XRF ANALYSIS ON BLACK GLAZED POTTERY

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The main purpose of the present research is to identify the production locations of Roman black glazed pottery in the Republican Age (IV-I B.C.) coming from the archaeological area of "Pratica di Mare" (ancient Lavinium).
Both X-ray Fluorescence (XRF)[1] and X-ray diffraction (XRD) due to their "Non Destructive Features" are powerful methodologies to determine the elemental composition and to identify the mineralogical phases of archaeological relics.
Qualitative and quantitative XRF analyses have been used on a group of thirty pottery samples of the Roman Republican period. Some samples come from previous excavations made in the sixties while others, collected in the same area, come from a new excavation started in 2005.
Micro-fluorescence analysis was performed using a spectrometer with a polycapillary optics able to focalize the X-ray beam down to 50 µm. According to the expectations, the XRF analyses have confirmed that the black glaze covering the fragments has the same composition of the pottery body enriched by Al, Fe and K.

Fig. 1 – Lazio: Map of Rome and its South-West coast. The archaeological area of *Lavinium* is between Pomezia and Torvaianica.

LAVINIUM: AN ARCHAEOLOGICAL AREA

According to the tradition *Lavinium* [2] was founded by Aeneas who escaped from Troy's destruction due to gods will. The town, located thirty kilometres in the South of Rome, was built on a few rises overlooking the Tyrrhenian Sea (Fig. 1). *Lavinium* (Fig. 2), seat of a Latin federal sanctuary (*Aphrodision*), is mentioned on the first treaty between Rome and Carthage (509 B.C.). During the VI and V century B.C *Lavinium* belongs to the Latin league. In 491 B.C., it was probably besieged and conquered by Coriolano. At the end of the Latin war (338 B.C.) a federation agreement (*foedus*) was renewed with Rome. During the III century B.C. *Lavinium* was annexed to the Roman State, as a consequence the town lost progressively its importance and during the Imperial Age it became a little village. Nevertheless *Lavinium* maintains a notable importance as a religious centre till the late Roman Age, due to the legend of the Trojan origin of Rome.
Since 1957 the University of Rome "La Sapienza" has carried out systematic excavations[3] in the town area and its surrounding with many important discoveries like: the localization of the extra urban sanctuary of the "Thirteen altars"[4], the "Minerva sanctuary"[5], the "Town forum", the "Aeneas' Heroon"[6].

Fig. 2 – Archaeological map of *Lavinium*: 1) Acropolis. 2) Iron Age huts 3) Public *Thermae* 4) College of *dendrofori* (joiners). 5) Private houses – kilns. 6) Middle Republican Age building. 7) Constantinian Age villa. 8) Forum. 9) Urban gate.

THE SANCTUARY OF SOL INDIGES

Fig. 3 - *Sol Indiges* coastal sanctuary.

The coastal sanctuary of *Sol Indiges* was localized near Torvaianica in 1966-67 by F. Castagnoli[7], after limited survey excavations and aerial photointerpretation. Since 2005 systematic excavations in the area have brought to light a big hexastyle temple on podium of *peripteros sine postico* type (Fig. 3). The temple, supposed to be dated back to the end of the IV century B.C., is the rebuilding of a more ancient structure as proved by the discovery either of many statues fragments of acroteria and of polychromatic architectural coverings made of "terracotta", supposed to be dated back to the first middle of the V century B.C.
The sanctuary was located at the entrance of a vast coastal lagoon, used as port by the *Laurentes*, the ancient inhabitants of *Lavinium*. According to the legend, as long as the Trojans disembarked, they have been quenched their thirst by a sudden miraculous gush of a rich water source in the place where the sanctuary has been founded. There, Aeneas performed the first sacrifice, consecrating two altars to the Sun, which were still visible at the time of Dionysus from Alicarnasso (I century B.C.).

THE SAMPLES

Fig. 4 -Some variety of black glazed ware (IV – I B.C.).

A considerable part of the black glazed ware samples that have been analyzed comes from the Sol Indiges Sanctuary area, and a minor group comes from the Eastern Sanctuary .

Fig. 5 -Bottom of a bowl belonging to the "*Atelier des petites estampilles*" (III B.C.) group (sample num. T936).

Some samples have been taken from the bottom of the bowls belonging to the "Atelier des petites estampilles" (III B.C.) group, while others belong to pieces of black glazed ware that have recognisable shapes.

