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Archaeometric characterization of amphorae and bricks of Imperial Age found in a roman villa near the Luzzi town (Cosenza, Calabria, Italy)

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Abstract

The present work illustrates the results of the archaeometric characterization of 10 amphorae fragments of Imperial Roman age and 10 bricks of the same period, found at Muricelle, nearby Luzzi, close to Cosenza in Calabria (Italy). The sherds include amphorae of different shape and production, some of which *Keay LII type*.

Petrographic study on ceramic fragments using the optic microscope, mineralogical analysis on powders through X-ray diffraction (XRD) and chemical analysis with X-ray fluorescence (XRF) were carried out. Clayey materials from outcrops nearby the archaeological site undergone chemical, mineralogical and granulometric analysis, so as to define their characteristics as potential raw materials for the ceramic production. The realization of experimental firing of the clays, provide information on the technology and firing temperature of the ceramic production.

The obtained results indicate the presence of a probably local production represented by all the bricks; the majority of the amphorae, inclusive of the *KLII type amphorae,* may have been produced in Calabria on the basis of petrographic evidence, while only three amphorae may be considered as imported ceramics because of the petrographical and chemical composition.

Key words: Ceramic; Keay LII type Amphora; Imperial Roman Age; Petrography; XRD; XRF; Provenance; Raw Materials.

Introduction

Muricelle site (Figure 1) is located in the territory of Luzzi, a village close to Cosenza, situated at the right side of the valley of the Crati river, in Calabria - southern Italy, at a height of 190 m above sea level. The area is characterised by clayey sediments (Figure 2), where numerous archaeological finds and ruins of walls, belonging to a Roman *villa* of Imperial age, have been recovered.

The ruins of the *villa* are represented by walls

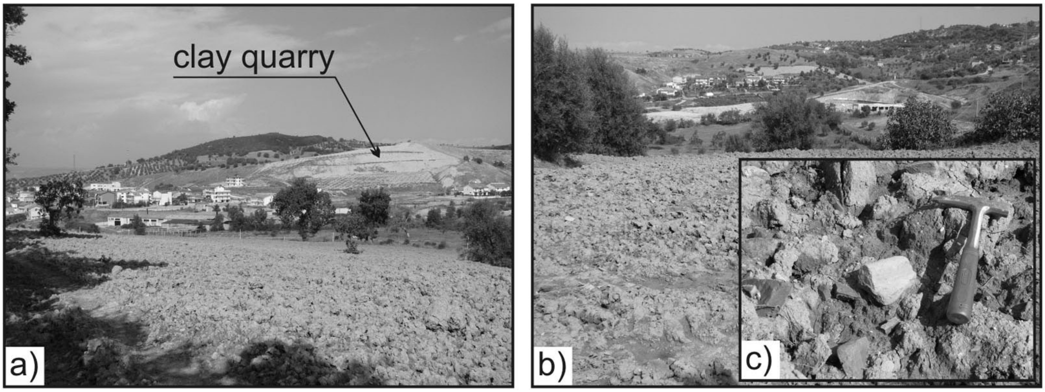

Figure 1. a) Archaeological site and in the background the clay quarry; b) terrain where the villa was situated; c) a detail of some ceramic fragments.

built with mortar and *cocciopesto* (*opus mixtum* showed in Figure 3a) and by a flooring in *opus spicatum* (Figure 3b). In addition, in the adjacent areas, after the ploughing, several ceramic fragments of different age and typology of Roman imperial period appear on the soil (Figure 1b and 1c).

The material found in Muricelle is extremely heterogeneous: amphorae, common ware and fine ceramics dating back to the whole Roman Empire (about 700 fragments) and glass fragments and coins that confirm this chronology were also found .

The quantity and quality of the archaeological

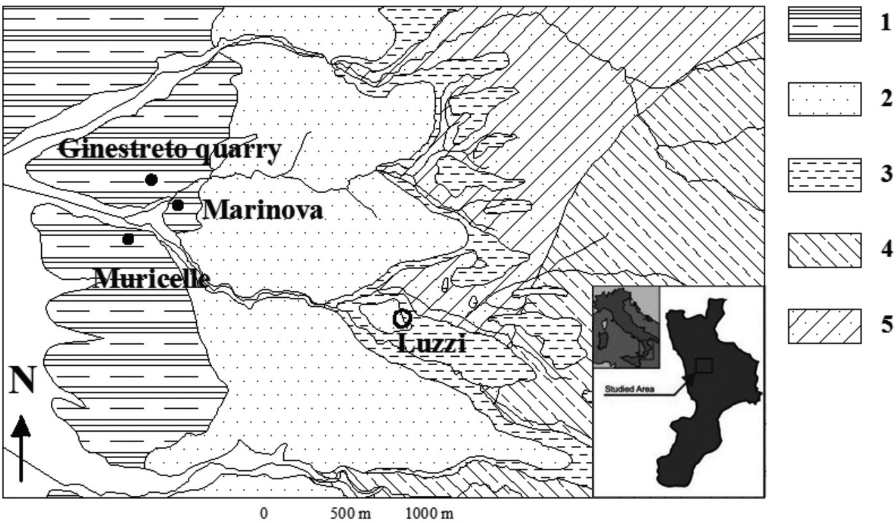

Figure 2. Simplified geological sketch-map of Luzzi area. 1 = Grey to greyish-blue silty Pliocene clays. 2 = Light brown sand and sandstone. 3 = Pliocene conglomerates with intercalation of coarse sands. 4 = Paleozoic gneiss and biotitic schists. 5 = gneiss with garnet.

