CHAPTER SEVEN

METALS AND MINING

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INTRODUCTION

The Iranian highlands are known for their rich metal resources which have supplied crucial raw materials to emerging states in Western Asia since ancient times (Figure 7.1). In the organisation of this supply system, the dichotomy between highlands and lowlands that is so significant in Elamite history (Amiet 1986) plays out: for a long time, lowland communities relied on materials travelling to them from the highland sources. A second potential supplier would have been the distant coasts of Oman, where copper was mined and shipped via the Persian Gulf to Mesopotamia and also to the coastal harbours of Khuzestan (Hauptmann et al. 1988; Prange et al. 1999). To reconstruct a metal supply system for Elam over time, we must combine evidence for the various steps of the metallurgical cycle from the mining of ores to the final product and its distribution. We must keep in mind that this evidence and its study are heterogeneous and patchy. On the supply side, some detailed research into specific source areas exists, but the coverage is uneven. A similar imbalance applies to the consumer side: a systematic archaeological and metallurgical analysis of thousands of objects from the Louvre partition of the Susa assemblage provides a fundamental overview for the older periods (Tallon 1987; Malfoy and Menu 1987), while assemblages from major highland sites remain little or understudied. With regard to workshops, direct observation is rarely possible and we rely on residue distribution and indirect data, including texts. A last note of caution is necessary with respect to the archaeological record in Elam, which is characterised by a series of well-documented periods alternating with centuries of limited documentation. These latter periods are largely products of the state of archaeological research and not real-life gaps. This introduction to metal production and use in the wider lands of Elam begins with a broad view over Iran as a supply country that was fully integrated into a long-distance contact network in the proto-Elamite period; subsequently, the perspective will narrow and focus more specifically on the regions that define the ancient entity of Elam, high and low.

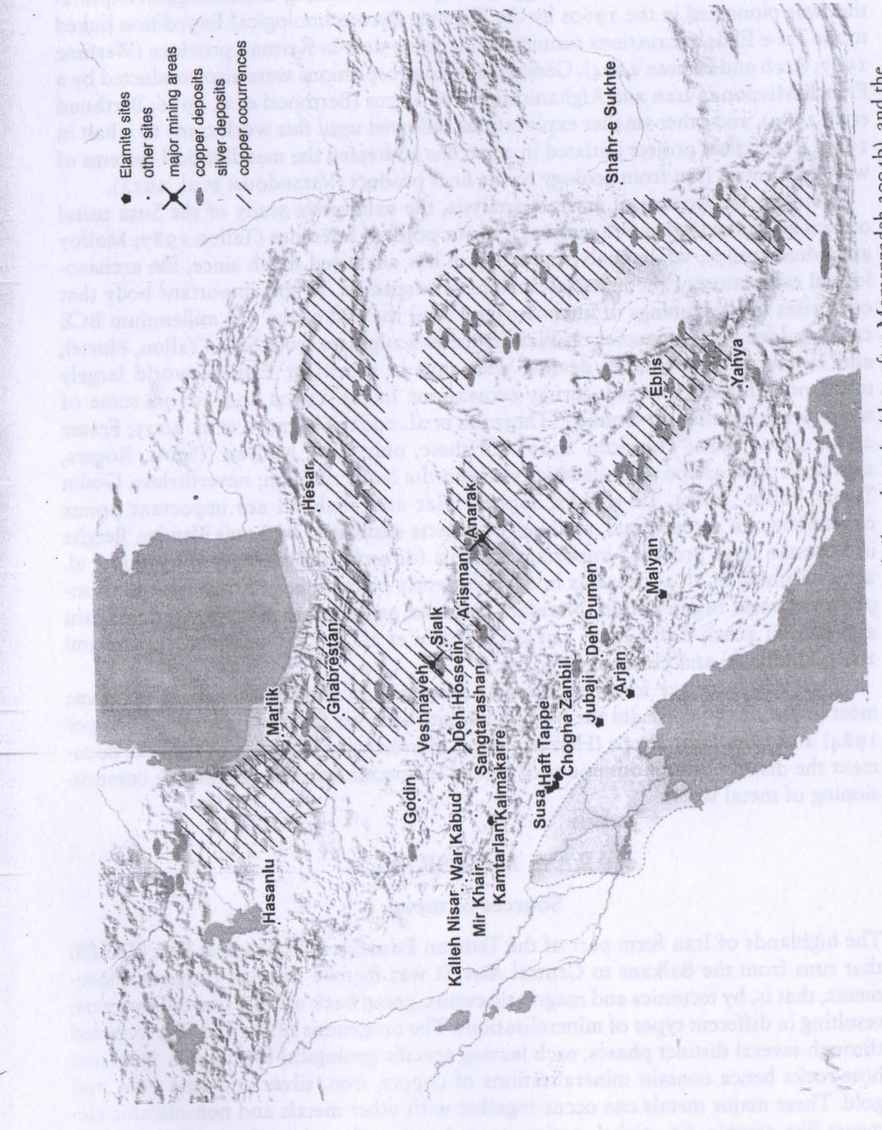

Figure 7.1 Map of Iran, showing known copper and silver deposits (data after Momenzadeh 2004b), and the archaeological sites discussed in the text.

RESEARCH AND RESOURCES

Iran as the now-proverbial "heartland of metallurgy" (Pigott 1999) has seen some targeted research on early metallurgy. Geological and mining archaeological exploration was pioneered in the 1960s by the Wertime Pyrotechnological Expedition linked to the Tal-e Eblis excavations running at the same time in Kerman province (Wertime 1967; Arab and Rehren 2004). Geological field prospections were also conducted by a French Mission in Iran and Afghanistan in the 1970s (Berthoud et al. 1976; Berthoud et al. 1982), and other smaller explorations followed until this work came to a halt in 1979. A new field project initiated in 2000 has addressed the metallurgical systems of western Central Iran from geology to the final product (Vatandoust et al. 2011).

From the perspective of artefact analysis, the exhaustive study of the Susa metal objects hosted in the Louvre remains a major point of reference (Tallon 1987; Malfoy and Menu 1987); while analytical protocol has advanced much since, the archaeological evaluation of the material remains unsurpassed. To this important body that comprises the beginnings of metalworking until the end of the 3rd millennium BCE can be added smaller studies on Elamite metal sculptures from Susa (Tallon, Hurtel, and Drilhon 1989). Studies dealing with sites in the wider Elamite world largely relied on samples collected during excavations in the 1960s and 1970s, some of which were recently (re-)studied (Thornton et al. 2002; Thornton et al. 2005; Frame 2004; 2009; 2010; Thornton 2009). Of these, only Tal-e Malyan (Pigott, Rogers, and Nash 2003a; 2003b) falls strictly within the lands of Elam; nevertheless, Godin Tappe, Tappe Yahya, Tal-e Eblis, Tappe Hesar and Shahdad are important points of reference. In recent years, analyses of objects excavated by Louis Vanden Berghe in Lorestan have provided important insights for archaeometallurgy (Fleming et al. 2005; Fleming et al. 2006); this body is currently being enlarged through new sampling programs begun in Iran (Nezafati, Pernicka, and Momenzadeh 2009; Oudbashi and Emami 2010; Rafiei Alavi 2012; Oudbashi et al. 2013; Oudbashi and Davami 2014; Oudbashi and Hasanpour 2016).

A last major source for understanding metal use in the Elamite world are texts; most important of these are the Middle Elamite archives from Tal-e Malyan (Stolper 1984) and from Haft Tappe (Herrero 1991; Herrero and Glassner 1990) that document the distribution of quantities of metals to specific workshops and the commissioning of metal works.

RAW MATERIALS

Sources of metal

The highlands of Iran form part of the Tethyan Eurasian Metallogenic Belt (TEMB) that runs from the Balkans to Central Asia. It was formed through orogenic movements, that is, by tectonics and magmatic events, going back at least one billion years, resulting in different types of mineralisations. The orogenesis of the TEMB proceeded through several distinct phases, each leaving specific geological formations. Different host-rocks hence contain mineralisations of copper, iron, silver and lead ores, and gold. These major metals can occur together with other metals and non-metallic elements like arsenic, tin, nickel, antimony and some others in polymetallic deposits. These associations may have led to the unintentional production of natural alloys

in the beginning, but systematic alloying practice is also attested since the 4th millennium BCE. From the point of view of pre-industrial metal exploitation (Momenzadeh 2004a), only some ore mineralisations were attractive, while others were not exploited when metal concentrations per ton of ore would have been too low or the depth of the deposit too deep to be accessed in antiquity.

While highland Iran is rich in metal deposits, this is not true for the lands of Elam: the coastal plain of Khuzestan naturally lacks metal, and the Alpidic formation of the Zagros Mountains does not host copper or other metal ore deposits. Elam would thus have relied on supplies from the neighbouring highland zones or from overseas. There were copper deposits in the Sanandaj-Sirjan area and close to the town of Arak that seem to have provided copper to Lorestan, if not beyond.

Copper

Copper is the earliest used major base metal, and it remains dominant until the 8th century BCE when it became successively replaced by iron. Sources for copper are concentrated in the tertiary porphyry zones of highland Iran (following Momenzadeh 2004a): the Orumiyeh-Dokhtar volcanic belt in south-central and north-central Iran, along the southern foothills of the Alborz and in eastern Iran, is the most important of these deposits, and early exploitation is attested in numerous zones. Ores occur in two major forms: (1) in host-rocks of andesite and basalt formed during eocene submarine volcanism, occur mineralisations of chalcosite, copper oxides and some metallic copper, mainly in the form of veins. The metal content in these veins is high, but the size of the deposits is limited; such deposits would have been attractive in ancient times but are not suitable for modern economic exploitation. (2) porphyry and skarn deposits formed during late tertiary hydrothermal events host mineralisations and vein deposits of copper, gold and silver.

Of importance are also polymetallic mineralisations of copper, tin, tungsten and gold, as they have been discovered in Deh Hossein in the Sanandaj-Sirjan belt in the Arak area. This deposit formed by cretaceous plutono-metamorphic events, and similar mineralisations exist also in central Iran, near Birjand and in northeastern Khorassan. However, these have not yet been investigated for traces of ancient mining.

Ancient copper mining

Traces of ancient copper mining often fall victim to modern mining activities, and modern prospectors rely often on traces of ancient mining in their field surveys. What is known today of ancient mining is thus certainly not representative for ancient mining activities but can nevertheless give us an indication of the technologies used. Two major factors determine these technologies: the type of deposit, and the technology known by the ancient miners.

