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Case study

Building a step by step result in archaeometry. Raw materials, provenance and production technology of Apulian Red Figure pottery

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1. Introduction

One of the most interesting issues in the archeological field involves the identification of places where archeological finds were produced and the production technologies which were used to make them. The answer to these questions can undoubtedly be provided by a systematic archaeometric study, which by providing compositional and structural information about bulk and surfaces, might make it possible to recognize the manufacturing processes of ancient objects and to help solve the larger question regarding the provenance of raw materials. However, this approach has only recently growing significance in the overall archeological research [1–5].

In this regard, the case of Apulian red figure pottery is emblematic. Historically, interest in this class has been exclusively of a stylistic-typological nature, and only based on stylistic-comparative criteria [6–8], provenance, dating, painters and workshops have been assessed. For more than 50 years, this methodology influenced archeological studies and results were recognized almost uncritically. In the end, although this kind of reconstruction is undoubtedly valuable, it also displayed many limits.

The technological features of Apulian red figure pottery have also so far received little attention, since this class acquired know-how coming from Attic pottery, and has been incorrectly considered up to now as a mere "imitation".

As regards this class of ceramics, many questions remain unanswered. A focus on the 4th to 3rd century BCE with its increasing and diversified production raises some important issues. During the proto-Apulian period, workshops organization was well arranged and complex (more craftsmen could work on a single vase, apprentices could co-work with the main painter, production could be diversified). This kind of management continued up to the next century, but in the Late period production increased and differences between low-quality mass production and excellent artistic items became more evident. The most interesting issue to be answered deals with the identification of the workshops, especially for the Middle and Late periods, when production increased. The most likely theory accepted so far hypothesizes that a transitory transfer of expert craftsmen and artists took place from Taras (Taranto) to the wealthiest Apulian villages, the most interested in acquiring such expertise, at least for the most prized pottery pieces. Then these became branch centers of production outside the main polis (city). However, the production of items of minor importance for local use was arranged locally. Vessels both of a very different size and formal/iconographic quality are found together, but does this diversification depend on what the item was to be used for (daily use, burial, etc.) and/or on who it was made for?

1.1. Archeological framework

The materials analyzed come from Arpi (Foggia), where, between 2011 and 2012, excavations for the recovery of three distinct hypogea, which had previously undergone a clandestine excavation, were carried out by the Superintendence in collaboration with the Guardia di Finanza of Foggia. The most interesting

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area concerned small farm ONC28, where numerous findings from a Hellenistic settlement were found. They include a peristyle domus with mosaic floors made of pebbles from the second half of the 3rd century BC and a peristyle domus, with mosaics of "griffins and panthers" and "dolphins", dating back to the end of the 4th to 3rd century BCE. Excavation made it possible to identify a grotticella tomb oriented in a north-south direction. The conservation state of the grotticella tomb was badly affected by previous clandestine excavation carried out with mechanical means, so as to make it difficult to reconstruct the architectural structure of the complex. The recovered finds, dated to the 4th to 3rd century BCE, consist of a Gnathia monoansed cup and many fragments of Apulian red figure, tempera with polychrome decoration pottery, Daunian subgeometric ceramic, overpainted black paint ceramic and cooking ware.

The excavation area had been identified by the Guardia di Finanza, based on independent investigative activities related to criminal affairs which a few months beforehand had led to the seizure of a group of Apulian red figure vases made using a high-quality manufacturing process in an excellent state of preservation.

Decoration of the vases is typical of the "ornate" style, developed in the second half of the 4th century BCE in Apulia and later widespread throughout Magna Graecia. On all the vases the ornamental richness of the vegetables is evident, enhanced by the splendor of the colors used.

The recurring decorations for these vases, with the image of a naìskos on one side and with a stele on the other, indicates mass production, which makes it very difficult to attribute the work to one specific painter in particular. Although an archeological study of the vases is still in progress [9], it has been possible to distinguish at least three groups, corresponding to three workshops which were connected to each other and active between 340 and 320 BCE.

These vases – 8 volute craters (C1–C8), 5 amphorae (A1–A5) and 5 hydrìai (I1–I5), escaped illegal export, and testify to the economic, cultural and social changes that affected Arpi, when Alexander the Molossus, king of Epirus and uncle of Alexander the Great arrived in southern Italy.

