Chapter 16

The Use of Bronze Objects in the 3rd Millennium BC: A Survey between Atlantic and Indus

Lorenz Rahmstorff

The spread of tin bronze technology is considered to have been ‘a unified process that accompanied the transformation of society from a simple to a higher degree of organisation [...] The spread did not occur by chance – now here, now there – but in a clear pattern from a relatively large region of origin’ (Pernicka 1998, 140–141, translated from the German). The origins were to be sought in the Near East, with the technology subsequently spreading to the west through Anatolia in the Aegean Sea and finally to the rest of Europe as well as eastwards to the Indian subcontinent and finally to China. The whole distribution pattern followed the assumed dissemination routes of copper technology from south-west Asia to the west and east (Roberts et al. 2009; Mei 2009; Vandkilde 2016, fig. 1). These diffusion models, as they are called, have been contested, so it is worth reconsidering the material their assumptions are based on.

The present article provides a survey on the appearance of bronze, an intentional alloy of copper and tin, before the end of the 3rd millennium BC, or more precisely before 2200/2100 BC. More than 140 sites have been assembled between the Atlantic in the west and the Indus or north-west India in the east. The analysis was originally intended as a detailed overview of the chronology and geographical distribution of early bronze objects and their contextual associations. Another aim was to investigate the kind of objects that were made of bronze when this material was still new and in most cases difficult to come by. No more than a preliminary outline of all these interesting aspects can be given here. Nevertheless, the data may hopefully provide a basis for others to investigate these questions further on a broader material basis than has been possible so far.

Tin is obtained from cassiterite (SnO₂), which occurs in primary deposits as mountaneous tin, in secondary deposits, and as stream tin in rivers and coastal areas ‘where weathering processes have destroyed the host rock and have deposited the chemically and physically stable, dense (SG 6.5–7) and hard (Mohs hardness 6–7) cassiterite mineral in a natural physical concentrating process’ (Charles 1975, 20–21). The latter type of tin was probably often recovered with fluvial placer gold. Archaeological remains (slag) from the extraction of tin from tin oxide cassiterite cannot really be expected because alluvial tin is very pure and smelting produces virtually no slag (Wang et al. 2016, 88). The use of a copper-tin ore, stannite (Cu₄FeSnS₄), is also possible and will be discussed below. Compared to other important metals such as copper and iron, tin deposits are very rare, but Europe is relatively well supplied with them, notably on the western Iberian Peninsula, in Cornwall, in Brittany, in the Massif Central and the Ore Mountains, Vogtland and the Fichtelgebirge (Muhly 1985, fig. 1; Cierny et al. 2005, fig. 1; Hauptmann 2007, 567–568, fig. 109). By contrast, no significant deposits are known in the eastern Mediterranean and in the Near East (but cf. below). However, the oldest regular tin bronzes have been found in this region, arguably far away from substantial tin deposits. Considerable distances had to be overcome to obtain the raw materials, most probably necessitating exchange and trade networks. The enormous distances from potential sources, for example in the case of the Aegean, was the reason why some scholars (Renfrew 1967, 13) have considered it problematic that such distant places should have provided the tin used in the Early Bronze Age Aegean. The ‘tin problem’ has long been a feature of Bronze Age research. V. G. Childe (1928, 157) remarked nearly 90 years ago: ‘The Sumerians drew supplies of copper from Oman, from the Iranian Plateau, and even from Anatolia, but the source of their
tin remains unknown’ (cited by C. C. Lamberg-Karlovsky in Weeks 2003, VIII). In recent decades, the ‘tin problem’ has been frequently discussed in the literature (e.g. Muhly 1985; Stech and Pigott 1986; Weeks 2003; Kaniuth 2007; Helwing 2009; Pigott 2011; Lehner 2014; Steinkeller 2016, 133–137). There are different perceptions about when it is legitimate to speak of a deliberate alloy of copper and tin to make bronze. For some, 1% tin is sufficient to blur the edges between unalloyed copper and tin bronze. To further reduce the possibility of accidentally produced tin bronze, others contend that tin bronzes are those that contain at least 2% tin (cf. Pernicka et al. 1990, 272). In some cases, we unfortunately lack precise information on the composition of the object. These sites have nevertheless been included in the distribution maps here. Older analyses are especially open to criticism for their accuracy. In heavily corroded samples, the tin content may now be higher than it was originally, since corrosion reduces copper more than it does tin (Pernicka and Schleiter 1997, 220).

**Tin bronzes before the 3rd millennium BC**

There are few tin bronzes that we know of from the 4th, let alone the 5th millennium BC, and in many cases their dating is questionable. A number of pins from Susa in south-west Iran allegedly date back to the 4th millennium BC (Susa A–B), but either they could not be relocated in the storerooms or their dating is simply open to debate (Müller-Karpe 1989, 184). The earliest graves in the cemetery of Kalleh Nissar in the Pusht-i Kuh-region in Zagros, western Iran, which also contained tin bronzes, seem to date back to around 3000 BC, the Jemdet Nasr phase (Fleming et al. 2005). A few sites in Armenia with tin bronzes (Thornton 2007, 129 with further references) may again date back to the late 4th millennium, but once more reliable data is missing. In the Balkans, there are allegedly tin bronzes from sites of the 5th and 4th millennia BC (Óttaway 1979; Glumac and Todd 1991), but the reliability of their dates/stratigraphic positions has been questioned (Chapman 1991; Pernicka et al. 1993, 12). This discussion has recently been revived by the publication of tin bronze foil from the Vinča culture site of Pločnik in Serbia which is said to date back to c. 4650 BC (Radivojević et al. 2013). The authors discuss 15 other potentially very early tin bronzes from the 5th millennium BC in the Balkans, which they consider to have been produced from the smelting of the copper-tin ore stannite. This claim for much earlier use of tin bronze in the Balkans has proved controversial and the contextual date of the find has been rejected (Šljivar and Borić 2014). The debate remains open, but even if one accepts the results published by Radivojević and others (Radivojević et al. 2014), it is obvious that this potentially very early horizon of tin bronze did not last long. Similar claims for very early tin bronzes have also been made also for other parts of Europe and western Asia. A high percentage of tin was found in the copper on the walls of a crucible from the settlement of Mandaloi II (Papaelathymiou-Papanthimou and Piliali-Papasteriou 1997, 146; Zachos 2007, 171) in western Macedonia. This phase can be dated to the later stages of the 5th millennium BC (Maniatis and Kromer 1990, fig. 1). For typological reasons, a hammer axe of the Širia type from Gopol in Poland must date back to the early 4th millennium BC, but in its material composition it remains an exceptional piece (Matuschik 1997, 87, 103, fig. 6; Krause 2003, 212, fig. 192; Rahmstorf 2011a, 105, fig. 9.1. 1). At Tel Tsaf in Israel, a copper awl with 6% tin was found in layers dating to the very late 6th and early 5th millennium BC (Garfinkel et al. 2014). At Aruchlo in Georgia, a copper bead with tin, iron and arsenic has even been dated to the middle of the 6th millennium BC (Hansen et al. 2012, 101, fig. 36), but the excavators do not rule out the eventuality that the small bead may have been moved by bioturbation. Once more, exceptionally tin-rich copper ore (stannite) was probably used. Hence these alloys were produced accidentally. The dating of tin bronzes (embossed sheets) allegedly from the late 6th millennium at Ghar-i-Mar in the Balkh province of Afghanistan is also questionable (Srivastava 1998, 176–177 with further references). It is important to note that, despite these early occurrences, there is no single site in Europe and Asia in the 5th or 4th millennium BC where regular and deliberate alloying of copper and tin can be documented. All these finds are exceptional and episodic. Fully deliberate production of tin bronzes and an understanding of tin as a specific metal cannot be proved to have existed in this period, which is therefore still correctly referred to as the Copper Age.

**Tin bronzes in the 3rd millennium BC**

In this section, I discuss the occurrence and frequency of tin bronzes in various regions between the Atlantic and north-western India in the 3rd millennium BC. A synopsis of the earliest tin bronzes in Europe has been published recently by C. Pare (2000b; for an earlier study, see Spindler 1971). The total distribution of tin-bronze objects between the European Atlantic coast and central Asia encompasses more than 140 sites (Fig. 16.1), most of them between the Aegean and western Iran (Fig. 16.2).

**Tin bronzes in central Europe**

As part of his study on early metallurgy and based mainly on the data from the Stuttgart project analysing the composition of early metal objects (SAM; Junghans et al. 1968; Junghans et al. 1974), R. Krause has recently dealt with early tin-bronze objects from Late and Final Neolithic contexts before the beginning of the Early Bronze Age, which in central Europe dates to around 2200 BC. Krause assembled eleven sites in central Europe that in his opinion are Final Neolithic
Figure 16.1: Distribution of tin-bronzes before c. 2200/2100 BC between the Atlantic and western India.

