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Production and circulation of thin walled pottery from the Roman port of *Neapolis*, Campania (Italy)

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ABSTRACT

Seventeen samples of thin walled pottery from the Roman port of *Neapolis* (late II century BC - early III century AD) were studied in order to ascertain the type of clay and temper utilised, and their provenance. Seven samples of thin walled pottery from a homogeneous group (based on mineralogical and chemical characteristics) represent a local production of this ceramic class within the *Neapolis* area. This group was manufactured with a low-CaO clay, that probably derived from a weathered or alluvial deposit, together with reworked pyroclastic material (e.g., Sorrento area or Sebeto River plain) and volcanic sand from the Neapolitan area, containing both Somma-Vesuvius and Phlegraean Fields products. Two other fragments could be attributed to different Campanian production areas, such as the Pozzuoli area. Eight outlier fragments found in the port of *Neapolis* probably originate from extra regional production sites (e.g., southern Tuscany or the Arno valley).

Keywords: thin walled pottery; Neapolitan production; *Neapolis;* Roman port; Southern Tuscany.

INTRODUCTION

One of the most characteristic and diffused fine ware of the Roman period is the thin walled pottery (or TWP). Its production and circulation broadly corresponds with a flourishing period dating from the II century BC to the II century AD The production of TWP seems to be organised in regional production but some archaeological evidence confirms that these vessels were also transported over rather long distances, despite their brittleness (Millet, 1993). The interest of archaelogists in such ceramics has recently promoted an on-going archaeometric research, making available a wide data set of provenance and technological characteristics (Montana et al., 2003).

The presence of TWP in the Campania region is widespread and well documented. It has been unearthed, along with other contemporary ceramic classes, not only in *Neapolis* (this work), but also in the "Bay of Naples", such as in Cuma (unpublished data), Pompeii (Mangone, 2011; Cavassa et al., 2014; unpublished data) and Herculaneum (Mangone, 2011), as well as in the north-eastern area of the Campania region, such as in Alife (Grifa et al., 2013a; 2015).

In the Neapolitan area, the archaeological excavations carried out in 2003-2004 during the realisation of the Naples Metro-Line 1, brought to light that the present-day Piazza Municipio and Piazza Bovio were once occupied by the sea and were part of a big port (Figure 1). This area maintained the function of port from at least the end of the IV - first half of the III century BC to the V century AD The area of interest is located in the inner sector of Piazza Municipio. The

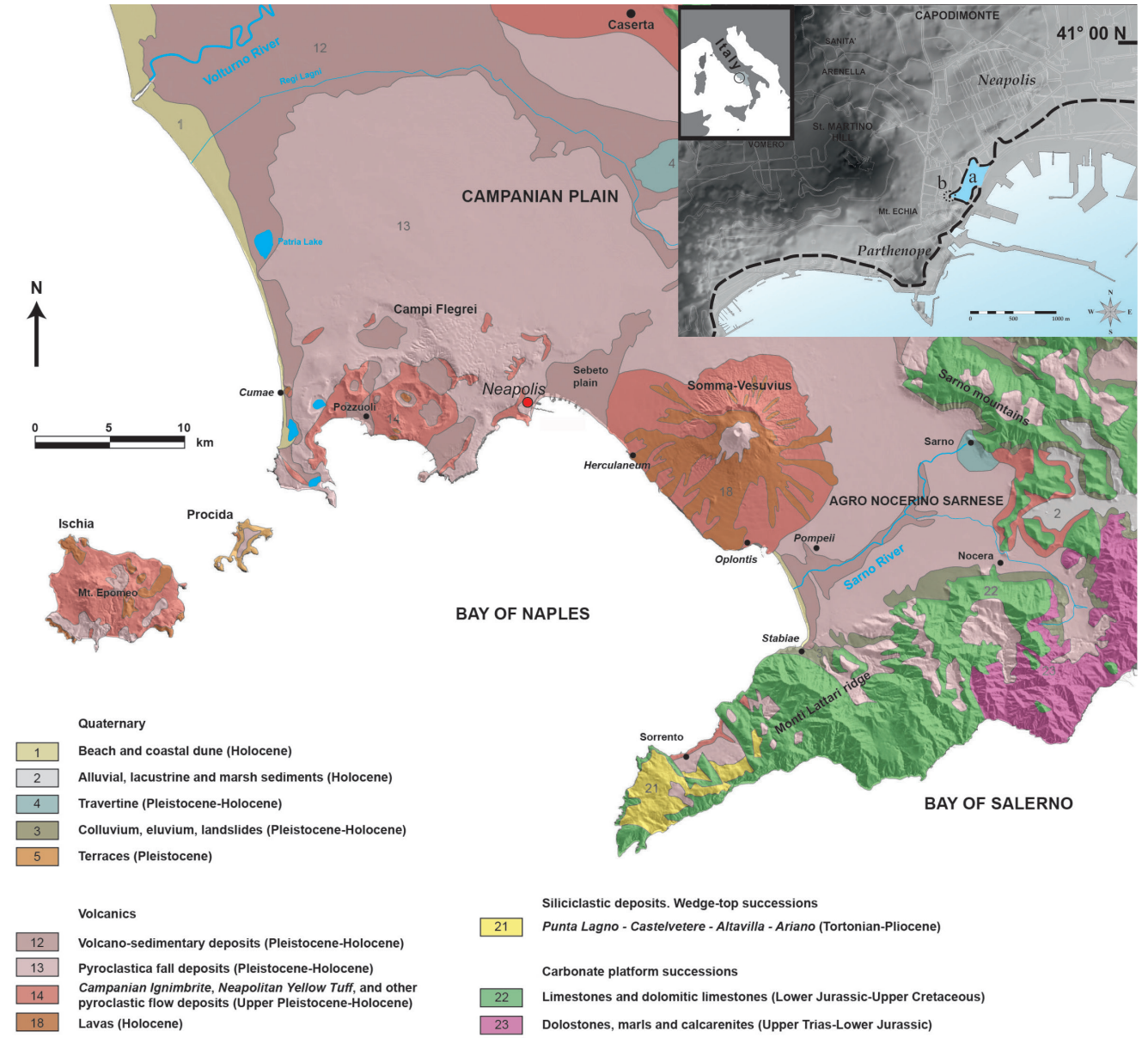

Figure 1. Geological sketch map of the Bay of Naples (modified from Bonardi et al., 1988). The inset illustrates Naples with the Roman coastline (dashed line) and the bay hosting the oldest Greco-Roman port (a) in Piazza Municipio (b) during the Roman period (after Liuzza, 2014).

geoarchaeological investigation revealed the existence of a stratified sedimentary sequence. Approximately four meters of sediments represent the port seabed layers deposited in a protected environment, currently affected by phreatic fresh water circulation. These conditions have perfectly preserved the stratigraphic sequence and the chronological homogeneity of the recovered potteries, which probably were part of a ship cargo or board furnishings (Giampaola et al., 2006; Carsana et al., 2009).

A huge amount of pottery fragments (approximately 350,000 fragments) of amphorae, lamps, fine ware, common and cooking ware was found in the layers of the Roman port, dating from between the middle II - I century BC and the first half of the III century AD (Faga, 2009; 2011a).

This current research, focused on a set of TWP samples collected in an archaeological site within the town of Naples, aims at understanding the technology, provenance and circulation of this ceramic class in Campania and in extra-regional sites. It is part of an ongoing project involving other Campanian TWP productions (Cuma, Pompeii and Alife).

GEOLOGICAL AND PALAEOENVIRONMENTAL SETTING

The town of Naples is located on the eastern boundary of the Phlegraean Fields, along the rim of the Neapolitan Yellow Tuff (NYT) caldera formed 15 ky BP (Di Vito et al., 1999; Deino et al., 2004). The geological bedrock is constituted by the Ancient Tuff sequence (Rittmann, 1950), Campanian Ignimbrite (39 ky BP; Fedele et al., 2008) and Neapolitan Yellow Tuff. A younger sequence of loose pyroclastic deposits (<15 ky BP), generated by recent eruptions within the NYT caldera and Vesuvius, blankets the hilly landscape of the town. The narrow coastal plains, stretching west and eastward to the Posillipo Cape, are constituted by reworked pyroclastic deposits interbedded with marine and transitional deposits, and by deposits reworked by long-term human activity such as quarries, buildings, roads constructions and river bed infilling.

The archaeological excavations, undertaken in Naples since the '90s, have provided significant information for a reconstruction of the palaeoenvironmental evolution of the coastal sector during the Mid-Late Holocene, and have shed light on the history of the human-environmental relationship since the first human settlement of Parthenope (Ruello, 2008; Amato et al., 2009; Romano et al., 2013; Russo Ermolli and Messager, 2013; Liuzza, 2014; Russo Ermolli et al., 2014). In particular, excavation for the Naples Metro-Line 1 permitted the identification of an ancient Greco-Roman port situated in a sheltered bay located in the area between Piazza Municipio and Piazza Bovio (Figure 1).

