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Western production of "Ionian cups of type B2": a preliminary archaeometric study to identify workshops in eastern Sicily

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Abstract - This work focuses on the petro-chemical characterisation of Ionian cups of type B2, a ceramic class that was widespread in the Mediterranean during the Archaic period. These cups were manufactured initially in eastern areas of Greece and then became extensively used also in the western Greek colonies, where they were produced until the early fifth century B.C. This contribution represents a first attempt to identify workshops in eastern Sicily. With this aim, Ionian cup fragments from five archaeological sites in eastern Sicily (Mendolito, Monte Castellaccio, Poira-Poggio Cocola, Piano Casazzi, Francavilla di Sicilia) were studied petrographically and geochemically. The resulting data were also compared with ceramic materials that can be identified as indigenous artefacts at each study site, as well as with the presently scanty literature data on Ionian cups from the Greek colonies of eastern Sicily.

The results allow us to make some significant observations on the production areas of the studied sherds. Specifically, the Ionian cups from the above archaeological sites are quite different from the indigenous pottery, while both the petrographic and geochemical features of all the Ionian cups indicate a single production site, probably in a still unidentified colony of eastern Sicily. Alternatively, compositional homogeneity may indicate different but extremely specialised production, with the use of similar raw materials and techniques. This uniform production, although similar from a petrographic point of view to that previously identified in the Messina area, is distinguishable for its particular chemical signature.

Riassunto - Il presente lavoro riguarda la caratterizzazione petro-chimica di coppe ioniche di tipo B2, una classe ceramica ampiamente diffusa in area Mediterranea durante l'età arcaica. Questi materiali furono fabbricati originariamente in ambito greco-orientale, e successivamente largamente diffusi anche in Occidente, dove furono prodotti dalle colonie greche fino all'inizio del V sec. a.C.

Questo contributo rappresenta un primo tentativo di identificazione dei centri di produzione nella parte orientale della Sicilia. A tal fine, sono stati analizzati da un punto di vista petrografico e geochimico diversi resti di coppe ioniche provenienti da cinque siti archeologici della Sicilia orientale (Mendolito, Monte Castellaccio, Poira-Poggio Cocola, Piano Casazzi, Francavilla di Sicilia). I dati sono stati messi a confronto sia con manufatti di produzione indigena per ciascun sito investigato, sia con i pochi dati archeometrici ad oggi disponibili dalla letteratura riguardanti coppe ioniche provenienti da colonie della Sicilia orientale.

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I risultati ottenuti hanno consentito di fare alcune importanti osservazioni sulle aree di produzione dei reperti esaminati. Le coppe ioniche provenienti dai cinque siti archeologici sopra menzionati risultano infatti composizionalmente differenti rispetto alle ceramiche indigene; tuttavia, i caratteri petrografici e chimici di tutte le coppe ioniche analizzate sembrano indicare un unico sito di produzione, ancora non identificato, che potrebbe essere localizzato in una delle colonie della Sicilia orientale. L'ipotesi alternativa è che l'omogeneità composizionale riscontrata possa essere indicativa di produzioni differenti ma estremamente specializzate, con l'utilizzo di materie prime e tecniche molto simili. In ogni caso, questa produzione, sebbene petrograficamente affine a quella precedentemente identificata da altri autori nell'area di Messina, risulta essere ben distinguibile per i suoi peculiari caratteri chimici.

Key words: *Ionian cups, eastern Sicily, chemical investigations, multivariate statistics.*

Introduction

Ionian cups of type B2 are a peculiar ceramic class, characterised by a flared rim separated from a shallow basin. Their slightly oblique handles are of the stick type, and the hollow foot is conical, with flexed walls. The covering paint has a metallic lustre and is reddish-brown in colour, and the interior wall is entirely varnished except for the rim, whereas only the rim, the bottom of the basin and the foot are painted on the exterior wall (Fig. 1).

The production of this type of pottery, widespread in the Mediterranean during the Archaic period, started in about 580 B.C. in eastern areas of Greece (this is the origin of the reference to the Ionian region in their definition) and was then continued in western regions until about 540 B.C. (Vallet and Villard, 1955; Van Compernolle, 1996). Abundant finds in several western stratigraphic contexts lower the final time of production to the end of the sixth century B.C. (Boldrini, 1994; Frasca *et al*., 1994; 1995) or even the early fifth century B.C. (Lyons, 1996; Tigano, 1999).

The question concerning the production centres of these ceramics in western regions is still hotly particularly debated. The presence of many workshops, both in the actual Greek colonies and in the indigenous hinterland, have been hypothesised. In Sicily, the only workshops presently identified on the basis of finds of waste products are those at Himera (Allegro, 1988; 1989), Messina (Tigano, 1999), Naxos, San

Fig. 1 - An example of Ionian cup of type B2 from Poira (tomb n.1).

Gregorio-Caltagirone (Lyons, 1996) and Monte Bubbonia-Gela (Tigano, 1999).

This work focuses on the petrographic and geochemical characterisation of many Ionian cups from five archaeological sites in the provinces of Catania and Messina (Fig. 2): Piano dei Casazzi (Mineo, Catania), Poira - Poggio Cocola and Monte Castellaccio (Paternò, Catania), Mendolito (Adrano, Catania) and Francavilla di Sicilia (Messina).

Archaeological Sites

The archaeological site of *Piano dei Casazzi*, located on a plateau in the south-eastern part of the Erei Mountains, is one of the four Greek centres in the territory of Mineo (province of Catania). Here, the earliest known settlement dates to the Early Bronze age, as documented by ceramic finds attributed to the Castelluccio *facies* (2200-1400 B.C.). Later archaeological documentation relates to the remains of a village found at the top of the plateau, dating to the Archaic period (Lamagna, 2005a). The Piano dei Casazzi settlement is interpreted as an ancient indigenous village that came into contact with the coastal Greek colonies during the Archaic period, thus participating in that complex process of acculturation, which so deeply characterised relationships between the Greeks and the

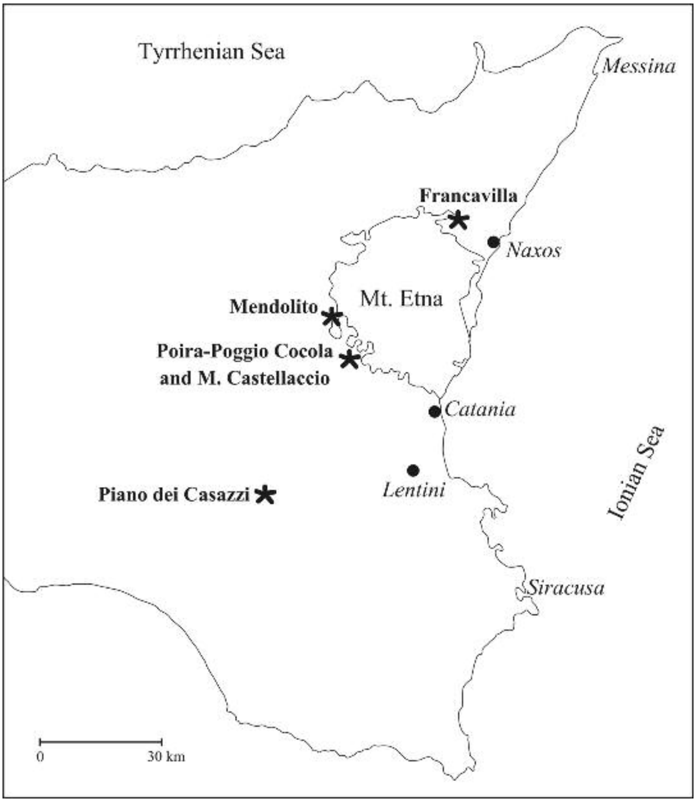

Fig. 2 - Sketch-map of eastern Sicily, showing the locations of all investigated archaeological sites (stars) and the nearby Calcidian colonies (full circles).

indigenous inhabitants of Sicily during the sixth and fifth centuries B.C.

The site of *Mendolito* is located in the valley of the Simeto river, near the modern town of Adrano (province of Catania). It is largely known to archaeologists for some highly interesting archaeological evidence, such as the bronze closet (the largest ever found in Sicily), which dates between the late eighth and mid-seventh centuries B.C. (Lamagna, 1992). This important find has earned the site its definition as "one of the most significant centres of indigenous archaeology in Sicily", in the words of the late Luigi Bernabò Brea (1975). The material culture suggests that the site is indigenous in origin, with pottery of the Licodia Eubea *facies* clearly predominating over other colonial and Greek-imported ceramic classes, such as Ionian cups of type B2, as well as Corinthian and Attic ceramics (Lamagna, 2005b).

Monte Castellaccio is located in the area of Contrada Pietralunga (near Paternò, province of Catania), along the Simeto valley. An extensive settlement on the south-eastern flank of Mt. Castellaccio had already been identified by Ignazio Paternò principe di Biscari in the eighteenth century (Paternò, 1781). This site shows progressive development from the Early Bronze Age through the Archaic period (McConnell *et al.*, 1996; McConnell, 1997, 2009). Ceramic remains found here include common wares, storage jars and tablewares (cups and hydriae, sometimes with geometric decoration).

Poira - Poggio Cocola is another Archaic and Classical indigenous centre in the Simeto valley, near Paternò. Poggio Cocola is the highest point of the Pietralunga relief, and excavations here during the 1960s identified a large settlement with a defensive, circuit wall dating back to the Greek period, probably the ancient city of *Inessa*, first identified by Rizza in 1959. Excavations by the Soprintendenza per i Beni Culturali ed Ambientali di Catania in 1995 confirmed the earlier findings and revealed a grid-like consistency to the overall layout of the settlement (McConnell *et al.*, 1996; McConnell, 1997). The *masseria* Poira (a large farm structure) is located not far away to the south. It was here, during excavations in 1965, that a Hellenistic necropolis dated from the sixth to the mid-fifth centuries B.C. was found. The type of tombs, together with the nature and consistency of the objects found inside them, suggests a purely indigenous cultural horizon; however, the abundant presence of Greek materials among the ceramic finds, both colonial (mainly consisting of Ionian cups of type B2) and imported, again indicates consistent relationships with the coastal Greek colonies (Lamagna, 2009).

Francavilla di Sicilia, in the upper part of the valley of the Alcantara river (province of Messina), records a Greek centre, probably representing the gradual Hellenisation of a native settlement due to the arrival of the Calcidian Greeks from Naxos during their approach to the Tyrrhenian coast. The tradition of crafts in this area and local ceramic production in particular were revealed in the remains of two kilns. Three main chronological phases have been identified in the history of this site (Spigo and Rizzo, 1993; 1994; Spigo, 1994): I) late Archaic (late sixth to early fifth centuries B.C.); II) Classical (fifth century B.C.); III) late Classical to proto-Hellenistic (mid-fourth to mid-third centuries B.C.).

Figure 2 shows a sketch-map of eastern Sicily, with the locations of all investigated archaeological sites.