Systematic archaeometric studies on Apulian red figure pottery are quite recent [10–17], and few of these were carried out on excavation finds. Archaeometric research has highlighted the existence of a parceled production and the use of two different production technologies, during the 4th century BCE [5,13,14]. Certain vases were produced using Attic technology [18–27] and others with a different technique, recently reported in literature [5,13,14] and never highlighted in Attic items, which involved the application of a red engobe layer on the clay paste, before the black gloss painting. Causes that led to this change in production are not yet clear. Previously, it had been suggested that a production variation had occurred due to the need to employ a more suitable material to manufacture larger vases. However, further research points to an economic reason since this "new" production involved the use of less refined raw materials and a consequential cheaper cost for the buyer, which was probably a good compromise for less wealthy costumers.

2. Experimental

Some analyzed samples are shown in Fig. 1. C1–C7, A1–A5, I1–I5 are sampled by seized vases, F1–F4 are fragments coming from the ONC28 Tomb. As concern C3, C4 and C8 vases, two or three micro-samples (few square millimeters) were collected from different areas of vases to check if chemical and minero-petrographic differences among their ceramic bodies are much smaller than differences with ceramic bodies of objects sampled from different vases.

The samples were studied with polarized-light Optical Microscopy (Carl Zeiss), Scanning Electron Microscopy (EVO-50XVP [LEO]) with Energy Dispersive Spectrometry (Oxford-Link EDS), Powder X-ray diffraction (Philips X'Pert) and Inductively Coupled Plasma Mass Spectrometry (PerkinElmer Elan 9000). The analytical procedures are described in Ref. [5].

3. Results

3.1. Ceramic bodies

The compositional data of the bodies obtained (Table 1) were treated with Hierarchical Cluster Analysis and Principal Component Analysis. Multivariate statistical analyses of elemental composition were applied to distinct and correlated groups of items, aimed, for instance, to assign pottery of an unknown provenance or to define an archeological classification [16,28–30].

The software package Minitab® was applied on compositional and standardized data to perform the multivariate statistical treatment. Results are reported in Fig. 2 (a and b). Fig. 2a shows both the great similarity of samples belonging to the same vase (C3, C4 and C8) and the wide compositional diversity of the C2, C7 and I3 samples.

To verify if the compositional differences highlighted for samples C2, C7 and I3 are to be attributed to a different manufacture or to a different provenance, multivariate analysis was extended to the compositional data of the coeval red figure fragments from other sites of Apulia – included finds coming from another tomb from Arpi which we had previously analyzed [31]. Obtained results (Fig. 2b) substantiate the archeological hypothesis of a local production of red figure pottery in Apulia in the Late period, with a proliferation of manufacturing locations. Indeed, the outcome of the treatment highlights the formation of three macrogroups of objects, distinguished according to different geographical areas (Peucetia, Messapia and Daunia), which characterized ancient Apulia, so supporting the presence of polycentric production. Moreover, the placement of samples C2, C7 and I3 in Daunia and in particular in Arpi samples cluster suggests that their diversity is due to a different place of manufacture (workshop) rather than to a different provenance.

The results of minero-petrographic investigation show that, except samples C2, C7 and I3, the pastes are characterized (Fig. 3) by a very fine quartz-feldspathic silt with micas (muscovite, biotite and Ca-rich micas) in an abundant matrix of highly sintered clay (2–4 μm). Alkali feldspars, plagioclases, Fe-oxides and hydroxides, ilmenite, rutile and very small Ca-phosphate crystals (recrystallized hydroxyapatite?) can be also observed. Clay matrix shows a such amount of calcium to justify, in presence of suitable temperatures, the crystallization of neo-formed minerals like pyroxenes and gehlenites as highlighted in Table 2. The sintering degree is high (Fig. 3) and micas and pores were parallel orientated to the walls of the pottery wares. F1, F2, F3 and F4 samples (Fig. 3) are very similar to these samples. (The presence of Ca-phosphate in some open pores of the ceramic bodies demonstrates its post depositional nature, probably associated to the human bone dissolution in the tomb, suggesting even similar burial conditions [32,33].)

A very small amount of clayey matrix instead characterizes samples C2, C7 and I3 (Fig. 3). Differences with the other samples can also be identified in the paste texture (quantity and dimension of coarse inclusions). Indeed, a large amount of coarse grained silt (16–63 μm) and a consistent amount of very fine sand (63–125 μm) can be recognized. The non-plastic inclusions consist mainly of quartz, feldspars (alkali feldspars and plagioclase),

Fig. 1. Representative examples of the vases examined.

micas (muscovite, biotite and Ca-rich micas) and clusts of carbonatic rocks (limestone). Secondary calcite, formed during burial, is also observed. The sintering degree is medium-low (Fig. 3).

