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MORTARS AND PLASTERS FROM THE "GARUM WORKSHOP" AT POMPEI (ITALY): AN ARCHEOMETRIC STUDY

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This work presents the results of the archaeometric study of mortars and plasters from the "Garum Workshop" at Pompei, the ancient Roman city located in Southern Italy and buried by the Vesuvius' eruption in 79 AD. The study is part of the project "From Fishing to Garum at Pompeii and Hercolaneum. Exploitation of marine resources in the Vesubian area", directed by Dario Bernal Casasola (University of Cádiz) and Daniela Cottica (Ca 'Foscari University of Venice) from 2008 to 2012.

The Garum Workshop (Fig. 1) is located in the Regio I of the archaeological site of Pompeii (I, XII, 8) and was devoted to the manufacture, storage and sale of "garum", the famous Roman fish sauce. Probably the building was originally a private residence, later transformed into a workshop [1].

The purpose of this paper is to provide information on the production technology of mortars and plasters and the raw materials used in the mixtures.

A total of 29 samples were analyzed for this study. A petrographical and geochemical characterization of the samples was carried out through the application of different analytical techniques: Polarized optical Microscopy (OM), X-ray Powder Diffraction (XRPD), X-ray fluorescence (XRF), microanalysis SEM-EDS, thermal analysis DSC-TG and image analysis [2].

The compositional and petrographical analyses show the presence of a great homogeneity among most of samples. In particular, the aggregate is mainly composed of pozzolanic fragments, used by the Romans as additive to create hydraulic mortars. Pozzolana can be classified as volcanic tuff [3] that has different textures, with the presence of microcrystals immersed in a glassy groundmass or totally vitrified with vesicles texture (Fig. 2a,b,c). The composition of several pozzolana fragments identified in the samples shows a great variability. As Miriello et al. (2010) [4] have shown for the samples of the Regio VI at Pompeii, also here the composition of these fragments is compatible with the compositional fields of the Vesuvian ash reported in the literature [5].

In the aggregate of the samples from the Garum Workshop there are also few calcitic fragments (Fig. 2d) which, at first sight, may be interpreted as lime lumps [6]. However, as already shown by Miriello et al. (2010), these whitish nodules are calcitic fragments occurring naturally in the Vesuvian ash. They are usually found in the Plinian eruptions of the Vesuvius and their presence can be explained by the fact that the magma rises along the volcanic pipe and removes fragments of calcitic nodules from the sedimentary basement [7].

Therefore, the raw materials used in these samples are related to the geology of the area and are fully compatible with the pyroclastic deposits of the Vesuvius.

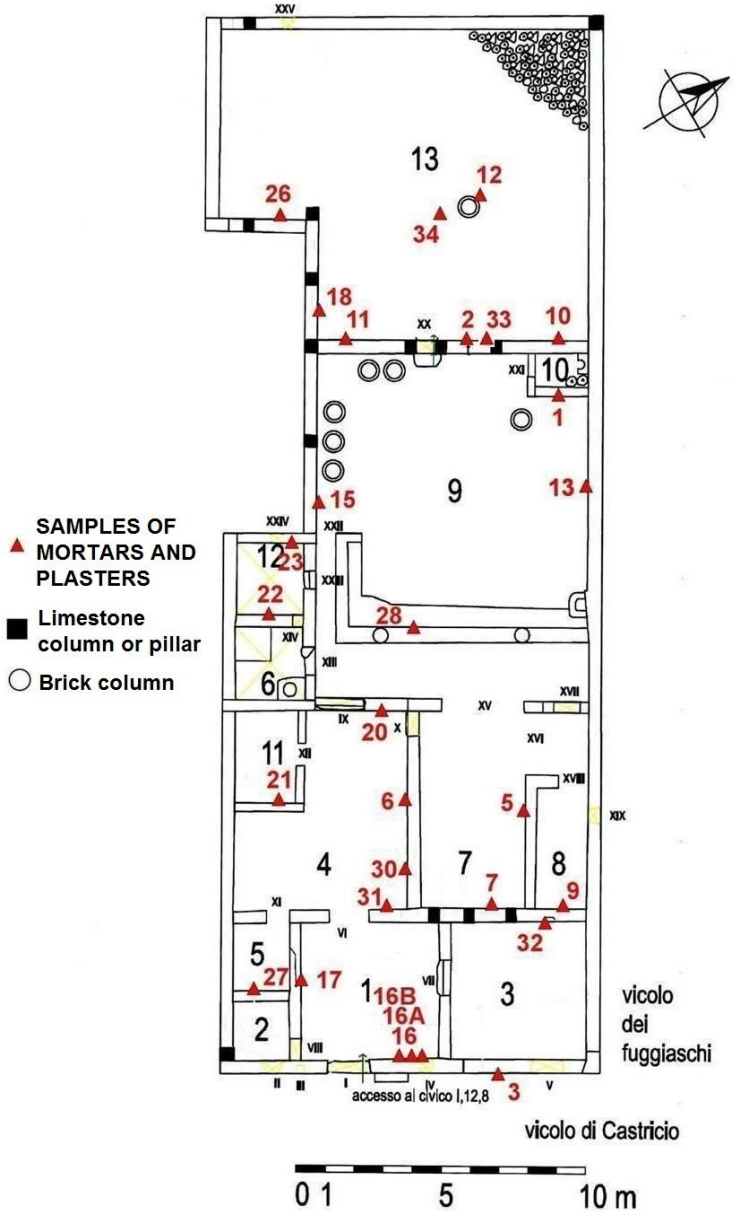

Fig. 1. Map of the Garum Workshop with the location of the samples taken in 2010 (modified by Cottica et al. 2009).