Materials and Methods

In this work, a set of 49 Ionian cup fragments from the five archaeological sites described above was analysed. In addition, for comparative information on their production area, indigenous sherds from each context sherds from each context were also examined. The pottery remains from the Piano dei Casazzi site include nine fragments of Ionian cups of type B2 (samples PAL 5-13), dating to the sixth - early fifth centuries B.C., and nine indigenous pieces, either unpainted or with geometrical decorations (PAL 14-22), belonging to the same period. Five Ionian cups of type B2 (MEND 7-11) and six local unpainted and decorated ceramics (MEND 1-6), the latter belonging to the Licodia Eubea *facies* (sixth - mid-fifth centuries B.C.), were examined from the Mendolito site. Selected sherds from Poira-Poggio Cocola and Monte Castellaccio include 25 fragments of Ionian cups of type B2 (POI 1-20 from the Poira necropolis, PTPCo 1-3 from Poggio Cocola, and PTPL 1-2 from Monte Castellaccio) and five both unpainted or decorated local ceramics (POI 21-25) of the Licodia Eubea *facies*, for comparison. Lastly, samples from Francavilla di Sicilia consisted of ten Ionian cups of type B2 (FRA 1-10). As comparative materials for petrographic features, eight locally manufactured pieces of unpainted ware (FR 10, 11, 13, 14, 15, 17, 19, 28) in existing scientific literature (Barone *et al.*, 2008) were considered. Table 1 lists all examined samples.

For a detailed account of the selected ceramic materials and information on their production area, petrographic thin-section analyses and chemical investigations by X-ray fluorescence spectrometry (XRF) were performed on all samples. Petrographic thin-section observations were made under a Zeiss Axioskop 40 polarising microscope. Descriptions were made following the scheme proposed by Whitbread (1995), which facilitates detailed characterisation of pottery in terms of microstructure, groundmass and inclusions.

For XRF analyses, a Philips PW 2404/00 spectrometer was used to determine concentrations of major, minor and trace elements. Loss on ignition (L.O.I.) was gravimetrically estimated after overnight heating at 950°C. Quantitative analysis was carried out with a calibration line based on 45 international rock standards. The lower detection limits (LDL) were: SiO_2=1 wt.%, TiO_2=0.01 wt.%, Al_2O_3=0.1 wt.%, Fe_2O_3=0.05 wt.%, MnO=0.01 wt.%, MgO=0.02 wt.%, CaO=0.05 wt.%, Na_2O=0.01 wt.%, K_2O=0.05 wt.%, P_2O5=0.01 wt.%, V=10 ppm, Cr=5 ppm, Co=2 ppm, Ni=5 ppm, Zn=15 ppm, Rb=5 ppm, Sr=10 ppm, Y=3 pm, Zr=20 ppm, Nb=2 ppm, Ba=30 ppm, La=5 ppm, Ce=10 ppm, Pb=4 ppm, and Th=3 ppm. Precision was monitored routinely by running a well-investigated in-house standard (obsidian). Average relative standard deviations (RDS%) were less than 5%. Accuracy was evaluated by an international standard, the composition of which was similar to that of the analysed samples, and was <3% for major elements and ≤5% for minor and trace elements.

Results

Petrographic analysis

Ionian cups

All the examined Ionian cup remains from Piano dei Casazzi, Mendolito, Poira-Poggio Cocola, Monte Castellaccio and Francavilla have very similar petrographic features in regard to groundmass, microstructure and inclusions (Fig. 3). Specifically, the observed fabric is characterised by a strongly purified mixture with very few voids. The groundmass is highly micaceous and reddish-brown to orange (rarely grey) in its plane polar light colour. Optical activity generally ranges between medium and low. The ratio between coarse and fine fractions (boundary between two components 10μm, i.e., upper limit of micromass) is constantly under 5:95, and sorting is good. The few observed aplastic inclusions mainly consist of quartz, micas (muscovite and biotite) and subordinate plagioclase and K-feldspar. Many samples also contain few to rare small to medium-sized

Table 1
Typological and chronological descriptions of the examined Ionian cups and indigenous pottery from all sites.

Archaeological site	**Sample**	**Typology**	**Age**
Piano dei Casazzi	PAL 5 PAL 6 PAL 7 PAL 8 PAL 9 PAL 10 PAL 11 PAL 12 PAL 13	Ionian cups of type B2	VI - early V centuries B.C.
	PAL 14 PAL 16	Decorated indigenous pottery	VI - early V centuries B.C. (Licodia Eubea *facies*)
	PAL 15 PAL 17 PAL 18 PAL 19 PAL 20 PAL 21 PAL 22	Unpainted indigenous pottery	
Mendolito	MEND 7 MEND 8 MEND 9 MEND 10 MEND 11	Ionian cups of type B2	VI - early V centuries B.C.
	MEND 1 MEND 2 MEND 3 MEND 5 MEND 6	Decorated indigenous pottery	VI - mid-V centuries B.C. (Licodia Eubea *facies*)
	MEND 4	Unpainted indigenous pottery	
Monte Castellaccio	PTPL 1 PTPL 2	Ionian cups of type B2	VI - early V centuries B.C.
Poggio Cocola	PTPCo 1 PTPCo 2 PTPCo 3		
Poira	POI 1 POI 2 POI 3 POI 4 POI 5 POI 6 POI 7 POI 8 POI 9 POI 10 POI 11 POI 12 POI 13 POI 14 POI 15 POI 16 POI 17 POI 18 POI 19 POI 20		
	POI 21 POI 22 POI 24	Unpainted indigenous pottery	VI - mid-V centuries B.C. (Licodia Eubea *facies*)
	POI 23 POI 25	Decorated indigenous pottery	
Francavilla di Sicilia	FRA 1 FRA 2 FRA 3 FRA 4 FRA 5 FRA 6 FRA 7 FRA 8 FRA 9 FRA 10	Ionian cups of type B2	VI - early V centuries B.C.

metamorphic and/or granitoid rock fragments.

Petrographic comparisons with data in existing scientific literature referring to Ionian cups of type B2 from Messina (Barone *et al.*, 2005), the production of which is ascribed to the Peloritani area, reveal textural and compositional features that are markedly similar to those of the examined samples. Conversely, Ionian cups of types B1 and B2 found at Solunto, the production of which was attributed to the Greek colony of Himera by Montana *et al.* (2009), display partially different petrographic characteristics with respect to those studied here, due to the sporadic occurrence of micas and the total absence of metamorphic rock fragments.

Local ceramics as comparison materials

Petrographic observations of indigenous ceramics from Piano dei Casazzi distinguished two fabrics: 1) samples PAL 14, 15, 16, 18, 19, 21 and 22 (Fig. 4a) show a fine to medium-grained mixture, with a poorly micaceous groundmass and low to absent optical activity. The temper mainly consists of quartz, variable in size, with subordinate and variable numbers of inclusions of a different nature; 2) samples PAL 17 and 20 (Fig. 4b) also display a fine to medium-grained mixture with low optical activity, although with a mica-rich groundmass and abundant remains of microfossils. Among inclusions, quartz is dominant, followed by

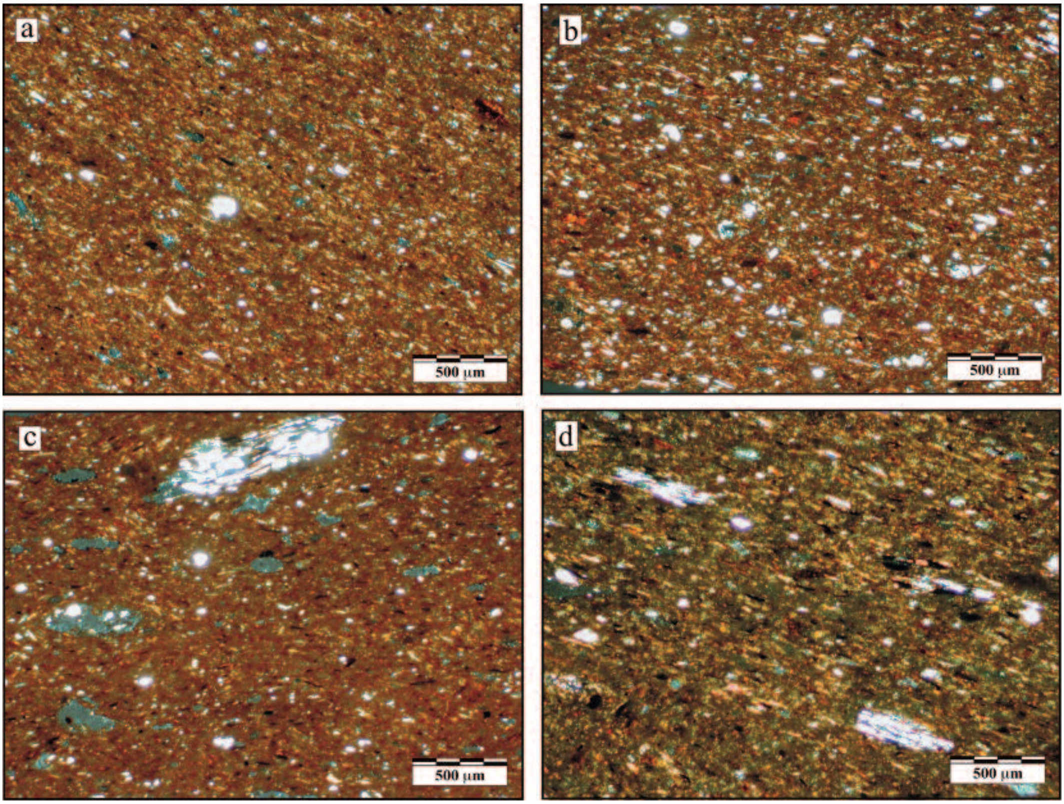

Fig. 3 - Photomicrographs showing the typical purified and mica-rich fabric of the studied Ionian cups: a) sample PAL9 from Piano dei Casazzi; b) sample MEND8 from Mendolito; c) sample POI6 from Poira; d) sample FRA3 from Francavilla. All images were taken in crossed polar light, magnification 2.5X.