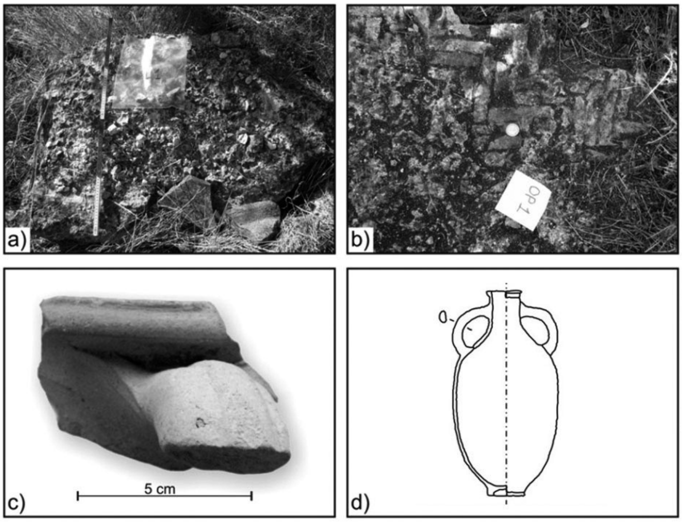

Figure 3. a) wall in *opus mixtum* of the villa; b) floor in *opus spicatum*; c) particular of a *Keay LII Type* amphora; d) technical draw of a *Keay LII Type* amphora.

finds, combined with the occurrence of fragments of walls and a floor of opus spicatum, clearly demonstrate that we are in the presence of a rural Roman villa, well placed within a circuit of exchange and trade.

The abundance of imported pottery, italian-sigillata, African-sigillata, thin-walled pottery, amphorae, that according to the shape, suggests a clear oriental-greek origin.

The oldest material refers to a chronology between the late first century B.C. and the beginning of the first century A.D. (Augustus), although the strongest growth was in the second century A.D., when probably the *villa* was abandoned (La Marca, 2002). The following periods are less documented but the presence of amphorae of Type Keay LII testifies a attendance in the area, even during the period of Late Antiquity. The chronology inferred from the pottery study is confirmed by the data obtained from the numismatic study and from the glasses recovered in the site (Colelli, 2011).

The absence of systematic surveys and excavations, preventsfurther stratigraphic interpretation of the Muricelle site, but it is quite sure that the site played a leading role within the middle valley of Crati River, as a link between the plain of Sybaris (on the Ionian coast) and the hinterland.

The occurrence of amphorae *Keay LII Type*, suggests the human presence in the area probably until the late Roman Imperial age (late 4th - 7th A.D.), because archaeological literature tends to regard the *Keay LII* amphora as a late Roman amphora, rather than a byzantine wine container (Keay, 1984). So far has not been documented the presence of kilns, indicating local production all around the area. The discovery of kilns for the production of *Keay LII* amphora are reported, until now, in southern Calabria, in the archaeological sites of Marasà and Pellaro - RC (Lattanzi, 1988; Andronico, 199; Di Gangi and Lebole, 1998).

In the present work, we studied 10 amphora fragments dated to all Roman Imperial age (some of which *KLII Type*; Figure 3c, 3d), and 10 bricks probably of the first period of the *villa*, (1st and the 2nd century A.D.) withdrawn from the

Table 1. Summary of archaeological characters, the Munsell color and the archaeological assignments of the analyzed samples.

Sample	Type	Chronology	Munsell Color	Archaeological Assignment
A1	Wine Amphora *Keay LII*	4th - 7th century A.D.	5YR - 6/6	Local
A10	unidentified Amphorae	Roman Imperial Age	5YR - 6/6	Local
A2	Wine Amphora *Keay LII*	4th - 7th century A.D.	5YR - 6/6	Local
A3	Wine Amphora of oriental shape	1st B.C. - 1st century A.D.	5YR - 5/8	Imported
A5	Wine Amphora *Keay LII*	4th - 7th century A.D.	5YR - 6/6	Local
A8	unidentified Amphorae	Roman Imperial Age	5YR - 5/8	Imported
A51	Wine Amphora of oriental shape	1st B.C. - 1st century A.D.	5YR - 6/6	Imported
A9	unidentified Amphorae	Roman Imperial age	5YR - 6/6	Local
AV2	Wine Amphora *Keay LII*	4th - 7th century A.D.	5YR - 6/6	Local
AV3	Unidentified Amphorae	Roman Imperial age	5YR - 6/6	Local
L1a	Brick Opus Mixtum	1st - 2nd century A.D.	5YR - 6/6	Local
L1b	Brick Opus Mixtum	"	7.5YR - 8/3	Local
L1c	Brick Opus Mixtum	"	5YR - 5/6	Local
L1d	Brick Opus Mixtum	"	5YR - 5/8	Local
L1e	Brick Opus Mixtum	"	5YR - 4/6	Local
L1f	Brick Opus Mixtum	"	7.5YR - 6/6	Local
OP1a	Brick Opus Spicatum	"	5YR - 6/8	Local
OP1b	Brick Opus Spicatum	"	5YR - 7/6	Local
OP1c	Brick Opus Spicatum	"	5YR - 7/6	Local
OP1d	Brick Opus Spicatum	"	5YR - 5/6	Local

walls and the flooring of the *villa*.

The archaeologists suggest local production for the bricks and both local and imported production for the amphorae investigated. In order to verify this hypothesis, we carried out an archaeometrical study on pottery and bricks, using several experimental techniques. The results were compared with the raw materials sampled in the neighbourhood of Muricelle site.

Ceramic archaeological finds of Muricelle

Ten amphora fragments, of different shape and production, and ten bricks from the opus mixtum and from the opus spicatum of the walls and of the floor (Figure 3a and 3b) from the Roman *villa* ruins of Muricelle site were studied.

Most of the amphorae are characterized by a uniform reddish colour, some others, described as wine amphora of oriental shape or as unidentified amphorae, show a deeper red colour, less homogeneous is the colour of the bricks ranging from pink to reddish yellow. Table 1 summarizes the archaeological characters, the Munsell color and the archaeological assignments of the analyzed samples. Some of the ceramic fragments, are reported in Figure 3c, 3d.

