Chapter 7
Ancient Technology and Archaeological Cultures: Understanding the Earliest Metallurgy in Eurasia

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Introduction

The appearance of the earliest metal objects and metal production practices in Eurasia has traditionally been seen as an argument between single and multiple inventions, following either Wertime (1964, 1973) or Renfrew (1969). The recent dating of copper smelting at Belovode, Serbia to c. 5000 BC, making it the earliest currently known evidence in the world, has served to reinvigorate these debates (Radivojević et al. 2010). The continuing proliferation of archaeometallurgical analyses on material from radiocarbon dated sites from Ireland to Thailand probably ensures their continuation but it also provides far more data which can be used to construct new models and interpretations of early metallurgy throughout Eurasia (Roberts et al. 2009; Thornton et al. 2010). The trends in global early metallurgy away from concentrating upon "origins" debates and towards the identification of mechanisms underlying technological transmission; the processes of adoption and adaptation; cross-craftsmanship and cross-material connections; and the role of metal in social dynamics are certainly encouraging. These are accompanied by the widespread, and perhaps long overdue, recognition that the appearance of metal should not automatically be equated with the emergence of elites and neither should it be assumed to be a cause of social change or even an important material within communities (Thornton and Roberts 2009). These trends are a reflection of the wider development of archaeometallurgy into a discipline that seeks to understand past societies through their metallurgy by drawing upon scientific and archaeological/anthropological methods of inquiry (Thornton 2009a).

It would appear that the old culture-historical frameworks, together their associated explanations of migration and diffusion, have finally been supplanted and can be discarded. The obvious obstacle to this is that all past experience of theoretical

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development in archaeology indicates that archaeological cultures remain in use, at the very least as classificatory tools, regardless of their pronounced demise (see Chap. 2). The adoption of metal attracted the early attention of two of the most influential practitioners of New Archaeology – both Lewis Binford (e.g. Binford 1962) and Colin Renfrew (Renfrew 1967, 1969, 1973, 1986) published extensive critiques of archaeological cultures together with proposals of new systemic approaches. Yet, the recent publication of papers spanning global early metallurgy by theoretically informed scholars, including this author, all involved archaeological cultures, suggesting at least a delayed abandonment of the concept (see papers in *Journal of World Prehistory* 22, 3–4). This tenacity is perhaps not so surprising given that the justifiably maligned Three Age system, whereby the appearance of metal structures the history of vast expanses of the human experience (see Rowley-Conwy 2007), remains firmly entrenched in Eurasia. The debates surrounding whether several copper objects within an archaeological culture or region should necessitate the addition of Fourth Age, if this should be termed Chalcolithic, Eneolithic or Copper Age, and whether this represents broader societal changes, continue even to this day (e.g. Childe 1944; Lichardus and Echt 1991; Chernykh 1992, 10–16; Guilaine 2006; Roberts and Frieman forthcoming a).

The purpose of this chapter is to evaluate the role that archaeological cultures could play in understanding the earliest metallurgy in Eurasia by going beyond using archaeological cultures to provide either the identity of the people responsible for bringing metallurgy or the identity of the metal objects being discussed. It seeks to build on an earlier article reviewing the early development of metallurgy in Eurasia (Roberts et al. 2009). It summarises the earliest dates for metal objects and metal production practices contained within it before proposing models for metallurgical transmission and metallurgical adoption and then exploring these in relation to archaeological cultures. Analysing the transmission and adoption of the earliest metallurgy requires an approach which systematically addresses the metallurgical knowledge, skills and equipment that would be required to perform each identifiable transformation from ore to metal – encompassing the prospecting, extraction, processing, smelting and casting and comparing them to pre-existing technologies (see Ottaway 2001; Roberts 2008a; Ottaway and Roberts 2008). This structure facilitates a cross-craft and cross-material comparison, whereby the choices identified as shaping metal are not understood in isolation but are instead interpreted relative to research on other contemporary and associated materials (e.g. Shimada 2007; Roberts and Frieman forthcoming a and b) as well as to burial, settlement and subsistence practices, which together with craft production, underpin the definition of archaeological cultures.

