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ORIGINAL PAPER

From the kilns to the fair: producing building materials at Faragola and *Canusium* (northern Apulia, Italy)

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Abstract Faragola and *Canusium* potters used Ca-rich clays—widely available nearby—for the production of building materials. The clayey materials were used as received, before being fired in the local kilns at temperatures between 600 and ~1000 ° C. No technological distinctions were made in relation to the type of object to be produced (tile, brick, etc). The investigated productions are compositionally distinguishable from both coarse wares for cooking and fine table ware produced in the same archaeological sites. A fine clayey material, very similar to that used for table ware, was supplied for the production of these building materials, which are chemically, mineralogically and petrographically very similar among themselves. Hence, the Faragola and *Canusium* bricks and tiles cannot be easily discriminated but the presence/absence of volcanites and volcanic glass represents an effective discriminating factor, able to indicate areas of different supplies within two main deposits: the Pleistocene marine and alluvial terraced deposits, typical of northern Apulia.

Keywords Faragola · Canusium · Building material · Geochemistry · Petrography · Bricks and tiles · Volcanite · Volcanic glass · Northern Apulia · Pleistocene · Marine deposit · Alluvial deposit · Clay

Introduction and objectives

The studies on Late Antique and Early Medieval artisanal activities in northern-central Puglia have greatly expanded only recently (Turchiano 2010). The archaeological investigations performed in some urban and rural areas led to the discovery of numerous production sites and multiple production indicators related to the processing of clay, glass and metal. Interesting data were acquired on brick production, through typological studies and the discovery of production areas in the city of *Canusium*, the capital of the *provincia Apulia et Calabria*, and in the rural site of Faragola, situated in the territory of the ancient *Ausculum*.

As part of the archaeological research, the study of bricks is of fundamental importance in establishing the chronology of the archaeological deposits as it provides significant contribution to the stratigraphic analysis. Reconstructing the production cycle of architectural materials, from the extraction of the raw materials to the use of the finished products, can provide indirect information on the theoretical and practical knowledge of the artisans, the dissemination of such knowledge, the availability or lack of certain raw materials and the social organisation of the building sites. In addition, the typological analysis combined with the close observation of dimensional characteristics, traces of processing and decorative elements helps to define the nature and organisation of production sites.

In Apulia, the study of Roman, Late Antique and Early Medieval manufacture is incomplete and disjointed. As it happens in other parts of Italy, the only exception is generally made for the stamped brick productions (see Gliozzo 2013 and references therein). At *Canusium*, the bricks stamped by the Bishop *Sabinus* (sixth century AD) have been investigated by Arthur and Whitehouse (1983), together with other central and southern Apulian productions (sixth to twelfth century AD). Another example is provided by the decorated tiles from

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the necropolis of Belmonte (Altamura; Ciminale et al. 1994); however, there is an almost total absence of systematic typological studies.

In this context, the accurate filing and typological analysis of Apulian bricks from Late Antique to Medieval sites (Baldasarre 2009) have been of fundamental importance for planning the present archaeometric research on the building materials found at Faragola and *Canusium*. From an archaeometric point of view, a few ceramic productions of northern Apulia have been systematically investigated, although including table ware or cooking ware or storage ware (Cioni et al. 2000; De Benedetto et al. 2004; Eramo et al. 2004, 2014; Gliozzo et al. 2005, 2010, 2014; Mangone et al. 2008; Thorn and Glascock 2010).

Hence, the main objective of this study was to characterise Faragola and *Canusium* building materials, in order to reconstruct the technological background and to infer provenance hypothesis. A further issue was to establish a compositional comparison between the production of building materials and the productions of coarse and fine wares from the same sites (Gliozzo et al. 2013, 2014), in order to verify whether the same supply basin was used.

Archaeological background

The presence of kilns for brick production and the great typological variability of building materials found at *Canusium* and Faragola provided the key starting point for this research.

In the suburbs of *Canusium*, the excavations carried out between 2001 and 2005 in St. Peter's quarter led to the discovery of a large religious complex, consisting of a three-nave church preceded by a courtyard with a portico and flanked by both residential and funeral structures. The complex was built by the powerful Bishop *Sabinus* (514–566 AD), who was a prominent ecclesiastical figure in southern Italy, skilled orator and diplomat, closely tied to the Church of Rome (Volpe et al. 2007, 2013; Volpe 2009). As documented in literary sources and archaeological data from *Canusium* and the entire territory of the diocese (especially from the *vici* of Barletta and Trani), *Sabinus* promoted intensive building activity, including both new constructions and the renovation of pre-existing religious buildings. Due to his intense building activity and his entrepreneurial ability, *Sabinus* has been described as a 'bishop manager' (Volpe 2014). He did not just complete only the construction of many religious buildings but also supervised the production of building materials, including the bricks with his monogram (in addition to other decorations alluding to Christian symbolism) found in all monuments associated with his activity (Baldasarre 2009; Giuliani and Baldasarre 2013).

It is likely that some of the workshops for the production of these bricks were located in the southern area of St. Peter's complex; in fact, from the Republican or Late Republican, a wide artisanal quarter was active there, as testified by the finding of numerous slags, wastes and moulds for lamps. With respect to the buildings, the *peripheral* location of the hill was perfect for the construction of the production plants, as it was well-served by roads and water but at a sufficient and safe distance. Indeed, the artisanal vocation of that area must have been stimulated by the immediate availability of clay, water and fuel.

Two kilns (A and B) were investigated (Figs. 1 and 2). The outer walls of a third kiln were further identified below a late sixth century AD *domus*. The kilns A and B showed a rectangular plan with a central corridor and a *praefurnium* located in the north-east side. Oriented along the north-east/south-west direction, the kilns can be typologically related to the Cuomo di Caprio (1971–1972) type II/b and the Le Ny (1988) type II. The lower firing chamber and the praefurnium of kiln A were almost entirely recovered, together with several pillars which originally sustained the intermediate perforated surface. The preservation state of kiln B was definitely better as both chambers (lower and upper) were preserved, as well as a portion of the perforated surface and its supporting pillars. The *praefurnium* showed a very short channel and peculiar building technique; in fact, also in the facade of the kiln, the tiles were turned so as to leave the flaps visible.

From a chronological point of view, kiln B was far older (Republican to Late Republican age) than kiln A, which may have been active at least until the construction phase of the religious complex. The subsequent construction of a residential building led to the abandonment of the kiln. It is a reasonable hypothesis to identify kiln A with one of the ateliers of the Bishop *Sabinus*, mainly based on chronological considerations.

The archaeomagnetic investigations performed by R. Lanza and E. Tema (University of Torino) dated kiln A to the Late Antiquity (personal communication). It is likely that the kiln had a temporary function, expressly built for the production of building materials to be used for the construction of the nearby religious complex, and then dismantled at the end of the building activities.

The artisanal activities promoted by *Sabinus* as by other bishops, acting at the same time as the owner and the buyer (Manacorda 2000), were not merely limited to building materials (brick, tuff, stone, wood, mortar) but also to the production of other ceramic, glass and metal objects. The bishop of Puglia, in fact, appeared as a promoter of ecclesiastical crafts which directly and/or indirectly involved ecclesiastical structures in all phases of the production process and perhaps even in the commercialization of the goods (Saguì 2002; Bernal Casasola 2010).

Another brick kiln was investigated at Faragola, in the territory of Ascoli Satriano, where a pre-Roman rural settlement, a Roman to Late Antique luxurious *villa* and an Early Medieval village were discovered (Volpe and Turchiano 2009,

Fig. 1 **a** Aerial view of the archaeological site of *Canusium*; **b** The kiln A; **c** The kiln B

2010, 2012). Next to the residential areas (a monumental *cenatio* and the large thermal bath), several iron and copper slags further indicated the presence of a metalworking site in the south-east portion of the site.

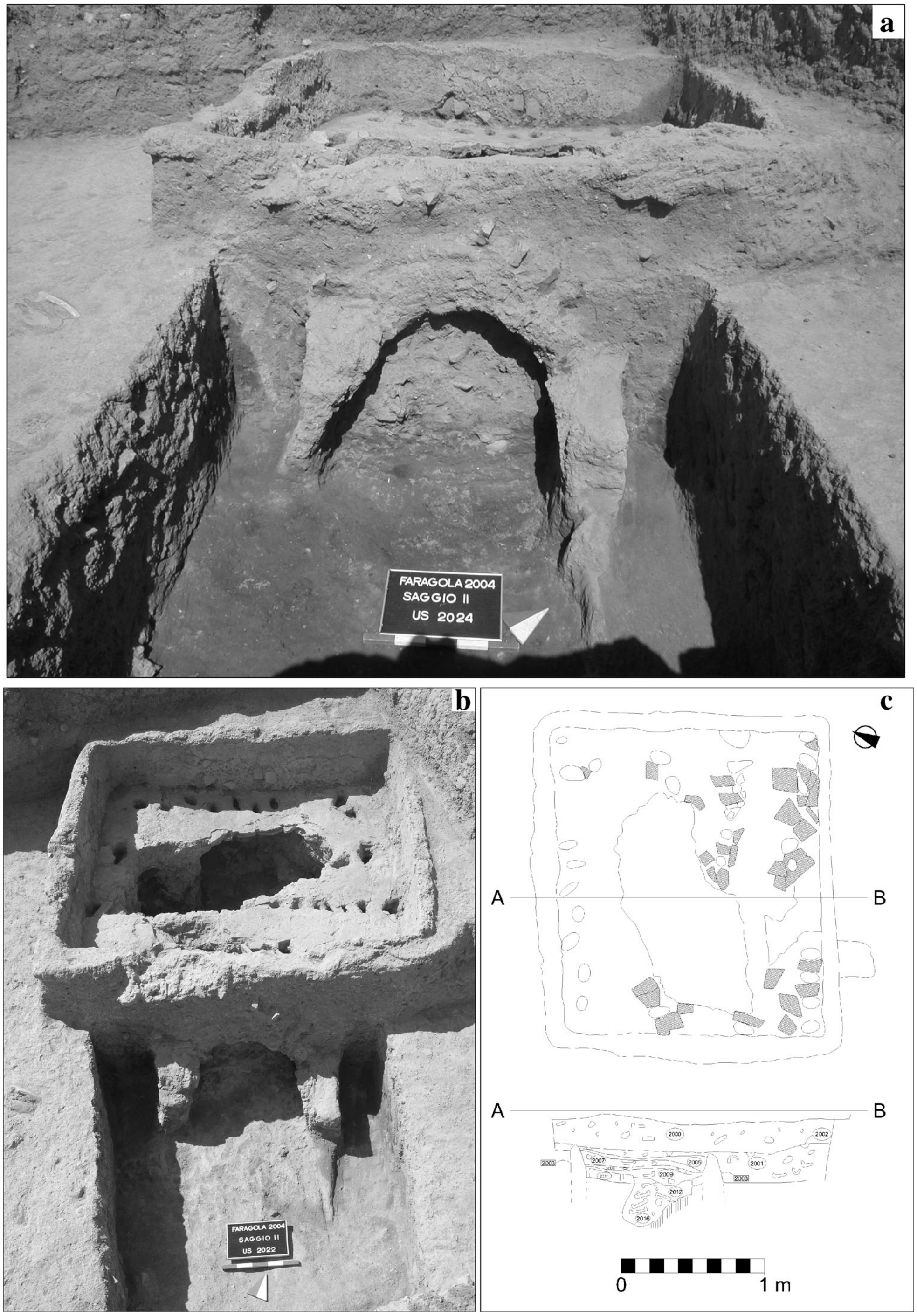
The brick kiln has a squared plan with a central corridor, similar to the Cuomo di Caprio (1971–1972) type II/b and the Le Ny (1988) type IIE. Oriented along a north-west/south-east direction, its walls were made of blocks of fired clay. The perforated surface (about 10–15 cm thick) was made of a mixture of fired clay and brick fragments. The holes for the passage of heat showed irregular shapes and sizes and appeared randomly distributed or approximately aligned in four irregular rows. A large gap in the central part of the perforated surface clearly indicated the causes of the abandonment of this kiln. Almost certainly, the uncontrolled rise in temperatures altered the firing process, melting together the sustaining pillars and the perforated surface, with the consequent occlusion of the *praefurnium*. In fact, the surfaces of the pillars showed evident traces of vitrification. The vault of the firing chamber was not preserved.

The archaeological data, the archaeomagnetic measurements on the kiln structure (Tema and Lanza 2005) and the ^{14}C dating of a wooden fragment (320–430 AD with 61 % probability; personal communication Cedad, Lecce) indicate a fourth to early fifth century AD chronology. Likewise at *Canusium*, this kiln was installed for temporary use, in connection with the construction or renovation phases of the *villa*. This reconstruction was corroborated by a great deal of evidence related to other temporary artisanal activities, such as a pit furnace for the melting of lead, below the floor of the dining room and other indicators of iron, stone and glass work.

Materials

The findsite and the typology guided the selection of 50 samples, 13 from Faragola and 37 from *Canusium* (Table 1; Fig. 3). Regarding the findsite, samples were collected among (a) bricks employed for the construction of the kiln structures, (b) bricks left inside the kilns after their collapse and abandonment and (c) bricks found in layers just outside the kiln and chronologically related to the life phase of the kiln. A few samples of fired clays were further taken from the kiln structures as well.

