./1935 native copper was being extracted from a depth of 80 m at the rate of 300 kg/m³. Not only is arsenical native copper found at both sites, but also these deposits are the only known southwestern Asian source with significant quantities of algodonite (Cu₅As) and domeykite (Cu₃As; Schurenbeg; Heskell, 1982, p. 9; Tylecote, 1970, pp. 289-90; Heskell and Lamberg-Karlovsky, 1980, p. 86), two copper arsenides that are quite easily reduced and would be ideally suited to smelting in a crucible.

That the Anārak deposits could have been supplying an extended region (Heskell, 1982; Berthoud et al., 1982) is supported by the existence of established trade routes as early as the Neolithic, when obsidian was traded extensively (Wertime, 1973, p. 876; Moorey, 1982, p. 84). Analyses of a native copper pin from Sialk suggest that Talmessi, some 200 km to the east, was the source of the copper (Smith, 1968). By the end of the Chalcolithic, interaction between plateau settlements and those in lowland Kūzestān and Mesopotamia was well developed (Moorey, 1982; Deshayes, 1960, I, p. 152). Analyses of arsenical-copper artifacts from 4th-millennium Susa, in Kūzestān, show a strong elemental correlation with copper from the Talmessi deposit (Berthoud



et al., 1982, p. 43).

This first flurry of metallurgical activity is attested on the Iranian plateau earlier than in Mesopotamia. Nevertheless, the first indications of bronze appear simultaneously on the plateau and in the lowlands in the 4th millennium. A bronze flat axe was excavated from the necropolis at Susa I(A) (Berthoud, p. 13 no. 974) and a bronze needle from Sialk III-5 (Ghirshman, 1938, p. 206). From Godin unpublished analyses indicate that bronze is present in period V, which dates to the second half of the 4th millennium into the early 3rd millennium B.C. (Godin Project Archives). These random initial occurrences of bronze may have resulted from trade with the east. Afghanistan, where abundant copper and tin deposits are juxtaposed, is a likely locus for the technological innovation of bronze.

The Bronze Age (ca. 3300-1400 B.C.). Arsenical copper continued dominant during the approximately two millennia of the Bronze Age. Bronze occurred with some frequency toward the end of the period but was still not common. Only at the dawn of the Iron Age did bronze become the dominant copper-base alloy, though its role was transformed as iron became more important.

After 3000 B.C. the bronze artifacts are found together with those in gold and lapis lazuli (Muhly, 1977, p. 76). The earliest simultaneous occurrence of these luxury materials is known from Mesopotamia (particularly in Early Dynastic III, ca. 2600-2350), though the sources lay considerably farther east. The northeastern Afghan province of Badakṣān is a primary source of lapis lazuli (Herrmann; Tosi, 1974), though small deposits are now being reported in northern Pakistani Baluchistan. Gold and tin for bronze are also found throughout much of Afghanistan, especially in the valleys of the major river systems (Shareq et al.; see map in Stech and Pigott, p. 40).

Transporting these raw materials to Mesopotamia over land meant interaction with the populations on the Iranian plateau. Lapis lazuli found at sites like Tepe Hissar and Shahr-i Sokhta (Šahr-e Sokta), where there is ample evidence that it was worked locally (Bulgarelli), attest to such contacts. Nevertheless, metalworking at the plateau sites continued to be dominated by arsenical copper. Only at Susa is there evidence of bronze technology from the mid-3rd millennium: the “vase à la cachette” containing four bronzes, sixteen arsenical coppers, and three artifacts containing both tin and arsenic (Amiet et al.; Berthoud, p. 14). Analyses suggest that tin was being alloyed with arsenical copper (Stech and Pigott, p. 43). In the final centuries of the 3rd millennium, a



period during which Susa had strong cultural ties with Mesopotamia (Amiet, p. 197), bronze was found with some frequency there; by that time many plateau settlements, including those at Tepe Sialk, Tall-i Malyan (Tall-e Mālīān), and Tepe Yahya had been abandoned.

