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Metal residues in 5th c. BCE–13th c. CE Estonian tools for non-ferrous metal casting

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ABSTRACT

This paper investigates Estonian tools for non-ferrous metal casting in the form of crucibles, moulds, and casting ladles dating to the Estonian Iron Age (500 BCE–1227 CE), adding elemental analysis and 3D modelling to the traditional typological comparison. In contrast to the neighbouring countries of Russia, Latvia, and Sweden, no comprehensive study has previously been published on this subject for Estonian material. The typological analysis sets Iron Age Estonia in the same metalworking tradition as that of other eastern Baltic countries and Northwestern Russia. However, some classes of casting tools present in Scandinavian and Slavonic areas have so far not been encountered in the Estonian archaeological record. The elemental analysis included qualitative pXRF analysis of 175 artefacts and detailed residue analysis using SEM-EDS of thirteen selected artefacts. This analysis identified for the first time Estonian Iron Age casting tools – crucibles – used for casting gold and silver. Most of the investigated crucibles were used for casting various copper alloys, while the casting ladles and most of the stone moulds were used for casting pewter. Casting of pewter and precious metals only occurred in regional centres such as hill forts and strongholds, while copper alloys were cast in all parts of Estonia. In addition to clarifying fundamental questions about Estonian Iron Age metal casting, this study also lays a foundation for using modern analytical techniques in future investigations of Estonian metalworking traditions.

1. Introduction

Crucibles, casting ladles, and mould fragments are the most common evidence of non-ferrous metalworking from archaeological Iron Age and early Medieval sites. In Estonia, no comprehensive study on such artefacts has been carried out, while studies on non-ferrous casting tools in the neighbouring countries of Latvia, Russia, and Sweden have improved our understanding of the history of metal-working in north-east Europe. In Latvia, Iron Age crucible and ladle residues have been characterized via elemental analysis (Daiga and Grosvalds, 1964), and 11th to 13th century casting moulds have been investigated with the help of experimental casts (Svarāne, 2013). In Russia, multiple aspects of non-ferrous metal casting have been investigated. Important research includes a study of crucible types from the early urban centres of north Russia (Goryunova, 1994), elemental analysis of crucibles and artefacts from the town of Novgorod (Eniosova and Rehren, 2012), and a study of alloy compositions in finds from various sites in Northwestern Russia (Eniosova et al., 2003). In Sweden, research on non-ferrous metal casting includes the Migration Period workshop in Helgö (Lamm, 2012), the Viking Age material from the Lake Mälaren region including Birka (Ambrosiani, 2013; Sahlén, 2016), and the Early Medieval material from Gotland (Gustafsson, 2013). In-depth analysis of silver cupellation has been carried out for Early Medieval material from Sigtuna and Gotland (Söderberg, 2011; Söderberg and Gustafsson, 2006). The few previous Estonian studies include a paper on stone moulds and pewter casting (Moora, 1963), a short summary of Estonian 5th to 11th century crucibles, ladles and moulds (Tvauri, 2012), and a recent study on tin plaques and stone casting moulds (Keeman, 2017). To the best of our knowledge, non-ferrous metal casting in Iron Age and early Medieval Finland is even less researched than in Estonia.

Here, we present the first systematic study of Estonian tools for casting non-ferrous alloys from the time period 5th c. BCE, i.e. the beginning of the Estonian Iron Age, to the 13th c. CE. The year 1227 CE is a landmark year in Estonian history, as German and Danish crusaders then conquered the region corresponding to present-day Estonia, which at the time was one of the last non-Christian parts of Europe. As the conquest bound Estonia to Catholic Europe, it is considered the starting point of the Estonian Medieval Period. In Estonian Chronology, the studied time period consequently encompasses the entire Iron Age,

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which is divided into Pre-Roman Iron Age (500 BCE–50 CE), Roman Iron Age (50–450 CE), Migration Period (450–550), Pre-Viking Age (550–800), Viking Age (800–1050) and Final Iron Age (1050–1227) (Lang, 2007, 15; Tvauri, 2012, 12). Although hundreds of crucible and casting mould fragments have been excavated from Estonian Late Bronze Age (850–500 BCE) casting sites (Lang, 2007), only occasional crucible fragments have been encountered in casting sites dating to the period 500 BCE to 600 CE. Thus, most of the studied objects are from the 7th to the early 13th century. In total, 175 excavated moulds, ladles, and crucible fragments were first screened for traces of metal residue with a portable X-ray fluorescence (pXRF) unit. Next, thirteen of these objects were selected for detailed residue analysis with Scanning Electron Microscopy combined with Energy-Dispersive Spectroscopy (SEM-EDS), and five objects were selected for 3D–model investigation. The results obtained allow us to address fundamental metallurgical questions: What kinds of casting tools were used where and when? Which alloys were cast with these tools? Are there correlations between the type of site, the tools used, and the alloys cast? How do the findings compare to those in neighbouring countries?

2. Materials

The studied sample consists of 175 casting-related artefacts, excavated in Estonia from 29 different sites and currently housed at the Tallinn University Archaeological Research Collection, the University of Tartu Archaeological Collection, the Tartu City Museum, and the Vana-Võromaa Museum. A detailed list of the samples and their origins is given in appendices as Tables A.1 and A.2. The finds originate from burial sites, rural settlement sites, strongholds, and hill forts (Fig. 1). To some extent this reflects the state of Estonian archaeological research: strongholds and hill forts are the most recognizable monuments in the landscape, and together with burial sites they have been the main focus for many Iron Age field projects (Fig. 1). The details of the different find contexts are presented in Chapter 3, and are summarised in Table 1.

