

TECHNOLOGICAL CHARACTERIZATION OF CAMPANIAN POTTERY OF TYPE A, B AND C AND OF REGIONAL PRODUCTS FROM ANCIENT CALABRIA (SOUTHERN ITALY)*

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Sherds of Campanian pottery were studied by SEM-EDX. SEM images show that slips of Campana C are scarcely sintered and are thicker than the well vitrified coatings of Campana A and B and imitations of Campana B. Slips of products with a grey slip on a grey body are very thin and well vitrified. EDX analyses indicate that slips are richer in aluminium and iron, and poorer in silicon and calcium, with respect to the bodies. Higher potassium is also found in all of the coatings except those of Campana A. Here relatively high sodium makes the total alkalis comparable with those of the other products, except Campana C, where it is somewhat lower. Measurement of thermal expansion and X-ray powder diffractograms suggest that firing temperatures were mostly in excess of 900°C, but some samples of Campana C seem to have been fired below 800°C.

KEYWORDS: ITALY, CALABRIA, LATE HELLENISTIC, SEM-EDX, DILATOMETRY, X-RAY DIFFRACTION, POTTERY, TECHNOLOGY

INTRODUCTION

Campanian pottery is the name given to the black gloss pottery produced between the fourth and the first centuries BC in the western part of the Mediterranean basin (Lamboglia 1952; Morel 1980, 1981a) and widely traded across the Mediterranean. The original forms are classified as Campana A, Campana B and Campana C, depending on their macroscopic features and the area of production; in addition, regional imitations of original products were made in many areas of the late Hellenistic and early Roman world.

Campana A was produced exclusively in the area around Naples and in Naples itself (hence the name given to this form of production; Morel *et al.* 1985). It is characterized by a non-calcareous paste (Picon *et al.* 1971; Morel 1981b; Mirti *et al.* 1998), which allows the development of a red body under the black slip. Forms of Campana A seem to have been the object of mass production by standardized working procedures and were widely exported by sea to coastal areas of the Mediterranean (Morel 1981b). In contrast, Campana B was originally produced in central Italy by the use of a highly calcareous clay (Picon *et al.* 1971; Morel 1981b; Mirti *et al.* 1998); this inhibits the development of a red colour of the body, leading to the formation of a creamy paste. Regional imitations of forms of Campana B (B-oids) are also known, and may often be difficult to tell apart from original central Italian products on simple visual examination.

The peculiarity of Campana C is the development of a grey calcareous body, as a consequence of the maintenance of reducing conditions during the final firing step and during cooling (Mirti *et al.* 1998). It was a typical product of Greek Sicily, from where it could reach other areas of the

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Greek western world (Morel 1980). Besides black glossy coatings, grey slips are frequently found in products characterized by a grey body. This ware (henceforth 'g/g ware') was particularly widespread in southern Italy, where it may have been produced from the late third century BC.

Black slips were produced by coating the leather-hard body with a fine grained non-calcareous clay, which could reach a high degree of sintering, and could vitrify in a shorter time and at a lower temperature than the clay used for the body itself (see, for example, Hofmann 1962; Tite *et al.* 1982a; Maniatis *et al.* 1993; Mirti *et al.* 1999 and references therein). The creation of a reducing atmosphere before low-melting constituents began to melt, and its maintenance until slip vitrification occurred, allowed potters to re-oxidize the body at a lower temperature, without affecting the black colour of the coating, due to the acquired impermeability to the furnace gases. Of course, this last step was omitted if the body had to retain the grey colour.

To obtain a high-quality slip, potters had skilfully to master a series of parameters that concurred in promoting vitrification. This involved careful selection, refinement and processing of suitable clays, and control of the firing conditions. In fact, a small particle size, a proper amount of flux and a limited content of alkali-earths were preferable features of the clay used for obtaining well vitrified slips, together with a proper choice and control of the temperature and time of the various firing steps. Furthermore, the atmosphere of the furnace had to be controlled during each step, to cause the bodies and slips to develop the desired colour.

The present paper reports the results of a study on the technology of production of the black and grey coatings of Campanian pottery. The study was addressed to sherds of Campana A, B and C, of B-oid imitations and of g/g ware, selected from a bulk of more than 150 pieces that had previously been analysed and classified (Mirti *et al.* 1998).

DESCRIPTION OF SAMPLES

Eighteen samples were selected from a group of 157 sherds of Campanian pottery, which had previously been analysed by inductively coupled plasma optical emission spectroscopy (Mirti *et al.* 1998). This previous work had concerned pieces excavated at six sites in ancient Calabria (southern Italy); namely, Sibari (at the site of the pan-Hellenic colony Thurii, where the Roman colony Copia was successively founded; hence the name Thurii-Copia), Locri and Reggio (at the site of the ancient Greek towns), Crotone (at Capo Colonna, the site of a sanctuary dedicated to Hera Lacinia) and Cosenza and Oppido (at the sites of inland indigenous centres). These sites are shown in Figure 1 of Mirti *et al.* (1998). The analytical data (15 elements per sample) and their statistical treatment by hierarchical cluster analysis and principal components analysis had allowed the identification of groups indicative of different provenances. Neglecting minor groups, which are not considered here, the characteristics of the main groups are briefly summarized below.

Group A collected products of Campana A, most probably imported from the Naples region, and group C was made up of samples of Campana C, which probably came from Syracuse or its territory. Group B contained suspected regional products, with a high proportion of forms of Campana B; these were more properly considered as regional imitations (B-oids). A further group (group E) contained forms of Campana B together with part of the g/g sherds; a common origin of these two kinds of production was considered highly improbable, and a closer inspection of the analytical data and archaeological features allowed a separation between suspected original forms of Campana B (group E1 here) and g/g sherds (group E2 here). Finally,

the rest of the g/g wares were to be found in another group (group F), which was definitely separated from group E2.

