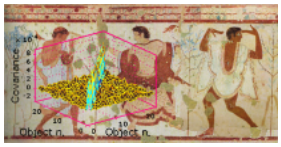

The Roman Ceramics Industries in the Sado Basin, Portugal: Multivariate Analysis and Geochemical Fingerprinting the Production Centers

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Abstract

Several archaeological sites of the Sado estuary (western Portugal) show evidences of an important ceramic production, including amphorae, related to the Roman Tróia industrial centre of fish preserves. The chemical analysis of amphorae sherds found in Barrosinha, Bugio, Zambujalinho, Herdade do Pinheiro, Xarroqueira and Vale da Cepa (Lower Sado), were performed by INAA. The application of multivariate analysis allowed characterize and differentiate the different archaeological sites, where one or two types of raw materials were used, as two compositional groups were found to be related with the geological materials available in the area.

Introduction

Roman ceramic production centres have been identified in the Sado and Tagus basins, western Portugal, related with areas of production and handling of fish-based products. Previous archaeometric studies of production centres of both estuaries have been done [1,2,3]. As far as the Sado basin is concerned, several archaeological sites with evidences of ceramic production have been identified, particularly related to the Roman Tróia industrial centre of fish preserves located in the mouth of the river. In this work amphorae from archaeological sites of the Lower Sado, namely Barrosinha, Bugio, Zambujalinho, Herdade do Pinheiro, Xarroqueira and Vale da Cepa, are studied. Chemical analyses of the amphorae sherds were performed by instrumental neutron activation analysis (INAA). Multivariate statistical analysis of the chemical data was performed and the results are discussed taking into account geochemical considerations and the geological context. The characterization and differentiation of ceramic productions in the Lower Sado is the major goal of this work, which is fundamental to pursue studies of amphorae distribution and exchange.

Materials & Methods

Amphorae sherds (142 objects) were prepared for INAA. Irradiations were performed in the core grid of the Portuguese Research Reactor at a thermal flux of 3.34 x 10^{12} n cm^{-2} s^{-1};Φepi/Φth = 1.4 %; Φth /Φfast = 12.1. Two γ-ray spectrometers were used, one with a 150 cm3 coaxial Ge detector connected through a Canberra 2020 amplifier to an Accuspec B (Canberra) multichannel analyser (FWHM of 1.9 keV at 1.33 MeV), and the other with a low energy photon detector (FWHM of 300 eV at 5.9 keV and of 550 eV at 122 keV). More details can be found in [4]. Na, K, Fe, Sc, Cr, Co, Zn, As, Rb, Cs, Ba, La, Ce, Nd, Sm, Eu, Tb, Yb, Lu, Hf, Ta, Th and U abundances were determined. Relative precision and accuracy are in general less than 5%.

Multivariate statistical methods were employed by using the Statistica program [5]. The joining-tree and K-means clustering using the absolute concentration of the chemical elements and also the normalized values to Sc as variables were employed. The goal of the k-means clustering procedure was to classify cases into a specified number of clusters, comparing the within cluster variability to the between-cluster variability (small and large respectively if the classification is good). Principal component analysis (PCA) was also used.

Results

The results obtained point to two main compositional groups of sherds. The main differences can be clearly seen in the plot of means for each group obtained by k-means clustering for k=2 (Fig. 1): (i) cluster 1 (comprising all samples from HP, and some of Xarroqueira, Vale da Cepa and Zambujalinho) is enriched in K, Rb, Cs, rare earth elements (REE), Ta and Th; and (ii) cluster 2 (comprising all sherds analysed from Barrosinha and Bugio and the remaining samples from Xarroqueira, Vale da Cepa and Zambujalinho) is enriched in Na, Co and Sb. These differences can also be observed in Fig. 2 showing the projection of the cases on the factor-plane (1 x 4), where the variables (element/Sc) that contribute more significantly are also shown.