Clay raw materials

The investigated area is situated in the northern sector of the Calabrian-Peloritan Arc, at the slopes of the Silan Massif, towards the Crati river valley (Figure 2).

This area is characterized by the presence of acid metamorphic and intrusive crystalline rocks of Palaeozoic age of the Sila Massif, predominantly represented by gneiss and biotitic schists and fractured or altered granites; sands and sandstones, grey blue silty clays and alluvial sediments from the Late Pliocene to Pleistocene-Olocene (Amodio Morelli et al., 1976).

The Pliocenic clays of the Crati valley probably derive from the chemical alteration of the crystalline rocks of the Sila Massif (Le Pera et al., 2001) and could have been deposited trasgressively on the North-western side of the Sila Mountain behind the Crati valley, following a gradual deepening of the same basin (Lanzafame and Zuffa, 1976).

The deposits of blue-grey silty clays crop out extensively, showing a conchoidal fracture and an almost undefined stratification due to the lithological homogeneity; the thickness is variable and reaches 600 m in the area of Luzzi, at the top they gradually become sands that close the Calabrian cycle (Lanzafame and Zuffa, 1976).

Clay sediments from the area, around the remains, were sampled for comparisons with the selected pottery and bricks, probably representing the potential raw materials used for the local production. We analyzed 5 clay samples, collected from a quarry situated in a place named Ginestreto, few hundreds meters away from the site. The quarry is about 60 m large and 30 m high. Although extensive, the outcrop is quite homogeneous from a macroscopic point of view, i.e., in colour and grain-size. The specimens were sampled at steps of 1.5 m vertically. In addition 2 silty clay samples deriving from smaller neighbouring outcrops were taken in the place named Marinova.

Methodologies

The ceramic samples were examined macroscopically and also characterised by several mineropetrographic and geochemical methods. The petrographical analysis was conducted using a polarizing microscope, on the thin-section of the archaeological remains. Mineralogical compositions were determined by XRD on a Philips PW 1730 diffractometer with vertical goniometer, Cu-Kα radiation, operating at 40 kV and 20 mA. The investigated areas ranged between 5° and 60° of 2θ. The chemical composition of all samples, in terms of major, minor and some trace elements, was determined on pressed powder pellets by X-ray fluorescence spectroscopy (XRF) on a Philips PW 1480 spectrometer, correction of matrix effects was made through computer processing (Franzini et al., 1975). Loss on ignition (L.O.I.) was gravimetrically estimated after overnight heating at 950° C and FeO content by wet titration.

Lastly, the local clay samples were analysed for particle size, for data on grain-size distribution. The granulometric separation of clay, silt and sand fractions was obtained by sedimentation, according to the method of Dell'Anna and Laviano (1987).

XRD analysis on the separated clay fraction (Ø < 2 μm) were carried after omoionization with Mg^{2+} and separation by centrifugation; XRD analysis were carried also on "tal quale" sample, glycoled sample and after eating up 335 °C and 550 °C, according to Laviano (1987).

To establish amphora and brick firing temperatures, firing tests were carried out on collected samples. Each sample, as it was, was mixed with the quantity of water necessary to produce a plastic, homogeneous paste. This was then used to make hand made square test samples measuring 3.2 x 3.2 x 0.5 cm (Cairo et al., 1997). Two test samples were prepared for each sample: one was fired to 650°C and the other to 900 °C (De Francesco et al., 2009; Pavìa, 2006), in a electric kiln, in order to simulate the possible conditions of ancient kiln firing. The firing cycle involved temperature increases of 100 °C/hour (Buxeda I Garrigòs et al., 2003), after which the test samples were exposed to the highest temperature for about 2 hours and then left to cool slowly. They were then pulverised and subjected to diffractometric analysis.

