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TECHNOLOGICAL HISTORY, EXPERIMENTAL ARCHAEOLOGY AND BRONZE CASTING: RESEARCH FINDINGS AND RESEARCH PERSPECTIVES IN EARLY MEDIEVAL STUDIES

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The past two decades have seen the spread of experimental archaeology in studies on technology and ways of life. However, it is regrettable that the growth of experimental archaeology into an independent discipline has often gone hand-in-hand with a neglect of its original goals. Experimental archaeology should not be an end unto itself, no matter how spectacularly it can be presented to the broader public, and neither should it become a toy in the hands of anachronistic historical live-interpretations, no matter how fashionable the latter have become. The principal goal of experimental archaeology is to provide new impulses to research in fields where traditional archaeological methods can no longer yield fresh results. This discipline has therefore, by necessity, become intertwined with modern archaeometric analyses and techniques, which owe their very existence to modern technology.
The author has undertaken the study of small finds cast from copper alloys dating from the Late Avar Period and has employed the techniques used in experimental archaeology for the study of this early medieval class of artefacts from the Carpathian Basin. The examples cited in this article offer an overview of the results of his studies, as well as of the potentials of this approach and the tasks of future studies.

According to our present knowledge, European metalworkers used predominantly the lost-wax technique until the post-medieval period. This technique was based on the use of moulds made from clay tempered with dung and animal hair. The molten metal was poured into the cavity left by the wax that had melted out when the mould was fired. Evidence for other casting procedures during the early medieval period is very scarce. The moulds known from the Mediterranean, Eastern Europe and the Baltic were generally made from sandstone and had two halves. They were either two-part moulds used for producing various artefacts of non-ferrous metals, or negatives for making and reproducing the wax models that perished during the lost-wax casting process. The four stone moulds known from the Carpathian Basin are so worn that they could, at the most, have been secondarily reused as whetstones *(Fig. 1)*. Other finds reflecting alternative techniques such as casting using moulds carved in sepia have been reported from the Mediterranean.

The possible use of two-part boxes filled with tamped sand for a technique known as sand-casting has been repeatedly suggested in studies on early medieval technologies. This procedure was used in China from the 6th century AD onward: on the testimony of the literary sources and the archaeological evidence, this technique was employed for the production of coins. In Europe, there is little archaeological evidence for its use because the sand was sieved, wetted and then re-used again, meaning that there would be nothing to indicate its use in the workshop waste. In other words, it is virtually impossible to prove or disprove the employment of this technique. The single indication of a possible familiarity with this technique in Central Europe comes from the 9th century centre at Mikulčice in the Moravian Basin, where archaeologists discovered three types of sands of differing gradation separated by three black layers in the corner of a sunken house or workshop.[1] Sands of differing fineness are used even today in modern foundries. The black stripes may have been the remains of the wooden chests in which the sand was stored or of the leather with which the sand was covered to ensure its even dampness.

[1] Profantová, N.: Awarische Funde aus den Gebieten nördliche der awarischen Siedlungsgrenzen. In: *Awarenforschungen* Bd. II., hrsg. Daim, Falko. Studien zur Archäologie der Awaren 4. (Wien: Institut für Ur- und Frühgeschichte der Universität Wien, 1992), 605–801, 652.