(Krause 2003, 210–213; Schickler 1981 provides an older compilation). On closer inspection, however, some of these archaeological contexts can be dated to the transition to the Early Bronze Age. For example, an assumed Bell Beaker grave at Pfützthal near Salzmünde in Saxony-Anhalt contained a bulbous undecorated vessel and a needle-shaped bronze device with 10.5% tin content (Schlette 1948, 36; Krause 2003, 211, fig. 190). F. Schlette attributes the vessel to his Group E, asserting that this group was present in both the late phase of the Bell Beaker period and the early stages of Unetice culture (Schlette 1948, 56, 63, fig. 10.1). B. Zich also considers its cultural affiliation questionable (Zich 1996, 470 cat. no. E729). Similarly, the spiral ring from a grave at Niederkaina in Saxony with 2.2% tin and a metal strip as a single find from the same site (with 4.6% tin) remain doubtful in their precise dating. They have been dated to the Final Neolithic period due to a ‘gehenkelter Schmirchner’ (Schickler 1981, 436), but this feature also figures in the early part of the Early Bronze Age. For the mid- and late 3rd millennium there is a small cluster of sites with tin bronzes from the Bell Beaker period in the Czech Republic and Bavaria mirroring the slight concentration of central European locations with early gold and silver artefacts (Meller 2015, fig. 3). In this area, the advanced metallurgy of the ‘Bell Beaker people’ was not limited to precious metals, gold and silver, but included bronze, albeit in exceptional cases. Nevertheless, R. Krause is still right when he says that ‘wir erst mit dem 23./22. Jahrhundert verlässlich mit Zinnlegierungen nördlich der Alpen rechnen können’ (Krause 2003, 213) [we cannot reliably expect tin alloys north of the Alps before the 23rd/22nd century BC] and not from the mid-3rd millennium BC. This is especially true because the absolute number of metal analyses of samples from the early Metal Ages in central Europe runs into thousands, while in other regions samples have been taken unsystematically and only samples from specific sites have been examined. Similarly intensive sampling in other regions would probably result in a much higher density. As M. Primas assumed, metallic tin from the Early Bronze Age seems to have been negotiated in the form of beads or rings, as is indicated by beads from the Netherlands (Odoorn–Exloërmond), Bavaria (Buxheim), from Lake Zurich (Wädenswil–Vorder Au) and now also Tollense Valley in north-eastern Germany and Whitehorse Hill, Dartmoor, Devon in south-west England (Primas 2002, 311–312; Rahmstorfer 2010, 687, fig. 7.1–3; Krüger et al. 2012; Jones et al. 2014). In central Europe, tin bronze is first used fairly frequently in the Bronze Age A1b (approximately from 2000 BC), but as C. Pare has demonstrated, only becomes widespread throughout central Europe a few centuries later with Bronze Age A2 (Pare 2000b, 16–20, figs. 1, 9–12, 14). The Unetice culture in central and eastern Europe seems to have been an innovation centre where halberds for example were produced in tin bronzes from approximately 2000 BC (Rassmann 2010). Addendum 2016: XRF analyses of copper-based metal objects from Bell Beaker Csepel Group sites in Hungary published in 2003 (Enrödi et al. 2003, tab. 1, nos. 4–5) revealed two bronze objects from the settlement at Albertfalva (not included in Figures 16.1 and 16.2).

**Tin bronzes in western Europe**

From western Europe, there are, to my knowledge, no tin bronzes before the start of the Early Bronze Age in the last
quarter of the 3rd millennium. From about 2200 BC, tin bronzes with a high tin content of 8–14% appear seemingly abruptly in the British Isles, while tin bronzes with only 1–5% tin are rare (Needham et al. 1989, 391–392, fig. 2; Bray 2012, 57). This coincides with S. Needham’s ‘fission horizon’ where a new diversification in grave goods is observable (Needham 2005, 205, 209). Tin bronzes are then found from around 2000 BC in northern and western France, southern England and Wales. This suggests that, firstly, bronze metallurgy was accepted very quickly and that, secondly, from this time on, local, most likely alluvial deposits in Cornwall (Wang et al. 2016, 88), Brittany and the Massif Central were used. This is borne out by the mapping of tin content in copper alloys in parts of Europe by 2000 BC (Rassmann 2004, fig. 3). The assumption of an independent technological development is unconvincing as no evidence of an experimental phase has been detected (Primas 2002, 304). It would be important to establish how, why, and from where this impulse came about (from metal prospectors?), unless one assumes an independent development in Britain. From the turn of the millennium, southern England may have supplied central Europe with tin (evidence summarised by Jockenhövel 2004). In comparison to other European countries, tin bronzes in the British Isles are generally liable to be found several hundred years earlier, i.e. before this technology asserted itself as standard in central Europe and other parts of Europe (Pare 2000b, 20–22, 27, fig. 1.14).

**Tin bronzes in southern Europe**

On the Iberian Peninsula, regular use of tin bronze for pendants and rings can only be detected from the earlier stages of the 2nd millennium (1800–1700 BC) with the
El Argar culture (Primas 2002, 308–309, fig. 5; Lull et al. 2013, 599). Very few sites (Fig. 16.3) with tin bronzes can be dated before 2200 BC (cf. Fernandez-Miranda et al. 1995; Delibes et al. 1996). The hoard of Barro found next to the circular grave of Barro not far from Zambujal in central Portugal contained not only two axes and two daggers of arsenic bronze and a limestone cylinder but also a chisel of high-alloy tin bronze (Spindler 1981, 101–102, 243, fig. 41). Because of this chisel, K. Spindler has assigned the entire hoard to the beginning of the Early Bronze Age (VNSP III = culture of Vila Nova de Sáo Pedro), although all other objects can be attributed to the late Copper Age/Bell Beaker period (e.g. the golden hair ornament, cf. Meller 2015, 617). In Spindler’s opinion ‘das Aufkommen der Zinnbronze auf der iberischen Halbinsel vor dem Einsetzen der Bronzezeit [ist] kaum denkbar’ (Spindler 1981, 101) [the occurrence of tin bronze on the Iberian Peninsula prior to the Bronze Age is hardly conceivable]. But he cannot exclude the eventuality that the Barro hoard may have been first compiled in this composition by quarry workers. Nevertheless, there is more sparse evidence of the scattered use of tin bronzes during the later Copper Age, compiled by C. Pare (2000b, 22). Three further cases are early tin bronzes in the form of awls and daggers that can interestingly be related to the Bell Beaker phenomenon of the late Copper Age, or more precisely the mid- and later 3rd millennium BC. These early tin bronzes are from Galicia (Guidoir Aroso on the island of Arousa) and the foothills north and south of the Pyrenees (Abri du Capitaine; Bauma de Serrat del Pont) (Fig. 16.3).

On the Italian peninsula and in Sardinia, some initial, isolated instances of tin bronzes occurred at the same time. In Sardinia, a blade with a blunt tip (spatula) was found in the fortified settlement of Monte Baranta within the fortified horseshoe-shaped tower on the hilltop. It can be dated to the Monte Claro-Facies (mid-3rd millennium) and is contemporaneous with the Bell Beaker phenomenon, to which it displays similarities. No parallels for the object with a 4.2% tin content can be found in Sardinia or neighbouring regions (Lo Schiavo et al. 2005, 194, fig. 2; Atzeni et al. 2005, 124, tab. 5). Singular finds of early tin bronzes from the 3rd millennium BC came to light at Poggio Olivastro in Tuscany and in a grotto in the Val Frascarese in Genoa (Campana et al. 1996; Bulgarelli and Giumlia-Mair 2008; Dolfini 2010, 719). Progress to regular production of tin bronze did not take place before the transition from the 3rd to the 2nd millennium BC or the early 2nd millennium. Nevertheless, we still have no large-scale investigation of copper-based artefacts from the Early Bronze Age in Italy.
with a regionally differentiated measurement series (cf. Pare 2000b, 23–24; Dolfini 2010, 719, tab. 4).

**Tin bronzes in south-east Europe**

Very few sites in southeastern Europe (Fig. 16.4) have revealed tin bronzes from contexts of the 3rd millennium or before 2200 BC (cf. Appendix). The unusual double-edged knife from the tumulus tomb of Velika Gruda in Montenegro, which has been dated as early as the early 3rd millennium BC has a tin content of about 7.6% (Primas 1996, 97–98, 100, 104, fig. 7.5–6, tab. 7.1). The bronze has lead-isotope ratios that are very similar to those of early Aegean tin bronzes (Primas 2002, 304–305, fig. 2), suggesting that the bronzes arrived ready alloyed from wherever this may have been and that the material may have come from the same source. So far, lead isotopes relate to the copper in the objects, not to the tin (but see below). We cannot entirely rule out the use of small local tin deposits in the Balkans (Durman 1997; cf. Maran 2007, 12). Analyses of metal objects from the Maros culture in southern Hungary and the

![Figure 16.4: Distribution of tin bronzes in southeast Europe, western Anatolia and Cyprus before c. 2200/2100 BC.](image-url)
Banat demonstrate that tin bronze was mainly used to make jewellery in the very late 3rd millennium BC (Primas 2002, 307–308, fig. 4). According to the findings from C. Pare’s investigation, the transition to a regular use of tin bronze took place in the Balkans no earlier than the middle of the 2nd millennium BC (Pare 2000b, 12–16, figs 1.5–7.14).

**Tin bronze in the Aegean**

A dozen Early Bronze Age sites with tin bronzes can be listed for Greece (Fig. 16.4). From Sitagroi IV–Va in Macedonia come four or five objects with up to 8.1% Sn (Renfrew and Slater 2003, 300–307). According to J. Maran, these phases at Sitagroi can be paralleled with Early Helladic (EH) I and the beginning of the EH II, which implies a date in the first or an early 2nd quarter of the 3rd millennium BC (Maran 1998, 124–126; see also Maran 2007, 12 with n. 61). Finds of tin bronzes and even bronze slag from Axiouchori/Vardarophta/Sartrase in Macedonia date to the end of the EBA, with the exception of a bronze fragment from Axiouchori settlement 5 which is contemporaneous with the late EH II period on the southern Greek mainland (see Maran 1998, 268 with further references). There are also a few sites with tin bronzes on the southern Greek mainland and islands. Due to documentation errors we can no longer ascertain which objects from the R-graves of Steno-Nidri on Lefkas are tin bronzes (McGehee-Liritzis and Taylor 1987, tab. 1; see Maran 1998, 267, n. 1109; Kilian-Dirlmeier 2005, 107, n. 244). A tweezer from Grave 23 (or found next to Grave 23) at Aghios Kosmas dates back to the transition from EH I to EH II, i.e. around 2800/2700 BC. Tin bronzes from Lithares (Tzavella-Evjen 1984, 140, cat. nos. 657, 663; Kaya et al. 2000, 41–42, tab. 2.2) also indicate that the alloy was occasionally used during the earlier 3rd millennium BC not only in Macedonia, but also on the southern Greek mainland and Crete (see below). A bronze pin from the cemetery of Manika on Euboea can probably be dated to the later EH II (Sampson 1985, 177, 305–306; Maran 1998, 268). A loop pin was unearthed in Room 196 of horizon 8a (late EH II) in the lower citadel of Tiryns, which also contained 14 spool-shaped potential balance weights. K. Kilian (1982, 421, fig. 44.5) explicitly states that the pin is made of tin bronze even though there is no published analysis of the metal. Nevertheless, it must be emphasized that in the EH heartland tin bronzes are rare exceptions. Not even one tin bronze object was found in the sample of 25 copper-based metal objects from Lerna III (EH II) and IV (EH III) and seven objects from EBA Tsoungiza taken by M. Kafaya, S. Stos-Gale and N. Gale. Arsenic bronzes are common, but in the authors’ opinion the variations in the ratios of arsenic to copper show that the alloy was probably not produced by a controlled process (Kafaya et al. 2000, 39–43, tabs 2.1, 2.2). It is also important to note that there are no changes in the popularity of arsenic in the copper-based artefacts from EH II to EH III in Lerna and Tsoungiza.