The studied casting tools fall into two categories. First, crucibles made from refractory material used for casting copper alloys, precious metals, and occasionally pewter. Second, stone moulds and ladles for casting low-temperature tin or pewter alloys. Most of the now broken crucibles were either round-bottomed (Figs. 2, 3:3, 6:2, 6:3) or conical (Fig. 3:1, 3:5, 3:6, and Fig. 6:1). Some display forms in between, such as oval-bottomed (Fig. 3:2 and 3:4), or unique forms such as the pear-shaped crucible from the Soontagana stronghold (Fig. 3:7). Whether conical or cylindrical in shape, all crucibles are relatively tall with small diameters compared to the low and wide forms that dominated during the Estonian Bronze Age (Sperling, 2014, 148). It is unclear when this shift in design took place. Latvian crucibles dating to the 1st millennium BCE resemble the Estonian low and wide Bronze Age forms (Daiga and Grosvalds, 1964), and it is possible that the Estonian counterparts were similar. This must however remain a speculation until more Estonian casting tools from the period 500 BCE–600 CE have been excavated. The tall and narrow form is typical for crucibles placed inside charcoal and heated from below (Bayley and Rehren, 2007). The use of a less refractory "sacrificial" layer (*ibid.*) is common in our sample, and many crucible fragments display outer layers that have vitrified (Fig. 3:3) or partly fallen off (Fig. 2:1, 2:5). Future analysis of the material composition of the crucibles – which is outside the scope of this paper – could likely shed further light on the different clay fabrics used and their relation to crucible shape and alloys cast (e.g. Martinón-Torres and Rehren, 2014).

The stone casting moulds were used for casting pendants or small ornaments that could be fastened onto cloth or leather (Fig. 4). Many of them are made from imported Mesozoic limestone (Tvauri, 2012). Rich deposits of this material are present in central Europe, and the closest area from which such limestone could have been imported is southern Lithuania (Moora, 1963). Some casting moulds appear to be made from local dolomitic marlstone or fine sandstone (*ibid.*). Future research

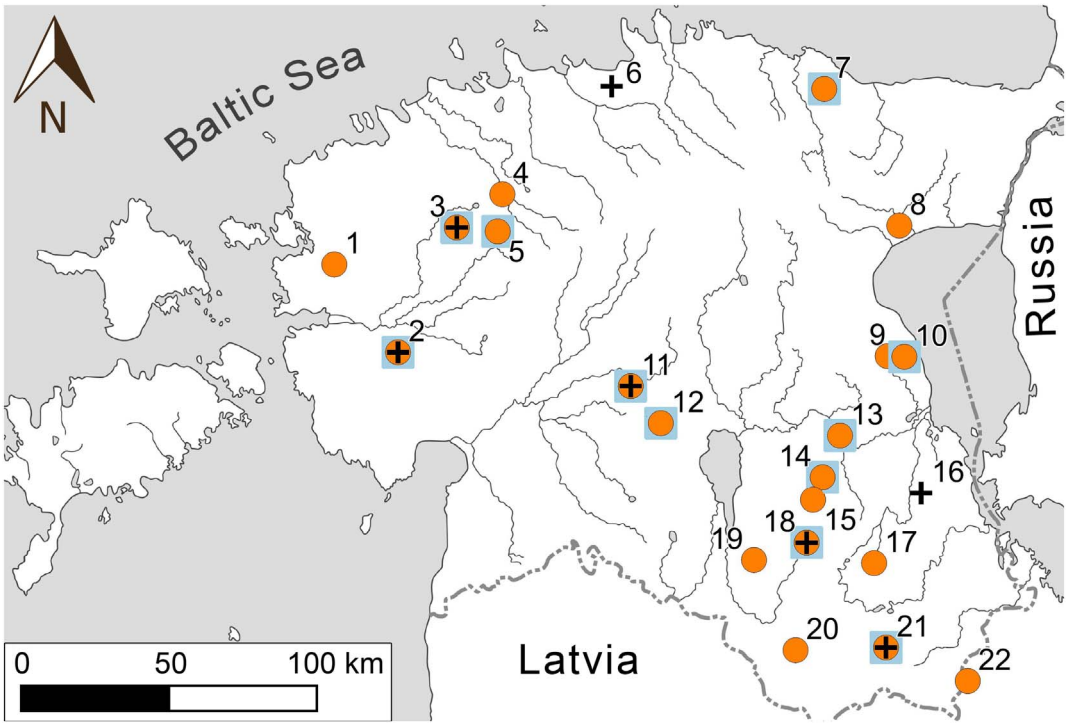

Fig. 1. Map of present-day Estonia showing archaeological sites dating to 5th c. BCE–13th c. CE where casting tools with metal residue have been excavated. Orange circles – copper alloys; Blue squares – precious metals (Au/Ag); Black crosses – tin or pewter. Sites: 1) Leedi hill fort; 2) Soontagana stronghold; 3) Varbola stronghold; 4) Lohu II stronghold; 5) Alu burial site; 6) Kuusalu stronghold; 7) Pada I settlement; 8) Lemmaku barrow; 9) Savastvere settlement; 10) Peatskivi hill fort; 11) Lõhavere hill fort; 12) Naanu hill fort; 13) Tartu hill fort and settlement; 14) Unipiha hill fort and settlement; 15) Kodijärve I settlement; 16) Arniko barrow; 17) Põlgaste *tarand*-grave; 18) Otepää hill fort; 19) Kuigatsi hill fort; 20) Madsa hill fort; 21) Rõuge hill fort; 22) Toodsi Liidva settlement. Figure by R. Saage; base map by Kristel Roog. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)