Fig. 2 **a**–**b** The kiln investigated at Faragola; **c** the plan of the kiln



At *Canusium*, 15 samples were taken from kiln B, 14 samples from kiln A and 6 samples from various walls of the settlement. The materials found inside kiln A represented the last firing production while materials related to the activity of kiln B were representative of an earlier production stage. Two samples were taken from bricks (*pedales*) stamped by *Sabinus*; these were found in layers contextual to the collapse of the facade of the San Pietro Basilica, whose construction was promoted by *Sabinus* himself. *Canusium* samples were divided as follows: 2 tiles (plus 2 uncertain), 5 imbrices, 2 rectangular bricks for paving (*opus spicatum*), 2 rhomboidal bricks, 2 hexagonal bricks, 1 triangular brick, 12 regular bricks, 2 bricks stamped by *Sabinus* and 1 brick/tile. All these samples were taken from fragmentary materials. A total of 6 fired clays was further sampled in different portions of the kilns.

Table 1 List of investigated samples with the indication of both the kiln and the stratigraphic unit where they were found. Their typological reference is indicated and the reference to Figure 3 has been added in brackets

Sample	Kiln	US	Type
Canusium			
SP 1	B	4240	Brick (SP_M1)
SP 2	B	4240	Brick (SP_M2)
SP 3	B	4218	Brick (SP_M3)
SP 4	B	4261	Brick or tile
SP 5	B	4237	Brick (SPM2/SP_M8)
SP 6	B	4250	Brick
SP 7	B	4237	Tile (SP_T2a)
SP 8	B	4225	Brick
SP 9	B	4225	Imbrex (PS_C3/C4–C6)
SP 10	B	4225	Imbrex (SP C3/C4)
SP 11	B	4263	Brick
SP 12	B	4221	Brick (SP_M3)
SP 13	–	1203	Brick (SP_M1)
SP 14	–	2209	Imbrex (SP_C2/C4–C7/C8)
SP 15	–	2209	Imbrex
SP 16	–	2209	Tile (?)
SP 18	–	2218	Imbrex
SP 19	–	2218	Tile (?)
SP 20	B	4622	Fired clay
SP 21	B	4223	Fired clay
SP 22	B	4220	Fired clay
SP 23	A	4015	Tile
SP 24	A	4014	Brick (SP_M2)
SP 25	A	4013	Brick (SP_M1)
SP 26	A	4013	Brick (SP_M1)
SP 27	A	4079	Rectangular brick for paving (SP_M9)
SP 28	A	4079	Rectangular brick for paving (SP_M9)
SP 29	A	4079	Rhomboidal brick (SP_M10)
SP 30	A	4079	Rhomboidal brick (SP_M10)
SP 31	A	4079	Hexagonal brick (SP_M11)
SP 32	A	4056	Hexagonal brick (SP_M11)
SP 33	A	4080	Triangular brick (SP_M12)
SP 34	A	4013	Fired clay
SP 35	A	4020	Fired clay
SP 36	A	4008	Fired clay
SAB 1	–	2209	Stamped *pedales*
SAB 2	–	2209	Stamped *pedales*
Faragola			
FAR 1		2012	Tile (FAR_T12)
FAR 2		2012	Tile
FAR 3		2012	Tile
FAR 4		1027	Tile (FAR_T6a)
FAR 5		2009	Tile
FAR 6		3001	Imbrex (FAR_C2)
FAR 7		3474	Brick (FAR_M6)
FAR 8		1118	Tile
FAR 9		1027	Tile
FAR 10		3474	Tile
FAR 11		3474	Tile
FAR 12		2008	Fired clay
FAR 13		2007	Fired clay

US stratigraphic unit

With respect to *Canusium*, the sample set collected at Faragola was reduced in number because several reference groups for this production were already available from a previous study (Gliozzo et al. 2014), together with the chemical and mineralogical-petrographical characterisation of locally outcropping clays (FARA 31, FARS 2-3 and TFA). At Faragola, six samples were taken from the kiln, while seven were taken from the walls of the *villa*. By a typological point of view, the samples from Faragola were classified as follows: nine tiles, one imbrex, one rectangular brick for paving (*opus spicatum*) and two fired clays, sampled in different portions of the kiln.

Methods

X-ray fluorescence

Samples were mechanically crushed in a planetary mill and manually ground into a powder in an agate mortar. Quantitative analyses were performed on powder discs obtained by pressing 6 g of sample (obtained by coning and quartering 10 g) on a support of boric acid. The X-ray fluorescence (XRF) apparatus was a Philips MagiX-Pro. Background and mass absorption intensities were calculated using calibrations based on 24 international geological reference materials. Loss on ignition (LOI) was determined by thermogravimetric way, heating samples to 1050 °C for about 1 h.

Statistical treatment of geochemical data

The statistical processing used the chemical composition of the major, minor and trace elements (except for loss on ignition and P_2O_5 values whose variability is heavily affected by weathering processes during burial) as variables. Principal component analysis (PCA) on the covariance matrix was performed without rotation of the axis, using major, minor and trace elements as variables. This statistical procedure is able to compress a dataset with many variables into a set with fewer

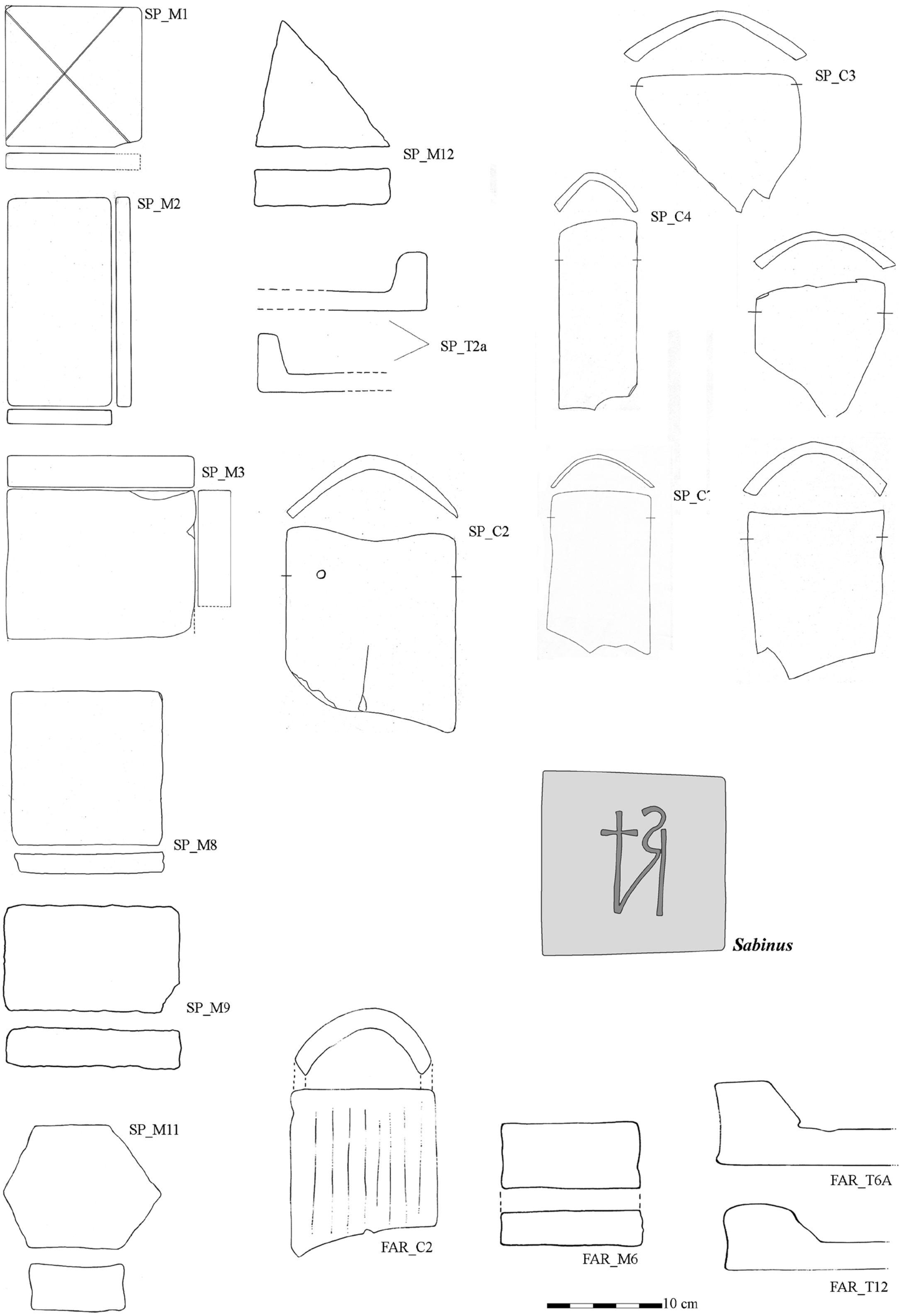


Fig. 3 Bricks, tiles and imbrices: the typology and the stamp of *Sabinus*

variables, called principal components, which explain as much of the variance in the original dataset as possible. The cluster analysis used the average linkage, based on the quadratic Euclidean distance.

Optical microscopy and scanning electron microscopy

The samples were prepared in thin sections, which were always cut perpendicularly to the thickness of the brick. Optical microscopy (OM) studies focused on phase identification, petrography and textural features. The microchemical composition of both phases and matrices were estimated by energy-dispersive spectrometry (EDS) coupled to scanning electron microscopy (SEM). The thin sections were carbon-coated. A total of 10 square analyses (20×20 μm side) per sample were performed on the matrices while point analyses were performed on single grains. The instrument was a Philips XL 30 scanning electron microscope, equipped with an energy-dispersive spectrometer EDAX-DX4, working at 20 kV. A variety of natural silicates, oxides and synthetic materials was used as primary and quality control standards. Observations were mainly performed in backscattered electrons.

Results

Bulk chemistry

Measured by X-ray fluorescence, the bulk chemistry of the ceramic samples from Faragola and *Canusium* is shown in Tables 2 and 3, respectively. Considering the entire collection, the amount of SiO_2 varied from 53.2 to 59.7 wt%, with an average value of 57.2 wt% (1.1 standard deviation; sd hereafter), Al_2O_3 contents varied between 12.0 and 15.7 wt%, with an average value of 14.2 wt% (0.9 sd), while CaO contents varied from 13.2 to 23.3 wt%, with an average value of 17.4 wt% (2.0 sd). The ternary ACS (Al_2O_3–CaO–SiO_2) diagram (Levin et al. 1964) characterised both collections as Ca-rich samples (Fig. 4a).

Fe_2O_3 contents ranged from 3.4 to 5.3 wt%, with an average value of 4.5 wt% (0.4 sd), while TiO_2 amounts varied between 0.52 and 0.70 wt%, with an average value of 0.62 wt% (0.04 sd). Fe_2O_3 was positively correlated not only to TiO_2 ($R^2=0.8176$) and Al_2O_3 contents ($R^2=0.6025$) but also to the amounts of several minor elements such as Ni ($R^2=0.6889$, although excluding sample FAR 8) and, less linearly, Co ($R^2=0.6213$). Also, Fe_2O_3 contents were negatively correlated to CaO contents ($R^2=0.7372$). Further correlations among components appeared weak ($R^2<0.35$) and non informative.

It was impressive how the average values obtained for these collections were characterised by very similar average values in terms of major, minor and trace element contents; although not completely convincing, only Zr and Ba weakly discriminated these two productions (Fig. 4b).

The PCA analysis has been used to identify which major, minor or trace element content explained most of the variance in the dataset (Fig. 5a) and to see how the samples plotted against one another (Fig. 5b). PC1 was strongly influenced by Rb, K_2O, Ba, La, Ce, Th, Na_2O, Fe_2O_3, MgO (positively), CaO and MnO (negatively); conversely, PC2 was mainly influenced by Sr, Co, Al_2O_3 (positively) and Pb (negatively).

In Fig. 5b, all samples were included in the upper-right quadrant of the loading plot. Samples from *Canusium* and Faragola were mixed, even though almost all Faragola samples were concentrated in the upper portion of the diagram, except for FAR 8. Among raw materials, the clays outcropping nearby Faragola and the fired clays sampled from the kilns were above the ceramics which instead plotted together to the clay FARA 31 (i.e. the clay found in the seventh century settling tank; see Gliozzo et al. 2014). Conversely, the fired clays sampled from the *Canusium* kilns plotted together with the ceramic samples and they spread along the entire diagram. However, the lower part of the diagram is occupied by *Canusium* samples only, except for sample FAR 8. The distance of the sample SP 16 was due to very high Sr contents, associated with high amounts of CaO and Ba corresponding to the frequent presence of limestone.

In summary, the chemical composition of Faragola and *Canusium* specimens was so similar that it was hard to discriminate these two productions. The average values of individual components such as Zr and Ba or the multivariate statistic such as the PCA were able to provide some discrimination, although not avoiding overlaps.

Texture and matrix composition

All ceramics showed a seriate fabric (i.e. crystal sizes varying continuously from the smallest to the largest), with an averagely fine granulometry. The ceramic body was generally homogeneous, non-oriented and microporous (‘Ho’ in Table 4). Several samples showed compositional bands or areas (‘He’ in Table 4), due to variable CaO contents in the matrices. A few samples showed such a high degree of sintering that it was impossible to tell what their original texture was (‘U’ in Table 4). Sintering varied from very low (vL; Fig. 6a) to low (L), medium (M; Fig. 6b), high (H) and very high (vH; Fig. 6c). There have been cases in which the attribution was unclear; therefore, a double and wider choice (e.g. LM=low/medium) was made. The chemical composition of the matrices was measured (Table 5), except for those samples with a very high level of sintering. CaO contents were comparable while SiO_2 and K_2O were depleted in matrices, which in turn resulted enriched in Al_2O_3, MgO and Na_2O and, to a lesser extent, Fe_2O_3.