The first phase of human activities in the bay can be dated back to the beginning of the III century BC (Amato et al., 2009) and is represented by dredging aimed at increasing the sea bottom depth in the port basin. Port activities in *Neapolis* continued for a long period, as indicated by the vast amount of archaeological findings identified in the Municipio excavation. In particular, wooden docks and shipwrecks, dating from the late I to the III century AD (Giampaola et al., 2006), were found in the marine sands of the upper shoreface environment, between 5 and 3 m a.s.l.

The multiproxy analysis carried out on the port sedimentary record (Bourillon, 2005; Irollo, 2005; Ruello, 2008; Amato et al., 2009; Liuzza, 2014) highlighted a palaeoenvironmental shifting from a shallow marine environment, which persisted in the bay from the III century BC to the III century AD, to a lagoon basin formed as a consequence of the spit bars growth at the bay entrance.

Towards the end of the V century AD, the human-induced activities, increasing in the sedimentary inputs from the catchments dissecting the hills, triggered a phase of bay infilling (Russo Ermolli et al., 2014). This led to a further progressive closure of the basin and brought an end to the port activities, which continued further eastward, as indicated by the archaeological remains unearthed in the excavation of the Superintendence (Giampaola et al., 2006) at Piazza Bovio. Since the definitive emergence of the area, at the end of the V century AD, the lagoon sediments have been covered by continental deposits, as represented by some meters of silts, sands and fine gravels of marsh and alluvial environments which seal the port sedimentary record (Liuzza, 2014; Russo Ermolli et al., 2014).

STUDIED POTTERY MATERIALS

Seventeen samples of TWP, embodying the most common type of vessels and ceramic bodies from the port of *Neapolis*, were analysed to establish their provenance and production technologies (Table 1; Figure 2). Their shape classification was carried out by simply comparing the shapes identified by Marabini (1973) for the samples from Cosa (Orbetello, Grosseto province), those identified by Ricci (1985) for the vessels from Italy and the Roman provinces and those identified by Chiaramonte Trerè (1984) for the material from Pompeii.

All the samples have thin ceramic walls of reddish/dark brown or grey colour (Table 2). Portions of the surface are not well preserved and in several cases surface treatments, probably attributable to slip or burnishing (Ionescu et al., 2015) are visible (Figure 3). The wheel marks on the surface indicate the use of a potter's wheel.

All the samples, listed in Table 1, belong to a seabed of the Early Imperial time with the exception of samples M1, M13, and M14. Figure 2 represents their shapes, with the exclusion of sample M15, which is slightly deformed.

The oldest sample (Late Republican time) is a beaker (M1), referable to the Marabini Form III, commonly believed to be manufactured in the area between northern Lazio and southern Tuscany, as testified by productive sites identified in the low Arno valley (Menchelli, 1994) and at Marcianella, near Chiusi (Aprosio et al., 2003).

The cups M3 and M11, beaker M4, and the jugs M9 and M10, have their closest analogies in central Italy, at Cosa. The double handled cup, M5, recalls Ricci type 1/166, dated to the Augustan-Tiberian time and manufactured in the Tiber and Arno valleys, in the workshops of Scoppieto near Terni (Faga, 2011b) and Vingone in Scandicci near Florence (Fabbri, 2008; 2010). The decoration consists of grooves in the middle of the pot (as in M3) or of small groups of comb parallel incised lines (as in M9 and M10).

Samples M2, M6, M7, and M16 have parallels in Campania (M2 in Alife: Soricelli, 2009; and M6 in Pozzuoli: Laforgia, 1980-1981). Samples M7 and M16 are particularly interesting. They are only generically similar to the mugs Chiaramonte Trerè 6 from Pompeii and found in abundance in the sea-beds of the port of *Neapolis*, dating from Augustan to Tiberian-early Claudian times (Faga, 2010). In relation to their shape and decoration, they represent a homogeneous group and probably a local production. With the exception of M6, that is polished,

Table 1. Morphological characteristic of the thin walled pottery and their presumed archaeological provenance.

Sample	Typology	Contexts	Chronology of the contexts	Presumed archaeological provenance
M1	Beaker Marabini III, 30-31	Stratigraphic Unit 1157	SU 1157: layer of sand that covers the dredged sea-bed (Late Republican Times, mid II century BC - I century BC)	central Italy
M2	Beaker Marabini XXXIII	Stratigraphic Unit 1156	SU 1156-1155: sea-beds of Augustan ages (late I century BC)	Campania
M5	Cup Ricci 1/166	Stratigraphic Unit 1156		central Italy
M3	Cup Marabini XXXVI, 191	Stratigraphic Unit 1155		central Italy
M6	Beaker Marabini XXXV	Stratigraphic Unit 1155		Campania
M9	Jug Marabini XV, 267	Stratigraphic Unit 1155		central Italy
M4	Beaker Marabini XXXIII, 169	Stratigraphic Unit 1154	SU 1154: sea-bed of Augustan - Tiberian ages (late I century BC - early I century AD)	central Italy
M10	Jug Marabini XV, 267	Stratigraphic Unit 1154		central Italy
M7	Mug Chiaramonte Trerè 6	Stratigraphic Unit 1154		Neapolis (Local)
M8	Cup Marabini XXXVI	Stratigraphic Unit 1154		Campania
M16	Mug Chiaramonte Trerè 6	Stratigraphic Unit 1154		Neapolis (Local)
M15	Cup Marabini XXXVI	Stratigraphic Unit 1153	SU 1153: sea-bed of Tiberian ages (early I century AD)	Campania
M17	Cup Marabini XXXVI, 275	Stratigraphic Unit 1153		Campania
M12	Cup Marabini XXXVI	Stratigraphic Unit 1146	SU 1146-1145: sea-beds of Tiberian - early Claudian ages (first half I century AD)	Campania
M11	Cup Marabini XXXVI, 222	Stratigraphic Unit 1145		central Italy
M13	Cup Marabini LXI	Stratigraphic Unit 1106	US 1106: sea-bed of Antonine-early Severan ages (second half II century AD - early III century AD)	Tiber valley
M14	Jug Ricci 1/117	Stratigraphic Unit 1106		Ager Falernus or Pozzuoli

the surface of the other samples is rough. The decoration consists of grooves (M2) or moulding at mid-body (M7 and M16) or incisions (M6).

The cups M8, M12, M15, and M17, recall the Marabini Form XXXVI, manufactured in different productions areas, not only in Italy but also in the Roman provinces (Ricci 1985). However the samples are closer to the cups produced in Campania, at Alife (Soricelli, 2009; Olcese, 2011-2012; Grifa et al., 2013a; 2015), and are similar to the possible local/regional products described above (M2, M6, M7, and M16).

Cup M13, from the seabed of Antonine-early Severan times, recalls the Marabini Form LXI that was produced in workshops located in central Italy (Ruga, 1992) and in the Tiber valley (Duncan, 1964; Carbonara and Messineo, 1991-1992; Faga, 2011b), from the second half of the I century AD to the II century AD and, probably, in the Phlegraean Fields, in the Hadrianic-Antonine time (Miraglia, 1983-1984). The decoration consists of a light and sparse sand-coating, extended to both the inner and outer surface of the ceramic wall. Under the lip, there is a free-of-sand zone.