The presence of abundant pozzolanic fragments in the mortars and plasters, increases considerably the hydraulicity index of the samples that, in some cases, it is comparable to that of modern cements [8]. In general, the presence of pozzolanic materials increases the strength and durability of the mortars. In fact, the reactive silica contained in the pozzolanic fragments, reacts with the calcium hydroxide that is present in the mixtures, and leads to the formation of calcium silicate hydrates, commonly called C-S-H phases [9]. These phases increase the hydraulicity and the resistance of the materials.

In spite of the high values of hydraulicity, the samples coming from the Garum Workshop, don't show a high mechanical strength and, in most cases, are friable or incoherent.

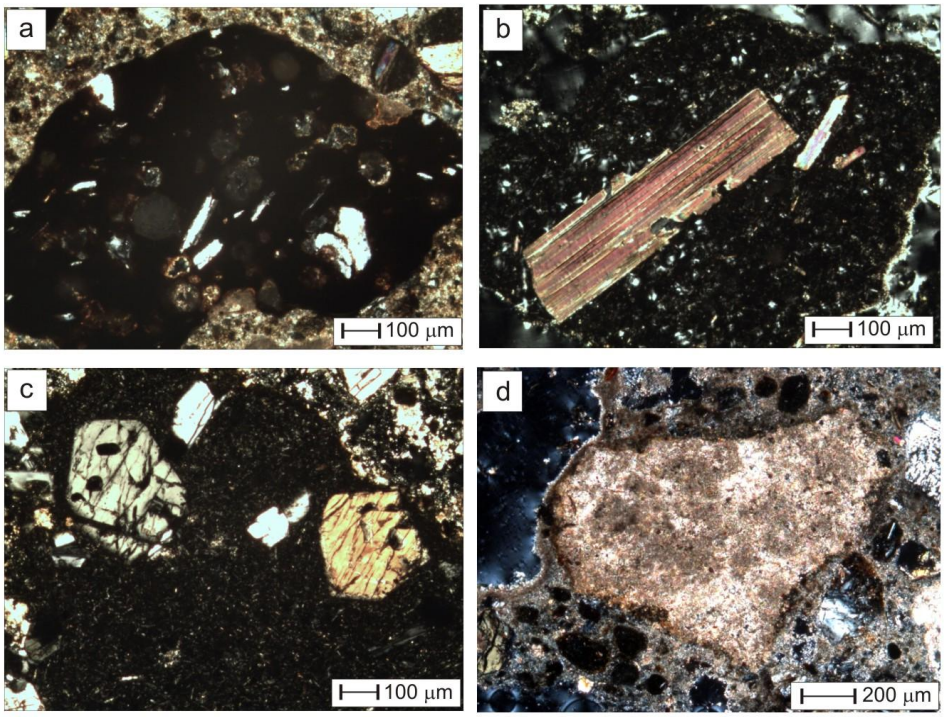

Fig. 2. Microphotographs of samples at optical microscope in polarized light. a) Pozzolanic fragment with crystals of plagioclase immersed in a glassy groundmass with vesicles texture. b) Pozzolanic fragment with macrocrystals of biotite. c) Pozzolanic fragment with macrocrystals of clinopyroxene. d) Example of calcite nodule present in the samples, occurring naturally in Vesuvian ash [4].

Therefore, the formation of the C-S-H phases cannot be considered the only factor that affects the durability and the resistance of mortars, and probably, also the method used for the working of the dough has an important role, as it has been recently shown [10]. For instance, the prolonged milling of a mixture containing lime and material with hydraulic characteristics, affects the physical and mineralogical characteristics of the final product. In fact, the prolonged milling eliminates the initial calcite, and therefore the calcite resulting from the hardening process is entirely neoformed calcite, ensuring that the fully hardened product has a great binding power [10].

The presence of a ceramic fragment with a series of superficial lime layers, inside the aggregate of sample PM_BG31 it is very interesting. In the SEM-EDS microanalysis, these layers show a variable content of MgO, CaO and P_2O_5. It is possible that this was a fragment of an amphora that contained lime, that was re-used in time. In fact in the Garum Workshop two amphorae with a lime content were identified [11]. The lime on the ceramic fragments of sample PM_BG31 that in some cases was made of magnesian calcite, was probably mixed with the "bone white", a well known pigment in Roman times, that was made of calcium phosphate and calcium carbonate [12].

The XRF results from all the samples (SiO_2, TiO_2, Al_2O_3, Fe_2O_3, MnO, MgO, CaO, Na_2O, K_2O, P_2O_5, Nb, Zr, Y, Sr, Rb, Ni, Cr, V, La, Ce, Co, Ba) were simultaneously integrated with techniques of multivariate analysis to obtain information on the constructive phases of the building. Data were processed according to the Aitchison model [13], in order to calculate additived-log-ratio (alr) transformations. The alr coefficients of the mortar and plaster samples were subjected to Multivariate Cluster Analysis to identify the construction phases of

the Garum workshop; the Square Euclidean distance and Centroid's method were used for calculation of clusters.
The integration of all petrographical and chemical data show that most of the samples belong to a large group, suggesting the presence of a principal constructive phase, probably associates to the first phase of the house, belonging to the Samnite period (2nd century BC).
Apart from the main group, there are other samples that show differences probably related to the different function of the material (mortar v.s. plaster), or their belonging to different manufactures.
This archaeometric work shows that mortars and plasters are a very powerful instrument for recovering information on the production technology of these materials, the row materials employed in the buildings and the constructive phases of the buildings analyzed. Moreover, the data obtained will be useful in the future to prepare mortars of high compatibility to be used in the conservation of the building.
Finally, the study of the mortars and plasters from the Garum workshop has also helped to clarify several aspects on the production of the lime used in the mixtures at Pompeii, some of which will be discussed in detail during the presentation of the work.

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