

## EDXRF, ICP-OES AND METALOGRAPHY RESEARCH OF AREFACTS FROM VRŠAČKO GORJE – LATE BRONZE AGE

D.Jovanović<sup>1</sup>, V.Andrić<sup>2</sup>, M.Stojanović<sup>3</sup>

<sup>1</sup> *The Town Museum of Vršac, Vršac, Feliksa Milekera 19,*

<sup>2</sup> "Vinča" Institute for Nuclear Sciences, Belgrade, P.O.X

<sup>3</sup> National Museum Belgrade, Terazije 1a, Belgrade (milica65@live.com)

The region of Vršačko Gorje is exceptional for its large concentration of hoards of metal objects on a relatively small area. Main reason for this phenomenon is that this region is representing the crossroad for the trade routes and is connecting main metalurgical centers of late Bronze Age (1200-1000 B.C.) in between the rivers Sava and Danube with Transylvania on the East, which was at that period the main source of copper. These hoards consist usually of various materials and besides the fragments of bronze artefacts, they consist very often of ingots of pure copper. Bronze artefacts which are found in these hoards are usually the objects that are thrown off, broken or are unfinished objects and they are used for recycling metal. Typological analysis of objects from the hoards of region Vršačko Gorje, is suggesting the close relations with the metalurgical centres in middle Danube and central Europe zone.

The goal of physico-chemical and metallographical research was to try to get more information on used metalurgical processes in production of these artefacts (knives, daggers and spears) and finding the origin of raw materials and ingots as well to find out how this material was circulating in region.

For chemical and metallography analyses we have selected knives, daggers and spears from hoards. We assume that these materials are the representative samples, according with the fact that the bronze materials at that time were practically "standardised quality" concerning the weapons and tools. The investigation was carried out on Si(Li) detector with excitation with radioisotopes (<sup>109</sup>Cd and <sup>241</sup>Am) and 13 different types of artefacts have been investigated. On the basis of these results the samples for ICP-OES analyses have been taken in order to get information on trace elements. These results have shown that the tools are made of bronze with similar contents of copper and tin as the major components (with less than 10% of tin) and with trace elements like arsenic (average of 0.50%), antimony, lead, silver and iron. On the other hand the analyses of ingots have shown that the ingots are made of copper with no presence of tin and antimony or lead. Since there was no evidence of tin ingots in the hoards and the objects are of standardized quality, we suppose that the weapons are imported. The fact that they have been found with copper ingots may suggest that they have been put in the hoards for later recycling or trade.

Metallography studies of the artefacts show that the objects are made by casting and cooled slowly. All objects are porous because of realising the gases during the process of cooling, with numerous inclusions of slag and oxides (blue grains). The main structure in the investigated objects is of finely shaped cored dendrites and an infill of the alpha + delta eutectoid structures. In one object there is the loss of dendritic structure and there is formation of twinned crystals due to reheating after casting and annealing.

This can be seen on polished cross sections of the artefacts etched with  $\text{FeCl}_3$  in ethanol solution with HCl. On the surface of cross sections of all objects it can be seen that the tin was unevenly spread in the metal so the spots of undissolved tin in the alloy are visible as silvery grains.

### References

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