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«Pantellerian Ware» from Miseno (Campi Flegrei, Naples)

CELESTINO GRIFA[1]*, ALESSIO LANGELLA[2], VINCENZO MORRA[1] and GIANLUCA SORICELLI[3]

[1] Dipartimento di Scienze della Terra, Università degli Studi Federico II, Via Mezzocannone, 8, 80134 Napoli
[2] Dipartimento di Studi Geologici e Ambientali, Università del Sannio, Via Portarsa, 11, 82100 Benevento
[3] Dipartimento di Scienze Umane Storiche e Sociali, Via De Santis, 86100 Campobasso

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ABSTRACT. — Samples of cooking ware from the Sacello degli Augustali, a worship place of the ancient *Misenum*, were investigated from an archaeometric point of view. On typological basis (shape, accurate polished surface, typical volcanic inclusions) some of them were considered as belonging to the so-called «Pantellerian Ware». The petrographical and mineralogical study allowed to identify three groups characterized by different volcanic temper. Six samples instead of four were attributed to Pantellerian Ware due to the occurrence of phases typical of magmatic evolved peralkaline rocks. A second group was identified for the presence of a volcanic temper typical of calcalkaline rocks and tentatively assigned to an Aeolian provenance. The third group shows abundant trachytic and leucititic rock fragments and likely represents a local production.

It is remarked the good technological properties of the cooking ware from Pantelleria due to the use of abundant and well sorted temper, non calcareous clays and low firing temperatures that provide the manufact a low dilation coefficient and good resistance to strong thermal shocks. These features along with a well standardized manufacture that makes these potteries suitable to be transported, allowed to achieve a large diffusion of the «Pantellerian Ware» within the Mediterranean Sea, from the African through the Spanish coasts, and in the Gulf of Naples and Pozzuoli.

RIASSUNTO. — Sono state condotte analisi archeometriche su dieci campioni di ceramica comune da fuoco, provenienti dal Sacello degli Augustali, un antico luogo di culto dell'antica *Misenum*. Sulla base dei dati tipologici (forma, superficie esterna steccata e tipici inclusi vulcanici) alcuni di questi campioni vengono considerati come appartenenti alla ceramica da fuoco da Pantelleria (Pantellerian Ware). Le osservazioni mineralogiche e petrografiche hanno permesso di identificare tre gruppi caratterizzati da differente smagrante vulcanico. Sei campioni sono stati attribuiti alla Pantellerian Ware in base al contenuto di fasi mineralogiche tipiche di rocce evolute a carattere peralcalino. Un secondo gruppo è stato identificato per la presenza di inclusi vulcanici tipici di rocce calcalcaline ed è stata ipotizzata una provenienza eoliana. Infine, è stato riconosciuto un terzo gruppo di produzione locale, caratterizzato dalla presenza di abbondanti frammenti di rocce trachitiche e leucititiche.

La ceramica comune da fuoco da Pantelleria mostra delle buone proprietà tecnologiche, dovute all'utilizzo di smagrante ben calibrato di grosse dimensioni, argille non calcaree, e basse temperature di cottura che garantiscono al manufatto un basso coefficiente di dilatazione e una buona resistenza agli shock termici. Le forme ben standardizzate dei

* Corresponding author, E-mail: celgrifa@unina.it

manufatti atti ad essere facilmente trasportati, insieme alle buone caratteristiche tecnologiche, giustificano la grande diffusione di questa classe ceramica nell'intera area mediterranea, dalle coste africane a quelle spagnole, attraverso il golfo di Napoli e di Pozzuoli.

KEY WORDS: *Campi Flegrei, Miseno, Sacello degli Augustali, Cooking ware, Ceramic Petrography, Pantellerian ware.*

INTRODUCTION

The *Sacello degli Augustali* is one of the most representative monuments of the ancient Miseno (Campi Flegrei), a military harbour of Imperial Age. Due to its strategical position in the Gulf of Naples and a favourable morphological site, *Misenum* (from the trumpeter of Enea drown in those waters) was founded in the IV century B.C. by Greek settlers and soon appointed as fundamental support of the defensive system of Cuma. Afterward the devastating transit of Hannibal, the restoration of the *Misenum* territory was mainly devoted to the construction of luxury buildings and villas.

Starting from the I century A.D., under the Empire of Augustus *Misenum* got back its role of strategical and military area. A harbour was built where the *Classis Praetoria,* a powerful fleet under the direct control of the Emperor, set up (Miniero, 2000a).

The *Misenum* harbour was constituted by two natural basins: the inner one corresponding to the current Miseno lake, also used as shipyard; the external one, the Miseno Bay, was the real harbour. They were connected by an artificial channel, today silted up, whereas the entrance to the harbour was protected by two piers on arcades, extensions of two natural bastions, *Punta Terone* and *Punta Pennata,* that represent the remnants of the border of *Porto Miseno* tuff ring (Insinga *et al.*, 2002 Insinga, 2003, Fig. 1).

With the only exception of a short wartime (68-69 A.D.) in the ligurian gulf, the *Misenum* fleet was inactive for many centuries with the only aim to serve the members of the imperial family.

The presence of the *Classis Praetoria*, a personal tool of power for the emperor, made *Misenum* a sort of domain of the imperial family. Within this framework the *Sacello* represented an important place of worship, where the *Augustales* accomplished rites, played games and attended ceremonies in honour of the divinised emperors and in suffrage of the *genius* or *numen* of the emperor in charge. The *Sacello degli Augustali* is one of the best preserved monuments of the old *Misenum Forum* (Fig. 2), found during the excavation of 1967 (Miniero, 2000b). This complex (Fig. 3) is constituted by a central and two lateral rooms opening on an arcade courtyard where a cipolline marble columns tetrastyle pronao was erected and that supported the epistyle with the dedicatory inscription and the decorated pediment.

The whole settlement was buried under a thick cover of pyroclastic products mainly deriving from the reworked materials of Miseno Tuff Cone (Insinga *et al.*, 2002; Insinga, 2003; Insinga *et al.*, 2004).

After its abandonment the *Sacello* was used as dump area where coarse, fine and even cooking wares, the latter object of the present research, have been found.

The scarce attention devoted to the archaeological and volcanological stratigraphy during the excavation did not allow to reconstruct the modality and the time of deposition of these materials, with loss of precious data necessary to interpret the material culture, reflection of the activities and life conditions in the Gulf of Pozzuoli.