Results

Petrography

The petrographical study conducted on the

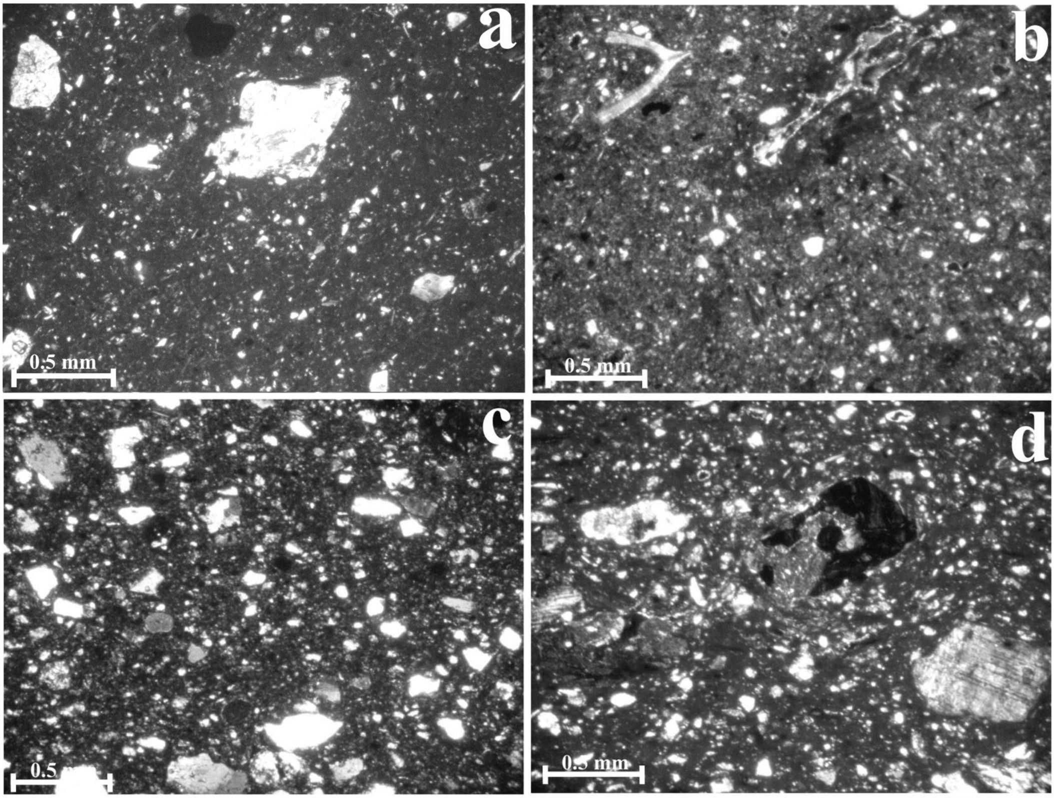

Figure 4. Thin section of representative pottery (crossed polars): a) *Keay LII Type* amphora A1; b) bioclasts in the unidentified amphorae A10; c) wine amphora of oriental shape A3; d) brick OP1d from the *opus spicatum*.

thin-sections of all the amphorae and brick fragments made it possible to assess the relative amount of the matrix and clasts, and to distinguish between minerals and rock fragments.

The grain size and the abundance of mineral and rock fragments is larger in the bricks; compared to the amphorae. The amphora show either small and large grains up to 2 mm of diameter.

The amphora fragments have been separated into two groups, on the basis of the different quantity and grain size distribution of the clasts.

The first group (A1, A2, A5, A9, A10, AV2 and AV3) consists of ceramics that show a fine and homogeneous matrix with a reddish-brown colour. Some samples has an oriented and micaceous matrix. Bimodal grain size distribution is present: the relative amount of the larger clasts (up to 2mm), vary from 5 to 10% (Figure 4a), respect to the matrix, while the smaller grains are more abundant and finely dispersed in the matrix. The clasts are composed by minerals and rocks of granitic and metamorphic origin: quartz, feldspars (plagioclase and K-feldspar), biotite and muscovite, represent the main mineralogical phases, together with gneissic and granitoid rock fragments. Rarely prismatic sillimanite, perthitic K-feldspar and large biotite occur. The carbonatic component (from rare to frequent), appears as fragments of bioclasts (Figure 4b) and Phoraminifera shells or as secondary microcrystalline calcite of pore filling, probably due to post-burial alteration, calcite recrystallization from pre-existing carbonates in the mixture or external contamination (Cau Ontiveros et al., 2002). Small flakes of muscovite and biotite are abundant in most of the samples and show a slight orientation, justified by a probable use of wheel.

The second group (A3, A8, A51) shows a crystalline, slightly porous matrix of intense red colour and a higher quantity of non plastic fraction, up to 20 - 30% (Figure 4c). The medium grain size is prevailing, only few clasts show size up to 2mm;. Quartz is the most abundant mineral, with subordinate plagioclase and k-feldspar. The carbonates, are present only in A51 amphora, completely lacking in A8 sample and quite rare in A3 amphora as rare calcarenite clasts or as secondary calcite in the fossil moulds. Muscovite and biotite are poorly represented in all the ceramics of this group. The metamorphic and igneous rock fragments are frequent in A8 and A51 amphorae; those last two samples contain also few clasts of volcanic origin. Rare fragments of chert occur only in A3 sample.

The bricks contain homogeneous structural and textural characters. The matrix is well oxidized, brown-red in colour. The porosity is medium; often flattened and filled by secondary calcite. The medium-sized percentage of clasts with respect to the matrix is about 20-30% and it is not regularly distributed (Figure 4d). The clasts are similar to those of the first group of amphorae, composed by minerals and rock of granitic and metamorphic origin, quartz, plagioclase, K-feldspar, together with gneissic and granitoid rock fragments. Biotite and muscovite are elongated parallel to the main preferred orientation as the porosity. The bricks contain abundant carbonate fraction, both as bioclasts (mainly Phoraminifera shells) and as secondary calcite of pore filling.

Table 2. Mineralogical phases and relative abundances identified by XRD analysis of sherds.

Sample	Qtz	Pl	Kfs	Cal	Ill/Ms
A1	****	***		**	
A2	****	***	**	*	
A5	****	***		**	
A9	****	***	**	*	
A10	****	**		***	
AV2	****	***		**	
AV3	****	***		**	
A3	****			***	**
A8	****	***	**		
A51	****	***	**	**	*
L1a	****	***		**	
L1b	****		***	**	
L1c	****	**		***	*
L1d	****	***		**	*
L1e	****	**		***	*
L1f	****	***		**	
OP1a	****	***	**	***	*
OP1b	****	***	***	**	
OP1c	****	***	**	***	*
OP1d	****		***	***	

Qtz: Quartz; Pl: Plagioclase; Kfs: K-feldspar; Cal: Calcite; Ill/Ms: Illite/Muscovite. **** = very abundant; *** = abundant; ** = present; * = scarce.

X-Ray Diffraction Analysis (XRD)

The diffrattometric data results (Table 2) show that the amphora and brick samples have a very common mineralogical composition, mainly represented by quartz and calcite followed by plagioclases, K-feldspar and mica; only in the A8 ceramic no calcite was found. Furthermore high-temperature Ca-silicates, like diopside or gehlenite, were not detected in the archaeological samples. The abundance of the identified mineral phases, estimated on the basis of the intensity of reflection peaks in the XRD spectra, varies depending on sample.

Results On The Raw Clayey Materials

Quartz and, in decreasing order, calcite, plagioclase, micas was detected by XRD on the clay samples. The XRD analysis on Ø < 2 μm fraction show that the Pliocene clays contain

Table 3. Chemical analysis of all major elements and some trace elements of the amphorae (A) and of the bricks (L-OP) from Muricelle.