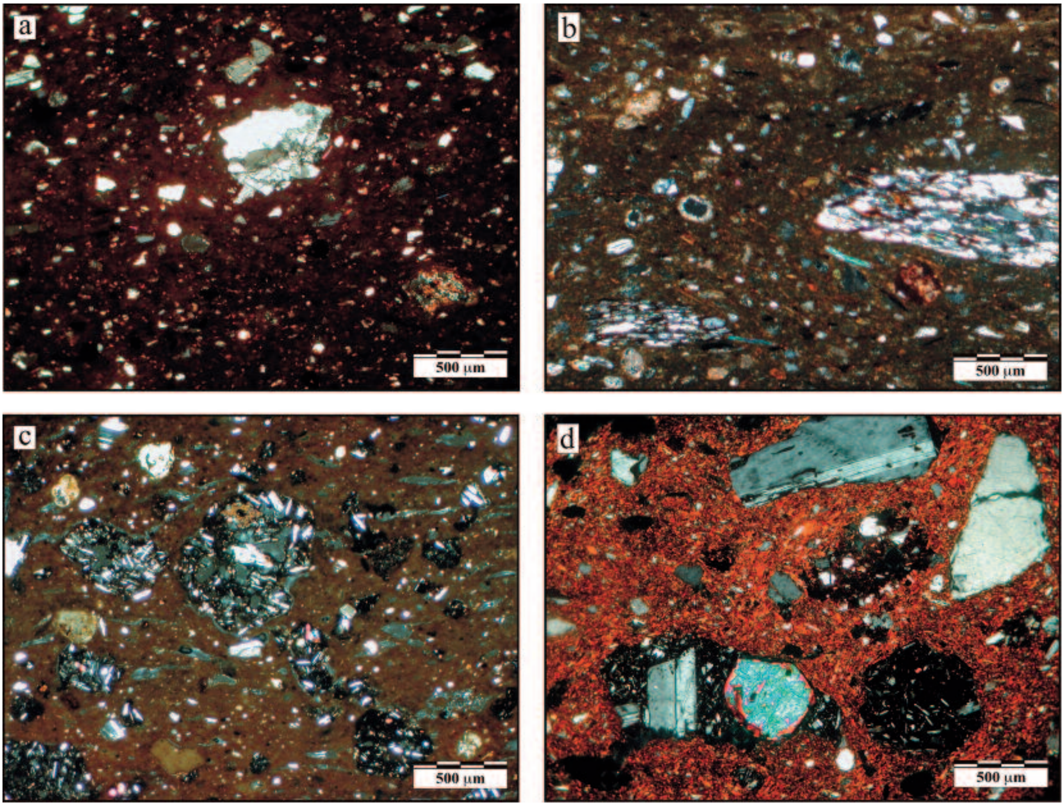

Fig. 4 - Photomicrographs showing the fabric of the examined indigenous pottery from: a) and b) Piano dei Casazzi [sample PAL15 (a), representative of the *fabric 1*, and sample PAL17 (b) representative of the *fabric 2*]; c) Poira-Poggio Cocola, Mendolito and M. Castellaccio (sample MEND3); d) Francavilla (sample FR1, from Barone *et al.*, 2008). All images were taken in crossed polar light, magnification 2.5X.

frequent micas, common granitoid and metamorphic rock fragments, and variable amounts of feldspar.

All the indigenous ceramics from Mendolito, Poira-Poggio Cocola and Monte Castellaccio show the same fabric, characterised by a medium to coarse mixture, with abundant volcanic inclusions and a poorly micaceous groundmass (Fig. 4c). The coarse fraction of temper (Φ>0.125 mm) includes abundant plagioclase, augitic clinopyroxene, quartz and volcanic rock fragments. The latter exhibit the typical features of Etnean products, with a porphyritic texture containing phenocrysts of plagioclase, augite and olivine, and a holocrystalline to hyalopilitic micromass of plagioclase, augite and opaque oxides. Rare scoriaceous textures are also observed. The fine fraction of inclusions (Φ<0.125 mm) consists of abundant quartz, scarce augitic clinopyroxene and plagioclase, and very scarce to rare mica.

The local unpainted ware from Francavilla, described in detail by Barone *et al.* (2008), also displays a coarse mixture with dominant volcanic temper, although metamorphic and quartzarenite inclusions are also present (Fig. 4d). Under plane polar light, the colour of the groundmass varies from orange and grey to dark brown, and optical activity ranges from birefringent to almost isotropic. The coarse fraction of inclusions consists of: a) predominant volcanic rock fragments of porphyritic texture, with plagioclase, clinopyroxene and olivine phenocrysts and a holocrystalline groundmass formed of microlites of the same phases; b) frequent to common zoned plagioclase and augitic clinopyroxene; c) a little olivine and quartz, together with metamorphic (gneiss and micaschists) and quartzarenite rock fragments; d) rare to very rare microcline crystals and micas. The fine fraction of the temper mainly consists of quartz and plagioclase, with subordinate micas.

XRF analysis and statistical treatment of chemical data

Concentrations of major (in wt%), minor and some trace elements (in ppm) in both Ionian cups and indigenous ceramics are listed in TABLES 2, 3, 4 and 5, including mean values and standard deviations for each analysed group.

To better highlight possible chemical differences among the examined sherds, the results were processed by a statistical approach. It should be noted that the data on Ionian cups from Mendolito, Poira-Poggio Cocola and Monte Castellaccio, sites which are all located within a relatively small area and very similar to each other, are considered as a single group in the following treatment. In addition, in the procedure used, data on Ionian cups from the Messina area (re-analysed in order to have the same analytical conditions as for the studied samples) were considered as comparison materials. Conversely, no comparisons were possible with the Ionian cups from Solunto, since published results regarding them (Montana *et al.*, 2009) only refer to major elements, with no information on minor or trace elements, thus could only lead to insignificant comparisons.

In the statistical treatment of chemical data for pottery samples, Buxeda I Garrigòs (1999) and later Belfiore *et al.* (2006, 2007) put the attention on the variability observed within the dataset, modelling this variance according to the equation by Bieber *et al*. (1976):

$$var_T = var_N + var_S + var_A$$

where var_T is total variance, var_N is natural variance (referring not only to the natural variability of the clay sources, but also to variability introduced during technological processes and/or post-burial alteration and contamination), var_S is sampling variance, and var_A is analytical variance.

Therefore, as a first step in our statistical approach we investigated the variability which characterizes the dataset in order to ascribe its source either to technological processes (selection of raw materials, preparation of paste, firing conditions) or unintentional alteration and contamination taking place during the later phases of use and burial.

The variation matrices for each pottery group were calculated with CoDaPack software (Thìo-Henestrosa and Martín-Fernández, 2005). In order to avoid the constant sum problem of compositional data, both major and trace elements (separately recalculated to 100) were first transformed into additive logarithmic ratios (alr) (Aitchison, 1986) according to:

$$x \in S^d \rightarrow y = \ln (x_d / x_D) \in R^d$$

where x is a compositional vector with D parts, S^d is a *d*-dimensional simplex (d = D-1), y is log transformed composition, and R^d is real space with d dimension.

TABLE 6 shows the variation arrays, in which the upper and lower diagonals contain the logratio variances and logratio means, respectively. Variances ($\tau_{.i}$) for each element and the total variance (*vt*) are also reported in the same tables.

The lower *vt* values are those observed for the cups from Piano dei Casazzi (*vt* = 0.06 for major elements; *vt* = 0.15 for trace elements) and Poira-Mendolito-Monte Castellaccio (*vt* = 0.19 for major elements; *vt* = 0.8 for trace elements).

Table 2

Concentrations of major elements (wt%), obtained by XRF analysis of the Ionian cups from all investigated sites, including average values and relative standard deviations for each group.

Sample	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	L.O.I.
Piano dei Casazzi											
PAL 5	54.37	0.78	21.40	8.57	0.10	3.17	6.47	1.02	3.95	0.16	1.80
PAL 6	53.24	0.75	22.08	8.86	0.10	3.27	6.39	0.90	4.25	0.15	1.46
PAL 7	54.29	0.74	19.76	7.19	0.09	3.22	10.18	0.89	3.45	0.17	2.70
PAL 8	53.55	0.75	21.55	8.51	0.10	3.44	6.80	1.01	4.15	0.16	1.30
PAL 9	54.71	0.78	20.68	7.88	0.09	3.36	7.59	0.98	3.77	0.16	1.63
PAL 10	53.46	0.74	21.25	8.37	0.10	3.45	7.54	0.97	3.97	0.16	1.78
PAL 11	54.73	0.76	21.00	8.22	0.10	3.27	6.83	1.15	3.78	0.15	2.47
PAL 12	53.35	0.74	21.46	8.45	0.10	3.45	7.34	0.96	3.99	0.16	1.34
PAL 13	55.08	0.77	20.80	8.38	0.11	3.19	6.56	1.19	3.77	0.16	1.77
Average	*54.09*	*0.76*	*21.11*	*8.27*	*0.10*	*3.31*	*7.30*	*1.01*	*3.90*	*0.16*	
St. Dev.	*0.69*	*0.02*	*0.66*	*0.48*	*0.01*	*0.11*	*1.17*	*0.10*	*0.24*	*0.01*	
Mendolito											
MEND 7	53.79	0.72	23.00	9.11	0.11	3.12	4.39	1.07	4.55	0.15	1.62
MEND 8	54.08	0.70	21.95	8.73	0.10	3.18	5.86	1.06	4.20	0.15	2.46
MEND 9	52.85	0.68	22.66	9.22	0.10	3.17	5.74	1.24	4.17	0.15	1.50
MEND 10	54.32	0.76	22.14	8.75	0.10	3.28	5.49	0.93	4.08	0.15	1.91
MEND 11	57.33	0.78	20.46	8.12	0.10	2.90	5.10	1.19	3.86	0.18	2.01
Average	*54.47*	*0.73*	*22.04*	*8.79*	*0.10*	*3.13*	*5.31*	*1.10*	*4.17*	*0.16*	
St. Dev.	*1.69*	*0.04*	*0.98*	*0.43*	*0.01*	*0.14*	*0.60*	*0.12*	*0.25*	*0.01*	
Poira-Poggio Cocola - M. Castellaccio											
POI 1	53.57	0.70	23.21	9.66	0.12	2.98	3.79	1.41	4.36	0.19	2.11
POI 2	55.24	0.78	20.14	7.78	0.10	3.25	7.71	1.19	3.64	0.17	2.82
POI 3	55.67	0.82	19.89	7.97	0.10	3.08	7.25	1.43	3.62	0.17	1.51
POI 4	54.30	0.75	21.79	8.61	0.10	3.08	5.96	1.13	4.10	0.17	1.75
POI 5	54.09	0.71	21.86	8.66	0.09	3.08	6.17	1.21	3.98	0.14	1.88
POI 6	55.11	0.76	21.83	8.81	0.10	3.20	4.89	1.05	4.09	0.15	2.24
POI 7	53.97	0.72	21.92	8.71	0.10	3.09	6.22	1.05	4.05	0.16	2.08
POI 8	53.54	0.74	21.39	8.58	0.10	3.19	7.62	1.05	3.64	0.14	1.46
POI 9	54.33	0.72	20.66	8.12	0.10	3.12	7.75	1.24	3.79	0.16	1.23
POI 10	54.74	0.77	20.71	7.96	0.09	3.47	6.85	1.51	3.74	0.15	1.60
POI 11	55.76	0.81	19.71	7.77	0.09	3.00	7.81	1.38	3.49	0.17	1.21
POI 12	56.00	0.73	20.20	7.74	0.10	2.89	6.98	1.41	3.76	0.18	1.90
POI 13	54.40	0.73	20.16	7.73	0.09	3.20	8.99	1.00	3.55	0.15	1.80
POI 14	53.91	0.74	20.79	8.20	0.10	3.30	7.93	1.12	3.77	0.14	0.69
POI 15	55.69	0.79	20.78	8.13	0.10	3.31	6.36	1.06	3.65	0.14	1.97
POI 16	55.12	0.73	20.89	8.14	0.09	3.06	6.68	1.25	3.86	0.17	1.95
POI 17	55.09	0.75	22.10	8.85	0.10	3.15	4.66	1.03	4.11	0.17	2.60
POI 18	54.53	0.73	20.53	7.84	0.10	3.13	8.19	1.06	3.76	0.15	2.41
POI 19	52.22	0.67	22.94	9.20	0.11	3.28	5.50	1.15	4.80	0.15	1.64
POI 20	52.21	0.65	22.52	8.99	0.11	3.08	6.22	1.53	4.54	0.14	1.09
PTPL 1	53.38	0.18	14.36	7.80	0.52	5.44	5.20	0.70	12.35	0.08	1.26
PTPL 2	53.39	0.22	14.39	7.71	0.59	5.22	4.28	0.79	15.17	0.09	1.49
PTPCo 1	54.52	0.07	14.23	8.17	0.88	7.26	11.54	0.94	13.71	0.12	3.89
PTPCo 2	54.16	0.16	14.57	7.81	0.50	5.71	6.22	0.63	14.89	0.10	1.32
PTPCo 3	56.07	0.20	14.36	7.56	0.50	5.98	5.71	0.74	15.24	0.10	1.68
Average	*54.44*	*0.63*	*19.84*	*8.26*	*0.20*	*3.70*	*6.66*	*1.12*	*5.99*	*0.15*	
St. Dev.	*1.05*	*0.24*	*2.93*	*0.55*	*0.21*	*1.18*	*1.65*	*0.24*	*4.27*	*0.03*	

Table 2
Continued...