On this regard, some useful considerations can be drawn by carefully taking into account the rims counting of the «*Terra Sigillata*» (Fig. 4) between the 180/200 and the 660/680 A.D. Two important dumping periods can be likely identified: a first one between the 200/220 A.D. and 240/260 A.D. and a second one between the 320/340 A.D. and 400/420 A.D. From this last period on the rims of «*Terra Sigillata*» start to lose their value, even if they maintain

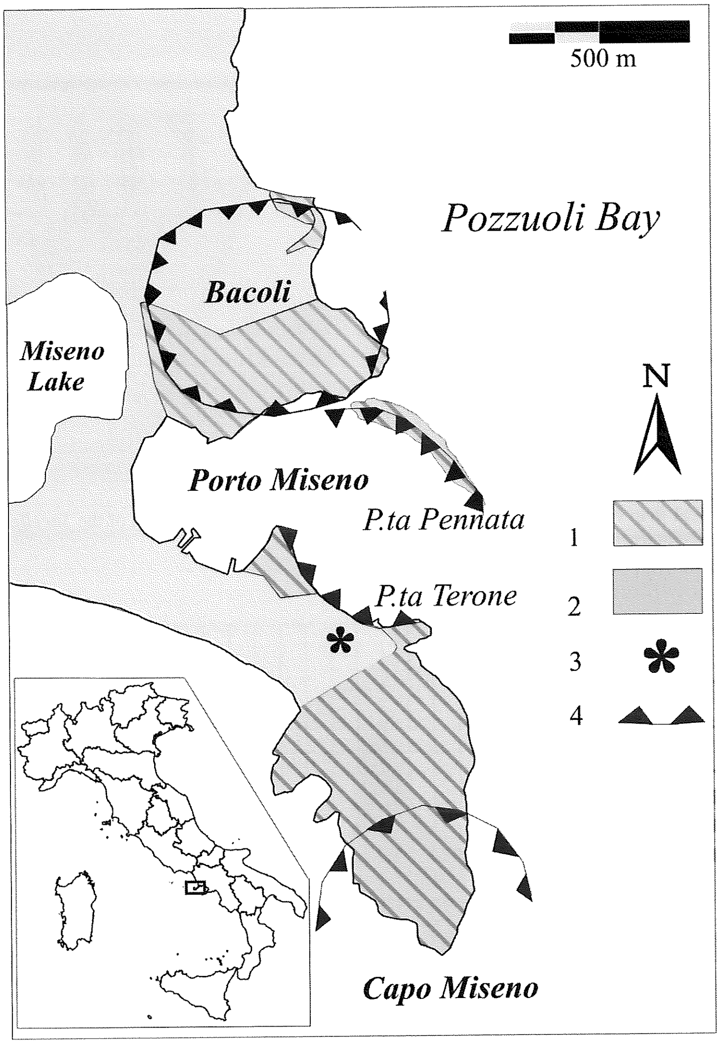

Fig. 1 – Schematic geological map of Miseno area (Modified after Insinga, 2003):
1. *Capo Miseno, Porto Miseno, Fondi di Baia* and *Bacoli* trachytic volcanic products. 2. Beach deposits and reworked pyroclastics. 3. Location of the *Sacello degli Augustali*. 4. Crater rim.

some relevance until 480 A.D. From that time on, refuse materials have been continuously dumped, but the current knowledge does not enable to state whether the reduced amount of «*Terra Sigillata*» derives from a decrease of the dumping activity in the *Sacello* area or it witnesses a drastic reduction of African tableware importation within the Phlaegrean area.

Among the cooking ware, a small group of fragments has been identified as belonging to the Pantellerian ware due to their workmanship and shaping (Santoro Bianchi and Guiducci, 2001; Santoro Bianchi, 2002 and references

Fig. 2 – Archaeological map of *Misenum*. Arrow indicates the location of the *Sacello degli Augustali*.

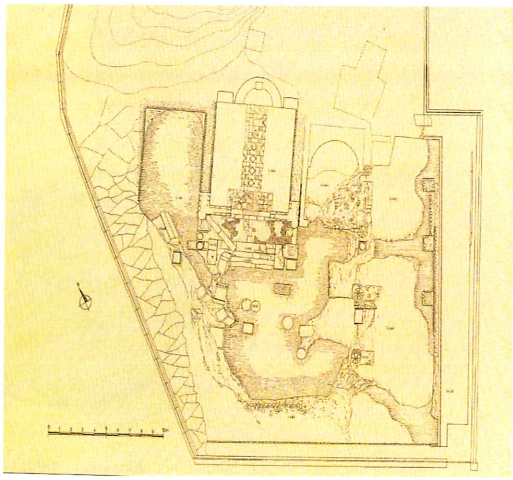

Fig. 3 – Schematic plan of the *Sacello*.

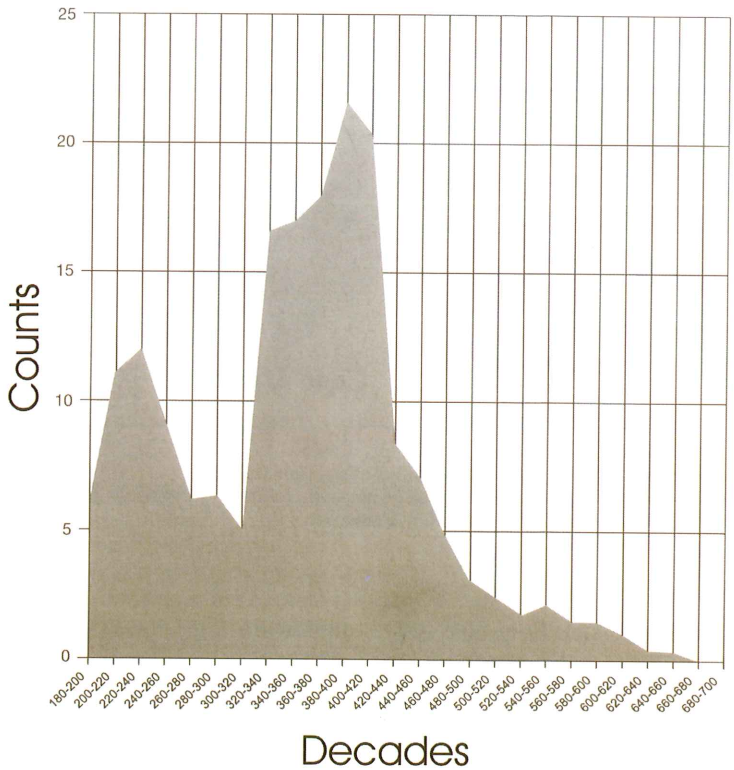

Fig. 4 – Rims counting of the *Terra Sigillata* in the *Sacello degli Augustali* excavation (Soricelli, 2000)

therein). Furthermore, another group of fragments characterized by shapes quite similar to those of Pantellerian origin but with a slight different fabric were likely attributed to a local or regional production (Soricelli, 2000).

The above mentioned groups (Pantellerian ware and local or regional crafts) were jointly discovered along with a homogeneous group of fine wares and cooking wares, likely produced in the first half, or second quarter, of the V century A.D.