The Sumerians were active in trade and the acquisition of exotic luxury materials. The rarity of tin may have enhanced its status in Mesopotamia, whereas the peoples of the Iranian plateau remained uninfluenced by such pressures (Stech and Pigott, p. 48). At any rate, tin “bypassed” the plateau en route to Mesopotamia (Beale, p. 144; Moorey, 1982, p. 88). Iranian metallurgical traditions can thus be characterized as technologically conservative, for, though copper artifacts were manufactured in quantity and in a variety of forms, simple smelted or melted arsenical copper was the main material used. At Tepe Hissar, for example, the quantities of slag, fragments of furnace lining, and molds suggest large-scale production of arsenical copper: tools, weapons, and elaborate ornaments (Schmidt, 1937; Pigott et al.). There is also evidence of lead and silver production. Bronze, however, was found only very rarely in the analysis of metal artifacts from the site (Pigott et al., p. 230; Berthoud et al., 1982, p. 50 n. 66; Reisch and Horton apud Schmidt, 1937, p. 359). Assemblages from Shahr-i Sokhta to the southeast, Tepe Yahya to the south (Heskel and Lamberg-Karlovsky, 1980; 1986; Heskel, 1982, pp. 73-97; Tylecote and McKerrell, 1971; 1986), and probably Shahdad, also to the south (Vatandoost-Haghighi; Moorey, 1982, pp. 83, 90-91; Salvatori; Salvatori and Vidale), consist primarily of arsenical copper artifacts, with rare bronzes (Heskel 1982, pp. 97-120; Hauptmann; see also Tosi, 1993). An arsenical-copper shaft-hole axe from a burial at Khurab (K̲vorāb; Stein, 1937, p. 121) in Baluchistan has been the subject of several studies (Maxwell-Hyslop; Zeuner; During Caspers), including a detailed metallurgical analysis of its composition and manufacture (Lamberg-Karlovsky, 1969; Lechtman). Farther west at Tall-i Malyan in Fārs province artifacts from the late 4th- and early 3rd-millennium Banesh (Baneš) phase (Nicholas, 1980; forthcoming) are exclusively of arsenical copper, but preliminary analyses of finds from the subsequent Kaftari phase (early 2nd millennium) indicate that several are of bronze (Pigott, 1980, pp. 107; unpublished analyses of the Museum of Applied Science, Center for Archaeology/MASCA). Slags with entrapped metal prills from Malyan have been shown by analysis to be derived from copper/bronze production (Carriveau, pp. 63-66). Unpublished analyses from the site of Godin indicate that a number of bronze artifacts occur in period III contexts, about early 3rd to early 2nd millennium B.C. (Godin Project Archives). Thus the Godin III and



Kaftari Malyan contexts may be the earliest on the plateau to contain bronze with some frequency, probably reflecting the geographical and cultural proximity of these sites to the lowlands of Mesopotamia and Kūzestān.

The suggestion of Afghanistan as an early locus of bronze metallurgy, though attractive, cannot yet be fully substantiated archeologically. The only well-documented artifacts in bronze from the region were excavated at Mundigak (Mondīgak), in levels dating from the mid-4th through the 3rd millennium (Shaffer, p. 144; Jarrige, p. 291; see also Lamberg-Karlovsky, 1967, pp. 146-48). A few were of bronze, principally axes and a single adze, and their occurrence over a long span of time may indicate regular use of the alloy (Stech and Pigott, p. 47). Unfortunately, the bronze artifacts from Ghar-i Mar (Ġār-e Mār “snake cave”) in northern Afghanistan cannot be firmly dated (Caley, 1971, 1972, 1980; Shaffer, p. 89; cf. Moorey, 1982, p. 99 n. 62).

In Turkmenistan bronze is not recorded at all until the late 3rd millennium (Terekhova, p. 319). Artifacts from Anau (Anāv; see [anaw](#)) include at least four bronzes and six arsenical-copper artifacts from Bronze Age deposits (Gooch, pp. 238-39; see also Chernykh). Analyses of bronzes of this period from Sarazm on the Zeravshan (Zarafshān) river in Tajikistan revealed only unalloyed copper (Isakov et al.), particularly significant in view of the proximity of known tin sources in the Zeravshan valley (Stech and Pigott, p. 44) southwest of Samarkand and along the Köksu river in Uzbekistan (Ryzanov).

The most comprehensive typological studies of a large corpus of Iranian copper-base artifacts from the region between the Indus and the Danube have been published by Deshayes (1958; 1960; 1963; 1965; Deshayes and Christophe). They include extensive discussions of techniques of fabrication and evolution of forms, as well as of the general development of metallurgy in various culture areas of southwestern Asia and adjacent regions.

The Iron Age (ca. 1400-600 B.C.). Among copper-base artifacts from Iron Age sites that have been analyzed bronze is by far the most common alloy: from Geoy (Gūy/Gök) Tepe (Burton Brown, pp. 179-97; Crawford, pp. 26-27; Eaton and McKerrell), Tepe Giyan (Halm, 1935, pp. 135-38), Sialk (Halm, 1939, pp. 205-08), and several sites in Deylamān (Egami et al.; Sono and Fukai; Fukai and Ikeda). As a result it is assumed that most Iron Age copper-base artifacts were of bronze and that the use of arsenical copper had waned significantly.

Bronze is not necessarily functionally superior to arsenical copper, and it has



the disadvantage of requiring imported tin. On the other hand, whereas the amount of arsenic in a copper alloy is determined by the amount present in the copper ore and on smelting conditions, in bronze the proportions of copper and tin can be controlled to a useful degree by the metalworker. Products of predictable color and mechanical properties became possible after the innovation of bronze metallurgy. There are indications that in the Iron Age alloying techniques produced bronzes of controlled composition, close to the optimum 10 percent tin and 90 percent copper, which were then hardened by working. Mesopotamian texts of the 2nd millennium record alloying proportions for bronze (see Muhly, 1973, pp. 243-44, and 1983, p. 350). Mesopotamia, particularly Assyria, strongly influenced western Iranian craft traditions, including metalworking. A desire to emulate attractive items from neighboring lands in “local styles” (Winter, 1977) has been argued from stylistic similarities and must also have influenced the techniques of working materials such as copper and bronze.