Earliest Metal Objects and Metal Production in Eurasia

The exploitation of copper ores and naturally occurring copper in southwest Asia by early agricultural and agro-pastoral communities as at Rosh Horesha in Israel (Bar-Yosef Mayer and Porat 2008) to Shanidar Cave in northeast Iraq (Yener 2000)

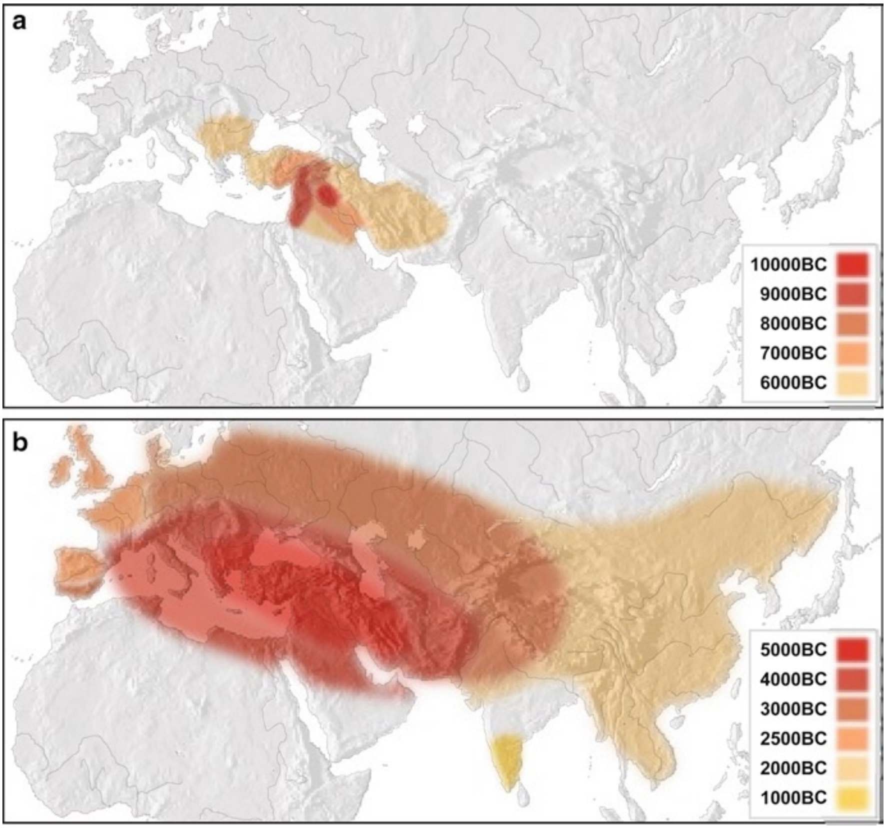

Fig. 7.1 (**a**) The spread of copper ore and native copper use in Eurasia. The exploitation of copper ores and naturally occurring copper metal in Eurasia. (**b**) The spread of copper smelting technology in Eurasia

from the 11th to 9th millennium BC represents the earliest evidence in Eurasia (Fig. 7.1a). It is within this region that the earliest annealing of copper metal is evidenced at Cayönü Tepesi, east Turkey at the end of the ninth millennium BC (Maddin et al. 1999) as well as the earliest probable smelted metal, the lead bracelet from Yarim Tepe, dating to the seventh millennium BC (Schoop 1999). The appearance of copper objects further afield occurs during the late eighth millennium BC as at Tell Ramad in southwestern Syria (Golden 2009) and Ali Kosh in southwestern Iran (Thornton 2009b). By the end of the seventh millennium BC, copper is exploited as far east as Mehrgarh in central Pakistan (Moulherat et al. 2002) and potentially as far west as Rudna Glava, Serbia (Borić 2009). On the current evidence, the appearance of copper beyond these two sites is related to the later appearance of copper smelting technology rather than the manipulation of ores or naturally occurring copper metal.