Representative samples from each of the above groups were selected to investigate the technology of production of Campanian pottery of types A, B and C, of the B-oid imitations, and of the two forms of production of g/g ware. The sherds were labelled using an alphanumeric sequence that indicated the site of excavation (CN for Cosenza, HL for the sanctuary near Crotone, L for Locri, R for Reggio, and TC for Thurii–Copia), a sample number and a final letter that indicated the kind of product (A for Campana A, B for both original forms and imitations of Campana B, C for imported forms of Campana C, and CR for regional g/g products).

The final selection consisted of three samples of Campana A from group A (L1A, R3A and TC4A); two sherds of Campana B from group E1 (L3B and L52B); three B-oids from group B (CN2B, L4B and TC3B); three sherds of Campana C from group C (L1C, L5C and TC6C); and five samples of g/g ware, two of them from group E2 (HL2CR and TC10CR) and three from group F (CN10CR, TC16CR and TC21CR). In addition, two sherds were considered that had not been analysed before: sample N1A, from an excavated kiln in Naples, as a specimen of Campana A of certain provenance; and sample MP1CR, excavated at Metaponto in ancient Lucania, as a specimen of the possible production of g/g ware outside ancient Calabria, but not far from it.

On visual examination, the samples of Campana A, B and C and the B-oids imitations all seemed to be coated with a good quality smooth black slip; the bodies were red for Campana A, creamy for Campana B and B-oids, and grey for Campana C. The g/g sherds were coated by grey slips with shades quite similar to those of their body; some of the slips were smooth, but a few of them had a typical slight roughness. Apart from displaying a different shade of grey, the g/g bodies seemed to have been obtained from a more refined clay than the bodies of Campana C. As will be shown in this paper, not all of these macroscopic inferences were confirmed by the technological study.

EXPERIMENTAL PROCEDURE

SEM-EDX investigation

SEM-EDX examination was carried out on sherd cross-sections. Two fresh fracture sections were obtained from each sample; one was used for the morphological investigation, and the other was polished and used for the EDX analysis.

Morphological investigations were carried out on fresh fracture sections coated with a thin gold layer using a Polaron Division Bio-rad E 5000 M apparatus; samples for EDX analysis were impregnated in an epoxy resin (Epo-Kwick, Buehler) and polished using Buehler Minimet 100 equipment. Polishing was carried out using 500 and 1200 grit silicon carbide papers and 6 μm and 1 μm diamond pastes, in sequence. Before the analysis, the polished samples were coated with a graphite layer, using an Emitech K 950 apparatus.

SEM-EDX investigations were carried out using a Cambridge Stereoscan 360 scanning electron microscope coupled with a Link Analytical QX-2000 energy-dispersive detector for the analysis of the X-rays emitted by the sample. SEM images were obtained by either secondary electrons (SE) or back-scattered electrons (BE).

EDX analyses were carried out on sample bodies by scanning the electron beam on $180 \times 240 \mu\text{m}^2$ areas. In contrast, due to the limited thickness, slip compositions were determined by spot analysis, focusing the electron beam on 5 μm diameter areas; however, in the case of Campana C, the higher thickness of the coating allowed analyses to be performed by scanning

the electron beam across $22.5 \times 30 \mu\text{m}^2$ areas. Comparison of the data obtained by spot analysis and beam scan indicated that the two techniques gave similar results; this allowed us to consider that the loss of sodium due to volatilization was not a major problem in spot analyses.

Both the bodies and the slips were generally analysed carrying out between five and seven determinations on different areas of the sample. Operating conditions were as follows: acceleration voltage 15 KV, filament current 2.4–3.0 A, working distance 25 mm. The relative abundance of the elements determined was calculated by Oxford QX 2000 software, using the ZAF-4 correction to account for matrix effects. Pure element oxides and natural minerals were used as standards for the quantitative analysis. A cobalt standard was used for instrumental calibration.

Sample compositions were given as percentages by weight of element oxides, expressing the iron concentration as iron(II) oxide; the elements determined in the body and slip of each sample were silicon, aluminium, iron, calcium, magnesium, potassium, sodium and titanium. As the analytical totals were generally lower in the case of bodies (60–80%) than for slips (80–100%), due to sample porosity, all data were normalized to a total of 100%.

Investigation on firing conditions

Body samples for measurements of thermal expansion were cut as small blocks (about 5 mm in height) from the examined sherds and their surfaces were made flat by a diamond saw. The pieces were mounted on the quartz holder of a Mettler TMA device and refired from 35°C to 1000°C at a heating rate of $10^\circ\text{C min}^{-1}$, while exerting a force of 0.1 N. The experiments were performed in air, as well as in a nitrogen atmosphere, with a nitrogen flux of 100 ml min^{-1} .

Samples for X-ray diffraction were obtained as small pieces cut from each sherd after removal of the sintered slip by a diamond saw; the cut pieces were powdered in an agate mortar and the powders used for recording X-ray diffractograms.

The X-ray powder diffractograms were recorded on samples that had not been refired, using a SIEMENS D5000 diffractometer, using graphite monochromatized copper radiation ($\lambda = 1.54178 \text{ \AA}$). Patterns were collected in the 2θ range 0–50°, and phase identification was performed using the Diffrac AT set of programs.

RESULTS AND DISCUSSION

SEM images

Figure 1 shows representative SE images of sherds of Campana A, Campana B and B-oids. All of these sherds (including N1A) display well vitrified slips and a sharp interface between slip and body. The thickness of the slip is 10–15 μm for Campana A and the B-oid imitations, and about 20 μm for Campana B.