Whereas in earlier periods settlements had been spread across the Iranian plateau, by the Iron Age evidence of settled occupation is limited primarily to western Iran, in and along the Zagros mountains and in Kūzestān (see Hole, 1987). Most Iron Age sites in these areas have yielded copper or bronze artifacts and from the 10th-9th centuries onward both bronze and iron (for discussions of iron on the Iranian plateau see Pigott, 1980, 1981 [see bibliog., p. 41], 1984; Moorey, 1982, pp. 92-93). A primary indicator of the transition from bronze to iron in the region is the occurrence of bimetallic artifacts, for example, iron objects with cast-bronze decoration or bronze rivets (Moorey, 1971, p. 315; Pigott, 1981, p. 181).

Among the large number of excavated Iron-Age sites several are of particular archeometallurgical interest. From Haft Tepe (Middle Elamite period, ca. 13th century) in Kūzestān an unusual pyrotechnological installation was associated with a craft workroom containing such materials as mosaics of colored stones framed in bronze, a dismembered elephant skeleton used in manufacture of bone tools, and several hundred bronze arrowpoints and small tools. “Situated in a courtyard directly in front of this workroom is a most unusual kiln. This kiln is very large, about 8 m long and 2 and one half m wide, and contains two long compartments with chimneys at each end, separated by a fuel chamber in the middle. Although the roof of the kiln had collapsed, it is evident from the slight inturning of the walls which remain in situ that it was barrel vaulted like the roofs of the tombs. Each of the two long heating chambers is divided



into eight sections by partition walls. The southern heating chamber contained metallic slag, and was apparently used for making bronze objects. The northern heating chamber contained pieces of broken pottery and other material, and thus was apparently used for baking clay objects including tablets . . .” (Negahban, 1977; and forthcoming).

Recent examination of the archeological evidence for bronze suggests that the district of Gīlān on the Caspian littoral was a production center (Haerinck). A number of graves excavated in the necropolis at Marlik (Mārlik; very late 2nd-early 1st millennium; Negahban, 1964) produced abundant evidence of metalworking: a diverse array of bronze artifacts, including human figurines (1979a), vessels (1983), stamp seals (1977; 1979b-c), and weapons (e.g., maceheads, Negahban, 1981; see also Muscarella, 1984, for a discussion relating to fibulae and chronology). Iron was not common at Marlik. Analyses of finds from Deylamān (Egami, et al.; Sono and Fukai; Fukai and Ikeda), as well as analyses of Marlik metal by Vatandoost-Haghighi (1978), contributed to the following assessment of the metalwork industry in Gīlān: “Arsenical copper and relatively pure coppers were still used, but a fully fledged tin-bronze production is evident. Even with the small existing group of analyses, a pattern has begun to emerge that correlates with comparable results from other parts of the Near East at the end of the second millennium B.C. The average Iranian tin-bronzes of the period have 5%-7% tin. Arrowheads fall generally below this range, spearheads and simpler dagger blades into it, or just above, whilst some of the fine swords of Iron I in northwest Iran may have tin percentages up to and above 12%. A double-headed hammer from Marlik weighing 1080 grammes, was at the top of the scale (13.5% Sn), suggesting that the smith knew the effective limits for an annealed and work-hardened alloy that would not be dangerously brittle With wax rather than clay as their medium . . . modelers easily found a cast metal counterpart for . . . vessels and figures. Their lost-wax castings are not as accomplished as those of Luristan at this time. In Gilan, the wax parts of which the figure was built up are much more evident. But, as in Luristan, there seems to have been no appreciation that the controlled use of lead would have facilitated casting; only the tin content seems to have been controlled, usually below the average for tools and weapons” (Moorey, 1982, pp. 94-95; see also Tylecote, 1972).

The adjacent region of Azarbaijan also produced distinctive bronzes in the Iron Age (de Schauensee, 1988). The Hasanlu (Ḥasanlū) project (see bibliography in Levine and Young) has provided the major portion of



excavated bronze artifacts from the region. Aside from Hasanlu itself, the type site, Iron Age graves at Dinkha (Denkā) Tepe to the southwest (Muscarella, 1974) yielded a number of bronzes, as did the Urartian occupation level at Agrab ('Agrab) Tepe (Muscarella, 1973).