In order to verify the accuracy of these attributions and to characterize technologically the samples, 10 selected fragments affected by uncertainty in terms of provenance were investigated from an archaeometric point of view. These selected wares belong to Pantellerian and to supposed local or regional production (archaeological attribution; Soricelli, 2000).

Samples and methods

Table 1 reports for all the investigated samples typological information and the presumed provenance on the basis of archaeological observations (Soricelli, 2000).

Some drawings showing the main shapes of cooking ware from the *Sacello degli Augustali* are represented in Figure 5 (Soricelli, 2000).

The archaeometric study was carried out with the analytical procedures commonly used in mineralogical and petrographical researches.

Optical microscopy on parallel thin sections of wall's fragment (Leitz Laborlux 12 POL) allowed to evaluate the textures of the different handmade (temper/matrix ratio) and to evidence crystal phases as well as all the other components.

Mineralogy was investigated by X-Ray powder diffraction (XRD) with a Philips PW 1730/3710 diffractometer (CuK_α radiation 40kV, 30 mA, curved graphite monochromator, scanning interval 3-80°, step size=0.020° 2θ, counting time 5s per step), on micronized ($\phi <$ 5μm) aliquots of about 1 gr for each sample.

Bulk chemical analyses (ten major and nine trace elements) were performed by X-ray fluorescence (Philips PW1400). Analytical procedures were carried out according to Franzini *et al.* (1975), Leoni and Saitta (1976) and Melluso *et al.* (1995).

Scanning Electron Microscope observations (Jeol JSM 5310) were carried out on freshly fractured cross-sections of the sample to

TABLE 1

Cooking ware samples from the Sacello degli Augustali

Sample	Typology	Presumed provenance*	Chronology
1	Saucepan	Pantelleria	IV-V century A.D.
2	Saucepan or dish	Pantelleria	IV-VI century A.D.
3	Saucepan or dish	Pantelleria	IV-VI century A.D.
4	Casserole	Local	V-VIII century A.D.
5	Casserole	Local	IV-VII century A.D.
6	Saucepan	Pantelleria	V century A.D.
7	Saucepan	Local	V century A.D.
8	Saucepan	Local	V century A.D.
9	Lid	Local	IV-VII century A.D.
10	Casserole	Local	V-VIII century A.D.

* The presumed provenance is based on morphological and macroscopic observation (Soricelli, 2000).

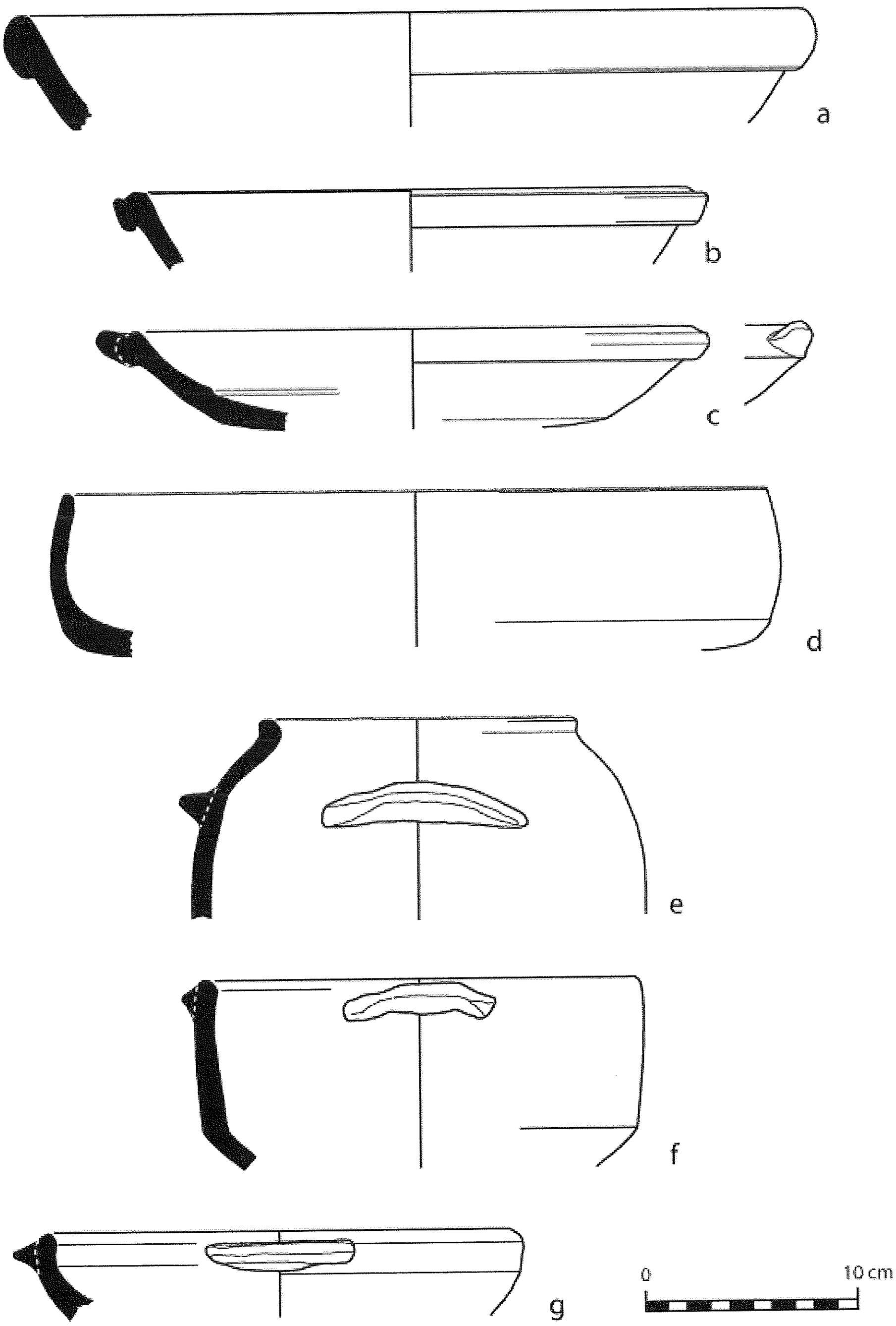

Fig. 5 – Drawings representing the main shapes of cooking ware from the *Sacello degli Augustali* (Soricelli, 2000); a) Saucepan; b) Saucepan or dish; c) Saucepan or dish; d) Saucepan, e) Casserole, f) Casserole, g) Saucepan.

investigate the microstructures and to evaluate the degree of vitrification of the clay matrix.