Early mining (Stöllner 2014) first proceeded by open cast mining, that is, by digging up ores from the ground in open pits. Open cast mining would be efficient in deposits that are close to the surface; therefore the technology alone is not a chronological indicator. Open cast pits are in some places still visible in the landscape, for example, at the Deh Hossein polymetallic deposit in northern Lorestan (Nezafati, Pernicka, and Momenzadeh 2006).

The mining of vein deposits is mainly carried out by digging underground shafts and galleries that follow the veins. To break the rock, the miners used a technique called "fire setting": the rock is first heated through a fire lit underneath and then is rapidly cooled by pouring cold water over it (Weisgerber and Willies 2000). This procedure cracks the rock and leaves characteristic concave traces on the remaining rock. Fire setting was used from at least the 3rd millennium BCE to access underground veins.

Miners furthermore used an array of tools to crack the rock: hammers and mallets of hard stones like andesites or basalts were used in great quantities. Discarded mining tools in gravels descending from slopes are a good indicator of ancient mining. Stone tools like mortars or grinding stones are also used for the further beneficiation of the ores.

Further processing of the ores took place in workshops, which were often located at a distance from the mines and were probably chosen for a number of reasons, most importantly the availability of fuel. With the appearance of domesticated donkeys as pack animals in the 4th millennium BCE (Helwing 2011; Potts 2011), bulk transport over greater distances became possible. Together with other crucial innovations appearing in the proto-Elamite period, new transport technology may have contributed to the apparent boom in the early metal industry in the Iranian highlands.

The best-known copper and silver deposit in the Iranian highlands is the Anarak – Talmessi zone of central Iran (Berthoud et al. 1976; Pernicka et al. 2011). Attempts to link this deposit with textual references to the copper mountains of Kimash (Lafont 1996) mentioned by Gudea should, however, take into account that there are hundreds of copper deposits known to this day, and many have yielded traces of ancient workings. However, only few have been geochemically referenced, and even fewer were investigated by mining archaeologists. Hence, the documentation of the Central Iranian Veshnaveh mining district can be considered exemplary (Stöllner et al. 2011); it attests to the systematic mining of copper in shafts and galleries following the ore veins at least since the 2nd millennium BCE, if not earlier. A similar date applies to the Deh Hossein open cast mines as far as these have been surveyed and tested (Nezafati and Pernika 2011: 220).

Lead and silver

Silver occurs in association with lead and zinc in carbonate host rocks all over the Iranian highlands and in the Zagros in the form of galena (lead sulfide) or cerrrusite (lead carbonate). Iranian deposits are in modern times exploited for zinc but were probably silver mines in antiquity (Momenzadeh 2004a: 16–18 and Figure 5). Altogether, more than 35 sites with evidence for ancient exploitation are known today.

Extracting silver from argentiferous lead ores requires a refinement process to separate the silver from lead: the ore is smelted and heated to a temperature much above the melting point of silver; under oxidizing conditions, lead oxide (litharge) forms and metallic silver is separated. This complex so-called "cupellation" method is attested in Iran since the 4th millennium BCE in Arisman and Tappe Sialk (Nezafati and Pernicka 2006).

A by-product of silver mining may have been kohl (Persian: sormeh), a black eye cosmetic that could be produced from litharge (Momenzadeh 2004a). Lead was also

the basis of a white cosmetic paste recently discovered as the content of a cosmetic container in Shahdad (Vidale et al. 2012).

Gold

Gold occurs in Iran mainly in relation with porphyry copper deposits, and is mined together with copper (Momenzadeh 2004a: 18 and map Figure 7). More than 100 occurrences of copper with associated gold are known. These mountain-gold deposits require underground mining, and the retrieved ores had to be ground into a fine powder. This could then be washed to let light-weight elements be carried away and the heavy gold would remain. Today gold is mined in 13 locations in Iran that all also have documented traces of ancient exploitation.

Tin

Tin is also bound to the TEMB and occurs in considerable quantities east of Elam, in Afghanistan and Central Asia (for the most recent overview see Thomalsky et al. 2013). It has long been assumed that these were the sources that provided tin to the emerging states in western Asia from the later 3rd millennium BCE onwards. While this model by and large remains valid for the bulk tin supply that was necessary to sustain the Elamite bronze industry, the discovery of the polymetallic Deh Hossein ancient mining district in northern Lorestan has for the first time also provided potential evidence for exploitable tin resources in Iran. Radiocarbon dating indicates the use of the Deh Hossein mines in the 2nd millennium BCE. Whether Deh Hossein was indeed exploited for its tin, or rather its copper, remains to be tested. The recognition of tin in Iran opens a new avenue of research into early tin bronze use in Iran and Western Asia in general, as more such deposits can be expected in Central and eastern Iran. The Deh Hossein ores would have been suitable for the production of "natural" tin bronzes that would have stood out from normal copper by their silvery colour, or could have been targeted for their tin content. However, given the size of the deposit, the Deh Hossein mine could never have fully replaced imported tin that came from afar, probably from the East via the Persian Gulf.

Iron

Iron is the fourth most frequent metal present in the earth's crust and is found in the porphyric and metamorphic formations that frame the central highland of Iran (Momenzadeḥ 2004a: 18). The limiting factor in its exploitation was technological knowledge rather than its availability. Evidence for iron working is still extremely rare: E. Schmidt reported iron slag from Kamtarlan I, used as pavement material but possibly also residue of a smelter (van Loon 1989: 16 Plot M, area 3 and room 1). In NW-Iran, iron smelting slags were observed by G. Weisgerber in Andab Jadid, and a date in the Iron Age II/III is suggested by radiocarbon dates (Stöllner 2004: 56; only in the German version of text); however, neither Godin Tappe II nor Hasanlu IVB, both excavated on a large scale, yielded evidence for on-site production of iron. Since iron occurs in the same formations as silver ores, it has been suggested that recorded traces of iron mining may actually have targeted the silver (Momenzadeh 2004b: 18).

THE METAL INDUSTRY IN ELAM OVER TIME

Proto-Elamite metallurgy

Proto-Elamite metal production is currently best documented in Arisman in western central Iran (Vatandoust, Parzinger, and Helwing 2011), where the complete chaîne opératoire of metalworking is attested from primary smelting to the finished artefact. The technology had developed in this area along the desert fringe of the Dasht-e Kavir throughout the Chalcolithic period with workshop contexts and cottage industry attested, for example, in Ghabrestan, and evidence also from Tappe Sialk and Arisman (Helwing 2013; Thornton 2014). Without any visible interruption in the technology, metalworking then gained an unprecedented scale and momentum in the last centuries of the 4th millennium BCE. In Arisman, large-scale copper smelting took place in furnaces located at the outskirts of the settlement; these furnaces were built from mud-brick and clay plaster, and had to be partly destroyed to extract the metal. The smelting process was not yet very efficient and resulted in an enormous amount of slag that still contained a considerable percentage of copper, altogether amounting to 180 tons of slag (Steiniger 2011). Casting and finishing of copper objects took place in workshops set up inside abandoned houses. The use of open moulds or two-piece flat moulds is attested for flat axes, and mechanical hammering and annealing served to shape the final objects. Among the artefacts are mainly personal ornaments from proto-Elamite grave contexts but also some tools like chisels. From the casting moulds it is, however, evident that these sets are not representative and that flat axes and ingots were produced as well. These objects seem to have circulated in a wider exchange net, as evidenced by the occurrence of similar axes of a comparable elementary composition in the piedmont area of the Zagros, up to the Hamrin (Helwing 2013).

Analyses of the Arisman copper and copper slag indicates the systematic production of arsenical copper, from which all copper artefacts at the site are made. It has been proposed that this was a deliberate alloying process that involved in a first step the production of arsenic speiss, which was then in a second step added to the molten metal to prevent the arsenic from volatilisation (Rehren, Boscher, and Pernicka 2012). However, other scholars maintain that natural arsenical copper ores might have been used in a furnace that produced in the end a layered cake of metal of differing quality (Nezafati 2016).

Arisman is now also established as a major producer of silver by cupellation. Attested largely through litharge and one lump of metallic lead as production residues, Arisman silver was used for jewelry: one silver pendant was found in a deposit near the ground surface, probably a destroyed proto-Elamite grave; it belongs to a group of similar works distributed widely within the proto-Elamite exchange network (Helwing 2013).

The Arisman investigations considerably enrich our understanding of proto-Elamite copper working in other areas, as is also attested in Tal-e Malyan (Pigott, Rogers, and Nash 2003a; 2003b). Excavations at Malyan had not targeted specific workshop areas, and areas TUV and ABC rather randomly contained residues of metalworking, including copper prills from primary or secondary copper smelting. Malyan material contained small but consistent amounts of arsenic alongside nickel and antimony as trace elements, and it has been suggested that this arsenical copper might have been a natural alloy derived from ores of the Talmessi area. Working seems to have taken place inside the large house complexes uncovered in areas TUV and ABC, but these were not specialized workshop areas. Most artefacts are considered scrap metal for recycling, hence it remains to be determined whether a primary industry had existed in Malyan at all during the proto-Elamite/Banesh period.

In Susa IIIA, a large number of artefact analyses attests to the consistent use of arsenical copper and also of other copper alloys, including lead-copper with up to 15% lead used for cast objects (Tallon 1987: 316–320). Besides copper, lead, silver and gold or natural electrum are attested. With a large number of artefacts, the Susa record allows for a description of the techniques and typology used. Cold and hot hammering and annealing are attested, and the majority of artefacts were small tools and personal gadgets and ornaments. There are also a number of vessels that show the development of metal sheet and chasing techniques, as well as repoussé whereby the wall of the vessel is deformed from inside, which enabled the formation of three-dimensional figures. Complex objects were cast in the lost wax technique that had appeared in western Asia in the late 5th millennium BCE (Roux, Mille, and Pelegrin 2013). In Susa lost wax casting was used for pins with complex figurative heads and small sculptures cast in the round, like two anthropomorphic figurines found in the vicinity of the High Terrace on the acropolis that date from the Uruk period (Tallon 1987: 307–308 no. 1320; Kargar and Loyrette 2001: 51, Figure 7). The same technique was also used for noble metals; for example, it was used for two dog pendants, one in silver and one in gold (Tallon 1987: nos. 1161–1162).

Trace element analyses on the copper artefacts indicate a possible supply from the Iranian highlands, possibly the Kashan – Tappe Sialk and Arisman region; another possible source could once more be the Talmessi area. Silver was used in Susa for jewelry and artful vessels. Silver sheet pendants with soldered-on casings for inlays are found in original shapes (Tallon 1987: nos. 1159–1160); vessels made of silver replicate forms known in ceramics such as spouted jugs. Some vessels, in particular small conical beakers, were made from lead and seem to imitate silver vessels (Tallon 1987: nos. 800–805). The Susa silver vessels and jewelry, however, only allow a glimpse at an evolving industry, whereas the major production seems to be lost to science.