The best indications of Iron Age bronze working come from the 9th-century levels at Hasanlu, where at least three distinct metalworking areas were found (Muscarella, 1973, pp. 46, 55-56). Sir Aurel Stein's 1936 sounding on the north side of the citadel mound produced a cache of artifacts, including some possible bronze bar ingots, strips, and at least three stone molds for small artifacts (1940, pp. 390-404, pl. 26). More recently excavations at the Artisan's House in the outer town have yielded remains of intense burning, crucible fragments, a possible ingot, a shaft-hole axe mold, and an open flat-axe mold, as well as other mold fragments, clearly suggesting a workshop. Heavy modules of hematite or magnetite also found there were probably used for working and planishing sheet bronze (Pigott, 1981, p. 48). In Burned Building III on the citadel mound crucible fragments, a pair of bivalve sandstone molds for a ribbed-bladed shaft-hole axe, and fragments of a similar mold in clay were excavated (Pigott, 1981, pp. 138-39).

Altogether Hasanlu produced more than 2,000 copper and bronze artifacts in the following major categories: equestrian gear, architectural and domestic decoration, vessels and handles, personal ornaments, tools, weapons and armor (de Schauensee, 1988, pp. 47-55; see also Lamberg-Karlovsky, 1965). Many were ornamental and were themselves decorated. Very frequently artifacts in bronze had counterparts in iron. Only hoes, sickles, knives, and saws were exclusively made of iron (de Schauensee, p. 47). In fact, at Hasanlu the number of iron artifacts was approximately equal to that of copper and bronze.

Emission-spectrographic analyses of twenty Hasanlu artifacts indicates that they are of bronze with a tin content ranging from 2 to 9 percent (Hasanlu project archives). Proton-induced x-ray emission spectroscopy of a lion-shaped pin (12.7 Percent tin) and a snaffle bit (4.7 percent tin) further corroborates the existence of bronze at the site (de Schauensee, p. 58 no. 9). Stylistic analyses of bronze artifacts from Hasanlu have been undertaken by Irene Winter (a decorated bronze horse breastplate, 1980), Oscar White Muscarella (a fibula, 1965), and Maude de Schauensee and Robert H. Dyson, Jr. (horse trappings). The type of pointed bronze helmet found at Hasanlu and also worn by Assyrian and Urartian soldiers has been discussed by B. J. Overlaet (1979).



Such studies have helped to define a “local style” of artistic bronze production at Hasanlu, as well as influences from the north and west. The elaborate decoration suggests a sophisticated understanding of the properties of bronze and the technology of its production.

According to current opinion, Hasanlu was destroyed in about 800 B.C. by Urartian invaders from strongholds in northwestern Iran. The 7th-century fortress at [Beštām](#) (Elamite Rusa-i URU.TUR) is the largest Urartian site in Iran to have undergone major excavation (Kleiss). The use of bronze there parallels that at sites elsewhere in western Iran, including both personal ornaments like rings, beads, bracelets, and fibulae, domestic decorations like bronze furniture fittings, bosses, and vessels, and bronze weaponry including trefoil and two-bladed arrowpoints. Unfortunately, none of the Beštām finds has been analyzed (for discussion of bronzeworking in Urartu, see Seidl).

Perhaps the region that has received the most attention in the study of Iron Age bronze artifacts is Luristan (see [bronzes of luristan](#); Muscarella, 1988), particularly ornate bronze lost-wax castings. Although most of these have no provenience, some have been found at Surkh Dum (Sorkdom; Schmidt, 1938; Muscarella, 1981; Van Loon et al.), Baba Jan ([Bābā Jān](#); Goff, pp. 38-39, 56, 63-65), and the cemeteries excavated by Louis Vanden Berghe (see references in Vanden Berghe, 1979; Vanden Berghe and Haerinck). The bronzes of Luristan apparently represent the culmination of a long tradition of bronze casting and sheet-metal working lasting from the 3rd millennium to the 7th century B.C.

Datable to the 7th-6th century B.C., are the finds from a neo-Elamite tomb at Arrajān in Kūzestān (Tawḥīdī and Kālīlān). A lidded bronze coffin was found together with a stand, a lamp, a jar, a cup, and ten cylindrical vases, all in bronze, and artifacts in gold and silver (Alizadeh; see Curtis, 1983). Another bronze coffin, possibly from Ziwiye (Zīwīya), may also belong to this period, though its context is still in dispute (Wilkinson; Dyson, 1963; Muscarella, 1977b). Finally, evidence from the ca. 6th-century B.C. Median fortress at Nush-i Jan (Nūš-e Jān) near Malāyer includes a small corpus of bronze fibulae (one of them bimetallic), pins, earrings, beads, “buttons,” bosses, a Pazuzu (apotropaic demon) head, a spatula, a kohl stick, and nine arrowpoints. Iron is not common at the site, and no analyses of the bronze artifacts have yet been undertaken. A discussion of the bronze arrowpoints served as the basis for a thorough review of the origin and occurrence of this type of artifact throughout western Iran (Curtis, 1984, pp. 26-35). Important related studies of



Iranian copper and bronze arrowpoints include those by S. Cleuziou and I. N. Medvedskaya (1980). The recent collection of papers edited by J. Curtis (1988) has opened the way for more detailed assessment than has previously been possible of bronze in the Iron Age, not only in western Iran but also in Assyria, Urartu, and beyond.