In Table 2 we report the semi-quantitative mineral content by XRPD analyses of representative samples and also sintering degree, according to the samples' mineralogical features. Relevant production technology indications can be obtained from Table 2. The mineralogical paragenesis of neoformed minerals, pyroxenes and gehlenites, together with sintering degree allow to state the Estimated Equivalent Firing Temperatures (EFT) [35,36]. The EFT is 1000–1100 °C for all samples and in the range between 800 and900 °C for samples C2, C7 and I3.

3.2. Coatings

3.2.1. Black gloss

The black gloss present on all analyzed samples shows the same compositional and structural characteristics of the black gloss of all samples of Apulian and Attic red figure pottery analyzed so far [5,13–15,21,31].

3.2.2. White overpaintings

The characteristics of the white overpaintings are the same as all the white overpaintings analyzed up to now on Apulian red figure pottery [37]. Kaolinite, with albite and k-feldspars added as low melting, were probably raw materials used [38]. In this case, the presence of albite and k-feldspars indicate a voluntary addition by craftman. Indeed, kaolinite is formed by a complete alteration of igneous and sedimentary rocks that leads to an almost total destruction of silicate minerals [39].

3.2.3. Yellow overpaintings

The samples' yellow areas are of two types. In addition to the typical yellow overpainting found on Apulian and Attic pottery [21–37] -compact and vitrified with transitional characteristics between black gloss and white pigment, on the Arpi samples another kind of yellow with different characteristics in terms of texture, sintering degree and chemistry is found (Fig. 4). Its structure is not very compact, scarcely vitrified and structurally similar to white pigment, from which it is distinguished by the presence of small quantities of iron. These data are consistent with the use of kaolin added with small amounts of iron oxides.

Table 1
Chemical composition and vase shape of the samples analyzed.

Sample	Vase shape	Element concentration												
		w/w, %							$\mu g\, g^{-1}$					
		Al	Fe	K	Mg	Ca	Ti	Na	Ni	Sr	Cr	Mn	V	Zr
C1	Crater	10.07	5.63	2.72	1.48	8.34	0.54	0.98	74	266	160	1059	225	170
C2	Crater	10.62	4.07	2.82	1.36	10.37	0.41	1.64	70	318	120	673	158	70
C3_1	Crater	10.30	5.25	1.3	1.45	8.38	0.49	1.19	61	324	150	1278	297	145
C3_2	Crater	10.62	5.09	1.35	1.43	8.75	0.52	1.20	68	313	136	1289	275	152
C3_3	Crater	10.67	5.22	1.42	1.50	7.98	0.54	1.30	62	299	149	1300	280	156
C4_1	Crater	9.70	5.27	2.33	1.48	8.71	0.51	1.08	70	242	139	932	196	103
C4_2	Crater	9.62	5.20	2.47	1.50	9.08	0.54	0.96	68	266	147	946	220	99
C4_3	Crater	9.66	5.15	2.39	1.44	8.74	0.51	0.99	66	282	144	898	232	113
C5	Crater	10.26	5.53	2.68	1.66	7.98	0.53	0.98	73	274	158	1033	215	116
C6	Crater	9.86	5.38	2.89	1.54	8.75	0.51	0.96	73	266	148	928	198	105
C7	Crater	10.03	4.11	2.22	1.20	9.85	0.40	1.38	75	299	179	685	54	22
C8_1	Crater	9.95	5.29	2.83	1.59	9.03	0.50	1.10	64	262	149	930	190	160
C8_2	Crater	9.78	5.30	2.95	1.50	8.46	0.52	1.00	62	270	147	926	206	164
A1	Amphora	9.17	5.01	1.98	1.39	8.06	0.51	1.22	74	261	113	930	186	109
A2	Amphora	9.42	5.11	2.50	1.44	7.84	0.52	0.77	70	268	147	808	213	146
A3	Amphora	9.32	5.71	2.49	1.40	8.65	0.50	1.12	60	253	197	929	205	145
A4	Amphora	10.25	4.97	1.91	1.32	7.37	0.51	0.80	57	260	139	752	198	121
A5	Amphora	9.59	4.95	2.42	1.45	7.70	0.52	1.24	56	314	52	1009	241	160
I1	Hydria	9.77	5.06	2.88	1.39	7.42	0.53	0.99	54	287	134	950	259	157
I2	Hydria	10.74	5.54	3.52	1.55	6.52	0.56	1.19	58	313	126	971	234	145
I3	Hydria	9.01	3.53	2.03	1.11	8.64	0.38	1.64	60	288	87	613	133	83
I4	Hydria	9.09	4.92	2.60	1.35	7.56	0.51	0.94	85	273	137	933	217	148
I5	Hydria	13.19	4.87	2.28	1.39	8.84	0.52	1.24	61	323	50	781	213	144
F1	Fragment	9.57	5.08	1.44	1.37	7.83	0.52	1.33	72	307	152	959	219	130
F2	Fragment	10.00	5.28	1.74	1.44	8.02	0.54	1.51	77	316	161	1051	254	144
F3	Fragment	10.27	5.19	2.36	1.49	7.87	0.53	1.67	73	323	54	924	227	136
F4	Fragment	11.49	5.04	2.80	1.39	7.87	0.51	0.83	59	252	133	1018	249	158