Completely different features were observed for the samples of Campana C (Fig. 2). Here the coating is scarcely sintered and may be mainly distinguished from the underlying body because of the more regular alignment of the clay platelets parallel to the surface of the piece. Moreover, the thickness is generally higher than in the sherds of Campana A, Campana B and the B-oids, and highly variable within the same sherd, as a consequence of a very irregular contact between slip and body. Measured values range from 20 μm up to 50 μm or even more in a single sherd, but one has to stress the uncertainty encountered in confidently locating the body-to-slip separation.

Still different features were observed for the g/g products (Fig. 2), with no sensible differences

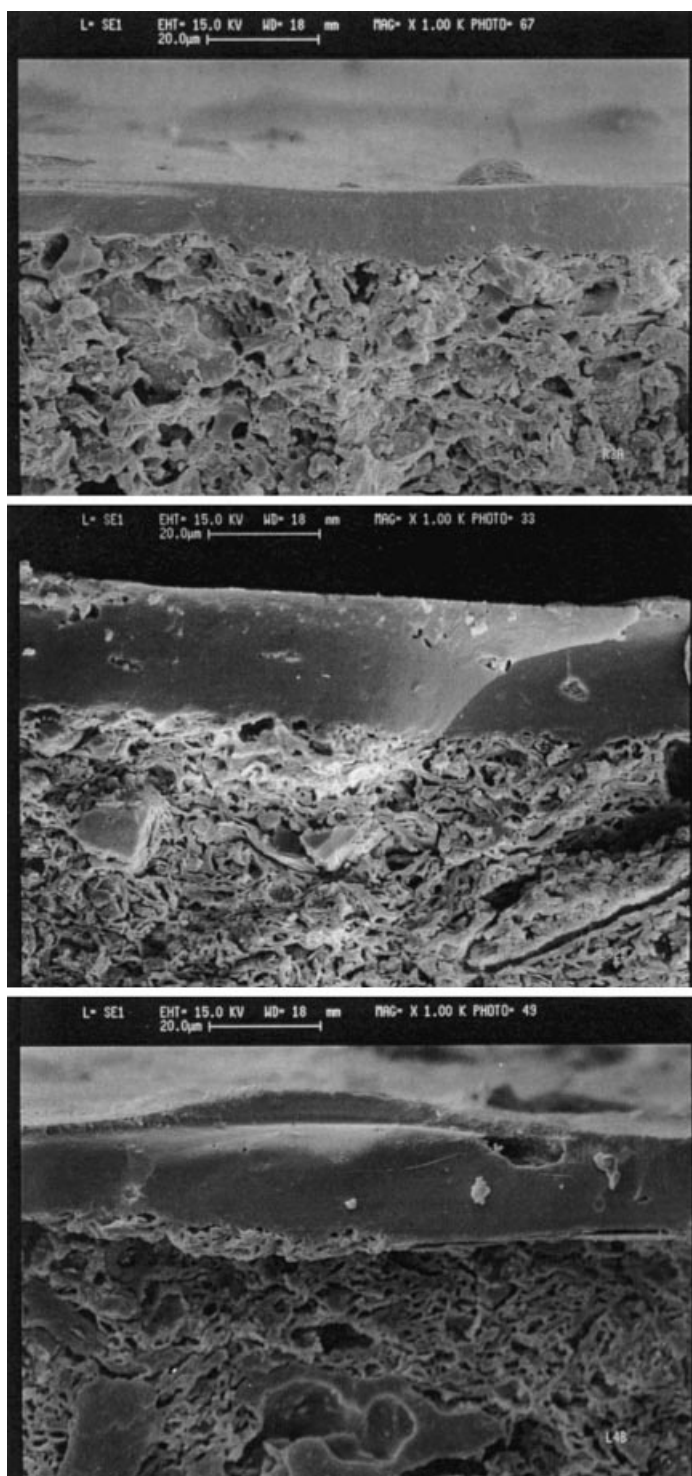


Figure 1 Secondary electron images of fresh fracture sections of sherds R3A (Campana A, top), L52B (Campana B, middle) and L4B (B-oid, bottom). $\times 1000$.