	A1	A2	A5	A9	A10	AV2	AV3	A3	A8	A51
SiO_2	57.11	56.18	58.08	58.33	58.51	56.21	59.40	68.09	69.45	55.07
Al_2O_3	16.13	17.44	16.79	16.89	15.82	18.01	16.15	14.90	17.36	15.75
Fe_2O_3	6.25	6.79	5.29	5.87	6.53	6.45	6.16	5.55	5.40	6.68
FeO	0.45	0.50	1.50	0.99	0.40	0.85	0.69	0.15	0.20	0.16
MnO	0.12	0.12	0.13	0.13	0.12	0.14	0.14	0.08	0.03	0.11
MgO	4.38	4.11	4.35	4.05	3.57	4.73	3.95	1.82	1.58	2.82
CaO	10.40	9.62	8.54	8.34	10.13	8.56	8.37	6.06	1.45	14.25
Na_2O	1.25	0.96	1.24	1.19	1.00	1.13	1.22	0.47	1.29	1.23
K_2O	2.81	3.06	2.83	2.96	2.78	2.74	2.77	1.89	2.35	2.81
TiO_2	0.80	0.83	0.81	0.82	0.79	0.83	0.80	0.76	0.72	0.76
P_2O_5	0.25	0.34	0.27	0.31	0.30	0.25	0.28	0.21	0.15	0.34
L.O.I.	3.09	6.94	3.00	4.67	10.20	3.22	6.97	6.99	5.43	5.86
Nb	17	18	18	18	19	19	17	18	19	20
Y	29	30	28	30	28	27	28	33	23	23
Rb	133	135	133	134	126	125	125	85	105	133
Zr	196	200	199	203	196	189	202	215	200	261
Sr	368	382	326	325	346	358	320	152	163	449
Ni	56	59	57	56	58	59	58	96	29	161
Cr	116	111	125	125	106	130	116	172	88	180
V	110	119	125	127	118	131	123	119	87	97
La	54	44	39	47	40	47	47	45	44	49
Ce	85	84	82	82	71	96	88	84	70	107
Co	19	19	18	18	19	19	19	18	13	19
Ba	412	565	506	556	549	511	516	548	576	685

Major elements are expressed in percentage by weight (wt %), while trace elements are expressed in ppm.

montmorillonite, minor percentage of caolinite, mixed layers clayey minerals, illite and chlorite.

Granulometrical analysis of all the clay samples, according to Shepard's classification (Shepard, 1954), show that the samples are clayey silt; the averages are about 30 - 40% of clay, 50-60% of silt and the sand fraction in fact does not exceed 10%.

The XRD powder analyses of the clays fired at the temperature of 650 °C reveal an abundant presence of quartz followed by calcite, plagioclase, micas, chlorite and k-feldspar, very similar to the original mineralogical composition, while in the clayey materials fired at 900 °C, it is worthy to note the formation of diopside (Peters and Iberg, 1978) and the complete disappearance of the calcite. Comparison of the mineralogy of the test samples with that of the bricks and amphorae, as diopside was not present, shows that they were fired at temperatures lower than 900 °C (Maggetti, 1982).

The clayey sediments fired at the temperature of 900 °C, show a well oxidized matrix, characterized by red colour very similar to the matrix colour of the amphorae of the first petrographic group and to the matrix of quite all the bricks.

X-ray fluorescence analysis (XRF)

The chemical analyses of the ceramic fragments and clayey materials are shown in Table 3 and Table 4, respectively.

In the CaO + MgO vs SiO_2 binary diagram of Figure 5a, the amphorae and the bricks were compared with the sampled clays. It is evident

Table 3. Continued ....

	L1a	L1b	L1c	L1d	L1e	L1f	OP1a	OP1b	OP1c	OP1d
SiO_2	54.91	53.49	54.36	55.42	54.21	52.34	56.71	54.68	55.47	55.31
Al_2O_3	16.79	15.02	14.85	16.05	15.59	14.80	17.04	16.75	16.85	16.08
Fe_2O_3	7.03	6.18	6.17	6.50	6.75	6.31	6.51	6.34	6.56	6.38
FeO	0.16	0.19	0.40	0.29	0.40	0.33	0.18	0.41	0.29	0.19
MnO	0.13	0.14	0.12	0.14	0.13	0.13	0.12	0.13	0.13	0.12
MgO	4.93	5.82	4.02	4.35	4.56	4.80	3.84	4.09	4.12	4.11
CaO	11.10	15.49	15.39	12.66	13.41	17.40	10.65	13.04	11.96	13.24
Na_2O	0.71	1.07	0.68	0.90	0.66	0.82	0.95	1.19	1.06	0.90
K_2O	3.25	1.69	3.03	2.69	3.23	2.05	3.05	2.39	2.60	2.74
TiO_2	0.85	0.76	0.78	0.79	0.82	0.77	0.79	0.79	0.79	0.77
P_2O_5	0.14	0.12	0.15	0.18	0.19	0.22	0.13	0.14	0.14	0.13
L.O.I.	12.83	6.04	11.65	8.95	14.56	9.55	8.94	6.05	7.19	10.57
Nb	17	14	14	14	15	15	15	17	15	15
Y	27	25	22	25	27	26	22	26	26	25
Rb	124	83	113	101	120	72	104	96	87	102
Zr	183	169	173	186	182	187	191	190	191	182
Sr	401	496	390	414	405	465	570	464	465	474
Ni	58	58	50	56	58	55	51	55	55	52
Cr	91	109	102	105	89	113	105	112	116	105
V	114	86	120	91	114	108	85	103	97	93
La	42	45	32	35	40	52	46	43	38	35
Ce	83	61	62	78	67	70	63	66	64	73
Co	18	18	17	19	17	17	17	18	18	17
Ba	445	384	481	468	519	413	516	462	545	467