Mineralogy and petrography

The mineralogical and petrographical investigations distinguished the sample set into three groups (Table 4). The main

Table 2 The bulk chemical composition of building materials from *Canusium*

Sample	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MgO	MnO	Na_2O	K_2O	CaO	P_2O_5	LOI	Total	Nb	Zr	Y	Sr	Rb	Ni	Cr	V	Ba	La	Ce	Pb	Co	Th	U	Zn
SP 1	53.73	0.62	13.92	4.46	2.63	0.09	0.83	2.34	14.69	0.17	6.39	99.87	16	146	26	330	102	40	112	106	242	24	56	26	16	10	4	84
SP 2	53.08	0.61	13.57	4.33	2.42	0.09	0.70	2.32	15.05	0.19	7.52	99.87	14	143	25	304	90	42	107	114	251	24	39	25	16	11	3	84
SP 3	53.20	0.58	12.92	4.15	2.99	0.09	0.99	2.29	16.42	0.18	6.06	99.86	14	142	25	389	88	41	114	104	281	23	42	24	15	10	2	81
SP 4	55.50	0.62	14.06	4.64	2.24	0.09	0.81	2.25	15.03	0.19	4.44	99.86	16	152	26	346	96	42	129	107	253	24	72	13	18	10	3	73
SP 5	51.97	0.59	13.24	4.16	2.22	0.09	0.46	2.29	16.83	0.18	7.85	99.86	13	135	24	371	91	39	94	101	288	25	43	23	16	9	3	79
SP 6	53.66	0.62	14.09	4.49	2.28	0.08	0.85	2.14	15.40	0.18	6.09	99.87	15	140	25	305	95	42	107	99	283	25	34	25	16	10	4	83
SP 7	56.98	0.58	12.42	4.36	1.75	0.09	0.96	2.61	15.55	0.16	4.39	99.86	16	153	27	342	103	40	134	103	255	27	59	21	15	9	4	93
SP 8	54.00	0.58	12.69	4.19	2.43	0.08	1.23	2.49	16.55	0.16	5.47	99.86	14	139	25	427	79	41	133	89	229	19	56	17	14	9	2	97
SP 9	51.19	0.55	11.89	3.86	2.65	0.08	0.76	2.01	19.01	0.23	7.65	99.86	14	136	24	445	80	39	117	76	273	18	34	22	13	9	2	93
SP 10	53.37	0.59	13.42	4.31	2.19	0.09	0.78	1.95	17.31	0.20	5.66	99.87	14	140	25	342	91	40	110	83	262	25	57	23	16	10	3	81
SP 11	49.24	0.59	13.37	4.02	2.49	0.08	0.42	2.22	14.29	0.17	13.00	99.88	13	129	23	283	80	38	100	100	233	23	56	21	15	7	3	73
SP 12	53.50	0.58	13.22	4.23	2.47	0.09	0.68	1.97	17.43	0.21	5.47	99.87	14	141	25	351	97	40	116	98	266	20	40	33	16	10	3	81
SP 13	53.14	0.60	13.43	4.34	2.41	0.09	0.79	2.58	14.87	0.18	7.45	99.87	14	136	26	307	98	38	96	101	285	31	47	30	16	10	4	80
SP 14	54.38	0.67	15.05	5.00	2.79	0.10	1.18	2.34	14.29	0.33	3.74	99.84	18	141	27	360	105	46	115	107	394	30	59	23	18	11	5	95
SP 15	50.33	0.47	10.77	3.09	1.96	0.08	0.79	1.77	20.52	0.26	9.84	99.87	13	132	22	354	84	31	94	71	329	27	34	17	12	9	3	61
SP 16	48.13	0.54	12.41	3.57	2.31	0.06	1.08	1.10	21.11	0.16	9.27	99.74	14	132	28	1517	75	40	99	113	452	20	47	13	14	13	0	71
SP 18	51.49	0.50	11.37	3.54	1.52	0.07	1.32	1.44	19.15	0.17	9.31	99.87	13	143	23	343	66	33	93	78	316	18	58	17	14	10	2	64
SP 19	55.41	0.62	14.16	4.38	2.43	0.09	0.88	2.35	13.95	0.19	5.40	99.87	14	163	26	292	96	42	101	63	327	22	37	22	16	13	3	85
SP 20	53.57	0.55	13.00	3.92	1.79	0.09	0.62	2.35	16.57	0.20	7.22	99.88	13	141	23	287	97	36	81	99	285	24	41	26	15	9	3	74
SP 21	54.37	0.51	11.53	3.75	1.61	0.08	1.35	1.69	17.92	0.20	6.86	99.87	13	131	24	364	62	35	109	89	240	21	64	16	12	9	3	87
SP 22	52.40	0.51	11.24	3.77	1.63	0.09	1.21	2.21	18.35	0.19	8.29	99.87	12	136	25	397	82	38	98	83	269	21	40	36	13	9	2	90
SP 23	53.49	0.61	13.80	4.39	2.15	0.08	0.69	2.44	14.61	0.18	7.43	99.86	15	150	25	340	102	42	101	88	323	23	32	30	15	10	3	79
SP 24	52.89	0.60	13.55	4.30	2.80	0.09	0.66	2.08	16.74	0.27	5.91	99.87	15	139	25	383	93	41	107	81	283	18	32	26	16	10	3	81
SP 25	54.28	0.62	13.83	4.33	2.29	0.09	0.70	2.10	16.12	0.18	5.34	99.87	15	137	25	334	96	42	112	93	228	19	67	22	16	11	4	83
SP 26	54.77	0.59	13.56	4.23	2.44	0.09	0.74	2.09	16.03	0.18	5.15	99.87	14	140	25	319	94	40	106	97	258	26	46	24	15	11	3	81
SP 27	53.92	0.61	13.77	4.63	2.28	0.10	0.70	2.28	14.89	0.22	6.48	99.86	14	143	25	349	97	42	108	88	328	26	52	25	17	10	3	82
SP 28	55.12	0.67	14.91	5.11	2.85	0.11	0.79	2.38	13.60	0.23	4.10	99.86	15	144	27	353	101	46	123	104	327	25	56	18	19	10	4	87
SP 29	52.92	0.60	13.72	4.25	2.28	0.09	0.82	2.24	16.38	0.18	6.39	99.86	14	144	25	351	95	40	110	97	321	23	37	20	17	11	3	72
SP 30	53.34	0.58	13.90	4.32	2.29	0.09	0.80	2.08	16.27	0.22	5.99	99.86	14	129	25	367	92	40	114	97	277	26	62	16	16	9	4	71
SP 31	53.97	0.60	13.97	4.56	2.43	0.09	0.70	2.49	13.98	0.25	6.82	99.86	14	141	26	358	103	42	114	90	313	25	56	37	16	9	3	83
SP 32	52.76	0.58	13.33	4.39	2.26	0.08	0.55	2.33	14.82	0.20	8.57	99.86	13	136	24	340	96	39	111	107	283	22	61	33	15	9	3	84
SP 33	53.48	0.59	14.00	4.39	2.51	0.09	0.77	2.10	15.56	0.19	6.19	99.87	16	149	26	336	98	40	108	80	265	26	35	26	15	12	3	84
SP 34	55.18	0.52	12.83	3.83	1.70	0.09	0.74	1.78	16.81	0.17	6.24	99.87	13	137	24	305	91	36	108	92	256	27	48	24	14	9	3	72
SP 35	50.60	0.52	12.80	3.59	1.97	0.08	0.42	2.24	15.43	0.23	12.00	99.88	12	126	22	340	86	34	86	94	267	18	39	26	13	7	3	70
SP 36	48.81	0.50	12.80	3.57	1.93	0.08	0.35	1.91	15.71	0.23	14.00	99.88	12	121	20	282	90	32	87	113	230	23	43	28	13	8	3	67
SAB 1	56.03	0.66	15.33	5.09	3.10	0.10	1.16	2.45	12.88	0.76	2.30	99.85	16	163	29	392	104	46	117	118	320	28	65	18	16	14	3	104
SAB 2	55.17	0.59	14.09	4.37	2.80	0.08	1.08	2.12	14.50	0.23	4.84	99.86	14	147	25	344	95	39	106	89	285	21	54	28	14	10	3	81
Minimum	48.13	0.47	10.77	3.09	1.52	0.06	0.35	1.10	12.88	0.16	2.30	–	12	121	20	282	62	31	81	63	228	18	32	13	12	7	0	61

Table 2 (continued)

Sample	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MgO	MnO	Na_2O	K_2O	CaO	P_2O_5	LOI	Total	Nb	Zr	Y	Sr	Rb	Ni	Cr	V	Ba	La	Ce	Pb	Co	Th	U	Zn
Maximum	56.98	0.67	15.33	5.11	3.10	0.11	1.35	2.61	21.11	0.76	14.00	–	18	163	29	1517	105	46	134	118	452	31	72	37	19	14	5	104
n=35	53.23	0.58	13.30	4.21	2.30	0.09	0.82	2.16	16.07	0.22	6.90	–	14.1	140.5	24.9	377.0	91.6	39.6	107.5	94.9	285.9	23.4	48.6	23.6	15.2	9.9	3.0	80.8
St.dev.	1.96	0.05	1.02	0.43	0.39	0.01	0.25	0.31	1.85	0.10	2.44	–	1.3	8.7	1.7	193.4	9.9	3.4	11.8	12.4	45.2	3.3	11.1	5.8	1.6	1.4	0.8	9.1

Oxides are expressed as wt%, and minor and trace elements as ppm

criterion was the presence and the type of glass; the latter being absent in group 1 (‘no glass’), associated with feldspars and clinopyroxene (glass type I) in volcanites of group 2, isolated (glass type II) but accompanied by holocrystalline lithic fragments made of feldspars and clinopyroxene in group 3.

Figures 7 and 8 provide numerous examples of lithic fragments of both groups 2 and 3 from Faragola (Fig. 7) and *Canusium* (Fig. 8), while Table 6 includes the chemical composition of the glass types I and II and their CIPW norm. It should be noted that (a) the two types of glass mainly differed based on Al_2O_3, SiO_2 and CaO contents; (b) glass I has orthoclase, albite, anorthite, olivine, hypersthene, ilmenite and corundum (in order of relative abundance) in the CIPW norm, indicating therefore a silica-undersaturated, subaluminous and subalkaline rock; (c) glass II has orthoclase, albite, anorthite, hypersthene, quartz, ilmenite and diopside (in order of relative abundance) in the CIPW norm, indicating therefore a silica-saturated, subaluminous and subalkaline rock.

Group 1 (no glass) was further characterised by (a) ubiquitous quartz, generally of small dimensions (<200 μm) but of larger dimensions in sample SP 16; (b) ubiquitous K-feldspar, with comparable dimensions to that of quartz, showing high Ba and Sr contents in sample SP 27; (c) plagioclases, showing the entire compositional range, but being prevalently Na-rich (albite-andesine); (d) rare to sporadic clinopyroxene, except for sample SP 27 with abundant phenocrysts; (e) rare pargasite-type amphibole; (f) very rare foids, observed in sample FA 9 only (nepheline); (g) very rare forsteritic olivine, observed in sample SP 25 only; (h) rare to sporadic lithic fragments, also related to sedimentary (limestone and/or sandstone) and metamorphic environments; and (i) variable micropalaeontological content (foraminifera and molluscs) or their traces remained after firing. Further phases such as staurolite, paragonite and chloritoid were occasionally found, while grog was observed in sample FA 12.

Group 2 was further characterised by (a) ubiquitous quartz of small dimensions (<200 μm), often showing high sphericity in sample SP 10; (b) ubiquitous K-feldspar, often present as phenocrysts, showing high Ba and Sr contents in sample FA 7; (c) plagioclases, showing the entire compositional range, but being prevalently Ca-rich (labradorite-bytownite); (d) clinopyroxene generally abundant and of large dimensions, except for sample SP 6; (e) frequent amphibole of variable composition, such as kaersutite, pargasite, sadanagaite and hornblende; (f) frequent nepheline and leucite; (g) sporadic forsteritic olivine; (h) rare to frequent lithic fragments related to volcanic environment; and (i) variable micropalaeontological content (foraminifera and molluscs) or their traces remained after firing. Further phases such as orthopyroxene were typical of samples SP 12 and SP 14; the