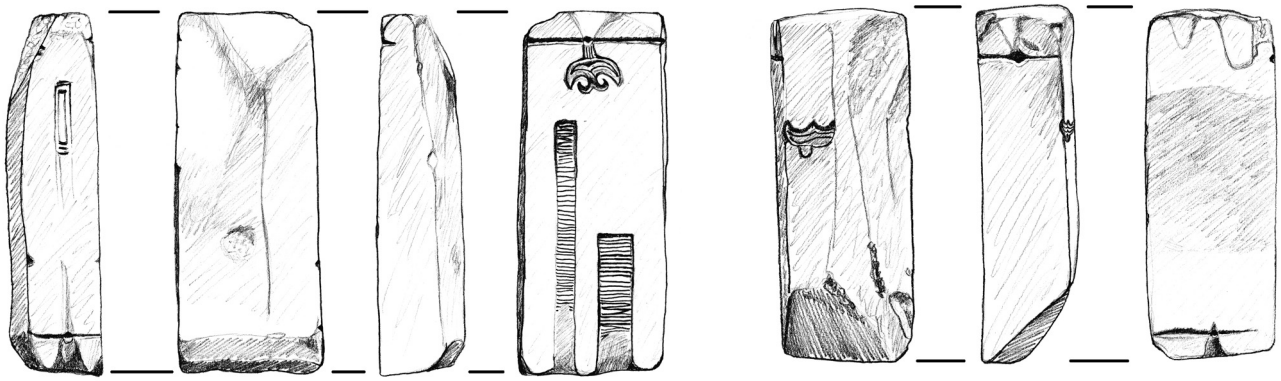

Fig. 1: Two-part stone mould from Vác–Kavicsbánya, found in a female burial

Many artefacts usually associated with lost-wax casting have been found in Northern, Western and Southern Europe, where considerably more workshops and workshop finds have been brought to light than in Central Europe.[2] The best documented and most realistically reconstructed among these are the work processes in the Viking period workshops of the Baltic *(Fig. 2)*.[3] The archaeological finds, usually the finished, cast pieces, and – more rarely – the archaeological traces of casting, waste and workshop finds suggest that lost-wax casting was the most widespread procedure, although several regional and cultural variants can be distinguished, despite the virtually identical technique itself. A detailed comparison of the minor details of bronze casting techniques and a comprehensive overview of the regions where studies of this kind have since long been conduced or have only begun remains a task for the future. The most important comprehensive regional studies have been conducted in the Baltic and

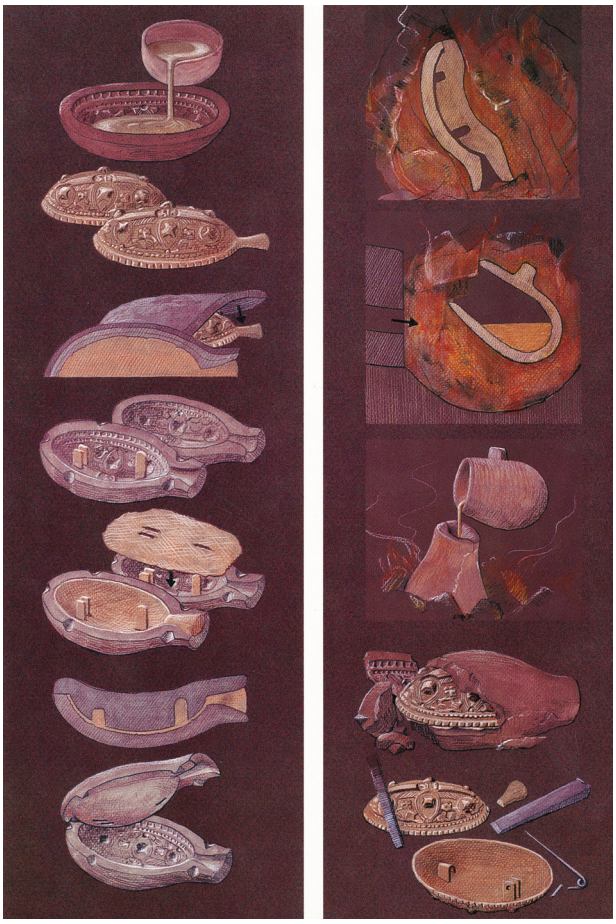

Fig. 2: Lost-wax casting in a 9th century Baltic workshop. After Jensen, Stig: Ribe zur Wikingerzeit (Ribe: Den Antikvariske Samling , 1991), Abb. 23.

[2] A site of this type, dating from the Carolingian and the Ottonian period, has been investigated at Soest; Dieter, Lammers: *Das karolingisch-ottonische Buntmetallhandwerker-Quartier auf dem Plettenberg in Soest*. Soester Beiträge zur Archäologie. Bd. 10 (Soest: Westfälische Verlagsbuchhandlung Mocker & Jahn, 2009), in Moravia; Profantová, N.: Awarische Funde aus den Gebieten nördliche der awarischen Siedlungsgrenzen. In: *Awarenforschungen* Bd. II., hrsg. Daim, Falko. Studien zur Archäologie der Awaren 4. (Wien: Institut für Ur- und Frühgeschichte der Universität Wien, 1992), and workshop remains from Preslav, Bulgaria Pletnyov, Valentin: Proizvodsztvoto na kolanni garnituri v rannoszrednevekovna Blgarija (Produktion of belt ornaments in early medieval Bulgaria). *Preszlav* 6 (2004), 236, Tab. 5. At Ribe in Scandinavia, the excavations brought to light the furnaces and the fragments of countless moulds used during the lost-wax casting procedure; Jensen, Stig: *Ribe zur Wikingerzeit* (Ribe: Den Antikvariske Samling, 1991), 31–36.

