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Original article

Early evidences of vitreous materials in Roman mosaics from Italy: An archaeological and archaeometric integrated study

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Abstract

This work displays the lines of a project about vitreous materials used in Roman Republican Age *opus vermiculatum* mosaics from Italy. This mosaic technique, originated in Egypt and Greece during the Hellenistic Age, testifies the fist evidences of vitreous materials used in mosaics: faience and glasses. The use of these materials in *vermiculata* mosaics from Italy was almost unknown when this research was started, so it was necessary to map and characterize the whole mosaic production. After a survey operated by a portable digital microscope, a reduced number of samples were collected to perform a laboratory characterization (OM, SEM–EDS, XRD). Data have been completed by an isotope ratio characterization (SIMS) to investigate the glasses raw materials provenance.

Keywords: Hellenistic mosaic; Roman age Italy; Opus vermiculatum; Sealing-wax red glass; Faience; Vitreous materials microstructure; Oxygen isotope ratio

1. Research aims

This research comes from the idea that the mosaic is a complex system and its correct study needs to consider several aspects: the archaeological context, the style, the iconography and the mosaic technique. In fact, in the past, mosaics were considered mostly as artwork pieces and it was paid attention almost exclusively to the artistic analysis. This is actually true for objects with a high artistic value, as like the Hellenistic *opus vermiculatum* mosaics, object of this research. In this paper the lines of a project concerning the study of this mosaic technique in Italy is reported and the first results about the characterization of vitreous materials tesserae are presented.

2. Experimental section

2.1. Introduction

During the Republican Roman Age (2nd–1st century BC) a production of luxurious mosaics made in the so-called *opus vermiculatum* technique is attested in Italy. This technique uses tiny tesserae (1–4 mm) to obtain a pictorial effect, suitable to reproduce paintings as in the taste of this age. Because of the long times of execution required, these mosaics were usually assembled in the workshop on a stone or terracotta tray to create small pictures, called *emblemata*, suitable to be set into the centre of the floor as ready-made works. Otherwise, *opus vermiculatum* is sometimes attested to create great dimension mosaics, masterpieces assembled in situ.

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One of the main archaeological problems linked to these findings is, for the *emblemata*, the production site identification and, in general, the identification of the workshops provenance. In fact, there are similar mosaics, the oldest dating back to the end of the 3rd century BC, in other Mediterranean sites, such as Delos, Rhodes and Samos islands in Greece, Pergamon in Asia Minor, Alexandria in Egypt, Malta island and, in Spain, Empuries. *Vermiculata* mosaics from Egypt and Greece have been already studied [1] and here it was recognized the earliest use of vitreous tesserae, made in Egyptian faience, glass and Egyptian blue. Otherwise, an archaeometric characterization was performed only on a small group of glass tesserae from Delos [2], while faience used in mosaics has never been characterized.

The solving of the provenance problem was not possible with the existing literature data, because there is a total lack in the study of the *opus vermiculatum* technique in Italy, not only as it concerns the technical aspects, but also in the basis of the archaeological investigation. For example, it is noticeable that the exact number of evidences and their distribution is not clearly known. In this perspective this project [3] has been divided in two steps: the first step is the archaeological study, aimed to build a background suitable to carry on the second step, i.e. an archaeometric characterization aimed to reach a good knowledge of the materials used. Mosaics have been considered in all their constitutive elements: tesserae, mortars, trays and the painted surface finishing, but in this paper only the vitreous materials will be discussed.

2.2. *Vermiculata mosaics from Italy: the project*

2.2.1. *The archaeological investigation*

The archaeological study started with the creation of the evidences catalogue: the mosaics resulted to be in total eighty-three, mainly located in Pompeii and in Latium, but also in Sicily and in the North of the country. Observing the whole production it was possible to draw up its technical features and to find peculiar elements, index of a local production. In fact, in the entire production it was detected a frequent use of faience tesserae in the shades of blue and green, as like in mosaics from the Southern and Eastern Mediterranean region, but in Italy glass presence is lower attested and it is mainly of a bright homogeneous red colour. Moreover, in Alexandria and Delos, tesserae are cut from glass rods, while in Italy they are obtained from glass cakes. As it concerns other elements, thin lead stripes, used in Greece and Egypt to draw up the contour lines, are not attested in Italy, while, as like in the other Mediterranean sites, it was detected the practice to finish the surface with a painting layer [4], minimizing the perception of the mortar joints (Fig. 1).