Table 3 The bulk chemical composition of building materials from Faragola

Sample	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MgO	MnO	Na_2O	K_2O	CaO	P_2O_5	LOI	Total	Nb	Zr	Y	Sr	Rb	Ni	Cr	V	Ba	La	Ce	Pb	Co	Th	U	Zn
FAR 1	52.68	0.58	13.54	4.27	1.94	0.10	0.84	2.67	15.73	0.20	7.31	99.86	15	169	25	358	107	38	104	99	338	23	37	26	17	11	3	80
FAR 2	54.79	0.60	13.97	4.32	2.23	0.10	1.01	2.19	15.49	0.17	5.01	99.86	15	167	25	340	92	41	105	92	300	25	56	19	16	12	3	83
FAR 3	55.07	0.59	13.77	4.38	1.90	0.09	1.25	2.50	14.63	0.24	5.43	99.85	18	176	25	338	109	41	104	104	330	26	59	29	16	13	4	87
FAR 4	55.80	0.58	12.56	4.50	1.89	0.11	0.80	2.24	15.89	0.60	4.90	99.86	15	167	26	335	97	41	120	93	297	27	46	18	16	10	4	89
FAR 5	54.33	0.60	13.53	4.33	2.05	0.10	0.87	2.29	15.89	0.21	5.67	99.86	16	161	25	334	103	41	114	96	324	25	47	27	15	11	4	86
FAR 6	52.67	0.55	13.61	4.11	2.11	0.11	1.00	2.58	15.89	0.26	6.96	99.84	18	167	24	392	115	37	87	85	435	25	64	29	15	13	4	79
FAR 7	49.55	0.55	12.94	3.89	1.89	0.10	0.58	3.03	14.90	0.22	12.20	99.83	16	153	23	432	104	37	88	92	537	22	48	31	15	12	3	78
FAR 8	50.72	0.53	12.15	4.15	4.24	0.10	1.34	1.98	17.92	0.17	6.53	99.84	17	130	23	466	135	59	119	92	374	25	50	24	16	13	4	84
FAR 9	52.58	0.59	13.45	4.37	2.47	0.11	0.77	2.11	17.13	0.20	6.09	99.86	14	162	26	361	97	41	102	82	310	29	56	23	17	12	3	85
FAR 10	52.54	0.61	14.00	4.43	2.93	0.10	1.12	2.17	16.57	0.23	5.15	99.85	19	146	24	361	120	48	114	96	342	25	65	26	17	13	4	86
FAR 11	55.26	0.54	12.41	3.87	1.71	0.10	1.07	2.24	16.08	0.51	6.07	99.85	16	173	25	351	100	37	105	80	392	25	37	23	13	12	3	85
FAR 12	53.27	0.53	12.58	3.89	1.44	0.13	0.50	2.57	17.14	0.26	7.55	99.86	12	165	24	300	96	36	98	87	379	27	45	30	16	10	3	76
FAR 13	50.51	0.50	11.68	3.46	1.42	0.12	0.41	2.35	18.38	0.24	10.80	99.87	11	147	22	295	86	34	78	82	390	20	32	24	15	8	3	70
Minimum	49.55	0.50	11.68	3.46	1.42	0.09	0.41	1.98	14.63	0.17	4.90	–	11	130	22	295	86	34	78	80	297	20	32	18	13	8	3	70
Maximum	55.80	0.61	14.00	4.50	4.24	0.13	1.34	3.03	18.38	0.60	12.20	–	19	176	26	466	135	59	120	104	537	29	65	31	17	13	4	89
n=13	53.06	0.56	13.09	4.15	2.17	0.10	0.89	2.38	16.28	0.27	6.90	–	15.5	160.2	24.4	358.7	104.7	40.8	102.9	90.8	365.2	24.9	49.4	25.3	15.7	11.5	3.5	82.2
St.dev.	1.96	0.03	0.75	0.30	0.74	0.01	0.28	0.28	1.11	0.13	2.23	–	2.2	12.4	1.1	46.0	12.4	6.2	12.2	6.9	63.3	2.2	9.9	3.9	1.1	1.4	0.5	5.1

Oxides are expressed as wt%, and minor and trace elements as ppm

former also showed large crystals of biotite and phlogopite while grog was found in the latter. Also, chloritoid was rarely found in sample SP 10.

Group 3 was further characterised by (a) ubiquitous quartz of small dimensions (<200 μm), showing high sphericity in sample SP 28; (b) ubiquitous K-feldspar, sporadically present as phenocrysts; (c) plagioclases, showing the entire compositional range, but generally being Ca-rich (labradorite-bytownite) and of large dimensions; (d) rare to frequent clinopyroxene, generally of small dimensions; (e) rare pargasite-type amphibole; (f) very rare foids, observed in SP 19 only (leucite); (g) olivine not found; (h) sporadic to frequent fragments of holocrystalline rock mainly made of K-feldspar/plagioclase and subordinate clinopyroxene (like a monzonite/gabbro); and (h) sporadic micropalaeontological content (foraminifera and molluscs) or their traces remained after firing.

To conclude the mineralogical and petrographical description of these ceramics, some more features are listed. Phyllosilicates were ubiquitous and generally very abundant. Micas (especially Ti-rich biotite) prevailing over Mg–Fe chlorites were a common feature of the entire collection. Other minor phases were garnet, generally with a majority of almandine-component, which was sporadic to frequent in samples from *Canusium* while rare in Faragola ones. Accessory minerals were invariably represented by apatite, Fe-oxides (sometimes framboidal), ilmenite, titanite and zircon. Chert is ubiquitous in all groups.

Discussion

Local production and provenance of raw materials

Building materials sampled at Faragola and *Canusium* were very similar in terms of bulk chemical composition, while several distinctions were possible based on their mineralogical and petrographical assemblage. Both collections used Ca-rich clays, as evidenced by the absence of spatic calcite (OM) and the close chemical similarity among CaO contents determined by bulk and matrix analysis (XRF and SEM-EDS, respectively). Evidenced by the same comparison, the depletion in SiO_2 and K_2O in the fine matrix and the enrichment in Al_2O_3, MgO, Fe_2O_3 and Na_2O were in agreement with the mineralogical observations, describing the fine matrix rich in small and abundant phyllosilicates (esp. biotite) and the larger fraction of the skeleton mostly made of quartz and K-feldspars.

Both collections used materials as received as evidenced by the unsorted grain size of phases and lithic fragments constituting the ceramic body. The overall granulometry was fully comparable to that of fine and painted wares found in these sites and investigated in earlier works (Gliozzo et al. 2005, 2010, 2013, 2014). Also, the bulk chemical composition of

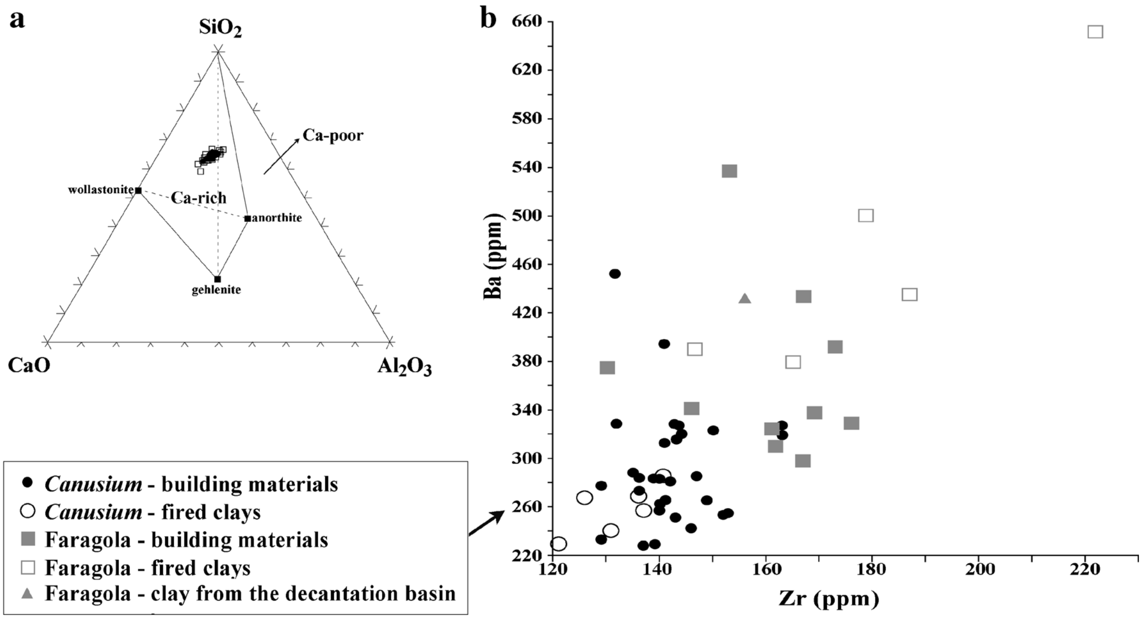


Fig. 4 **a** Bulk chemical composition of the samples, reported on ACS diagram. Mineral compositions and compatible phases are also shown. The *open squares* represent the samples from *Canusium* while the *filled circles* are the samples from Faragola. **b** Binary diagram Zr:Ba showing the samples from Faragola and *Canusium* partially discriminated

building materials was comparable to that of fine and painted wares and, consequently, well-distinguishable to that of coarse wares produced in the same localities. The binary diagram provided in Fig. 9a exemplifies this assumption, clearly distinguishing coarse wares, on one side, and fine/painted wares and building materials, on the other. The example provided here was based on their SiO_2 and CaO contents, but such a neat distinction was equally provided by all other major, minor and trace measured components. Interestingly, the presence of wads was a common feature of Faragola coarse ware that has never been found in building materials, therefore, representing a further discriminating component.

By eliminating coarse wares and enlarging the observation scale of the same binary diagram (Fig. 9b), it was possible to notice that fine and painted wares could be distinguished by building materials as well, even though the discrimination was less neat than the previous one. This distinction worked until we observed the material category; in fact, the dotted line separated two areas broadly corresponding to the preferential distribution of fine and painted wares (lower portion) or of building materials (upper portion). Conversely, this distribution was not influenced by the findsite, as demonstrated by the large fields drawn in the same binary diagram, indicating the distribution of Faragola, *Canusium*, *Herdonia* and Posta Crusta materials.

Hence, based on the bulk chemical composition of the investigated ceramics, it was possible to distinguish building materials from coarse wares and from fine/painted wares produced in the same site or in the neighbouring ones. Conversely, the attempts to discriminate building materials from *Canusium* from those of Faragola provided unconvincing results, based on the Zr:Ba ratio and multivariate statistics.

It is further worth noticing that the chemical composition of the tiles, bricks and imbrices was very similar to that of (a) the fired clays sampled as part of the kiln structures and (b) the clay found in the seventh century AD settling tank that, centuries later, will be used for the production of fine painted ware (Gliozzo et al. 2014). This evidence clearly indicated the use of raw selected materials, not requiring laborious processing.

The dendrogram provided in Fig. 10 includes fine and painted wares from San Giusto, *Herdonia*, Posta Crusta, together with those from Faragola and *Canusium*. The distinction between table ware and building materials was evident, except for two samples (FAR 8 and SP 16) which were already indicated as outliers. The latter samples were allocated in the close proximity of the Faragola raw clays, although separating themselves with a significant distance. All the other samples of building materials were mixed at the top of the dendrogram, together with the fired clays from the kiln structures and the raw material from the Faragola settling tank.

It is reasonably conceivable that different raw materials were used for building materials, fine table ware and coarse cooking ware, respectively, while it is not possible to indicate the related sources with the same level of certainty. The mineralogical and petrographical assemblages described so far in north Apulian productions were various but lacking of strong discriminant features as expected based on regional geology (Eramo et al. 2004, 2014; Gliozzo et al. 2005, 2010, 2013, 2014). The presence or the absence of clinopyroxene and volcanites allowed the creation of the groups 1–3.

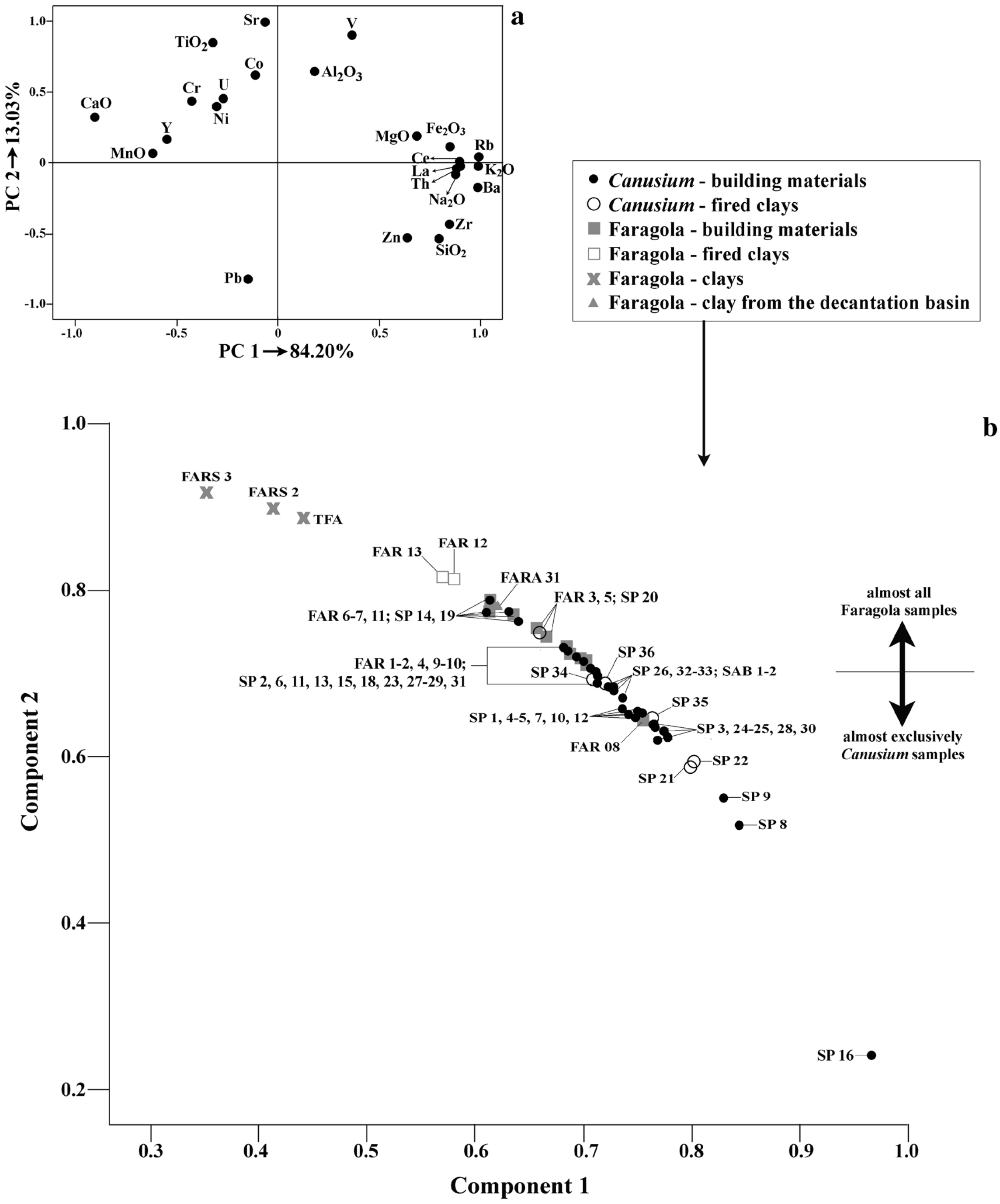


Fig. 5 2-D charts plotting the projections of different variables (major, minor and trace element contents) in **a**; compositional data per sample in **b** on a reduced two dimensions by first two principal components. In diagram **a**, the first three principal components account for 98.7 % of the total variation, with the first, second and the third principal components accounting individually for 84.208, 13.029 and 1.471 %, respectively. In diagram **b**, the first three principal components account for 99.8 % of the total variation, with the first, second and the third principal components accounting individually for 93.301, 5.696 and 0.793 %, respectively

Group 1 showed no volcanic glass and rare clinopyroxene, hence, using a completely different type of raw material than that used for groups 2 and 3 where both these components were frequent. Widely used for the production of a large part of the Apulian fine painted wares, the terraced marine deposits may be addressed as the potential source of the group 1 productions; however, also sub-Apennine clays may have further provided a suitable source for raw materials.