Finally, jug M14, likewise from the seabed of Antonine-

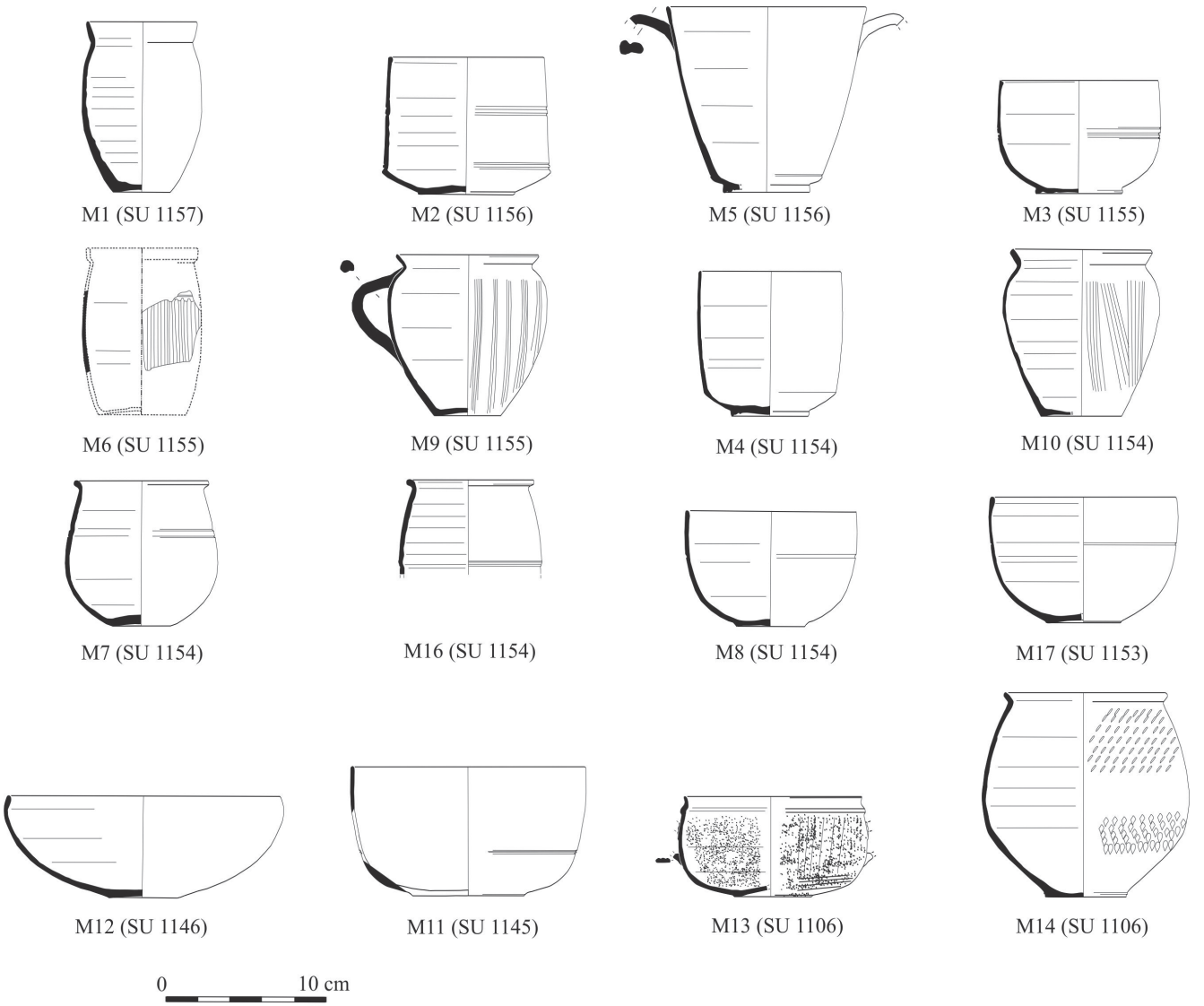

Figure 2. The shapes of sixteen thin walled pottery, listed according to their stratigraphic unit (SU), with the exception of sample M15, which is slightly deformed.

early Severan times, recalls Ricci type 1/117 that was produced in central Italy (Ruga, 1992) and in the Tiber valley (Duncan, 1964; Carbonara and Messineo, 1991-1992; Faga, 2011b), from the second half of the I century AD to the II century AD and probably in Campania, in the ager Falernus, in the early II century AD (Arthur, 1982; 1997). As far as shape and rouletting decoration is concerned, the sample from Naples is similar to a jug found in a dump at Cratere Senga, near Pozzuoli, dating back to the Hadrianic-Antonine time (Miraglia, 1983-1984). The sample surface is rough and shows traces of a brown slip.

ANALYTICAL METHODS

Optical microscopy enabled a careful investigation of the petrographic features of the ceramic samples, such as texture, colour and birefringence of the clay matrix, as well as the composition of inclusions. Image acquisition and grain size measurements were carried out using a Leitz Laborlux 12 POL microscope equipped with a Leica DFC280 camera and Leica Q Win image analysis software (De Bonis et al., 2015 and reference therein). Inclusion amount was also estimated via comparative charts (Terry and Chilingar, 1955).

Sixteen samples [excluding sample M2 due to the scarce amount of material] were ground in a steel jaw crusher, and powdered in an agate mortar, after removal of the external coatings. Their bulk chemical analyses were obtained, on pressed powder pellets, via X-ray fluorescence (XRF)

Table 2. Optical microscopy observations for the thin walled pottery.

Sample	Matrix		Grain size distribution	Packing (% of inclusions)	Fine Inclusions	Coarse inclusions							
	Colour	Activity				Quartz	Alkali feldspar	Plagioclase	Clino-pyroxene	Biotite	Amphibole	Garnet	Leucite
main petrographic group													
M2	reddish/ dark brown	birefringent	bimodal	5-10%	quartz; muscovite	xx	xx	xx	xx				
M6	reddish/ dark brown	birefringent	bimodal	5-10%	quartz; muscovite	xx	xx	xx	xx				
M7	reddish/ dark brown	birefringent	bimodal	20-30%	quartz; muscovite	xx	xx	xx	xx	x	x		x
M8	reddish/ dark brown	birefringent	serial	10-20%	quartz; muscovite	xx	xx	xx	xx	x	x		x
M12	grey	isotrope	bimodal	5-10%	quartz; muscovite	xx	xx	xx	xx	x			
M14	reddish/ dark brown	birefringent	bimodal	5-10%	quartz; muscovite	xx	x	x	xx	x			
M15	brown - green	birefringent - isotrope	bimodal	20-30%	quartz; muscovite	xx	xx	xx	xx	x			x
M16	grey core - brown rim	isotrope - birefringent	bimodal	20-30%	quartz; muscovite	xx	xx	xx	xx		x	x	x
M17	reddish/ dark brown	birefringent	serial	10-20%	quartz; muscovite	xx	xx	xx	xx	x	x		
outlier fragments													
M1	dark brown	isotope	bimodal	15-25%	quartz; muscovite	xxx	xxx		x			tr	
M3	grey	isotrope	bimodal	10-15%	quartz; muscovite	xxx	xx	x	x				
M4	grey	isotrope	bimodal	10-15%	quartz; muscovite	xxx	xx	tr					
M5	brown	birefringent	bimodal	10-15%	quartz; muscovite; biotite	xxx	xx	tr					
M9	brown	birefringent	serial	10-15%	muscovite; quartz; biotite	xxx	xx						
M10	brown	birefringent	serial	10-15%	muscovite; quartz; biotite	xxx	xx						
M11	grey	isotrope	bimodal	10-15%	quartz; muscovite	xxx	xxx	x	tr	x		tr	
M13	dark brown	isotrope	bimodal	10-15%	quartz; muscovite	xxx	xxx	x	tr	x			

Legend: xxx = abundant; xx = frequent; x = scarce; tr = trace. Lithics are described into the text.

Table 2. ... Continued

Sample	Coarse inclusions															Thickness (mm)	Weight (gr)
	Staurolite	Apatite	Monazite	Rutile	Ti-Magnetite	Ilmenite	Titanite	Zircon	Volcanic Glass	Leucite-bearing lithics	Lithics	Sandstone	Chert	Argillaceous Rock Fragments			
main petrographic group																	
M2										x	xx	x		x		3.5	2.34
M6											x	x	x			1	4.34
M7									x	x	x		x	x		1.75	11.29
M8									x	x	xx	x	x	x		1.5	4.94
M12									xx	x	x	x		x		2	4.65
M14											x		x			2	5.46
M15					x						xx	x	x			1	5.77
M16									x	x	x			x		2.5	26.09
M17									x	x	xx			x		1.75	10.18
outlier fragments																	
M1	x	x	x	x							tr	xx	x			3.5	5.60
M3												xx				1.5	4.49
M4		x	x				tr					xx	xx			1.5	3.54
M5												xx				1.75	6.53
M9												xx				1.5	4.83
M10				tr		tr		tr				xx				1.45	6.62
M11		x									tr	xx	xx			1.5	5.84
M13											tr	xx	xx			2	4.48

Legend: xxx = abundant; xx = frequent; x = scarce; tr = trace. Lithics are described into the text.