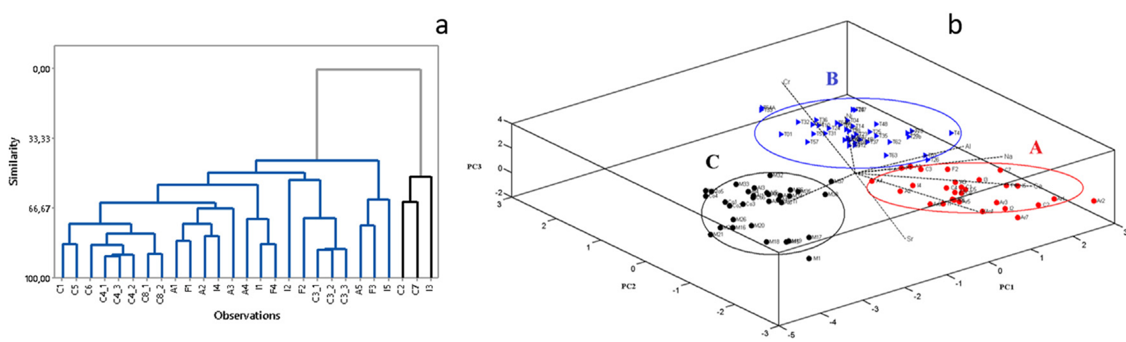

Fig. 2. (a) Hierarchical clustering dendrogram by complete linkage method with Euclidean distance metric of autoscaled variables. (b) Scores and loadings diagram for the first three principal components related to the ceramic bodies of Apulian red figure pottery from different Apulian sites. The accounted variance is 70% of the total variance. Clusters: (A) finds from 5/2005 and ONC28 tombs from Arpi, (B) finds from Taranto and (C) finds from Monte Sannace, Altamura and Conversano.

3.2.4. Red overpaintings

The red overpainting on all the analyzed samples shows a heterogeneous, coarse-grained structure in which large aggregates of iron oxides are visible (Fig. 4). These characteristics, together with the average chemical composition of this layer, are compatible with the use of *terre rosse*, continental sedimentary layers, very common in Apulia. The mineralogical composition consists of mostly partially crystalline Fe and Al oxides and hydroxides, clay minerals (illite and kaolinite) and traces of quartz, feldspars, micas, pyroxenes and other minerals [40].

These compositional and structural characteristics are different from the red overpaintings of samples of Apulian red figure pottery analyzed so far [37].

3.2.5. Light brown overpaintings

The light brown pigment is used to give three-dimensionality to the architectural elements of the naiskoi. Its structure is compact and vitrified, structurally similar to black gloss. However, its composition shows a lower Fe and a greater Ca content, as compared to black gloss.

4. Conclusions

The obtained results indicate that the differences found for some vases of the analyzed sample are due to a different manufacture and not to a different provenance.

With the exception of the samples C2, C7 and I3, for all the samples taken from the ONC28 tomb, results suggest the use of a very accurate manufacturing process, from the choice of raw materials to the refining, making and firing of the vase. This hypothesis is supported by the small dimension of inclusions – indicative of the use of a refined clay, by the high sintering degree – indicative of a high firing temperature being employed for a long time – and by the orientation of the micas and the pores to walls of the pottery wares – indicative of a very accurate throwing and turning.