Both group 2 and 3 showed clinopyroxene and volcanites, and further distinction based on their relative amounts can be misleading. In fact, the total amount of lithic fragments in the ceramic body may be affected by settling processes or, more

Table 4 The mineralogical characterisation of ceramics and fired clays

	Site	Sample	Kiln	Type	Matrix	Sintering	K-feldspar	Plagioclase	Calcite I	Clinopyroxene
Group 1	*Canusium*	SP 2	B	Brick	Homogeneous	vL	–	–	A	–
	Canusium	SP 3	B	Brick	Homogeneous	vL	R (phenocrysts)	–	–	–
	Canusium	SP 5	B	Brick	Homogeneous	M	–	Mainly sodic	–	–
	Canusium	SP 8	B	Brick	Uncertain	H			–	–
	Canusium	SP 15	–	Imbrex	Heterogeneous	M	–	–	A (reacting)	S
	Canusium	SP 16	–	Brick	Heterogeneous	LM	F (phenocrysts)	–	–	–
	Canusium	SP 18	–	Imbrex	Homogeneous	M	–	–	S	S
	Canusium	SP 20	B	Clay	Homogeneous	M	–	Mainly sodic	A (reacting)	–
	Canusium	SP 21	B	Clay	Homogeneous	vH	–	–	–	S
	Canusium	SP 22	B	Clay	Homogeneous	vL	–	–	A	–
	Canusium	SP 25	A	Brick	Homogeneous	L	–	–	A	–
	Canusium	SP 26	A	Brick	Uncertain	vH	–	–	–	–
	Canusium	SP 27	A	Brick	Homogeneous	LM		Mainly sodic	A	A (phenocrysts)
	Canusium	SP 30	A	Brick	Homogeneous	MH	–	–	–	R
	Canusium	SP 31	A	Brick	Homogeneous	M	–	Mainly sodic	–	–
	Canusium	SP 32	A	Brick	Homogeneous	LM	–	–	vA	–
	Canusium	SP 36	A	Fired clay	Homogeneous	vL	–	–	A	vR
	Faragola	FA 9	–	Tile	Homogeneous	MH	–	–	–	vR
	Faragola	FA 12	–	Fired clay	Heterogeneous	L	–	–	S	–
	Faragola	FA 13	–	Fired clay	Homogeneous	vL	–	Mainly sodic	VA	vR
Group 2	*Canusium*	SP 6	B	Brick	Heterogeneous	L	–	–	VA	R
	Canusium	SP 7	B	Tile	Uncertain	vH	R (phenocrysts)	Mainly calcic	–	S
	Canusium	SP 10	B	Imbrex	Homogeneous	MH	F (phenocrysts)	–	–	A (phenocrysts)
	Canusium	SP 11	B	Brick	Homogeneous	vL	–	–	vA	F (phenocrysts)
	Canusium	SP 12	B	Brick	Homogeneous	H	F (phenocrysts)	Ca (phenocrysts)	–	A (phenocrysts)
	Canusium	SP 14	–	Imbrex	Homogeneous	vL	S (phenocrysts)	Ca (phenocrysts)	–	vA
	Canusium	SP 34	A	Fired clay	Homogeneous	L	–	–	F	S
	Canusium	SP 35	A	Fired clay	Homogeneous	MH	–	–	A	–
	Faragola	FA 1	–	Tile	Homogeneous	L	F (phenocrysts)	–	A	A (phenocrysts)
	Faragola	FA 2	–	Tile	Homogeneous	L	S (phenocrysts)	Mainly calcic	S	F (phenocrysts)
	Faragola	FA 3	–	Tile	Heterogeneous	M	–	Mainly calcic	A	F
	Faragola	FA 4	–	Tile	Uncertain	H	S (phenocrysts)	Mainly calcic	–	S
	Faragola	FA 5	–	Tile	Heterogeneous	M	F (phenocrysts)	–	S	F (phenocrysts)
	Faragola	FA 6	–	Imbrex	Homogeneous	M	F (phenocrysts)	–	S	F (phenocrysts)
	Faragola	FA 7	–	Brick	Homogeneous	L	F (phenocrysts)	Mainly calcic	F	A (phenocrysts)
	Faragola	FA 8	–	Tile	Homogeneous	MH	F (phenocrysts)	Mainly calcic	–	A (phenocrysts)
	Faragola	FA 10	–	Tile	Homogeneous	MH	F (phenocrysts)	Mainly calcic	–	A (phenocrysts)
	Faragola	FA 11	–	Tile	Homogeneous	H	F (phenocrysts)	Mainly calcic	–	A (phenocrysts)
Group 3	*Canusium*	SP 1	B	Brick	Homogeneous	vL	R (phenocrysts)	–	F	–
	Canusium	SP 4	B	Brick	Uncertain	vH	–	–	–	–
	Canusium	SP 9	B	Imbrex	Homogeneous	L	–	Ca (phenocrysts)	–	F (phenocrysts)
	Canusium	SP 13	–	Brick	Homogeneous	M	–	Mainly sodic	F (reacting)	R
	Canusium	SP 19	–	Brick	Heterogeneous	LM	F (phenocrysts)	–	S	R
	Canusium	SP 23	A	Tile	Homogeneous	vL	F (phenocrysts)	Ca (phenocrysts)	F	vR
	Canusium	SP 28	A	Brick	Heterogeneous	M	–	–	A (reacting)	F (phenocrysts)
	Canusium	SP 29	A	Brick	Homogeneous	LM	–	–	S	–
	Canusium	SP 33	A	Brick	Homogeneous	LM	–	Ca (phenocrysts)	S	vR

Table 4 (continued)

	Site	Sample	Kiln	Type	Matrix	Sintering	K-feldspar	Plagioclase	Calcite I	Clinopyroxene
	Canusium	SP 24	A	Brick	Homogeneous	L	–	–	–	–
	Canusium	SAB 1	–	Brick	Homogeneous	M	–	Ca (phenocrysts)	–	R
	Canusium	SAB 2	–	Brick	Homogeneous	M	–	–	–	–

	Site	Amphibole	Foids	Olivine	Glass type I	Glass type II	Lithics	Lithics	Micropalaeontological content	Other observations
Group 1	*Canusium*	–	–	–	–	–	–	–	F	–
	Canusium	–	–	–	–	–	R	MET?	–	Staurolite
	Canusium	–	–	–	–	–	–	–	Tr	–
	Canusium	–	–	–	–	–	–	–	–	–
	Canusium	–	–	–	–	–	–	–	–	–
	Canusium	–	–	–	–	–	S	SD	–	–
	Canusium	–	–	–	–	–	–	–	Tr	Paragonite
	Canusium	–	–	–	–	–	–	–	Tr	–
	Canusium	Pargasite	–	–	–	–	–	–	Tr	–
	Canusium	Pargasite	–	–	–	–	–	–	vA	Paragonite
	Canusium	–	–	Fo_{95}	–	–	S	SD	–	–
	Canusium	–	–	–	–	–	–	–	–	–
	Canusium	–	–	–	–	–	S	SD	–	Ba-, Sr-rich Kfs
	Canusium	–	–	–	–	–	–	–	–	–
	Canusium	–	–	–	–	–	–	–	–	–
	Canusium	–	–	–	–	–	–	–	F	–
	Canusium	–	–	–	–	–	–	–	A	–
	Faragola	–	Nepheline	–	–	–	S, R	SD, MET	–	Chloritoid
	Faragola	–	–	–	–	–	S	–	F	Chamotte
	Faragola	–	–	–	–	–	S	–	F	–
Group 2	*Canusium*	–	Nepheline	–	S	–	S	PF	vR	–
	Canusium	–	–	–	S	–	R	P	–	–
	Canusium	Kaersutite	–	–	R	–	R	aR	Tr	Qtz sph, Chloritoid
	Canusium	–	–	–	F	S	F	P	A	–
	Canusium	–		–	S	–	F	P	–	Phlogopite, orthopyroxene
	Canusium	Pargasite	Leucite	Fo_{63}	A	–	F	AF	vR	Chamotte; orthopyroxene
	Canusium	–	–	–	R	–	R	P	S	–
	Canusium	–	–	–	Vr	–	R	Ar	A	–
	Faragola	Sadanagaite/hornblende	Nepheline	Fo_{58}	A	–	F	P	F	–
	Faragola	Sadanagaite/hornblende	Leucite	–	A	–	F	P	R	–
	Faragola	–	–	–	F	–	F	P	–	–

Table 4 (continued)

	Site	Amphibole	Foids	Olivine	Glass type I	Glass type II	Lithics	Lithics	Micropalaeontological content	Other observations
	Faragola	–	–	–	A	–	S	P	–	–
	Faragola	Sadanagaite/hornblende	Nepheline	–	A	–	F	P	–	–
	Faragola	Sadanagaite/hornblende	–	–	A	–	F	P	–	–
	Faragola	–	–	Fo_{52}	A	–	F	P	S	Ba–,Sr–rich Kfs
	Faragola	–	–	–	A	–	F	P	–	–
	Faragola	–	–	Fo_{70}	A	–	F	P	–	–
	Faragola	Pargasite	–	–	A	–	F	P	–	–
Group 3	*Canusium*	Pargasite	–		–	vA	S	OAP	Tr	–
	Canusium	–	–	–	–	S	–	–	–	–
	Canusium	–	–	–	–	S	–	–	–	–
	Canusium	Pargasite	–	–	–	vA	–	–	–	–
	Canusium	–	Leucite	–	–	F	F	OAF	–	–
	Canusium	–	–	–	–	F	S	OP	F	–
	Canusium	–	–	–	–	S	S	OP	–	Qtz sph
	Canusium	–	–	–	–	S	–	–	S	–
	Canusium	–	–	–	–	A	S	OP	F	–
	Canusium	–	–		–	S	–	–		–
	Canusium	–	–	–	–	S	S	OAP	–	–
	Canusium	–	–		R	F	–	–		

A abundant; *F* frequent; *S* sporadic; *R* rare; *Tr* traces; *H* high; *L* low; *v* very; *AF* volcanic rock mainly made of K-feldspar, clinopyroxene and foids, like a phonolite; *AP* volcanic rock mainly made of K-feldspar and plagioclases and subordinate clinopyroxene, like a latite; *Ar* volcanic rock mainly made of K-feldspar and clinopyroxene, like a trachyte; $Fo_{1,2,3\ldots}$ forsterite; *P* volcanic rock mainly made of plagioclase and clinopyroxene, like a basalt; *PF* volcanic rock mainly made of plagioclase, clinopyroxene and foids, like a tephrite; *OAF* holocrystalline rock mainly made of plagioclase, clinopyroxene and foids like a foidosienite; *OAP* holocrystalline rock mainly made of K-feldspar and plagioclases and subordinate clinopyroxene, like a monzonite; *OP* holocrystalline rock mainly made of plagioclases and K-feldspar and subordinate clinopyroxene, like a gabbro; *Met* metamorphic rock; *SD* limestone and/or sandstone

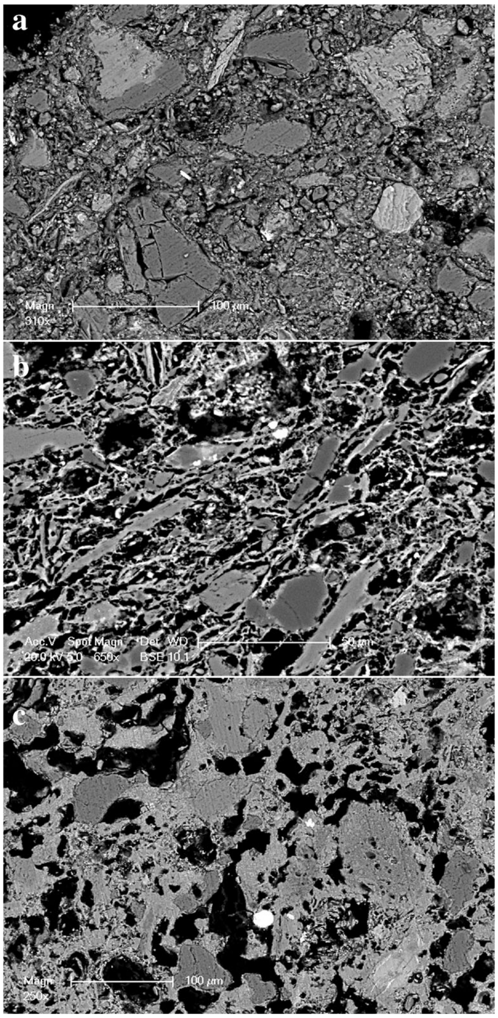


Fig. 6 Sintering degree. **a** very low in SP 22; **b** medium in SP 10; **c** high in SP 21

simply, by problems related to the representativeness of the sample taken from the object. The latter problem should not be neglected, particularly in relation to large building materials; conversely, the type and the composition of these particular lithic fragments can be safely introduced as discrimination parameters.

