"A preliminary study of copper navel *phiales* from the Louvre Museum, France and the National Archaeological Museum of Athens, Greece with non-destructive physicochemical analysis and preventive conservation"

Evmorfia Kasimi[1,4], A.P. Panagopoulou[2,3], Christos Karydis[4]

[1] *Department of Archeology and Ethnography at C2RMF, Palais du Louvre - Porte des Lions 14 quai François Mitterrand, 75001 Paris.*

[2] *University of Leiden, Faculty of Archaeology, Einsteinweg 2, 2333 CC Leiden, The Netherlands.*

[3] *National Center for Scientific Research "Demokritos", Institute of Nanoscience and Nanotechnology, 15310, Aghia Paraskevi, Athens, Greece.*

[4] *Ionian University, Department of Environment, Division: Conservation of Antiquities & Works of Art, Zakynthos, Panagoula 29100, Greece.*

Email: eua.kasimi@hotmail.gr

Introduction

The production technology and the decoration of the *phiales* were investigated based on 2 copper *phiales* from France and Athens. The objects came from the Louvre Museum and the Archaeological Museum of Athens and date back to the 4-5th and 6-7th century BC. Additionally, the *phiale* (Br2980) has two maintenance restorations that make it very special. Its origin is disputed (Br2980) as to whether it is Greek or Roman and an attempt is made to make a comparative study with a similar *phiale* in the construction technology, the morphological characteristics and the composition of the material. The *phiale* (Br 2980) belongs to the Campana collection. Campana collection is a large collection of antiques which were collected in the early 19th century by the Marquis Giampietro Campana. The *phiale* (16193) was found in Heraio of Perachora, Corinth, which is considered one of the most important sanctuaries of the Greek world, along with the temples of Hera in Samos and others in southern Italy. The *phiale* (16193) consists of a cup without a handle. This type of *phiales* first appeared in Corinth at the beginning of the 6th century and later in Attica. (Kissas, 2013).

The aim of the study

This study taken place in C2RMF, the conservation laboratory of the department in Archeology and Ethnography and aimed at investigating the chemical analysis and manufacturing technology of these phiales. The aim of the study was to find common characteristics between the *phiales* under investigation in order to determine if they have common production technology or origin. Furthermore, the comparative study allows us to determine whether the Louvre *phiale* (Br2980), the *phiale* of the Archaeological Museum of Athens (16193) and the *phiale* from the sanctuary of Hercules (BE 46152) in Sesklo of Volos (Stamelou et all, 2018) have common technological characteristics.

Figure 1. *Phiale* from Louvre museum (Br2980)

Figure 2. *Phiale* from Archaeological museum of Athens (16193)

Experimental method

- The structural analysis refers to the non-destructive physicochemical analysis of the copper *phiales* studied and sections of the samples were examined, by using special equipment and methods: Optical microscopy, Ultraviolet fluorescence - ultraviolet light and X-ray fluorescence spectroscopy.
- The non-invasive energy dispersive XRF provided information towards the identification of chemical elements, the optical microscopy was very helpful of structural analysis and the ultraviolet light for the delimitation of fluorescent materials.
- Condition operation in XRF: Anode Ag, Mining mode 4X 30s., Spot 3mm, acq 30s, treatment: NDT8.4. Ref. Specters: 196 (4).
- Microscope operation condition: Hirox KH8700 3D digital microscope with REVO 35-200 optics equipped with a confocal system and a polarizing filter.

Results

Chemical analysis with non-invasive XRF energy dispersion provided information for the identification of chemical elements such as Copper (Cu), Tin (Sn) and Lead (Pb). Quantitative examination of bottle 16193 showed that copper-tin alloy was used for the manufacture of objects while the percentages indicate the presence of lead at a small quantity. This typology is characteristic of artifacts used in the Hellenistic period for the manufacture of artifacts. Combining the alloys and manufacturing and constructing techniques it appears that:

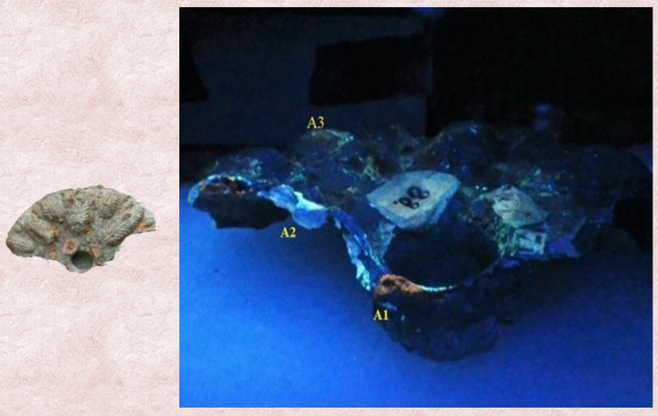
1. The tin percentage that is included and the small concentration of lead indicates the configuration of objects for the manufacture of alloys suitable for forging.