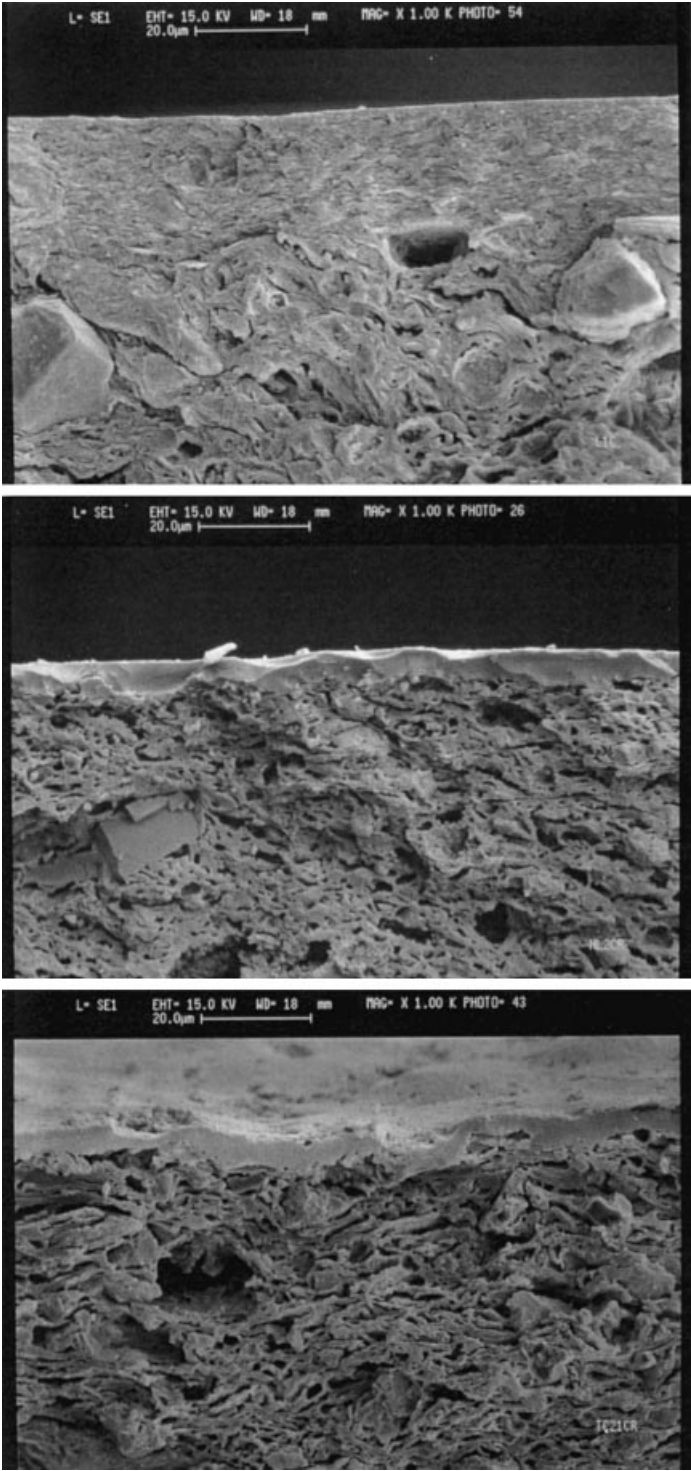


Figure 2 Secondary electron images of fresh fracture sections of sherds L1C (Campana C, top), HL2CR (g/g ware of group E2, middle) and TC21CR (g/g ware of group F, bottom). $\times 1000$.

between the pieces previously classified in groups E2 and F, and between these pieces and sherd MP1CR. Bodies are generally characterized by a more regular texture than the other wares, while the slips, still well vitrified, are definitely thinner, at around 5 μm .

EDX analysis

The results of the EDX analysis of slips and bodies are given in Table 1. As is generally observed in glossy clayey coatings (Willgallis and Heyer 1976; Maggetti *et al.* 1981; Tite *et al.* 1982a; Maniatis *et al.* 1993; Mirti *et al.* 1996, 1999), the slips of the Campanian sherds are lower in silicon and calcium, and richer in aluminium and iron, with respect to their bodies. Potassium is also higher in the slips of Campana B and the B-oids, and of the g/g wares of group E2, but much less so in those of Campana C and the g/g ware of group F, and it is even lower in the coating of the sherds of Campana A. Finally, sodium is lower in the slips of Campana A, while magnesium is significantly lower only in the slips of the g/g products.

This can be the result of the refinement of the clay used for the coating, which removes the coarser quartz grains and leaves a higher proportion of clay minerals in the refined fraction (Tite *et al.* 1982a; Freestone 1982); however, it may also stem from the selection of a more appropriate (illitic) clay, different from that used for the body. Alumina-to-silica ratios of around 0.30 are found in the bodies of most of the products considered here, with the exception of the g/g sherds of group F, where the ratio reaches up to about 0.40 (Fig. 3). In contrast, values of between about 0.50 and 0.75 are found in the slips. As long as the Al:Si ratio depends on the extent of refinement of the clay, it may possibly be related to the grain size of the selected fraction, and hence to the thickness of the layer deposited upon the body. In fact, the various kinds of products are characterized by a slip thickness that diminishes with an increase in the Al:Si ratio; therefore, the thick and irregular slips of Campana C are matched by the lowest content of aluminium and the lowest Al:Si ratio, while the thin slip of the g/g products may be related to the use of a particularly fine grained and/or highly refined clay, characterized by the highest aluminium content and the highest Al:Si ratio.

With regard to the iron content (Fig. 3), this is mostly between 11% and 15% FeO in the slips (but even reaches up to 17–18% in one sherd of Campana C and two of Campana A), against 4–9% in the bodies. A relatively high iron content in the slip may be useful, considering that iron(II) compounds may act as fluxes during firing; in this case, however, data concerning the sherds of Campana C suggests that the contribution of iron to the development of well vitrified slips is subordinate to the presence of suitable amounts of alkalis and/or to sufficiently high temperatures of firing (see below).

Figure 4 reports the cumulative content of sodium and potassium as a function of that of calcium and magnesium in the slip and the body of the sherds studied here. Our interest in this diagram stems from the fact that these groups of elements give opposite contributions to the development of high-quality slips. In fact, alkalis may act as fluxes during firing, thus promoting liquid sintering and vitrification, and it has been suggested that, apart from its natural occurrence, the potassium content could be increased through the addition of wood ash to the clay selected for the coating (Hofmann 1962). In contrast, calcium and magnesium have a detrimental effect on the possibility of obtaining well developed and shiny coatings, in that alkali-earth carbonates may disrupt the alignment of the clay platelets parallel to the surface of the ware; besides, carbon dioxide may be trapped within the slip, if this begins to vitrify and becomes viscous at a temperature at which these carbonates decompose. Finally, at higher temperatures, the formation of alkali-earth iron silicates prevents the full development of iron oxides (Freestone 1982; Tite *et al.* 1982a,b).