The distribution of the pore access size, as well as the pore volume were determined by Mercury Intrusion Porosimetry (MIP) on freshly cut sherd of about 2 cm^3 with a Thermo Finnigan Pascal 140 porosimeter (range = 0.1-400 kPa; pressure resolution 0.1 up to 400 kPa; accuracy = higher than 0.25%; pore range size measure = 1.900-58.000 µm; volume pore field measure = 0.1-500 μm^3) and a Pascal 240 porosimeter (range = 0.1-200 MPa; pressure resolution 0.01 up to 100MPa, 0.1 up to 200MPa; volume resolution 0.1 mm^3; accuracy = higher than 0.2%; pore range size measure = 3.7-7500 µm; volume pore field measure = 0.1-500 mm^3).

Analytical results

Petrographic studies

The petrographical study evidences the optical features of the thin section in terms of colour, optical activity of the matrix, packing, sorting, distribution and composition of a-plastic inclusions (Maggetti, 1991). The interpretation of these parameters can provide useful information on the provenance and manufacture of the ceramics materials. For all the samples, in agreement with their prevalent use as cooking ware, the presence of abundant a-plastic inclusions necessary to buffer the clay shrinkage during the firing operation, was pointed out. The concomitant use of moderate firing temperatures (between 750-850°C) enables to produce low stiff structures with a low dilation coefficient α (Olcese and Picon, 1994; Tite *et al.*, 2001).

The following descriptions of the samples grouped on the basis of mineralogical and petrographical observations take into account the international notation of Wentworth scale (Greensmith, 1989) to define the size fraction of the inclusions, the comparative diagrams of Terry and Chilingar (1955) to estimate packing of the a-plastic inclusions.

• Group 1 (samples 2, 3, 6, 7, 8, 9)

The matrix, predominant component of the mixture, is optically isotropic and shows a colour ranging between brown and dark brown. Some portions of the matrix have a darker colour as a possible consequence of the combustion of organic matter added to the mixture. A-plastic inclusions range in size between 1.5 and 2.0 mm (very coarse sand), their packing ranges between 20 and 30 vol% and grains show angular rims (Hodgson, 1974). They represent the remaining portion of the mixture mainly constituted by volcanic materials such as scoriae, pumices (Fig. 6a), obsidian fragments, lithic fragments and crystals.

In order of abundance the following minerals were recognized: anorthoclase, alkali feldspars, aegirine (Fig. 6b) and subordinate quartz, biotite and muscovite. The crystal size distribution is bimodal (iatal) and the size of the volcanic matter is larger than the residual crystal (quartz and alkali feldspars, essentially) fraction of the clay.

• Group 2 (samples 1 and 5)

Samples of this group show a darker central body (core) due to reduction conditions settled during the firing operation, with external surfaces light brown coloured, a typical *sandwich* structure (Letsch and Noll, 1983; Harrel and Russel 1967). A-plastic inclusions show a low sorting grade, size ranging from 0.10 mm and to 1.75 mm (very fine sand to very coarse sand, serial texture), a packing of about 30-40 vol% and subangular rims (Hodgson, 1974). Scoriae, pumice and obsidian fragments constitute the volcanic lithics. Carbonate grains sometimes occur as microcrystalline calcite in the pores or indirectly recognizable by *casts* (pores by marks) related to firing process. The main mineral phases are: quartz (abundant tiny fragments), plagioclase (Fig. 6c), alkali feldspar, biotite, augite (Fig. 6d) and rare brown amphibole.

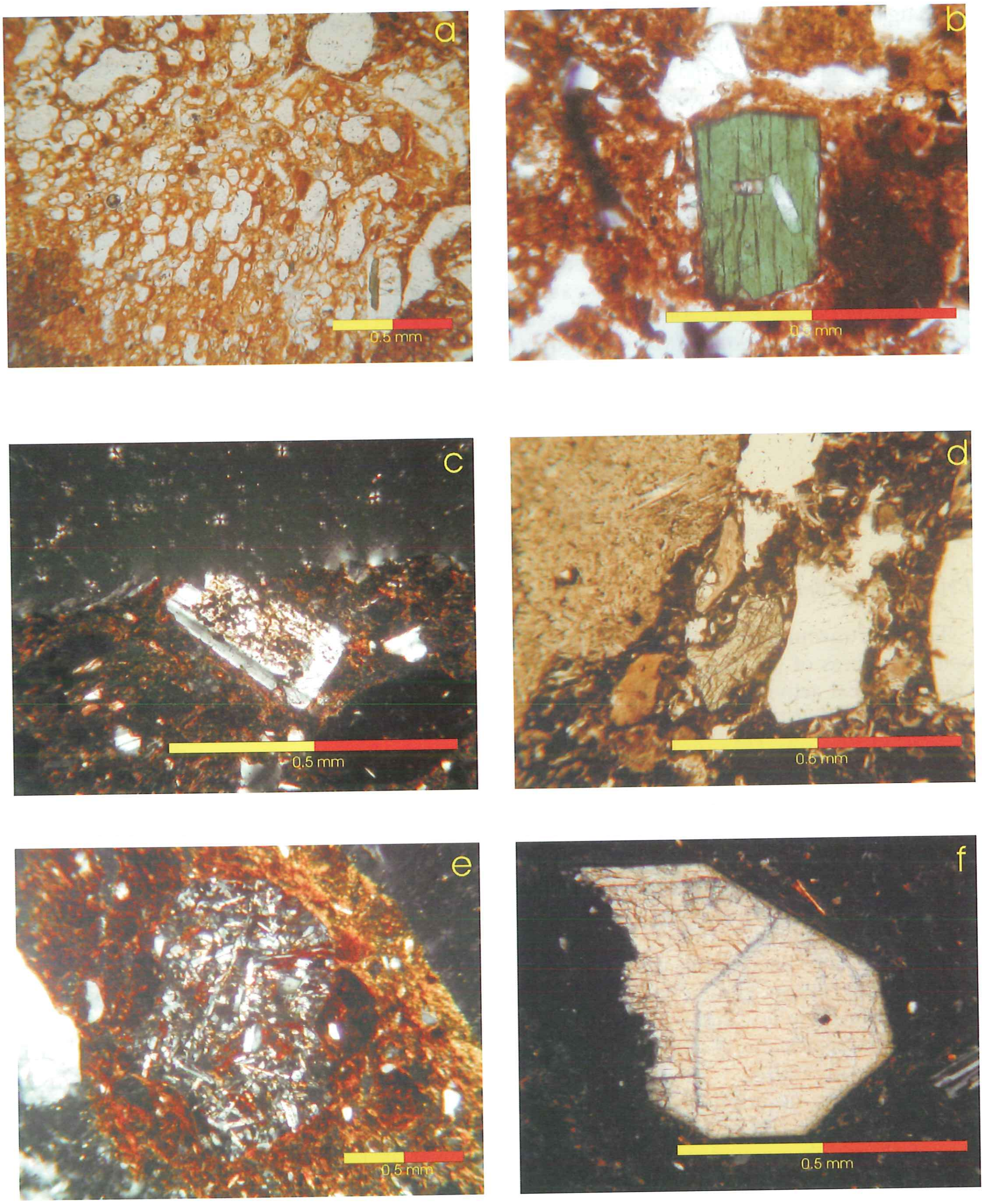

Fig. 6 – Representative micrographs of thin sections. a) Group 1. Large pumice with a small aegirine crystal in the lower right portion (Plane polarized light); b) Group 1. Large green aegirine crystal (Plane polarized light); c) Group 2. Dusty plagioclase (Crossed polars); d) Group 2. Pumice, augite, and plagioclase (Plane polarized light); e) Group 3. Trachytic scoria (Crossed polars); f) Group 3. Large diopside crystal (Crossed polars).