Because of the adoption of tin-bronze technology in the Cyclades along with new ‘Anatolian’ vessel forms, the Lefkandi 1-Kastri type has been understood by some authors as an indication of the advent and presence in the central Aegean islands of a foreign population from western Anatolia (see Maran 1998, 269, n. 1132 for further references). Until recently, this assessment was based only on the settlement of Kastri on Syros. All derive from the hoard found in room 11, which among other things also includes six spool-shaped potential balance weights and a slotted spearhead of tin bronze. The copper based metal objects from the hoard have tin ratios of 1.85/4.8 to 7.9% (Bosser 1967, 76, figs 1.1–12, 2.6). New data has now come from the contemporaneous settlement of Markiani on Amorgos. Twelve of the 17 copper-based metal objects have been analysed for their composition. Five of them are dated in Markiani III, 4 in Markiani IV and 3 remain undated. Only two of them are tin bronzes: a one-edged blade or knife (Birtacha 2006, 214–217, figs 8, 24.16, tab. 8.18: EE 639) derived from a layer (Marangou et al. 2006, 54) of late Markiani III, parallel with the earlier EBA II, i.e. 2800/2700–2500 BC (Marangou et al. 2006, 77–80, fig. 5.6), even though the ceramics have not yet been published. The second object is a pin with a hemispherical head (Birtacha 2006, 213, fig. 8.24.6, tab. 8.18: EE 241) from a layer in section 2 corresponding to Markiani IV, i.e. the younger EBA II (Lefkandi 1-Kastri). It has recently been argued that the shape of this pin shape is Anatolian in origin, and it is worth mentioning that the earliest bronzes in the Aegean (and Anatolia) are often pins of this kind with spherical heads (Rahmstorf 2015, 156–159, figs 6–8). The other objects are made of pure copper (one object in Markiani III) or arsenic bronzes (three objects in Markiani III and IV, see Birtacha 2006, 216, 219, tab. 8.16, 8.18). It is interesting to note that in both cases the tin bronzes were found in direct relation or close proximity to the spool-shaped potential balance weights, but not in the same layers. The third site with EBA tin bronzes in the Cyclades is also situated on Amorgos. From a grave in the cemetery of Dokathismata we have two bronze bracelets that were bought with other inventory by the Archaeological Society of Athens before the excavations by C. Tsountas started in the late 19th century. One of the bracelets has a tin content of 13.52%. A closed find context is unfortunately missing, but the other finds from graves suggest a date in late EC (Early Cycladic) I or early EC II, although a much later, possibly even Middle Bronze Age dating cannot be entirely ruled out (Tsountas 1898, 187, pl. 8.2; Rambach 2000, 9, 13, pl. 3, 9–10). Finally, hardly any Early Bronze Age tin bronzes can be cited from Crete. Platanos in the Mesara plain in Crete, which was mentioned by Schillinger and Apakidze (Schillinger 1997; Apakidze 1999, 515, fig. 2), is not accepted here as an early site of tin bronze because numerous finds from the end of the 3rd millennium
(EM III) and Middle Bronze Age (Middle Minoan) have also been recovered from the site. However, two small daggers (Marinatos 1929, 131, 119, fig. 13, 30–31) from the Tholos of Krasia in north-east Crete with a tin content of 6% and 10%, can be dated to EM I–IIA or EM I. J. Muhly advocates a date in EM I (Muhly 2006, 170). In the north-eastern Aegean at Poliochni on Lemnos, a steady increase of tin bronzes is discernible from the Green settlement phase, datable to before the middle of the 3rd millennium BC. Tin bronzes are particularly common in the Yellow phase of the later 3rd millennium. But the ratio of arsenic bronzes also increases steadily from the Blue phase (early 3rd millennium BC) to the Yellow (Pernicka et al. 1990, 272, fig. 1; Pernicka et al. 2003, 163). Five of the six metal artefacts (with the exception of the pin) from the ‘Potter’s Pool’ hoard found in Thermi IV (= late Troy I) consist of tin bronze (Begemann et al. 1992, tabs 1–2). In sum, I believe that we cannot reconstruct a time horizon from the point when tin bronzes suddenly occur in the Aegean. While there seems to be an accumulation of tin bronzes from the later phase of EBA II on the Greek mainland, on Euboea and the Cyclades, quite a few tin bronzes also date to early EBA II or even to EBA I (Sitagroi, Aghios Kosmas, Krasia). If metallic tin or alloyed tin bronze did indeed start coming into the Aegean from the east as of the early 3rd millennium BC, this eastern impact would have been paralleled by the adoption and local interpretation of the foreign innovations of sealing and weighing during this period (Rahmstorf 2016).

Of major significance are the results of recent investigations on copper-based artefacts found at several EBA Aegean sites: Katsambas, Dhaskalio Kavos and Çukuriçi Höyük. As mentioned earlier, Kayafa and others drew upon their analyses of samples from Lerna and Tsoungiza to argue that the intentional production of another copper-based alloy – arsenical copper, sometimes also called arsenic bronze – was not possible for Aegean metallurgists during the EBA. But crucial slags from Poros Katsambas on Crete indicate the ‘purposeful admixing of arsenic-rich minerals to the copper melt’ (Doonan et al. 2007, 112). This evidence is further underpinned by the recent find of a speiss fragment, the ‘often accidental by-products of smelting arsenic or antimony-rich multmetallic ores’ (Georgakopoulou 2013, 684–685, fig. 32.34) from Dhaskalio Kavos. This may have been used as an alloying agent to produce arsenical copper. In addition, a new find from Çukuriçi Höyük on the west Anatolian coast points in the same direction (see below). As arsenical copper has many of the advantages of real bronze, the Early Bronze Age metallurgists were apparently able to produce a substitute that was nearly as effective as tin bronze. This considerably underlines the importance that has been ascribed to this material and has (in modern research) given the whole period its name. It is a reasonable assumption that it was especially the near-gold colour that made real bronze such a coveted material (see also below).

**Tin bronzes in Anatolia**

The earliest tin bronzes from western Anatolia (Fig. 16.4) belong to the Troy I period and come both from Troy itself and from nearby Beşiktepe. These bronzes contain up to 11.5% tin (Pare 2000b, 9; Begemann et al. 2003). From Tell Judaidah in the Amuq area on the Turkish-Syrian border, already part of the Mesopotamian catchment area, come numerous bronzes with tin contents of 5–37% that can be dated to Amuq phase G (c. 3000–2900 BC). Famous are the naked figurines (three female and three male: Braidwood and Braidwood 1960, 300–313, figs. 240–245, pls. 65–64) from this phase, though their stratigraphic and stylistic placement around 3000 BC has been doubted (Marchetto 2000). Nevertheless, a crucible from phase G shows that tin or bronze was processed (Yener 2009, 144–145 with further references). Apart from tin, arsenic was apparently used intentionally to produce arsenical copper. The compositional analysis of copper-based seals (Goldman 1956, fig. 392.13–14) of the Early Bronze (EB) 2 period at Gözlü Kule-Tarsus in Cilicia disclosed a 10% share of arsenic, which again can only be achieved through the deliberate smelting of copper and arsenic-rich ore material (Özbal et al. 2005). In addition, the recent findings of copper sulphides and iron arsenides in smelting debris from Çukuriçi Höyük on the delta of the Küçük Menderes River on the west Anatolian coast near ancient Ephesus indicate that in the Aegean and in Anatolia, intentionally produced arsenic-rich speiss was melted together with copper or copper ore to obtain arsenical copper (Mehofer 2014, 467–468) during the EBA. Although some 20 EBA locations with tin bronzes are known from Anatolia (see appendix), this is no proof of regular production at that stage. Nevertheless, they appeared in a developed phase of the EB 1 (early to mid-3rd millennium BC) and their number increased during EB 2 and EB 3. J. Yakar noted that tin bronzes occurred simultaneously with the earliest gold objects in Anatolia (Yakar 1984, 72). Now that the dating of the allegedly Early Bronze Age ring idols of gold and silver from Ikiztepe, Kalkaya, Göller and other sites has been corrected to the 4th millennium (Lichter 2006, 528; Zimmermann 2007; Schoop 2011, 55, 59, fig. 3 – the latter for a Late Chalcolithic ring idol mould from Çamlıbel Tarlasi), this assumed nexus is no longer tenable.