The earliest evidence for copper smelting is securely dated at Belovode, Serbia to the end of the sixth millennium BC (Radivojević et al. 2010) followed by the less securely dated Tal-i-Iblis, southeast Iran to the early fifth millennium BC (Frame and Lechtman forthcoming). In the absence of further archaeometallurgically analysed and securely dated sites between these sites, the debate of single vs. multiple centres of invention in Eurasia does not find a resolution (Fig. 7.1a). It has been argued elsewhere that the earlier metal exploitation and manipulation in northern Iraq and eastern Turkey implies a high probability that an earlier smelting site is found (Roberts et al. 2009). What is clear is that by the late fifth millennium BC, copper smelting can be identified in the southern Levant as at Abu Matar (Golden 2009, 2010) and probably in Central Europe at Brixlegg, Austria (Höppner et al. 2005; but see review in Kienlin 2010), where it would be broadly contemporary with the earliest metal objects in the region (Kienlin 2010). By the late fifth to early fourth millennium BC, copper objects containing lead and arsenic were being produced from Central Asia to southeast Europe (Chernykh 1992). The appearance of mainly copper objects dating the late fourth-early third millennium BC further east on the western and northern borders of modern China is followed by the local production of copper, arsenical copper and tin-bronze in northwest China at the beginning of the third millennium BC (Chernykh 1992; Linduff and Mei 2009). Copper and tin-bronze metallurgy in central China in the early-mid second millennium BC appears to be virtually contemporary with tin-bronze production in southeast Asia as at Ban Chiang in northeast Thailand (Pigott and Ciarla 2007; Higham and Higham 2009; White and Hamilton 2009; Pryce et al. 2011).

Copper axes and ornaments are found in northern Europe from the fourth millennium BC and, in the absence of any copper ores, would have represented the long distance movement of ores or, more probably, copper metal (Klassen 2000; 2004; Roberts and Frieman forthcoming a). In the central Mediterranean, copper objects are present in northern Italy from the early-mid fifth millennium BC (Skeates 1994; Pearce 2007, 48–52) and there is extensive copper ore extraction at Monte Loreto in northwest Italy from the mid fourth millennium cal BC (Maggi and Pearce 2005). Copper and silver production occurs on Sardinia during the late fifth to later fourth millennium BC (Lo Schiavo et al. 2005) – probably towards the end of this range given the recent radiocarbon dated sequence for early metallurgy in east-central Italy (Dolfini 2010).

In the west Mediterranean, the absence of secure contexts means that dating the earliest metal or metal production remains under debate. Copper smelting at Cerro Virtud, southeast Spain dating to the early-mid fifth millennium BC (Montero Ruiz et al. 1999; Ruiz Taboada and Montero 1999; Montero-Ruiz 2005) is potentially unreliable (see Roberts 2008a; 2009). The copper production activities at the third millennium BC sites of (Müller et al. 2007) Zambujal, Cabezo Juré (Nocete 2006), Almizaraque (Müller et al. 2004) and Los Millares (Montero Ruiz 1994) in southern Iberia remain the most comprehensively dated and analysed. In the absence of further evidence, a date of late fourth-early third millennium BC for the appearance of copper objects and production practices seems likely. This would parallel evidence in Mediterranean France, where copper and lead objects at Roquemengarde, southeast France (Guilaine 1991) slightly precede the copper mining at Les Neuf Bouches and copper smelting at the nearby La Capitelle du Broum which date to the end of the fourth millennium BC (Ambert et al. 2005; Mille and Carozza 2009). In northwest Europe, the earliest securely dated copper objects date to the mid fourth millennium BC at Vignely, northern France (Mille and Bouquet 2004). However, it is not until the mid third millennium BC that the earliest copper and gold objects are found on islands off the western Eurasian landmass as at Amesbury, southern England (Fitzpatrick 2002, 2009) and earliest copper mining as at Ross Island, southwest Ireland (O'Brien 2004). However, this is still over two millennia before the earliest metal (iron rather than copper alloy) objects in Japan, which represents the equivalent islands off the eastern Eurasian landmass (Mizoguchi 2002).

Modelling Metallurgical Transmission

The dating of the earliest metal objects and metal production across the Eurasian landmass indicates a punctuated transmission from southwest Asia that reaches the western and eastern extremities around eight millennia later, and even longer if its offshore islands are included. The temporal and spatial rate at which this transmission process occurred appears to have been highly variable, especially when the models of rapid metallurgical adoption in a few centuries across East Asia (e.g. Pigott and Ciarla 2007; White and Hamilton 2009; Higham and Higham 2009; Pryce et al. 2011) are compared with their equivalents in Europe which unfold over three millennia (e.g. Krause 2003; Roberts 2008a; Ottaway and Roberts 2008; Strahm and Hauptmann 2009; Kienlin 2010). The patterns revealed by these earliest dates provide the temporal and spatial framework within which models of metallurgical transmission can be proposed. However, the dates do not provide any suggestions of underlying mechanisms until they are integrated with evaluation of the expertise required for each stage of metal production against the relevant pre-existing expertise. Older ideas based on the determining role played by geology in the spread and development of metallurgy might seem initially appealing (e.g. Charles 1980, 1985), especially given the large expanses without copper ores. However, the distances between ore sources do not easily correlate with the duration of metallurgical transmission as evidenced by the relatively rapid transmission of copper objects across the northern European Plain to Scandinavia (Klassen 2000, 2004) or the relatively slow transmission of copper production from the copper ore sources in eastern Serbia across the Adriatic sea to copper sources in northern Italy (Ottaway and Roberts 2008; Radivojević et al. 2010). Nonetheless, the geological hypothesis has yet to be systematically tested.