2.2.2. *The archaeometric study*

After the acquisition of a good archaeological knowledge of the mosaics, it was performed the archaeometric characterization, aimed to investigate the microstructure and the chemical composition of the vitreous materials.

2.2.3. *Analytical techniques*

Firstly it was performed an on site surface observation by a portable optical microscope (Olympus Mic-D, magnification 20–225×): this instrument gave the chance to collect a great number of information about the surface materials microstructure and to identify the presence of non-original parts. The characterization was completed collecting a group of samples prepared in polished sections to be characterized by different techniques: optical microscopy (Olympus SZX16), electron microscopy (SEM, Philips XL 40) with microanalysis EDS, XRD (Panalyitcal X'Pert, radiation Cu Kα, 2θ 5–70°, on polished sections with focused beam, acquisition time 3 h), Secondary Ion Mass Spectrometry measurements (IMS 4f mass spectrometer, Cameca, Padova, Italy, using a 14,5 KeV Cs+ primary beam and by negative secondary ion detection).

2.2.4. *Experimental data and results*

2.2.4.1. Faience tesserae. Faience tesserae have been detected in a variety of green and blue shades in eighty-two mosaics i.e., with one exception, in the whole production. It was possible to sample ten tesserae from different sites (Table 1) which, after the optical microscope observations, appeared to be divided in two groups: the first one, attested only in light green colour, is opaque and with few pores, while the second, turquoise, green or blue, is richer in pores and stones, visible as gray and dark brown grains (Fig. 2). Electron microscopy confirmed the division in two groups: the first one presents a non-homogeneous structure, with high silica, containing crystals not very well distinct from the matrix. The EDS chemical composition (Table 2) reveals the use of iron as colouring agent and a high concentration in magnesium and alumina indicating the use of sands rich in impurities.

The second type presents isolated silica crystals with sharp edges embedded into a glass matrix and, occasionally, it was also possible to analyze traces of the colouring agents: in a yellowish green sample, it was detected the presence of an unmolten spot containing lead and antimonies, testifying the use, as well documented in Ptolemaic faience [5,6], of lead antimoniate to obtain this particular green shade, resulting from the mixing of the green colour, due to the iron and copper content, and the yellow of lead antimoniate. Moreover, in a turquoise tessera, it was detected a spot containing cobalt, testifying the mixing between the green of iron and copper and the blue of cobalt. In general, comparing the overall compositions with the samples of the first group, here it is possible to detect values higher in silica and lower in alumina. In the whole sampling, analyzing the overall composition, low alkalis values were detected: this is due to the low quantity of glass phase in fact, performing the analysis on the vitreous matrix, higher values were detected (Na_2O 7.4–12.5 Wt%; K_2O 0.8–2.9 Wt%).

In both the structures there is no evidence of a vitrified layer on the surface, so the samples can be classified as glassy faience, a non-glazed faience variant [7].

The mineralogical analyses show mainly the high temperature phases of SiO_2: cristobalite and trydimite. Low quartz, and an amorphous phase is common to both microstructures.