• Group 3 (samples 4 and 10)

The matrix is optically inactive and shows a colour ranging from brown to dark brown; a low compact structure is characterized by frequent voids and fractures. The a-plastic inclusions with a serial grain distribution (0.2–1.0 mm, fine to coarse sand), packing ranging from 20 to 30 vol%. and subangular rims (Hodgson, 1974), are represented by trachytic (Fig. 6e) to leucititic volcanic lithics, pumice, scoriae, crystal fragments and chamotte (particularly abundant in sample 4). Alkali feldspar (sanidine), clinopyroxenes (diopside and salite, Fig. 6f), biotite, white mica (in tiny lamellae as residual mineral of clays), titanite, garnet and quartz (residual mineral of clays), were also recognized.

The petrographical observations allow to draw the following considerations:

– the distinguishing feature of group 1 is represented by the combined occurrence of anorthoclase and aegirine; group 2 is characterized by plagioclase (dusty and patchy-zoning), augite and amphibole, group 3 by trachytic and leucititic lithics, abundant sanidine, diopside, salite and garnet. Within this last group a further distinction should be carried out between the two samples in terms of abundance of components: sample 4 is richer in chamotte and pumice whereas sample 10 displays a higher amount of alkali feldspar.

XRD analysis

Mineral assemblages can often provide useful information on the firing process dynamics; the appearance of new formed phases, the loss of others, the persistence of prograde phases may suggest the lowest and the highest temperatures reached during the firing process (e.g. Riccardi *et al.*, 1999).

Table 2 reports the semi-quantitative results of the XRD analyses carried out on the potteries of the *Sacello degli Augustali.*

All the investigated samples have quartz as common phase, even though, as residual mineral in clays, it is not always detectable on microscope observations. Feldspars are abundant in all the samples, in agreement with the petrographical observations. Pyroxenes are always present showing higher contents in samples 4 and 2. Evidences of residual illite in eight samples out of ten may suggest firing temperatures not exceeding about 850°C, above which this clay mineral undergoes a breakdown. Illite only lacks in samples 1 and 5 that, on the other hand, show calcite in traces. This evidence can be explained by firing temperatures close to 850°C but not as much

TABLE 2

XRD semi-quantitative mineralogical evaluation of the investigated samples.
Legend: xxxx=predominant; xxx=abundant; xx=frequent, x=sporadic, tr=traces.

Sample	Biotite	Feldspars	Quartz	Calcite	Hematite	Clinopiroxene	Illite
1	x	xxx	xxxx	tr	—	x	—
2	—	xxxx	xx	—	x	xx	x
3	—	xxxx	xxx	—	x	x	x
4	—	xxx	xxx	—	tr	xx	x
5	—	xxxx	xxx	tr	tr	x	—
6	—	xxxx	xx	—	x	x	tr
7	—	xxxx	xx	—	xx	x	x
8	—	xxxx	xx	—	x	x	x
9	—	xxxx	xx	—	x	x	x
10	—	xxxx	xx	—	tr	x	x

high to achieve a complete dissociation of calcite; it should be remarked that petrographical observations do not indicate calcite as formed by processes settled after the firing process (*i.e.* by calcite precipitation after burial).

XRF analysis

The bulk chemical analyses of the cooking ware reported in table 3 and carried out by X-ray fluorescence (major elements: Si, Ti, Al, Fe, Mn, Mg, Ca, Na, K, P wt% oxides; trace elements: Rb, Sr, Y, Zr, Nb, Sc, V, Cr, Ba ppm) evidence the wide variability of the chemical composition both in terms of major and trace elements.

Variation diagrams always allowed to discriminate at least two different chemical groups (Fig. 7a) one of which perfectly corresponding to the previously identified petrographical group 1. Cooking ware belonging to this group (samples 2, 3, 6, 7, 8, 9) show SiO_2 values ranging between 56.8% and 61.5% (wt % LOI free), higher TiO_2 (1.00 - 1.27 wt%) and Fe_2O_3 (8.54 - 10.8 wt%) contents. As far as trace elements are considered Ba (710 - 957 ppm), Zr (736 - 1195 ppm) and Nb (144 - 264 ppm) turned out particularly concentrated.

Group 2 (samples 1 and 5) shows generally high SiO_2 values (65.78 and 61.10 wt%), low K_2O content and the lowest values for Zr (163-255 ppm) and Nb (19-22 ppm).