The earliest metal encountered in the geographical regions spanning the Eurasian landmass is copper or a copper alloy, such as arsenical copper or tin-bronze. Although the earliest copper can be accompanied by other metals, such as lead as in southern France (Guilaine 1991), silver as in Sardinia (Lo Schiavo et al. 2005) or gold as in Britain (Fitzpatrick 2009), the evidence for the production tends to be far more fragmentary. The prospecting for copper ores throughout Eurasia could have been relatively straightforward for the experienced practitioner, especially given their abundance. However, there were plenty of other similarly coloured mineral sources that could be a source of confusion. The early selection of copper ores among other aesthetically comparable green stones in the Levant (Bar Yosef-Mayer and Porat 2008) demonstrates that this was a real possibility which could have proved problematic to later communities wishing to smelt copper ores to create metal. The extraction of copper ores from the surface would have sufficed for the earliest metallurgy. If ore veins were followed underground as at early copper mining sites, such as Rudna Glava, eastern Serbia (Borić 2009), expertise would have been required to facilitate the movement of miners, their equipment and the ore, and to provide them with adequate ventilation, illumination and drainage, all while ensuring that the underground structures did not collapse. Organisation was necessary to source, make and transport the mining tools and equipment, such as stone hammers and antler picks (e.g. Pascale De 2003) the large quantities of fuel for fire-setting (cf. Weisgerber and Willies 2001), and food for the miners. Whether close to the settlements or not, the implication is that there would have to have been dedicated mining expeditions containing several individuals with relevant expertise that had access to the ore. However, it is probable that the expertise required for copper mining could have been gained through a continuation of existing traditions of flint and stone mining (e.g. Korlin and Weisgerber 2006).

The earliest transformation of copper ore to copper metal throughout Eurasia not only involved the ability to obtain and prepare through beneficiation of the correct raw material, but also the construction of specialised ceramics for crucibles and moulds, the use of a fuel, such as charcoal, and the ability to control air flow (Bourgarit 2007). By modern standards, the earliest copper smelting in Eurasia can be characterised as relatively simple – small scale, relatively low temperature processes carried out under poorly reducing conditions on oxidic and/or sulphidic ores in small stone and clay structures and/or ceramic crucibles with no intentional addition of fluxes and little consequent slag (see Bourgarit 2007; Hauptmann 2007 Roberts et al. 2009;). The smelting would have yielded only small quantities of copper that would then have to be refined in a separate process. Yet, it would have been the smelting of the copper ore that potentially provided the greatest challenge to a metallurgical novice, especially in a different environment with new fuels or a wetter climate. Pottery precedes metal throughout in many regions of Eurasia, and it has traditionally been argued that the pyrotechnological demands involved in the making of the former would lead to the making of the latter. The presence or role of charcoal before metal production is hard to establish, as neither the surviving evidence nor the necessity can be found. However, charcoal would have been of fundamental importance in smelting not simply due to its ability to create high temperatures using relatively small quantities in a small space, but as a source of highly reducing carbon monoxide gas (see Horne 1982; Craddock 2001). In replicating the bonfire firings involved in the production of pottery, it is evident that there is a relative lack of control, rapid changes in temperature, an oxidising atmosphere and a variable duration varying from several minutes to several hours. Although temperatures of c. 1,000°C can be reached, this is only for a very short duration and cannot be maintained before dropping back to c. 600–800°C or lower (e.g. Gosselain 1992; Livingstone-Smith 2001; McDonnell 2001). It is possible that more pre-metallurgical control could have been achieved, as shown by the analysis of Neolithic red ochre decorated pottery from southeast Spain (Capel et al. 2006), but this would not be sufficient in terms of temperature, atmosphere or control to smelt oxidic and/or sulphidic ores according to experimental reconstructions (e.g. Rovira and Guttierez 2005; Timberlake 2005, 2007; Bourgarit 2007).