Table 1 SEM-EDX data of body and slip composition of sherds of Campanian pottery (weight percent of element oxide and corresponding standard deviation, *s*)

Sample	Group	SiO ₂	<i>s</i>	Al ₂ O ₃	<i>s</i>	FeO	<i>s</i>	CaO	<i>s</i>	MgO	<i>s</i>	K ₂ O	<i>s</i>	Na ₂ O	<i>s</i>	TiO ₂	<i>s</i>
<i>Slip</i>																	
L1A	A	44	1	27.3	0.9	18	1	0.45	0.07	2.4	0.4	5.0	0.2	2.0	0.2	–	–
N1A	A	44	2	27.7	0.8	18	2	0.7	0.2	2.5	0.2	4.8	0.4	2.3	0.1	–	–
R3A	A	46	2	29	1	15	2	1.1	0.1	1.7	0.2	4.6	0.4	2.1	0.1	–	–
TC4A	A	46	2	30.2	0.2	15	2	0.92	0.09	1.7	0.2	4.0	0.3	1.3	0.2	0.63	0.04
L3B	E1	49	2	26.5	0.7	12	2	1.23	0.09	3.5	0.1	6.6	0.2	0.8	0.4	–	–
L52B	E1	50	1	27	1	11	2	1.4	0.2	3.4	0.4	5.7	0.3	1.2	0.1	–	–
CN2B	B	47.1	0.7	28.2	0.8	14	1	1.1	0.3	2.4	0.2	6.3	0.3	–	–	–	–
L4B	B	46.0	0.9	28.7	0.8	12.7	0.7	1.1	0.1	2.7	0.2	7.1	0.3	1.3	0.2	–	–
TC3B	B	48	1	28	1	13.0	0.4	0.5	0.3	2.5	0.3	6.3	0.5	–	–	–	–
L1C	C	48	2	25	1	15	2	5.0	0.5	1.7	0.3	3.9	0.2	0.78	0.09	0.6	0.3
L5C	C	49	3	23	2	17	5	4.0	0.3	1.5	0.2	3.6	0.4	0.8	0.2	0.8	0.4
TC6C	C	52	2	24.4	0.9	13	1	2.0	0.3	2.7	0.3	4.3	0.3	0.9	0.3	0.8	0.3
HL2CR	E2	45.9	0.4	31.5	0.4	11.9	0.9	1.6	0.3	1.6	0.2	6.8	0.2	–	–	0.7	0.3
MP1CR	E2	45	2	33.0	0.8	11	1	1.6	0.2	1.3	0.1	6.4	0.3	0.78	0.06	0.8	0.3
TC10CR	E2	45	1	32.2	0.2	11.3	0.6	1.3	0.2	1.5	0.1	6.99	0.05	–	–	1.0	0.3
CN10CR	F	44	2	33.3	0.4	13.8	0.5	0.9	0.2	1.0	0.3	5.4	0.3	0.8	0.3	1.0	0.4
TC16CR	F	45.0	0.7	33.5	0.8	11	1	0.9	0.1	2.0	0.3	5.9	0.3	0.98	0.05	0.8	0.1
TC21CR	F	44.9	0.4	34.0	0.3	10.8	0.4	0.77	0.08	1.4	0.1	5.6	0.1	1.38	0.08	1.2	0.4
<i>Body</i>																	
L1A	A	62	1	18.9	0.7	4.9	0.4	3.4	0.7	1.1	0.1	5.6	0.2	3.3	0.3	0.8	0.2
N1A	A	61.4	0.7	19.1	0.4	4.8	0.4	3.9	0.4	1.5	0.2	5.2	0.4	3.8	0.3	–	–
R3A	A	62.3	0.9	19.3	0.2	4.3	0.6	3.0	0.3	1.4	0.2	5.7	0.3	3.5	0.2	–	–
TC4A	A	61	1	19.0	0.1	5.8	0.6	3.9	0.6	1.5	0.2	5.5	0.4	2.6	0.2	0.7	0.2
L3B	E1	53.8	0.8	16.2	0.4	7.0	0.3	16.0	0.7	2.8	0.1	2.6	0.2	1.0	0.4	0.8	0.2
L52B	E1	56.6	0.8	18.3	0.3	7.3	0.4	9.9	0.3	3.1	0.2	2.8	0.1	1.2	0.1	0.9	0.3
CN2B	B	58	2	15.9	0.7	6.8	0.2	12.5	0.7	2.5	0.2	3.1	0.4	–	–	1.0	0.2
L4B	B	57	4	15	2	6.0	0.6	16	2	2.6	0.4	2.5	0.3	1.0	0.3	–	–
TC3B	B	57	2	15.4	0.4	6.9	0.5	14	2	2.5	0.1	2.8	0.2	0.8	0.4	0.8	0.2

Table 1 (continued)

<i>Sample</i>	<i>Group</i>	<i>SiO₂</i>	<i>s</i>	<i>Al₂O₃</i>	<i>s</i>	<i>FeO</i>	<i>s</i>	<i>CaO</i>	<i>s</i>	<i>MgO</i>	<i>s</i>	<i>K₂O</i>	<i>s</i>	<i>Na₂O</i>	<i>s</i>	<i>TiO₂</i>	<i>s</i>
L1C	C	58.7	0.6	16.1	0.8	6.8	0.5	11.9	0.8	1.8	0.1	2.6	0.3	1.2	0.3	1.0	0.1
L5C	C	56	2	16.8	0.9	8.7	0.4	12	2	2.6	0.1	2.7	0.2	—	—	1.01	0.08
TC6C	C	56	2	14.9	0.8	7.4	0.5	16	1	1.8	0.2	2.4	0.3	1.0	0.3	0.7	0.2
HL2CR	E2	55.3	0.5	18.1	0.2	8.2	0.3	11.2	0.2	2.42	0.09	3.1	0.1	0.8	0.3	1.1	0.2
MP1CR	E2	57	1	18.7	0.6	7.0	0.4	10.6	0.4	2.4	0.2	2.6	0.2	0.9	0.2	0.9	0.2
TC10CR	E2	56.4	0.6	17.8	0.2	7.5	0.4	11.4	0.4	2.5	0.3	2.7	0.1	0.8	0.3	1.0	0.2
CN10CR	F	53.5	0.5	20.4	0.6	9.1	0.6	7.8	0.4	3.19	0.09	4.0	0.3	1.1	0.4	1.0	0.1
TC16CR	F	53.0	0.9	20.7	0.2	9.0	0.6	7.7	0.6	3.56	0.05	3.7	0.2	1.5	0.1	0.9	0.2
TC21CR	F	52	1	20.7	0.5	9.5	0.9	8.0	0.3	3.2	0.2	3.6	0.3	1.7	0.1	0.9	0.4