The Achaemenid period (ca. 6th-3rd centuries B.C.). With the rise of the Achaemenid dynasty in Fārs in the 6th century B.C. and the expansion of its empire to the east and west of the Iranian plateau, ancient metalworking traditions continued, with considerable stylistic elaboration. The inventory of copper and bronze artifacts from the period is considerable, though published accounts have tended to focus only on the most elaborate examples of the metalworker's craft. As the materials are from all over the far-flung empire and often without provenience, it is difficult to characterize the industry (Moorey, 1982, pp. 856-57). These problems are compounded by the proliferation of forgeries of Achaemenid objects (Muscarella, 1977; 1978; 1980).

The largest Achaemenid sample from the Iranian plateau comes from the treasury at Persepolis, clearly a very particular assemblage (Schmidt, 1957; see also Muscarella, 1977a, pp. 193-96). Not only highly decorated functional artifacts are included; there are also many that are purely decorative. The inventory includes a bronze plaque, a bimetallic tripod with three lions in the round, the cast leg of a quadruped, a pair of felines, a pair of horses cast in one piece, and fragments of wings, bands, rosettes, disks, moldings, and sheet metal. Personal ornaments in bronze were also found, including earrings, finger rings, pins, and gilded buttons. Functional categories include pulley wheels(?), a mortar and pestle, a mirror, and a duck weight. Military equipment is not well represented; though almost 4,000 bronze arrowpoints were excavated, the only other distinctly military artifacts were a battle axe, several sword hilts, and bowstrap guards (Schmidt, 1957, p. 9).

The most comprehensive assemblage of Iranian military equipment from the period was excavated in the cemeteries at Deve Hüyük in Syria (Moorey, 1980). Copper and bronze vessels, lamps, ladles, equestrian gear, domestic and personal ornaments, and weapons were found. Most of the weapons were of iron, but certain categories of distinctively Achaemenid military equipment, such as trilobate arrowpoints and battle axes, were of bronze. It is believed that certain categories, for example, the trilobate arrowpoints, battle axes, and iron *akinaki* (daggers), actually originated in Transcaucasia (Sulimirski, pp.



10-11). The trilobate points are thought to have originated with the Scythians and to have been adopted later by the Medes. They are usually interpreted as a hallmark of Median troops in the Achaemenid army (Curtis, 1984, p. 28; see also Gorelick on Median and Persian defensive armor).

Other major Achaemenid sites in Iran are Pasargadae and what Ghirshman called the “Persian Achaemenid village” at Susa. The assemblages from these sites include much the same basic categories of bronze for military and decorative purposes, as well as a few other implements. From Pasargadae there are a model of a ram, buckles, signet rings, fibulae, trilobate arrow-points, and scale armor (Stronach). At Susa (Ghirshman, 1954) a small group of bronze artifacts from a context not connected with a court (Moorey, 1980, p. 130) included trilobate arrowpoints, javelin points, pins, needles, and items of personal ornament (Moorey, pp. 31-34; see Muscarella, 1977; 1979; 1980, for the few remaining classes of Achaemenid bronze artifacts from controlled contexts in the empire; Besenval).

Few bronze artifacts from the Achaemenid period have been analyzed: Some of the more elaborate pieces, for example, a bimetallic tripod and complex forms like the trilobate arrowpoints must have been cast. Four Persepolis artifacts have been analyzed: a bronze arrowpoint; a pin shaft of copper, silver, and iron; a fragment of copper or bronze slag; and an iron arrowpoint (Howell, apud Schmidt, 1957, p. 136). A thorough study of a possibly Achaemenid bimetallic mirror (bronze with iron rivets) has also been conducted; x-ray fluorescence indicated a tin content of 10.3 percent. It is assumed that the mirror was cast; metallography revealed a cold-worked and annealed structure in the vicinity of the rivet holes, which may have been made in the final stages of shaping. Tool marks suggest that the mirror was decorated long after it had been manufactured (Meyers apud Muscarella, 1977a, pp. 196-98; cf. p. 183 n. 84).

One important clue to the technology of Achaemenid metalwork actually comes from a post-Achaemenid Egyptian tomb. In the late 4th-century tomb of Pedusiri (Petosiris), an official buried in the necropolis of Hermopolis Magna, there are reliefs depicting a metal workshop in which Achaemenid-style vessels are being shaped (cf. Wulff, pp. 24-28): hammering of sheet metal, hammering to shape a bowl over a stake (cf. Wulff, figs. 23-24), chasing of details on vessels (including rhyte, probably in gold and silver), and working of other objects in metal are shown (Moorey, 1980, p. 127; Muscarella, 1977, p. 194 n. 100; 1980, pp. 28-29).