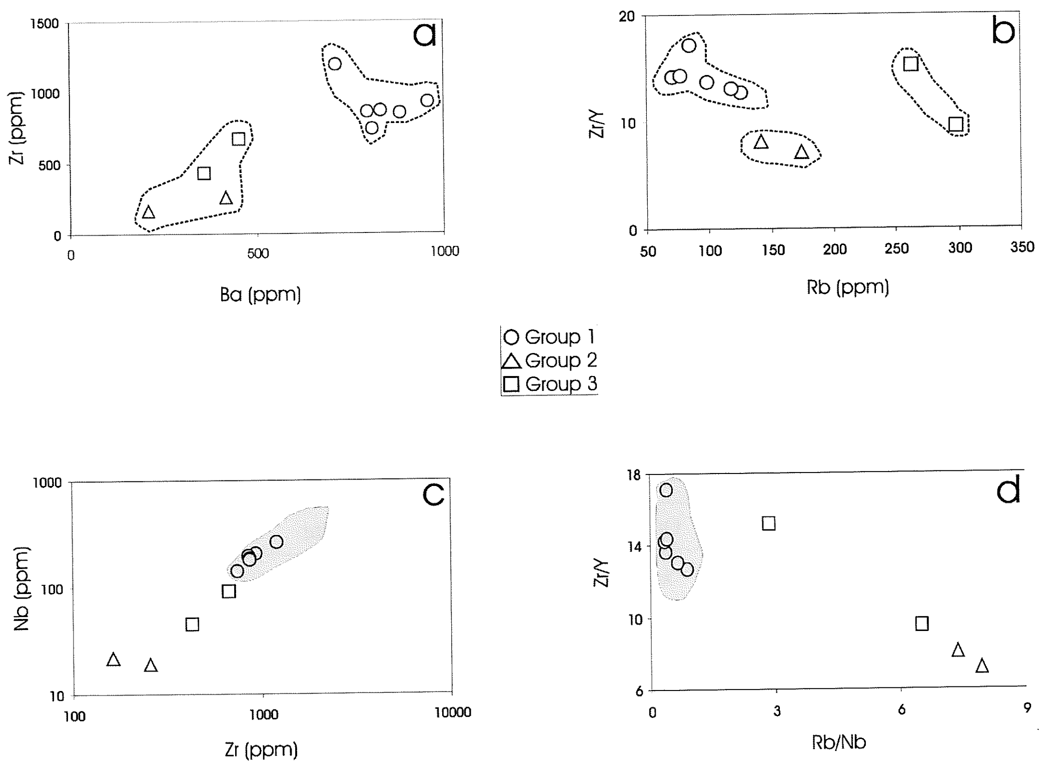

Fig. 7 – a) Ba vs Zr (ppm) diagram; b) Rb (ppm) vs Zr/Y ratio diagram; c) Zr vs Nb (ppm) diagram; d) Rb/Nb vs Zr/Y ratios diagram. The dashed area in c) and d) represents the compositional range of some Pantelleria vulcanites (Civetta *et al.*, 1988 and references therein).

TABLE 3

XRF analyses of the cooking ware from the Sacello degli Augustali.

wt%	1	2	3	4	5	6	7	8	9	10
SiO_2	65.78	56.81	61.55	54.36	61.10	59.29	59.51	60.41	59.11	54.78
TiO_2	0.47	1.27	1.14	0.89	0.79	1.00	1.01	1.10	1.21	0.60
Al_2O_3	21.43	23.17	18.15	24.92	20.77	17.69	19.71	18.17	22.02	26.65
Fe_2O_3	5.11	9.26	9.52	7.69	6.58	10.81	9.39	9.92	8.54	5.51
MnO	0.02	0.11	0.16	0.14	0.13	0.27	0.16	0.18	0.13	0.15
MgO	1.26	1.55	1.81	2.85	2.42	1.75	1.51	1.700	1.19	1.59
CaO	1.19	1.28	1.27	3.41	3.02	1.64	1.23	1.39	1.19	2.49
Na_2O	1.67	3.53	2.92	2.27	2.50	3.76	4.23	3.45	3.60	2.41
K_2O	2.93	2.90	3.38	3.29	2.56	3.24	3.21	3.55	2.91	5.71
P_2O_5	0.14	0.11	0.10	0.19	0.13	0.54	0.04	0.12	0.10	0.10
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
LOI	6.50	5.00	5.00	6.70	2.20	2.40	4.00	4.00	4.00	1.20
ppm										
Rb	174	77	126	298	142	99	85	118	71	263
Sr	138	206	185	261	288	178	207	185	205	224
Y	23	60	58	45	32	87	54	66	60	44
Zr	163	860	736	427	255	1195	925	864	849	667
Nb	22	187	144	46	19	264	206	181	199	92
Sc	4	8	8	13	17	5	5	11	6	4
V	49	23	49	153	72	33	21	47	26	47
Cr	42	b.d.	31	93	20	11	b.d.	32	b.d.	17
Ba	207	797	808	357	415	710	957	831	882	451

Group 3 (samples 4 and 10) is characterized by the lowest SiO_2 (54.4 and 54.8 wt%) and the highest Al_2O_3 values (24.9 and 26.6 wt%). The peculiar abundance of sanidine in sample 10 also accounts for the highest K_2O content; furthermore, Rb displays the highest values for both samples (263-298 ppm; figure 7b).

Finally, as far as calcium oxide is concerned, its values ranging for all the samples between 1.19 and 3.41 wt%, confirm the non-calcareous character (CaO<7-8 wt% for Olcese e Picon, 1994 and CaO<5 wt% for Tite and Maniatis, 1975) of the clay used for the mixture.

Scanning electron microscopy (SEM)

Scanning electron microscopy is generally used to evaluate the micromorphology of the body of the pottery. This observation may provide useful information on the degree of vitrification of the clay matrix thus suggesting the possible firing temperature of the cooking ware (Kilikoglou, 1994, Tite and Maniatis, 1981).

Micrographs of figure 8 are representative of the analysed samples.

The upper portion of figure 8a (sample 2) shows a still preserved laminar structure of a phyllosilicate exfoliated along basal planes, most probably due to dehydroxylation (Cultrone *et al.* 2001). The lower portion of the same micrograph shows the fired clay matrix.

The detail of figure 8b (sample 9) evidences an initial stage of vitrification in the clay matrix with diffuse welding of clay particles and smoothed and deformed edges of phyllosilicates (Maniatis and Tite, 1981).

Figure 8c (sample 5) witnesses the continuous vitrification of clay matrix where fine bloating pores appear (Maniatis and Tite 1981). The welding of the particles is here extensive.

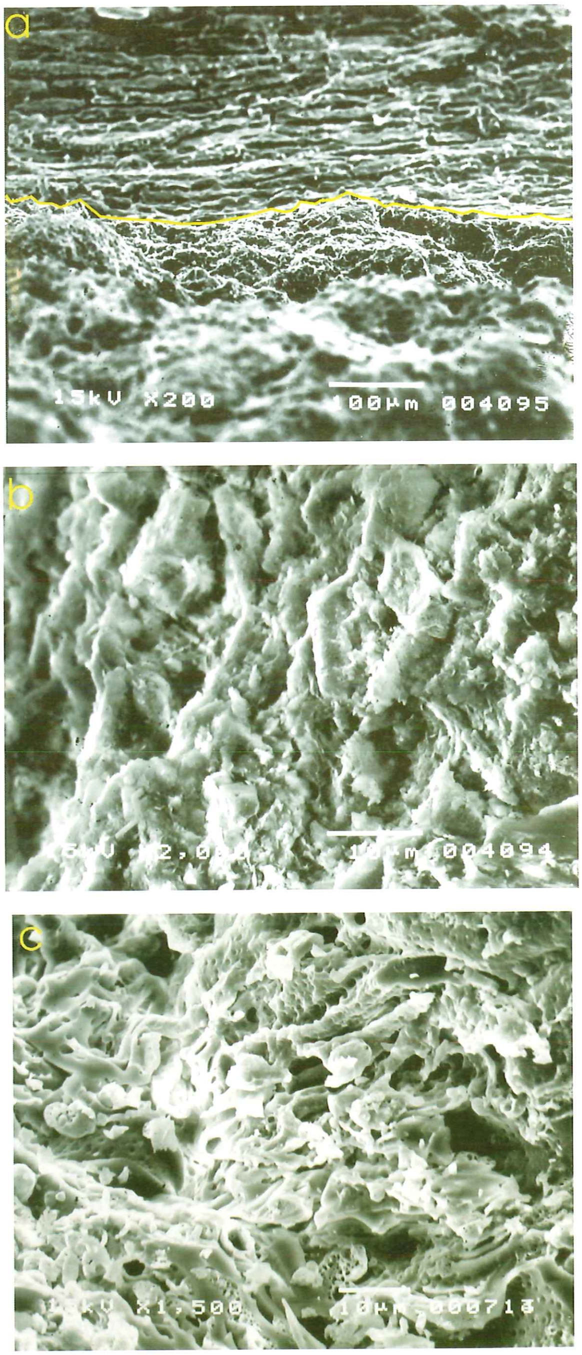

Fig. 8 – SEM micrographs; a) sample 2, laminar structure of a phyllosilicate and clay matrix; b) sample 9, Initial Vitrification of the clay matrix (Maniatis and Tite, 1981); c) sample 5, Continuous Vitrification (Maniatis and Tite, 1981).