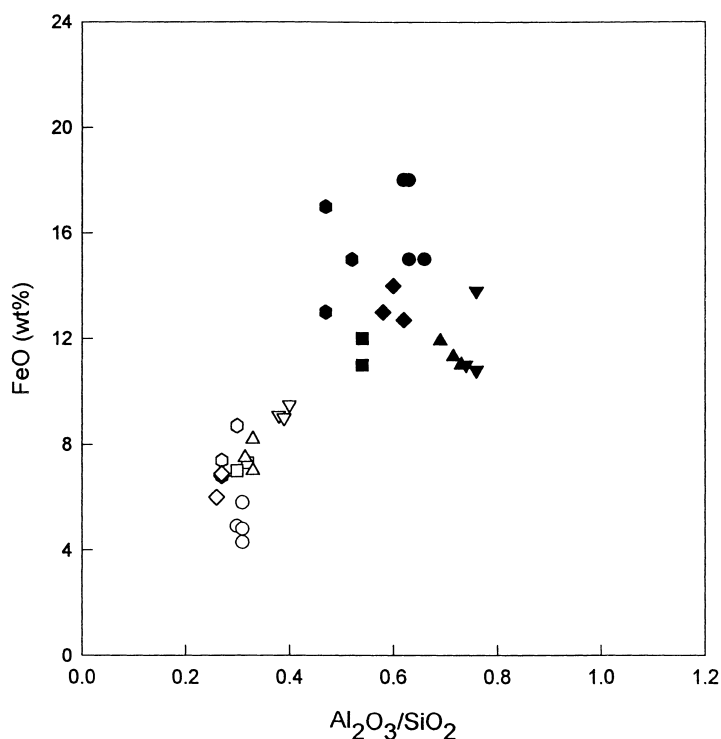


Figure 3 *FeO* percentage content versus alumina-to-silica ratio in sherds of Campanian pottery. ●, Campana A; ■, Campana B; ◆, B-oids; ◐, Campana C; ▲, g/g ware of group E2; ▼, g/g ware of group F. Full symbols indicate slips; open symbols indicate bodies.

One of the most peculiar features of Campana A is apparent from Figure 4, and is its non-calcareous body (4–6% CaO + MgO, including the sample from Naples); this contrasts with the calcareous or highly calcareous paste that characterizes all of the other products. Furthermore, the two groups of g/g bodies cluster separately from each other in the diagram, due to the less calcareous paste of the sherds of group F. An interesting result here is that the body of the piece excavated at Metaponto clusters together with the E2 sherds, which supports the hypothesis of a different provenance for the two classes of products (Mirti *et al.* 1998).

Figure 4 well represents the general trend of clayey slips to be richer in alkalis and lower in alkali-earths, with respect to the bodies. As already said, this stems, on the one hand, from the possible use of K-rich illitic clays and/or the addition of wood ash and, on the other, from the removal of alkali-earth carbonates through sedimentation. An important exception is again given by the sherds of Campana A, whose slips are only slightly less calcareous than their bodies, mainly because the latter already contain low quantities of alkali-earths. More importantly, this is the only case of higher alkali contents in the body than in the slip, which makes the addition of wood ash to the clay used for the latter unlikely; the total alkali content of the slip, however, is still comparable with that of all the other products, except Campana C, and is consistent with the development of a well vitrified coating. In this respect, however, one must not underestimate the role of the temperature reached during firing (see below).

Figure 4 also gives interesting information on the slips of Campana C, which show a relatively low content of alkalis and a relatively high content of alkali-earths. Apart from any contribution

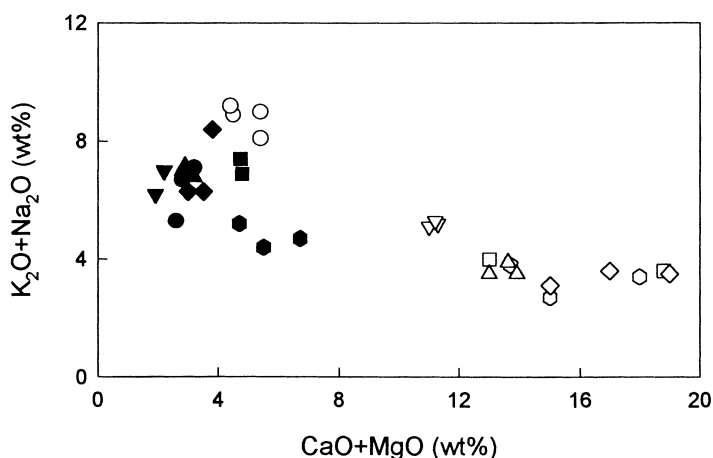


Figure 4 K_2O+Na_2O versus $CaO+MgO$ percentage content in sherds of Campanian pottery. ●, Campana A; ■, Campana B; ◆, B-oids; ●, Campana C, ▲, g/g ware of group E2; ▼, g/g ware of group F. Full symbols indicate slips; open symbols indicate bodies.

from the firing temperature, this accords with the fact that these slips do not show the high degree of sintering observed in all of the other products. In particular, the slips of Campana C are characterized by alkali-earth contents comparable to those of the bodies of Campana A, but have a definitely lower content of alkalis. A more or less similar content of alkali-earths is also found in the slips of Campana B, but here the higher content of alkalis (together with a suitable firing temperature, see below) allowed the full development of a well vitrified slip.