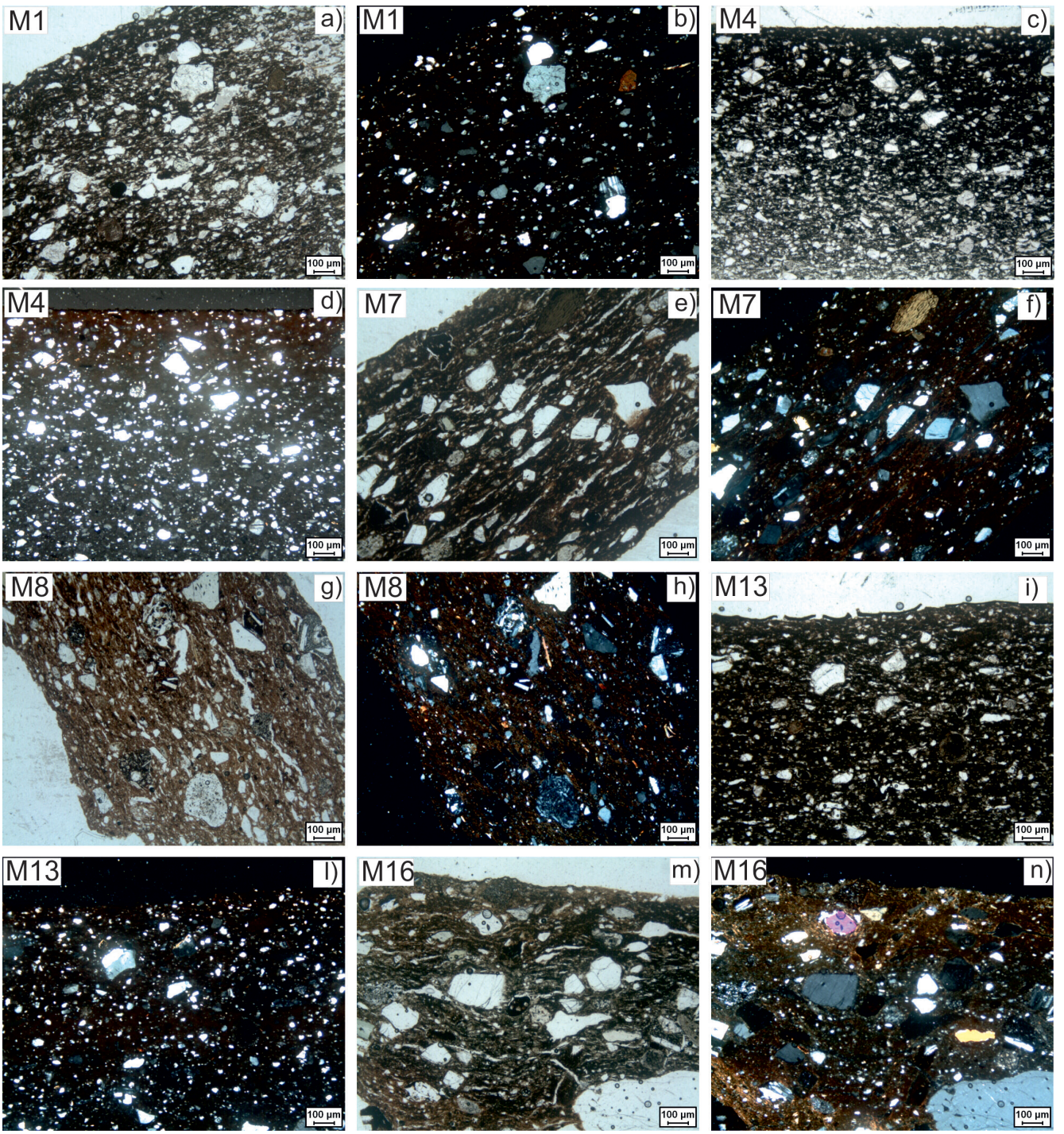

Figure 3. Photomicrographs of the main optical features of the studied samples, in plane polarised light (a,c,e,g,i,m) and in cross-polarized light (b,d,f,h,l,n).

(Axios Panalytical Instrument) at the University of Napoli Federico II. Analytical uncertainties were in the order of 1%-2% for the major elements (SiO_2, TiO_2, Al_2O_3, Fe_2O_{3Tot}, MnO, MgO, CaO, Na_2O, K_2O and P_2O_5 in wt%) and 5%-10% for the trace elements (Rb, Sr, Y, Zr, Nb, Ba, Cr, Ni, Sc, V, La and Ce in ppm) (Cucciniello et al., 2011). Loss on Ignition (LOI) was determined by heating 1 g of pre-dried (overnight at 110 °C) sample powder at 1000 °C for 4 hours.

Microchemical analysis of mineral and glass phases in the ceramic body was determined, through spot analyses, with a scanning electron microscope coupled with an Energy Dispersive Spectrometer (SEM-EDS). This method provided good results for provenance attribution of ceramics in pioneering studies such as Barone et al. (2010) and Belfiore et al. (2010; 2014). The analyses were carried out at the University of Napoli Federico II, utilizing an Oxford Instruments Microanalysis Unit, equipped with an INCA X-act detector and a JEOL JSM-5310 microscope operating at a 15 kV primary beam voltage, 50-100 mA filament current, a 15-17 ηm spot size and a net acquisition-time of 50 s. Measurements were done with an INCA X-stream pulse processor. Details of standards are provided in Melluso et al. (2010; 2014). SEM examination of ceramic microstructure on freshly fractured samples was carried out in order to refine information on firing temperatures on the basis of the sintering degree of the most representative samples (Maniatis and Tite, 1981).

Semi-quantitative X-ray powder diffraction analyses (XRPD) were carried out on some representative ceramic samples (M3, M7, M10, M11, M14, and M15) with a PANalytical X'Pert PRO 3040/60 PW diffractometer (CuKα radiation, 40 kV, 40 mA, scanning interval 4-50° 2θ, step size 0.017° 2θ, and counting time 15.5 seconds/step), in order to identify the bulk mineralogical composition of the potsherds, which depends on the base-clay and possible sub-microscopic phases related to the firing dynamics (temperature, oxidising or reducing conditions of the kiln atmosphere).

RESULTS AND DISCUSSION

Microscopic observations and mineral chemistry

The petrographic features and mineral chemistry are summarised in Table 2, Table 4 and in Figure 3.

Microscopic observations (Figure 3) permitted the identification of a main petrographic group, which includes samples M2, M6, M7, M8, M12, M14, M15, M16, and M17. Since, the other studied samples (M1, M3, M4, M5, M9, M10, M11, and M13) cannot be grouped, they will be regarded as outlier fragments.

The main petrographic group is characterised by a birefringent reddish/dark brown matrix, with the exceptions of M12 (with a grey, isotropic matrix), M15 (with zoned paste, brown and birefringent, and green and isotrope, respectively) and M16 (with a grey isotropic core and a brown birefringent rim). Sample M14 has a birefringent matrix due to the presence of microcrystalline calcite ('crystallitic b-fabric' of Kemp, 1985). Samples M2, M6, M12, and M14 show poorly sorted inclusions, with a bimodal distribution of inclusions (approximately 5-10%). Samples M7, M15, and M16 show well sorted inclusions, with a bimodal distribution of inclusions (packing 20-30%). Samples M8 and M17 have a serial distribution of the inclusions (packing 10-20%). As far as the shape and size of inclusions are considered, samples M2, M6, M7, M8, M12, M14, M15, M16, and M17 show fine elements (up to 30 μm) in the matrix, with a sub-rounded or rounded shape, and a coarser fraction, with a sub-rounded or rare sub-angular shape (up to 500 μm). The crystals are quartz, muscovite, alkali-feldspar, diopsidic clinopyroxene, rare plagioclase, amphibole [from sadanagaite to hastingsite (Locock, 2014)], biotite, garnet [andradite (56-67 mol%) and grossular (18-31 mol%) solid solution (Locock, 2008)] (Figure 4 a,b), as well as leucite. Plagioclase- and/or leucite-bearing volcanic fragments, together with sporadic volcanic glasses and sedimentary fragments (sandstone, mudstone and chert), are also present. The volcanic glass fragments (pumice and obsidian) in samples M16 and M17 (Figure 4 a,b) show a trachytic (SiO_2 57.2-58.3 wt%, Na_2O+K_2O 12-13.1 wt%) and only minor phonolitic (SiO_2 58.2 wt%, Na_2O+K_2O 14.8 wt%) compositions.

Among the outlier fragments, sample M1 shows a dark brown isotropic matrix, and a bimodal distribution of inclusions (packing 15-25%). Their shape is sub-rounded (30-40 μm) for fine inclusions and sub-angular for coarser fraction (100-200 μm). Quartz is the predominant phase, associated with alkali-feldspar, muscovite and diopsidic clinopyroxene. Staurolite (Figure 4 c,d) and a garnet [almandine (75 mol%) and pyrope (18 mol%) solid solution (Locock, 2008)] are accessory minerals. Sporadic plagioclase- and clinopyroxene-bearing volcanic fragments together with sedimentary fragments (sandstone, mudstone and chert), were also identified.

The outlier samples M3 and M4 have a grey isotropic matrix and show a bimodal distribution of the inclusions (packing 10-15%). The inclusions in sample M3 are poorly sorted, whereas in sample M4, they are well sorted. The fine inclusions and coarser fraction (20-120 μm) show a sub-rounded shape. Quartz and muscovite mostly represent fine inclusions, with minor amounts of a coarser fraction of alkali-feldspar, plagioclase and biotite. In sample M3, Al-rich- and diopsidic clinopyroxene and almandine (78-79 mol%) garnet (Locock, 2008), were found. In both samples, sedimentary fragments (sandstone, mudstone and chert) were also identified. Sporadic calcite outlines the pore surface.