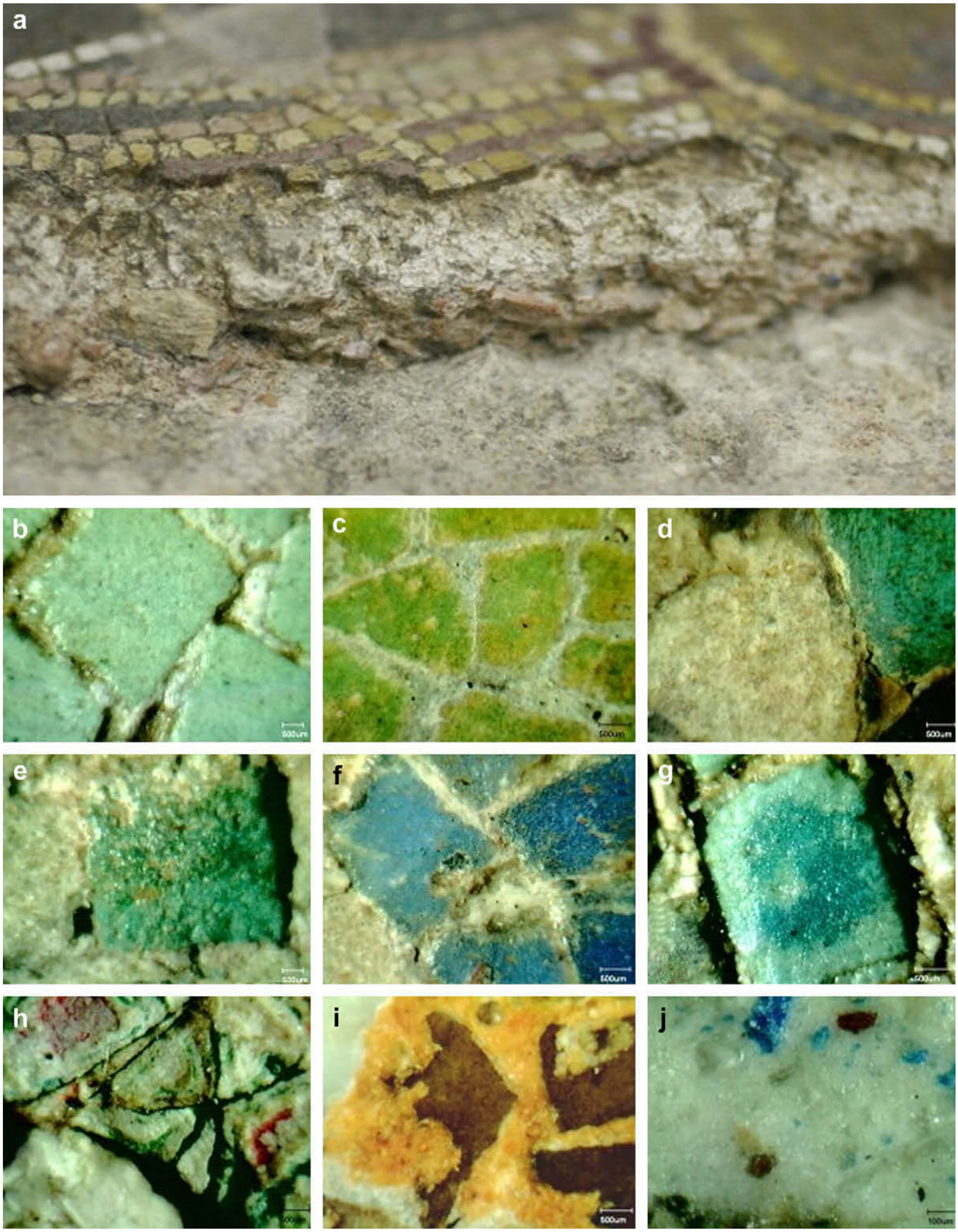

Fig. 1. An emblema mosaic seen in section (a): starting from the bottom it is possible to observe the tray, the mortar layers and the tesserae. Below, a sequence of images taken by the portable optical microscope on the tesserae surface: the faience colour variation (b−g), a group of *sealing-wax red glass* tesserae covered, as usual, by a green-whitish deterioration layer (h) and the painting on the surface in orange (i) and light blue (j) (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

Quantitative analyses are not useful to identify minor crystalline phase or quartz level to discriminate the raw materials used in the two cases.

2.2.4.2. The glasses. During the on site observation, the use of glasses in different colours, as like yellow, orange, green and blue, was mapped, but the number of evidences is so insignificant that it was decided to focus the sampling only on red (Figs. 1 and 2), the colour, with twelve evidences, highly attested. Six samples were collected from three mosaics and other six samples have been taken from Italian wall mosaics dated from the beginning to the first half of the 1st century

Table 1
Description and provenance of the faience samples analyzed

Sample	Colour	Mosaic	Provenance	Conservation place
Roma VN camp2	Green	Emblema with Nile landscape	Roma, via Nazionale, house	Roma, Antiquarium del Celio
Roma VN camp3	Turquoise			
Chiusi camp1	Green	Emblema with boar and deer hunting scene	Montevenere di Chiusi (Siena)	Chiusi (Siena), Museo Archeologico Nazionale
Pollenza camp1	Green	Emblema with boar and deer huntig scene	S. Lucia di Pollenza (Ancona), villa	Ancona, Museo Archeologico Nazionale delle Marche
Pollenza camp2	Blue			
Pollenza camp3	Turquoise			
Pompei L camp1	Turquoise	Emblema with Theseus and the Minothaurus	Pompeii, VII, 11, 8−10, House of the Labyrinth, triclinium (42)	On the place
Pompei L camp2	turquoise			
Pompei L camp3	Yellowish green			
Solunto L camp8	Green	Emblema with armillary sphere	Solunto (Palermo), Leda house, triclinium	On the place