Table 4 summarizes same technological features of the investigated cooking ware that take into account the interpretation of the SEM observations, mineralogical and textural data and CaO content.

The sherds show a non-calcareous character and, on the basis of the colour of the paste, were fired in conditions of oxidizing atmosphere. The only exception is for samples 1 and 5 manufactured under reducing atmosphere at the body and oxidizing condition at the slip.

The vitrification stage evaluated by scanning electron microscopy was defined as Initial Vitrification (Tite and Maniatis, 1975) for samples 2, 3, 4, 6, 7, 8, 9, 10; the remaining samples (1 and 5) show a Continuous Vitrification with Fine Bloating (Tite and Maniatis, 1975). Thus, the inferred firing temperatures for samples 1 and 5 (petrographic group 2) are between 850°-900°C, and for all remaining samples between 800°-850°C.

Mercury intrusion porosimetry (MIP)

The porosity and in particular the pore-size distribution (PSD) have been considered as a key parameter for predicting technological features of pottery; in fact, these physical parameters play a fundamental role on thermal shock resistance of the cooking ware.

The results of this test confirm the occurrence of three different groups each characterized by a peculiar behaviour (Fig. 9). The pore size radii for samples of group 1 (Fig. 9a) display a quite regular and uniform distribution above the entire investigated range (~ 58μ – 0.004 μ) with a very slight increase of frequency towards the finest pores. This situation is strongly enhanced in samples of group 3 (Fig. 9c) where the highest frequency falls within the pore range 0.02 – 0.004 μ. A completely different pattern was finally recorded for samples of group 2 (Fig. 9b). Here the most represented pore size radii are drastically shifted towards the highest values (~ 0.8μ – 7 μ) (Cultrone *et al.*, 2004).

Discussion and conclusions

The mineralogical, petrographical and geochemical data allow to univocally identify three groups of samples; the technological features of this specific type of ceramics were also verified. In fact, cooking ware are required to stand high thermal shocks, namely the different temperatures settled between the internal portion of the manufact and the external one exposed to the fire. This thermal difference establishes a differential dilation between the two portions thus generating

Table 4

Hypothesized firing temperature on SEM observation (Maniatis and Tite, 1981).

Sample	Clay type	Atmosphere	Vitrification stage	Firing temperature (°C)
1	NC	R	CV (FB)	850-900
2	NC	O	IV	800-850
3	NC	O	IV	800-850
4	NC	O	IV	800-850
5	NC	R	CV (FB)	850-900
6	NC	O	IV	800-850
7	NC	O	IV	800-850
8	NC	O	IV	800-850
9	NC	O	IV	800-850
10	NC	O	IV	800-850

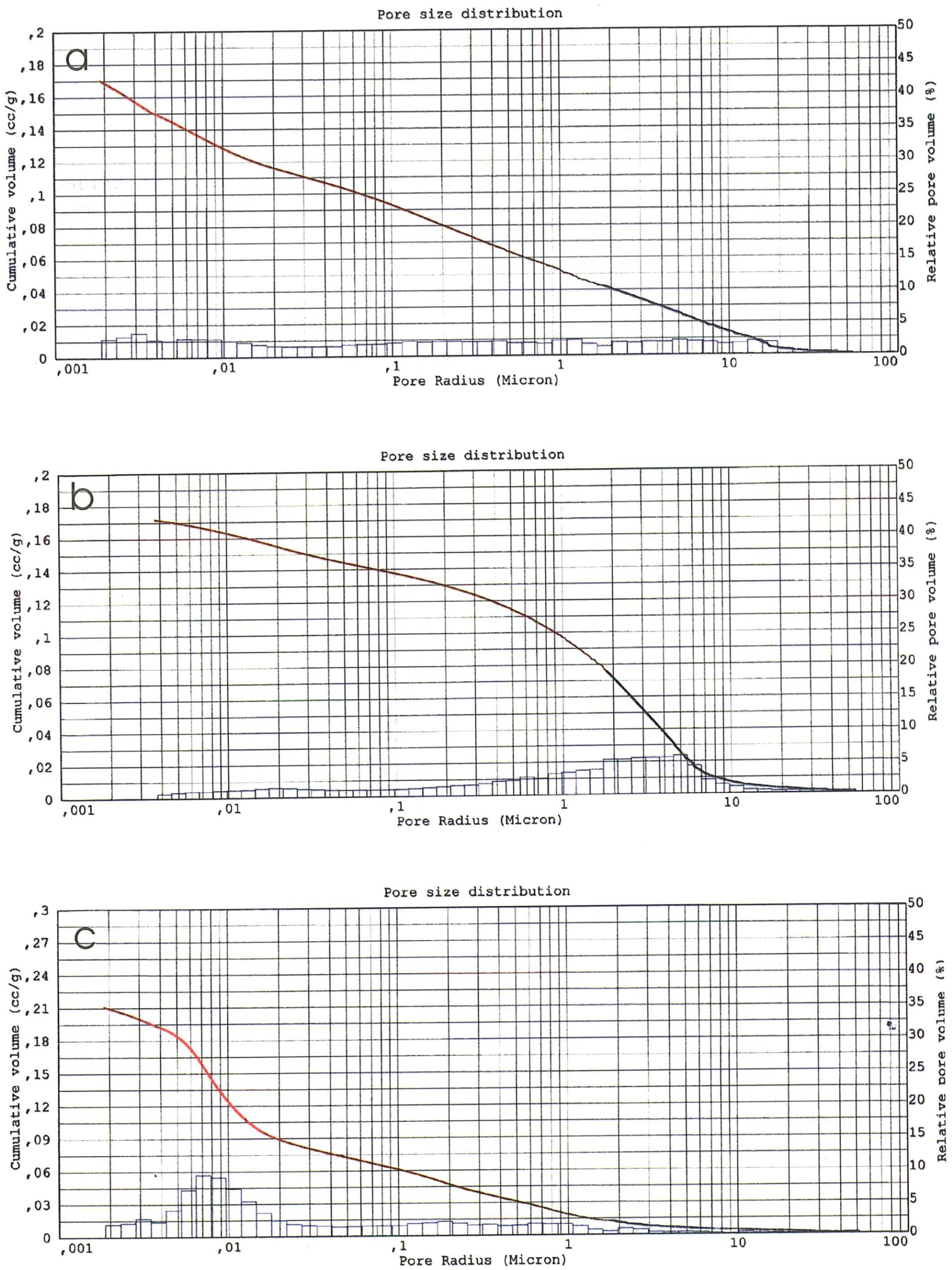

Fig. 9 – Pore size distribution curves by mercury intrusion. a) sample 3 representative of group 1; b) sample 5 representative of group 2; c) sample 4 representative of group 3.