**Tin bronzes in eastern Europe**

To my knowledge, tin bronzes have not been recorded for the 3rd millennium BC in eastern Europe. In the North Pontic area metal objects were made of pure or arsenical copper until well into the 2nd millennium BC (Chernykh 1992; Pare 2000b, 13–16, fig. 1.6).
Tin bronzes in the Caucasus

The earliest tin bronzes from the Caucasus date from the turn of the 4th to the 3rd millennium and to the first half of the 3rd millennium BC, as in Telebi of the late Kura-Araxes culture (Kavtaradze 1999, 84) in eastern Georgia. A grave at mound 11 at Talin in Armenia contained a bronze curl ring with more than 10% tin (Meliksetian et al. 2003, 310–314; Avetisyan et al. 2010, 164, fig. 3.1). A single 14C date from the grave of Talin has a calibrated margin of error (2σ) between 3330 and 2936 BC (Avetisyan et al. 2010, 163). Tin bronzes (‘a curl ring and a standard’) were also found in kurgans 3 and 5 in Markkopi (Kavtaradze 1999, 84) dating to the final stage (III) of the Kura-Araxes culture or the Bedeni culture, as it is called by the kurgans in the Bedeni Plateau. In absolute terms, this culture or phase dates to c. 2700–2200 BC (Batiuk and Rothman 2007, 9, fig. [without no.]; but cf. Bertram 2010, 255: ‘die Chronologie [im Südkaukasus] hängt für weite Abschnitte des 3. Jts. v. Chr. bedauerlicherweise in der Luft’). Kavtaradze also lists an alleged bronze pin and an awl from Delisi dating from the Middle Neolithic period, but there are ‘certain doubts concerning the circumstances of their discovery’ (Kavtaradze 1999, 71). Tin bronzes from the later EBA seem to be more common in the southern Caucasus. For example, an awl from Telebi contains 11.3% tin, two spearheads, a dagger and a thorn from Bakuricxe have tin ratios of 10 to 13.7% (Kavtaradze 1999, 84–86 with references). Other sites with tin bronzes in the southern Caucasus have been listed by C. P. Thornton (2007, 129) and A. Bobokhyyan (2008, 67, map 15). On the other hand, of the 80 copper-based artefacts of Early Bronze Age sites in Armenia, only three are tin bronze while the rest are either arsenical copper or arsenical copper with a high lead content (Meliksetian et al. 2011, fig. 5 – no allocation of artefacts to sites). In the western and northern Caucasus, finds of tin bronzes from the second half of the 3rd millennium BC are unknown. The most northerly localisation is Velikent in Daghestan (Fig. 16.5). The 195 sample analyses from the total of 1,500 metal artifacts from Hill 3, Grave I revealed 15 tin bronzes (8% of the total sample analysed) that are mainly rings and pendants with no tools or weapons (Kohl 2002, 174, fig. 12; Kohl 2003, 19, fig. 1, 7; Peterson 2003, tab. 2.1–2; cf. Rahmstorf 2010, 688, figs 7, 9a–b). In addition to these artefacts, there is also a slightly curved, approx. 7 cm-long object with a square-rounded cross-section designated by the excavators as bronze ingots, albeit with a question mark (Gadzhiev 1997, 191, fig. 8.3). P. Kohl therefore assumes that tin bronze arrived in Velikent in the shape of semi-finished products or ingots that were then further processed by local artisans (Kohl 2007, 108). Of particular interest are the lead-isotope analyses of tin bronzes from Velikent (L. Weeks in Kohl 2002, 178–183). For copper, they indicate similar lead-isotope ratios as in the sampled tin-bronze alloys from the EBA Aegean (Poliochni, Troy, Thermi, Kastrı) and from the United Arab Emirates (Al Sufouh, Shimal, Tell Abraq). This may suggest that all these places received their bronze (traded as an alloy) from the same deposit(s) (cf. Weeks 2003, 163). Addendum 2016: A few analyses of tin bronze artefacts from Early Bronze Age sites in Azerbaijan have been published (Hasanova 2014, 66, tab. 1). They are not mapped in Figure 16.5.

Tin bronzes in Cyprus and the southern Levant

No tin bronzes are known from Late Chalcolithic Cyprus in the first half of the 3rd millennium. This was assumed (Coleman et al. 1996, 373) to also hold true for the second half of the millennium (Philia culture; Early Cypriote I–II), although the impact of Anatolian influences and of potential migration from the Anatolian coastal area to Cyprus has been established for this period in recent years and substantial cultural change has been emphasised (Webb and Frankel 2007; Petlenburg 2007; Kouka 2011). Recently, four rings with a tin content of 4.8–13.1% have been published from Grave 6 (Swiny et al. 2003, 111–114) at Sotira Kaminoudhia, which is assigned to the Philia culture (Swiny 2003, 376–377, 379, fig. 8.1 M13–M14, M21–M22; Giardino et al. 2003, 388–390, fig. 8.1.5, M13–M14, M21–M22). According to J. Webb and others, the tin bronzes (flat celt, a spearhead and a very early sword) from the richly endowed Kolokassides hoard, which may come from Vasilia in Northern Cyprus, are plausibly datable to the Philia culture (Webb et al. 2006, 268, tab. 2, fig. 1, 2, 4.8).

In the southern Levant, tin bronzes from the Early Bronze Age are also quite a rare phenomenon (Fig. 16.4). This is demonstrated by the results of the analysis of Early Bronze Age metal finds. Nine copper-based metal objects from the EBA layers at Tell Abu al-Kharaz in the Jordan Valley have been analysed (Fischer 2008, 303–306, tab. 65). None of them contained amounts of tin that could be interpreted as resulting from a deliberate alloying process. So far, the only tin bronzes we know of from the southern Levant are individual objects, often daggers. In the chamber tombs cemetery of Tiwil Esh-Sharqi, a bronze dagger with four rivets was found with a tin content of 12%. The burial is dated to EB IV in the late 3rd millennium BC (Tubb 1990, 55, 58, 95–96, figs 39b, 40b SE1.6) Also from this period is a bronze dagger from Jericho (Prag 1974, 91, n. 63). Another bronze dagger from Bab edh-Dhra is slightly earlier, dating from EB III (Maddin et al. 2003, 513). The tin bronzes from Khirbet ez-Zeraqon (EB II–III) have not yet been published in detail (cf. Hauptmann 2000, 180).

Tin bronzes in Egypt

As is unfortunately often the case with ancient Egyptian artefacts, the exact origin and hence the precise dating has not been securely established for many metal objects from the First Dynasties and the Old Kingdom. R. M. Cowell has analysed 52 metal artefacts dated either by
Figure 16.5: Distribution of tin bronzes in eastern Anatolia, the Levantine coast, the Caucasus, Mesopotamia and western Iran before 2200/2100 BC.
inscriptions, the archaeological context or $^{14}$C datings. Only two of these are tin bronzes; both are bronze vessels from the grave of Khasekhemwy (2nd dyn.) at Umm el-Qa‘ab at Abydos (Cowell 1987, BM 25571, BM 35572). These results are confirmed by the findings of modern settlement excavations in Egypt. Only one of the ten metal analyses of copper-based artefacts from prehistoric and early historic Buto in the Delta turned out to be tin bronze. This object, the function of which is unclear, was recovered from an early dynastic pit (Pernicka and Schleiter 1997, 220, tab. 2). Tin bronzes from 3rd millennium Egypt are therefore very rare (cf. Wertime 1978; Eaton and McKeerell 1976, fig. 9 [left], tab. 2; Muly 1985, 283), which also holds true for the Middle Kingdom in the earlier part of the 2nd millennium BC, when metal objects made of this material were getting slightly more frequent. Only from the Second Intermediate Period and especially from the New Kingdom do tin bronzes become common in Egypt (Garenne-Marat 1984, 113). The opening up of Egypt to (Levantine) Hyksos domination and the imperial power of New Kingdom Egypt in the eastern Mediterranean apparently led to new and fundamental links between Egypt and the international metal exchanges in the eastern Mediterranean and the Near East. Much greater Egyptian arturary with regard to innovations and resources can be observed for the Old and Middle Kingdoms. This fits in perfectly with the results of weight studies in Ancient Egypt. Only with the advent of the New Kingdom did the weight unit of c. 9.1–9.4g become common in Egypt (cf. Weigall 1908, 1X). It had already been in use for more than 1000 years in many parts of the eastern Mediterranean, especially in Syria (nevertheless, this weight unit is still often referred to as the Egyptian qedet). Similarly, the typical east Mediterranean theriomorphic metal weights only occur in Egypt from the middle of the 2nd millennium in Egypt (already observed by Petrie 1926, 7). While other innovations that only arrived probably from northern Levant/Mesopotamia (cf. Genz 2013, 101–102) in the country during the Hyksos period are connected with warfare (chariots/horses, composite bows, etc.), tin bronze and especially weights are related to material and commercial improvements. In the Old and Middle Kingdom, the country was apparently supplied almost exclusively by metal deposits from the Egyptian eastern desert and Nubia (Sudan). Theoretically, tin could also have been mined, and there are deposits of alluvial cassiterite in the eastern desert as well (Wertime 1978, 42; Garenne-Marat 1984, figs 2–3; Cierny et al. 2005, fig. 1; Nezafati et al. 2011, tab. 2 with further references), but given the few tin bronzes dating from this period, this is unlikely. Accordingly, the relative absence of tin bronzes is another indication of the country’s marked autonomy over and against the exchange networks in the eastern Mediterranean and western Asia in the mid- and late 3rd millennium BC. Of course, it is also conceivable that cultural and ideological reasons may have led to reservations about tin bronze in Egypt. But Egypt’s trade links differed at the time, and the extreme shortage of tin in the 3rd and early 2nd millennium BC is probably more convincingly explained by the fact that Egypt was not really a part of common trade networks during this period. Nevertheless, the potential correlations between object function, composition and colour would repay closer investigation in the Egyptian case as well (Ogden 2000, 154 with examples).

