Analysis by neutron activation analysis a some ancient Dacian ceramics

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1 Introduction

Ceramics is the most common archaeological material and therefore it is very used material by the historians to draw temporal and cultural characterizations. The importance of knowledge the compositional scheme of the pottery is well known\textsuperscript{1−5} although very rarely one can get important conclusions from the elemental analysis of the potsherds\textsuperscript{6,8}. Perlman and Assaro\textsuperscript{7}, on the basis of an analysis of thousands of objects of ancient ceramics by neutron activation analysis established a method of classification on the objects in well defined groups, characterized on the historic point of view (culture, dating, style, etc).

In this paper we have been analyzed by neutron activation analysis (NAA) samples of ancient Dacian ceramics, from Romanian territories, from 3 different establishments from Romanian territory: Strei San Giorgiu, Hunedoara, Popesti, Giurgiu and Fierbinti, Ialomita. Ceramics was delivered by National Museum of History from Bucharest. We have searched the characteristic element or the ratio of elements for a given Dacian archaeological settlement.
2 Experimental method

The samples listed in the Table 1 have been analyzed by neutron activation analysis. We considered that the analysis should give an image of the bulk of the objects and therefore the surface of the shards was removed. Also we had into consideration the homogeneity of the samples and that the samples must be representative for the whole object. Samples of potsherds have been cut, weighted and wrapped individually in plastic foil. The samples of 10-30 mg have been irradiated at at the rabbit system of VVR-S reactor of the NIPNE, Bucharest-Magurele, at a flux of $1.3 \times 10^{12}$ neutrons/cm$^2$·sec$^{-1}$, for a period of 15 minutes. A standard spectroscopic pure metallic copper was used as neutron flux standard.

The measurements have been performed with a Ge(Li) detector, 135 cm$^3$ coupled at PC with a MCA interface. The system gave a resolution of 2.4 keV at 1.33 MeV ($^{60}$Co). The radioactivity of the samples has been measured after a decay of $^{27}$Al ($T_{1/2}=2.54$ min), the major element in the structure of ceramics. Then after a decay time of 10 min we have observed in the $\gamma$ spectra of the irradiated samples $\gamma$ rays of the isotopes corresponding to the elements: Ba, Mn and Na. After a decay time of 3-4 d we measured again the radioactivity in the ceramics samples and we could observed the elements: Sm, Eu, Sc, La and K.

3 Results and discussions

In the Table 2, 3 and 4 are shown the results of the NAA of the three groups of ancient Dacian potsherds S, P and F, from the three different establishments: Strei San Giorgiu, Hunedoara, Popesti, Giurgiu and Fierbinti, Ialomita. The concentrations are given in ppm, and when the concentration was larger than 10,000 ppm the result was given in percents. The considered statistical errors have been $\approx1\%$ for Mn and Na and $<5\%$ for the others elements.

One could observe from the Fig. 1 that the concentration of Ba seams to vary relatively
from one group to other. The mean values and the standard deviations for the concentration of Ba for each group are the following:

Ceramics Strei San Giorgiu \(C_{Ba}=2248\pm833\) ppm  
Ceramics Popesti \(C_{Ba}=796\pm226\) ppm  
Ceramics Fierbinti \(C_{Ba}=4138\pm467\) ppm

Then we applied the procedure to consider the ratio Na/Mn found to be constant in ancient ceramics, for a given archaeological settlement, for Maya period. The values of the means and the standard deviations of the ratio Na/Mn, for the 3 groups of analyzed Dacian ceramics are the following:

Ceramics Strei San Giorgiu \(Na/Mn=28.3\pm22.9\) ppm  
Ceramics Popesti \(Na/Mn=7.40\pm3.53\) ppm  
Ceramics Fierbinti \(Na/Mn=7.92\pm1.68\) ppm

We could remove in calculus of the means, the values of the concentrations far away of the mean and one get the following values:

Ceramics Strei San Giorgiu \(Na/Mn=15.04\pm0.07\) ppm  
Ceramics Popesti \(Na/Mn=5.91\pm1.30\) ppm  
Ceramics Fierbinti \(Na/Mn=7.32\pm1.18\) ppm

For the case of analyzed samples of ancient Dacian potsherds we could say that the ratio of the concentrations of Na/Mn is not constant and can not characterize a given settlement. Ba is the elements that could be considered to relatively differentiate the three groups of ceramics. To draw conclusions it must to improve the statistics of analysis and also to pay more attention to the homogeneity of the samples, that in the case of ceramics it is a very important parameter of the analysis.
References

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**Table 1.** List of analyzed ancient Dacian potsherds

| Sample   | Period       | Source                        |
|----------|--------------|-------------------------------|
| S1, S2, S3 | cent. I B.C.- I. A.D. | Strei San Giorgiu, Hunedoara |
| P1, P2, P3, P4, P5 | cent. I B.C. | Popesti, Giurgiu             |
| F1, F2, F3, F4, F5 | cent. IV - III B.C. | Fierbinti, Ialomita          |

**Table 2.** Ancient ceramics from Strei San Georgiu, concentrations in ppm, by NAA

| Sample | Sm  | Eu  | Ba  | La  | Mn  | Sc  | Na  | Na/Mn |
|--------|-----|-----|-----|-----|-----|-----|-----|-------|
| S1     | 7.54| -   | 2910| 42.8| 599 | -   | 8969| 14.9  |
| S2     | 7.13| -   | 2520| 109 | 336 | 8.1 | 18400| (54.8) |
| S3     | 7.74| -   | 1313| 21.9| 388 | 9.1 | 5864| 15.1  |

**Table 3.** Ancient ceramics from Popesti, concentrations in ppm, by NAA

| Sample | Sm  | Eu  | Ba  | La  | Mn  | Sc  | Na  | Na/Mn |
|--------|-----|-----|-----|-----|-----|-----|-----|-------|
| P1     | 8.8 | -   | 953 | 48.3| 703 | 23.3| 4488| 6.4   |
| P2     | 7.1 | -   | 749 | 44.0| 888 | 19.6| 6497| 7.3   |
| P3     | 7.5 | -   | 505 | 43.1| 90  | 11.0| 1205| 14.1  |
| P4     | 8.6 | -   | 1083| 50.8| 690 | 11.4| 3940| 5.7   |
| P5     | 9.7 | -   | 692 | 47.3| 789 | 13.6| 333 | 4.5   |
Table 4. Ancient ceramics from Fierbinti, concentrations in ppm, by NAA

| Sample | Sm  | Eu  | Ba  | La  | Mn  | Sc  | Na  | Na/Mn |
|--------|-----|-----|-----|-----|-----|-----|-----|-------|
| F1     | 10.6| 0.95| 4110| 51.1| 495 | 16.9| 3803| 7.7   |
| F2     | 8.8 | 1.2 | 5860| 40.3| 503 | 24.2| 4036| 8.0   |
| F3     | 8.1 | 1.0 | 3150| 30.7| 767 | 16.9| 4269| 5.6   |
| F4     | 7.2 | 0.91| 4070| 55.6| 488 | 18.6| 5032| 10.3  |
| F5     | 7.6 | 1.02| 3500| 30.3| 663 | 17.9| 5303| 8.0   |
Fig. 1. Barium Dacian ceramics NAA