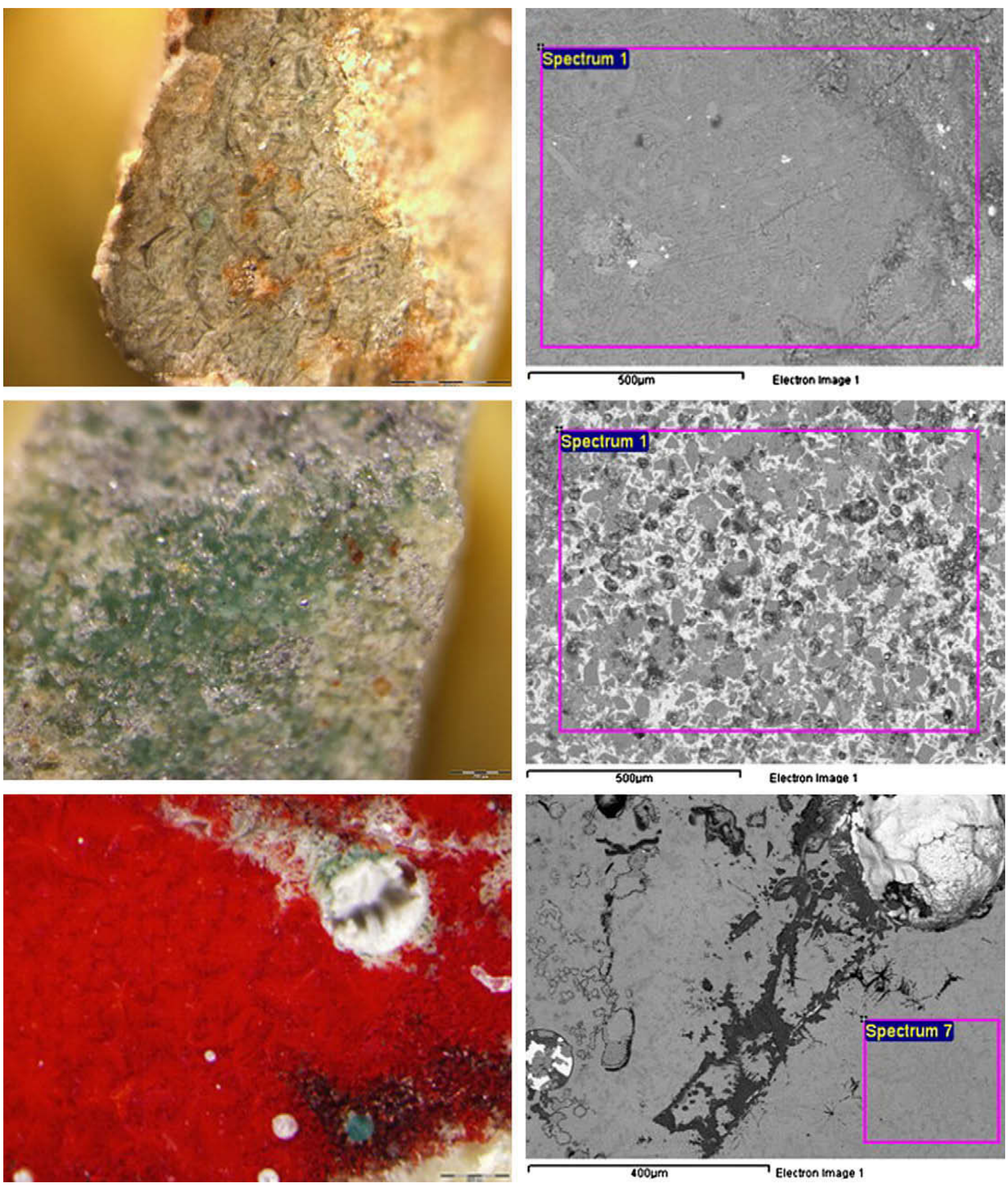

Fig. 2. Microstructure observation on faience and *sealing-wax red glass* tesserae: the optical microscope images (left) are compared to the observation at the electron microscope (right). From the top: Pollenza_camp1, a first type faience tessera, Pompei_L_camp3, a second type faience tessera and a *sealing-wax red glass* tessera from the Navarca house in Segesta (Trapani). Pink rectangles mark the area analyzed by EDS to calculate the chemical composition (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

Table 2
The EDS composition of faience tesserae: in green the samples with the first microstructure and in yellow the group with the second one