Sample	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	L.O.I.
Francavilla											
FRA 1	56.74	1.20	22.66	9.12	0.08	2.82	2.31	0.86	3.83	0.40	2.84
FRA 2	52.09	1.10	20.23	9.75	0.17	3.86	6.81	0.56	1.69	3.75	10.52
FRA 3	53.20	0.92	18.69	8.19	0.15	4.07	9.80	0.63	2.37	1.97	4.97
FRA 4	52.58	1.01	19.65	9.07	0.14	3.83	8.36	0.59	2.30	2.48	7.47
FRA 5	53.37	0.79	20.64	8.86	0.11	3.29	7.50	1.11	3.90	0.44	1.33
FRA 6	53.82	0.86	20.44	8.40	0.10	3.29	7.57	0.98	3.32	1.20	3.28
FRA 7	52.04	0.78	20.68	8.51	0.09	3.64	8.98	1.01	3.49	0.79	2.31
FRA 8	52.98	0.90	19.32	8.25	0.15	3.94	9.20	0.60	2.39	2.27	6.54
FRA 9	47.77	1.11	21.82	10.32	0.20	3.70	5.93	0.57	0.65	7.93	14.07
FRA 10	53.11	0.82	18.11	7.67	0.14	4.17	11.45	0.70	2.35	1.47	3.67
Average	*52.77*	*0.95*	*20.22*	*8.81*	*0.13*	*3.66*	*7.79*	*0.76*	*2.63*	*2.27*	
St. Dev.	*2.20*	*0.15*	*1.37*	*0.79*	*0.04*	*0.41*	*2.49*	*0.21*	*1.02*	*2.24*	
Messina (data from Barone et al. 2005, re-analysed)											
ME116	52.43	0.72	23.13	9.47	0.10	3.53	4.74	0.92	4.68	0.27	3.45
ME120	53.10	0.86	20.67	9.31	0.12	4.03	6.78	1.07	3.84	0.22	2.76
ME124	57.89	1.01	19.03	8.08	0.06	2.96	6.79	0.92	3.03	0.23	1.46
ME125	52.06	1.02	22.57	10.45	0.11	3.67	4.72	1.08	4.11	0.21	2.34
ME126	52.22	0.96	22.76	9.58	0.10	3.61	5.44	1.04	4.05	0.24	3.20
ME137	53.41	0.93	21.67	9.94	0.12	3.97	4.48	1.28	3.95	0.26	1.69
ME138	52.99	0.72	20.98	8.34	0.09	3.51	7.95	1.22	3.94	0.27	1.87
ME141	55.90	0.94	19.50	8.63	0.13	3.42	6.67	1.09	3.42	0.31	2.31
ME142	52.90	1.10	19.90	10.92	0.20	4.02	6.24	1.04	3.18	0.50	2.53
ME143	52.88	0.79	21.02	8.33	0.09	3.59	8.32	1.07	3.71	0.20	2.07
ME144	52.87	1.01	21.40	10.47	0.17	3.92	4.92	1.07	3.88	0.30	1.88
Average	*53.51*	*0.91*	*21.15*	*9.41*	*0.12*	*3.66*	*6.10*	*1.07*	*3.80*	*0.27*	
St. Dev.	*1.77*	*0.13*	*1.34*	*0.97*	*0.04*	*0.32*	*1.33*	*0.11*	*0.46*	*0.08*	

Table 3
Concentrations of minor and trace elements (ppm), obtained by XRF analysis of the Ionian cups from all investigated sites, including average values and relative standard deviations for each group.

Sample	Sr	V	Cr	Co	Ni	Zn	Rb	Y	Zr	Nb	Ba	La	Ce	Pb	Th
							Piano dei Casazzi								
PAL 5	391	149	112	18	58	129	167	33	177	11	766	45	87	21	29
PAL 6	349	145	119	21	58	140	177	36	167	13	635	35	102	24	29
PAL 7	464	145	101	14	56	104	115	20	113	2	550	36	98	14	24
PAL 8	367	158	116	16	58	131	174	37	174	14	642	38	114	23	30
PAL 9	406	147	110	17	58	124	155	29	163	11	594	38	92	20	28
PAL 10	390	153	114	16	56	129	165	34	159	11	577	42	93	20	28
PAL 11	415	152	106	15	55	125	156	29	156	10	738	35	95	21	28
PAL 12	391	157	121	18	57	137	174	35	169	15	617	39	89	22	30
PAL 13	365	145	109	17	54	128	168	37	180	14	682	38	104	21	28
Average	*393*	*150*	*112*	*17*	*57*	*128*	*161*	*32*	*162*	*11*	*645*	*39*	*97*	*21*	*28*
St. Dev.	*34*	*5*	*6*	*2*	*1*	*10*	*19*	*6*	*20*	*4*	*72*	*3*	*9*	*3*	*2*
							Mendolito								
MEND 7	241	139	114	22	58	110	179	33	180	16	686	44	128	28	21
MEND 8	273	152	116	22	62	102	150	23	132	11	670	36	125	15	14
MEND 9	261	149	126	21	67	114	161	29	163	14	737	46	147	19	20
MEND 10	274	162	110	19	59	94	153	25	137	14	634	33	121	16	14
MEND 11	287	128	102	15	57	94	143	25	157	14	630	35	136	18	14
Average	*267*	*146*	*114*	*20*	*60*	*103*	*157*	*27*	*154*	*14*	*671*	*39*	*131*	*19*	*17*
St. Dev.	*17*	*13*	*9*	*3*	*4*	*9*	*14*	*4*	*20*	*2*	*44*	*6*	*11*	*5*	*3*
							Poira-Poggio Cocola and M. Castellaccio								
POI 1	297	145	109	23	55	119	183	38	192	17	780	44	106	28	20
POI 2	573	125	103	17	58	94	136	24	151	14	660	28	89	14	14
POI 3	447	133	93	14	47	99	149	31	158	19	544	29	102	19	18
POI 4	385	137	122	17	57	102	161	30	169	14	595	39	98	22	18
POI 5	338	140	113	22	59	105	160	26	163	15	615	44	121	20	18
POI 6	540	159	108	15	58	106	158	25	153	14	601	33	125	20	14
POI 7	450	161	121	22	63	104	158	27	167	15	557	43	123	20	17
POI 8	418	151	123	20	63	106	145	25	155	13	566	41	141	14	16
POI 9	342	142	114	19	58	106	144	23	140	11	572	40	110	14	14
POI 10	870	156	108	19	52	95	141	26	151	18	516	38	103	10	13
POI 11	393	135	102	16	52	95	142	28	160	18	491	44	130	19	18
POI 12	427	135	102	17	56	94	133	21	153	9	684	36	133	11	11
POI 13	577	147	109	17	57	95	136	28	150	18	493	42	125	15	14
POI 14	432	163	116	18	59	106	151	30	147	16	589	38	108	19	17
POI 15	589	146	109	18	57	98	127	17	124	10	503	40	113	7	9
POI 16	431	142	113	19	55	100	144	23	140	12	555	34	110	18	12
POI 17	362	158	113	17	54	95	160	25	157	18	575	40	113	23	17
POI 18	1118	158	107	20	55	92	141	26	160	16	481	33	137	11	12
POI 19	406	153	114	23	61	117	160	21	137	8	691	49	128	10	14
POI 20	400	165	117	22	60	116	163	28	155	12	656	50	132	13	16
PTPL 1	396	153	118	21	60	112	166	34	175	18	726	33	136	22	20
PTPL 2	316	158	123	19	59	113	171	28	157	13	726	35	128	20	17
PTPCo 1	1021	136	87	12	44	88	131	28	169	18	593	29	116	12	13
PTPCo 2	449	147	108	20	58	104	158	28	155	16	682	39	124	19	16
PTPCo 3	379	147	109	20	54	95	145	26	155	15	779	34	137	15	15
Average	*494*	*148*	*110*	*19*	*56*	*102*	*151*	*27*	*156*	*15*	*609*	*38*	*120*	*17*	*15*
St. Dev.	*210*	*11*	*9*	*3*	*4*	*8*	*14*	*4*	*13*	*3*	*88*	*6*	*14*	*5*	*3*

Table 3
Continued...

Sample	**Sr**	**V**	**Cr**	**Co**	**Ni**	**Zn**	**Rb**	**Y**	**Zr**	**Nb**	**Ba**	**La**	**Ce**	**Pb**	**Th**
Francavilla															
FRA 1	159	167	123	13	53	168	166	36	173	18	548	47	100	16	9
FRA 2	274	132	138	27	63	106	67	28	133	12	1001	38	92	4	0
FRA 3	493	152	132	11	67	88	88	29	138	15	806	39	85	15	2
FRA 4	434	161	143	16	62	80	90	29	133	15	830	38	90	6	11
FRA 5	307	150	116	25	58	106	149	40	180	15	603	41	98	4	14
FRA 6	340	119	112	15	52	105	135	33	171	15	720	37	77	15	13
FRA 7	362	134	120	24	57	124	134	30	151	14	643	39	108	16	13
FRA 8	572	138	133	2	62	80	89	27	134	14	815	39	69	5	9
FRA 9	336	77	120	30	58	145	52	29	138	13	1387	31	89	4	6
FRA 10	574	152	126	67	66	98	81	27	135	13	664	36	94	2	9
Average	*385*	*138*	*126*	*23*	*60*	*110*	*105*	*31*	*149*	*15*	*802*	*39*	*90*	*9*	*8*
St. Dev.	*133*	*26*	*10*	*18*	*5*	*28*	*38*	*4*	*19*	*2*	*244*	*4*	*11*	*6*	*5*
Messina (data from Barone et al. 2005, re-analysed)															
ME116	297	148	126	25	52	164	171	32	147	12	233	62	308	7	13
ME120	314	150	139	25	60	177	114	29	125	31	277	53	347	0	6
ME124	263	157	133	15	53	124	65	24	121	0	277	59	324	11	5
ME125	197	154	109	22	49	185	150	29	127	1	135	63	195	0	13
ME126	196	145	94	18	46	155	113	27	0	6	144	54	201	0	10
ME137	247	142	132	28	59	172	139	31	206	9	186	55	256	3	7
ME138	311	147	126	20	51	160	114	24	84	0	274	51	341	0	14
ME141	378	145	118	19	55	170	148	26	351	17	369	55	437	117	8
ME142	672	149	123	27	62	176	146	27	326	27	594	50	705	0	8
ME143	323	136	122	24	54	153	123	32	105	9	291	45	356	0	6
ME144	260	146	124	26	60	179	88	29	108	9	209	68	282	22	13
Average	*314*	*147*	*122*	*23*	*55*	*165*	*125*	*28*	*155*	*11*	*272*	*56*	*341*	*15*	*9*
St. Dev.	*130*	*6*	*12*	*4*	*5*	*17*	*31*	*3*	*103*	*10*	*127*	*7*	*140*	*35*	*3*

Table 4

Concentrations of major elements (wt%), obtained by XRF analysis of the indigenous pottery from all investigated sites, including average values and relative standard deviations for each group.