Finally, Figure 4 shows that the g/g products contain relatively low amounts of alkali-earths in the slip, together with the sherds of Campana A and the B-oid imitations; this suggests an extensive refinement of the clay used and accords with the fact that the Al:Si ratios are relatively high here.

Firing conditions

The firing temperatures of ancient pottery may be evaluated by several experimental techniques. In the present case, X-ray diffraction (XRD) (Küpfer and Maggetti 1978; Maggetti 1982) and the measurement of thermal expansion (or thermomechanical analysis, TMA: Roberts 1963; Tite 1969) were used.

One sample was selected from each of groups A, C, E1, E2 and F for the evaluation of the equivalent temperature of firing by XRD; the selected pieces were TC4A, L5C, L52B, HL2CR and CN10CR.

The same samples, plus an additional one from each of groups A, E1, E2 and F, and two from group C, were subjected to the measurement of thermal expansion; these samples were L1A, L3B, TC10CR, TC21CR, L1C and TC6C.

XRD indicated the presence of quartz, potassium feldspars, plagioclases, hematite and calcium silicates in all of the selected samples, apart from L5C; this suggests firing temperatures reaching up to at least 900°C. The possible presence of residual illite further suggests that this temperature may not have been exceeded by sample CN10CR.

The thermal expansion curves mostly confirm the XRD results (Fig. 5). Here, the base assumption is that a refired body expands until it reaches the equivalent temperature of firing;

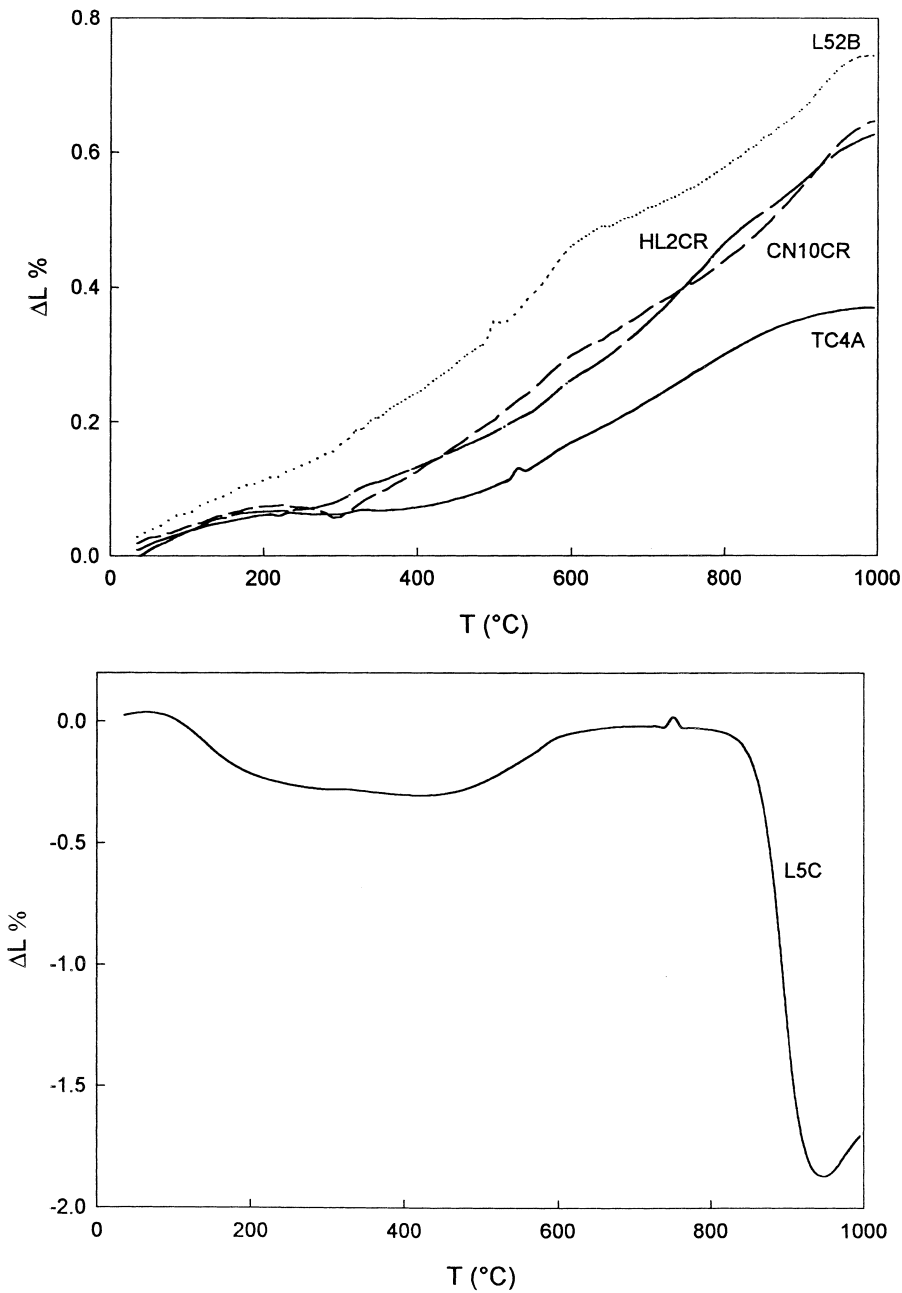


Figure 5 Thermal expansion curves recorded on samples TC4A, L52B, HL2CR and CN10CR (top) and L5C (bottom).

when this is exceeded, resumption of sintering may eventually lead to a contraction (Roberts 1963; Tite 1969). The curves obtained show that the expansion of samples TC4A and L1A begins to slow at about 900°C and is completely counteracted by sintering at 1000°C; even though the descending part of the curve could not be recorded by the available instrument, this suggests that the equivalent temperature of firing is between 900 and 1000°C. A similar result was obtained for samples L3B and L52B, but here the change of slope begins at a slightly higher temperature. Equivalent temperatures of firing near 1000°C are finally also suggested for the g/g pieces; this shifts upwards the temperature estimated for CN10CR by XRD.