	Chiusi camp1 (Wt%)	Pollenza camp1 (Wt%)	Roma_VN camp2 (Wt%)	Solunto_L camp8 (Wt%)	Pollenza camp2 (Wt%)	Pollenza camp3 (Wt%)	Pompei_L camp1 (Wt%)	Pompei_L camp2 (Wt%)	Pompei_L camp3 (Wt%)	Roma_VN camp3 (Wt%)
Na_2O	0.85	1.07	2.21	–	0.81	3.68	2.42	1.98	2.86	3
MgO	0.97	1.19	4.39	0.37	5.5	0.43	0.57	0.38	0.58	0.39
Al_2O_3	12.84	13.75	12.45	1.58	11.43	2.73	1.25	1.24	1.19	1.44
SiO_2	77.62	73.15	44.37	95.83	31.03	87.2	82.48	86.29	74.04	87.24
Cl	0.39	–		–	–	0.1	0.31	0.19	0.66	0.43
K_2O	1.11	0.99	0.67	0.15	–	0.62	0.36	0.7	0.7	0.65
CaO	4.83	7.79	29.96	0.8	46.05	3.65	4.14	4.08	9.99	3.87
FeO	1.1	1.31	4.42	1.27	5.18	0.47	1.16	1.87	1.7	1.68
CuO	–	–	–	–	–	1.13	1.83	1.48	1.36	tr
PbO	–	–	–	–	–	–	–	–	6.91	–
SO_3	0.29	–	0.66	–	–	–	5.46	1.79	–	1.31
TiO_2	–	0.75	0.87	–	–	–	–	–	–	–
CoO	–	–	–	–	–	–	–	–	–	tr
BaO	–	tr	–	–	–	–	–	–	–	–
V_2O_5	–	–	–	–	–	–	–	–	–	tr
P_2O_5	tr	–	–	–	–	–	–	–	–	tr
SnO	–	–	–	–	–	–	tr	–	–	–
Sb_2O_5	–	–	–	–	–	–	–	–	tr	–
	100	100	100	100	100	100	100	100	100	100

AD. Because of the complex problems linked to this material, the analytical data will be discussed in detail elsewhere. For the moment, it is possible to report that all the red glasses were identified by SEM–EDS with the so-called *sealing-wax red* glass [8], a silica–soda–lead glass of composition of SiO_2 38–51, PbO 16–35, Na_2O 8–12, CuO 7–11, CaO 2–5, Al_2O_3 1–2(Wt%). Minor elements are: K_2O, Cl, MgO, FeO, MnO, P_2O_5, Sb_2O_3. As a conclusion it can be stated that these glasses were coloured and opacified by cuprous oxide crystals, clearly detected by the X-ray diffraction. The colouring raw material, as attested by literature data [9], is clearly metallic copper, detectable as unmolten particles.

2.2.4.3. The isotope signature characterization. To make clear the identification of the production site, a characterization (SIMS) of the isotope ratio of a group of meaningful elements (O, Sr, Cu, Fe, Pb) in glasses and faiences is in course. For the moment the work has been concluded only in red glasses for oxygen isotope ratio, suitable to trace the provenance of the sand [10]. The samples analysis revealed the existence of four different groups: the first one is formed by *sealing-wax red glasses* dated 2nd–1st century BC and, with small values variation, mosaic tesserae and vessels of the 1st century AD. These values are well distinct from the ones obtained from a base glass chunk found in Pompeii and other glasses (colourless and dullish red, with low lead and copper content) forming a second group. A *sealing-wax red glass* tessera from Sicily (Segesta) has distinct values, so it must be attributed to a different production. The difference between sealing-wax reds and dullish red glasses could not be only index of a distinct production site, but also of a different technology: for the firsts it is true-life to hypothesize the melting of a batch containing all the components while, for the seconds, the remelting of a base glass with the addition of the coloring agent: this model of production was confirmed by an experimental reproduction in electric kiln and in a wood fired furnace, at the moment still ongoing.

3. Conclusions

This study gave the possibility to draw up the main technical features of *vermiculata* mosaics from Italy, permitting to hypothesize a local production. Moreover, the use of glass and faience tesserae was never reported before and thanks to the characterization it was possible to enhance the knowledge of these materials and, in the future, it will be possible to link these data to the literature. Otherwise, the frequent use of the sealing-wax red glass is meaningful, because it testifies the choice of a refined material difficult to produce and certainly expensive. The isotope signature suggests the existence of a specialized production, but in the future data shall be completed with a more comprehensive characterization.

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