Sample	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	L.O.I.
Piano dei Casazzi											
PAL 14	59.83	0.78	14.86	6.18	0.08	3.15	12.28	0.58	1.99	0.27	1.80
PAL 16	58.99	0.79	15.79	6.06	0.07	2.53	12.88	0.50	2.11	0.27	1.46
PAL 17	55.20	0.62	15.82	5.42	0.08	3.26	15.17	1.25	2.99	0.19	2.70
PAL 18	56.58	0.71	15.82	6.10	0.07	2.96	14.52	1.06	2.00	0.18	1.30
PAL 20	56.68	0.72	17.46	6.51	0.08	3.68	10.15	1.36	3.23	0.13	1.63
PAL 21	60.09	0.66	13.53	5.09	0.04	2.28	15.52	0.63	1.96	0.22	1.78
PAL 22	59.85	0.66	13.86	5.11	0.04	1.93	15.67	0.62	2.02	0.24	2.47
Average	*58.17*	*0.71*	*15.30*	*5.78*	*0.07*	*2.83*	*13.74*	*0.86*	*2.33*	*0.21*	
St. Dev.	*1.98*	*0.06*	*1.34*	*0.57*	*0.02*	*0.61*	*2.05*	*0.36*	*0.54*	*0.05*	
Mendolito											
MEND 1	56.66	0.91	17.10	7.51	0.07	3.85	9.95	1.31	2.36	0.27	1.48
MEND 2	56.46	0.85	16.60	7.05	0.08	3.28	11.49	1.41	2.45	0.33	2.09
MEND 3	55.77	0.88	16.91	7.32	0.08	3.27	11.60	1.49	2.37	0.31	2.58
MEND 4	56.27	0.90	17.80	7.47	0.08	2.99	10.23	1.42	2.49	0.36	2.06
MEND 5	56.66	0.85	16.51	7.11	0.08	3.33	11.32	1.38	2.38	0.39	2.26
MEND 6	56.22	0.99	17.38	8.05	0.09	3.56	9.27	1.65	2.40	0.38	1.61
Average	*56.34*	*0.89*	*17.05*	*7.42*	*0.08*	*3.38*	*10.65*	*1.44*	*2.41*	*0.34*	
St. Dev.	*0.34*	*0.05*	*0.49*	*0.36*	*0.01*	*0.29*	*0.96*	*0.12*	*0.05*	*0.05*	
Poira-Poggio Cocola and M. Castellaccio											
POI 21	56.41	0.67	14.55	5.63	0.08	3.13	14.70	1.34	2.42	1.08	3.70
POI 22	57.36	0.95	17.65	8.04	0.15	2.94	7.64	2.20	2.81	0.27	1.37
POI 23	56.26	0.59	14.04	5.04	0.09	2.91	16.70	1.26	2.79	0.32	7.21
POI 24	57.24	0.98	17.36	7.94	0.15	2.98	8.45	1.93	2.73	0.24	1.90
POI 25	57.38	0.98	17.55	7.94	0.14	2.80	7.95	2.45	2.55	0.26	1.28
Average	*56.93*	*0.83*	*16.23*	*6.92*	*0.12*	*2.95*	*11.09*	*1.84*	*2.66*	*0.43*	
St. Dev.	*0.55*	*0.19*	*1.78*	*1.46*	*0.03*	*0.12*	*4.28*	*0.53*	*0.17*	*0.36*	
Messina (data from Barone et al. 2005, re-analysed)											
ME 112	53.35	1.18	20.16	11.31	0.17	4.60	3.96	1.48	3.52	0.26	1.76
ME 115	52.36	1.23	20.51	12.32	0.16	4.96	3.70	1.09	3.34	0.34	1.88
ME121	55.34	0.80	20.58	7.80	0.09	3.41	6.90	0.88	3.91	0.28	2.35
ME 127	52.97	0.89	22.55	9.33	0.14	4.18	4.56	1.17	4.00	0.21	2.77
ME 128	52.57	0.73	22.37	8.84	0.11	3.52	6.37	0.96	4.32	0.20	3.02
ME 111	54.59	0.82	21.15	8.50	0.10	3.38	6.23	1.20	3.83	0.19	1.56
ME 113	53.47	0.76	22.38	9.23	0.10	3.41	5.11	1.02	4.24	0.30	1.79
ME 114	54.59	0.75	20.90	7.88	0.10	3.37	7.25	1.17	3.79	0.20	2.23
ME 131	51.71	0.72	22.32	9.07	0.11	3.76	7.04	0.94	4.15	0.17	2.45
ME 133	52.68	0.73	22.31	8.99	0.10	3.52	6.15	1.04	4.29	0.21	3.09
ME134	53.60	0.75	21.45	8.45	0.09	3.52	6.88	0.92	4.10	0.23	1.90
ME140	52.77	0.75	22.18	8.90	0.10	3.57	6.54	1.04	3.94	0.20	2.13
Average	*53.33*	*0.84*	*21.57*	*9.22*	*0.11*	*3.77*	*5.89*	*1.08*	*3.95*	*0.23*	
St. Dev.	*1.06*	*0.18*	*0.88*	*1.32*	*0.03*	*0.53*	*1.24*	*0.16*	*0.30*	*0.05*	

Table 5

Concentrations of minor and trace elements (ppm), obtained by XRF analysis of the indigenous pottery from all investigated sites, including average values and relative standard deviations for each group.

Sample	**Sr**	**V**	**Cr**	**Co**	**Ni**	**Zn**	**Rb**	**Y**	**Zr**	**Nb**	**Ba**	**La**	**Ce**	**Pb**	**Th**
Piano dei Casazzi															
PAL 14	813	133	90	7	42	80	84	26	258	11	906	29	92	10	20
PAL 16	798	143	98	8	40	83	88	30	246	15	988	31	81	12	21
PAL 17	1444	116	85	9	56	82	112	27	175	10	911	26	71	8	18
PAL 18	799	135	101	14	54	91	79	29	241	14	554	35	93	11	22
PAL 20	783	123	100	10	62	92	130	29	179	12	734	31	81	15	24
PAL 21	996	93	83	5	46	77	75	26	196	12	573	31	76	10	19
PAL 22	952	94	82	6	41	78	78	27	210	13	621	24	79	12	21
Average	*941*	*120*	*91*	*8*	*49*	*83*	*92*	*28*	*215*	*12*	*755*	*30*	*82*	*11*	*21*
St. Dev.	*237*	*20*	*8*	*3*	*8*	*6*	*21*	*2*	*34*	*2*	*180*	*4*	*8*	*2*	*2*
Mendolito															
MEND 1	619	156	108	16	66	73	87	25	190	24	484	34	160	9	12
MEND 2	707	150	83	16	52	77	88	24	176	22	507	33	108	8	10
MEND 3	695	152	84	17	49	74	87	24	180	25	563	36	125	8	11
MEND 4	671	156	102	16	55	80	89	23	166	22	489	30	112	9	11
MEND 5	674	147	86	14	50	73	88	25	185	22	537	38	120	8	12
MEND 6	719	169	84	15	47	79	84	25	175	25	612	45	129	5	11
Average	*681*	*155*	*91*	*16*	*53*	*76*	*88*	*24*	*179*	*23*	*532*	*36*	*126*	*8*	*11*
St. Dev.	*35*	*7*	*11*	*1*	*7*	*3*	*2*	*1*	*8*	*1*	*49*	*5*	*19*	*1*	*1*
Poira															
POI 21	1881	120	75	15	44	72	74	18	189	18	425	32	114	-4	1
POI 22	567	163	93	19	47	89	90	24	180	26	449	41	131	11	12
POI 23	1347	106	71	14	38	59	71	19	185	13	1082	30	105	0	3
POI 24	1209	162	87	19	42	76	87	25	207	34	671	37	144	5	9
POI 25	770	168	84	19	43	79	85	26	199	32	777	41	131	4	12
Average	*1155*	*144*	*82*	*17*	*43*	*75*	*81*	*22*	*192*	*24*	*681*	*36*	*125*	*3*	*7*
St. Dev.	*515*	*28*	*9*	*3*	*3*	*11*	*8*	*4*	*11*	*9*	*269*	*5*	*15*	*6*	*5*
Messina (data from Barone et al. 2005, re-analysed)															
ME 112	209	152	139	31	66	187	99	34	106	0	138	62	201	26	11
ME 115	291	166	160	35	75	200	118	33	246	13	204	41	276	8	9
ME121	189	98	91	14	46	88	105	8	74	9	182	28	230	6	1
ME 127	87	107	88	21	46	111	88	41	113	14	69	37	118	7	0
ME 128	307	154	135	26	57	179	171	32	285	14	299	50	379	14	14
ME 111	208	128	110	20	51	133	88	23	108	14	162	41	217	2	5
ME 113	279	151	127	22	52	156	122	27	95	0	240	32	310	228	7
ME 114	178	112	121	20	52	120	109	9	51	9	139	36	189	370	3
ME 131	237	142	123	24	55	164	98	25	80	9	182	44	245	0	8
ME 133	274	145	127	23	55	178	141	34	115	19	218	37	288	4	9
ME134	315	138	119	21	52	157	147	33	137	13	289	45	357	12	5
ME140	297	164	133	23	56	173	149	32	160	8	243	62	314	8	6
Average	*239*	*138*	*123*	*23*	*55*	*154*	*120*	*28*	*131*	*10*	*197*	*43*	*260*	*57*	*7*
St. Dev.	*68*	*22*	*20*	*5*	*8*	*34*	*27*	*10*	*69*	*6*	*66*	*11*	*75*	*117*	*4*

TABLE 6

Variation matrices of major and minor-trace elements for Ionian cups from each investigated site. Variances (τ_i) for each element and the total variance (vt) are also indicated.