2. The percentage of tin included allows both hot and cold forging. In addition, the BR2980 *phiale* consists of Copper (Cu), Tin (Sn) and Lead (Pb) alloy with a significant concentration of lead, improving the cast properties and workability of the alloy, in order to better capture the decorative details, also characteristic of the Hellenistic period.

During the quantitative analysis of the *phiale* 16193 (figure 10), it was observed that the percentage of the elements was Copper (Cu) 54.0%, Calcium (Ca) 5.0%, Silicon (Si) 4.5%, Sulfur (S) 3.3 %, Zinc (Zn) 2.7 %, Tin (Sn) 1.7%, Aluminum (Al) 1.2% and Chlorine (Cl) 1.0%. The presence of chlorine is due to the fact that the object was found in a sea area. The quality analysis of the *phiale* (Br 2980) consists Cu, Tin, Sn, Pb, Au, Fe, Si, Ca and Ag is similar (figure 9). The quantitative examination of the *phiale*, 16193 showed that the copper-tin alloy was used for the construction of the objects at a rate of 1.7% tin, while the percentages of the small presence of lead is characteristic for crater used in the Hellenistic period for the construction of objects (figure 10).

The UV technique of the showed the points of interventions with the previous cosmetic restoration procedures on CaSO4 calcium sulphate (figure 3) and probability the welding of both *phiales* was done by use of shellac (restoration of Campana, 19th century). In addition was detected the intense corrosion of the metal in order to avoid intense cleaning.

Under optical microscope, the observation of stratigraphy (Br2980) (figure 5) flask revealed: the layer of corrosion of the metal with the oxides of cyprite (Cu_2O) and malachite ($Cu_2(OH)_2CO_3$). The layer of the authentic gold leaves, the shellac and calcium sulphate CaSO4. The gold leaves also with oxidized bronze for the appeared to imitate the original gilding (figure 4). It was distinguished in layers, the layer A (authentic gold) as well as the shellac that settles on the calcium sulfate and the remnant of an old label (19th century) where Campana had been previously restored. Additionally, observed detailedly (figure 6) the shellac and calcium sulphate CaSO4. While observation of the *phiale* (16193) flask through the optical microscope (figures 7,8) revealed the corrosion of the metal with the oxides of cyprite (Cu_2O) and malachite ($Cu_2(OH)_2CO_3$) as well as the damages such as cracks and abrasions.



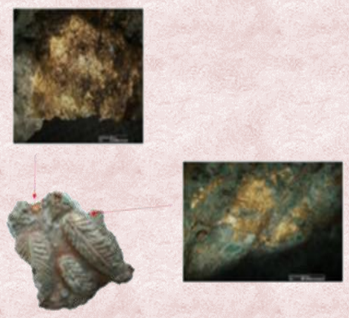


Figure 3. (Br2980) of Uv light. Previous aesthetic restorations, Shellac and calcium sulfate (CaSO4) are observed.

Figure 4. (Br2980) of Optical microscopy (Hirox KH8700 3D digital microscope). Details: Gold leaves with oxidized bronze.

Figure 5. figure of Optical microscopy: detailed stratigraphy.

Figure 6. of Optical microscopy: shellac and CaSO4.

Conclusion

After a comparative study of the two bronze *phiales*, we conclude that the *phiale* from the Louvre (Br2980) belonged to the Hellenistic period (323-30 BC) where the Roman conquest and thus explains the fact that the bronze *phiale* (Br2980) was found in Rome, in the collection of the Marquis Giampietro Campana. It also has many similarities with the Greek *phiale* of the Archaeological Museum of Athens (16193). These similarities are in the composition of the material, in the construction technology and in their morphology.

Similarities:

- In terms of their morphology, they are both spherical *phiales* with decorative lanceolate leaves. In addition, their dimensions are similar and they used them for offering to deities and less for drinking.
- Regarding the technology of their construction, their configuration was done by forging because the thickness of the copper sheets is 2mm.
- The decorative leaves were made with the help of a design and a chisel for the engraving that brings the decorative effect
- Finally, in terms of material composition, they are both mainly made of copper (Cu), lead (Pb) and tin (Sn).

