

## USE OF SOME CHEMOMETRIC METHODS FOR ORIGIN DETERMINATION OF TERRA COTTA ICONS FOUND IN VINICA FORTRESS

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In the Vinica Fortress, Republic of Macedonia, 50 undamaged terra cotta icons and 100 fragments, all dated 6<sup>th</sup>–7<sup>th</sup> century, were found. Ten fragments of the terra cotta icons and 33 samples of clays from 8 different sites from the region were previously analysed using X-ray fluorescence spectroscopy, atomic absorption spectrophotometry and flame photometry. The mass fractions of 19 different parameters were determined (SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, Fe<sub>2</sub>O<sub>3</sub>, CaO, MgO, MnO, P<sub>2</sub>O<sub>5</sub>, TiO<sub>2</sub>, K<sub>2</sub>O, Na<sub>2</sub>O, Cr<sub>2</sub>O<sub>5</sub>, V<sub>2</sub>O<sub>5</sub>, Sr, Pb, Ni, Co, Zn, Cu and Ag). The results from the chemical analyses were treated with hierarchical cluster analyses and it was concluded that the terracotta icons have been produced from clay from the region.

This work is a result of an effort to determine more precisely the origin of these unique terra cotta icons. In order to extract this information and due to the dimensionality and complexity of the data collected in the experimental part, the archaeometric results were treated with principal component analysis (PCA) and self-organising maps (SOM). Before these chemometric methods were applied, the collected data were autoscaled in order to give equal importance to all the input variables.

Principal component analysis was used for reduction of the dimensionality of the data. Using this algorithm, new variables are obtained. Most of the data variation can be usually described with a few of these variables, called principal components. As a result of the data reduction, the analyzed objects are grouped in the space defined by the obtained principal components, according to their similarities. This was used for determination of the origin of the clay used for the terra cotta icons production.

Self-organizing maps are an other valuable algorithm for reduction of the dimensionality of the data and it is used by chemometricians as a tool for unsupervised classification. The algorithm performs mapping of the high-dimensional data on a two-dimensional grid. During the mapping of the data into a low-dimensional grid, the data are grouped according to the similarities of their properties (measured parameters). Even if the geographic region of the analysed clays is rather small, using SOM, most of the samples are grouped in different clusters of neurons. Using SOM, we were also able to identify which of the analysed parameters are characteristic for different types of clays from Vinica region.

The results obtained using both chemometric methods showed that Vinica terra cotta icons were made from clay from Grnčarka, 2.5 km South East from the Vinica Fortress. This work can be regarded as a significant contribution to the application of these chemometric methods for classification of the artefacts according to their composition and for origin determination.