These differences suggest that the ability to smelt copper would have required verbal instructions and visual demonstrations from an experienced individual or community if the expertise was to be transmitted. As smelting experiments have shown, even "simple" smelting technology needed to be carried out within a fairly narrow margin of error or else the entire process would fail. It seems very probable that at least some aspects of the metal production process would either have been inevitably or deliberately restricted to certain individuals or groups. The transmission of copper production expertise throughout Eurasia would therefore have to involve the movement of a sufficiently skilled individual or a group to a new ore source. This introduces two interrelated mechanisms for metallurgical transmission – the movement of metalworker(s) and the learning of metallurgy from experienced metalworkers. This would have created an extensive yet fragile network of metallurgical expertise, potentially over substantial distances.

Analysing the movements of individual metalsmiths is only going to be feasible in exceptional circumstances, such as the "Amesbury Archer", where oxygen isotope analysis indicates that he may well have spent his formative years in an Alpine environment before making the journey to southern England, where he was buried with copper and gold objects and a cushion stone during the mid third millennium BC (Fitzpatrick 2002, 2009; Evans et al. 2006). Tracing the movements of metalworking communities is also potentially possible, especially for the earliest evidence of a new and distinctive technology in a region. This has been proposed by White and Hamilton (2009) who have argued that the earliest metallurgy in southeast Asia is due to the rapid migration of southern Siberian metalworkers, or at least metalworkers trained by them, as part of the "Seima-Turbino trans-cultural phenomenon" (but see Pryce et al. 2011 for a review). They surmise that the evidence in southeast Asia is similar enough to make it one of the regions encompassed in the rapid creation of relatively uniform metallurgical traditions across the Eurasian steppes during the late third millennium BC. This is thought to have been the consequence of the aggressive movement of tribes bringing their distinctive "Seima-Turbino" metallurgy, including binary tin-bronzes and casting in blind sockets, with them (cf. Chernykh 1992, 2008; Sherratt 2006; Kohl 2007; Hanks et al. 2007; Anthony 2007). This movement of metal technology by archaeologically identifiable mobile communities has also been identified between the southern Levant and northeast Africa by Anfinset (2010) who demonstrates that this phenomenon represented the transmission of only one of many locally unobtainable materials and commodities across the Sinai desert.

Modelling Metallurgical Adoption

In order to model metallurgical adoption, the assumption of inevitability must first be discarded. There was no inherent functional reason why metal objects or metal production should be adopted by local communities or introduced by non-local communities. Early metal tools did not provide an advantage over existing materials in performing everyday tasks – they were less effective than stone, bone or flint counterparts (e.g. Mathieu and Mayer 1997), and may not even have been hardened or used. The distinctive colours, lustre and malleability can be proposed as attractive qualities. The ability to recycle meant that object forms created elsewhere could be melted down and converted into more familiar shapes, even in regions far from ore deposits or primary production centres. But none of these imply that the appearance of metal objects and production practices throughout Eurasia was a foregone conclusion.

It could be assumed that in using the same underlying technology, and one which would have to have been learnt elsewhere, the earliest metalworking communities throughout Eurasia would make and use similar objects. The application of a vast programme of compositional analyses on copper and tin-bronze objects across the former Soviet Union by E.N. Chernykh (1992, 2008) enabled broad-scale similarities and variations in metal composition and technology to be evaluated. The desire to look at the underlying patterns evidenced in the metal rather than grouping the results by individual archaeological cultures led Chernykh (1992, 7–10) to develop a hierarchical and dependent system of regionally distinct metallurgical "provinces" whose dynamism depends on the characteristics of the primary or secondary metal production centres or "focuses", associated with one or more archaeological cultures, and frequently grouped into early metal "zones". The approach facilitates the identification of observed metallurgical patterns at a vast spatial scale, such as the Carpatho-Balkan metallurgical province during the mid fifth-early fourth millennium BC stretching across eastern Europe and deep into the Eurasian steppes, substantially beyond the scope vast majority of archaeological cultures. It is hard to underestimate the influence of this pioneering model for understanding early metallurgy in the Eurasian steppes, yet it is undermined by fundamental flaws. In identifying "foci", "zones" and "provinces" within a hierarchical framework, the model presupposes and advocates relationships based on metal-consuming peripheries being dependent on metal producing cores. The uneven distribution of copper and tin ores throughout the Eurasian steppes does mean that connections have to be established and maintained to ensure a regular supply of metal ores or objects, but it does not immediately equate to a binding relationship of dependency and inequality. Perceptions of the consumption of the metal objects being made, whether of quantity, type or composition, are inevitably highly influenced by past practices of deposition or discard, as well as recycling or re-melting (e.g. Taylor 1999). It also does not address regions, such as Western Europe, where there is a mosaic of frequently diverse metallurgical traditions within and beyond archaeological cultures distinguished by form, composition and metalworking techniques (Roberts 2008a). Fundamentally, it does not provide a model that can *explain* the earliest adoption of metal.