Major elements are expressed in percentage by weight (wt %), while trace elements are expressed in ppm.

that the bricks and the clays show a similar variation range of CaO+MgO content (varying from 14,49% to 22,20%), while the amphorae evidence higher values of SiO_2 , varying from 55,07% to 69,45%. In the diagram, the first group of amphorae, identified through petrographical analysis, is quite homogeneous for CaO + MgO content, but slightly different for the SiO_2 content. The A51 sample in this diagram remains in the group of bricks because of the high value of CaO (14,25%), due to the presence of carbonates observed under the microscope. Only the A3 and A8 samples clearly diverge from the rest of the group, both for the higher SiO_2 and for the lower CaO + MgO contents. In the Ni vs Cr binary diagram (Figure 5b), we observe that the first group of amphorae and all the bricks totally overlap with the sampled local clays (around 100 ppm of Cr and 50 ppm of Ni), with the exception of A51 and A3 amphora fragments, that show higher Ni and Cr content (Barilaro et al., 2006; Barone et al., 2002). The A8 sample has the lowest Ni content and differs from all the others.

Discussion

The petrographic characteristics showed by of the first group of amphorae (some of which *Keay LII Type*) and of the bricks, mainly the presence of the clasts composed by minerals and rocks of medium to high metamorphic grade and granitic origin together with the fossils remains, suggest a local origin. In fact, quartz, feldspars (plagioclase and K-feldspar), biotite and muscovite of magmatic origin, with gneissic and

Table 4. Chemical analysis of all major elements and some trace elements of the clay samples from Muricelle.

	T1	T2	T3	T4	T5	T6	T7
SiO_2	53.60	53.47	53.78	53.29	53.71	51.53	50.87
Al_2O_3	16.60	16.59	18.47	16.74	17.07	16.31	15.90
Fe_2O_3	3.57	3.46	3.05	4.11	5.17	3.04	4.26
FeO	3.42	3.50	3.97	2.86	1.89	3.42	2.71
MnO	0.13	0.13	0.11	0.14	0.13	0.13	0.09
MgO	4.32	4.44	4.43	4.48	4.06	4.50	4.32
CaO	12.88	12.92	10.36	12.95	13.11	15.83	16.59
Na_2O	1.11	1.09	1.03	1.12	0.79	0.92	0.94
K_2O	3.02	3.04	3.34	3.02	2.87	2.99	3.05
TiO_2	0.84	0.82	0.90	0.85	0.87	0.83	0.84
P_2O_5	0.14	0.14	0.12	0.13	0.11	0.11	0.13
L.O.I.	14.95	15.59	13.81	16.55	16.55	16.49	16.53
Nb	17	17	17	18	18	15	15
Y	26	29	29	26	25	29	26
Rb	140	141	151	141	143	132	140
Zr	186	190	200	187	191	192	195
Sr	356	356	336	369	396	597	682
Ni	61	58	56	60	59	60	58
Cr	121	123	123	123	123	113	112
V	153	154	159	152	149	132	133
La	39	39	42	48	48	46	42
Ce	66	72	82	66	79	83	63
Co	19	19	21	18	19	17	17
Ba	372	366	420	366	394	387	470

Major elements are expressed in percentage by weight (wt %), while trace elements are expressed in ppm.

granitoid rock fragments are the most abundant grains in both amphorae and bricks. This kind of rocks are very common in the Sila Massif, on the eastern side of the river valley Crati, and are extremely similar to the lithic clasts contained in the studied ceramics coming from the ruins of the *villae*.

The petrographical analysis results, suggest a common local origin for the bricks and the first group of amphorae, but different production technology. The mineralogical composition of the aplastic fraction of the bricks is similar to that of the first group of amphorae but differ because of the higher relative amount of clasts (30%) and carbonates, both as the largest amount of fossil shells or as secondary calcite.

The petrographic characteristics of the second group of ceramics diverge from those of the first group of amphorae and from all the bricks. The common petrographic features of the second group of amphoras consist mainly in the high percentage of the aplastic inclusion (up to 30%) but on the contrary are very different with respect to the mineralogical composition. The metamorphic rocks prevail in the sample A51 that also contains rare volcanic fragments. Granitic rocks are present in A8 amphora together with rare volcanic fragments, instead A3 sample does not contain either granite or metamorphic rocks and it differs because of the occurrence of several chert grains. The carbonate fraction is present as micro-fossils in the sample A51, as rare calcarenite fragments in A3 amphora, completely absent in the A8 sample.

Because of this evidences we suppose an importation of this three manufacts.

The results of chemical analysis of all the ceramics suggests a probable common local production for all the bricks, using the sampled clayey materials without any manipulation; an high affinity between the first group of amphorae and the local raw materials is also evident. The composition of the second group of amphorae differs from the local clays confirming the petrographic observations (Figure 5a, b).

Hierarchical Clustering Analyses (Ward method, euclidean distance) obtained by all the analyzed major and trace elements (Figure 6), shows the presence of two main groups. The first one is divided in two subgroups: all the bricks (subgroup 1) and quite all the amphorae (subgroup 2). This last subgroup, recognized as first petrographic group (A1, A2, A5, A9, A10, AV2 and AV3), include also the A51 samples, that anyway has some affinity with the main group because of the calcium content. The second group include only the A3 and A8 samples, completely separated from the other amphorae. The dendrogram resume and confirm the differences and the affinities observed by petrographical and chemical analysis.