Lastly, use of metal is also attested from graves in Lorestan. Assemblages of metal objects, including jewelry and weapons, are known from the Early Bronze Age graveyards in the high valleys excavated by Louis Vanden Berghe, like Kalleh Nisar and Mir Khair (Haerinck and Overlaet 2005; 2008; 2010). Many of these graves were used and re-used over a long period of time, making any period-specific statement difficult. Early tin bronzes are known from these graveyards, but no distinction between early and late 3rd millennium BCE is possible (Fleming et al. 2005). However, it is probably no coincidence that some of the earliest tin bronzes on record for Mesopotamia occur in Kish (Helwing 2009) and hence not too distant from the polymetallic mining district of Deh Hossein, which may have been exploited during early experimentation with local ores.

THE 3RD MILLENNIUM BCE

After the collapse of the proto-Elamite centers in the highlands, settled occupation is maintained only in a few areas of highland Iran. The former metallurgical centers in the highlands like Arisman were fully abandoned around 2900 BCE, and no settled occupation is attested in that area before the mid-2nd millennium BCE. The same is true for Malyan and southern Iran, although some continuity may have existed there in less visible zones. Only in Susa can continuous settlement layers and a few related graves be observed in phase Susa IIIB. The metallurgical record seems impoverished in comparison with the preceding period: gold and lead are not attested, silver only occurs in small spirals and complex cast copper objects have disappeared. New shapes are daggers and spearheads as well as curved knives that find comparisons in the Hamrin ED I/II graveyards (Tallon 1987: 320–321). The material, insofar as it has been analysed, continues to be made of arsenical copper, and it seems that Susa still relied on supply from the Iranian highlands.

Around the 24th century BCE appear with phase IVA some new aspects in the metal industry of Susa (Tallon 1987: 322–332) that are shared over a wider area and that integrate impulses from the sumptuous burial culture of the southern Mesopotamian city states, in particular Ur. Some graves in Susa contained chariots like those known from Ur, and the typology of copper vessels was also closely related. Tin bronze makes a first appearance in Susa but at a much lesser scale (Tallon 1987: 333–335) than at Ur, where it makes up about 40% of the copper-based objects in the cemetery. At Susa, the majority of the assemblages was still dominated by arsenical bronzes and this remained so into the 2nd millennium BCE. Noteworthy is a hoard of tin bronze drinking vessels from the famous "vase à la cachette", dating to the very end of Susa IVA (Tallon 1987: 329 Figs. 53; 54; 333), that corroborates the impression that tin bronze use was then reserved for members of the elite.

A second avenue for influence on the Susa IVA industry is exchange with southeastern Iran, where urban centers had emerged around the same time that the proto-Elamite central highland sites were abandoned. Shahr-e Sukhte, Shahdad and the Jiroft region yielded a rich record of metal objects, mainly from graves (Hakemi 1997; Piperno and Salvatori 2007; Pittman 2013). Shahdad and Shar-e Sukhte also yielded slags and ores, evidence for primary copper working. It has been proposed that ovens excavated in the "craftsmen's quarter" site D in Shahdad were ancient copper furnaces (Hakemi 1992), but this reconstruction remains highly doubtful, as the kilns closely resemble domestic ovens known from settlement sites of the Bactrian-Margiana Archaeological Complex (BMAC), for example, in Gonur Depe (Boroffka 2015: Figure 4). While the site was certainly a primary production site, we have to rely largely on analyses of slags and of artefacts. Finds from the various graveyards are highly distinctive and comprise objects of arsenical copper and of silver, and to a much lesser extent of gold. Most characteristic are cast objects, like decorated tube-shaped maceheads (Hakemi 1997: type Go. 4) or magnificent decorated axe heads (Hakemi 1997: type Gp. 8, Gp. 9); also famous are metal basins with hollow animal figures in repoussé (Hakemi 1997: Gs. 4–7). Cast copper stamp seals of BMAC type allude to the distinct cultural influences that all leave a mark on the local record (Hakemi 1997: type Ia).

These urban centers of southeastern Iran developed in lockstep with the later ED period in Mesopotamia and with Susa IVA. Although strictly speaking outside of the sphere of Elamite interest, they are noteworthy for having maintained a primary metal industry based on arsenical copper. In between southeastern Iran and Susa, only a few related assemblages are known, but these are of high significance for the

relations between the two regions: some *leitfossils* from Shahdad, in particular daggers with long, flat tang and drooping shoulders (Hakemi 1997: Gq. 1–3) find a direct comparison in the recently excavated graveyard Deh Dumen in the Kohgiluyeh-Boyer Ahmad province (Oudbashi, Naseri, and Malekzadeh 2015). However, the vessels analysed from Deh Dumen are made from tin bronze with up to 15% of tin, unlike the Shahdad materials that only use arsenic bronze. This pattern indicates that the two sites participated in different supply networks for copper and tin.

When the Akkadian kings began expanding their territory and integrated Susa at least temporarily into their administration (Susa IVB), the previously existing sphere of shared styles and technologies across the Persian Gulf and the Iranian highlands disappeared. Those urban centers of southeastern Iran that continued to exist turned towards the Persian Gulf and the Indus. From a metallurgical point of view, these centres maintained an industry based on arsenical copper well into the 2nd millennium BCE. This observation remains somewhat puzzling, as the tin sources that were tapped into for supply of tin to the Mesopotamian states lay in the East, and most probably in Afghanistan, hence were spatially close. Possibly the tin supply to the emerging Mesopotamian states was rather negotiated through oversea trade. This was certainly the case when the Akkadian expansion reached out to distant regions of raw material supply, most ostentatiously by using imported black diorite or gabbro from Magan, modern Oman, for major monuments. This same supply area was then probably also used for a supply in copper, which was difficult to obtain from the notoriously unruly mountain people.

For Susa, the integration into Akkadian administration in phase IVB had repercussions in its material record (Tallon 1987: 337–339), and Susa's immediate hinterland seems to have participated in this shift. Forms and types were now strongly oriented toward Mesopotamian models, as is best evident from new types of battle axes whose prototypes we recognize in the Akkadian pictorial record. However, unlike the situation in Mesopotamia, it seems that the Susa IVB metal industry saw little technical innovation and had limited access to raw materials, both copper and alloying agents. A text from Susa provides a guideline for bronze alloying by adding one part of tin to eight parts of copper (Limet 1972; Tallon 1987: 339), however, tin bronze remained a rare material until the 2nd millennium BCE, and existing bronzes have minimal tin contents. Only two objects, both obviously prestige items, are exceptions to this rule: the battle axe of Ilish-mani with 5.9% tin and another axe with a ridged neck and a tin content of 4.9%. This uneven distribution corroborates the model that tin bronze was probably still reserved for prestige users as before in the "vase à la cachette" hoard. The only major innovation of period IVB is the introduction of silver as a currency, which aligns Susa with the administrative habits of the Akkadian state (Sallaberger 2013).

In the subsequent Susa V period (Ur III-Shimashki), the formerly unbalanced situation seems to have rapidly evened out (Tallon 1987: 340–352). Tin bronze has now become more common, in particular for weaponry. Some exceptional trace element compositions, for example, copper with antimony, also point to distant sources from where material was probably imported. Other unusual trace elements are lead, nickel and iron, and arsenic also appears, sometimes in high amounts. These unusual mixtures may indicate a fairly high degree of recycling. Susa V also witnessed some important technical innovations: a new method to create a strong connection between a dagger blade and handle is "casting-on", whereby a handle is cast in a clay mould that has been formed around the already existing blade tang; by pouring liquid bronze into this mould, the blade surface also melts and forms solid metal bonds with the handle material. The use of soldering as a technique to connect pieces of bronze relies on the same principle, and its discovery could be related; soldering had previously been observed only on silver jewelry in the proto-Elamite period.

The Susa V metal industry was embedded in a strictly urban setting with fully regulated administrative activities. The building undertakings of the Ur III kings at Susa made use of the same types of standardized foundation figures that are known from other monuments in Mesopotamia. Sixteen "basket bearers" inscribed with the name of Shulgi were found in Susa, eight each in the Inshushinak and in the Ninhursag temple (Rashid 1983: 32–165, Pl. 33; Tallon 1987: nos. 1321–1336, 308–310). These figures are solid casts that derive from two-valve moulds; some still have a burr visible around the outer contour of the figurine. However, they are all slightly different, which may indicate that they were indeed made in lost wax technique but that the wax model was cast in a mould and then finished by a different hand. It can only be speculated whether this technique may have influenced the change in the production of clay figurines as well, by introducing the use of unilateral clay moulds that standardised the treatment of the figurines (Spycket 1992: 54).

Bronzes from phase Susa V are largely found in graves, so the record must be considered biased. The assemblages contain objects of local production and types that link to Mesopotamian prototypes as well as materials related typologically to productions in either Lorestan or the distant East. A hammer axe inscribed in Sumerian with the name of the Ur III king Shulgi was certainly produced in the wider BMAC area, where the distinctive zoomorphic design was at home, and was used as a votive offering (Amiet 1966: 243 no. 176). A more likely Susian production is a distinctive axe type with a baroque inflated shaft named type "Attahushu" following the inscription on one such axe found in the Ville Royale at Susa (Tallon 1987: nos. 46–65).

A major component of the Susa V metal production was jewellery. While the record is certainly exaggerated due to the high number of grave inventories in this phase, it is nevertheless obvious that the Susa gold and silversmiths accomplished new forms and techniques during this time (Tallon 1987: 350). Golden pieces are often, in fact, electrum with 15 to 40% silver, which may indicate usage of placer gold imported from the East. The jewellery shapes stand out by their clear and elegant shaping, but the craftsmanship remains rather sloppy and sometimes merely imitates techniques established in Mesopotamia. For example, gold filigree and granulation were imitated in relief form.

This extensive discussion of Susa's metal industry and its wide-ranging contacts is necessarily biased, as the contemporary record for highland Fars in the Kaftari period remains fairly patchy. From the Tal-e Malyan excavations, only a handful of objects was retrieved, mainly rods or scrap metal (Carter 1996: 34–35). Six of the ten objects contain tin (Pigott, Rogers, and Nash 2003), which indicates that Malyan, like Susa, participated in a network that received its supply via the Persian Gulf trade.