**Tin bronzes in Syria and Mesopotamia**

The project systematically analysing metal objects from the 3rd millennium BC headed by H. Hauptmann and E. Pernicka was the first to produce a large database of metal analyses from Bronze Age sites in Syro-Mesopotamia (for older series of analyses, see Potts 1994, 154, n. 86 with references). Nearly three dozen locations with tin bronzes, notably in southern Mesopotamia, are worthy of mention (Fig. 16.5). Few sites with tin bronzes are known from the earlier 3rd millennium in Syro-Mesopotamia and none at all from the 4th millennium. Only from Tepe Gawra VII do we have a bronze pin with a tin content of 5.6% (Speiser 1935, 102; Yakar 1984, 70). The dating problems besetting Tepe Gawra are well known (cf. Butterlin 2002). For this reason, Tepe Gawra should not be considered evidence for the presence of tin bronze in Mesopotamia in the 4th millennium BC. Examples of early tin bronzes are the vessels from Kiš in southern Mesopotamia dating back to the Early Dynastic (ED) I period at the beginning of the 3rd millennium BC (Hauptmann and Pernicka 2004, 116, 118, pls 30.458, 35.580; Rahmstorf 2011a, 105, fig. 9.1, 3) and from Tell Qara Quzaq (Montero Fenollosa 1999, tab. 1) on the Syrian Euphrates. During this period (ED I) the word ‘bronze’ (Zabar) is mentioned for the first time in connection with a vessel in cuneiform (Reiter 1997, 292, 465). But it is only with the arrival of ED III that we observe a tremendous increase in the number of sites with tin bronzes (Tab. 16.1). ‘Tin-bronze is not attested by analyses as a consistent feature of Mesopotamian and Susian metallurgy until Early Dynastic III’ (Potts 1994, 154), which started around 2600 BC.

However, the ratio of tin bronzes at the individual sites is still very unevenly distributed. In Tello/Girsu there are almost no tin bronzes among the metal objects analysed, which are made of more or less pure copper or arsenical copper. By contrast, the ratio of tin bronzes in the large sample of metal objects from Ur (especially from the Royal Cemetery) is generally very high, but here again other copper-based alloys are present (Hauptmann and

**Table 16.1: Chronological distribution of tin bronzes from 28 sites in Mesopotamia between the Uruk and Akkad period (n = 157) (from Miller-Karpe 2004 and Helwing and Miller 2004)**

<table>
<thead>
<tr>
<th>Uruk</th>
<th>Gemdet Nasr</th>
<th>EDI</th>
<th>EDII</th>
<th>EDIII</th>
<th>Akkad</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>2</td>
<td>3</td>
<td>8</td>
<td>65</td>
<td>79</td>
</tr>
</tbody>
</table>
Pernicka 2004, 122–141). This finding corresponds well with the written documentation, where different concepts for specific metals appear to reflect the different chemical composition of the various types of copper and copper-based alloys (Waetzoldt and Bachmann 1984). In short, there may be many reasons for the irregular frequency of tin bronzes in Early Bronze Age Mesopotamia. First, the difficulties involved in getting at the remote ore deposits and organising the tin trade meant that demand was not consistently covered and needs could frequently not be satisfied. Second, in terms of the hardness, viscosity or colour of the final product, it is fair to assume that the different properties of the materials were intentionally and deliberately exploited. Since with the exception of colour, arsenical copper and tin bronze do not differ greatly in their material properties, it would have been easy for metal-workers to switch to arsenical copper. Often, arsenical copper, tin bronzes and bronzes containing both arsenic and tin occur simultaneously at individual sites in Mesopotamia (cf. Fleming et al. 2005). Finally, it is conceivable that certain types of object were made preferentially of a specific copper-based metal. An initial, not very sophisticated analysis of the published material does not point to any specific clusters. Vessels are often made of tin bronze, as are pins and weapons (Tab. 16.2). Differentiation may be possible by closer examination of individual sites or the chronological sequence, but this topic cannot be discussed here in any detail.

The sheer amounts of tin referred to in the texts can be quite considerable, e.g. over 30 kg tin (66.66 mines) in a text from Early Bronze Age Ebla. At this juncture, tin is no longer a rarity in the economic records (Reiter 1997, 268). The price of tin was also very high at Ebla, and the ratio to silver was 1:1.5. From the Akkadian period a ratio of 1:6 is attested (we have no other textual documentation from the Early Dynastic and Akkadian periods), but during the Ur III period at the very end of the 3rd millennium BC, the value ratios are closer to 1:12–1:30, while during the Old Babylonian period in the earlier stages of the 2nd millennium, the value relations leveling out at 1:10 (Reiter 1997, 273–276, appendix IV). This may imply a much more regular supply of tin to Mesopotamian cities in the late 3rd millennium than had been possible a few centuries before. The very high price in Ebla may also indicate a price increase for the material in trading from southern Mesopotamia to Syria. The depreciation from the middle of the 3rd to the earlier 2nd millennium BC is also noticeable for bronze. During the Early Dynastic and Akkadian periods, the value relation of silver to bronze was 1:12.8 and 1:9, while during the Old Babylonian period it was 1:120 (Reiter 1997, 334–336, appendix IV). The cities of Upper Mesopotamia are generally considered to have played a major role in the supply and trading of tin bronze during the second half of the 3rd millennium BC, especially between 2500 and 2300 BC (Lebeau 2006, 2; for the tin trade, especially in subsequent eras, see Mari 1985 and Schmidt 2005).

### Tin bronzes in Iran

The vases à la cachette hoard from Susa contained three vessels and a flat celt made of tin bronze (more than 7% tin). The hoard is dated to the ED IIIb period (Amiet 1986, 126; Benoit 2003, 304–305, n. 7 with further references). From this time on, tin bronzes appear regularly at Susa, but the ratio between these and all copper-based artefacts remains below 10%–15% in the second half of the 3rd millennium (Weeks 2003, 175 with further references). Apart from Susa, there are few other EBA sites with tin bronzes in Iran (Fig. 16.6). Among them are Giyan Tepe, Tepe Godin and Tal-i Malyan (see appendix). At the two latter sites, the tin bronzes originate from layers of the Kaftari phase, which covers not only the final centuries of the 3rd but also encompasses the first centuries of the 2nd millennium. Tepe Godin and Tal-i Malyan may therefore fall well out of the time range (until 2200/2100 BC) under consideration here. The point on the map for Tepe Hissar may perhaps distort the general picture because of 203 artefacts analysed, only two objects contained more than 1% tin (Pigott 1989, 32). At this site, arsenical copper was clearly the rule. Tin bronzes in Iran are comparatively rare. C. C. Lamberg-Karlovsky (in Weeks 2003, VIII) remarks: ‘There is a paucity, indeed a very great poverty, of contemporary tin-bronzes on the Iranian Plateau’. It is only with the arrival of the Iron Age that tin bronze becomes a common alloy in this region (cf. Helwing 2009, 213–214).

### Tin bronzes on the Persian Gulf and the Gulf of Oman

We owe our basic understanding of bronze metallurgy in the Persian Gulf to the fundamental and pioneering work of L. Weeks, which has brought the ‘tin problem’ much closer to a solution. Weeks analysed the composition of copper-based artifacts from several archaeological sites (Al Sufouh, Shimal, Tell Abraq) of the Umm al-Nar culture in the United Arab Emirates (Fig. 16.6). These bronzes often bear a high tin content (15–20%; Weeks 2003, 94–96, tab. 4.1–23, figs 4, 16–17). One individual sample even contained a significantly higher tin content (up to 52%), but the objects

---

**Table 16.2: Number of tin bronzes from 28 sites in Syro-Mesopotamia representing specific object groups between the Uruk and Akkad period (n = 205) (from Müller-Karpe 2004 and Helwing and Müller 2004)**

<table>
<thead>
<tr>
<th>Vessel</th>
<th>Pin</th>
<th>Dagger</th>
<th>Axe</th>
<th>Spear/Bident</th>
<th>Celt</th>
<th>Chisel</th>
<th>Ring</th>
<th>Toilet set</th>
<th>Figure</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>45</td>
<td>25</td>
<td>23</td>
<td>17</td>
<td>10</td>
<td>7</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>5</td>
</tr>
</tbody>
</table>
in question were subject to progressive corrosion, which increased the percentage of tin (Weeks 2003, 95–96). The objects are primarily rings or fragments of rings. The high-percentage tin bronzes from Shimal and Tell Abraq in the Emirates are particularly striking, since in the central Gulf and Oman there are no, or only minute, indications for tin bronzes dating from the 3rd millennium BC. In addition, Weeks carried out lead-isotope analyses that yielded very similar results to the tin bronzes from the Aegean andVelikent in the North Caucasus. This may indicate that the tin in the bronzes originates from the same deposit(s) (Weeks in Kohl 2002, 178–183; Weeks 2003, 163; L.).

Tin bronzes in Baluchistan, the Indus Valley and north-west India

It is still difficult to judge the role tin bronze really played in the Harappan culture. One reason is that only relatively few copper-based artefacts from different sites have been analysed. As tin bronze seems not to be very common, this might indicate the irregular use of tin bronze in the Harappan culture, which would by no means be unusual in comparison to some of the other regions already discussed. After all, there are eight Harappan sites that have yielded up bronzes with (in some cases) a high tin content. Of the sampled objects, 30% had a tin content of more than 1% (Agrawal 1984, fig. 6; Lahihi 1995, 123, tab. 2; Anthony 2007, 419). For example, three of the six analysed metal artifacts from Rangpur dating to the second half of the 3rd millennium (Rangpur period IIA) are tin bronzes (a celt, a hollow bangle and a pin with 4% and nearly 7% tin, respectively). Three other objects from period IIA only have trace amounts of tin (Rao 1962–63, 149–153 [nos 141, 169, 663], fig. 55, 1. 6). In Mohenjodaro and Harappa, almost one third of the objects analysed have a
tin content of more than 1% (Agrawal 1984, 164; Weeks 2003, 177).