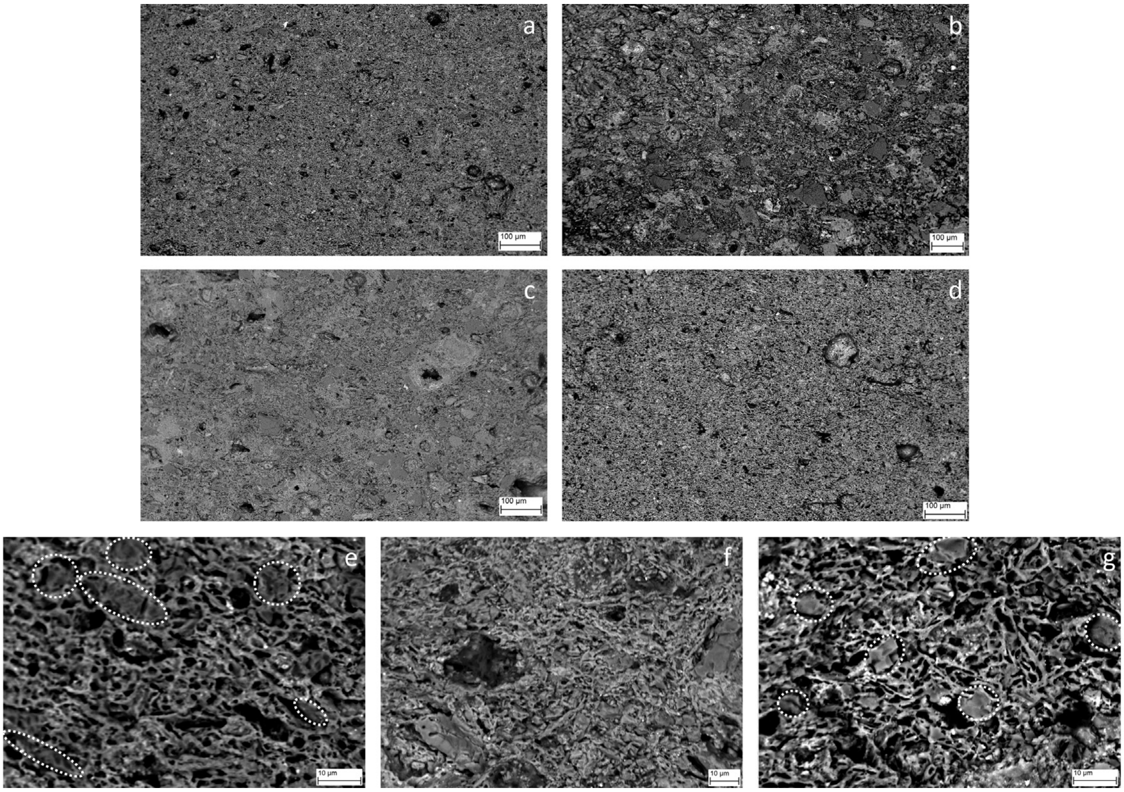

Fig. 3. Top clockwise: SEM-BSD photomicrographs of ceramic pastes of samples: A2 (a), C7 (b), I3 (c), F2 (d). Bottom: SEM-BSD photomicrographs of ceramic pastes of samples A3 (e), I3 (f) and F1 (g), showing their sintering degree. Dotted circles highlight pastes characterized by a very fine quartz-feldspathic silt with micas.

Table 2
Semi-quantitative mineral content, by XRPD, of representative samples and estimated maximum firing temperature (EFT).

sample	Non-plastic inclusions								EFT (°C)	Sintering
	Ms + Bt	Qtz	Kfs	Pl	Cal	Px	Gh	Hem		
A5	Tr	XXXXX	XXX	XX	Tr	XX	Tr	X	1000–1100	H
C1	Tr	XXXXX	XXXX	XX	X	XX	–	X	1000–1100	H
C2	Tr	XXXXX	XXX	X	–	X	X	Tr	800–900	M
C3	–	XXXXX	XXX	X	XX	XX	X	X	1000–1100	H
C5	–	XXXXX	XXXX	XX	Tr	XX	Tr	X	1000–1100	H
C6	–	XXXXX	XXXX	XX	Tr	XX	Tr	X	1000–1100	H
C7	–	XXXXX	XXX	X	X	X	X	X	800–900	M
C8	Tr	XXXXX	XXXX	XX	Tr	XX	Tr	X	1000–1100	H
I1	Tr	XXXXX	XX	X	Tr	XX	X	X	1000–1100	H
I2	Tr	XXXXX	XX	X	–	XX	–	X	1000–1100	H
I3	–	XXXXX	XXX	X	XXX	X	Tr	X	800–900	L
I4	–	XXXXX	XXX	X	X	XX	Tr	X	1000–1100	H
I5	–	XXXXX	XXX	X	X	XX	X	X	1000–1100	H

Key: Ms = muscovite; Bt = biotite; Qtz = quartz; Cal = calcite; Pl = plagioclase; Kfs = k-feldspar; Px = pyroxene (diopside); Gh = gehlenite; Hem = hematite [34]. EFT, equivalent firing temperature. tr, traces; X-XXXXX, relative abundance. Sintering degrees: H, high; M, medium: L, low.