The presence of glass as part of a lithic fragment constituted by feldspars and clinopyroxene (group 2) indicated a volcanic provenance, while the association of isolated glass fragments with holocrystalline rocks (similarly made of feldspars and clinopyroxene; group 3) likely referred to intrusive rocks and could indicate a fluvial environment. Meandering and erosional phenomena often create heterogeneous context where these kinds of rocks can be easily mixed. The quaternary alluvial deposits extensively outcropping along with sub-Apennine clays (lower Pleistocene) are the best candidates for these groups of materials (Fig. 11); furthermore, it could be reasonable to search for a supply area close to the river Ofanto in the case of group 3, including samples from *Canusium* only.

However, the fact that groups 1 and 2 included materials from both Faragola and *Canusium* does not mean that a production was local (e.g. the most represented) and the other imported; in these cases, the differences observed were too weak to support such a reconstruction. Furthermore, sporadic peculiarities, such as the Ba- and Sr-rich composition of a few K-feldspars, or the presence/absence of olivine and other infrequent phases (e.g. chloritoid, staurolite etc.), are variables that cannot be appropriately weighted, apart from the evident relation to a volcanic or metamorphic environment.

Technological features

From a technological point of view, the possibility of observing calcite and microfossils were closely connected to the firing temperatures; therefore, the absence of primary calcite did not mean that this phase was originally absent from the ceramic body but rather that it was destabilised. This reconstruction was further supported by the fact that such high quantities of CaO in the ceramic bodies could not be explained otherwise (e.g. Ca-plagioclase, clinopyroxene etc). Based on this consideration and on the variable sintering degree of the matrices, it was possible to distinguish (1) low-fired (calcite and microfossils intact, low to medium sintering degree); (2) medium-fired (calcite and microfossils reacting; medium sintering degree) and (3) high-fired materials (calcite, absent; medium to very high sintering degree). The limit between the three categories was roughly estimated as follows: (1) below 600 °C, corresponding to the temperature at which the decomposition of calcite in clayey matrices begins; (2) around 650–850 °C, corresponding to the temperature at which the decomposition of calcite mainly occurs; and (3) above 850 °C, corresponding to the temperature at which the transformation of calcite into Ca-bearing silicates is concluded (Tschegg et al. 2009). However, it is known that these limits change depending on the grain size, the crystallinity and the chemistry of the carbonates present the ceramic body (see e.g. Riccardi et al. 1999; Cultrone et al. 2001; Tschegg et al. 2009); therefore, accurate estimation would require ad hoc experimental tests using the same raw clay used by ancient potters. In this case, however, the total lack of technological connection between the firing temperature and a production centre (*Canusium* or Faragola) or the type of manufactured product (tiles, bricks, imbrices etc.) excludes that a greater accuracy in the estimation of the firing temperatures might have some archaeometric or archaeological significance.

Conclusions

Ca-rich clays were used for the production of Faragola and *Canusium* building materials. The raw materials were prepared without the addition of elements extraneous to the

Table 5 Microchemical analyses of the matrices (10 areas per sample) performed by SEM-EDS

	Na_2O		MgO		Al_2O_3		SiO_2		K_2O		CaO		TiO_2		MnO		FeO	
	n=10	sd	n=10	sd	n=10	sd	n=10	sd	n=10	sd	n=10	sd	n=10	sd	n=10	sd	n=10	sd
FAR 1	1.0	0.2	2.5	0.5	15.4	0.5	52.6	2.0	2.2	0.1	20.1	0.8	0.5	0.1	0.3	0.2	5.4	0.9
FAR 2	1.6	0.6	3.2	0.6	17.5	1.8	52.9	2.3	1.6	0.4	16.0	1.6	0.8	0.1	0.2	0.1	6.1	0.8
FAR 3	1.1	0.3	2.4	0.4	14.4	0.9	56.6	7.1	2.0	0.5	17.2	5.5	0.8	0.3	0.2	0.1	5.0	0.7
FAR 4	1.5	0.2	3.2	0.3	15.6	0.8	53.6	1.4	1.9	0.4	17.4	2.1	0.6	0.1	0.3	0.1	5.7	0.3
FAR 5	1.5	0.4	3.1	0.4	15.8	1.4	54.9	3.4	2.1	0.3	15.9	3.8	0.7	0.2	0.3	0.2	5.5	0.8
FAR 6	1.3	0.2	2.9	0.4	15.9	1.2	54.2	2.0	1.9	0.3	17.5	2.4	0.6	0.1	0.3	0.1	5.2	0.6
FAR 7	1.0	0.6	2.2	0.3	16.3	1.0	50.8	2.4	3.3	0.2	20.2	3.8	0.6	0.2	0.1	0.1	5.4	0.7
FAR 8	1.9	0.4	5.4	0.8	14.5	0.9	49.9	3.8	1.5	0.8	20.8	4.4	0.5	0.1	0.2	0.1	5.2	0.8
FAR 9	1.3	0.4	3.1	0.5	15.9	1.7	53.5	3.3	1.5	0.3	18.0	3.1	0.7	0.2	0.2	0.1	5.8	0.5
FAR 10	1.6	0.4	3.5	0.2	15.6	0.2	53.3	1.1	1.6	0.2	18.2	0.6	0.6	0.1	0.2	0.0	5.4	0.6
FAR 11	1.5	0.3	2.9	0.3	15.1	1.0	55.2	2.4	2.0	0.5	17.2	2.6	0.7	0.2	0.2	0.1	5.0	0.5
FAR 12	1.2	0.1	2.5	0.3	15.1	1.7	57.0	3.1	2.6	0.6	17.0	2.2	0.6	0.1	0.2	0.2	3.8	0.6
FAR 13	0.8	0.3	2.5	0.3	15.1	0.9	55.7	2.9	2.6	0.2	17.0	1.5	0.6	0.2	0.2	0.1	5.5	0.3
SP 01	1.3	0.3	3.4	0.4	15.9	1.1	52.9	3.4	1.7	0.4	18.3	3.3	0.7	0.1	0.2	0.1	5.5	0.8
SP 02	0.9	0.2	3.2	0.6	16.6	1.0	49.1	1.0	1.8	0.4	22.5	1.1	0.6	0.0	0.1	0.1	5.1	0.3
SP 03	1.6	0.3	3.6	0.4	16.6	1.5	51.9	2.6	2.2	0.9	17.7	2.4	0.7	0.2	0.3	0.2	5.2	0.4
SP 05	0.8	0.4	2.9	0.5	16.9	1.2	51.5	2.7	2.0	0.4	19.3	1.5	0.7	0.2	0.3	0.1	5.5	0.6
SP 06	1.5	0.4	3.2	0.2	18.6	1.0	52.3	3.3	1.4	0.4	14.7	1.4	0.8	0.2	0.2	0.1	7.1	3.2
SP 07	1.5	0.3	2.6	0.1	17.1	0.9	54.8	3.1	3.2	0.3	13.5	1.3	0.6	0.1	0.1	0.1	6.3	2.1
SP 08	1.8	0.3	3.4	0.4	15.4	0.9	52.6	0.5	1.7	0.3	18.7	1.5	0.7	0.4	0.2	0.2	5.4	0.5
SP 09	1.2	0.4	3.5	0.5	14.0	2.1	52.5	2.0	0.9	0.3	22.2	4.3	0.5	0.1	0.3	0.2	4.9	0.4
SP 10	1.3	0.3	2.8	0.5	16.1	0.2	52.1	2.1	1.6	0.3	20.2	2.9	0.7	0.3	0.2	0.1	4.9	0.5
SP 11	1.0	0.3	3.5	0.2	17.2	1.2	53.6	1.8	2.6	0.2	16.1	2.1	0.7	0.1	0.2	0.1	5.1	0.4
SP 12	1.1	0.3	5.0	0.9	16.4	1.0	51.1	2.5	1.3	0.9	18.6	2.3	0.7	0.1	0.3	0.2	5.2	0.4
SP 13	1.3	0.3	3.1	0.6	15.1	1.2	53.3	2.6	2.2	0.4	18.6	3.0	0.8	0.3	0.3	0.1	5.1	0.6
SP 14	1.5	0.5	3.3	0.6	16.9	0.9	54.0	2.3	1.6	0.3	15.9	1.7	0.6	0.1	0.2	0.1	5.9	0.5
SP 15	1.3	0.5	3.2	0.3	15.0	1.3	50.5	2.2	0.9	0.6	21.9	4.2	0.6	0.2	0.9	1.6	5.5	0.6
SP 16	1.6	0.5	3.3	0.5	14.4	3.8	44.9	8.7	0.9	0.5	29.4	15.0	0.6	0.3	0.2	0.2	4.5	1.4
SP 18	1.5	0.3	2.7	0.5	15.4	1.9	48.8	3.6	0.8	0.4	24.2	4.4	0.6	0.2	0.2	0.2	5.7	0.8
SP 19	1.3	0.3	3.5	0.8	17.4	1.7	53.2	1.7	1.7	0.5	16.3	2.1	0.7	0.1	0.2	0.1	5.7	0.7
SP 20	1.9	0.3	2.8	0.4	15.2	1.2	51.5	0.4	3.1	1.0	19.4	2.8	0.7	0.2	0.3	0.1	4.9	0.6
SP 21	1.6	0.3	2.6	0.2	13.8	1.1	49.6	4.0	1.2	0.5	25.1	4.8	0.6	0.1	0.2	0.1	5.1	0.4
SP 22	0.8	0.6	2.9	0.4	17.3	2.1	55.9	4.6	2.8	0.6	13.8	1.8	0.7	0.3	0.2	0.1	5.6	1.2
SP 23	1.2	0.3	2.8	0.5	16.7	1.4	51.7	3.5	1.9	0.2	19.6	3.3	0.6	0.2	0.2	0.1	5.1	0.4
SP 25	0.7	0.6	2.5	0.3	15.8	2.5	56.4	4.8	1.2	0.9	16.7	0.3	0.6	0.3	0.2	0.2	5.9	0.2
SP 27	1.1	0.3	2.9	0.4	15.6	1.3	49.7	3.3	1.6	0.4	22.5	5.3	0.9	0.2	0.2	0.1	5.4	0.7
SP 28	1.2	0.3	3.0	0.7	15.4	1.3	54.7	3.8	1.3	0.5	17.4	2.7	0.7	0.3	0.3	0.1	5.8	0.9
SP 29	1.2	0.3	3.3	0.3	17.2	1.1	47.4	1.6	1.5	0.7	21.5	3.0	0.8	0.1	0.3	0.1	6.8	0.7
SP 30	1.7	0.3	3.1	0.3	16.9	1.0	55.5	2.5	1.9	0.5	13.5	2.3	0.7	0.1	0.3	0.1	6.3	0.5
SP 31	0.8	0.3	2.7	0.3	16.7	1.8	55.1	2.8	2.4	0.6	15.9	2.6	0.7	0.1	0.1	0.1	5.5	0.7
SP 32	0.9	0.2	2.6	0.3	15.7	0.8	55.0	2.6	2.3	0.2	17.2	1.4	0.7	0.3	0.1	0.0	5.2	0.8
SP 33	0.7	0.2	2.7	0.4	14.3	1.6	53.3	4.0	1.4	0.6	21.6	3.7	0.5	0.1	0.3	0.1	5.0	0.4
SP 34	1.4	0.1	2.6	0.4	16.4	1.8	56.1	3.7	1.5	0.2	15.0	1.9	0.6	0.2	0.3	0.1	6.1	0.5
SP 35	0.6	0.3	2.7	0.4	15.9	1.3	54.5	4.2	2.5	0.2	17.5	3.1	0.8	0.3	0.2	0.2	5.2	0.4
SP 36	0.8	0.5	2.5	0.4	15.8	1.7	55.1	5.0	2.5	0.3	16.9	4.0	0.7	0.2	0.3	0.2	5.2	0.9
SAB 1	1.7	0.3	3.3	0.3	16.9	1.2	54.3	2.8	2.2	0.6	14.7	2.2	0.7	0.3	0.2	0.1	6.0	0.8
SAB 2	2.0	0.3	3.7	0.5	17.6	2.7	53.4	3.2	2.0	0.4	14.5	1.1	0.5	0.2	0.1	0.1	6.0	0.4

