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Crucible technologies in the Late Bronze–Early Iron Age South Caucasus: copper processing, tin bronze production, and the possibility of local tin ores

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ABSTRACT

The South Caucasus was a major center of metal production in the Late Bronze and Early Iron Ages. Nowhere is this more clear than in the hills and mountains in the southeastern Black Sea region (ancient Colchis), where exceptionally large numbers of metal production sites have been found. Chemical and microscopic analysis of slagged technical ceramics at these sites illuminates several aspects of both raw copper and tin bronze alloy production. Copper ores were smelted in a complex multi-stage process designed to extract metal from sulfide ores. Technical ceramics served as containers for a range of different reactions, from the first phase of smelting, in which the copper sulfides were likely consolidated into a matte, though later stages of matte processing and metal copper production in smaller crucibles. In addition, a single crucible fragment, recovered from a late 2nd millennium BC slag heap, demonstrates that tin bronze was created by the direct addition of cassiterite tin ore, probably of alluvial origin, to metallic copper. The crucible's context, the use of cassiterite ore rather than tin metal, and a review of local geology suggests that the tin used in this crucible came from nearby, with the most likely source being the Vakijvari and Bzhuzhi gorges roughly 10–15 km away. While a single fragment does not speak to the regularity of this practice, at the very least it raises the possibility that the Colchian bronze industry was based on local rather than imported tin.

1. Introduction

Copper and copper-alloy production flourished in the southeastern Black Sea region (modern western Georgia) during the Bronze Age (Abesadze, 1958; Abesadze and Bakhtadze, 2011 [1988]; Tavadze and Sakvarelidze, 1959). The region has a large number of copper ore deposits, and there was substantial ancient copper mining and smelting, especially during the height of the Late Bronze–Early Iron Age Colchis Culture (c. 1500–600 BC) (Erb-Satullo et al., 2014; Gzelishvili, 1964; Khakhutaishvili, 2009 [1987], 2006; Khakhutaishvili and Tavamaishvili, 2002; Mudzhiri, 2011). Large numbers of slagged technical ceramic fragments have been recovered from copper production sites in the region. Previous analyses of production debris (Erb-Satullo et al., 2014) demonstrated that copper was extracted from sulfide ore deposits in a complex process involving ore roasting, and possibly involving an intermediate stage of matte production. In the present study, the examination of the slagged fragments of technical ceramics allows us to clarify several aspects of the production of raw copper. In addition, the in-depth analysis of one crucible fragment, which has a tin-rich slag on its interior surface, illustrates the techniques of alloying and tin bronze production. Although tin bronze is widely distributed in the South Caucasus by the Middle–Late Bronze Age, the processes of tin acquisition and the spatial organization of bronze production remain open questions (Abramishvili, 2010). A clear understanding of the dynamics of production and trade is a necessary prerequisite for discussing political and economic developments in these societies.

Analyses of technical ceramic slags are supplemented with analyses of metal inclusions in a range of different slags from these

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sites. Several slags without adhering technical ceramic from the same site as the tin-rich sample were also analyzed. The goal of these additional analyses is to confirm that, as suspected from macroscopic observations and comparisons with neighboring sites, the bulk of metallurgical activities related to copper smelting. Taken together, these data clarify several aspects of raw copper production and illuminate how and where the tin bronze was produced.

2. The question of tin supplies in the Near East and the South Caucasus

The search for Bronze Age tin sources, tin ore distribution networks, and tin production debris has a long pedigree. Afghanistan is often cited as a likely source of tin for Mesopotamia (Cleuziou and Berthoud, 1982; Crawford, 1974), though there are some outstanding questions, at least for the Early Bronze Age (Thornton and Giardino, 2012). Direct evidence of 3rd millennium BC tin mining is lacking for this region. Tin mining remains dating to the 2nd millennium BC have been found in Tajikistan and Uzbekistan (Boroffka et al., 2002), as well as Kazakhstan (Stöllner et al., 2011). Early 2nd millennium BC textual evidence from Anatolia and Mesopotamia points unequivocally to the east as a source of tin, but the "sources" named in the texts probably refer to way stations rather than points of origin (Thornton and Giardino, 2012:254; Weeks, 2003:179). Overall, while 3rd millennium BC tin sources are hotly debated, eastern tin sources for Near Eastern bronzes are more widely accepted for the 2nd millennium BC.

Controversy surrounds the discovery of an ancient tin mine at Kestel and its accompanying settlement, Göltepe, in the Taurus mountains of Anatolia (Earl and Özbal, 1996; Yener, 2000; Yener and Goodway, 1992; Yener et al., 1989). Based on analytical and experimental work, researchers argue that tin oxide was reduced to tin metal in crucibles, while alloying took place elsewhere (Earl and Özbal, 1996; Vandiver et al., 1993). Many critiques (Hall and Steadman, 1991; Muhly, 1993; Pernicka et al., 1992) have focused on the low tin content (averaging about 0.2 wt.%) of the remaining ore, the apparent lack of tin bronzes in contemporary local metal assemblages (however, see Lehner and Yener, 2014:544–545 for counterexamples), and early 2nd millennium BC textual evidence for tin importation. Ongoing research suggests that there is still much to learn about ancient tin sources on the Anatolian Plateau (Lehner, 2014; Lehner and Yener, 2014:532; Yener et al., 2015).