[3] Jensen, Stig: *Ribe zur Wikingerzeit* (Ribe: Den Antikvariske Samling, 1991).

Viking centres, the Frankish workshops of the Carolingian period, and the Southern European and the North African workshops. Studies on the history of metal casting in the Carpathian Basin also play a prominent role in research on ancient metallurgy.

The interpretation of certain archaeological features and finds is uncertain because the technologies used in early medieval times have fallen into oblivion, and in some cases, we cannot even determine the types of crafts which left an imprint in the archaeological record. Owing to the laconity of sources and the small number of relevant finds, whose interpretation is far from unambiguous, experimental archaeology plays a crucial role in research on early medieval technologies. One basic tenet of experimental archaeology is that it strives to re-create the techniques used during a particular period based on the use-wear marks on artefacts and the observations made during excavations, using the period's implements and materials under authentic circumstances. At the same, researchers engaged in experimental archaeology must remain aware of the fact that owing to the scarcity of the sources, the results of their experiments cannot be regarded as final despite the success of the experiment and that every reconstruction is acceptable that is compatible with the archaeological record. It is therefore crucial to document every phase and procedure during the experiment in order to ensure verifiability.

The realisation that earlier theoretical studies did not lead to new advances prompted us to embark on a series of archaeological experiments with complementary archaeometric studies. Our goal was the reconstruction of the workshops and the casting techniques of the various bronze articles of the Late Avar Period, representing the largest body of artefacts – whose number runs into several tens of thousands – from the Late Migration Period in the Carpathian Basin.[4] The use of experimental archaeology was in this case justified by the very fact that virtually nothing is known about the bronzesmiths of the Avar Period. Despite the high number of their products, not one single 8th or early 9th century workshop is known from the Avar settlement territory. The single exception is the base of a mould for bell casting discovered at Zalavár.[5] However, the significance of the Zalavár centre eclipses by far the importance of all other settlements in the Carpathian Basin and the bell itself is also a unique item in the ocean of the cast metal costume accessories and other small finds (predominantly belt mounts, brooches and harness ornaments).

Our experimental studies were in part based on the examination of these articles whose surface preserved traces of the casting process and in part on negative evidence, namely the lack of workshops. We therefore strove to reconstruct the activities of the period's craftsmen in a manner that would not leave few, if any, securely observable traces in the archaeological record during the excavation of a settlement. The examination of the various cast articles indicated that they had been made using the lost-wax procedure. Our experiments suggested that the casting process was made up of the following phases.

1. Creation of the master model

The master model was probably a positive model carved in wax or perhaps wood *(Fig. 3)*. The master model is the carefully modelled original piece, from which all the secondary models used for casting can be reproduced *en masse*. Owing to its careful modelling, the master model bore all of the article's traits intended for display. At the same time, such details that would not be visible (such as the reverse of the mounts attached to straps) were given no attention. In the case of unique articles such as large strap-ends, the model might be identical with the master model.

Fig. 3: Master model carved from beeswax: parts of a belt buckle

[4] Bíró, Csaba – Szenthe, Gergely: Öntéstechnikai vizsgálatok késő avar kori bronztárgyakon (Sorozatok modellezése és sokszorosítása) [Investigations of Casting Techniques of Bronze Artefacts from the Late Avar Period (Modelling and Production of Serial Pieces)]. In: *Corolla Museologica Tibor Kovács Dedicata*, ed. Tóth, Endre (*Budapest:* Magyar Nemzeti Múzeum, 2011), 155–174.

[5] Szőke, Béla Miklós: A korai középkor hagyatéka a Dunántúlon [The heritage of the Early Middle Ages in Transdanubia]. *Ars Hungarica* 26 (1998)/2, 257–319.