The situation is different with the samples of Campana C. Here, the XRD pattern of sample L5C indicates the presence of quartz, plagioclases, illite and calcite, and is consistent with a maximum firing temperature below 900°C. TMA confirms this inference, as the curve of thermal expansion of this sample, as well as that of sample L1C, is characterized by a wide plateau between about 600 and 800°C; after that, a dramatic sintering occurs (Fig. 5).

However, a different curve, more similar to those for the samples of the other groups, was displayed by the third sherd of Campana C (TC6C). Here, in fact, expansion of the ceramic body proceeds up to at least 1000°C, which suggests a relatively high temperature of firing. It seems, therefore, that different firing conditions may have been adopted for the production of the studied samples of Campana C, even though they show similar microscopic features.

Indeed, the maximum temperature was presumably reached under reducing conditions during the original firing of Campanian pottery. Moreover, cooling also proceeded, in part (Campana A and B) or completely (Campana C and g/g ware), under reducing conditions. Instead, samples were normally refired in air during TMA experiments. For this reason, the thermal expansion curves were also recorded operating in a nitrogen atmosphere in the case of three samples with a grey body (L5C, TC6C and TC10CR). The equivalent temperatures of firing evaluated in this way were consistent with those obtained from the experiments performed in air, which indicates that the working atmosphere does not affect the general meaning of the information provided by TMA.

CONCLUSIONS

The results of this work stress the role of firing conditions and slip composition in the development of black glossy coatings.

The Campana A products owe their well sintered coating to a fairly high temperature reached during firing, and to a suitable amount of flux and a low content of alkali-earths in the slip. Even though the K₂O content is not particularly high, the total alkali content may reach up to 7%, due to a relatively high concentration of Na₂O. This makes the K₂O + Na₂O amount comparable with that of the other Campanian products, apart from Campana C, and with that of other black or red glossy slips (Willgallis and Heyer 1976; Maggetti *et al.* 1981; Tite *et al.* 1982a; Maniatis *et al.* 1993; Mirti *et al.* 1996). A K₂O content of around 4–5%, as observed here for the Campana A coatings, was also reported in previous studies on black Attic and Campanian slips (Maggetti *et al.* 1981; Tite *et al.* 1982a,b; Vendrell-Saz *et al.* 1991; Maniatis *et al.* 1993).

A feature peculiar to the fragments of Campana A is the lower concentration of both potassium and sodium in the coating with respect to the body; as already said, this would exclude the addition of wood ash to the refined clay fraction selected for the slip. Indeed, the alkali contents in the bodies of Campana A exceed those of the slips of the other Campanian products considered here, and of other glossy slips (Willgallis and Heyer 1976; Maggetti *et al.* 1981; Tite *et al.* 1982a; Vendrell-Saz *et al.* 1991; Maniatis *et al.* 1993; Mirti *et al.* 1996, 1999). Under these circumstances,

complete vitrification of the body at the temperature reached was probably prevented by the larger average grain size and the higher amount of high-melting non-plastic inclusions.

Slips on the suspected original forms of Campana B and their B-oid imitations are characterized by potassium contents of about 6–7%, which largely accounts for the development of high-quality vitrified coatings. A maximum firing temperature of around 900–1000°C contributed to this achievement in the case of Campana B, even though the amount of alkali-earths is greater than in the slips of the other products, excluding Campana C. Maximum temperatures of firing were not evaluated for the B-oid, but, in view of their microscopic features, it seems possible that they were close to those reached by the pieces of Campana A and B.

The morphological features of the Campana C sherds are quite different, as here the coatings are rather thick and irregular, and scarcely sintered. This may be surprising, due to the visual appeal of these slips, which would lead one to suppose a good control of the production steps. Total alkali contents hardly reaching up to 5% (with K₂O alone around 4%) would largely account for the microscopic features observed. In addition, two out of the three pieces studied here were most probably fired at temperatures below 800°C; this implies incomplete decomposition of carbonates and a failure to promote liquid sintering by the fusion of low-melting compounds. The other Campana C sherd seems to have been fired up to about 1000°C, a suitable temperature for the vitrification of adequately selected and processed clays, as observed in the case of the other Campanian products. A similar situation (a relatively high temperature, but an inadequate composition) had been found in the case of red gloss Roman products from northern Italy (Mirti *et al.* 1999).

The production of Campanian pottery of type C therefore seems to be characterized by less sophisticated and standardized procedures than in the case of the other products, particularly as far as the control of the firing conditions is concerned. It remains to be seen whether all this indicates limited technological skills of the Sicilian potters, or whether it was a deliberate choice that could allow them to spare fuel and time, and yet still produce items that would find favour in the market place.

The peculiarity of the g/g sherds is the similar shade of grey of the body and the slip. At a microscopic level they feature thin vitrified slips, and this may stem from the use of a highly refined clay, as suggested by the rather high aluminium to silicon ratio. A small grain size of the clay, its total alkali content of around 6–7% and a firing temperature of around 900–1000°C were all factors that contributed to the extensive vitrification observed for these slips. While differing in the composition of the body, the products of groups E2 and F are similar with regard to the features of the surface coating.

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