

The bronze arrowheads, which are the most common type of Scythian material culture, have been examined the least. First and foremost, one point must be addressed how were they cast? There have been no definitive conclusions about the technology of arrowhead casting [1]. Some sources recommend using a metal mould for this, while others recommend using the lost-wax casting technique. Our knowledge of casting technique is critical because it influenced the organisation of the manufacturing process for this major category of material and, as a result, the supply of necessary weapons to Scythian soldiers.

Several efforts were carried out to tackle this difficulty, including casting the arrowheads in a metal mould, using metal moulds to make wax models, and lost-wax casting. The ancient Scythian arrowheads and their experimental equivalents, cast in various methods, were subjected to comparative metallographic studies [2]. The findings of the trials show that lost-wax casting was the most plausible process for making Scythian arrowheads. These findings were supported by metallographic investigations, which revealed that the cooling rate of crystallisation of arrowheads produced using different casting processes had an impact on the characteristics of the alloy's crystal structure.

Throughout the entire Scythian period, arrowheads were produced and consumed en masse, with only a small fraction of them reused. The rest were irretrievably spent, including through their deposition in burials [3-5]. The number of quivers containing arrowheads deposited in Scythian burials and their capacity differ, but in some burials multiple quivers were found with a total capacity of up to 1,056 arrows, as well as individual quivers containing more than 100 identical arrowheads. Conversely, there are quivers from different burials that contain arrowheads cast in the same. This suggests that Scythians were able to quickly replenish their ammunition and that the production of arrowheads must have been as cheap and simple as possible. Yet the question regarding the technology of Scythian arrowhead manufacture remains hotly debated in archaeological literature.

Five arrowheads from four archaeological contexts ranging in date from the seventh to the early fourth century BC were used for metallographic analysis. The contextual data and metric parameters are summarised. With the exception of the arrowhead from Zhabotin, which is a relatively rare type, the remaining arrowheads are serial.

In order to estimate the influence of the casting mould's material on the cooling rate at the crystallization front, computer simulation of heat exchange processes was performed with the application of the finite elements method. This simulation was performed within the framework: molten metal – casting mould. The simulation was focused on the cooling process of the triangular arrowheads similar to samples 4 and

Samples were cut along the arrowhead length using Delta Abrasimet cutting machine with the application of the abrasive wheel Buehler Met II Wheels, and supply of metal-cutting lubricant. The cut samples were compression mounted into a bakelite chase using SimpliMet 1000 automated press for subsequent polishing

The difference of the cooling rate at the crystallization front for arrowheads produced using different methods influences the crystal structure of their alloy. Thus, when comparing the metal structure of archaeological arrowheads with the structure of the experimental samples, produced using similar fusion, it is possible to determine the method by means of which a certain archaeological arrowhead had been produced. Casting experiments confirmed the influence that the cooling rate has on the parameters of crystal structure in the obtained billets

The performed work is the first of its kind in which an attempt was made to use an integrated approach to solve the problem of manufacturing technology of Scythian bronze socketed arrowheads.

The production of metal moulds for various types of arrowheads, experiments of casting into these moulds and metallographic analyses of archaeological and experimental arrowheads clearly demonstrate both the advantages and disadvantages of various casting methods. Metallographic analysis of archaeological and experimentally cast arrowheads indicates the use by the Scythians of wax-casting for this category of weapons.

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