**Tin bronzes in central Asia**

Before the late 3rd millennium, *i.e.* before Namazga V, tin bronzes from central Asia are very rare (Fig. 16.6). This is a sound assertion given that some 1800 copper-based artefacts from the Bronze Age of central Asia (Turkmenistan, Uzbekistan, Tajikistan – but not Kyrgyzstan) have been analysed. The beginning of Namazga V is usually dated to c. 2300 or 2200 BC. A bronze rod with 7% tin from Aktepe at the lower Kopet Dag in southern Turkmenistan can be dated prior to this period (Ruzanov 1999, 104). From the Middle Bronze Age (Namazga V) about 10% of the copper-based artefacts are tin bronzes. From the BMAC (Bactria-Margiana Archaeological Complex), early Namazga VI and the beginnings of the Sapalli culture (in local terminology the Late Bronze Age!), only about 10% of the copper-based objects are tin bronzes, for example those in Daşly 3 (Anthony 2007, 425 with references) or at Altynt-Depe, where arsenical copper is typical and not tin bronze (Salvatori et al. 2002, 86–87). It was not until the Late Bronze Age II from c. 1700 BC onwards that the ratio increases to 30–45% (see Kaniuth 2007, 29–31, tabs 1–2 and Ruzanov 1999, 104). But from the middle of the 2nd millennium BC and the Andronovo culture, the ratio of tin bronzes nearly reaches 100% in the Eurasian steppe region (Kaniuth 2006, 169, n. 921 with further references). Information on Afghanistan is unfortunately absent due to lack of excavations and metal analyses. However, from a late stage of settlement phase III (early 3rd millennium BC) at Mundigak, we have an axe with 5% tin (Casal 1961, 244, 246-247, 249, fig. 139, 10, pl. XXXIX, B; Rahmstorf 2011a, 105, fig. 9.1 4), and some objects from Mundigak I in the late 4th millennium BC already contain at least about 1% tin (intentional alloys?). Not enough metal objects have been analysed from the 3rd millennium BC of Shortugai (I–II) (Francfort 1989, 75, 208) for us to assess whether and to what extent tin bronze was used at this site.

**Tin bronzes, tin deposits and trade in tin during the 3rd millennium BC: some results**

Promising new results suggest that in future it may be possible to determine the origin of tin by means of tin isotopes. For example, preliminary results have shown that the tin of the Nebra Sky Disc cannot come from the Erzgebirge or the Vogtland (Haustein and Pernicka 2008, 413–414). As with lead-isotope studies, the source cannot be determined beyond doubt, as only similarities and dissimilarities in the isotope ratios can be observed. The development of tin-isotope analysis is still in its infancy, and it is not yet clear whether all potential tin resources are chemically distinct. But more and more research teams are starting to test the potential of this new method (Haustein et al. 2010; Yamazaki et al. 2013; Molofsky et al. 2014; Nessel et al. 2014; Mason et al. 2016). In the meantime, all we can do is to use the results produced by lead-isotope analysis. The isotopic composition of the lead in an ore deposit is more or less constant and cannot be changed by chemical reactions caused by melting or corrosion (Nezafati et al. 2011, 223). The lead-isotope ratios of a deposit can therefore be regarded as a kind of fingerprint compared with those of finished products. Nevertheless, it may be that not all deposits are measurably different from each other (Begemann and Schmitt-Strecker 2008, 126–128). Re-melting and mixing of copper-based artefacts can distort the results considerably. Similarly, good interpretive results are only to be expected if the metal was not melted together from different deposits. Primarily, the lead will have come into the tin bronze with the copper, so lead-isotope analysis provides evidence of whether local copper was used or not. Accordingly, the local deposits have to be determined for their lead-isotope ratios. If this does not coincide with the signature of the sampled artifacts, one can be sure that the copper was brought in from elsewhere. Hence a very large database with the signatures of all European and Asian deposits is needed (and in part has already been built up) to verify potential sources of origin in the elimination procedure. Without results from the promising tin-isotope method not yet available, I shall give a brief summary here of the evidence for the possible exchange and trade of tin in the 3rd millennium BC. Lead-isotope analysis provides some clues. There has long been considerable controversy about whether there were tin deposits in the Aegean and Anatolia worth mining and whether they were identifiable by the ancient prospectors and metal-workers of the Early Bronze Age. As we have seen, the earliest tin bronzes occur in the Aegean at an early stage just after the beginning of the 3rd millennium, which has been taken by some as evidence of an indigenous development in bronze metallurgy. However, although numerous intensive archaeometallurgical surveys have been undertaken in recent decades in Greece and Turkey, not one undisputed deposit has been identified (Pernicka et al. 2003, 146).

The significance of the deposits at Kestel in the Taurus mountains of Turkey remains highly controversial. This was first presented in 1989 (Yener et al. 1989) as a kind of solution for the ‘tin problem’ (cf. Weeks 2003, 167–169, 180–181). The deposits only have minor concentrations of cassiterite (0.1–1%). By modern, but perhaps not by prehistoric standards, mining tin would not have been worthwhile or would at least have been very difficult (Muhly 1993, 246). While the ancient shafts and galleries that have been preserved do indicate ore mining both prehistoric and historical, it remains unclear which metal was in fact being mined at the site. At the nearby EBA settlement of Göltepe, tools for the processing of ores and powdered ore have been
found (Earl and Özbål 1996, 289, 298; Yener 2000, 73–74). Concentrations of tin oxide were traceable in crucibles, but the individual results of analysis are contradictory (cf. the comments by Weeks 2003, 169 with references). Projections of the tin that could have been gained amount to only a few hundred kilograms, and this would have been obtained over a period of several hundred years (Bachmann 2004, 257). E. Pernicka points out that the glazed interiors of the crucibles with traces of tin oxide may have been caused by the fusion of loose gold grains. Accordingly, he feels that Kestel is more likely to have been a gold mine. In addition, cassiterite occurs at Kestel in mineralization with hematite and could therefore not have been detected by the ancient metallurgists (Pernicka 1998, 143). There are other arguments against the claim that during the Early Bronze Age much of the east Mediterranean and Near Eastern tin originated from Kestel and Gültepe. Lead-isotope studies by E. Pernicka, F. Begemann and others demonstrate that the copper of many EBA artefacts cannot have come from the Aegean or Anatolia because of its high precambrian age, which does not occur geologically in this region (Pernicka et al. 1984; Pernicka et al. 1990; Begemann et al. 1992; Pernicka 1998, fig. 2). Such copper is in fact typical of central Asia and Afghanistan. Thus, the conclusion for Kestel must be that ‘die Lagerstätte […] in der Zinnversorgung der Bronzezeit, wenn überhaupt, höchstens lokale Bedeutung gehabt haben kann’ (in terms of Bronze Age tin supply, its significance can only have been local at best: Hauptmann 2007, 568).

In addition, cuneiform sources (literary sources, lexical lists, royal inscriptions and administrative texts) from 3rd-millennium Mesopotamia consistently point to the east when tin is mentioned, even if the geographic terms used sometimes make it difficult to pinpoint the locations that are being referred to (cf. Potts 1994, 9–36, fig. 2; Reiter 1997, 4, 7, 156; Steinkeller 2016, 133). In particular, the regions Dilmun (probably Bahrain/eastern Arabia), Magan (probably United Arabian Emirates and Oman) and Meluhha (probably Baluchistan and the Indus region) referred to in the texts can be sufficiently well localised (Reiter 1997, 212–258; Weeks 2003, 178–180 with further references). Nothing in the written sources indicates that tin may have come from the west. Nevertheless, most recent fieldwork indicates that tin may have been mined at Hisarcık near Kültepe in central Anatolia in the later stages of the 3rd millennium BC (Lehner 2014, 31–34; Yener et al. 2015). This is especially challenging evidence in the light of the cuneiform texts from Karum Kanis/Kültepe documenting extensive importation of tin from Mesopotamia to central Anatolia during the 19th century BC.

Investigations of metal objects from different locations in the United Arab Emirates on the Persian Gulf and the overall evaluation by L. Weeks have yielded interesting new results. Firstly, the lead-isotope ratios observed are similar to those from the EBA sites in the Aegean (Kastri, Thermi, Poliochni, Troy), Montenegro (Velika Gruda) and Dagestan in North Caucasus (Velikent). The lead-isotope ratios present in some Aegean tin bronzes indicate that the copper cannot have come from the Aegean-Anatolian region. This suggests that the copper or the bronze was imported, probably already as an alloy, and that this material may have originated from the same deposit(s). Since tin bronzes with high tin content from the United Arabian Emirates in the Persian Gulf are primarily small rings or the fragments left of them, it would be worth considering whether bronze or tin may not have been imported in the form of bronze rings/ingots. I have pointed out elsewhere (Rahmstorf 2010, 686–688, fig. 7) that tin bronzes from the eastern Mediterranean to the Indus region are frequently encountered in the shape of rings. Another clue is given by the written evidence, which suggests that metal was stored and transported in a ring form of some kind (Powell 1978, 213; Reiter 1997, 87–88, 334). Finally, we need to consider the shape of the earliest tin objects, for example, the famous tin bangle from Thermai on the east Aegean island of Lesbos or the oldest tin objects from central Europe, which are sectioned rings or beads (Primas 2002, 311–312). It would be worthwhile examining some questions in further detail, for example whether and to what extent rings were used as ingots during the 3rd millennium BC as in the Harappan culture, since they are remarkably common as tin bronzes in the Persian Gulf. Both L. Weeks and T. Potts assume that the tin or bronze reached the Persian Gulf during the Bronze Age via the Arabian Sea from Baluchistan and the Indus, i.e. the geographical sphere of the Harappan culture (Potts 1994, 281; Weeks 2003, 186, 200) and that the ‘Harappans’ controlled the tin trade. To clarify this question, we would need a concerted research programme involving the chemical examination of large series of copper-based artefacts of the Harappan culture plus lead-isotope analyses. Research programmes with lead-isotope studies have only recently begun in the Indus (Law and Burton 2006; Hoffman and Miller 2014) and there are fundamental obstacles: ‘There is no comparative database of geological isotopic values from many potential sources surrounding the Indus, and there are potential logistical difficulties in obtaining the samples from several of these possible source areas’ (Hoffman and Miller 2014, 703). Without these investigations, it can only be assumed that it was most likely the ‘Harappans’ who organised the tin/bronze trade westward across the Persian Gulf. The proximity and thus the possible control of the tin deposits in Afghanistan could have been a great advantage for traders of the Harappan culture. Locations such as Shortugai acted as Harappan trading bases in Afghanistan from which the trade of tin, gold and lapis lazuli to the Indus Valley was organised, although admittedly all these materials have hardly been found in Shortugai itself (however, we should bear in mind that hardly any tin or silver dating to the early 2nd millennium BC has been excavated at the well-known
trading center of Karum Kanesh in central Anatolia although we know that dozens of tons of tin are referred to in the cuneiform texts from this site). In southern Afghanistan, the deposits of Mesgaran (with up to 6.6% tin content in the ore), in Herat and in the Iranian–Afghan–Pakistani border area would have been convenient sources of tin for the Harappan culture (Kaniuth 2006, 170; Nezafati et al. 2011, tab. 2 with references). Without fieldwork, which in this region will hardly be possible in the foreseeable future, such claims must unfortunately remain conjectures for the moment.