The raw materials used for the bricks production are probably well identified in the clays sampled in the quarry of Ginestreto and we hypothesize the use of the clayey materials that

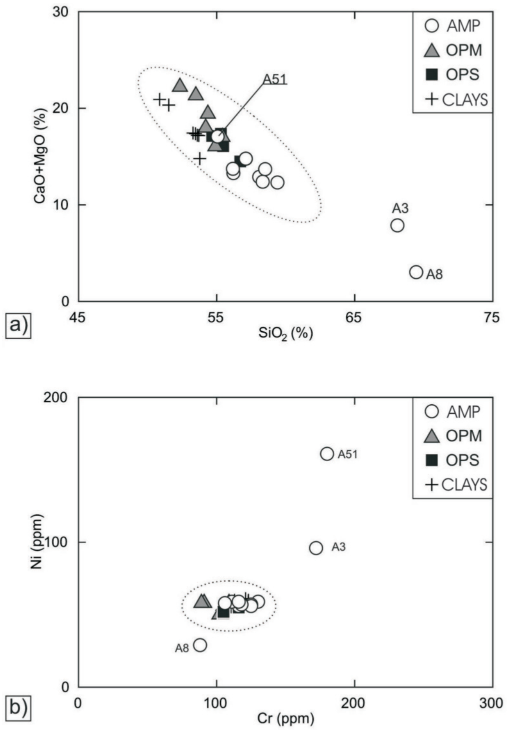

Figure 5. Comparison between ceramics and sampled local clayey materials. a) CaO+MgO vs SiO_2; b) Ni vs Cr. (AMP) indicate the amphorae. (OPM) the bricks of the opus mixtum. (OPS) the bricks of the *opus spicatum* and the collected clays (cross).

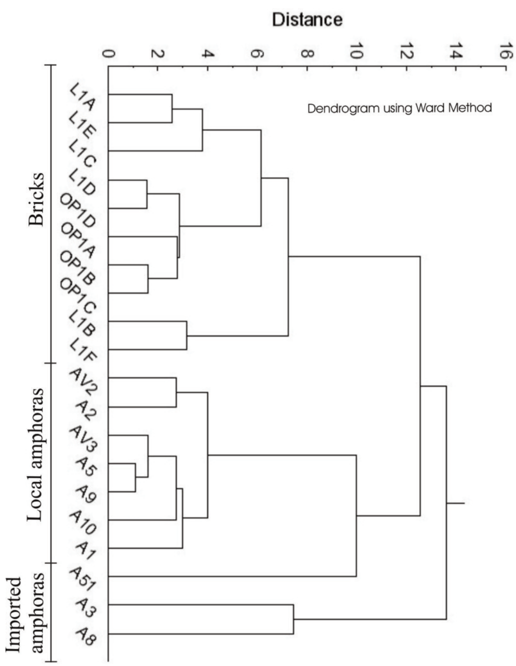

Figure 6. Dendrogram obtained using XRF analysis data of all the bricks and the amphorae from the Muricelle site.

are richer in silty fraction. The firing experiments of the local clay suggest firing temperature of about 800 °C for the bricks, because of the mineralogical composition without gehelenite or diopside (Maggetti, 1982), that instead were formed in the clayey sediments fired at the temperature of 900 °C.

The archaeometric study of the examined material turns out extremely important from an archaeological point of view: particularly interesting are the relative data on the amphorae of the *Keay LII* Type (samples A1, A2, A5, AV2). This kind of container, that between the end of the 4th and the end of 6th and beginnings of the 7th century B.C, caught up all the greatest markets of the roman world, believed until few years ago produced exclusively in the zone of the Stretto di Messina (Keay, 1984; Sciallano and Sibella, 1997; Sangineto, 2001; Arslan, 1990), located southernmost of about 200 Km far away.

On the basis of the petrographic composition, the first group of amphorae, which includes four *Keay LII* Type (samples A1, A2, A5, AV2), because of the high affinity with the rocks of the Sila Massif, might be of local origin.

Until now, kilns for the production of *Keay LII* Type amphorae have not been reported in northern Calabria, but only at Marasà near Locri, and at Pellaro (RC) in southern Calabria (Lattanzi, 1988; Andronico, 199; Di Gangi and Lebole, 1998). Subsequently, for the first group of amphorae, cannot be excluded the provenance from other areas of southern Calabria or northeastern Sicily, where similar rock types outcrop.

Conclusions

The results, obtained using different methodologies, on 10 ceramic fragments of Imperial Roman age and 10 bricks of the same period, allowed their characterization and suggest about their provenance and technology. On the basis of petrographical evidence, two groups were recognized: the first group includes all the bricks and the majority of ceramic fragments that, show high compatibility with the local clayey materials.

The bricks of Muricelle site could be produced locally, given also the presence of a bricks kiln in the area, active until a few years ago. As regard the first group of amphorae, which also show a high compositional affinity with the local raw materials, cannot be excluded their provenance from other Calabrian areas, where similar rocks outcrop, because kiln for the amphorae production, around the Muricelle site, are not known.

The second group comprises three amphora fragments that because of dissimilar petrographical, mineralogical and geochemical features, in respect to the local raw materials, may be considered imported, testifying trade exchange related to the rural economy of the families that lived in the *villa*.

The presence in almost all the samples of the carbonatic component and the absence of mineralogical phases of high temperature allow us to hypothesize, for all the ceramics and for the bricks firing, temperatures ranging from 700 °C to 800 °C.

This paper provides preliminary data useful for future researches aimed to a systematic excavation in this area.

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References

Andronico E. (1991) - Il sito archeologico di Pellaro, *Mélanges de l'Ecole francaise de Rome: moyen-age.* 103, 2, 731-736.

Arslan E. (1990) - La dinamica degli insediamenti in Calabria dal tardo antico al medioevo, in: *L'Italia* *meridionale tra Goti e Longobardi, XXXVII Corso di Cultura sull'Arte Ravennate e Bizantina*, Ed. del Girasole, Ravenna, 59-92.