The outlier samples M5, M9, and M10 have a birefringent brown matrix. Sample M5 shows a bimodal distribution of grains with a well sorted coarse fraction (50-100 μm), while samples M9 and M10 are characterised by a serial distribution (20-120 μm) for the inclusions (packing 10-15%). The predominant crystal in M5 is quartz, followed by muscovite, alkali-feldspar, plagioclase, and biotite. Sedimentary fragments (sandstone, mudstone and chert) were observed. Samples M9 and M10 contain the same

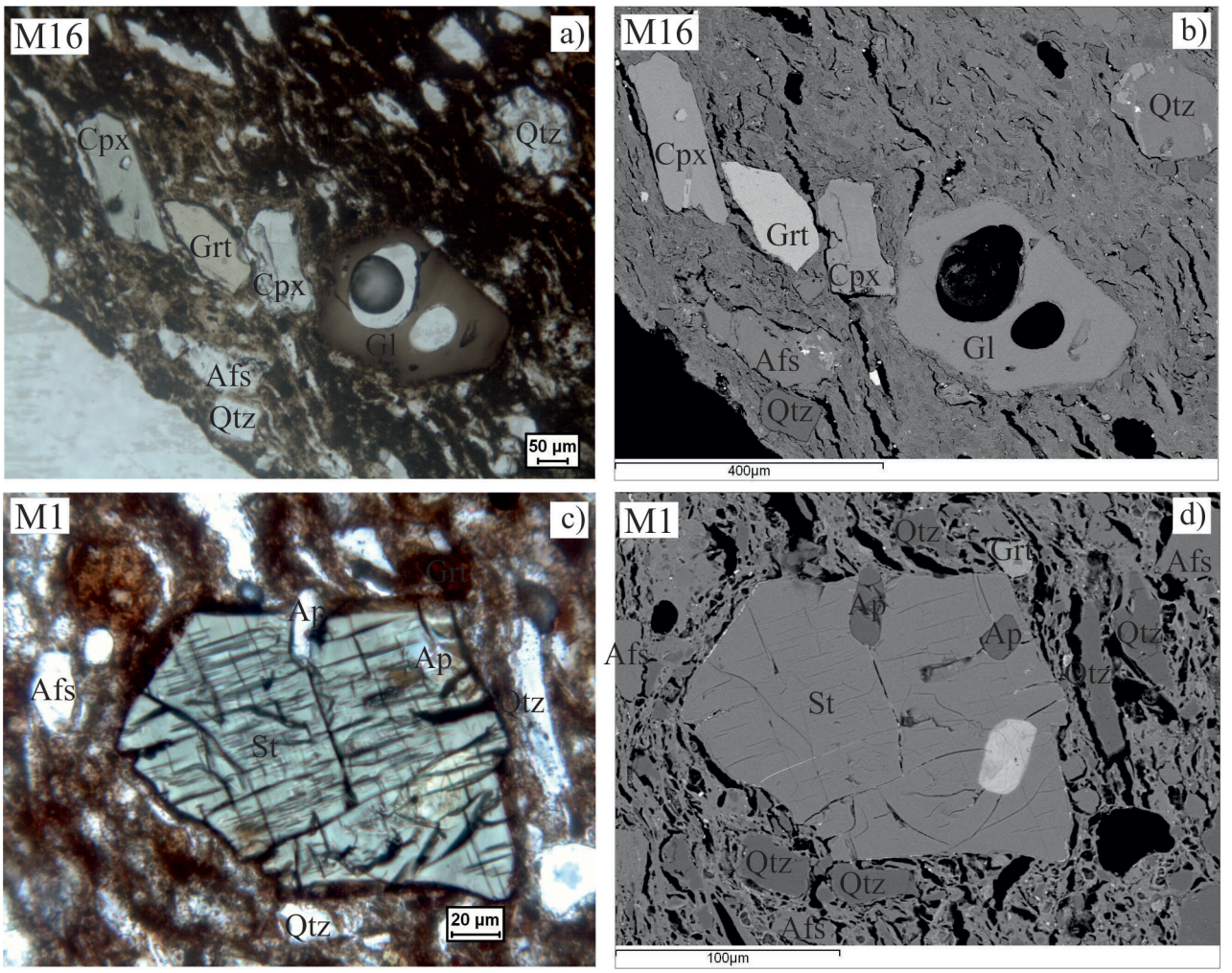

Figure 4. Polarized light (a,c) and back scattered electron (b,d) images of samples M16 (a,b) and M1 (c,d). Abbreviations: Cpx, clinopyroxene, Grt, garnet; Afs, alkali feldspar; Qtz, quartz; St, staurolite; Ap, apatite; Gl, volcanic-glass.

phases observed in M5, but micas (muscovite and biotite) are the predominant minerals.

The outlier samples M11 and M13 are characterised by a grey or dark brown isotropic matrix, with a bimodal distribution of inclusions (packing 10-15%). The size of the fine inclusions ranges from 30 to 40 µm for M11 and is approximately 15 µm for M13. Coarse inclusions (125-210 µm for M11, 50-120 µm for M13) are poorly sorted and show a sub-rounded shape. The crystals in samples M11 and M13 are quartz and muscovite, followed by alkali-feldspar. Clinopyroxene and biotite are subordinate. Abundant sedimentary fragments (sandstone, mudstone and chert) and sporadic plagioclase-bearing volcanic fragments were observed. The analysed minerals in sample M11 are quartz, alkali feldspar (anorthoclase to sanidine), rare plagioclase, diopsidic clinopyroxene and garnet [grossular (70 mol%) and andradite (18 mol%) solid solution (Locock, 2008)].

Mineralogical analyses

The XRPD analyses performed on some samples (Table 3) revealed the ubiquitous and abundant presence of quartz along with minor amounts of feldspar.

Three samples of the main petrographic group are characterised by the presence of clinopyroxene in low amounts (M14) or in traces (M7 and M15); the same phase was only detected in traces in the outlier fragments M3 and M11. Clay minerals are represented by illite-like phases detected in a scarce amount (M14) or only in traces (M3, M7, M11, and M15). Samples of the main petrographic group are characterised by the ubiquitous presence of hematite in low amounts (M7) or in traces (M14 and M15), other Fe-oxides such as maghemite in M14 and M15, and hercynite in M15. In the outlier fragments, Fe-oxides are represented by magnetite in sample M3, and by hematite in samples M10 and M11. Calcite occurs in traces only in M14 and M3.

Table 3. Mineralogical analysis (XRPD) and estimated firing temperatures of some representative ceramic samples.

	Quartz	Feldspar	Clinopyroxene	Calcite	Hematite	Other Fe-oxides	Illite	Firing atmosphere	Vitrification stage	Firing temperature (°C)
main petrographic group										
M7	XXX	XX	traces	-	X	-	traces	ox	extensive vitrification	850-950
M14	XXX	XX	X	traces	traces	maghemite	traces	ox/red	-	~950
M15	XXX	X	traces	-	traces	hercinyte, maghemite	X	ox/red	-	850-950
outlier fragments										
M3	XXX	XX	traces	traces	-	Magnetite	traces	red	-	900-950
M10	XXXX	X	-	-	traces	-	X	ox	initial vitrification	800-850
M11	XXXX	X	traces	-	traces	-	traces	ox	continuous vitrification	~950

Abbreviations: XXXX = very abundant, XXX = abundant, XX = frequent, X = sporadic. red = reducing; ox = oxidising.

Microstructural analysis by SEM

The SEM observations of the ceramic microstructure of fresh fractured representative samples show an extensive vitrification of M7 (Figure 5a). Sample M10 shows an initial stage of vitrification, which is characterised by isolated smooth-surfaced glassy areas (Figure 5b) and phyllosilicate plates partially deformed or welded (Figure 5c). A continuous vitrification stage with fine bloating pores (Figure 5d) was observed in sample M11.

Chemical analysis

The chemical composition of the samples is reported in Table 4. Some representative binary diagrams (Figure 6) have been used to better illustrate the chemical characteristics of the ceramics.

Samples belonging to the main petrographic group, previously identified (M2, M6, M7, M8, M12, M14, M15, M16, and M17), also show a chemical homogeneity, except for samples M14 and M15. Indeed, samples M6, M7, M8, M12, M16, and M17 can now be identified as a reference chemical group.

In addition to being different from a petrographical point of view, the outlier samples M1, M3, M4, M5, M9, M10, M11, and M13, also show different chemical features.

As far as CaO concentrations are concerned, the reference chemical group (M6, M7, M8, M12, M16, and M17) and sample M15 show low values (<2.5 wt%), whereas sample M14 accounts for the highest value (11.2 wt%). Al_2O_3 concentration in the reference chemical group is higher than 21 wt%, and Fe_2O_3 varies in a narrow range (6.4-7.3 wt%). The highest Fe_2O_3 value was recorded in sample M15 (9 wt%), whereas M14 has the lowest SiO_2 (54 wt%) concentration (Figure 6 a,b). Low Na_2O concentrations (0.9-1.8 wt%) were observed in the reference chemical group, M14 and M15.

The outlier samples (M1 M3, M4, M5, M10, M11, and M13) show an Al_2O_3 concentration (<20 wt%) lower than the reference chemical group. CaO and Fe_2O_3 concentrations range from 0.9 to 7 wt% and from 5.8 to 7.6 wt%, respectively. Similarly to the reference chemical group, and samples M14 and M15, the outlier samples also have a low and limited Na_2O (0.9-1.5 wt%) concentration.