The central Asian region and, further north, the Eurasian steppe region cannot be regarded as the origin of early tin bronzes in the Near East because there are not many tin bronzes known from this region at all before 2200 BC. In the Eurasian steppes, the use of tin bronze does not occur before the Okunovo culture, where it has been detected in bronzes of the Sejma-Turbino type (Parzinger 2003, 160–164, 175, figs 2–3). The central Asian tin deposits sometimes displaying traces of mining at Karmah, Lapas and Çangali in Uzbekistan, at Mušiston (a site that gave its name to the copper-tin ore mushistonite, which may be up to 34% tin, see Nezafati et al. 2011, tab. 2) and Takfon in Tajikistan and now also in Kalai Topkan, Novaya Schulba and Askaraly in Kazakhstan (Stöllner et al. 2011) cannot help in solving the ‘tin problem’ for the early and middle 3rd millennium BC because so far tin mining has only been documented via field work relating to the turn of the 3rd to the 2nd millennium BC at the earliest (Parzinger and Boroffka 2003; Cierny et al. 2005). In my view, this evidence only leaves the Afghan area as a possible origin of tin demand in the Near East and the eastern Mediterranean during the earlier and middle 3rd millennium BC. Recently, the relatively small Deh Hosein deposit in the central eastern part of the Zagros Mountains in western Iran has been referred to as a possible origin of this early tin. In some cases, the lead-isotope analyses show a good correlation with analysed objects from Luristan (2nd and 1st millennium, partly also 3rd millennium BC). Some objects from the Persian Gulf, Mesopotamia and sometimes even the Aegean have similar isotopic ratios. But there is still no proof that Deh Hosein might be the area of origin for tin in the 3rd millennium, because once again the mining remains from Deh Hosein have as yet only been dated to the 2nd millennium BC, not before (Nezafati et al. 2006; Nezafati et al. 2011, 225).

For the 3rd millennium BC, we can rule out tin deposits in Europe having any significance for tin supply in the Near East and the East Mediterranean, although this has been suggested (e.g. Gerloff 1993, 86). As we have seen, tin bronzes are very rare at this time in Europe (outside the Aegean area) and this is a very serious argument against the region (as in the case of central Asia referred to earlier). However, it is certainly no coincidence that almost all early tin-bronze sites in central and southern Europe can be connected to the Bell Beaker phenomenon.

The particular affinity of the ‘Bell Beaker people’ to metals such as copper, and more importantly to gold and silver (Meller 2014, 616–620, figs 3–4), is further indicated by the numerous burials of metal craftsmen (e.g. Fitzpatrick 2009, 180–181). Also, the mobility of at least some Bell Beaker individuals was very high (Chenery and Evans 2011). They may have brought initial knowledge of the bronze alloy to central, western and southern Europe. The case of Velikent, though pre-Bell Beaker in date, indicates that assumptions about initial impulses from the Aegean and the eastern Mediterranean world should not be excluded outright as an explanatory hypothesis.

This survey of the use of tin bronzes before c. 2200 BC in the large area extending from the Atlantic to the Indus region can only afford a glimpse of the complicated issues posed by the early occurrence of tin bronzes. If we consulted all the recently published site reports, most likely dozens of sites could be added. This survey covers the evidence known to me until 2011. It also falls short in terms of an in-depth analysis of the data. For example, more precise dating and chronological mapping of the sites with tin bronzes would be possible. A detailed contextual analysis of the find spots (where were they, what else was found?) at the various sites could also be rewarding. Another question of interest is the kind of objects produced using this material. Early tin bronzes were objects of adornment, weapons or tools. No clear preference is detectable, but maybe regional differences will emerge. Finally, tin bronze was often only one option among the different copper-based alloys metal-workers could intentionally produce during the 3rd millennium BC. It has been emphasised that ‘at least originally, the preference of tin bronze over arsenic bronze was an aesthetic and cultural choice, and not a utility consideration’ (Steinkeller 2016, 136). It would be especially interesting to differentiate (regionally, chronologically, contextually and in object classes) between copper, arsenical copper and tin bronze (cf. Chernykh 1992 and Wilkinson 2014). It seems that the significance of tin bronze has been exaggerated since the beginnings of Bronze Age archaeology, in part quite simply because the material gave the whole period its name. In addition, as T. C. Wilkinson put it recently, ‘the simple view of a unilinear technological evolution in which the discovery of the functional advantages of arsenic-bronze, then tin-bronze, facilitate the replacement of one material by another, does not account for the complex patterns of metal consumption’ (Wilkinson 2014, 189).

Appendix: Tin bronze objects before c. 2200 BC (cf. also Jablonka 2014, fig. 10)