The South Caucasus has long been marginalized in the discussion of tin sources for the wider Near East. Nonetheless, references to possible tin deposits in the Caucasus have surfaced from time to time. Early work mentions a source of tin ore in the vicinity of Metsamor, Armenia, and tin-rich slags found on the site itself (Crawford, 1974:242; Mkrtiachan, 1967), but this contrasts with a contemporary report, which states that cassiterite and stannite are found only as insignificant accessory minerals in a few deposits (Akopyan, 1967). Moreover, the only published analytical measurement of a Metsamor slag yielded only 0.005% Sn (Mkrtchyan et al., 1967:72), so it is difficult to confirm the statements about tin ore and tin-rich slags. Several sources mention a possible tin deposit in South Ossetia in the central portion of the Greater Caucasus range (Crawford, 1974:242; de Jesus, 1978:37), but these can be traced back to a single remark in a secondary source (Sulimirski, 1970:230–231). Other scholars are more skeptical of the presence of tin ores anywhere in the Caucasus (Selimkhanov, 1978:57). A recent review of early metallurgy in the Caucasus states that the geological conditions are generally unfavorable for the formation of tin deposits, while acknowledging the possibility of unexplored deposits (Courcier, 2014:580). There are some brief references to tin deposits and tin-bearing slags in both the western-central Greater and Lesser Caucasus ranges (Bezhanishvili, 1933; Hasanova, 2014:65; Kharashvili, 1958:162–165; Tavadze and Sakvarelidze, 1959:53). Until now, no production debris from tin processing or tin bronze production in the Caucasus has been analyzed in detail.

Despite a lack of mining and production evidence, significant amounts of tin were clearly circulating in the Caucasus by the 2nd millennium BC, if not earlier. Traditionally, arsenical copper is considered the dominant alloy in the Early Bronze Age, with an increasing reliance on tin bronze during the Middle and Late Bronze Ages (Abramishvili, 1999; Kavtaradze, 1999; Meliksetian et al., 2003; Tedesco, 2006:115, 118). However, tin bronzes do occasionally show up earlier, appearing in a late-Neolithic context at Aruchlo (Hansen, 2012) and at Early Bronze Age Velikent in the North Caucasus (Kohl, 2003; Peterson, 2003). The former case is one of the earliest tin bronze objects found in the Near East (for other, not entirely uncontroversial examples from the Near East and southeastern Europe, see Garfinkel et al., 2014; Radivojević et al., 2014; Radivojević et al., 2013; Šljivar and Borić, 2014). Moreover, even in the Late Bronze–Early Iron Age, tin bronze was not a universal alloy (Abesadze, 1958:58–59, 98–99; Kavtaradze, 1999:86–87). Certainly by the Late Bronze Age, people in the Caucasus used metallic tin and lead–tin alloys, a practice that continued into the Early Iron Age (Khanzadian and Piotrovskii, 1992:68; Prange and Yalçin, 2001; Selimkhanov, 1978). Some hypothesize that the Caucasus region maintained long-distance trading contacts, importing tin, gold, and lapis lazuli from Central Asia in the 3rd millennium BC (Apakidze, 1999; Edens, 1995:60–61). However, the suggestion that Central Asia or the Eurasian steppes served as the main source of tin for the Late Bronze Age Caucasus has some paradoxical corollaries, given the dramatic scale of metal production and increasing frequency of tin bronze in the late 2nd millennium BC. If this were the case, the expansion in the long-distance trade in tin would correspond to the period when the shared metalworking traditions of the preceding Early–Middle Bronze Age – Chernykh's (1992) Circumpontic Metallurgical Province – took on a more regionalized character in the Caucasus. The result is an implausible, though not impossible, juxtaposition of increasing long distance metal trade with decreasing exchange of metallurgical ideas (Kohl, 2007:122).

Given the lack of well-investigated production evidence for the alloying, mining, or smelting of tin, any evidence of tin processing has the potential to address key questions. First, was tin bronze created by mixing of separately smelted tin and copper metal, by adding tin ore to copper metal, or by direct co-smelting of copper and tin ores (Charles, 1978)? Second, at what stage in the production process did alloying take place? Third, does the context or composition of the production debris suggest a possible source for the tin ore?

3. Technical ceramics at copper production sites in western Georgia

In three field seasons (2010, 2012, and 2014), our project has mapped about 50 copper production sites in the Supsa-Gubazeuli production area (Erb-Satullo et al., 2014) (Fig. 1). Fragments of friable gray technical ceramic with signs of heavy burning and partial melting on their interior concave surfaces were ubiquitous at production sites. Macroscopic examination of these ceramics suggests that they served a number of different purposes. In several cases, pieces of technical ceramic have been fused to the edges of large slag cakes (Fig. 2), while many other slag cakes have traces of vesicular glassy material where the ceramic has broken off. Measurements of 28 slag cakes yielded an average diameter of 24 cm with a standard deviation of 5 cm. The ceramic probably served as a furnace lining, creating a parting layer between the