Piano dei Casazzi	**SiO_2**	**TiO_2**	**Al_2O_3**	**Fe_2O_3**	**MnO**	**MgO**	**CaO**	**Na_2O**	**K_2O**	**P_2O_5**
SiO_2		0.000	0.003	0.001	0.007	0.012	0.001	0.002	0.006	0.002
TiO_2	0.929		0.002	0.003	0.009	0.012	0.001	0.004	0.009	0.004
Al_2O_3	5.371	4.442		0.008	0.016	0.008	0.005	0.007	0.014	0.010
Fe_2O_3	1.856	0.927	-3.515		0.002	0.013	0.002	0.002	0.004	0.000
MnO	1.122	0.193	-4.249	-0.734		0.017	0.009	0.004	0.001	0.002
MgO	3.042	2.113	-2.329	1.185	1.920		0.017	0.010	0.013	0.014
CaO	1.684	0.755	-3.687	-0.173	0.562	-1.358		0.004	0.010	0.003
Na_2O	4.904	3.975	-0.467	3.048	3.782	1.863	3.221		0.004	0.003
K_2O	0.141	-0.788	-5.230	-1.716	-0.981	-2.901	-1.543	-4.764		0.004
P_2O_5	1.075	0.146	-4.296	-0.781	-0.047	-1.967	-0.609	-3.829	0.934	
τ_i	*0.036*	*0.044*	*0.074*	*0.036*	*0.067*	*0.117*	*0.051*	*0.041*	*0.065*	*0.042*
vt	*0.057*									

Piano dei Casazzi	**Sr**	**V**	**Cr**	**Co**	**Ni**	**Zn**	**Rb**	**Y**	**Zr**	**Nb**	**Ba**	**La**	**Ce**	**Pb**	**Th**
Sr		0.004	0.008	0.025	0.004	0.008	0.011	0.022	0.009	0.043	0.012	0.008	0.019	0.014	0.006
V	0.934		0.002	0.017	0.002	0.002	0.003	0.010	0.004	0.025	0.012	0.007	0.009	0.005	0.001
Cr	1.220	0.286		0.008	0.002	0.000	0.001	0.006	0.004	0.018	0.017	0.008	0.010	0.002	0.001
Co	3.105	2.170	1.885		0.011	0.007	0.008	0.013	0.012	0.020	0.028	0.020	0.022	0.009	0.010
Ni	1.910	0.976	0.690	-1.195		0.002	0.003	0.011	0.003	0.027	0.012	0.006	0.010	0.004	0.001
Zn	1.079	0.145	-0.141	-2.026	-0.831		0.000	0.006	0.003	0.018	0.013	0.009	0.009	0.002	0.001
Rb	0.833	-0.101	-0.387	-2.272	-1.077	-0.246		0.003	0.002	0.015	0.014	0.009	0.007	0.001	0.001
Y	2.430	1.496	1.210	-0.674	0.520	1.351	1.597		0.005	0.008	0.022	0.014	0.009	0.006	0.007
Zr	0.826	-0.108	-0.394	-2.278	-1.084	-0.253	-0.007	-1.604		0.017	0.009	0.007	0.008	0.005	0.002
Nb	3.436	2.502	2.216	0.331	1.526	2.357	2.603	1.006	2.610		0.043	0.034	0.022	0.016	0.019
Ba	-0.533	-1.467	-1.753	-3.637	-2.443	-1.612	-1.366	-2.963	-1.359	-3.969		0.016	0.021	0.016	0.011
La	2.294	1.359	1.074	-0.811	0.384	1.215	1.461	-0.136	1.468	-1.142	2.826		0.022	0.016	0.008
Ce	1.378	0.444	0.158	-1.726	-0.532	0.299	0.545	-1.052	0.552	-2.058	1.911	-0.915		0.006	0.008
Pb	2.878	1.944	1.658	-0.227	0.968	1.799	2.045	0.448	2.052	-0.558	3.411	0.584	1.500		0.002
Th	2.593	1.659	1.373	-0.512	0.683	1.514	1.760	0.163	1.767	-0.843	3.126	0.299	1.215	-0.285	
τ_i	*0.193*	*0.103*	*0.086*	*0.211*	*0.097*	*0.081*	*0.078*	*0.141*	*0.092*	*0.326*	*0.247*	*0.183*	*0.180*	*0.105*	*0.079*
vt	*0.147*														

Poira- Mendolito- M. Castellaccio	**SiO_2**	**TiO_2**	**Al_2O_3**	**Fe_2O_3**	**MnO**	**MgO**	**CaO**	**Na_2O**	**K_2O**	**P_2O_5**
SiO_2		0.002	0.004	0.008	0.009	0.003	0.048	0.018	0.009	0.008
TiO_2	4.303		0.009	0.014	0.014	0.005	0.045	0.022	0.016	0.008
Al_2O_3	0.936	-3.367		0.001	0.003	0.004	0.069	0.022	0.002	0.016
Fe_2O_3	1.864	-2.439	0.929		0.002	0.007	0.081	0.024	0.002	0.021
MnO	6.310	2.007	5.374	4.445		0.008	0.081	0.023	0.004	0.021
MgO	2.851	-1.452	1.916	0.987	-3.458		0.048	0.023	0.008	0.016
CaO	2.160	-2.143	1.225	0.296	-4.149	-0.691		0.064	0.082	0.054
Na_2O	3.834	-0.469	2.898	1.969	-2.476	0.982	1.673		0.025	0.020
K_2O	2.624	-1.679	1.689	0.760	-3.685	-0.227	0.464	-1.209		0.021
P_2O_5	5.845	1.542	4.910	3.981	-0.464	2.994	3.685	2.012	3.221	
τ_i	*0.108*	*0.134*	*0.131*	*0.160*	*0.165*	*0.121*	*0.573*	*0.242*	*0.168*	*0.185*
vt	*0.199*									

TABLE 6
Continued...

Poira-Mendolito-M.Castellaccio	**Sr**	**V**	**Cr**	**Co**	**Ni**	**Zn**	**Rb**	**Y**	**Zr**	**Nb**	**Ba**	**La**	**Ce**	**Pb**	**Th**
Sr		0.144	0.176	0.217	0.177	0.178	0.188	0.188	0.153	0.151	0.219	0.205	0.173	0.380	0.250
V	1.056		0.006	0.021	0.007	0.008	0.009	0.029	0.016	0.052	0.025	0.021	0.015	0.108	0.040
Cr	1.341	0.285		0.013	0.002	0.005	0.007	0.030	0.016	0.062	0.020	0.016	0.016	0.094	0.032
Co	3.123	2.067	1.782		0.014	0.015	0.018	0.045	0.033	0.093	0.027	0.018	0.029	0.114	0.045
Ni	2.005	0.949	0.664	-1.118		0.006	0.009	0.034	0.018	0.069	0.018	0.017	0.014	0.102	0.037
Zn	1.423	0.367	0.081	-1.700	-0.582		0.003	0.022	0.012	0.060	0.014	0.015	0.017	0.088	0.025
Rb	1.030	-0.027	-0.312	-2.094	-0.976	-0.393		0.015	0.008	0.048	0.013	0.020	0.020	0.067	0.017
Y	2.773	1.716	1.431	-0.351	0.768	1.350	1.743		0.008	0.021	0.030	0.045	0.038	0.052	0.010
Zr	1.006	-0.051	-0.336	-2.118	-0.999	-0.417	-0.024	-1.767		0.029	0.020	0.030	0.021	0.072	0.019
Nb	3.390	2.334	2.048	0.267	1.385	1.967	2.360	0.617	2.384		0.077	0.084	0.067	0.079	0.038
Ba	-0.373	-1.429	-1.714	-3.496	-2.378	-1.796	-1.402	-3.145	-1.379	-3.763		0.040	0.026	0.090	0.033
La	2.413	1.357	1.071	-0.710	0.408	0.990	1.383	-0.360	1.407	-0.977	2.786		0.025	0.117	0.042
Ce	1.254	0.197	-0.088	-1.870	-0.751	-0.169	0.224	-1.519	0.248	-2.136	1.627	-1.159		0.118	0.047
Pb	3.258	2.202	1.916	0.135	1.253	1.835	2.228	0.485	2.252	-0.132	3.631	0.845	2.004		0.037
Th	3.319	2.263	1.978	0.196	1.314	1.896	2.290	0.547	2.314	-0.071	3.692	0.906	2.066	0.061	
τ_i	*2.799*	*0.500*	*0.494*	*0.701*	*0.523*	*0.469*	*0.441*	*0.567*	*0.455*	*0.930*	*0.651*	*0.695*	*0.625*	*1.517*	*0.672*
vt	*0.803*														

Francavilla	**SiO_2**	**TiO_2**	**Al_2O_3**	**Fe_2O_3**	**MnO**	**MgO**	**CaO**	**Na_2O**	**K_2O**	**P_2O_5**
SiO_2		0.026	0.006	0.013	0.101	0.021	0.213	0.062	0.245	0.937
TiO_2	4.028		0.017	0.012	0.087	0.047	0.319	0.138	0.383	0.790
Al_2O_3	0.960	-3.068		0.004	0.100	0.032	0.253	0.064	0.292	0.904
Fe_2O_3	1.792	-2.236	0.832		0.074	0.028	0.247	0.091	0.346	0.812
MnO	6.020	1.992	5.060	4.228		0.044	0.163	0.275	0.621	0.468
MgO	2.674	-1.354	1.713	0.881	-3.346		0.124	0.125	0.352	0.742
CaO	1.982	-2.046	1.022	0.190	-4.038	-0.692		0.306	0.516	0.808
Na_2O	4.272	0.244	3.312	2.480	-1.748	1.598	2.290		0.148	1.364
K_2O	3.099	-0.929	2.139	1.307	-2.921	0.425	1.117	-1.173		2.058
P_2O_5	3.527	-0.501	2.567	1.735	-2.493	0.854	1.545	-0.745	0.428	
τ_i	*1.625*	*1.820*	*1.672*	*1.627*	*1.933*	*1.515*	*2.948*	*2.573*	*4.961*	*8.884*
vt	*2.956*									

Francavilla	**Sr**	**V**	**Cr**	**Co**	**Ni**	**Zn**	**Rb**	**Y**	**Zr**	**Nb**	**Ba**	**La**	**Ce**	**Pb**	**Th**
Sr		0.200	0.138	1.119	0.111	0.359	0.412	0.230	0.223	0.195	0.179	0.195	0.215	0.979	1.708
V	0.983		0.043	0.971	0.049	0.145	0.096	0.056	0.056	0.035	0.216	0.024	0.056	0.603	1.702
Cr	1.058	0.075		0.900	0.004	0.085	0.173	0.035	0.036	0.020	0.068	0.015	0.026	0.644	1.789
Co	3.053	2.071	1.996		0.856	0.765	1.099	0.868	0.861	0.939	0.920	0.930	0.710	1.996	2.777
Ni	1.804	0.822	0.747	-1.249		0.093	0.186	0.039	0.039	0.027	0.067	0.022	0.027	0.686	1.792
Zn	1.220	0.237	0.162	-1.834	-0.585		0.158	0.049	0.045	0.060	0.141	0.063	0.040	0.576	1.688
Rb	1.298	0.315	0.240	-1.756	-0.507	0.078		0.084	0.077	0.087	0.395	0.090	0.130	0.410	1.326
Y	2.475	1.493	1.417	-0.578	0.671	1.256	1.178		0.002	0.009	0.126	0.013	0.024	0.559	1.580
Zr	0.898	-0.084	-0.160	-2.155	-0.906	-0.321	-0.399	-1.577		0.008	0.130	0.012	0.023	0.541	1.552
Nb	3.220	2.237	2.162	0.166	1.415	2.000	1.922	0.744	2.321		0.123	0.004	0.026	0.517	1.557
Ba	-0.759	-1.742	-1.817	-3.812	-2.563	-1.979	-2.057	-3.234	-1.657	-3.979		0.127	0.113	0.827	2.064
La	2.246	1.263	1.188	-0.807	0.441	1.026	0.948	-0.229	1.348	-0.974	3.005		0.021	0.547	1.664
Ce	1.398	0.416	0.341	-1.655	-0.406	0.179	0.101	-1.077	0.500	-1.821	2.157	-0.847		0.617	1.693
Pb	3.990	3.008	2.932	0.937	2.186	2.771	2.693	1.515	3.092	0.771	4.749	1.744	2.592		1.935
Th	4.130	3.147	3.072	1.076	2.325	2.910	2.832	1.654	3.231	0.910	4.889	1.884	2.731	0.139	
τ_i	*6.263*	*4.250*	*3.977*	*15.710*	*4.000*	*4.267*	*4.725*	*3.672*	*3.606*	*3.607*	*5.498*	*3.727*	*3.721*	*11.437*	*24.827*
vt	*6.886*														

TABLE 6
Continued...