The situation is different for the western Zagros in the late 3rd millennium BCE, at which time the rugged highland terrain of Lorestan and Ilam can be identified with Awan and Shimashki, home of the first Sukkalmah rulers of Susa. A highly original style of metalwork emerged there in the late 3rd millennium BCE, the beginning of

a tradition that would last into the Iron Age. Unfortunately, many graves containing the so-called Lorestan bronzes have fallen victim to looting,[1] but the excavations by Louis Vanden Berghe have yielded invaluable information from documented contexts for the later Early Bronze Age and the Iron Age. Elemental composition analysis of some of his finds initially located the Early Bronze Age metal work from Lorestan squarely within the overall picture of a regulated Mesopotamian metal industry with access to tin bronze (Fleming et al. 2005). Lead isotope analysis, however, contradicts this finding and seems to indicate local supply systems based on sources in northern Lorestan in the Arak region (Begemann et al. 2008: 38). Arsenical copper was also still in use, and some objects were cast from lead-copper alloys.

THE 2ND MILLENNIUM BCE

The masterful study of F. Tallon and her colleagues on the Susa metals ends with Susa V (Tallon 1987, although some anecdotical 2nd millennium materials are included in the catalogue), hence before Elam came into being as a political player. This end date can be explained by the major interest of archaeometallurgists in questions of early supply systems and alloy practices, which are assumed to have been less significant in later periods when a high degree of recycling and mixing should be taken into account (although this too requires systematic testing). This by no means reflects an ancient reality, since Susa and Elam remained a major broker in the long-distance tin trade, which became ever more important (Reiter 1997: 213–239 on tin traffic according to 2nd millennium BCE texts). Susa has been the scholarly focus of Elamite studies, with attention directed largely to sculpture and works of figurative art (Tallon, Hurtel, and Drilhon 1989; Amiet 2006) and no longer to mundane artefacts and technologies. A notable exception is the recent study of daggers from Haft Tappe, which combines typological and analytical methods (Rafiei Alavi 2012). Hence, for the major part of Elamite history in the 2nd and 1st millennium, we have only selective studies of individual or just a few metal objects at our disposal, a situation made worse by the gaps in the archaeological record of the highlands.

The first excavator of the Middle Elamite site of Haft Tappe (c. 1500–1300 BCE) claimed that scant metal finds had been preserved, as the city was raided before it was sacked around 1300 BCE (Negahban 1991: 45–46). This provides a misleading impression, as a recent study lists about 900 metal artefacts from the site.[2] Many metal objects were found in the workshop area of terrace complex I next to a pottery kiln; the excavator assumes that this kiln served alternatively for firing ceramics and for working metal. Several bronze ingots were found alongside a pile of arrowheads, some daggers and spearheads (Negahban 1991: 46–48 nos. 207–215, Pls. 30–31). Recent scientific analyses of the daggers, which are characterised by lunate-shaped guards forming the connection between hilt and blade, revealed that the guard was created through a complex process of casting-on onto a previously cast blade (Rafiei Alavi 2012). Among the axes found at Haft Tappe, one was identified as iron at the time of excavation (Negahban 1991: 47), but the finds were not submitted to analysis. Haft Tappe also yielded examples of decorative and prestige items. One is a massive shafthole axe inscribed with the owner's name in Elamite (Negahban 1991: 48 no. 217; Pl. 31, color Pl. 3A). Others are furniture and wall decorations, like two silver tubes (Negahban 1991: 113–114, Pl. 56) discovered in front of a door to terrace complex I, probably belonging together as end fittings of a wooden rod. A small bronze plaque with high relief and repoussé showing a ritual scene (Negahban 1991: 114 no. 481; Pl. 56) was collected from the environs of terrace complex I.

Late Middle Elamite Chogha Zanbil was largely deserted after the 11th century, although a modest settlement continued to exist on the site. The metal objects remained there in the temples together with other votives, and a number of metal weapons with inscriptions have been discovered in and around the Kiririsha temple. A decorative battle axe head dedicated by king Untash-Napirisha to the two Elamite deities, Napirisha and Ishnikarab, discovered in the Kiririsha temple is an interesting example for the artful combination of different metals, silver and electrum (Amiet 1966: 358 no. 265): the axe has an asymmetrical shaft that ends in the head of a lion holding the axe blade in its wide-open mouth. The neck of the axe is adorned by a three-dimensional figurine of a crouching boar made of electrum. The hatchet of Untash-Napirisha as well as many other objects, for example, a spade-shaped object with a joint between shaft and spade in the shape of a serpent's head discovered in a chapel northwest of the ziqqurat and identified with the symbolic spade of Marduk (Amiet 1966: 359 no. 266), demonstrate the potential of casting-on technology to safely combine different pre-fabricated modules, and hence also to join together different alloys and metals. This procedure allows the selection of materials best suited for specific purposes, like durable dagger blades versus soft but easy-to-decorate handles. It also provides possibilities for deliberately combining materials of different colours.

STATUETTES FROM DEPOSITS ON THE ACROPOLIS OF SUSA

For the 2nd millennium BCE, two groups of statuettes from the acropolis of Susa are important; proposed dates range from the early 2nd millennium to the 12th century BCE and the Middle Elamite period.[3] One group comprised 26 copper and bronze statuettes of mixed date, some going back to the early 2nd millennium (Tallon, Hurtel, and Drilhon 1989). The deposit was found underneath a Middle Elamite pavement close to the Inshushinak temple and was henceforth dubbed "Inshushinak deposit" (de Mecquenem 1905a). Most figurines are shown in a gesture of adoration and therefore the complex has been interpreted as a hoard of abandoned temple inventory; however, other scholars advocated its interpretation as a temple foundation deposit. The second group comes from a real hoard discovered in the cult precinct halfway between the ziqqurat and the Inshushinak temple (de Mecquenem 1905b). With its splendid objects, which included a solid figurine of silver and another of gold, as well as faience figurines, carnelian beads and a lapis lazuli dove, the hoard became known as "trouvaille de la statuette d'or". It has been proposed that these objects may have formed part of the inventory of a treasury associated with the royal funerary cult, a *suhter* (Grillot 1983). As is the case with the above-mentioned hoard, not all objects must date to the same time, and it has been suggested that the silver and gold figurines may be as old as the early 2nd millennium BCE (Pittman 2003).

In the Inshushinak group is a figurine of a deity seated on a chair in the shape of a coiled serpent and surveyed by three upright serpents from behind (de Mecquenem 1905a: Pl. XVIII, 1; Tallon, Hurtel, and Drilhon 1989, no. 3). Despite a mediocre

state of preservation, the deity's long layered skirt is in line with standard iconography of the early 2nd millennium BCE, while the emphasis on serpents refers to the Elamite pantheon. The figure has been cast in the lost wax technique from a rather pure, un-alloyed copper. This choice of material sets it apart from the other objects in the group.

The other figurines in the Inshushinak deposit are humans in postures of worship or bearing offerings (see Figure 7.2). They differ in size and iconography but also quality of the representation. As a rule, these figurines were cast in one piece, but some have detached arms. A few pieces with some detail are produced as hollow casts; this sophisticated technique correlates with the use of alloys, copper with either tin or lead or both, indicating that the ancient craftsmen were aware of how to improve casting behaviour by using alloys; however, alloys were also used for solid casts, and with the small sample size no clear robust correlation between alloys and techniques can be determined.

Two figures from the Inshushinak hoard stand out by their quality of representation (Tallon, Hurtel, and Drilhon 1989, nos. 5, 12). One shows a worshipper with a raised hand and a long skirt (Figure 7.2, centre). His hair protrudes far over his

Figure 7.2 Anthropomorphic figurines from Susa, 2nd millennium BCE, as an example of casting in lost wax technique (Courtesy J. Álvarez-Mon).

forehead in a typical Elamite fashion. The other figure bears a dove as an offering; he has a shaved head and a long, dotted skirt (Figure 7.2, left). Together with a third, broken figurine, these are the only examples of hollow casting in the hoard. Interestingly, all three figures differ in their composition: the offering bearer is made from un-alloyed copper, while the worshipper is cast from tin bronze, and the fragmented figurine is made from a lead-copper alloy.

The offering bearer from the Inshushinak deposit closely resembles the two solid figurines from the "trouvaille de la statuette d'or" (Figure 7.3) (de Mecquenem 1905b: Pl. XXIV). One is made of gold with some 6.5% silver and 1% copper; the other is of silver with traces of gold, copper and zinc (Harper, Aruz, and Tallon 1992: 146–148 Nos. 89, 90, F. Tallon). Both are mounted on a rather irregular piece of copper and both are shown carrying an animal and wearing a long, dotted skirt with fringes at the hemline. They differ in gesture and in particular in their hairdo, as they have a beard and wear a braid over their head, which may identify them as royal figures. Both figures were cast in the round in the lost wax technique.

Gesture and garment as well as the purity of its material link the god figurine from the Inshushinak deposit to three other deity images from Susa. All these deities are dressed in layered garments and wear the typical horned crown. One figurine is part of a composition, with the god seated like a rider on a chariot that has been cast separately from copper of a different origin. One standing god has his left hand covered in gold sheet, probably the residue of an original gold plating of the complete figurine (Tallon 1987: 310 no. 1337). Such sheet gilding procedures were widely applied

Figure 7.3 Statues of worshippers in solid gold (right) and silver (middle and left) from the so-called *trouvaille de la statuette d'or* at Susa (Courtesy J. Álvarez-Mon).

to sculptures made from less expensive material like wood. A silver "mask" found together with two silver hands also on the acropolis (de Morgan 1905: Pl. VII) may have belonged to such a wooden statue.[4] The silver mask is a good example of how materials could be combined, as the eyes were inlaid in ivory. From the same cache came two "wigs", probably parts of composite figurines, that combine frit and gold, or frit and bronze (de Morgan 1905: Pl. VIII, IX).

The two figurines from the "trouvaille de la statuette d'or" are fixed to their support by a rod described as "anchor-shaped". Others have simple rods indicating that they were once fixed onto a support; some figurines are shaped as if to fit a support; we can therefore assume that many of these small figurines did not serve as an end in themselves but adorned practical equipment like chariots or pieces of furniture.

MORE METAL FROM THE DEPOSITS ON THE ACROPOLIS

Numerous small hoards of valuables and scrap gold and silver were found on the acropolis in the zone of the Inshushinak temple foundations (de Mecquenem 1905a). Stratigraphic control is poor, and the distinction between the Ur III temple foundation and the Middle Elamite temple remained doubtful in many instances, but a good number of the objects belong to the Middle Elamite period. Besides the bronze figurines already described above, a wealth of small-scale metalwork, including golden sun discs and inscribed gold sheet fragments, was discovered. Among the "trouvaille de la statuette d'or" objects was also a golden whetstone finial in the shape of a lion's head with fine granulation (de Mecquenem 1905b: Pl. XXIV). A gilded dragon head made of silver (de Mecquenem 1905a: Pl. XIII, 1a-b) has not been subject to an examination of the technique used.