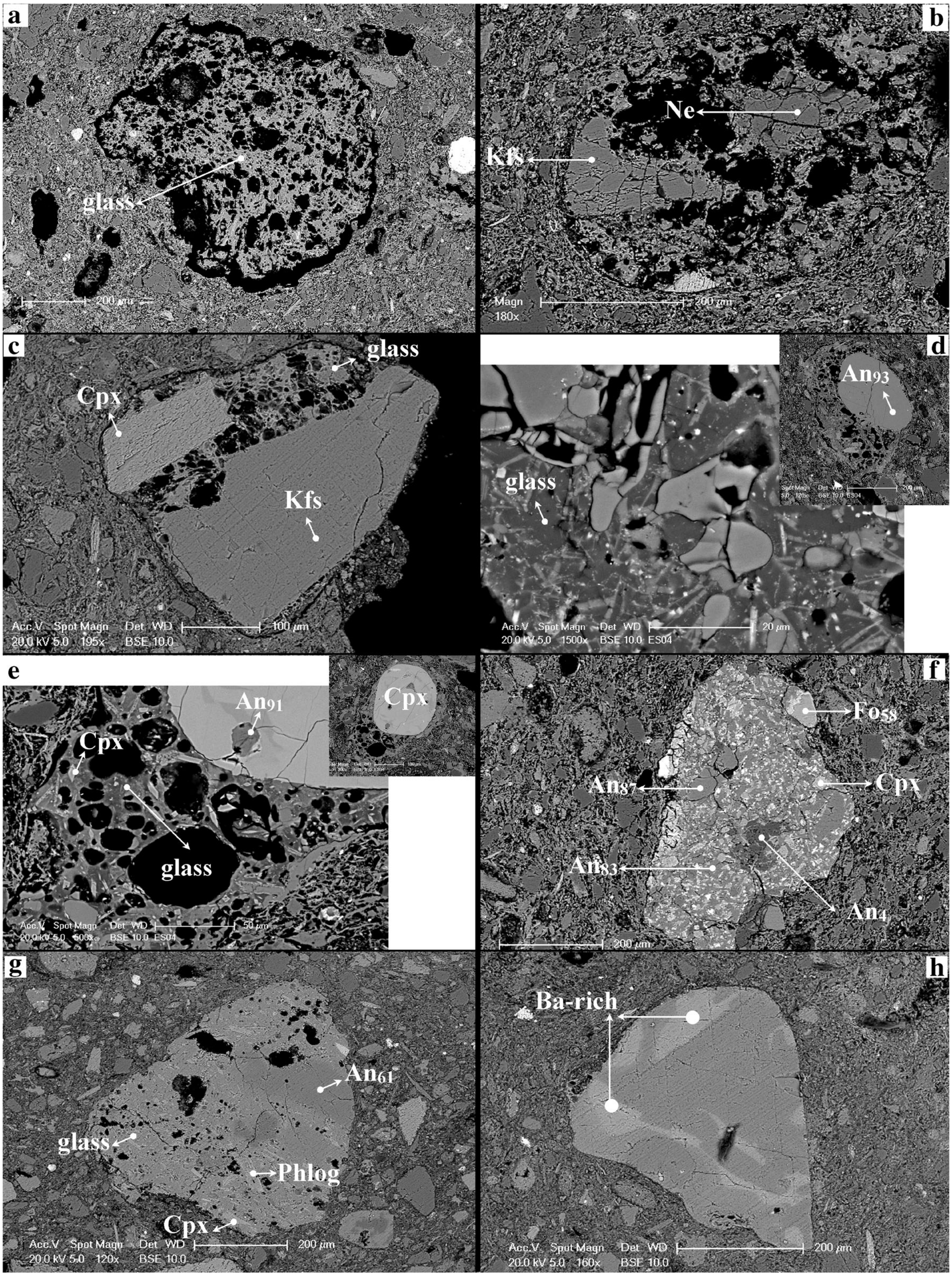


Fig. 7 Lithic fragments in Faragola samples. SEM-BSE images: **a** isolated fragment volcanic glass in FAR 1; **b** K-feldspar (kfs)+ feldspathoid (Ne=nepheline)+glass in FAR 1; **c** K-feldspar+ clinopyroxene (cpx)+glass in FAR 7; **d** plagioclase (An=anorthite)+ glass in FAR 2; **e** clinopyroxene+plagioclase+glass in FAR 2; **f** plagioclase+clinopyroxene+olivine (Fo=forsterite) in an anorthitic groundmass in FAR 1; **g** plagioclase+clinopyroxene+phlogopite (phlog)+glass in FAR 7; **h** Ba-rich K-feldspar in FAR 7

sediment, or the separation of particular granulometric fractions. The local kilns fired the ceramic bodies at variable temperatures comprised between 600 and ~1000 ° C. It was interesting to notice that bricks, tiles and imbrices were

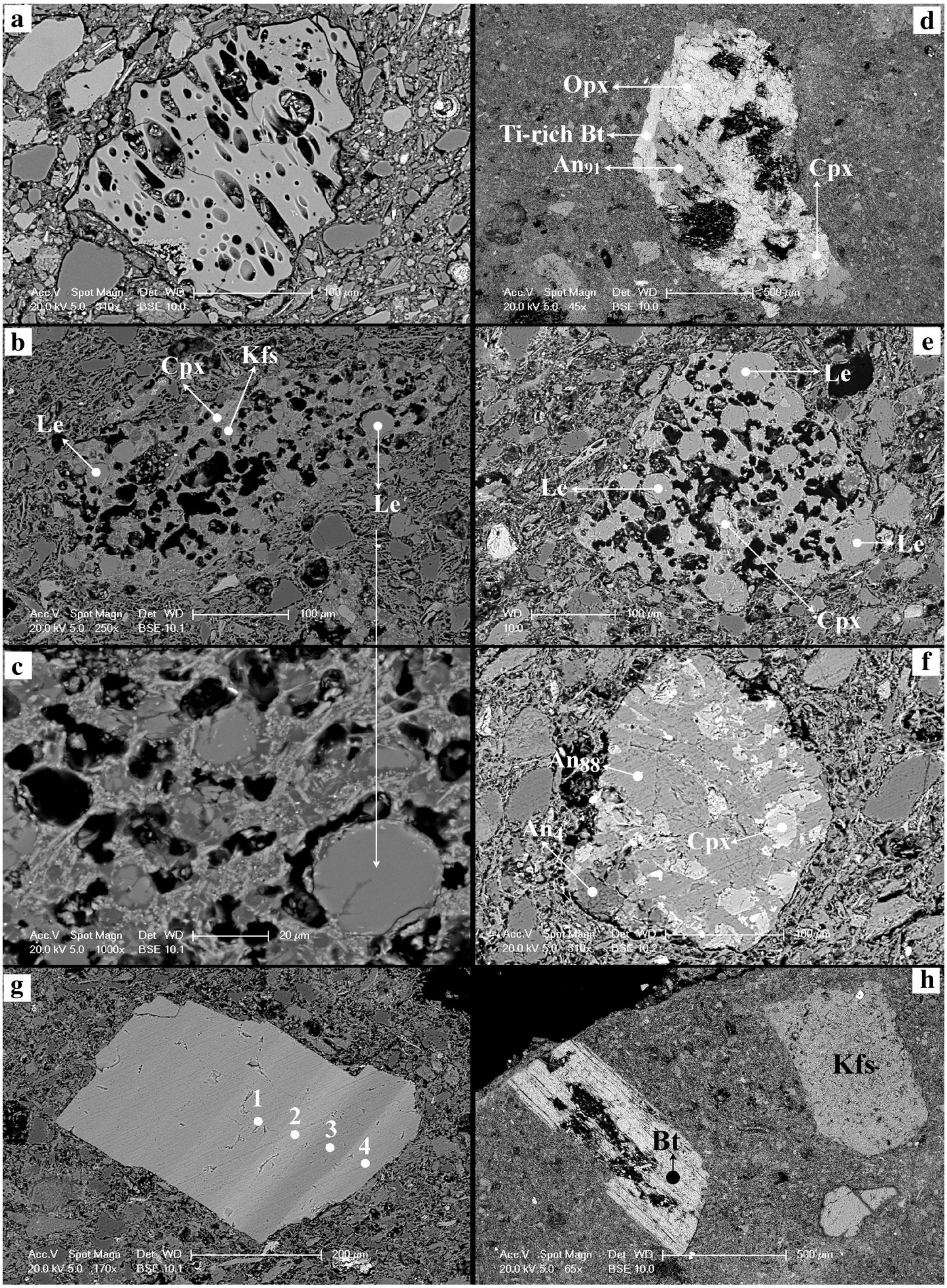


Fig. 8 Lithic fragments in Canusium samples. SEM-BSE images: **a** isolated fragment of volcanic glass in SP 11; **b–c** K-feldspar (kfs)+feldspathoid (Le=leucite)+clinopyroxene (cpx)+glass in SP 14; **d** plagioclase (An=anorthite)+clinopyroxene+orthopyroxene (opx)+biotite (Bt) in SP 12; **e** feldspathoid+clinopyroxene in SP 19; **f** plagioclase+clinopyroxene in SP 23; **g** Ba-rich K-feldspar in SP 27; **h** Ti-rich biotite in SP 12

prepared and fired without any technological distinction in terms of paste preparation and firing temperature.

The objects produced in Faragola were hardly distinguishable from those produced in *Canusium* and vice versa while

Table 6 The chemical composition of the volcanic glass determined by SEM-EDS and their CIPW norm calculation. *sd* standard deviation

	Glass type 1		Glass type II	
	n=52	sd	*n*=37	sd
SEM-EDS (wt%)				
Na_2O	3.5	1.3	3.2	1.4
MgO	1.5	1.0	1.3	0.5
Al_2O_3	21.6	3.0	18.2	1.6
SiO_2	57.7	3.3	63.2	1.6
K_2O	6.3	2.8	7.1	2.1
CaO	4.6	2.1	3.0	0.6
TiO_2	0.5	0.3	0.5	0.1
MnO	0.1	0.1	0.2	0.1
FeO	4.2	0.1	3.3	0.1
Total	100		100	
CIPW norms (wt%)				
Quartz	–		6.61	
Anorthite	22.82		14.33	
Diopside	–		0.47	
Hypersthene	2.56		8.61	
Albite	29.62		27.08	
Orthoclase	37.23		41.96	
Olivine	6.17		–	
Ilmenite	0.95		0.95	
Corundum	0.66		–	
Total	100		100	

the entire collection of building materials here investigated showed distinctive features in relation to both coarse and fine wares produced in the same archaeological sites or territory (i.e. including materials found at San Giusto, *Herdonia* and Posta Crusta).

Regarding the supply areas for the raw materials, the presence/absence of volcanites and volcanic glass represented an effective discriminating factor between the Pleistocene marine and alluvial terraced deposits, or rather two typical and widespread deposits of clayey materials in northern Apulia.

The archaeometric and morpho-typological research performed in recent years on a plethora of types of ceramic materials (cooking ware, table ware and storage ware) is now enriched with the study of Faragola and *Canusium* bricks. The overall results can be compared, and several considerations can be drawn on the character and the level of specialisation of the artisanal ceramic production in Puglia from Roman times to Late Antiquity.

The comparison shows the substantial persistence of the Roman models of production. Evidences of neither a technical decline nor a dimensional deconstruction of this artisanal sector were observed. Conversely, there were numerous features which clearly indicated a high standard level of these activities, such as the multiplicity of the morphological repertoire, the size of the artisanal quarters and their kilns, the deliberate exploitation of the territory, oriented to a targeted selection of the raw materials and, in the case of *Canusium*, the wide distribution of the products.

The result of greatest interest obtained from this research refers to supply strategies and production technologies. The former seem unchanged over the centuries that separate the activity of kiln A from that of kiln B; in fact, their products are compositionally indistinguishable in terms of bulk chemistry and mineralogical-petrographical assemblage. On the other hand, the supply basins are different, but this distinction did not correspond to a different chronology, technology or production site.

These ancient kilnsmen identified at least three supply areas (not necessarily far from one another) useful for the production of bricks and kept them distinct both from those exploited for the production of fine table ware, coarse cooking ware and storage ware. The deep knowledge that they had of their territory becomes clear. A knowledge that allowed them to exploit selectively the available geosources and—as it could be in this case—to rotate the supply basins on the basis of contingent needs.

The use of brick in *Canusium* is in continuity with the Roman building tradition. During the fifth and the sixth centuries AD, the production focused on two forms of brick (the pedal and the brick type 2) and was intended almost exclusively for buildings of worship. Indeed, the Church acted as the main operating entity in the productive sector while the public demand was far more limited.

The analyses substantially confirmed the hypothesis which located several workshops of the Bishop *Sabinus* on the site of St. Peter: the stamped bricks, in fact, were compositionally comparable to those of the same type, widely found in the firing chamber of kiln A.