2. Creation of an intermediary mould of two halves from the master model *(Fig. 4)*

The reverse of the overwhelming majority of the examined artefacts indicates that their models had been prepared in two-piece moulds. The simplest procedure is pressing clay plaques on both sides of the master model. Our experiments suggested that the models of the thin mounts hollow from their rears had been made in a different manner, in part to economise on the use of metal and in part owing to the properties of cast metal (the surface of thin-walled cast articles is more pleasing). After drying the clay plaque pressed against the relief of the master model with a plain reverse, then firing it in an open fire (in the furnace for melting the metal), we obtained an intermediary, still one-sided mould that was adequately resistant to dampness. We wetted the negative to prevent the wax from being absorbed. After the wax had been poured into the negative, its outer layer in contact with the moistened clay hardened first. If the still molten part of wax was poured out, a thin, but firm wax layer conforming to the form of the mould was left –a finished model in essence *(Fig. 4. 1)*. The reverse of the intermediary mould was made by pressing another layer of clay on that first model *(Fig. 4. 2)*. The new two-piece intermediary mould was suitable for creating any number of wax models with an identical volume and form *(Fig. 4. 3)*.

Fig. 4: Fired negative with the first model of even thickness. 1. Raw clay plaque, prepared for pressing against the reverse, 2. with the clay reverse, 3. removal of the wax model from the negative

3. Reproducing models from the intermediary mould *(Fig. 5)*

After removing the model, the two-part intermediary mould could be used for creating models identical to the first one. The differences between two-sided artefacts such as large strap-ends that were not part of a series suggest that the master model was probably used as the model, generating the crafting of articles with a unique decoration.

Fig. 5: The obverse and reverse of the reproduced models

4. Chasing and sprueing the models *(Fig. 6)*

The embellishment of the models removed from the intermediary mould ensured that the models would bear all the traits that would also appear on the cast artefact (rivet holes, openwork elements, hinge loops created by perforating the wax). The reason for this procedure can be sought in the fact that wax can be worked more easily. Following the embellishment, sprues and, in the case of more sophisticated forms,

Fig. 6: The embellished wax model before embedding in the mould, with the wax model of the sprue and the clay-coated iron wire threaded through the hinges

Fig. 7: The process of embedding the model

Fig. 8: The embedded model

gas escape channels were added to the moulds, and iron wires coated with clay were threaded through the longer holes of the hinges that could have not been filled completely by the embedding material of the mould.

5. Making the moulds *(Fig. 8)*
The moulds were made by wrapping the prepared models in clay strongly tempered with organic matter.

6. Lost-wax casting
According to the description of Theophilus presbiter, the moulds were fired in the same fire in which the metal was smelted *(Fig. 9)*. After the wax had completely melted, the molten metal was poured into the mould. Depending on the proportion of the different components in the alloys (tin, phosphorus and lead, the latter often used in the Early Middle Ages on the testimony of the archaeometallurgical analyses), bronze can be cast between 1000 and 1100 °C. The furnace

Fig. 9: Firing of the model in the furnace with charcoal fire used for smelting the metal

Fig. 10: Smelting of the bronze in a crucible

Fig. 11: Broken, perishable moulds at the casting location

used during the experiment was a simple pit hollowed into the ground; the nozzle of the bellows was led under the crucible placed on the floor of the pit. We used hardwood charcoal for smelting *(Fig. 10)*. The shallow pit and the moulds removed from the cast articles after they had cooled left no archaeologically detectable trace: the moulds were extremely porous and brittle, and they also disintegrated when coming into contact with water *(Fig. 11)*.

7. Chasing of raw casts *(Fig. 12)*

After removing the mould, we also removed the sprues and the casting seams. The surface of the cast artefact was polished and perhaps decorated with punching. Tinning and gilding were also performed during this work phase.

Fig. 12: Raw cast (flawed piece with casting seams and metal in the air bubbles of the mould)

The reconstructed casting technique of the Late Avar Period, tested through a series of experiments, suggests that this technology represented a unique variant of lost-wax casting, which was nonetheless bound to the surrounding world by countless strands. It differed from the (reconstructed) technological culture represented by the "Viking" workshops of the Baltic and those of the Mediterranean not only by the lack of archaeologically visible workshops, but also regarding certain details of the lost-wax casting procedure. Experimental archaeology has in this case contributed to the placement of the Carpathian Basin and the metalworking technology of the Late Avar Period in the context of metalworking techniques practiced contemporary Europe, the Eurasian steppe and the Mediterranean world.

Recommended reading

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