1. Jeziorno Gopło, Poland (Matuschik 1997, 87, 103, fig. 6; Krause 2003, 212, fig. 192)
2. Altenmarkt, Germany (Krause 2003, 211, 213)
3. Gnetsch, Germany (Krause 2003, 211–212)
4. Landau, Germany (Krause 2003, 211, 213)
5. Chevroux, Switzerland (Krause 2003, 211–212)
6. St. Blaise, Switzerland (Krause 2003, 211–212)
7. Bohdalice, Czech Republic (Junghans et al. 1968, cat. no. 3248)
8. Bylny, Czech Republic (Junghans et al. 1968, cat. no. 3238)
9. Ledce, Czech Republic (Junghans et al. 1968, cat. no. 19935)
10. Smolin, Czech Republic (Novotný 1958, fig. 5, 13; Junghans et al. 1974, cat. no. 19936)
11. Vukovar, Croatia (Schmidt 1945, 71, pl. 28, 7; Junghans et al. 1968, cat. no. 2004)
12. Abri du Capitaine, Montpezat, France (Pare 2000b, 22)
13. Bauma del Serrat del Pont (Gerona), Spain (Alcalde et al. 1998; Pare 2000b, 22)
14. Guido A Reoso, Illa de Arousa, Spain (Comendant Rey 1999; Pare 2000b, 22)
15. Barro/Torres Vedras, Portugal (Spindler 1981, 102–103, fig. 41, 4)
16. Val Frascarese, Italy (Campana et al. 1996)
17. Poggio Olivastro, Itaz (Bulgarelli and Giumlia-Mair 2008)
18. Ovcharitsa, Bulgaria (Leshtakov 1996, 250)
19. Mudrets (Tell), Bulgaria (Leshtakov 1996, 250)
20. Vasilia (?), Bulgaria [source missing, could not be verified]
22. Aghios Kosmas, Greece (Mylonas 1959, 101, fig. 163, 13; McGeehan-Liritzis and Taylor 1987, 294, tab. 1)
23. Axiochori-Vardaropitsa, Greece (Maran 1998, 268 with further reference)
24. Dokathismata/Amorgos, Greece (Maran 1998, 268; Rambach 2000, 13, pl. 3, 9–10)
25. Kastri/Syros, Greece (Bosseret 1967, 63, 76; Maran 1998, 269, n. 1128)
26. Kras/Kreta, Greece (Marinatos 1929, 119, 131, fig. 13, 30–31; Muhly 2006, 170)
27. Lithares, Greece (TZavela-Evjen 1984, 140, n. 657, 663; Kayafa et al. 2000, 41–42, tab. 2.2.)
28. Manika, Greece (Sampson 1985, 177, 305–306; Maran 1998, 268)
30. Perivolaki-Saratse (?), Greece (Maran 1998, 268 with further references)
31. Poliochni/Lemnos, Greece (Pernicka et al. 1990; Maran 1998, 269, n. 1330 with further references)
32. Sitagroi, Greece (McGeehan-Liritzis and Taylor 1987, 293, tab. 1; Maran 1998, 267, n. 1106–1007 with further references)
34. Thermai/Lesbos, Greece (Begemann et al. 1992, tab. 1–2; Tin ring: Lamb 1936, 165, 171–172, fig. 50, 30.24; Pernicka 2001, 370, fig. 410)
35. Tırıns, Greece (Kilian 1982, 421, fig. 44, 5)
36. Ahtalibel, Turkey (Earl and Özel 1996)
37. Alaca Höyük, Turkey (Kaptan 1990, 76 with references)
38. Alişar Höyük, Turkey (von der Osten 1937, 92–93)
39. Aphrodisias, Turkey (Joukowsky 1986, 511, 519, fig. 368, 372, 374, 15–16 [not securely analysed])
40. Arslantepe, Turkey (Bobokhyan 2008, 67 with references)
41. Beşiktepe, Turkey (Pare 2000b, 9; Begemann et al. 2003)
42. Bakla Tepe, Turkey (Şahoğlu 2005, 247–249, n. 9)
43. Demircihüyük, Turkey (Bachmann et al. 1987, 23) [traces of tin in mould]; Demircihüyük-Sarket, Turkey (Pernicka 2000)
44. Gültepe/Kestel, Turkey (Earl and Özel 1996, tab. 6)
45. Güzelova, Turkey (Bobokhyan 2008, 67)
46. Horoztepe, Turkey (Earl and Özel 1996)
47. Judaida (Tell), Turkey (Yener 2009, 144–145 with further references)
48. Karataş-Semayük, Turkey (Warner 1994, 207)
49. Kayapınar, Turkey (Reeves 2003, Appendix 2 – generally referred to as bronze, but apparently no analyses performed)
50. Kusura, Turkey (Lamb 1936, 214–215)
51. Mahmatlar, Turkey (Earl and Özel 1996)
52. Mersin, Turkey (Giardino et al. 2003, 389)
53. Norşuntepe, Turkey (Bobokhyan 2008, 628, pl. 15)
54. Resuloğlu, Turkey (Zimmermann 2007, fig. 6)
55. Tarsus, Turkey (Kurucayırıl and Özel 2005 with further references)
56. Tiriş Höyük, Turkey (Palmieri and di Nocera 2004, 380, fig. 2, tab. 1)
57. Troia, Turkey (Pernicka et al. 1989, 575, 578, tabs 3–4)
58. Tülüntep, Turkey (Yalçın and Yalçın 2008)
59. Van, Turkey (Bobokhyan 2008, 628, pl. 15)
60. Yortan, Turkey (Pernicka et al. 1984 575, 579, tab. 3–4)
61. Zeytinli Bahçe, Turkey (Palmieri and di Nocera 2004, 380, fig. 3)
62. Velikent, Russia (Gadzhiev et al. 1997, fig. 8, 3; Kohl 2002, 174, fig. 12; Kohl 2003, 19, fig. 1, 7; Peterson 2003, tab. 2.1–2)
63. Ananuri, Georgia (Apakidze 1999, fig. 2)
64. Bakurcixe, Georgia (Kavtaradze 1999, 86, 97; Apakidze 2002, 762)
65. Bedeni, Georgia (Bobokhyan 2008, 67)
66. Tsnori/Cnori, Georgia (Apakidze 1999, fig. 2)
67. Martkopi, Georgia (Kavtaradze 1999, 84, 97; Apakidze 2002, 762)
68. Telebi, Georgia (Kavtaradze 1999, 84–86, 96; Apakidze 2002, 761–762)
69. Talin, Armenia (Meliksetyan et al. 2003, 310, 314)
70. Gymuri, Armenia (Apakidze 1999, fig. 2)
71. Kirovakan, Armenien (Bobokhyany 2008, 67 with further references)
72. Metsamor, Armenien (Bobokhyany 2008, 628, pl. 15)
73. Shengavit, Armenien (Bobokhyany 2008, 67 with further references)
74. Chatschkenaget, Aserbaidschan (Bobokhyany 2008, 67)
75. (Vasilia?) Kolokassides Hort, Zypern (Webb et al. 2006, 268, tab. 2, figs 1, 2, 4, 8)
76. Sotira Kaminoudhia, Zypern (Swiny 2003, 376–379, fig. 8.1, M13, M14, M21, M22; Giardino et al. 2003, 388–390, pl. 8.1.1)
77. Byblos, Libanon (Montero Fenollós 2001, 276 with reference)
78. Sultán (Tell es-), Jericho, Palestine (Prag 1974, 91, n. 63)
79. Bab edh-Dhra, Jordanien (Maddin et al. 2003, 513)
80. Hирbet ez-Zeraqon, Jordanien (Hauptmann 2000, 180)
81. Aydmos, Egypt (Pernicka and Schleiter 1997, 221, tab. 2)
82. Buto, Egypt (Cowell 1987, 96–118)
83. Ahmar (Tell)/Til Barsip, Syria (Lutz 2004, 148)
85. Brak (Tell), Syria (Oates et al. 2001)
86. Halawa (Tell), Syria (Lutz 2004, 148)
87. Hariri (Tell)/Mari, Syria (Lutz 2004, 149)
88. Mardikh (Tell)/Ebla, Syria (Peyronel 2012, fig. 3)
89. Qara Quzaq/Qarab Qazak, Syria (Montero Fenollés 2001, 275)
90. Ras Shamra/Ugarit, Syria (Montero Fenollés 2001, 276 with reference)
91. Sweihat (Tell), Syria (Montero Fenollés 2001, 276 with reference)
92. Abu Qasim (Tell), Iraq (Lutz 2004, 110)
93. Abu Salabikh (Tell), Iraq (Lutz 2004, 110)
94. Agrebi (Tell), Iraq (Lutz 2004, 110)
95. Asmar (Tell)/Eshounni, Iraq (Lutz 2004, 110–111)
96. Basmusian (Tell), Iraq (Lutz 2004, 112)
97. Fara/Šurupak, Iraq (Lutz 2004, 113)
98. Gawra (Tepe), Iraq (Lutz 2004, 113–114)
100. Khafadje/Tubub, Iraq (Lutz 2004, 115)
103. Mazhur (Tell), Iraq (Lutz 2004, 120)
104. Muqayyar (Tell al-)/Ur, Iraq (Lutz 2004, 123–141).
105. Nuffar/Nippur, Iraq (Lutz 2004, 120)
106. Oheimir (Tell el-)/Kiš, Iraq (Lutz 2004, 116–119)
107. Razuk (Tell), Iraq (Lutz 2004, 120)
108. Senkereh (Tell-es)/Larsa, Iraq (Lutz 2004, 120)
109. Sulaima (Tell as-), Iraq (Lutz 2004, 121–122)
110. Taya (Tell), Iraq (Lutz 2004, 122)
111. Tello/Girsu, Iraq (Lutz 2004, 122, 144–148)
112. Ubaid (Tell el-), Iraq (Lutz 2004, 122–123)
113. Umm al-Ağāq, Iraq (Lutz 2004, 123)
114. Uqair (Tell al-), Iraq (Lutz 2004, 123)
115. Warka/Uruk, Iraq (Lutz 2004, 141–143)
116. Yahlī (Tell), Iraq (Lutz 2004, 143)
117. Giyan (Tepe), Iran (Weeks 2003, 175 with reference)
118. Godin (Tepe), Iran (Weeks 2003, 175 with reference)
119. Kalleh Nissar, Iran (Fleming et al. 2005, 36–38, tab. 1)
120. Malyan (Tal-i), Iran (Pigott 2003, tab. 14.1)
121. Susa, Iran (Weeks 2003, 175 with reference; Benoist 2003, 304–305, n. 7)
122. Sialk, Iran (Ghirshman 1938)
123. Tepe Hissar, Iran (Pigott 1989, 32)
124. Tepe Yahya, Iran (Heskel and Lamberg-Karlovsky 1980)
126. Umm an-Nar, United Arab Emirates (Weeks 2003, 96 with reference)
127. Al Sufouh, United Arab Emirates (Weeks 2003, 72, tab. 4.1)
128. Tell Abraq, United Arab Emirates (Weeks 2003, 75, tab. 4.4)
129. Shimāl, United Arab Emirates (Weeks 2003, 73, tab. 4.2–3)
130. Chanhu-daro, Pakistan (Lahiri 1995, tab. 2)
131. Harappa, Pakistan (Agrawal 1984, 164)
132. Mehī, Pakistan (Marshall 1931, 488; Asthana 1993, 277)
133. Mohenjo-daro, Pakistan (Agrawal 1984, 164)
134. Segak, Pakistan (Marshall 1931, 488; Asthana 1993, 277)
135. Shahī Tump (Nundara), Pakistan (Marshall 1931, 488; Asthana 1993, 277)
136. Shahī Damb, Pakistan (Marshall 1931, 488; Asthana 1993, 277)
137. Kalibangan, India (Lal et al. 2003, 265–266)
138. Lothal, India (Lahiri 1995, tab. 2)
139. Rangpur, India (Agrawal 1984, 164)
140. Rojdi, India (Lahiri 1995, tab. 2)
141. Surkotada, India (Lahiri 1995, tab. 2)
142. Mundigak, Afghanistan (Casal 1961, 244, 246–247, 249, fig. 139, 10a, pl. XXXIX, B)
143. Akepte, Turkmenistan (Ruzanov 1999, 104)
144. Altyn-Depe, Turkmenistan (Salvatori et al. 2002, 86–87; Masoli et al. 2006)

Notes
1. I would like to thank Joseph Maran and Philipp W. Stockhammer for the invitation to the conference and the anonymous referee and the editors for suggestions for improvement. This paper is not the written version of the talk I gave in Heidelberg ‘And
Childe was right after all? Vere Gordon Childe’s thoughts on immigrant craftsmen, prospectors and the dissemination of key economic innovations during the 3rd millennium BC in the light of recent scholarship. Unfortunately, due to time restraints it was not possible for me to write this paper at the time, though some archaeological evidence presented in my talk can be found in a recently published paper (Rahmstorff 2015). This contribution is a slightly modified chapter from my Habilitation thesis ‘Studien zu Gewichtsmetrologie und Kulturkontakt im 3. Jahrtausend v. Chr.’, which was submitted at the University of Mainz in 2012 and which is currently being prepared for publication. The chapter will not be included in this forthcoming monograph, but this almost exclusively material survey may still prove useful, especially in the proceedings of a conference that is focussing on tin bronze as an important innovation.

Very recently, P. Jablonka presented a map with early bronzes that is similar in its geographical range (Jablonka 2014, fig. 10), but it only includes 116 sites. However, his list also contains 17 sites not included in the distribution maps presented here. They were either unknown to me or I believe that either their dates (e.g. finds from Middle Bronze Age Emenska Pest, cf. Pare 2000b, 13 or ‘Final Neolithik’ tin bronzes in central Europe, cf. above) or their analytical results (e.g. Ezerovo II, cf. Pare 2000b, 13) suggest that their relevance is questionable. We may confidently hope that future work will create web-based databases and distribution maps of such material evidence that will permit continuous addition to what we have already and enable specialized researchers to engage in critical reflection on the material.

References


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