All the samples (reference chemical group, M14, M15, and outliers) have low concentrations in P_2O_5 (<0.2 wt%).

Binary diagrams (Figure 6 c,d) report the behaviour of some representative trace elements. Samples of the reference chemical group show the lowest Cr (60-95 ppm) and Ni (30-37 ppm) values, and the highest Zr (448-552 ppm) and Nb (49-57 ppm) concentrations among the investigated samples. Samples M14 and M15 have higher concentrations in Cr (141 ppm for M14 and 164 ppm for M15) and Ni (74 ppm for M14 and 69 ppm for M15) but lower concentrations in Zr (272 ppm for M14 and 356 ppm for M15) and Nb (31 ppm for M14 and 40 ppm for M15) when compared to the reference chemical group.

The outlier samples have variable Zr (217-400 ppm),

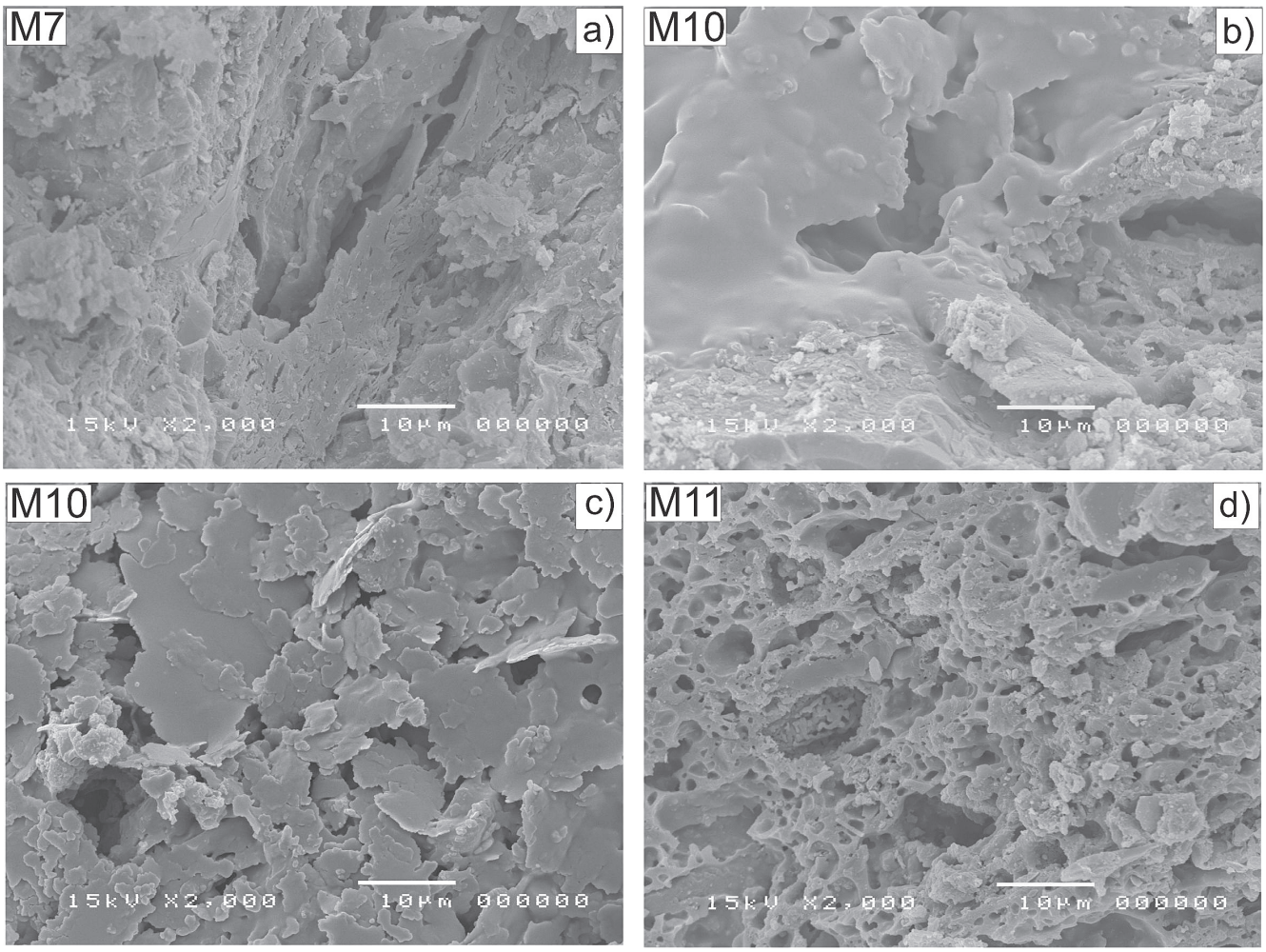

Figure 5. SEM images of freshly fractured samples showing vitrification stages according to Maniatis and Tite (1981). (a) Initial vitrification. (b) Extensive vitrification. (c) Partially deformed or welded phyllosilicates. (d) Continuous vitrification with fine bloating pores [CV(FB)].

Nb (21-41 ppm), Cr (108-180 ppm) and Ni (47-99 ppm) concentrations. The lowest Zr (217 ppm) and Nb (21 ppm) values were observed in samples M9 and M10, respectively. Sample M3 shows the overall highest Cr (180 ppm) and Ni (99 ppm) concentrations.

In addition, Figure 6 displays, by comparison, the compositional fields of other TWP productions originating from the Campania region such as Alife (Grifa et al., 2013a; 2015) and Cuma (unpublished data), as well as another important Neapolitan production, the Campana A ware (Giampaola et al., 2014; De Bonis et al., 2016). The reference chemical group can be clearly distinguished from the TWP samples from Alife and Pompeii (unpublished data), but shows a good chemical similarity with those of Cuma, although some petrographic differences still exist. No chemical similarity was recorded between the Campana A ware and the reference chemical group.

TECHNOLOGICAL INFERENCES AND PROVENANCE ATTRIBUTION

Chemical and mineralogical data combined with archaeological data provide significant information with regards to the technology, provenance and circulation of the TWP from the Roman port of *Neapolis*.

The analysed samples are listed in Table 5 based on their stratigraphic unit and their presumed (archaeological) and inferred provenance. All the samples were found in the inner sector of Piazza Municipio, in an unaltered stratified sequence of sediments of a phreatic fresh water zone (Giampaola et al., 2006; Carsana et al., 2009). Thus, despite having been found in the seabeds of a port, all the samples of this study do not show evidence of sea water contamination, such as crystallisation of soluble salts (i.e., halite, gypsum) or anomalous concentrations of Na_2O, MgO and K_2O, due to the fact that they had been buried in a fresh water phreatic zone for centuries (Jang et al., 2013). Other types of post-burial contamination, typical

of ceramics, such as an anomalous concentration of P_2O_5 (Maggetti, 2001) or the presence of secondary phases (i.e., analcime, pyrite), are also absent (Schwedt et al., 2006; Secco et al., 2011).

Technology

The samples of the reference chemical group along with samples M14 and M15 are characterised by the presence of a coarse fraction (up to 500 μm) mainly composed of volcanic inclusions and subordinate sedimentary fragments. The occurrence of both volcanic and sedimentary constituents suggests a mixed source of grains used as a temper (Grifa et al., 2015) added to a clayey material containing a quartz-rich fine fraction (<30 μm), representing the naturally occurring skeleton.

XRPD analysis indicates that two samples (M7 and M14) belonging to the main petrographic group were fired in a prevailing oxidising atmosphere (presence of hematite). The presence of calcite in traces in the calcareous sample M14 are related to the re-carbonation of the unreacted free lime, as evidenced by the microcrystalline calcite observed in thin section (Fabbri et al., 2014). Therefore, we believe that the original calcite was decomposed upon firing, suggesting that temperatures higher than 850 °C were reached (Cultrone et al., 2001). A more precise indication of the firing temperature can be provided by the persistence of illite in traces as a retrograde phase, which would indicate a temperature of approximately 950 °C (Cultrone et al., 2001).

A temperature range of approximately 850-950 °C can be inferred for the non-calcareous sample M7 due to the extensive vitrification of the microstructure observed at SEM (Maniatis and Tite, 1981).

Sample M15 is characterised by the presence of illite indicating a temperature lower than 950 °C, although the occurrence of hercynite suggests temperatures exceeding 850 °C (Ionescu et al., 2015). The simultaneous presence of Fe^{3+}- and Fe^{2+}-oxides (hematite and hercynite, respectively) also denotes an alternation of reducing/oxidising phases during firing, as frequently observed in other ceramic products from several Campanian sites (De Bonis et al., 2010; De Simone et al., 2013; Morra et al., 2013) which might indicate the difficulty of controlling firing dynamics in the ancient kilns.