Messina	**SiO_2**	**TiO_2**	**Al_2O_3**	**Fe_2O_3**	**MnO**	**MgO**	**CaO**	**Na_2O**	**K_2O**	**P_2O_5**
SiO_2		0.020	0.008	0.016	0.112	0.014	0.044	0.012	0.022	0.067
TiO_2	4.079		0.031	0.016	0.091	0.026	0.089	0.033	0.057	0.060
Al_2O_3	0.930	-3.149		0.009	0.103	0.009	0.068	0.013	0.005	0.080
Fe_2O_3	1.743	-2.336	0.813		0.061	0.005	0.091	0.018	0.020	0.051
MnO	6.164	2.086	5.234	4.421		0.062	0.189	0.093	0.114	0.048
MgO	2.686	-1.392	1.757	0.944	-3.478		0.069	0.009	0.016	0.058
CaO	2.194	-1.885	1.264	0.451	-3.970	-0.493		0.057	0.089	0.123
Na_2O	3.912	-0.166	2.982	2.170	-2.252	1.226	1.719		0.022	0.075
K_2O	2.652	-1.427	1.722	0.909	-3.512	-0.035	0.458	-1.260		0.102
P_2O_5	5.315	1.236	4.385	3.572	-0.849	2.628	3.121	1.403	2.663	
τ_i	*0.315*	*0.423*	*0.326*	*0.288*	*0.873*	*0.268*	*0.819*	*0.332*	*0.447*	*0.664*
vt	*0.475*									

Messina	**Sr**	**V**	**Cr**	**Co**	**Ni**	**Zn**	**Rb**	**Y**	**Zr**	**Nb**	**Ba**	**La**	**Ce**	**Pb**	**Th**
Sr		0.146	0.118	0.129	0.113	0.147	0.163	0.112	0.083	0.248	0.184	0.146	0.174	0.114	0.260
V	1.080		0.011	0.019	0.011	0.017	0.028	0.179	0.068	0.407	0.079	0.008	0.006	0.048	0.065
Cr	0.894	-0.185		0.022	0.008	0.031	0.045	0.161	0.045	0.423	0.091	0.023	0.021	0.049	0.110
Co	1.859	0.779	0.965		0.010	0.008	0.017	0.143	0.065	0.375	0.030	0.029	0.014	0.015	0.067
Ni	1.465	0.385	0.571	-0.394		0.017	0.038	0.161	0.063	0.409	0.060	0.022	0.015	0.041	0.092
Zn	0.805	-0.275	-0.089	-1.054	-0.660		0.011	0.159	0.083	0.379	0.031	0.026	0.014	0.024	0.047
Rb	0.739	-0.341	-0.156	-1.121	-0.727	-0.066		0.148	0.081	0.356	0.033	0.029	0.018	0.019	0.030
Y	2.683	1.603	1.788	0.823	1.217	1.877	1.944		0.056	0.114	0.194	0.200	0.200	0.100	0.192
Zr	0.835	-0.245	-0.060	-1.024	-0.630	0.030	0.096	-1.848		0.251	0.141	0.084	0.090	0.056	0.148
Nb	3.694	2.614	2.800	1.835	2.229	2.889	2.955	1.012	2.859		0.429	0.432	0.444	0.286	0.365
Ba	-0.690	-1.770	-1.584	-2.549	-2.155	-1.495	-1.429	-3.372	-1.525	-4.384		0.081	0.055	0.038	0.071
La	1.835	0.755	0.941	-0.024	0.370	1.030	1.096	-0.847	1.000	-1.859	2.525		0.010	0.056	0.067
Ce	0.998	-0.082	0.103	-0.862	-0.468	0.193	0.259	-1.685	0.163	-2.696	1.688	-0.837		0.046	0.049
Pb	2.441	1.361	1.546	0.581	0.975	1.635	1.702	-0.242	1.606	-1.254	3.130	0.605	1.443		0.078
Th	2.988	1.909	2.094	1.129	1.523	2.183	2.250	0.306	2.153	-0.706	3.678	1.153	1.991	0.548	
τ_i	*2.137*	*1.092*	*1.158*	*0.944*	*1.061*	*0.994*	*1.015*	*2.117*	*1.315*	*4.920*	*1.516*	*1.214*	*1.155*	*0.970*	*1.641*
vt	*1.550*														

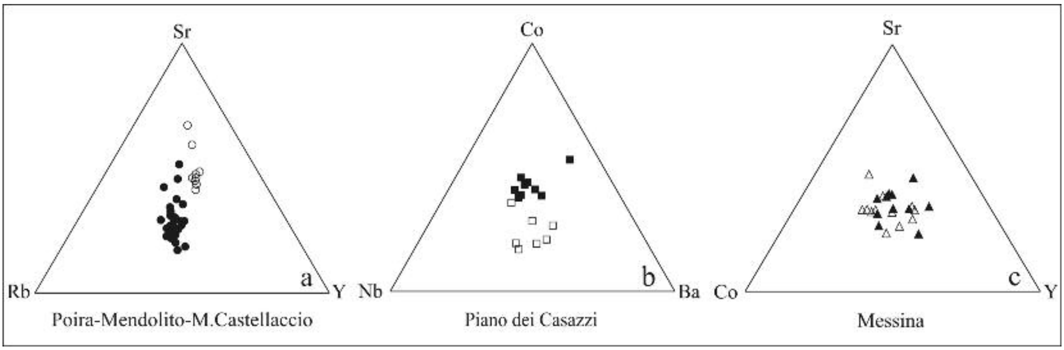

Fig. 5 - Triangular diagrams showing the chemical comparison between Ionian cups (filled symbols) and indigenous pottery (open symbols) for each investigated site.

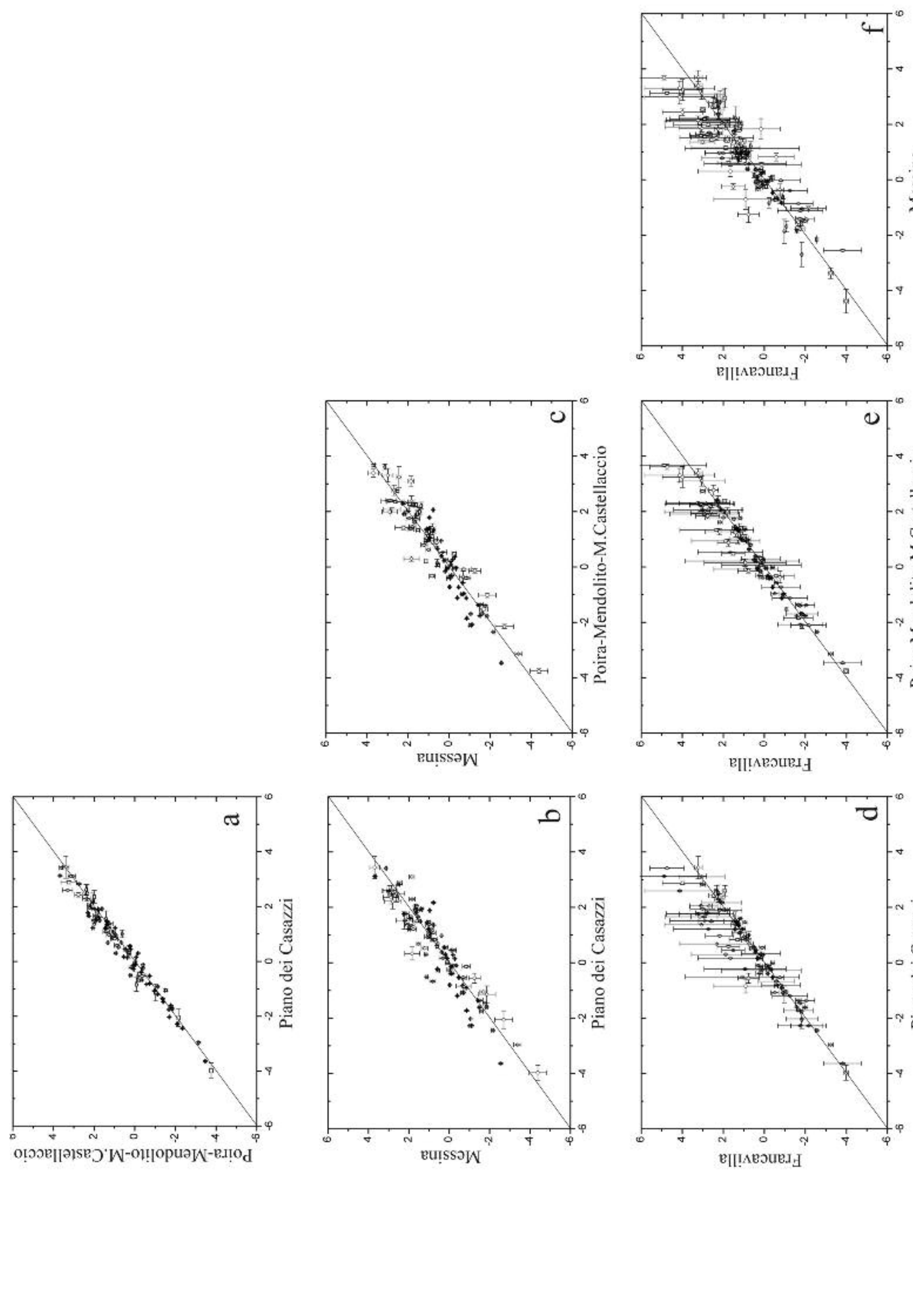

Fig. 6 - Matrix diagrams showing the mean values of the logratios for the various sites, with their variances as x and y error bars.