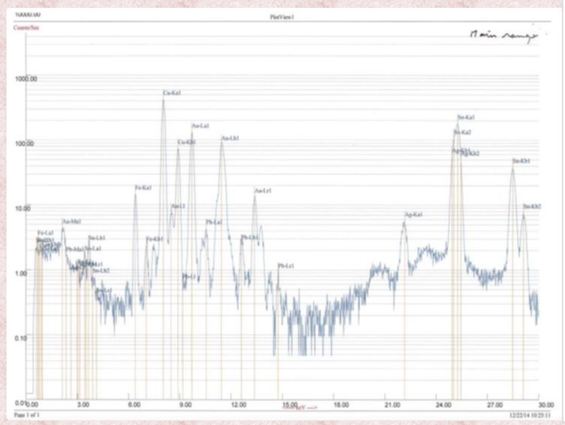
The compared bronze *phiales* from the Louvre Museum and the Archaeological Museum of Athens have common features with the copper navel *phiale* from the archaeological excavation of the temple of Hercules in Sesklo, Volos, as listed below:

- In terms of material composition, consisting of all three *phiales* mainly of copper (Cu) and tin (Sn).
- The copper *phiales* were made of forged copper due to the 2mm thin sheets.
- The two copper *phiales* with registration number: Br2980 and BE46152 have a Navel, which was used for finger placement.
- The dating of the *phiales* Br2980 and BE46152 is found in the bibliography in the 4th - 5th century BC.

Equally important preventive preservation plays an important role in the preservation by achieving a stable display and storage environment. Stable environmental parameters should be in the display and storage area such as: RH (45 -55%), T (18 ± 2 ° C), lighting (150-200 lux) and intensity of ultraviolet radiation at 60-80 Mw / lumen. For storaging acid free tissue paper can be used with a combination of polythene or polystyrene box and polythene foam following the usual methods from archaeological materials. For display the items can actually be support using a plexyglass as a basa inside the display case (Karidis et all, 2013).

Figure 7. Front view figure (16193) of Optical microscopy (20 Leica M3Z/M80 HD). Details: Cracks, sheeting with copper and corrosion of copper are observed.

Figure 8. Backside figure (16193) of Optical microscopy (20 Leica M3Z/M80 HD). Details from metal detachment and cracks.



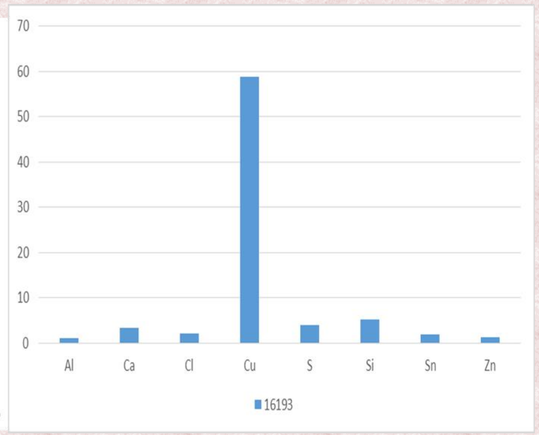


Figure 9. Quality analysis of *phiale* Br2980. The *phiale* with code Br2980 mainly consists of copper (Cu), lead (Pb) and tin (Sn).

Figure 10. Quality analysis of *phiale* 16193. The *phiale* with code Br2980 mainly consists of copper (Cu), lead (Pb) and tin (Sn).

Acknowledgments

The above study was carried out by the EU exchange student program "Erasmus+" with the collaboration of the Ionian University and in the context of my final dissertation. The authors are also grateful to the Conservation department staff (C2RMF) of the Louvre Museum in Paris: Mrs. Lorraine Mailho, Mrs. Sylvie Watelet, Mr. Dominique Robcis and Mrs. Noëlle TIMBART and the guidance of whom was crucial for this conservation to take place. Additionally, the authors are grateful to the stuff at the Conservation Laboratory of the National Archaeological Museum of Athens.

Bibliography

- Karydis, E. Kouloubi , N. Sakellariou, (2013). The science of preventive maintenance, conservation & collection management, Athens: Time Heritage.
- Kissas, K. (2013). Ancient Corinthia: From Prehistoric Times to the End of Antiquity. Athens: Foinikas Publications.
- Nadalini, G., (1998). La collection Campana au musée Napoléon III et sa première dispersion dans les musées français (1862-1863), Giovanni Pietro Campana (1808-1880), Journal des Savants, pp. 183-225.
- Stamelou. E., Tzoumerkioti. E., Vaxevanopoulos. M., Intzesiloglou. A., (2018). The sanctuary of Hercules in Sesklo Region, Volos, Greece: an archaeometric approach of the archaic bronze objects, vol 3, STAR: Science & Technology of Archaeological Research.

Figure 11. *Phiale* bronze from Perachora, Archaeological museum of Athens (16193)

Figure 12. *Phiale* bronze omphalos from temple of Hercules in Sesklo of Volos (BE46152).

Figure 13. *Phiale* bronze omphalos from Louvre museum (Br2980)