The outlier fragments (M1, M3, M4, M5, M9, M10, M11, and M13) show variable textural features. Samples M1, M3, M4, M5, M11, and M13 have a bimodal distribution of the inclusions, 20-40 μm for fine inclusions and up to 210 μm for coarser fraction. Instead, samples M9 and M10 show a serial distribution (20-120 μm for fine and coarser fractions). Regarding firing technology, sample M3 was probably fired in a prevailing reducing atmosphere (presence of magnetite) at a temperature of approximately 900-950 °C due to the persistence of illite in traces (Cultrone et al., 2001). Samples M10 and M11 were fired in an oxidising atmosphere, as indicated by the presence of hematite. The firing temperature was evaluated between 800 and 850 °C for M10 due to the initial vitrification of the ceramic microstructure. Instead, M11 was most probably fired at approximately 950 °C due to the continuous vitrification with the fine bloating pores observed at SEM (Maniatis and Tite, 1981).

Provenance

The occurrence of leucite in the samples of the reference chemical group (Augustan to Tiberian ages) and M15 (Tiberian age) suggests the use of a temper containing Somma-Vesuvius volcanic-related products. This assumption is further supported by the concomitant presence of garnet and amphibole, compositionally similar to those of Somma-Vesuvius (Scheibner et al., 2007; Melluso L. and Guarino V., unpublished data). Moreover, the trachytic and phonolitic composition of volcanic glasses in the reference chemical group (Figure 7) suggests that these products belong both to the Avellino pumice eruption from Somma-Vesuvius (phonolitic composition) and the Phlegraean Fields (trachytic composition). In fact, the temper exhibits the features of the volcanic sand occurring in the Neapolitan area (e.g., Lustrino et al., 2002), characterised by products of both Somma-Vesuvius (Grifa et al., 2009b; 2013b; Morra et al., 2013) and the Phlegraean Fields (Grifa et al., 2005; Morra et al., 2010; Giampaola et al., 2014).

As far as clayey raw materials are concerned, it is worth noting that the chemical composition of the samples of the reference chemical group and sample M15 is characterised by a low-CaO concentration (<2.5 wt%). Up until now, clayey deposits with a similar composition had not been found in the Naples area. However low-CaO clayey raw materials, such as weathered pyroclastics (e.g., Sorrento area; De Bonis et al., 2013) and alluvial clays (e.g., Volturno river plain; De Bonis et al., 2013 and reference therein), outcrop in the surrounding area or further inland, respectively. Hence, these clays most probably represent the exploited raw materials. However, the possibility that similar clays could even have locally outcropped at that time, for example in the marshy area of Naples (e.g., Sebeto River plain?) and thus, easily collected, cannot be excluded. Therefore, the archaeological, mineralogical and chemical data, along with the evidence of a temper from the Neapolitan area containing both Somma-Vesuvius and Phlegraean products, suggests that the TWP of the reference chemical group could represent a local production (Table 5).

Sample M14 differs from the samples of the reference chemical group and sample M15 owing to its high-CaO concentration (~11 wt%), indicating the use of a calcareous raw material. Clay deposits with this composition near the

Table 4. Major oxides (in wt%), trace elements (in ppm) and LOI (in wt%) concentrations for the analysed thin walled pottery.

			SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	sum
main petrographic group	*reference chemical group*	M 6	63.2	1.0	22.1	6.7	0.1	1.4	1.3	1.2	3.1	0.1	100
		M 7	61.5	0.9	21.0	7.2	0.1	1.6	2.2	1.5	3.8	0.1	100
		M 8	60.1	0.9	22.3	6.8	0.1	1.5	2.3	1.7	4.2	0.1	100
		M 12	59.8	1.0	23.4	7.3	0.1	1.3	1.6	1.3	4.2	0.1	100
		M 16	61.0	0.9	21.2	7.1	0.2	1.6	2.4	1.7	3.8	0.1	100
		M 17	59.8	0.9	23.0	6.4	0.1	1.6	2.3	1.8	4.1	0.1	100
		M 14	54.1	0.9	18.9	7.1	0.1	3.4	11.2	0.9	3.2	0.2	100
		M 15	59.9	1.1	19.9	9.1	0.2	2.4	2.5	1.0	3.7	0.1	100
outlier fragments		M 1	61.4	0.9	18.1	7.5	0.2	2.1	5.8	1.0	2.8	0.2	100
		M 3	60.2	0.9	17.5	7.6	0.1	2.8	7.0	0.9	2.8	0.1	100
		M 4	64.5	0.9	17.4	6.5	0.1	1.9	4.7	1.1	2.8	0.1	100
		M 5	64.4	0.8	18.9	6.4	0.1	2.1	1.2	1.5	4.5	0.1	100
		M 9	61.9	0.9	22.4	6.8	0.1	2.0	0.9	1.3	3.8	0.1	100
		M 10	65.9	0.9	18.7	5.8	0.1	2.3	1.0	1.0	4.1	0.1	100
		M 11	62.8	0.9	18.9	7.3	0.1	2.1	3.9	0.9	2.8	0.1	100
		M 13	63.7	1.0	18.2	7.6	0.1	2.0	3.8	1.0	2.5	0.1	100

Bay of Naples can be found on the island of Ischia (De Bonis et al., 2013; 2014). Some evidence indicated the use of this clay for the production of calcareous ceramics in the whole Bay of Naples area (Grifa et al., 2009b; Munzi et al., 2012; 2014; Greco et al., 2014). However, data obtained for sample M14 does not provide useful information regarding its precise provenance. An indication may come from the presence of amphibole with a composition similar to that found in the reference chemical group, which could suggest the use of a Somma-Vesuvius temper added to the Ischia clay. The archaeological information indicated a possible production site in the Pozzuoli area (Table 5). Indeed, our previous studies have already demonstrated that Somma-Vesuvius temper was imported in the Phlegraean area for pottery productions (Morra et al., 2013).

The outlier fragments (M1, M3, M4, M5, M9, M10, M11, and M13) show variable mineralogical, chemical and archaeological features. With the exception of sample M1 (mid II century BC - I century BC), all the other samples are more recent and come from the seabeds of the Roman port of *Neapolis* of the Augustan and Augustan-Tiberian-Severan times. Sample M1 is similar to the Marabini Form III and archaeological information indicates that similar shapes were produced in the area between northern Lazio and southern Tuscany. Its mineralogical assemblage (staurolite and almandine) is typical of a geological formation cropping out in southern Tuscany, i.e. the "Gneiss metamorphic unit" belonging to the Larderello plutono-metamorphic complex (Franceschini, 1995). A southern Tuscany production can be therefore envisaged (Table 5).

The other outlier samples (M3, M4, M5, M9, M10, M11, and M13) are characterised by a predominant quartzose/micaceous inclusions which most likely indicates a provenance different from the Bay of Naples. Samples M11 and M13 are characterised by a strong chemical affinity despite belonging to different seabeds. This could indicate a diachronic production in the same area.

Archaeological information on cups M3, M11, and M13, beaker M4, and jugs M9 and M10 indicate a provenance from southern Tuscany, but we do not exclude a production in a wider area of central Italy (Table 5). The marked chemical differences suggest a production in different workshops, exploiting different clay deposits during the Early Imperial time.

The archaeological information on the double handled cup M5 (Augustan-Tiberian ages) leads us to hypothesize

Table 4. ... Continued

			LOI	Rb	Sr	Y	Zr	Nb	Ba	Cr	Ni	Sc	V	La	Ce
main petrographic group	*reference chemical group*	M 6	3.2	242	201	42	507	57	524	82	32	11	97	98	116
		M 7	2.1	247	334	48	448	49	700	95	37	17	98	106	172
		M 8	2.5	261	340	49	543	57	708	67	32	14	87	123	200
		M 12	1.9	261	319	43	538	57	776	85	30	17	108	105	160
		M 16	3.3	241	378	42	461	54	752	81	36	14	101	100	219
		M 17	3.5	245	362	45	552	57	687	60	32	16	84	126	204
		M 14	4.0	195	444	33	272	31	428	141	74	24	99	64	101
		M 15	1.2	295	316	38	356	40	754	164	69	23	130	87	143
outlier fragments		M 1	1.2	225	329	43	380	25	961	144	71	23	101	117	195
		M 3	3.8	195	285	37	257	22	544	180	99	30	107	64	98
		M 4	2.6	190	234	37	342	23	581	150	65	21	95	54	67
		M 5	1.6	233	174	48	329	41	431	117	61	16	81	77	121
		M 9	1.8	218	114	44	217	24	478	108	47	25	96	51	93
		M 10	2.5	174	108	43	254	21	690	108	47	18	95	60	101
		M 11	1.8	220	422	48	387	26	1156	146	67	20	115	126	146
		M 13	2.7	234	282	44	400	29	1117	137	68	19	111	137	153

a possible production site in the Tiber or Arno valley workshops. The lack of a volcanic component in this sample supports a provenance from the Arno valley (Table 5). Indeed, products from the Arno valley have been found in other Campanian archaeological sites, such as terra sigillata in Cales (samples 38 and 39, I century BC - I century AD coming from Pisa; Guarino et al., 2011), thus indicating a thriving commercial trade.