With regards to the decorations used, the high artistic quality of the vases [9] is associated with extreme care being taken in the search for the most suitable raw materials and their conscious use to create three-dimensional effects and to make the different types of brightness found on the materials. This is the case of yellow overpainting, for which two pigments, with different covering power and brightness, have been employed. One is vitrified, glossy and is used to outline the contours and to paint weapons (helmet, armor, greaves, shields, lance and sword), the second is opaque with low coloring power and is used to make the lightness of the fabrics with which some clothes are made. Or the case of the brownish, vitrified and glossy color, used to make the 3D of the architectural structures.

Moreover, the obtained results confirm the hypothesis of a local production for late Apulian red figure pottery [31,41] and begin to highlight a differentiation of production according to the client's social rank. Indeed the archeological study of vases from Arpi analyzed so far, all coming from tombs referable to aristocratic classes, has confirmed that there was an increasing number of socially high-ranking clients for red figure vases from the second half of the 4th century BCE in Arpi, in towns such as Canosa and in the other towns in the Daunia area (i.e. Ascoli Satriano). This is testified by the grave goods found in previously investigated tombs in Arpi – the Niobidi tomb [42], the 5/2005 tomb [31], the ONC28 Tomb and the Tomb of glass. Unfortunately, neither the ONC28 nor the Tomb of Glass were intact due to clandestine excavations.

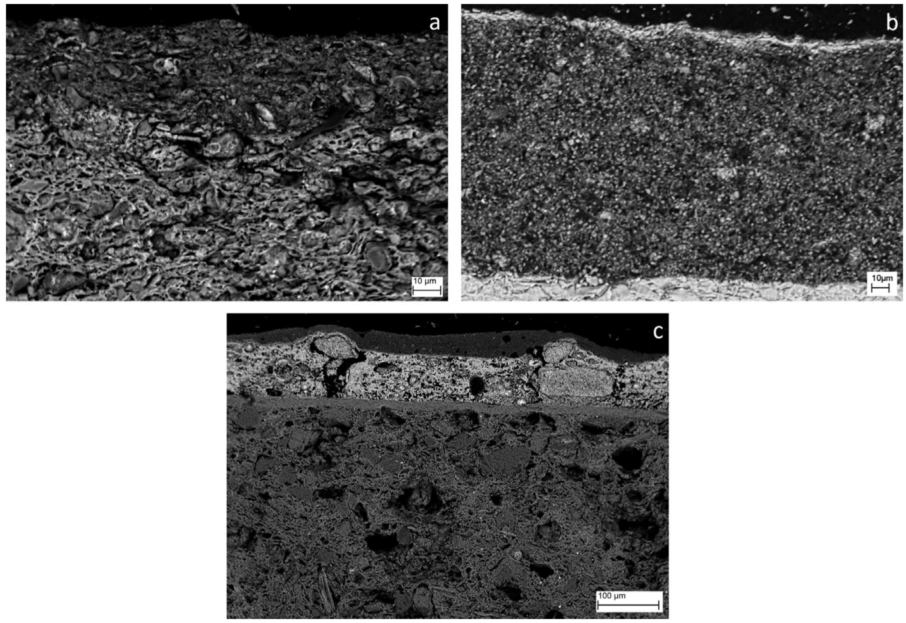

Fig. 4. SEM-BSD photomicrographs of the cross sections of craters C3 and I3, highlighting: the structures of the yellow background on the ceramic body (a), of the yellow relief line on the white pigment (c) and red overpainting (b) between the black gloss and the white overpainting. The heterogeneous, coarse-grained structure of the red overpainting is well evident (large aggregates – about 50–100 μm – can be identified in the right and left upper part of the layer).

