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The key role of zinc, tin and lead in copper-base objects from medieval Talgar in Kazakhstan

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ABSTRACT

Metallurgical examination of brass and bronze objects from the medieval (AD 9th–13th century) site at Talgar in Kazakhstan shows that they were mostly cast from the quaternary copper–zinc–tin–lead system with some exceptions that were forged from binary copper–zinc alloys. Evidence is found that brass was produced in the cementation process and that the addition of tin and lead to the parent brass was considered beneficial in casting but was strictly avoided in forging. The mutual effect of zinc, tin and lead for better casting and the advantages of the binary copper–zinc alloys in forging seem to have been the major factors driving the establishment of this unique brass tradition in a society with probably limited access to tin.

1. Introduction

Ever since the Romans generalized the use of brass (Tylecote, 1992), an alloy of copper and zinc, it could replace bronze, an alloy of copper and tin, particularly in localities where bronze production was restricted due to tin shortage. In their independent studies on the alloy composition of Islamic brass and bronze, Craddock (1979) and Allan (1979) found that brass produced from the cementation process was the dominant alloy in the Islamic world and ousted bronze by the medieval period. Nevertheless, tin continued in use in cast objects although the amount was relatively low, and tin addition was observed mostly in heavily leaded brass. Craddock inferred that a little tin may have inadvertently resulted from the mixing of tin-bearing lead or copper with brass, and would have no significant effect on the alloy properties by comparison to that of zinc and lead. Allen, on the other hand, suggested that a quaternary alloy of copper, lead, zinc and tin was being produced in the Islamic world as a means to reduce the overall cost of an object by the alloying of metals. The endless recycling of old metals was proposed as a probable source of the tin addition. According to the ternary copper–zinc–tin phase diagram (American Society for Metals, 1973), the addition of tin to brass lowers the liquidus temperature and considerably increases the freezing range. The ternary phase diagram also predicts the precipitation of the eutectoid at relatively lower tin contents in the presence of zinc.

In a project aiming at understanding the technological status in metallurgy at Talgar in the Republic of Kazakhstan, we found important information relevant for the tin problem in brass from examining brass and bronze objects from a medieval site (9th–13th century AD). This article presents the results obtained from both microscopic and compositional analysis of these objects with a dual purpose to characterize the brass tradition established at medieval Talgar and to clarify the mutual effect of tin and zinc on their segregation behavior that makes the tin addition particularly beneficial in brass casting.

2. Comments on the site and artifacts

The Talgar area, shown in Fig. 1, is approximately 25 km east of Almaty, one of the largest cities in Kazakhstan close to the Chinese border, and has long been one of the major settlements in south-eastern Kazakhstan called the Semirechye or Jetysu (the Seven Rivers) region. Semirechye is bounded by the Karatau Mountain ridges and the valleys of Chu and Talas River to the West, the Dzungaria Mountains and the Ili River valley to the East and the Balkhash Lake to the North. It occupies the foothills of the northern slopes of the Tien Shan Mountains and the valleys of the rivers flowing down from these slopes. The major rivers passing through

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Fig. 1. Map of the Republic of Kazakhstan. The arrow locates the medieval site at Talgar in the Semirechye region.

the region include Syrdariya, Talas, Chu, Ili, Karatal, Aksu and Lepsi. Located at the crossroads between the desert–oasis region of Central Asia proper and the semi-arid and desert areas of Mongolia and western China, Semirechye played an important role in the establishment and operation of a branch of the Great Silk Road from around the 2nd century BC through to the 14th–15th century AD.

Stone tools recovered from Semirechye and the related radiocarbon data of approximately 20,000 years show that human occupation began at the Palaeolithic. The Bronze Age in this region corresponds to the period from the 2nd millennium BC to the early 1st millennium BC, when a unique culture characterized by the combination of cattle breeding and farming prevailed. Bronze objects such as axes, adzes, sickles and other tools from Bronze Age sites located at the foothills of the Zailiiskiy Alatau Mountains signify the beginning of metallurgy. In the period from the 8th century BC to the 4th century AD, the Semirechye region was inhabited by the Saka tribe and then by the Wusun tribe (Akisev, 1977, 1978). The Saka period is characterized by the use of iron in weapons, tools, horse trappings and other artifacts. In the period from the 6th to 9th century AD, the Western Turks, Tyurgesh and Karluk khaganates took turns to govern the region, and localities used as headquarters by local rulers started to develop into urban centers, with progress in various craft specializations including metallurgy. The growth of urban centers was accelerated during the medieval period from the 10th to 13th centuries AD, when the Karluk dynasty ruled Semirechye under the auspice of the Kharkanid state. Medieval Talgar, one of these urban centers located along the Tien Shan branch of the Great Silk Road operating from the 6th century AD, served as a political and trade center. The abundance and variety of iron, brass and bronze objects recovered from the site reveal that metallurgy was one of the major industries (Savelieva, 1994; Baipakov, 1998; Chang et al., 2002). Talgar faced the Mongol invasion at the beginning of the 13th century AD.

We examined numerous brass and bronze objects, and found that the majority of them were cast from quaternary alloys of copper, zinc, tin and lead, with the exception of a few copper objects and unleaded high zinc brasses. The artifacts examined were all excavated from the same medieval site at Talgar. They were dated on typological grounds to the 9th–13th centuries AD. A scientific dating experiment was also carried out as a part of the present project by applying accelerator mass spectrometry (AMS) to carbon samples extracted from cast iron objects from the same site. Their radiocarbon age was measured at the Christian-Albrechts-University's Leibniz Labor AMS Facility in Germany to be approximately 1000 ± 25 years before present (yr BP, from 1950). This corresponds within 2σ probability range to the calendar date of late 10th to early 12th century AD and is in agreement with the estimated date based on typology. The extraction of carbon samples from cast iron and the dating experiments will be detailed in a separate paper.

Table 1 lists the objects examined here, together with brief information on their usage, composition, method of fabrication and color, which will be discussed shortly. The square brackets in the first column contain the labels relating the objects to their general appearances presented in Fig. 2a–o. The artifacts are mostly well preserved, and present no difficulty in estimating the original shape. Though the one in Fig. 2c is substantially deformed, one can readily see that it was in the form of a thin vessel. Fig. 2h is intended to show the basin at the bottom. Fig. 2o, the bottom view of a basin, shows that the bottom was repaired using a new plate, and two specimens were taken, one from the main body and one from the bottom plate. Most of them seem to have been made for ceremonial services, as parts of a lamp system or as articles for cleansing and other purposes (Baipakov and Savelieva, 2004; Baipakov et al., 2005). Some may have been used in practical situations. It is to be noted that some articles are similar in shape and size. The three-footed objects in Fig. 2a and b look similar and those in Fig. 2f and k also have a similar motif. The artifacts in Fig. 2g and n are in fact identical and have the surface incised with herbs and crosses.

3. Microstructure examination

The specimens were prepared following standard metallographic procedures of grinding and polishing for microstructure examination. A solution of 10 g iron chloride (III) in 100 ml water or methanol and 30 ml hydrochloric acid was used for etching. They were then examined under the optical microscope and scanning electron microscope (SEM). Their chemical composition was inferred using the energy dispersive x-ray spectrometer (EDS) attached to the SEM, and is given in weight percent to the nearest whole digit. The results for zinc and tin showed little variation in