MONUMENTAL SCULPTURE

With the development of hollow casts in the 3rd millennium BCE, most famously attested through the copper head of an Akkad ruler found at Nineveh (Strommenger 1962: Pl. XXII-XXIII), size limitations on bronze sculpture had been overcome and the only remaining limitation was the available amount of copper/bronze. In Elam a life-size sculpture is attested in the Middle Elamite period, when some of the most spectacular metal sculptures were made in Susa (de Morgan 1900a; de Morgan 1900b). Some sculptures were exceptionally large and heavy; they were cast in complex procedures that are best studied in the famous statue of Napir-Asu (see below) and a related fragment. We can only assume that despite these spectacular finds, much material is missing from the record: Many objects show traces of heavy mutilation, probably inflicted when Susa was defeated and sacked by the Assyrians.

The largest piece of bronze sculpture found in Susa during the excavations of de Morgan on the Susa acropolis in the area of the Ninhursag temple is the statue of Queen Napir-Asu (Figure 7.4) (Lampre 1905; Amiet 1966: 340, 372 no. 280; Amiet 1988: 97–98 Figure 57; Spycket 1981: 313–314 Pl. 204; Harper, Aruz, and Tallon 1992: 132 no. 83; Potts 1999: 218–220 Pl. 7.3), wife of Untash-Napirisha, who commissioned the construction of the ziqqurat at Chogha Zanbil. The inscription names the queen and ends with a curse formula that evokes the Elamite deities Napirisha,

Figure 7.4 Middle Elamite Statue of Queen Napir-Asu from Susa (Courtesy J. Álvarez-Mon).

Kirisisha and Inshushinak. It is the only monumental metal sculpture from Elam surviving almost intact, although the head and most of the left arm were removed in antiquity. This treatment of statues was not exceptional, since another fragment of a life-size statue in the Louvre museum (Amiet 2006) seems to have belonged to an even larger statue of better execution. The Napir-Asu statue is a standing female with hands crossed before the body in a posture reminiscent of the earlier worshipping figures. It is preserved to 1.29 m height (up to shoulder level) and weighs 1.75 tons.

Examinations of the statue (Lampre 1905; Harper, Aruz, and Tallon 1992: 132–135 no. 83, by F. Tallon, see 135 footnote 11; Meyers 2000) provide detailed insight into the complex casting process. The statue consists of an outer shell and a solid core of copper which are significantly different in composition: the outer shell consists of copper with some trace elements and about 1% tin; the core is cast of bronze with 11% tin. The two types of metal differ in their melting points: the copper from the outer shell melts at a much higher temperature than the tin bronze of the core. Casting Napir-Asu followed a multiple-step process: first, a core was constructed from small clay bricks, and fired; then the core was embedded in wax and sculpted, with solid arms and hands, and the major elements of the garment decoration were laid in. A metal plug on the top had been planned to accommodate a core pin to mount the separately cast, now lost, head. Copper chaplets were inserted through the wax into the clay core, and then this model was encased in clay. The wax was molten and a

cavity left behind to be filled with copper. In a next step, the clay core was removed, the copper shell turned upside down and the interior filled with consecutive casts of tin bronze. Further work steps would include the removal of grates, polishing and decorating. The copper of the outer shell is physically softer than the bronze used for the core, facilitating the chasing and punching of the details of the garments. It may also have helped to fix a gold foil wrapped around the statue in a way similar to the gold plating observed on smaller statues; the existence of a long vertical groove on both sides of the statue may indicate original plating for this piece as well. The solid bronze core remains a puzzle as it appears a remarkable waste of valuable material. It has been speculated that it helped to stabilize the (over-) fragile shell (Amiet 2006) or served to hide valuable material (Meyers 2000) and safeguard it from potential looting: in Mesopotamia, valuable materials were turned into temple inventory as a way to obtain divine protection for this material that was calculated according to weight, not according to the skill of craftsmanship. A second, but equally hypothetical alternative is that this core contained material recycled from a war booty of weapons that had been made from high-quality tin bronze.

Other extraordinary bronze works are two giant cylinders with inscriptions by Shilhak Inshushinak, each 4.36 m long, discovered in 1901 on the acropolis (de Mecquenem 1980: 14). The same king ordered the making of a bronze plate with a complex figurative cult scene that was found during excavations at the acropolis of Susa (Gautier 1911), not far from Napir-Asu's statue. This model, called Sit-Shamshi, shows two kneeling men involved in a ritual (Figure 7.5). They are surrounded by cult paraphernalia, men and objects rendered as three-dimensional models attached to a flat plinth. X-ray investigations allow the production process to be detailed (Harper, Aruz, and Tallon 1992: 137–141 no. 87 Figure 43; F. Tallon, analyses F. Drilhon): the

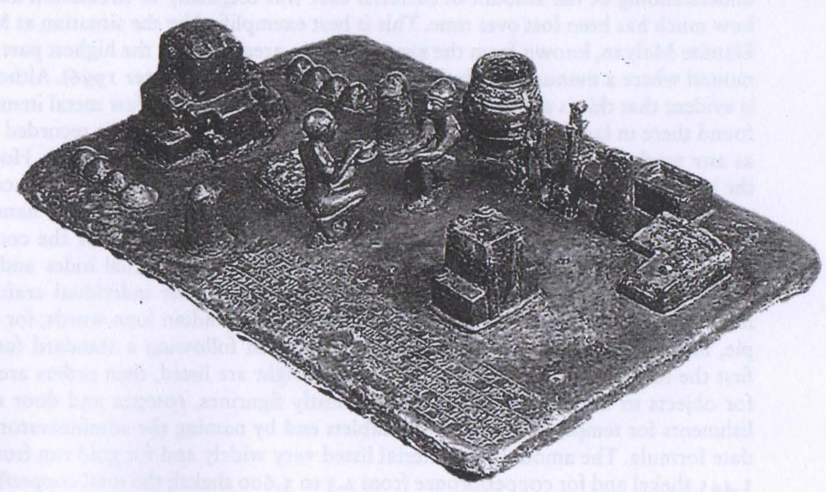

Figure 7.5 Model of a Middle Elamite ritual scene from Susa, so-called *sit-shamsi* (Courtesy J. Álvarez-Mon).

bronze plinth was cast upside down in a mould together with some solid modules. The figures of the two men had been cast separately beforehand and were joined to the model by casting-on the plate. Some larger objects like the basins and pillars were cast together with the plate; the altars, jars and trees were cast separately and secured with pins. The trees and other objects, some lost today, were fixed with rivets. The material used is low tin bronze, with a slightly higher tin amount in the elements cast separately like the altars. One side of an altar preserves residue of silver, indicating that possible silver and gold foil was originally added to the model for a colour effect.

A few more cast monumental bronzes were found in Susa. Among them are the "serpent table", a fragmented table of bronze framed by two large uncoiled snakes, surrounded by a row of five standing figures holding vessels before them in a posture comparable to that of the figures on the façade of the reconstructed Inshushinak temple (de Morgan 1900a). This table has variously been called an offering table or an altar cover. A fragment of a cast bronze vessel with high relief may originally have been covered by gold sheet as the finishing of the copper surface is rather rough (Amiet 2006, 74). The same may have been true for a fragment of a bronze stele from the acropolis mound (de Morgan 1900b) whose original size cannot be reconstructed. It is organised like a stone stele in registers, the main register showing a row of seven divine warriors.[5] An inscription in Elamite has been inserted between the figures of the main frieze. No technical investigation has been carried out, but it seems the plate was cast solidly from the back, and the botanical decoration of the lower register was punched.

MIDDLE ELAMITE TEXTS

With all the large-scale monumental pieces just listed, we may be able to gain a better understanding of the amount of material that was originally in circulation and also how much has been lost over time. This is best exemplified by the situation at Middle Elamite Malyan, known from the excavations in area EDD on the highest part of the mound where a monumental building was partly exposed (Carter 1996). Although it is evident that this is a building of monumental scale, only very few metal items were found there in layers IV and III; no evidence for metal production is recorded either, as any workshop would have been located away from the elite residence. However, the building contained the scattered remains of an archive of texts recording accounts and recipes for metalworking (Stolper 1984). As one of the major texts names the Elamite king Huteludush-Inshushinak, a date around 1100 BCE for the corpus is realistic. Texts belonging to a different archive dealt with animal hides and food, which indicates a spatially differentiated administration for individual crafts. The metal-related tablets are written in Elamite but use Akkadian loan words, for example, for copper and bronze. The tablets are written following a standard formula: first the relevant metals and their respective weight are listed, then orders are made for objects to be made from the metal, mostly figurines, rosettes and door embellishments for temple adornment. The tablets end by naming the administrator and a date formula. The amounts of material listed vary widely and for gold run from 1 to 1,445 shekel and for copper/bronze from 2.5 to 3,600 shekel; the total copper/bronze transactions recorded add up to 36,000 shekel, a little more than 300 kg (Stolper 1984: 10). This provides us a glimpse at the amount of material that went into the

lavish decoration of temples and palaces; it also reminds us of how much archaeological evidence we are missing. The texts from Haft Tappe, once fully read (Herrero and Glassner 1990; 1991; 1993; 1996), will probably provide a similarly impressive picture of the amounts of metal in circulation during the Middle Elamite period.

IRON

Worked iron occurs in Iran occasionally from the Late Bronze Age onwards, but it becomes more widespread only in the Iron Age II from the 10th to the 9th century BCE (Pigott 1977; 1980; 1989; Overlaet 2003: 150–151); initially, the majority of objects are decorative items and jewellery such as bracelets and rings. In weaponry, bronze was used for arrowheads alongside iron well into the 8th century BCE. Only in Iron Age III did iron become the material of choice for armament, while bronze remained in use for decorations and sheet metal objects that required chasing and repoussé. Iron was hence not used at first for any physical properties of the material, and most probably these were not known yet: to take advantage of the strength of iron, the material must be forged into steel; low-carbon wrought-iron objects would be at best equivalent to tin bronze in their efficiency as long as the technology of steel production had not yet been developed. As indicated by the recurrent usage of iron for objects of personal adornment in the early phase, the material seems then to have carried a certain prestige, at least during the early periods of its use.