Because the sample is skewed, it is difficult to draw conclusions about the impetus behind Achaemenid metalworking technology. The evidence suggests production for a luxury market and military needs. Although unique and elaborate artifacts are characteristic, bronze military equipment tended to be standardized. Given the geographic scope of the empire, organizational control of metallurgical production must have been centralized, as was control over the army itself. In this period, too, innovations in metalworking are in the realm of decorative techniques rather than in obvious technological changes.

The Parthian and Sasanian periods (ca. 250 B.C.-A.D. 642). During this period bronze was used primarily for ornament and for projectile points and other military hardware. As in the Achaemenid period, little is known about the sources of ore and the composition of copper-base artifacts. Stylistic analyses dominate the literature, and they are often focused on metal artifacts from various Asian sites, rather than from the Iranian plateau itself. One of the most useful studies of bronze in this period is *Parthian Art* by M. A. Colledge, whose classifications are followed here. The art of this period is characterized by diversity of style and influences: “Although the Parthians were the politically dominant ethnic group in the Near East, their ruling dynasty, the feudal Arsacids, did not maintain uniform control over their vassals. Parthian art echoes this diversity In contrast to Sasanian art, Parthian art was not the product of a strongly centralized monarchy. Rather, it reflects the social and political complexity of the time” (Kawami, 1979, p. 473).

For decoration bronze was used in a number of ways. Personal ornaments were the most frequent, but there were also statues, often used as architectural adornment, and figurines, utensils, vessels, and even some coins of low denomination (Colledge, pp. 80, 103-09). An important characteristic of the period is the prevalence of Hellenistic and Roman imports and influences. It is clear that a great deal of traffic crossed the empire. For example, Roman goods have been excavated as far east as Kāpīśī, the capital of the Kushan dynasty (250-50 B.C.) in Afghanistan (Colledge, p. 83). Indigenous bronze craftsmanship must have been influenced by Hellenistic and Roman traditions, and it is likely that the practice of casting large statues by the lost-wax method spread from the west, though the technique itself was already well known in the Near East in earlier millennia (for description of lost-wax casting, see Untracht, pp. 338-77). Shrines at Seleucia on the Tigris are known to have contained statues in clay with imported bronze extremities (Colledge, p. 82).



Western influence is most visible in a large number of figurines found throughout the Parthian empire. At Nehāvand in western Iran bronze figurines of deities, including Zeus, Apollo, Minerva, and Isis Fortuna have been found (Colledge, p. 82, pl. 3a); they are presumed to be imports, arguably of late Parthian date (Kawami,

1979, p. 472). Other figurines, probably cast within the empire, are listed by Colledge (p. 88), including an image of Hercules from Ai Khanum ([Āy Kānom](#)) in Afghanistan; an Eros and a statue of a kneeling youth from Babylonia; a griffin from Nisa (Nesā) in Turkmenistan; images of Hercules, Hermes, Eros, Nike, and an eagle from Hatra in northern Iraq; the bust of a ruler from Kurdistan; a warrior and a god with cornucopia from Bard-i Nishandeh ([Bard-e Nešānda](#)) and a piper, a dancer, and comic animals from Masjid-i Suleiman (Masjed-e Solaymān), both in Kūzestān; a nude goddess from Iran; and images in local costume from the Gandhara region. Large figural sculpture was also produced in bronze. At Hatra a bronze acroterion representing Victory (Nike) on a globe (A.D. early 3rd century) adorned the “Hellenistic” Temple E (Colledge, p. 70, pl. 10b). In the Baḳtīārī (Bakhtiari) mountains of northeastern Kūzestān at the dynastic shrine of Shami (destroyed ca. A.D. 50), a life-size standing male statue, possibly of a Parthian prince or vassal was found, as well as a headless bronze statuette of a standing male and two bronze arms (Kawami, 1987, pp. 64-65, 169-74; see also Stein, 1940, pp. 141-59, fig. 11).

Bronze plaques with figural representations in repoussé were another medium of decoration. At Masjid-i Suleiman two such plaques were found in the Parthian temple (ca. A.D. 200), and another is known from Hatra (Colledge, p. 101). Bronze also had functional uses in architecture, as in the bronze clamps that held blocks of stone together. Early Hellenistic column bases at Ai Khanum were held by such clamps, and in the colonnade of the temple of Bel at Palmyra, there was a bronze capital ornament (Colledge, p. 29).

Smaller bronze objects of the Parthian period also tended to be elaborate. From Parthian Nisa there are bronze platters decorated in relief, from Taxila and sites in Iran and Mesopotamia trays from perfume burners, from Masjid-i Suleiman lamps, ladles, and bowls (Colledge, p. 114). Unique small bronze finds include a lion-headed door knocker and a belt plaque (see [belts ii](#)). Such plaques are depicted on the sculptures from Hatra and Shami, and at Masjid-i Suleiman an actual example was recorded (Colledge, p. 112). This site also produced what may be a musical instrument, a bronze triangle (Colledge, p. 135). Bronze bells from the period have been studied (Keiko).