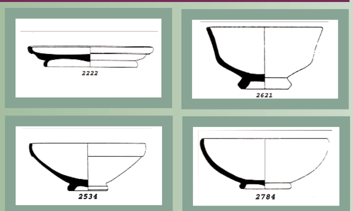

Fig. 6 -Some black glazed ware shapes (After Morel – 1981).

According to the classification proposed by Morel[9] some samples analyzed can be referred to the following shapes: 2222, 2534, 2621, 2784

XRF MEASUREMENTS

Fig. 7 -Micro-fluorescence spectrometer with a polycapillary optics (Unisantis – XMF 104).

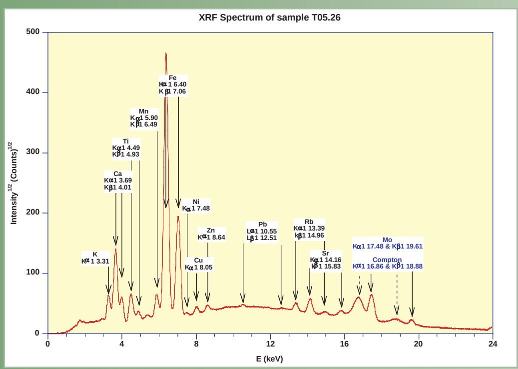

Fig. 8 -Typical µ-XRF body spectrum of a pottery (sample num. T05.26). The main elements are indicated.

Micro-fluorescence analysis has been performed using a spectrometer with a polycapillary optics able to focalize the X-ray beam down to 50 µm (Unisantis – XMF 104) (Fig. 7). The Mo X-ray tube operated at 40 kV and 120 mA. The collection time has been 2000 sec. To improve the statistics, on each sample, XRF data were acquired in four different points. As some light elements are below the instrument detection range a so called "Semi-quantitative analysis" has been performed. (Fig. 8).

CLUSTER ANALYSIS

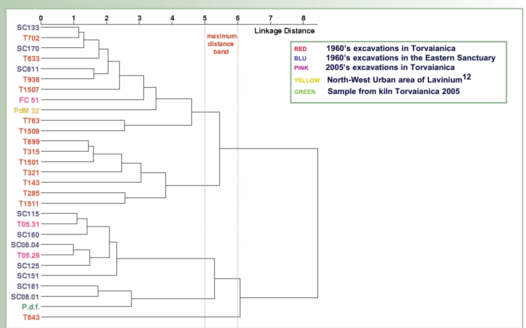

Fig. 9 -Horizontal Hierarchical Tree Plot showing the clustering of 29 samples (Ward's method, Euclidean distances).

The semi-quantitative XRF analysis of the samples has been used to determine the concentrations of the following 17 elements:

Al, Si, S, Cl, Ar, K, Ca, Ti, Cr, Mn, Fe, Ni, Cu, Zn, Pb, Rb, Sr.

The Tree Clustering method [10] has been used to group the wares with similar characteristics. Figure 9 shows a Horizontal Hierarchical Tree Plot[11], where 29 samples have been clustered. The graph represents the aggregation between the samples (y axis), obtained on similarities calculated by means of the *Euclidean distance* (x axis); which is the most straightforward way of computing distances in a multi-dimensional space (29 x 17). The *Agglomerative Clustering Technique*, that nests single classes in larger and larger groups, is based on the *minimum variance algorithm* (Ward's method). In Figure 9 five colours distinguish the samples origin.

REMARKS ON DENDROGRAM

If a starting hypothesis about a possible classification of the samples is not available, the number of clusters to be considered should be established by some reasonable criteria.
For example, a Cluster Analysis performed on a group of fragments known to belong to the same object may indicate a possible band of value for the maximum linkage distance to be considered. According to some preliminary indicative tests, which have to be refined, in our dendrogram we may identify two cluster groups probably due to wares coming from two different kilns.
Moreover, a classification attempt is conditioned by the fluctuation of the single element concentration due both to the structure unhomogeneity and to the experimental errors. For this reason the Euclidean distance is computed on normalized data: each concentration value is divided by the standard deviation of the concentration of all the samples. The new variables have zero average and standard deviation equal to 1. Work is in progress to improve the quality and the reliability of XRF evaluations, while XRD measurements and Rietveld analysis will allow to confirm our conclusions.

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