References

[1] C. Descantes, R.J. Speakman, M.D. Glascock, Compositional studies of Caribbean ceramics: an introduction to Instrumental Neutron Activation Analysis, J. Caribbean Archaeol. 2 (2008) 1524–4776.
[2] M. Glascock, in: H. Neff (Ed.), Chemical Characterization of Ceramic Pastes in Archaeology, Prehistory Press, Madison, WI, 1992, pp. 11–26.
[3] A. Mangone, L.C. Giannossa, R. Laviano, C.S. Fioriello, A. Traini, Late Roman lamps from Egnatia: from imports to local production. Investigations by various analytical techniques to the correct classification of archaeological finds and delineation of technological features, Microchem. J. 91 (2009) 214–221.
[4] L.C. Giannossa, M. Acquaviva, G.E. De Benedetto, P. Acquafredda, R. Laviano, A. Mangone, Methodology of a combined approach: analytical techniques to identify technology and raw materials of thin walled pottery from Herculaneum and Pompeii, Anal. Methods 6 (10) (2014).
[5] L.C. Giannossa, R.M. Mininni, R. Laviano, F. Mastrorocco, M.C. Caggiani, A. Mangone, An archaeometric approach to gain knowledge on technology and provenance of Apulian red figured pottery from Taranto, Archaeol. Anthrop. Sci. 9 (6) (2017) 1125–1135.
[6] A.D. Trendall, Red Figure vases of South Italy and Sicily (World of Art). A Handbook, Thames & Hudson, London, 1989.
[7] A.D. Trendall, A. Cambitoglou, The Red-Figured Vases of Apulia, vol. 1. Early and Middle Apulian, Oxford University Press, 1989.
[8] A.D. Trendall, A. Cambitoglou, The Red-Figured Vases of Apulia, vol. 2. Late Apulian, Oxford University Press, 1989.
[9] I.M. Muntoni, C. Pouzadoux, Una storia spezzata, in: Guerrieri ed eroi ad Arpi, Exposition – Museo del territorio di Foggia, 06.12.2017, 2017.
[10] E. Robinson, Archaeometric analysis of Apulian and Lucanian Red-Figure Pottery, in: T. Carpenter, K. Lynch, E. Robinson (Eds.), The Italic People of Ancient Apulia: New Evidence from Pottery for Workshops, Markets, and Customs, Cambridge University Press, 2014, pp. 243–264, http://dx.doi.org/10.1017/CBO9781107323513.017.
[11] E.G.D. Robinson, New Pixe-Pige analyses for South Italian pottery, Mediterr. Archaeol. 26 (2013) 15–41.
[12] P. Mirti, M. Gulmini, A. Perardi, P. Davit, D. Elia, Technology of production of red figure pottery from Attic and southern Italian workshop, Anal. Bioanal. Chem. 380 (4) (2004) 712–718.
[13] A. Mangone, L.C. Giannossa, A. Ciancio, R. Laviano, A. Traini, Technological features of Apulian red figured pottery, J. Archaeol. Sci. 35 (6) (2008) 1533–1541.
[14] A. Mangone, M.C. Caggiani, L.C. Giannossa, G. Eramo, V. Redavid, R. Laviano, Diversified production of red figured pottery in Apulia (Southern Italy) in the late period, J. Cult. Herit. 14 (1) (2013) 82–88.
[15] L.C. Giannossa, R. Laviano, F. Mastrorocco, G. Giannelli, I.M. Muntoni, A. Mangone, A pottery jigsaw puzzle: distinguish true and false pieces in two Apulian red figured vases by a poli-technique action plan, Appl. Phys. A 122 (2) (2016).
[16] A. Bitetto, A. Mangone, R.M. Mininni, L.C. Giannossa, A nonlinear principal component analysis to study archeometric data, J. Chem. 30 (7) (2016) 405–415.
[17] J. Thorn, M. Glascock, New evidence for Apulian red-figure production centres, Archaeometry 52 (5) (2010) 777–795.
[18] G.M. Ingo, G. Bultrini, T.T. de Caro, C. Del Vais, Microchemical study of the black gloss on red and black-figured Attic vases, Surf. Interface Anal. 30 (2000) 101–105.
[19] W.D. Kingery, Attic pottery gloss technology, Archeomaterials 5 (1991) 47–54.
[20] Y. Maniatis, E. Aloupi, A.D. Stalios, New evidence for the nature of the Attic black gloss, Archaeometry 35 (1993) 23–34.
[21] J.V. Noble, The technique of Attic vase-painting, Am. J. Archaeol. 64 (1960) 307–313.
[22] J.V. Noble, The Techniques of Painted Attic Pottery, first edition, Watson-Guptill Publications, New York, 1965.
[23] W. Noll, R. Holm, L. Born, Bemalung antiker Keramik, Angew. Chem. 87 (18) (1975) 639–651.
[24] W. Noll, R. Holm, L. Born, Material und techniken antiker vasenmalerei, in: Jahrbuch der Staatlichen Kunstsammlungen in Baden-Wurttemberg, Band X, 1973, pp. 103–126.
[25] W. Noll, R. Holm, L. Born, Painting of ancient ceramics, Angew. Chem. Int. Ed. Engl. 14 (9) (2003) 602–613.
[26] C.C. Tang, E.J. MacLean, M.A. Roberts, D.T. Clarke, E. Pantos, A.J.N.W. Prag, The study of Attic black gloss sherds using synchrotron X-ray diffraction, J. Archaeol. Sci. 28 (2001) 1015–1024.
[27] M.S. Tite, M. Bimson, I.C. Freestone, An examination of the high gloss surface finishes on Greek Attic and Roman Samian wares, Archaeometry 24 (2) (1982) 117–126.
[28] R. Aruga, P. Mirti, A. Casoli, Application of multivariate chemometric techniques to the study of Roman pottery (terra sigillata), Anal. Chim. Acta 276 (1993) 197–204.
[29] D.L. Massart, B.G.M. Vandeginste, S.N. Deming, Y. Michotteand, L. Kaufman, Principal components and factor analysis, in: Chemometrics: A Textbook, Elsevier, Amsterdam, 1988.
[30] H. Neff, Chemical Characterization of Ceramic Pastes in Archaeology, Prehistory Press, Madison, WI, 1992.
[31] L.C. Giannossa, I.M. Muntoni, R. Laviano, A. Mangone, Contribution of mineralogical and analytical techniques to investigate provenance and technologies of Hellenistic pottery from Arpi (Southern Italy), J. Archaeol. Sci. Rep. 24 (2019) 729–737.
[32] I.C. Freestone, N.D. Meeks, A.P. Middleton, Retention of phosphate in buried ceramics: an electron microbeam approach, Archaeometry 27 (2) (1985) 161–177.
[33] L. Maritan, C. Mazzoli, Phosphates in archaeological finds: implications for environmental conditions of burial, Archaeometry 46 (4) (2004) 673–683.
[34] R. Kretz, Symbols for rock-forming minerals, Am. Mineral. 68 (1983) 277–279.
[35] M. Maggetti, C. Neururer, D. Ramseyer, Temperature evolution inside a pot during experimental surface (bonfire) firing, Appl. Clay Sci. 53 (2011) 500–508.
[36] L. Maritan, L. Nodari, C. Mazzoli, A. Milano, U. Russo, Influence of firing conditions on ceramic products: experimental study on clay rich in organic matter, Appl. Clay Sci. 31 (2006) 1–15.
[37] A. Mangone, L.C. Giannossa, G. Colafemmina, R. Laviano, A. Traini, Use of various spectroscopy techniques to investigate raw materials and define processes in the overpainting of Apulian red figured pottery (4th century BC) from southern Italy, Microchem. J. 92 (2009) 97–102.