Bronze mirrors, though found across central Asia (Frumkin, pp. 41, 69) and in Iran (Egami et al., II, p. 10, pl. XLIX no. 29), may be linked technologically to China. Of particular interest are mirrors from Susa and Masjid-i Suleiman with handles in the form of nude female figures (Colledge, p. 111).

During the Parthian period traditional methods of casting, turning, chasing, and hammering (over molds) were applied in the production of jewelry and table wares of bronze and precious metals (Colledge, p. 124). The use of raised metal flanges to hold cloisons was common on table wares and other items, and on fine pieces figures were represented in repoussé. Among so-called “Bactrian bowls” such figures were formed separately and attached by means of hammered metal flanges. This technique was to become characteristic of Sasanian metalwork. Small metal figurines were cast in both solid and hollow examples. The lost-wax method was used for larger bronze statues.

Because few Sasanian sites have been excavated, none comprehensively (Harper, 1986), Sasanian bronzes from the Iranian plateau are quite rare. The principal evidence comes from Ctesiphon and Kish in Iraq and from Tepe Hissar in northeastern Iran, Takht-i Suleiman (Takht-e Solaymān) in Azarbaijan, and a number of sites in Fārs: Bīšāpūr, Fīrūzābād, and Qasr-i Abu Nasr (Qasr-e Abū Naṣr; possibly old Shiraz) in Fārs. Some of the best evidence for the use of bronze in the Sasanian period comes from the fortress at Qasr-i Abu Nasr, where a relatively large, well-dated assemblage was excavated (Whitcomb, pp. 16-19, 160-76). These objects are assumed to be of bronze, though no analyses have been conducted. They contrast sharply with those of the Parthian period in that most are items of daily use, but this contrast probably reflects a biased sample, rather than specific sociocultural differences, for studies of artifacts other than bronzes indicate that Sasanian material culture was as elaborate and as luxurious as that of the Parthians.

The artifacts from the fortress area at Qasr-i Abu Nasr include a more diverse array of tools and utensils than in earlier periods, among them a dipper, a ladle, bowls, plates or lids, closed vessels, handles, ringstands, forks, spoons, tongs, needles, awls, a fish hook, crucibles, and a mirror. Decorative artifacts cast in bronze are well represented: buckles, attachments, hooks, pendants in the shapes of animals, a seal, fibulae, bells, and pins. Bronze jewelry includes earrings, pendants, an amulet case, fragments of chain, finger rings, bracelets, buttons, bosses, and guards (Whitcomb, p. 176). Individual parallels for some of these objects have been identified at such sites as Pyandzhikent in Sogdia and Istakhr (Eṣṭakr), Nīšāpūr, Susa, Tal-i Malyan, Qaleh Yazdigerd (Qal'a-ye



Yazdegerd), and Mālamīr (Malāmīr) in Iran (Whitcomb).

Such military hardware as spear points, lance points, and arrowpoints, most often tanged, were also found at the fortress; they are “indicative of diverse chronological, and perhaps cultural associations . . .” (Whitcomb, p. 168). Of eight types one is exclusively made of iron and seven usually of bronze. Large points are rare. Parallels for many weapon types are recorded at such sites as Tureng (Tūrang) Tepe, Beštām, Persepolis, Pasargadae, Istakhr, Susa, and Tepe Yahya (Whitcomb, p. 168). A piece of armor is composed of thirteen iron scales and a single bronze spacer scale. Scale armor is also known from Pasargadae and Pyandzhikent (Whitcomb, p. 169).

From this assemblage it is clear that copper and bronze occurred in a variety of forms, many of them decorative, at Qasr-i Abu Nasr. The finest specimens are cast. A rare group of stucco molds excavated at Khokhe in southern Mesopotamia (Negro Ponzi) is evidence of the casting methods used in the Sasanian period. It has been suggested that terracotta models could have been produced from such stucco molds and distributed to workshops all over the empire, which would permit standardization in decorative bronze work (Harper, 1978, p. 87). Several detailed studies confirm increasing elaboration of bronze artifacts in the Sasanian period: a trimetallic helmet (bronze, iron, and gold; Granscay; Overlaet, 1982), ox-headed maces (Harper, 1985), a bronze plate (Eghbal), belts (Ghirshman, 1979), and horse trappings (Ghirshman, 1977).

The introduction of high-tin bronze. Toward the end of the Sasanian period high-tin bronze artifacts began to appear; they became common in early Islamic Iran (see ii below). These objects represent a technical apogee in the alloying of copper with tin. Only the earliest documented appearance of this particular kind of bronze and the possible sources of the technology are addressed here.