No workshops are known up to today, just a few slag fragments (see above, iron), and the only evidence for the introduction of iron are the artefacts proper. From Iron Age II onwards appear bi-metallic artefacts: pins with a figurative bronze head and an iron shaft, or daggers with iron blades and a bronze hilt. It has been remarked that the technology behind the production of bi-metallic daggers was unusually complicated, as it remained difficult to unite two such different materials in one object.

ROYAL TOMBS WITH JEWELLERY AND METALWORK

The dearth of settlement sites for the Neo-Elamite period that results by necessity in a lack of metal finds in the archaeological record is balanced out by the discovery of three extraordinary assemblages of the last decades of the Neo-Elamite occupation. Two are funerary constructions found by accident in Jubaji (Shishegar 2015) and in Arjan (Alizadeh 1985; Álvarez-Mon 2010), both in the Ram Hormoz area; these burial chambers contained bronze coffins in the shape of bathtubs, and a wealth of jewellery (e.g. the gold animal-headed terminal bracelet in Figure 7.6) and luxury vessels made of gold and electrum, silver and bronze; the third is a complex of silver vessels and other objects allegedly from the Kalmakarre Cave (Bashash Kanzagh 2000; for a critical discussion, see Henkelman 2003), that has partly been confiscated from looters and whose unity cannot be proved.

Many objects from these complexes attest Elamite-style iconography: both Jubaji and the Arjan tomb yielded gold rings with broadened disc-shaped open terminals; one of these "power rings" was inscribed with a royal name; noteworthy are also the small seated ladies with a fishtail that adorn the handles on some of the silver and bronze pans in Jubaji. No systematic archaeo-metallurgical analysis has yet been

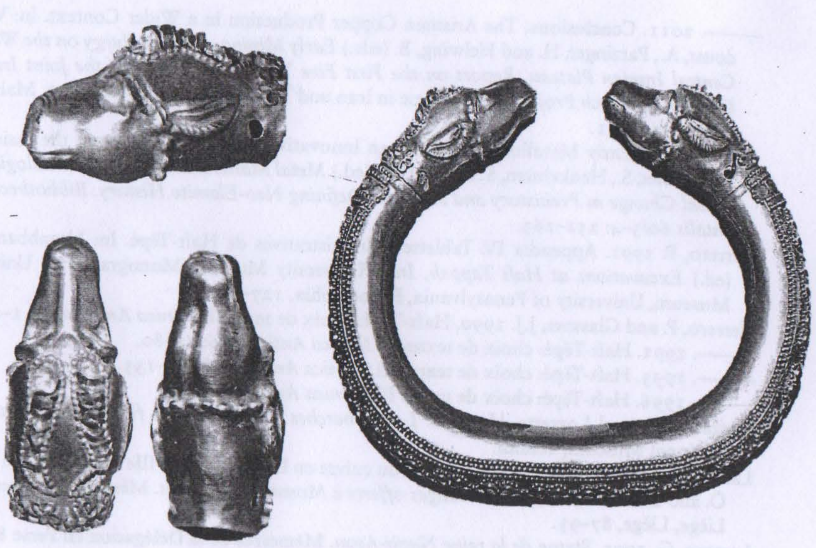

Figure 7.6 Animal-headed bracelet from the "tomb of the two Elamite princesses" at Jubaji (Courtesy J. Álvarez-Mon).

conducted on any of these objects. However, it is evident that Elamite artisans were familiar by now with all techniques of casting and chasing, repoussé and chiseling, as well as soldering, filigree and granulation.

CONCLUSION

A few patterns in the organisation of metalwork in Elam through time become evident from this brief overview, despite the biased research situation. Beginning with material provisioning, Elam always depended on supply from outside; first it was part of the proto-Elamite long distance network; when this waned, the mid-3rd millennium BCE saw the exchange prestigious items over long distances; Elam and Susa, in particular, form a node in this exchange, bringing substantial exotic material into the country. With the integration into the Mesopotamian state, the exchange and supply seems to have been temporarily cut off in two directions – the overland contacts had already waned, and the seaborne trade shifted under the control of imperial administrators. Only from the second millennium BCE onwards had a steady supply of tin built up that also reached the mountainous hinterland of Susa.

Silver supplies seem firstly to have been obtained from the Iranian highlands, but then probably shifted as well when the former highlands centres were abandoned. The origin of gold is not known; there would have been opportunities for gold mining in highland Iran as well as further east. Iron, lastly, appeared in the last centuries of the 2nd millennium BCE.

Technically, copper smiths and jewellers in Elam were at all times level with the Mesopotamian manufactures. Alleged elements of delay and a lack of refinement that have been raised previously cannot be verified against the material record due to the poor chronological control of the archaeological record from Susa, and it will remain a major effort for future research to scrutinise these claims. What is evident, however, is the enormous amount of material and skilled work that went into projects commissioned by the Middle-Elamite (and probably, but still less visible, also later the Neo-Elamite) state, as is attested from artefacts and from texts alike.

NOTES

1 For a brief overview on the history of research, see Overlaet 2003: 14–16.

2 A new investigation of 900 Middle Elamite metal artefacts from Haft Tappeh has recently been undertaken by Babak Rafiei-Alavi (Rafiei Alavi 2015). I wish to thank Babak for allowing me access to this still unpublished corpus.

3 The problem of dating these deposits that seem to contain some material which was old at the time of deposition is not pursued further here. The reported circumstances of the discoveries are sometimes vague or contradictory. Usually both groups are dated to the 13th century BCE, while the individual objects may well be considerably older, see (Braun-Holzinger 1984 to name but the most explicit statements; Tallon, Hurtel and Drilhon 1989; Pittman 2003).

4 This cache is often dated to the Neo-Elamite period for stylistic reasons, as the silver face seems a bit more "puffy" than is usual in the middle Elamite period. De Morgan himself insists on a middle Elamite date in the 11th century at the latest; interestingly, several iron blades are said to have been found with the silver mask.

5 While it is certainly a possibility that the fragment relates to an "archaizing Elamite" iconography, as proposed recently by (Alvarez-Mon 2015) in an attempt to date the piece to the 9th–8th century BCE, I would nevertheless classify it with the other monumental works of art in the final middle Elamite period, as the monumental bronze relief calls for display in a splendid and undefeated capital. Following the sack of Susa in 1153 BCE, the Elamites retreated into the mountain zones, and population and settlement in the plains was much reduced. No representative architecture is to be expected for the coming 200 years, and with this, no monumental sculpture either.

BIBLIOGRAPHY

Alizadeh, A. 1985. A Tomb of the Neo-Elamite Period at Arjān, Near Behbahan. *Archäologische Mitteilungen aus Iran* 18: 49–73.

Álvarez-Mon, J. 2010. *The Arjan Tomb: At the Crossroads of the Elamite and the Persian Empires*. Acta Iranica 49. Leuven: Peeters.

———. 2015. Like a Thunderstorm: Storm-Gods "Sibitti" Warriors from Highland Elam. *Annali, Università degli studi di Napoli "L'Orientale"* 74: 17–46.

Amiet, P. 1966. *Élam*. Archée, Auvers-sur Oise.

———. 1986. *L'âge des échanges inter-iraniens. 3500–1700 avant J.C.* Editions de la Réunion des Musées Nationaux, Paris.

———. 1988. *Suse, 6000 ans d'histoire*. Éditions de la Réunion des Musées Nationaux, Paris.

———. 2006. Les bronzes oubliés de Suse. *Revue d'Assyriologie et d'Archeologie Orientale* 100: 71–73.

Arab, R. and Rehren, T. 2004. The Wertime Pyrotechnological Expedition of 1968. *Institute for Archaeo-Metallurgical Studies* 24: 29–34.

Bashash Kanzagh, R. 2000. *Whispering of treasury. Objects attributed to Kalma Kare Cave.* Iranian Cultural Heritage Organisation, Tehran.

Begemann, F., Haerinck, E., Overlaet, B., Schmitt-Strecker, S. and Tallon, F. 2008. An Archaeo-Metallurgical Study of the Early and Middle Bronze Age in Luristan, Iran. *Iranica Antiqua* 43: 1–66.

Berthoud, T., Besenval, R., Cleuziou, S., Francaix, J. and Liszak-Hours, J. 1976. *Les anciennes mines de cuivre en Iran. Recherche cooperative sur programme 442.* Paris: University Pierre et Marie Curie.

Berthoud, T., Cleuziou, S., Hurtel, L.P., Menu, M. and Volfovsky, C. 1982. Cuivre et alliages en Iran, Afghanistan, Oman au cours des IVe et IIIe millénaires. *Paléorient* 8/2: 39–54.

Boroffka, N. 2015. Gonur Depe. Eine bronzezeitliche Königsstadt in Mittelasien. *Mitteilungen der Berliner Gesellschaft für Anthropologie, Ethnologie und Urgeschichte* 15: 15–24.

Braun-Holzinger, E.A. 1984. *Figürliche Bronzen aus Mesopotamien.* Prähistorische Bronzefunde, edited by H. Müller-Karpe. Beck, München.

Carter, E. 1996. *Excavations at Anshan (Tal-e Malyan): The Middle Elamite Period*, edited by W. Sumner. University of Pennsylvania, University Museum, Philadelphia.

Fleming, S.J., Pigott, V.C., Swann, C.P. and Nash, S.K. 2005. Bronze in Luristan: Preliminary Analytical Evidence from Copper/Bronze Artifacts Excavated by the Belgian Mission in Iran. *Iranica Antiqua* 40: 35–64.

Fleming, S.J., Pigott, V.C., Swann, C.P. et al. 2006. The Archaeometallurgy of War Kabud, Western Iran. *Iranica Antiqua* 41: 31–57.

Frame, L. 2004. Investigations at Tali-i Iblis: Evidence for copper smelting during the Chalcolithic period. BSc, Massachusetts Institute of Technology, Boston.

———. 2009. *Technological Change in Southwestern Asia; Metallurgical Production Styles and Social Values During the Chalcolithic and Early Bronze Age.* PhD, The University of Arizona, Department of Anthropology, Tuscon.

———. 2010. Metallurgical Investigations at Godin Tepe, Iran, Part I: The Metal Finds. *Journal of Archaeological Science* 37/7 (July): 1700–1715. doi:10.1016/j.jas.2010.01.030.

Gautier, J.-E. 1911. Le "Sit Samsi" de Silhak in Susinak. In: *Recherches archéologiques.* Mémoires de la Délégation en Perse 12. Paris: Ernst Leroux, 143–151.

Grillot, F. 1983. Le suhter royal de Suse. *Iranica Antiqua* 18: 1–23.

Haerinck, E. and Overlaet, B. 2005. *Luristan Excavation Documents VI. Bani Surmah. An Early Bronze Age graveyard in Pusht-i Kuh, Luristan.* Leuven: Peeters.