It might be expected, therefore, that a framework of specialised crafts was carried out by local workers, mainly devoted to the supply of urban religious buildings. This reconstruction would be very similar to that documented in other religious complexes such as San Vincenzo al Volturno, Torcello, Florence and San Giusto, but in the case of *Canusium*, the products were likely intended for a wider user base. Maybe due to the

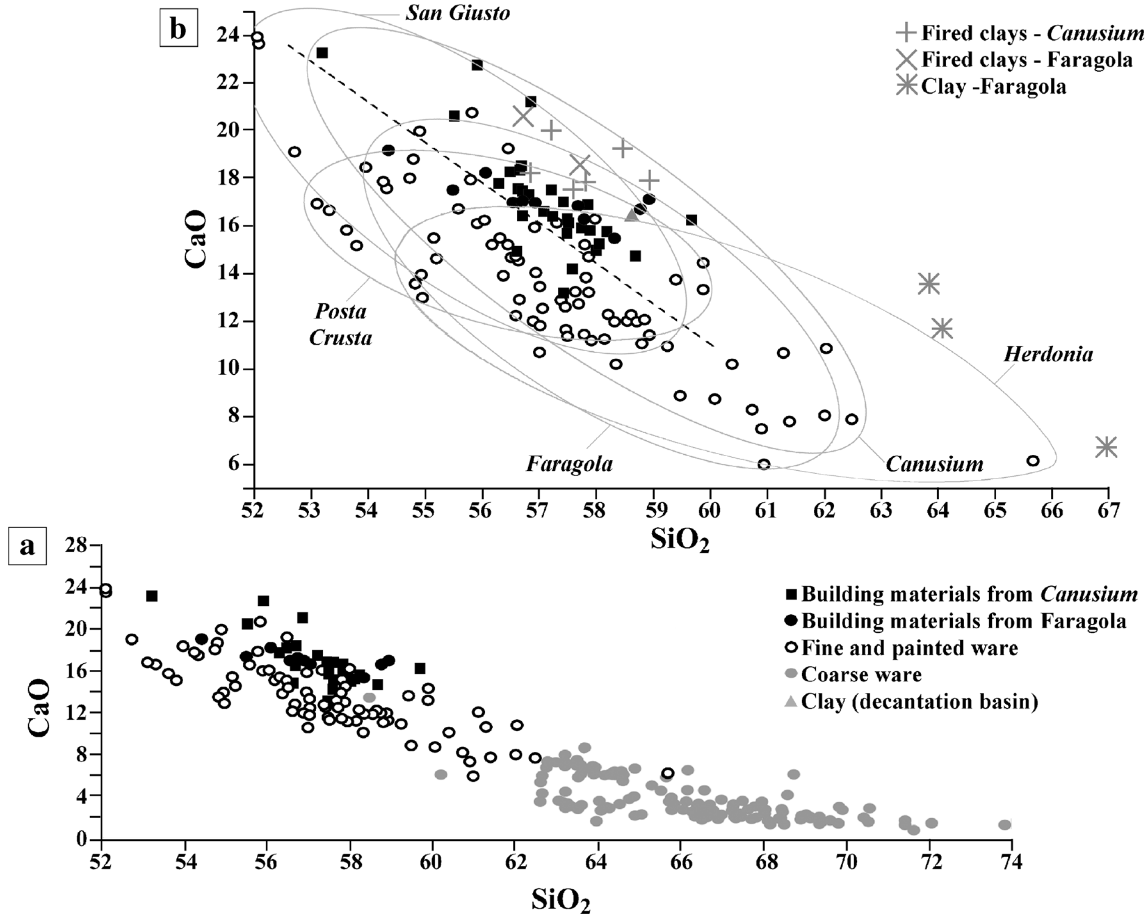


Fig. 9 SiO_2–CaO binary diagrams: coarse and fine wares from northern Apulia compared to building materials, clays and fired clays from the investigated sites. (Diagram **b** is an enlargement of diagram **a**)

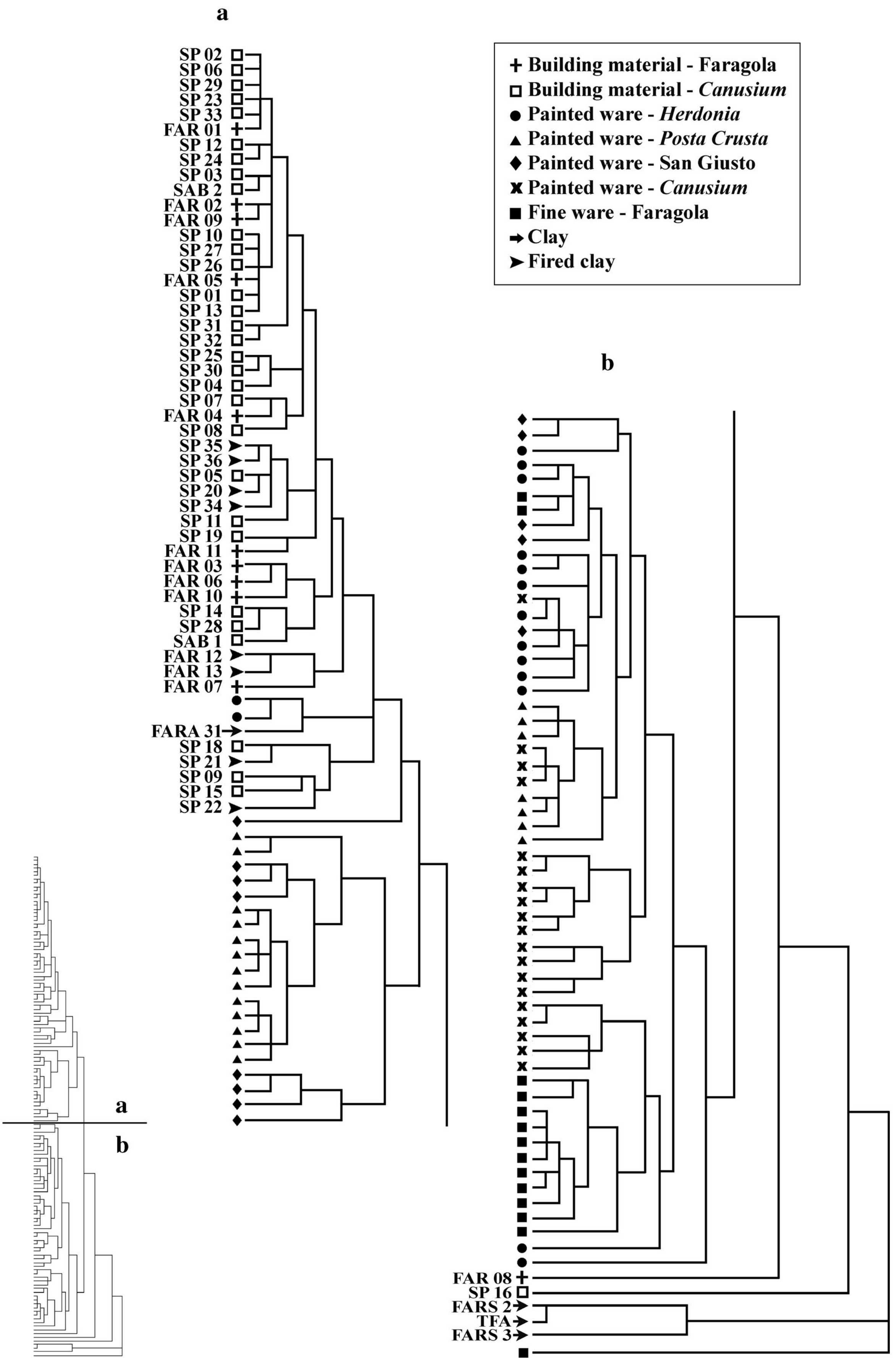
presence of efficient infrastructures; the *Canusium* building materials probably reached the other pole of the diocesan district (in particular the *vici* of Barletta and Trani) where the construction activity of *Sabinus* was well documented. The importance of the town of *Canusium* as a distribution and consumer centre had already emerged in the previous studies performed on coarse ware and table ware.

The urban brick production was oriented to satisfy the ecclesiastical requirements, while supply and demand in the countryside was in the hands of the land owners (*possessores*), patrons of the sumptuous villas which were built ex novo or more frequently renovated in Late Antiquity. The rich rural residences such as Faragola were places for the demonstration of aristocratic power and prestige. Attracting all levels of society and expertise, they were also places for the conservation of artisanal traditions handed down over the centuries and exchange of different skills.

The ceramic production was undoubtedly favoured by the presence of large clay deposits and the proximity to the river Carapelle, an ideal quarry for clay and other construction materials. The Faragola kiln mainly produced roofing tiles, based on the limited presence of bricks in the walls of this *villa*. The small size of the kiln can be explained in the light of the temporary function of the structure, built for a specific purpose, active for a limited period of time and then dismantled and buried when no longer useful.

Probably, the presence of other active kilns may have represented a further explanation. Although they have not been excavated, the widespread presence of waste and the data obtained by geophysical prospection indicated the presence of other kilns in the surroundings of the *villa*.

While manufacturing and agricultural activities characterised the economy of the *villae*, the tendency to focus the production activities in certain sites and to


a
+ Building material - Faragola
□ Building material - *Canusium*
● Painted ware - *Herdonia*
▲ Painted ware - *Posta Crusta*
◆ Painted ware - San Giusto
✖ Painted ware - *Canusium*
■ Fine ware - Faragola
➡ Clay
➤ Fired clay
SP 02
SP 06
SP 29
SP 23
SP 33
FAR 01
SP 12
SP 24
SP 03
SAB 2
FAR 02
FAR 09
SP 10
SP 27
SP 26
FAR 05
SP 01
SP 13
SP 31
SP 32
SP 25
SP 30
SP 04
SP 07
FAR 04
SP 08
SP 35
SP 36
SP 05
SP 20
SP 34
SP 11
SP 19
FAR 11
FAR 03
FAR 06
FAR 10
SP 14
SP 28
SAB 1
FAR 12
FAR 13
FAR 07
FARA 31
SP 18
SP 21
SP 09
SP 15
SP 22
b
FAR 08
SP 16
FARS 2
TFA
FARS 3
a
b

◀ **Fig. 10** Dendrogram including coarse and fine wares, building materials, clays and fired clays from northern Apulia (present research and previous ones performed by our research group, published in Gliozzo et al. 2005, 2010, 2014). Please note that **a** and **b** divides arbitrarily the dendrogram, in order to increase the visibility of the diagram itself

separate the *pars urbana* from the *pars rustica* and *fructuaria* are evident in the Late Antique Puglia, Lucania and other areas of southern Italy. In the *massae fundorum* (i.e. large estates, *latifundia*), presses, barns and kilns were probably distributed in various parts of the same property and probably settled in areas of villas previously abandoned, reconverted to suit a large-scale economy. In the case of Faragola, it is possible to believe that the agricultural and manufacturing production centre corresponded to the settlement located at Sedia d'Orlando, about 1.8 km north of Faragola and a few metres away from the river Carapelle. Artisanal quarters, stores and warehouses for the storage of wine, olive oil and wheat were found there. It could have been a 'service centre', with perhaps a river port, dependent on Faragola (fourth to sixth century AD) but closely related to the neighbouring sites.

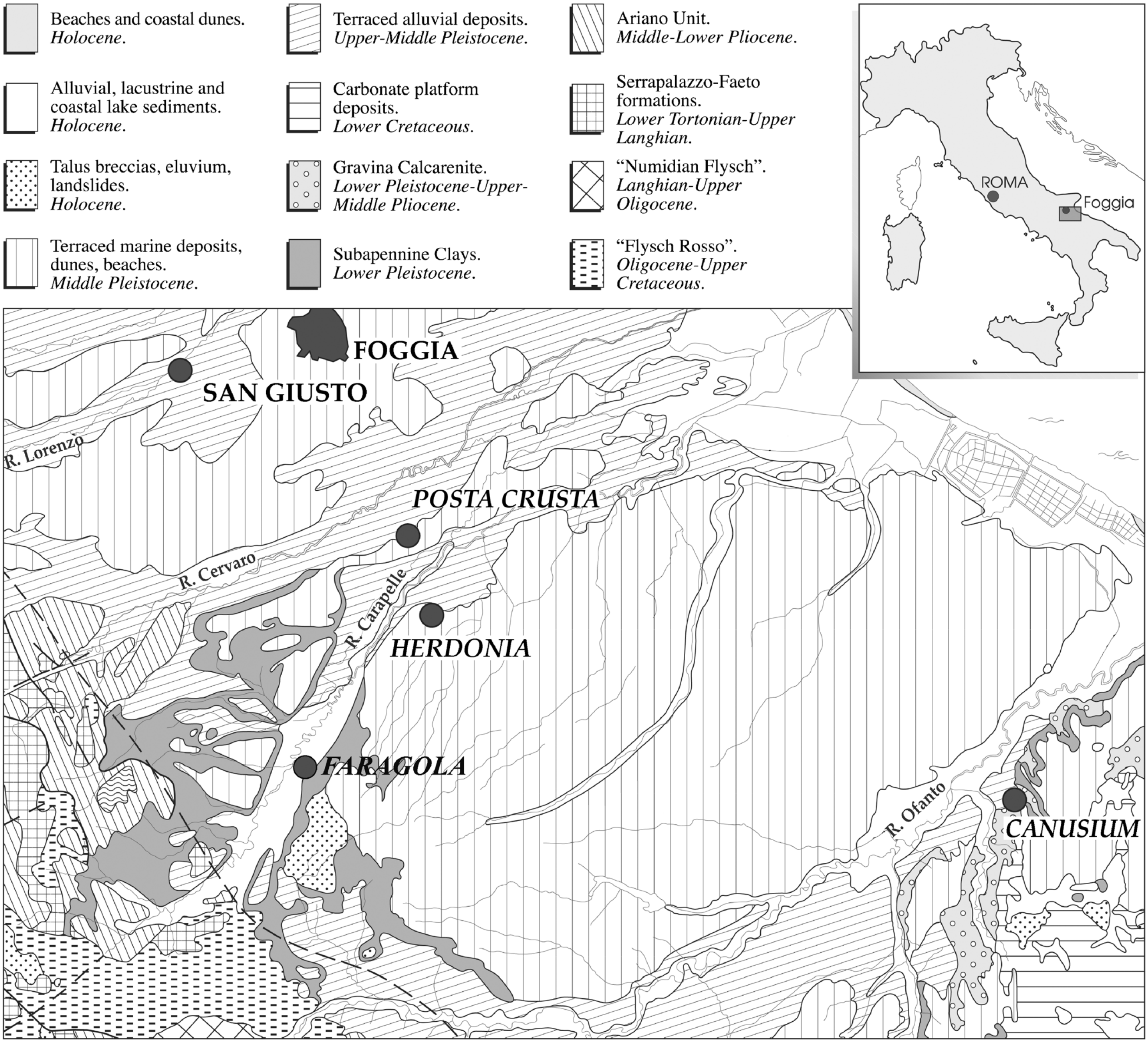


Fig. 11 The locations of the archaeological sites and a geological map of the territory under examination (modified after Gliozzo et al. 2013)

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