The problem lies in modelling metal adoption overwhelmingly from the perspective of metal producers rather than the metal consumers. Given that archaeometallurgical techniques enable far more data to be gathered from metal objects and workshops alike regarding the methods and organisation of production rather than the motivations of the metal-using communities, this is perhaps not so surprising. This bias is supported by the many myths and legends of involving metalsmiths and by early anthropological and modern ethno-archaeological accounts of the magic and taboos surrounding them (e.g. Budd and Taylor 1995; Blakely 2006). Early scholars felt that as metal represented an advanced technology, metal had to have been brought in by advanced colonisers, generally in search of new ore sources, in a manner not entirely dissimilar to contemporary colonial powers (see Roberts 2008b). This led to the long-held notion of metalsmiths whose technical expertise in creating a revolutionary new material provided them with a special status and whose movement led to the transmission of new ideas and practices (Roberts 2008b). This interpretation was articulated most influentially by V. Gordon Childe (1930), who made itinerant metalsmiths primary agents of social change in European societies, due to their mobility and perceived lack of tribal affiliations (see Rowlands 1971; Wailes 1996).

Yet, it is argued that the communities who supported the acquisition of metallurgical skills, assisted with the collective aspects of metal production (e.g. ore prospection, extraction and processing), and circulated and used the metal objects, were more influential in shaping early metallurgy than the metalsmiths. The small scale of the earliest visible metal production and consumption is more indicative of an occasional rather than continuous production process, with a relatively low level of circulation undertaken by part-time, rather than full-time smiths. It can be argued that metal production even ceased subsequent to its introduction and circulation as in northern Europe from c. 3200 to 3000 BC and northwest continental Europe from c. 3000 to 2500 BC (cf. Krause 2003, 34).

Once metal production is removed from its scholarly pedestal and copper and gold objects stop being ascribed high, yet frequently unspecified, values for prehistoric communities, it is possible to see the earliest metal in light of other materials. For instance, the burial of an individual in the Beaker culture burial rite in northwest Europe during the mid third millennium BC such as the 'Amesbury Archer' involved a thin-walled, elaborately decorated pottery vessel potentially together with polished stone bracers, finely made flint arrowheads, v-perforated buttons, possibly in amber or jet, daggers in flint or copper and earrings in gold or copper. The ability to acquire these materials or craft the desired objects required similar processes of gaining specific knowledge and skills – none of which can easily be used to elevate metal in the overall interpretation. Instead, all the materials are made to reflect a desired standard and are not rigorously demarcated (Roberts and Frieman forthcoming a). The traditional idea of Beaker culture representing an especially dynamic community with regards to metal is demolished further when it is explored in other regions. In southeast France, where copper metallurgy was established prior to the change in the inhumation practices to the Beaker burial rite actually led to fewer metal objects in more restricted range (Ambert 2001; Vander Linden 2006). Similarly, the extensive archaeometallurgical analysis of early metal objects throughout Spain failed to reveal a Beaker metallurgy as distinct from the pre-existing metallurgical traditions (Rovira and Delibes de Castro 2005). In modelling early metallurgical adoption, archaeological cultures can therefore provide a framework for exploring metal within its broader material context but not a secure framework for defining the adoption process.

Conclusion

The earliest metal objects and metallurgy in Eurasia have traditionally been classified according to the associated archaeological culture – a practice that doubtless will continue. The problematic variations in the definition of the relevant archaeological cultures, whether for example the Vinča culture in the Balkans through tell settlements and pottery types or the Beaker culture in central and western Europe through burials, pottery types and ornamental craftsmanship, will remain. However, it is argued that by analysing the earliest metal in the absence of a critical evaluation of archaeological cultures means that valuable insights into the modes of transmission and adoption could be missed.

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