CONCLUSIONS

This research reports the first archaeometric data on potteries found within the Roman Port of *Neapolis*. The analyses, in addition to providing important technological information on this ceramic class, permitted us to refine archaeological hypotheses and better identify ceramic productions originating from Campanian sites or Central Italy. High or low-CaO clayey raw materials were indifferently used for the production of these potteries, suggesting that no specific composition of the clay was required for the production of thin walled wares. A large group of samples is characterised by a chemical homogeneity and by the presence of volcanic and subordinate sedimentary inclusions of fine-medium sand size. These inclusions probably represent the temper added to the clay body, which provided a solid skeleton to these vessels characterized by extremely thin walls (2-5 mm thick). Firing was performed at temperatures ranging from approximately 850 to 950 °C, suitable for guaranteeing proper strengths to the artefacts and which correspond with those estimated for other thin walled wares from production centres identified up to now.

A peculiar feature of this pottery is the ubiquitous presence of a temper represented by volcanic sand collected in the Naples area, bearing products of only Somma-Vesuvius (M15) or mixed with those of the Phlegraean Fields. The same assemblage, found in a volcanic sand occurring in the Neapolitan area (Lustrino et al., 2002) leads us to hypothesize a Neapolitan production of thin walled pottery (samples of the reference chemical group).

Furthermore, the clay is a peculiar feature of this production due to the fact that it is always characterized by a low-CaO composition. Weathered pyroclastic (e.g., Sorrento area) or alluvial (e.g., Sebeto River plain?) materials might represent the supplying deposits. One sample (M14), probably representing a mixing of local volcanic sand and high-CaO clay (probably Ischia clay),

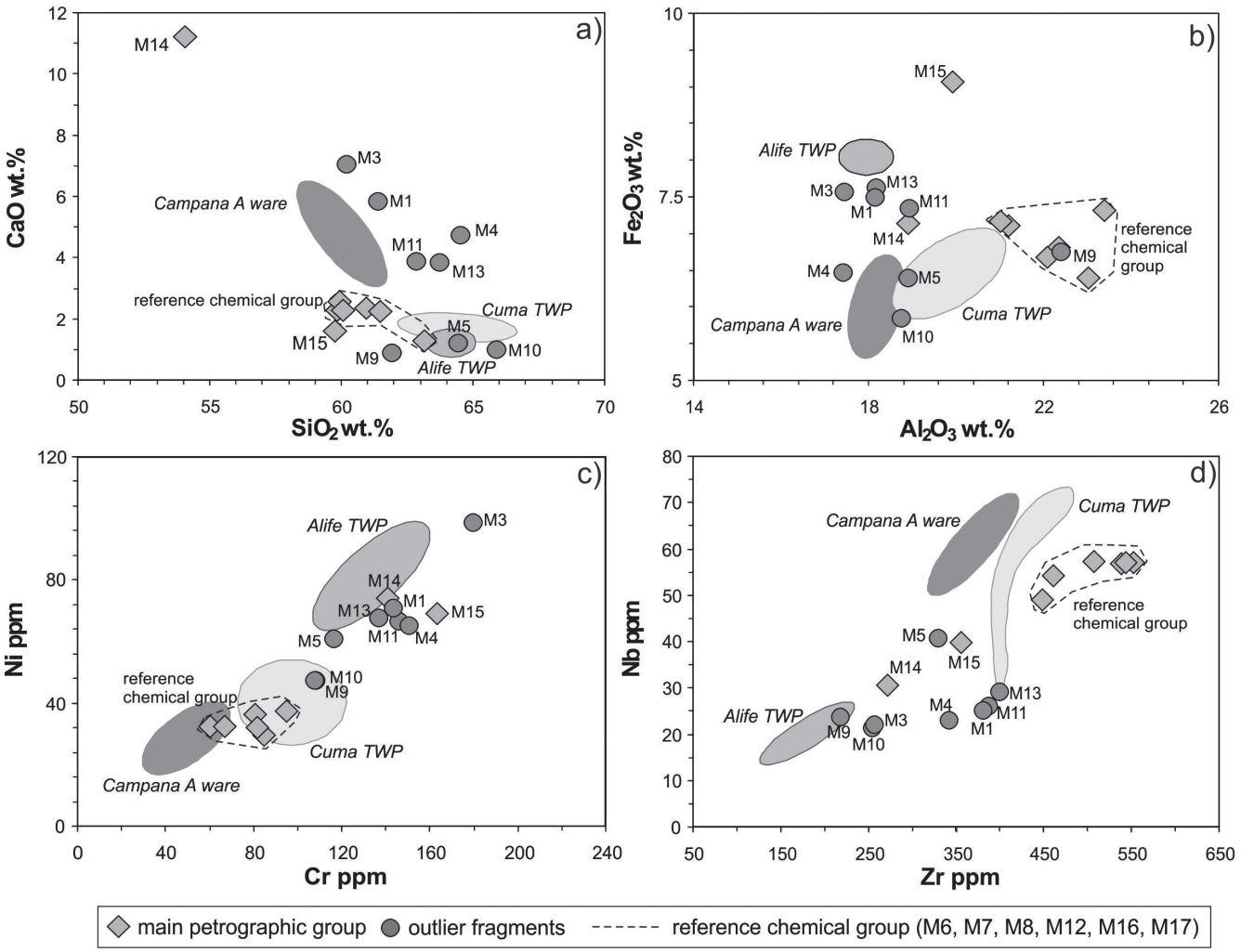

Figure 6. Representative binary diagrams of the major (wt%) and trace elements (ppm) for the analysed samples. The compositional fields of attested Alife (Grifa et al., 2013a; 2015) and Cuma (unpublished data) thin walled ware, together with Campana A ware (Giampaola et al., 2014; De Bonis et al., forthcoming), are reported for comparison.

could point to and attest a production from Pozzuoli, as also inferred on an archaeological basis.

All the other investigated samples, from an archaeological as well as an archaeometric point of view, seem to probably represent products of workshops located in a wide area between southern Tuscany and the Arno Valley.

Archaeometric studies, mainly based on typological and macroscopic analyses of ceramic bodies, have thus confirmed the classification of thin-walled vessels from the port of *Neapolis*. The results were then extended to vessels not included in the present investigation, but characterized by similar shapes and/or features of the ceramic body, allowing us to obtain a comprehensive view of the production of thin walled vessels from the port of *Neapolis*: this port represented a thriving stopover in which, since the late Republican age, productions of allogeneic origin, especially from Central Italy, are well documented. Starting from the Augustan age, it most probably became an important collection and distribution centre of local productions and other thin walled pottery from the Campania region.

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Table 5. Inferred provenance for the thin walled pottery.

Sample	Presumed archaeological provenance	Inferred provenance
M1	central Italy	southern Tuscany
M2	Campania	Neapolis
M5	central Italy	Arno valley
M3	central Italy	southern Tuscany
M6	Campania	Neapolis
M9	central Italy	southern Tuscany
M4	central Italy	southern Tuscany
M10	central Italy	southern Tuscany
M7	Neapolis (Local)	Neapolis
M8	Campania	Neapolis
M16	Neapolis (Local)	Neapolis
M15	Campania	Campania
M17	Campania	Neapolis
M12	Campania	Neapolis
M11	central Italy	southern Tuscany
M13	Tiber valley	southern Tuscany
M14	Ager Falernus or Pozzuoli	Pozzuoli

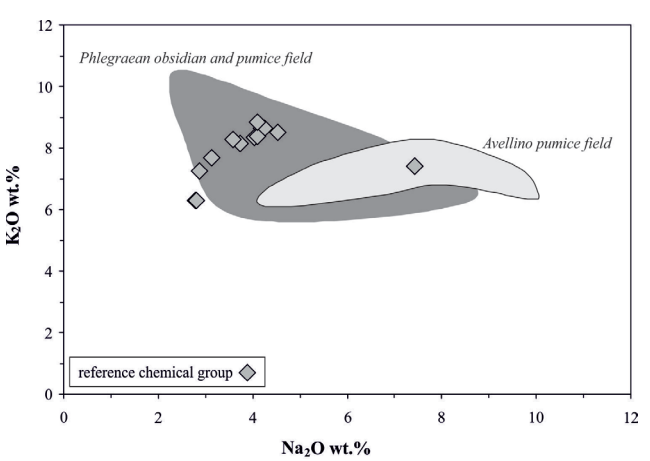

Figure 7. K_2O vs Na_2O diagram showing the comparison between the volcanic glasses analysed in some samples of the reference chemical group and the fields of Avellino pumice (Barberi et al., 1981; Morra et al., 2010 and references therein) and Phlegraean obsidian and pumice (Rosi and Sbrana, 1987; Melluso et al., 1995; Morra et al., 2010 and references therein).

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