A bronze with a tin content of 20 percent or higher can easily be produced by means of smelting together cassiterite (the common tin ore, SnO_2) with copper ore in proper proportions. Early in this century W. Gowland demonstrated this point by smelting 15 pounds of malachite with 10 pounds of cassiterite, 7.5 pounds of limestone (flux), and 10 pounds of charcoal (Gowland, 1912). The resulting bronze had a tin content of 22 percent. Though such an alloy can easily be produced by smelting, proper working of the metal requires a sophisticated understanding of its properties (Goodway and Conklin). The



technology required has been described by Cyril Stanley Smith: “A copper-tin alloy with a content of c. 22% tin becomes plastic at c. 550 C, melts at 725 C, and is very plastic between those two temperatures. Fully molten at 800 C, it is easy to cast. It can be red-hot forged; if cooled slowly it will shatter if hammered; if quenched it becomes moderately hard and reasonably malleable, though not as malleable as ordinary bronze. With time it acquires a black patina” (apud Allan, p. 46; see also Melikian-Chirvani, p. 124). The most significant aspect of this process is the danger that the alloy will become brittle. Castings break easily, with sharply defined, rectilinear edges not unlike those of shattered pottery, unless quenched. Artifacts made from this alloy usually have simple forms, for example, hemispherical and stem bowls, which can be hammered to shape. More complex contours would be difficult to produce, because the metal must be forged at red heat (Allan, p. 47). Whether forging and quenching have in fact occurred can be ascertained only by metallography, the study of the microstructure of polished and etched samples of metal (e.g., Goodway and Conklin, 1987, figs. 4-7).

Perhaps the earliest example of a high-tin bronze artifact of possibly Iranian origin is a “Luristan bronze” of unknown provenience in the Ashmolean Museum, Oxford (Moorey, 1976, p. 359; 1971, no. 205). Three artifacts from Ghar-i Mar in Afghanistan have been dated to ca. A.D. 300 and another to ca. A.D. 500 (Dupree; Caley, 1971, pp. 108-09). The earliest artifacts of high-tin bronze actually excavated in Iran are a bowl and a mirror from a tomb in Deylamān dated by the excavator to the latter half of the Parthian period (Egami et al., II, pp. 9-10, 18, pls. 43, 49; Allan, p. 47, has suggested A.D. the 4th century). The composition of the bowl is recorded as including 21.4 percent tin, 1.2 percent lead, and 0.7 percent iron (Dōno, pp. 112, 217, fig. 66; Melikian-Chirvani, p. 135 n. 40). However, it is not until the late Sasanian period that artifacts of high-tin bronze, primarily bowls and vessels, begin to appear with any frequency (Harper, 1978, p. 86).

By the early Islamic period the technology was sufficiently evolved to permit manufacture of standardized hemispherical and stem bowls in high-tin bronze. Unfortunately, no metallographic studies of well-dated pieces have been undertaken, but radiography of seven early Islamic bronzes revealed changes in wall thickness consistent with the conclusion that these artifacts had been forged, rather than simply cast (Van Zelst and Meyers apud Melikian-Chirvani, pp. 149-50).

It is clear that high-tin bronze artifacts were difficult to make and were



relatively rare until the later Sasanian and early Islamic periods. It has been argued that in the Sasanian period, when silver was the preferred metal for luxurious display, high-tin bronze, with its characteristic silvery hue, may have provided a cheaper alternative for lower social strata (Harper, 1978, pp. 86-87, 95). Its color is also close to that of unoxidized iron or steel, however; furthermore, both high-tin bronze and iron or steel develop a black surface coating when oxidized. Perhaps most significant is that both steel and high-tin bronze can be quenched and that quenching produces marked transformations in the physical and mechanical properties of both: Steel becomes markedly harder, whereas high-tin bronze becomes more malleable and gives a ringing sound when struck (Goodway and Conklin). Craddock (1979) has noted that the 4th/10th-century Islamic alchemist Jāber b. Ḥayyān included *kāršīnī* “chinese iron” among the seven metals, the others being gold, silver, lead, tin, copper, and iron (see *El*², s.vv. *Djābir b. Ḥayyān*, *Khāršīnī*). Other sources reported that *kāršīnī* was used for mirrors in China, and analyses of early Chinese mirrors have shown that they are indeed made of high-tin bronze (Allan, 1979, pp. 49-51). Craddock has equated *kāršīnī* in turn with *haftjūš* (lit. “boiled seven times”), which he interprets as referring to the necessity of reheating the alloy repeatedly during manufacturing (p. 74). Modern artifacts from Kermān identified by their craftsmen as of *haftjūš* have been shown by analysis to be high-tin bronzes (Allan, p. 51; Craddock, pp. 74, 77; Wulff, p. 18).

It is thus possible that high-tin bronze was being imported from China in the Parthian period and later and that this alloy was perceived in the West as a form of iron. During the Sasanian period, with the desire to emulate silver and perhaps to imitate imported wares, standardized production of cheaper high-tin bronze may have begun, reaching its full development in Iran in the early Islamic period (see ii below).

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