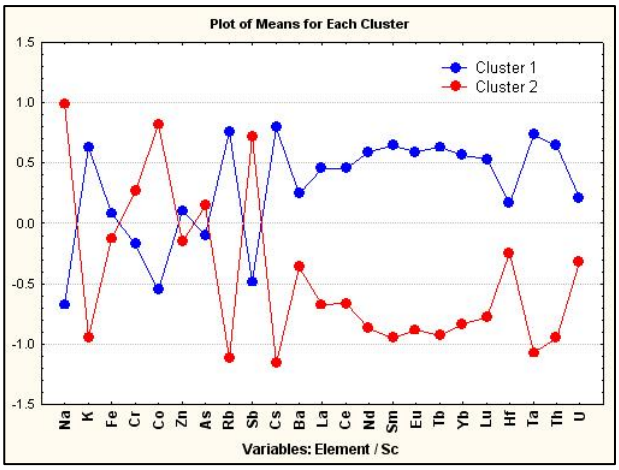

Fig. 1; Plot of means for two clusters (k-means).

Conclusions

The application of multivariate statistical analysis to chemical data of Roman amphorae found in several archaeological sites of the Lower Sado with evidences of ceramic production, allowed define two main compositional groups, which may reflect the use of different raw materials. The establishment of these reference groups can contribute to investigate the movement of goods and the distribution of amphorae produced in the Sado estuary in a spatial dimension of the Roman Empire.

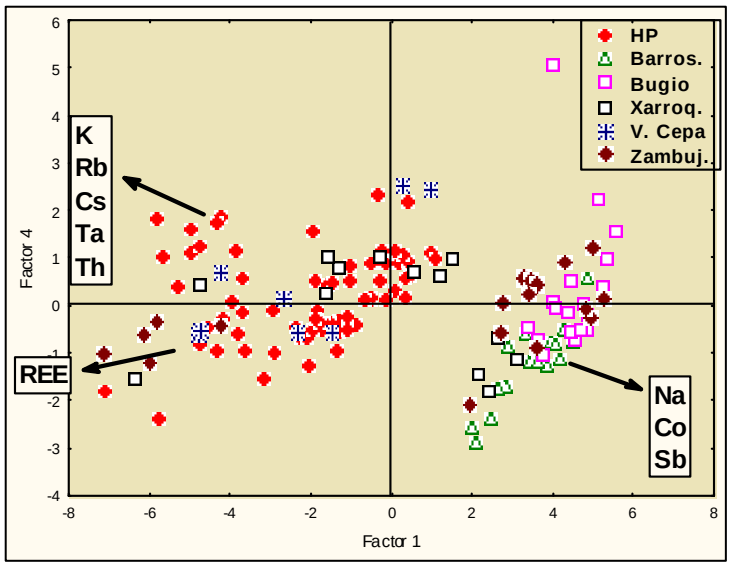

Fig. 2; Projection of the cases on the factor plane (1x4).

References

1) M.I. Dias, M.I. Prudêncio, Neutron activation analysis of archaeological materials: an overview of the ITN NAA laboratory, Portugal, Archaeometry, 49(2) (2007) 383-393
2) M.I. Prudêncio, M.I. Dias, J. Raposo, M.A. Gouveia, C. Fabião, A. Guerra, J. Bugalhão, A.L. Duarte, A. Sabrosa, Chemical characterisation of amphorae from the Tagus and Sado estuaries production centres (Portugal), in: Ceramic in the Society, Proceedings of the EMAC'01, S. Di Pierro, V. Serneels, M. Maggetti Eds. (2003) 245-253
3) J.M.P. Cabral, M.A. Gouveia, I. Morgado, Caracterização química das produções de ânforas do Vale do Tejo: II- Porto dos Cacos, in: Actas das Primeiras Jornadas sobre a Romanização dos Estuários do Tejo e do Sado, Câmara Municipal do Seixal e Publicações Eds (1996) 301-322, ISBN 972-20-1260-6
4) M.A. Gouveia, M.I. Prudêncio, New data on sixteen reference materials obtained by INAA. J. Radioanal. Nucl. Chem., 245(1) (2000) 105-108
5) StatSoft, Inc. (2003) STATISTICA (data analysis software system), version 6. www.statsoft.com