Conversely, the Francavilla and Messina samples show higher values, i.e., *vt* = 2.96 and 0.48 for major elements, and *vt* = 6.89 and 1.55 for trace elements, respectively. In some instances, the variations can be ascribed to post-burial alteration processes. This may be the case of the cups from Francavilla, in which high contributions of P_2O_5, K_2O,Th and Pb to total variability were observed. On the whole, the low variance found for the cups from Piano dei Casazzi and Poira-Mendolito-Monte Castellaccio and, to a lesser extent, from Messina and Francavilla (the latter excluding the above-mentioned elements with anomalously high variability) may attest to a broadly monogenic origin for each of these groups.

As a next step, with the aim of verifying the local production of the cups, comparisons with indigenous materials were performed for all sites, except for Francavilla, due to the lack of chemical data for local products. After a survey of variation matrices (not reported here, for the sake of brevity), some of the more variable elements were used to ascertain whether the chemical compositions of Ionian cups were comparable to those of local products. The triangular diagrams of figure 5 clearly separate the Ionian cups from the relative indigenous manufacts for Poira-Mendolito-Monte Castellaccio (Fig. 5a) and Piano dei Casazzi (Fig. 5b), whereas Ionian cups and local products from Messina largely overlap (Fig. 5c). These differences, although they may partially be due to the fact that the comparison materials were characterised by coarse pastes, indicate a different production for the Ionian cups.

Since the petrographic features turned out to be very similar for all samples, chemical comparisons can verify whether they belong to only one production. Attention therefore focused on the lower diagonal of the variation array of trace elements, where the means of each logratio are reported. The matrix diagrams of figure 6 show the mean values of the logratios for the various sites, with their variances as x and y error bars. If the means of chemical compositions of the grouped samples are similar, the points in the diagrams must be aligned along the x=y 'best fit' and the values of the sum of the squared residual (SSR) must be low. This condition is achieved in the Poira-Mendolito-Monte Castellaccio *vs.* Piano dei Casazzi diagram (Fig. 6a), whereas higher SSR values and a less good fit are observed in the case of Messina *vs.* Piano dei Casazzi (Fig. 6b) and Messina *vs.* Poira-Mendolito-Monte Castellaccio (Fig. 6c). The diagrams Francavilla *vs.* other sites (Fig. 6d-e-f) are characterised by the very high variance of the Francavilla samples, mainly due to the Pb and Th logratios. Figure 7 (a-b-c) shows the diagrams Francavilla *vs.* other sites without the Pb and Th logratios. Clearly, in this case, the quality of the fit is greatly improved.

These results, obtained with mean values, were further confirmed in the biplots of trace elements for the Ionian cups from all sites (Fig. 8). These statistical multivariate diagrams project both the samples and the variables in the principal components planes. The cumulative proportion explained by the first three principal components is 88 % of the variance. Figure 8 clearly shows that the Messina cups are distinct from all the others, mainly by their higher Co and lower Nb and Sr abundances. Although the Francavilla samples are more dispersed, on the whole they show a good match with the cups from Poira-Mendolito-Monte Castellaccio and Piano dei Casazzi, which overlap in all diagrams.

Discussion

Microscopic observations highlighted the fact that all the Ionian cups from the various sites show the same fabric, always characterised by markedly homogeneous textural and compositional features. The latter are also clearly comparable with those found in the scientific literature, which refer to Ionian cups from Messina, production of which was ascribed to the

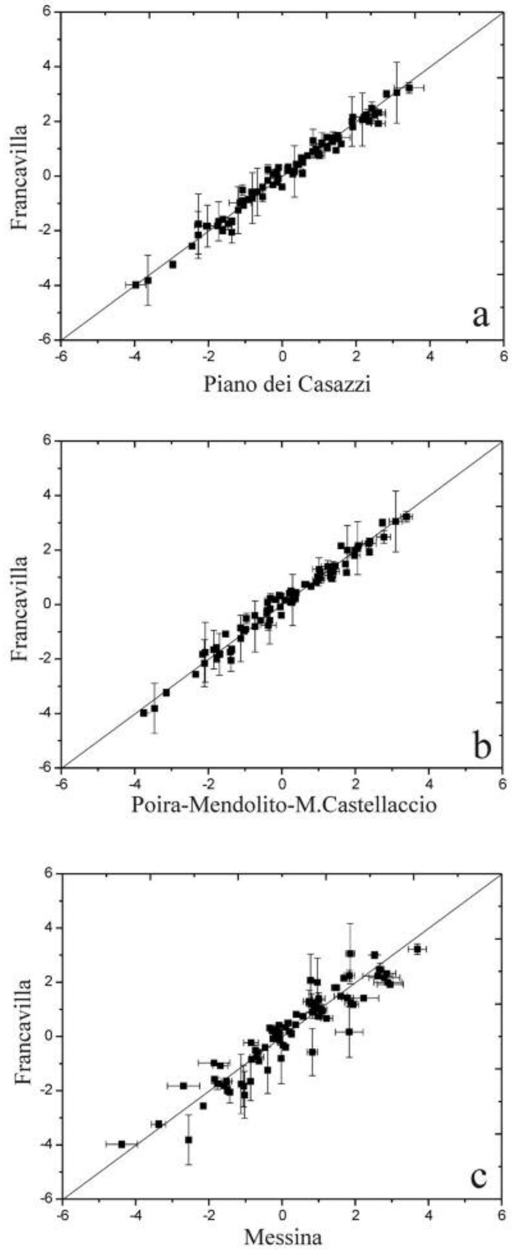

Fig. 7 - Matrix diagrams for Francavilla *vs.* other sites without the Pb and Th logratios.

Peloritani area by Barone *et al.* (2005). Instead, the chemical data and particularly the statistical treatment of trace elements have identified some discriminating features between the Ionian cups examined in this work and those from Messina. Indeed, a similar chemical composition was observed for the Ionian cups from Poira-Poggio Cocola, Mendolito, Monte Castellaccio, Piano dei Casazzi and Francavilla, whereas the chemical features of the Messina samples are rather different. Some data dispersion was observed within the main group for the Ionian cups from Francavilla, but this was due to the high variability of some elements, probably resulting from alteration processes during burial. Therefore, all samples from Poira-Poggio Cocola, Mendolito, Monte Castellaccio, Piano dei Casazzi and Francavilla probably constitute a homogeneous group, which may indicate a single centre of production, although it cannot be identified at present. Alternatively, the similarity which characterises the Ionian cups from all the above sites may be ascribed, rather than to a single centre of production, to a well-standardised manufacturing process with the use of very similar clay raw materials. Conversely, Ionian cups from Messina seem to form a distinct chemical group, thus pointing to a separate workshop.

Geochemical and petrographic comparisons with the respective local productions revealed the substantial diversity between the indigenous pottery and the Ionian cups from each site. For this reason, the workshop producing the latter could not be ascribed to any of the examined sites.

Concluding Remarks

The peculiar character of Ionian cups from various archaeological sites in eastern Sicily is due to their highly homogeneous petrographic and geochemical features. This may indicate a single centre of production, characterised by

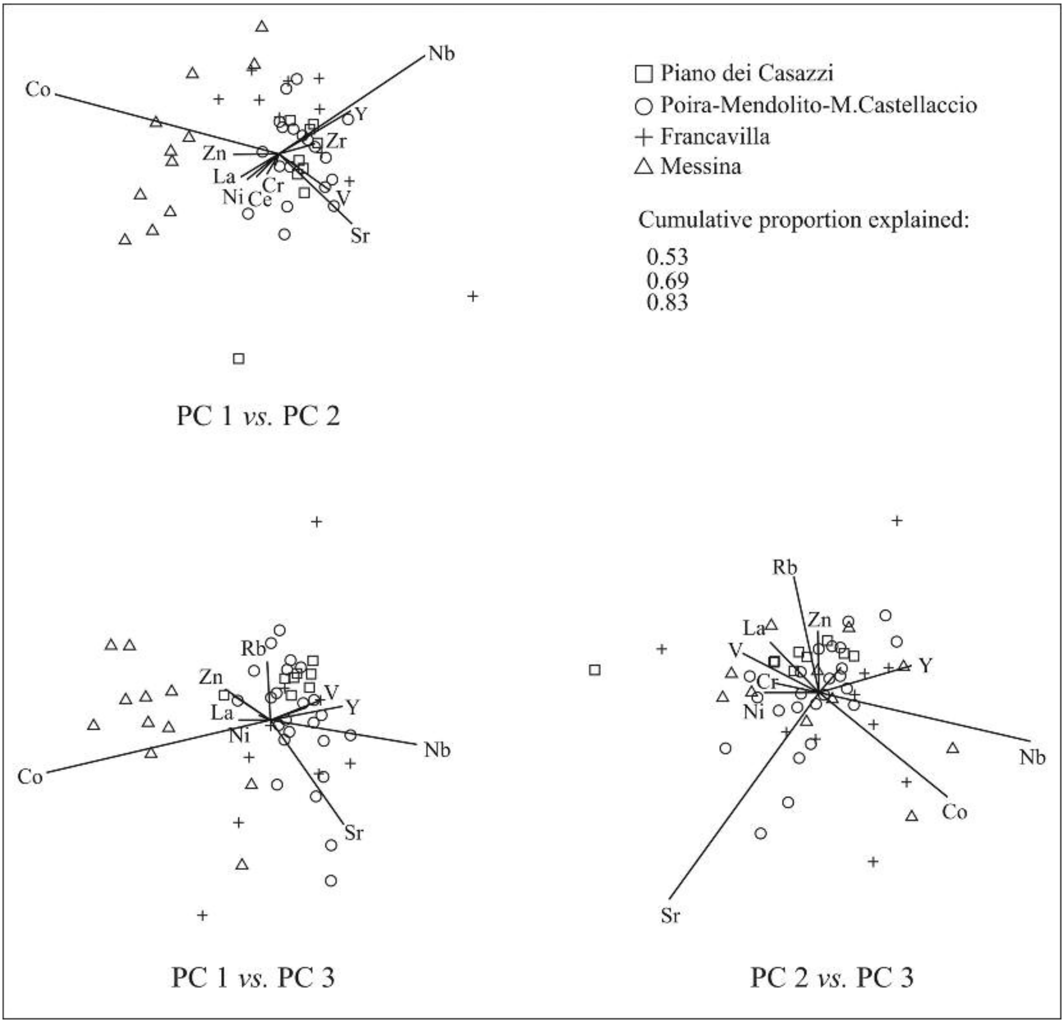

Fig. 8 - Biplots of the clr transformed data for trace elements of the Ionian cups from all sites. PC = principal component extracted.

abundant production and an extensive distribution of products, or an extremely specialised technique that was known to several workshops. The preliminary data presented here cannot solve this archaeological question and identify the production site(s). However, the marked differences between the geochemical data of the Ionian cups and those of local pottery suggest that none of the studied sites may be considered as a probable centre of production for the Ionian cups. In addition, provenance from Messina can also be excluded on the basis of the statistical processing of trace element data. On the contrary, production of the Ionian cups may have been located in one of the nearby Calcidian colonies, such as Naxos, Catania or Lentini.

Further studies, together with an increase in available data on sherds and waste products, will cast more light on this subject. Several data on waste products are still lacking for the Calcidian colonies, together with more from other important centres, such as Himera and San Gregorio di Caltagirone. The absence of this essential information, in fact, hinders the identification of the centres of production.

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