———. 2008. *Luristan Excavation Documents VII. The Kalleh Nisar Bronze Age Graveyard in Pusht-i Kuh, Luristan.* Leuven: Peeters.

———. 2010. *Luristan Excavation Documents VIII. Early Bronze Age Graveyards to the West of the Kabir Kuh (Pusht-i Kuh, Luristan).* Leuven: Peeters.

Hakemi, A. 1992. The copper smelting furnace of the Bronze Age at Shahdad. In *South Asian Archaeology 1989*, edited by J.-F. Jarrige, 119–132. Monographs in Old World archaeology. Madison, Wisconsin.

———. 1997. *Shahdad: Archaeological Excavations of a Bronze Age Center in Iran.* IsMEO, Roma.

Harper, P.O., Aruz, J. and Tallon, F. (eds.) 1992. *The Royal City of Susa: Ancient Near Eastern Treasures in the Louvre.* New York: The Metropolitan Museum of Art.

Hauptmann, A., Weisgerber, G. and Bachmann, H.-G. 1988. Early Copper Metallurgy in Oman. In: Maddin, R. (ed.) *The Beginning of the Use of Metals and Alloys.* Cambridge: MIT Press, 34–51.

Helwing, B. 2009. Rethinking the Tin Mountains: Patterns of Usage and Circulation of Tin in Greater Iran from the 4th to the 1st Millennium B.C. *TÜBA-AR. Turkish Academy of Sciences Journal of Archaeology* 12: 209–221.

———. 2011. Conclusions: The Arisman Copper Production in a Wider Context. In: Vatandoust, A., Parzinger, H. and Helwing, B. (eds.) *Early Mining and Metallurgy on the Western Central Iranian Plateau. Report on the First Five Years of Research of the Joint Iranian-German Research Project.* Archäologie in Iran und Turan 9. Philipp von Zabern, Mainz am Rhein, 523–531.

———. 2013. Early Metallurgy in Iran – an Innovative Region as Seen from the Inside. In: Burmeister, S., Henkelman, S. and W.F.M. (ed.) *Metal Matters. Innovative Technologies and Social Change in Prehistory and AntiquityDefining Neo-Elamite History. Bibliotheca Orientalis* 60/3–4: 251–263.

Herrero, P. 1991. Appendix IV. Tablettes administratives de Haft-Tépé. In: Negahban, E.O. (ed.) *Excavations at Haft Tappeh, Iran.* University Museum Monograph 70. University Museum, University of Pennsylvania, Philadelphia, 127–152.

Herrero, P. and Glassner, J.J. 1990. Haft-Tépé: choix de textes I. *Iranica Antiqua* 25: 1–45.

———. 1991. Haft-Tépé: choix de textes II. *Iranica Antiqua* 26: 39–80.

———. 1993. Haft-Tépé: choix de textes III. *Iranica Antiqua* 28: 97–135.

———. 1996. Haft-Tépé: choix de textes IV. *Iranica Antiqua* 31: 51.

Kargar, M.R. and Loyrette, H. 2001. *Les recherches archéologiques francaises en Iran.* Iran National Museum, Tehran.

Lafont, B. 1996. L'extraction du minerai du cuivre en Iran à la fin du IIIe millénaire. In: Tunca, Ö. and Deheselle, D. (eds.) *Mélanges offerts à Monsieur H. Limet.* Mémoires. Université de Liège, Liège, 87–93.

Lampre, G. 1905. *Statue de la reine Napir-Asou.* Mémoires de la Délégation en Perse 8. Paris: Ernest Leroux, 245–250.

Limet, H. 1972. Les métaux à l'epoque d'Agade. *Journal of the Economic and Social History of the Orient* 15: 3–24.

van Loon, M. 1989. Kamtarlan I. In: Schmidt, E.F., Loon, M.V. and Curvers, H.H. (eds.) *The Holmes expeditions to Luristan.* Oriental Institute Publications 108. Oriental Institute of the University of Chicago, Chicago, 15–18.

Malfoy, J.-M. and Menu, M. 1987. La métallurgie du cuivre à Suse aux IVe et IIIe millénaires: analyses en laboratoire. In: Tallon, F. (ed.) *Métallurgie Susienne.* Notes et Documents des Musées de France 15. Editions de la Réunion des musées nationaux, Paris, 355–377.

de Mecquenem, R. 1905a. Offrandes de fondation du Temple du Chouchinak. In: Morgan, J. (ed.) *Recherches archéologiques.* Mémoires de la Délégation en Perse 5. Librairie Ernest Leroux, Paris, 61–130.

———. 1905b. Trouvaille de la statuette d'or. In: Morgan, J. (ed.) *Recherches archéologiques.* Mémoires de la Délégation en Perse 7. Ernst Leroux, Paris, 131–136.

———. 1980. Les fouilleurs de Suse. *Iranica Antiqua* 15: 1–48.

Meyers, P. 2000. The Casting Process of the Statue of Queen Napir-Asu in the Louvre. *Journal of Roman Archaeology Supplementary Series* 59: 11–18.

Momenzadeh, M. 2004a. Metallic Mineralic Resources of Iran, Mined in Ancient Times. A Brief Review (English version on cd only). In: Stöllner, T., Slotta, R. and Vatandoust, A. (eds.) *Persiens antike Pracht.* Deutsches Bergbau-Museum, Bochum, 8–21.

———. 2004b. Metallische Bodenschätze in Iran in antiker Zeit. Ein kurzer Überblick. In: Stöllner, T., Slotta, R. and Vatandoust, A. (eds.) *Persiens antike Pracht.* Deutsches Bergbau-Museum, Bochum, 8–21.

de Morgan, J. 1900a. Déscription des objèts d'art. Table de bronze. In: Morgan, J. (ed.) *Recherches archéologiques. Fouilles à Suse en 1897–1898 et 1898–1899.* Mémoires de la mission archéologique en Perse 1. Librairie Ernest Leroux, Paris, 161–162 Pl. 12.

———. 1900b. Déscription des objèts d'art. Bas-relief de bronze. In: Morgan, J. (ed.) *Recherches archéologiques. Fouilles à Suse en 1897–1898 et 1898–1899.* Mémoires de la mission archéologique en Perse 1. Librairie Ernest Leroux, Paris, 163–164 Pl. 13.

———. 1905. Trouvaille du masque d'argent. In: Morgan, J. (ed.) *Recherches archéologiques. Mémoires de la Délégation en Perse* 7. Ernst Leroux, Paris, 43–47.

Negahban, E.O. 1991. *Excavations at Haft Tappeh, Iran.* University Museum Monograph 70. University Museum, University of Pennsylvania, Philadelphia.

Nezafati, N. 2016. Recent developments in ancient mining and archaeometallurgy in Central Iran. In *On salt, copper, and gold: the origins of early mining and metallurgy in the Caucasus. Proceedings of the International Conference, Tbilisi June 16th–19th 2016 under the auspices of the Georgian National Museum.* Tbilisi, June 17.

Nezafati, N. and Pernicka, E. 2006. The smelters of Sialk. Outcomes of the first stage of archaeometallurgical researches at Tappeh Sialk. In: Malek Shahmirzadi, S. (ed.) *The fishermen of Sialk. Sialk Reconsideration Project, Report 4.* Archaeological Report Monograph Series, Tehran, 79–102.

Nezafati, N. and Pernicka, E. 2011. Early tin-copper ore from Iran, a possible clue for the enigma of tin bronze. In *Anatolian Metal V/Ünsal Yalcin*, edited by Ünsal Yalçın, 211–230. neue Ausg. Deutsches Bergbau-Museum, Bochum.

Nezafati, N., Pernicka, E. and Momenzadeh, M. 2006. Ancient tin: Old question and a new answer. *Antiquity* 80: 308.

———. 2009. Introduction of the Deh Hosein Ancient Tin-Copper Mine, Western Iran: Evidence from Geology, Archaeology, Geochemistry and Lead Isotope Data. *TÜBA-AR: Journal of the Turkish Academy of Sciences* 12: 223–236.

Oudbashi, O. and Davami, P. 2014. Metallography and microstructure interpretation of some archaeological tin bronze vessels from Iran. *Materials Characterization* 97 (November): 74–82. doi:10.1016/j.matchar.2014.09.007.

Oudbashi, O. and Emami, S.M. 2010. A Note on the Corrosion Morphology of some Middle Elamite Copper Alloy Artefacts from Haft Tappeh, South-West Iran. *Studies in Conservation* 55(1): 20–25.

Oudbashi, O., Emami, S.M., Malekzadeh, M., Hassanpour, A. and Davami, P. 2013. Archaeometallurgical studies on the bronze vessels from "Sangtarashan", Luristan, W-Iran. *Iranica Antiqua* XLVIII.

Oudbashi, O. and Hasanpour, A. 2016. Microscopic study on some Iron Age bronze objects from Western Iran. *Heritage Science* 4(1) (April 6): 8. doi:10.1186/s40494-016-0079-0.

Oudbashi, O., Naseri, R. and Malekzadeh, M. 2015. Technical Studies on the Bronze Age Metal Artefacts from the Graveyard of Deh Dumen, South-Western Iran (Third Millennium BC). *Archaeometry* (January 1): n/a-n/a. doi:10.1111/arcm.12208.

Overlaet, B. 2003. *Luristan Excavation Documents IV. The Early Iron Age in the Pusht-i Kuh, Luristan.* Leuven: Peeters.

Pernicka, E., Momenzadeh, M., Vatandoust, A., Adam, K., Böhme, M., Hezarkhani, Z., Nezafati, N., Schreiner, M. and Winterholler, B. 2011. Archaeometallurgical Research on the Western Central Iranian Plateau. In: Vatandoust, A., Parzinger, H. and Helwing, B. (eds.) *Early Mining and Metallurgy on the Western Central Iranian Plateau. Report on the First Five Years of Research of the Joint Iranian-German Research Project*, 633–687. Archäologie in Iran und Turan 9. Philipp von Zabern, Mainz am Rhein.

Pigott, V.C. 1977. The question of the presence of iron in the Iron I period in Western Iran. In: Levine, L.C. and Cuyler Young, T. (eds.) *Mountains and lowlands: Essays in the Archaeology of Greater Mesopotamia.* Bibliotheca Mesopotamica 7. Undena, Malibu, California, 209–234.

———. 1980. The Iron Age of Western Iran. In: Wertime, S.F. and Muhly, J.D. (eds.) *The Coming of the Age of Iron.* New Haven: Yale University Press, 229–266.

———. 1989. The emergence of iron use at Hasanlu. *Expedition* 31(2–3): 67–79.