internal stresses that can damage the pottery. Therefore, a low stiff structure with a low dilation coefficient α is required. This kind of structure can be achieved by two different but complementary methods: a first one consists in adding to the mixture an abundant fraction of inert temper, possibly well sorted; the other one foresees low firing temperatures (between 700 and 800°C) as α is directly related to this parameter.

Both these two procedures were likely followed to prepare samples belonging to group 1, as they show the best technological features. Samples 1 and 5 (group 2) were fired at temperatures slightly higher (~850°C) and show a low sorted temper. Another feature worth to be considered is the calcareous or non calcareous nature of the clay. Non calcareous clays can give, considering the same dilatation coefficient (α), finer mixtures thus providing a better wheel workability (Olcese and Picon, 1994). The highest CaO content measured for the investigated samples was 3.41 wt%.

Petrographical group 1 shows, further than pumice and volcanic scoriae in the temper, mineral assemblages typical of differentiated peralkaline rocks (anorthoclase and aegirine). The diagram Zr-Nb of Figure 7c compares the chemical analyses of the studied samples and peralkaline rocks (pantellerites of the Pantelleria island). This comparison, justified by the high content of volcanic temper reflecting the original composition of the magma, evidenced that all the samples of group 1, representative of the Pantellerian Ware, perfectly overlap the compositional field of pantelleritic rocks (Civetta *et al.*, 1984; 1988).

In order to minimize problems concerning absolute concentrations elemental ratios have also been considered; again, cooking ware from group 1 show a chemical composition close to that of pantelleritic rocks (Rb/Zr and Zr/Y ratios in diagram of Figure 7d).

In summary the whole set of mineralogical, petrographical and geochemical data confirms the hypothesis that samples from group 1 come from the Pantelleria island.

Samples 1 and 5 of group 2 shows a peculiar mineralogical association, different from all the others, characterized by plagioclase, augite and amphibole. The presence of these calcalkaline magmatism phases (augite and amphibole), along with dusty and patchy-zoning plagioclase, leads to put forward a different origin for these cooking ware. A possible hypothesis could consider a provenance from Aeolian islands, a volcanic district characterized by diffused calcalkaline magmatism. As far as firing temperatures are concerned, the absence of any residual illitic minerals (Table 2) likely indicates slight higher values if compared to samples of group 1. Samples of group 3 (4 and 10) are characterized by an almost different mineral assemblage: alkali-feldspars (particularly abundant is sanidine in sample 10), Ca-pyroxenes (diopside and salite) and garnet. The concomitant presence of pumice, scoriae and volcanic lithics with a prevailing trachytic and subordinate leucititic composition, definitely allows to attribute to these manufacts a local provenance (phlegraean and/or vesuvian area).

The Pore Size Distribution analysis also support the above hypothesis of sample groupings. In fact, samples of group 2 show the highest frequency of large pore size (~ 0.8μ – 7 μ); this feature is in agreement with higher firing temperatures (850°-900°C), already hypothesized on the basis of mineralogical and petrographical data, which are responsible of an extensive vitrification and welding of the clay matrix as well as the presence of fine bloating pores (Maniatis and Tite, 1981). On the contrary, lower firing temperatures (800°-850°C) are likely responsible of the different frequency of pore size distribution (Fig. 9a, c) for all the other samples (group 1 and 3).

The most meaningful result of the present study is the ascertained provenance from Pantelleria of 3 samples formerly supposed to be of local or regional production (Table 5). Even if reasonable doubts arise about the fullness and the coherence of this ceramic assemblage, the number of Pantellerian ware found in the *Sacello* is significant especially if

TABLE 5

Comparison between archaeological (Soricelli, 2000) and archaeometric data (present study).

Samples	Archaeological attribution	Archaeometric attribution
2	Pantelleria	Pantelleria
3	Pantelleria	Pantelleria
6	Pantelleria	Pantelleria
7	Local	Pantelleria
8	Local	Pantelleria
9	Local	Pantelleria
4	Local	Local
10	Local	Local
5	Local	Aeolian islands ?
1	Pantelleria	Aeolian islands ?

compared to the occurrences in the Gulf of Naples (Grifa *et al.*, 2004) and in the Phlaegrean Fields (Carsana, 1994).

Another striking result was the possible aeolian origin of samples 5 and 1 formerly attributed to a local or Pantellerian production, respectively. Aeolian products were already pointed out in the Bay of Naples, where particularly frequent are the «Richborough 527 type» amphorae (Arthur, 1989; 2002) produced in Lipari and mainly used for the alum trade (Bogard, 1994). The wide distribution of the casserole (sample 5), within the Mediterranean area, could possibly be the reflection of the broad diffusion of the «Richborough 527 type» amphorae between the first and fourth century A.D.

In conclusion, archaeometric investigations allowed to distinguish three homogeneous groups of samples:

- Group 1 (samples 2, 3, 6, 7, 8, 9). Belonging to the Pantellerian Ware typology, produced in Pantelleria between the 1st and the 4th century A.D. It is characterized by abundant and well sorted volcanic temper, typical peralkaline rock phases, and a dark matrix due to the presence of organic matter. This is the most technologically advanced material.
- Group 2 (samples 1 and 5). This is a peculiar group from a technological point of view. It is in fact characterized by a black body coated by a thin red layer of selected clay fired at temperature higher than 850°C. The mineralogical association of the temper (dusty and patchy-zoning plagioclase, augite, amphibole) leads to hypothesize an Aeolian provenance.
- Group 3 (samples 4 and 10). These are the only samples of local production as witnessed by the composition of the volcanic temper (diopside-salite, abundant alkali feldspars, trachytic and leucititic rock fragments).

The ceramic potteries belonging to the *Pantellerian Ware* production (group 1), among all the studied samples best represent technological features of an excellent cooking ware. In fact, the well sorted volcanic temper, the non-calcareous character of the clay, the low firing temperatures, and the standardized shapes suitable for transportation, justify the exportation and the wide distribution in the western Mediterranean basin.

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