[38] G.E. De Benedetto, S. Nicoli, A. Pennetta, D. Rizzo, L. Sabbatini, A. Mangone, An integrated spectroscopic approach to investigate pigments and engobes on pre-Roman pottery, J. Raman Spectrosc. 42 (6) (2011) 1317–1323.
[39] M. Scalese, S. Fiore, R. Laviano, Indagini geochimiche su livelli a caolinite nei calcari della piattaforma carbonatica pugliese, in: FIST – Geoitalia 2001–3° Forum Italiano di Scienze della Terra, Chieti, 5–8 September, 2001, pp. 667–668.
[40] L. Dell'Anna, Ricerche su alcune terre rosse della regione pugliese, Period. Mineral. 36 (2) (1967) 539–592.
[41] A. Mangone, R. Laviano, L.C. Giannossa, I.M. Muntoni, Archeometria di due restauri, in: Atti del Convegno Giornata internazionale di studio – Savoir-faire antichi e moderni: tra Ruvo di Puglia e Napoli Il caso del cratere dell'Amazzonomachia e di una loutrophoros con il mito di Niobe, 13 Giugno 2013, Napoli (Italia), 2019.
[42] E.M. De Juliis, la tomba del vaso dei Niobidi di Arpi, Edipuglia, Bari, 1992.