———. 1999. A heartland of metallurgy. Neolithic/Chalcolithic metallurgical origins on the Iranian Plateau. In: Hauptmann, A., Pernicka, E., Rehren, T. and Yalçın, Ü. (eds.) *The Beginnings of Metallurgy. Proceedings of the International Conference "The Beginnings of Metallurgy", Bochum 1995.* Der Anschnitt, Beiheft 9. Deutsches Bergbau-Museum, Bochum, 107–120.

Pigott, V.C., Rogers, H.C. and Nash, S.K. 2003. Archaeometallurgical investigations at Malyan. In: Miller, N.F. and Abdi, K. (eds.) *Yeki Bud, Yeki Nabud: Essays on the Archaeology of Iran in honor of William M. Sumner.* Cotsen Institute of Archaeology at UCLA, Los Angeles, 160–175.

———. 2003a. Archaeometallurgical investigations at Tal-e Malyan: Banesh Period Finds from ABC and TUV. In: Sumner, W.M. (ed.) *Early Urban Life in the Land of Anshan: Excavations at Tal-e Malyan in the Highlands of Iran* Malyan Excavation Reports 3: 94–102. University Museum Reports 117. University of Pennsylvania Museum of Archaeology and Anthropology, Philadelphia.

———. 2003b. Appendix A Part IIA. Copper base metal finds from ABC and TUV. In: Sumner, W.M. (ed.) *Early Urban Life in the Land of Anshan: Excavations at Tal-e Malyan in the Highlands of Iran*, Malyan Excavation Reports 3: 149–159. University Museum Reports 117. University of Pennsylvania Museum of Archaeology and Anthropology, Philadelphia.

Piperno, M. and Salvatori, S. 2007. *The Shahr-i Sokhta graveyard (Sistan, Iran): Excavation campaigns 1972–1978*, edited by I.I.p.l.A.e. l'Oriente. Istituto Italiano per l'Africa e l'Oriente, Roma.

Pittman, H. 2003. Reconsidering the trouvaille de la statuette d'or. In Miller, N.F. and Abdi, K. (eds.) *Yeki Bud, Yeki Nabud: Essays on the Archaeology of Iran in Honor of William M. Sumner.* Cotsen Institute of Archaeology at UCLA, Los Angeles, 176–191.

———. 2013. Eastern Iran in the Early Bronze Age. In: Potts, d.T. (ed.) *The Oxford handbook of ancient Iran.* Oxford: Oxford University Press, 304–324.

Potts, D.T. 1999. *The Archaeology of Elam. Formation and Transformation of an Ancient Iranian State.* Cambridge: Cambridge University Press.

———. 2011. Equus Asinus in Highland Iran: Evidence Old and New. In: Conard, N.J., Drechsler, P. and Morales, A. (eds.) *Between Sand and Sea. The Archaeology and Human Ecology of Southwestern Asia. Festschrift in Honor of Hans-Peter Uerpmann.* Tübinger Monographien zur Urgeschichte. Kerns Verlag, Tuebingen, 167–176.

Prange, M., Götze, H.-J., Hauptmann, A. and Weisgerber, G. 1999. Is Oman the ancient Magan? Analytical studies of copper from Oman. In: S.M.M. Young, A.M. Pollard, P. Budd, and R.A. Ixer (eds.) *Metals in Antiquity*, 187–192. British Archaeological Reports International Series 792. Archaeopress, Oxford.

Rafiei Alavi, B. 2012. Ein Hinweis auf die Herstellungsmethode eines Dolchtyps aus Haft Tappeh. In *Contributions on history and culture of Elam and its neighboring regions*, edited by Behzad Mofidi Nasrabadi, 55–160. Elamica 2. Franzbecker, Hildesheim [u.a.].

———. 2015. *Archäologische Untersuchungen der Metallartefakte aus Haft Tappeh, Iran.* Goethe University Frankfurt, Frankfurt.

Rashid, S.A. 1983. *Gründungsfiguren im Iraq.* München: C.H. Beck.

Rehren, T., Boscher, L. and Pernicka, E. 2012. Large Scale Smelting of Speiss and Arsenical Copper at Early Bronze Age Arisman, Iran. *Journal of Archaeological Science* 39/6: 1717–1727. doi:10.1016/j.jas.2012.01.009.

Reiter, K. 1997. *Die Metalle im Alten Orient unter besonderer Berücksichtigung altbabylonischer Quellen.* Münster: Ugarit-Verlag.

Roux, V., Mille, B. and Pelegrin, J. 2013. Innovations céramiques, métallurgiques et lithiques au Chalcolithique: discontinuités techniques et sociales. In: *Transitions, ruptures et continuité en préhistoire = Transitions, rupture and continuity in prehistory: XXVIIe congrès préhistorique de France, Bordeaux-Les Eyzies, 31 mai – 5 juin 2010*, edited by Jacques Jaubert, Nathalie Fourment and Pascal Depaepe, 61–73. Congrès préhistorique de France 27. Société préhistorique française, Paris.

Sallaberger, W. 2013. On silver in the Mesopotamian textual record of the third millennium: its value and its internal circulation. Lecture, German Archaeological Institute Research Cluster in Ibiza, April 5.
Shishegar, A. 2015. *Aramgah-ye do banu-ye ilami. Az chandan-e shah-e Shutur-nahuntepesar-e Indada. Dore ilam-e no, marhale 3B (hodud 585 ta 539 p. m.); Tomb of the two Elamite princessesof the house of King Shutur-Nahunte son of Indada. Neo-Elamite period, Phase IIIB (ca. 585–539 B.C.).* Iranian Center for Archaeological Research, Tehran.
Spycket, A. 1981. *La Statuaire du Proche-Orient Ancien*. Leiden – Köln: E.J. Brill.
———. 1992. *Les figurines de Suse. Volume I – Les figurines humaines, IVe-IIe Millénaires Av. J.-C.* Mémoires de la Délégation Archéologique en Iran 52. Paris: Gabalda.
Steiniger, D. 2011. Excavations in the slagheaps in Arisman. In: Vatandoust, A., Parzinger, H. and Helwing, B. (eds.) *Early Mining and Metallurgy on the Western Central Iranian Plateau. Report on the First Five Years of Research of the Joint Iranian-German Research Project*. Archäologie in Iran und Turan 9. Philipp von Zabern, Mainz am Rhein, 69–99.
Stöllner, T. 2004. Prähistorischer und antiker Erzbergbau in Iran. In: Stöllner, T., Slotta, R. and Vatandoust, A. (eds.) *Persiens antike Pracht*. Deutsches Bergbau-Museum, Bochum, 44–63.
———. 2014. Methods of Mining Archaeology (Montanarchaeologie). In: Roberts, B.W. and Thornton, C.P. (eds.) *Archaeometallurgy in Global Perspective*. New York: Springer, 133–160.
Stöllner, T., Mireskandari, M., Roustaie, K. et al. 2011. Mining Archaeology in Iran – Investigations at Vesnave. In: Vatandoust, A., Parzinger, H. and Helwing, B. (eds.) *Early Mining and Metallurgy on the Western Central Iranian Plateau. Report on the First Five Years of Research of the Joint Iranian-German Research Project*. Archäologie in Iran und Turan 9. Philipp von Zabern, Mainz am Rhein, 535–608.
Stolper, M.W. 1984. *Texts from Tall-i Malyan*. Occasional publications of the Babylonian Fund 6. Distributed by the Babylonian Fund of the University Museum, Philadelphia, PA.
Strommenger, E. 1962. *Fünf Jahrtausende Mesopotamien. Die Kunst von den Anfängen um 5000 v. Chr. bis zu Alexander dem Großen*. Hirmer Verlag, München.
Tallon, F. 1987. *Métallurgie Susienne I. De la fondation de Suse au XVIIIe avant J.-C.* Notes et Documents des Musées de France 15. Editions de la Réunion des musées nationaux, Paris.
Tallon, F., Hurtel, L. and Drilhon, F. 1989. Un aspect de la métallurgie du cuivre à Suse. La petite statuaire du IIe millénaire avant J.-C. *Iranica Antiqua* 24: 121–158.
Thomalsky, J., Bräutigam, B., Karaucak, M. and Kraus, S. 2013. Early Mining and Metal Production in Afghanistan: The First Year of Investigations. *Archäologische Mitteilungen aus Iran und Turan* 45: 199–230.
Thornton, C.P. 2009. The Chalcolithic and Early Bronze Age metallurgy of Tepe Hissar, Northeast Iran: A challenge to the "Levantine paradigm." PhD, University of Pennsylvania, Philadelphia.
———. 2014. The Emergence of Complex Metallurgy on the Iranian Plateau. In: Roberts, B.W. and Thornton, C.P. (eds.) *Archaeometallurgy in Global Perspective*. New York: Springer, 665–696.
Thornton, C.P., Lamberg-Karlovsky, C.C., Liezers, M. and Young, S.M.M. 2002. On Pins and Needles: Tracing the Evolution of Copper-Base Alloying at Tepe Yahya, Iran, via ICP-MS Analysis of Common-Place Items. *Journal of Archaeological Science* 29/12: 1451–1460.
———. 2005. Stech and Pigott Revisited: New Evidence Concerning the Origins of Tin Bronze in the Light of Chemical and Metallographic Analyses of the Metal Artefacts from Tepe Yahya, Iran. In: H. Kars and E. Burke (eds.) *Proceedings of the 33rd International Symposium on Archaeometry, 22–26 April 2002, Amsterdam*. Geoarchaeological and Bioarchaeological Studies. Vrije Universiteit, Amsterdam.
Vatandoust, A., Parzinger, H. and Helwing, B. (eds.) 2011. *Early Mining and Metallurgy on the Western Central Iranian Plateau. Report on the First Five Years of Research of the Joint Iranian-German Research Project*. Archäologie in Iran und Turan 9. Philipp von Zabern, Mainz am Rhein.
Vidale, M., Craig, O., Desset, F., Guida, G., Bianchetti, P., Sidoti, G., Mariottini, M. and Battistella, E. 2012. A Chlorite Container Found on the Surface of Shahdad (Kerman, Iran) and Its Cosmetic Content. *Iran* 50: 27–44.
Weisgerber, G. and Willies, L. 2000. The use of fire in prehistoric and ancient mining: firesetting. *Paléorient* 26(2): 131–149.
Wertime, T.A. 1967. A Metallurgical Expedition Through the Persian Desert. In Caldwell, J.R. (ed.) *Investigations at Tal-i-Iblis*. Illinois State Museum Reports. Illinois State Museum, Springfield, Illinois, 327–339.