Amodio Morelli L., Bonardi G., Colonna V., Dietrich D., Giunta G., Ippolito F., Liguori V., Lorenzoni S., Paglionico A., Perrone V., Piccarreta G., Russo M., Scandone P., Zanettin-Lorenzoni E. and Zuppetta A. (1976) - L'arco calabro-peloritano nell'orogene appenninico-maghrebide. *Memorie della Società Geologica Italiana*, 17, 1-60.

Barilaro D., Barone G., Crupi V., Majolino D., Mazzoleni P., Triscari M. and Venuti V. (2006) - Characterization of ancient amphorae by spectroscopic techniques. *Vibrational Spectroscopy*, 42, 381-386.

Barone G., Ioppolo S., Majolino D., Migliardo P. and Tigano G. (2002) - A multidisciplinary investigation on archaeological excavation in Messina (Sicily). Part I: a comparison of pottery Findings In "The Strait Of Messina Area". *Journal Of Cultural Heritage*, 3, 145-153.

Buxeda I Garrigós J., Jones R.E., Kilikoglou V., Levi S.T., Maniatis Y., Mitchell J., Vagnetti L., Wardle K.A. and Andreou S. (2003) - Technology Transfer At The Periphery Of The Mycenaean World: The Cases Of Mycenaean Pottery Found In Central Macedonia (Greece) And The Plain Of Sybaris (Italy). *Archaeometry*, 45 (2), 263-284.

Cairo A., Muggia A. and Riccardi M.P. (1997) - Le temperature di cottura dei laterizi di epoca romana: i manufatti dello scavo di Pomello (PV), In: Atti della prima giornata di archeometria della ceramica. 1th Annual Meeting, Febrary 28, University Press Bologna, Bologna, 162-168.

Cau Ontiveros M.A., Day P.M. and Montana G. (2002) - Secondary calcite in archaeological ceramics: evaluation of alteration and contamination processes by thin-section study, Modern trends in scientific studies on ancient ceramics, in: Proceedings of 5th European Meeting on Ancient Ceramics, Athens 1999 (eds. V. Kilikoglou, A. Hein and Y. Maniatis), 9-18. *BAR International Series* 1011, Archaeopress, Oxford.

Colelli C. (2008) - Rinvenimenti ceramici di età imperiale romana da Muricelle Luzzi. In: Atti Convegno "Ceramica e attività produttiva a Bisignano ed in Calabria dalla protostoria ai giorni nostri", Bisignano 25-26 Giugno 2005.

De Francesco A.M., Iannelli M.T., Barrese E., Andaloro E., Imperitura V.G. and Bocci M. (2009) - Provenance and technology of bricks from the Greek colony of Kaulon (Calabria, Italy). *Periodico di Mineralogia*, 78 (3), 37-49.

Dell'Anna L. and Laviano R. (1987) - Analisi Granulometrica Di Argille: Esame Dei Principali Metodi, in: Atti Workshop "Procedure Di Analisi Di Minerali Argillosi". Enea, La Spezia, 215-234.

Di Gangi G. and Lebole C.M. (1998) - Keay LII ed altri materiali ceramici da contesti di scavo nella Calabria centro-meridionale (V-VIII secolo), in Saguì L. (ed.), La ceramica in Italia, VI-VII secolo (Roma 1995), Atti del Convegno in onore di J. Hayes, Firenze, 761-768.

Franzini M., Leoni L. and Saitta M. (1975) - Revisione Di Una Metodologia Analitica Per Fluorescenza X Basata Sulla Correzione Completa Degli Effetti Di Matrice. *Rendiconti della Società Italiana di Minereralogia e Petrologia*, 31, 356-378.

La Marca A. (2002) - Nuovi materiali per una carta archeologica del territorio di Luzzi. In: La Marca A. (eds.), Archeologia del territorio di Luzzi: stato della ricerca e prospettive, Rubettino ed., Soveria Mannelli, pp. 33-40.

Lanzafame G. and Zuffa G. (1976) - Geologia e Petrografia del Foglio di Bisignano (Valle del Crati, Calabria): con carta geologica 1: 50.000, *Geologica Romana*, 15, 223-270.

Lattanzi E. (1988) - L'attività archeologica in Calabria. *Atti Taranto*, 545-563.

Laviano R. (1987) - Analisi mineralogica quantitativa di argille mediante diffrattometria a raggi X. In: Atti workshop "Procedure di analisi di minerali argillosi", E.N.E.A. - S. Teresa, La Spezia, 215-234.

Le Pera E., Critelli S. and Sorriso-Valvo M. (2001) - Weathering of gneiss in Calabria, Southern Italy, *Catena*, 42, 1-15.

Keay S.J. (1984) - Late Roman Amphorae in the western Mediterranean. A tipology and economic study: the catalan evidence. *BAR International Series*, Oxford, 196.

Maggetti M. (1982) - Phase analysis and its significance for technology and origin. In: J.S. Olin, A.D. Franklin (eds.), *Archaeological ceramics*, Smithsonian Instit. Press., 121-133.

Pavìa S. (2006) - The determination of brick provenance and technology using analytical techniques from the physical sciences. *Archaeometry*, 48, 201-218.

Peters T. and Iberg R. (1978) - Mineralogical changes during firing of calcium-rich brick clays. *Ceramic Bulletin,* 57 (5), 503-509.

Sangineto A.B. (2001) - Trasformazioni o crisi nei brutti fra il II a.C. e il VII d.C. In: E. Lo Cascio, A. Storchi Marino (eds.), Modalità insediative e strutture agrarie nell'Italia meridionale in età romana, Bari, 203-246.

Sangineto A.B. (2006) - Il Vino e l'armonia dei paesaggi agrari dei Bruttii, Monteleone, Vibo Valentia.

Sciallano M. and Sibella P. (1991) - Amphores. Comment les identifier? Edisud, Aix en Provence.

Shepard F.P. (1954) - Nomenclature Based On Sandsilty- Clay Ratios. *Journal of Sedimentary Petrology,* 24, 151-158.

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