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p-XRF analysis of multi-period *Impasto* and Cooking Pot wares from the excavations at Stromboli-San Vincenzo, Aeolian Islands, Italy

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ABSTRACT

This exploratory study focuses on the elemental analysis by p-XRF (portable X-Ray Fluorescence Analyser) of 62 samples of coarse wares, consisting of Bronze Age handmade burnished ware, so-called *Impasto*, and of Cooking ware (dated from the Roman period to Modern times). All wares originate from the site of San Vincenzo, Stromboli, and Aeolian Islands. The question addressed here is whether it is possible to differentiate between local (Aeolian) and imported (non-Aeolian) fabrics with the use of the p-XRF; 42 of the 62 samples were also subjected to petrographic analysis as a way of testing our hypothesis. Our results show that p-XRF analysis can clearly assist in distinguishing between Aeolian *vs.* non-Aeolian wares. Analyses can take place in the field and large quantities of sherds can be processed as a result. We suggest that no further demands should be made of the technique in providing answers to more detailed provenance questions. This is because finer separation in subgroups (as achieved recently by combined petrographic and EPMA analysis on select samples) is not possible given the nature of coarse pottery and the limitations of the technique in measuring key light elements (Na, Mg). Furthermore, for some elements (e.g Cr) accuracy is below acceptable levels in which case results for these particular elements are considered semi-quantitative.

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p-XRF; handmade burnished ware; cooking wares; petrography; Stromboli

Introduction

Stromboli, the northernmost island in the Aeolian Archipelago in the southern Tyrrhenian Sea, is in a strategic position for controlling the maritime routes, in particular the Messina Strait (Figure 1). The new excavation at the site of San Vincenzo, directed since 2009 by Sara T. Levi in collaboration with the Soprintendenza of Messina and with the Parco Archeologico delle Isole Eolie e delle aree archeologiche di Milazzo, Patti e Comuni Limitropfi, has revealed a wide Early-Middle Bronze Age village (Capo Graziano *facies*. XXII-XV cent BC) with several oval stone-built huts inside a network of stone fences and terraces (Di Renzoni, et al., 2014; Ferranti, et al., 2015; Levi, et al., 2011, 2014; Levi & Martinelli, 2013; Zhao, et al., 2015). The occupation of the site continues into historical times with evidence of burials, buildings and abundant pottery from the Classical period to the present.

The pottery from San Vincenzo (SV) is considerable and varied. It includes *Impasto*, Mycenaean, Black Gloss, *terra sigillata*, amphorae, cooking wares, glazed pottery and maiolica. This paper sets out to investigate the role of p-XRF for the purpose of preliminary characterisation and determination of provenance of the coarse pottery retrieved from the Bronze Age and later levels at the excavation site. The coarse wares are attested only by:

a. Bronze Age handmade burnished ware, so-called *Impasto* pottery (Figure 2.1), the typical ware of central Mediterranean pre and proto-history (Levi 2010).
b. Cooking ware (Figure 2.2), a wheel made pottery, sometimes glazed, produced from the archaic period onwards and mainly used for cooking. The chronology of these cooking wares at San Vincenzo is insecure, but what is known is that production during the Roman period took place in southern Italy, Sicily and Lipari (Bernabò Brea, et al., 1998).

In the course of 50 weeks of fieldwork (2009–2014) a total of nearly 4000 artefacts have been processed in our field-based laboratory at Stromboli. Focusing on the goal of the present work, more than 2000 *Impasto*

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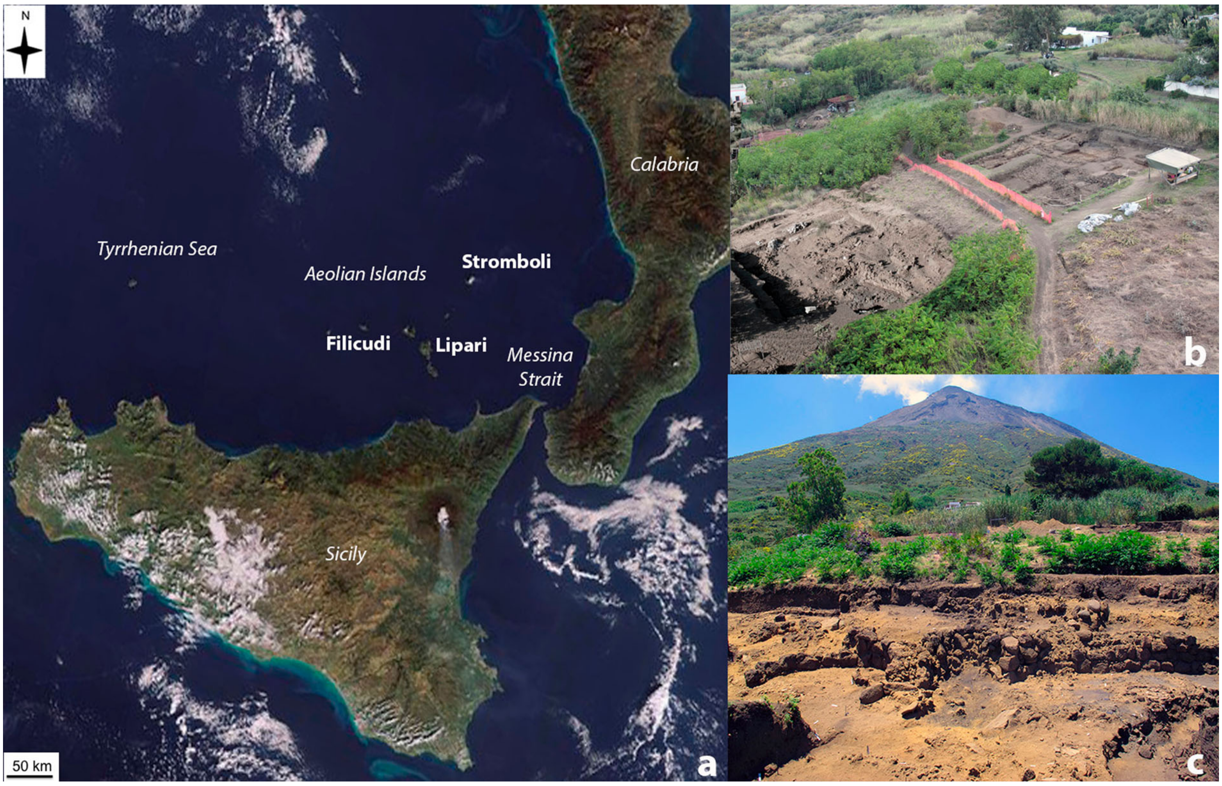

Figure 1. a. The Aeolian Islands and surrounding areas in the Southern Tyrrhenian sea; b. general view of the archaeological excavation at San Vincenzo-Stromboli; c. the archaeological site and the volcano.

and nearly 100 Cooking ware sherds have been individually examined and recorded (giving an average of about eight per day). Aeolian products have been satisfactorily differentiated from non-Aeolian ones primarily thanks to the petrography-based pioneering work of Williams (1980, 1991). More specifically and

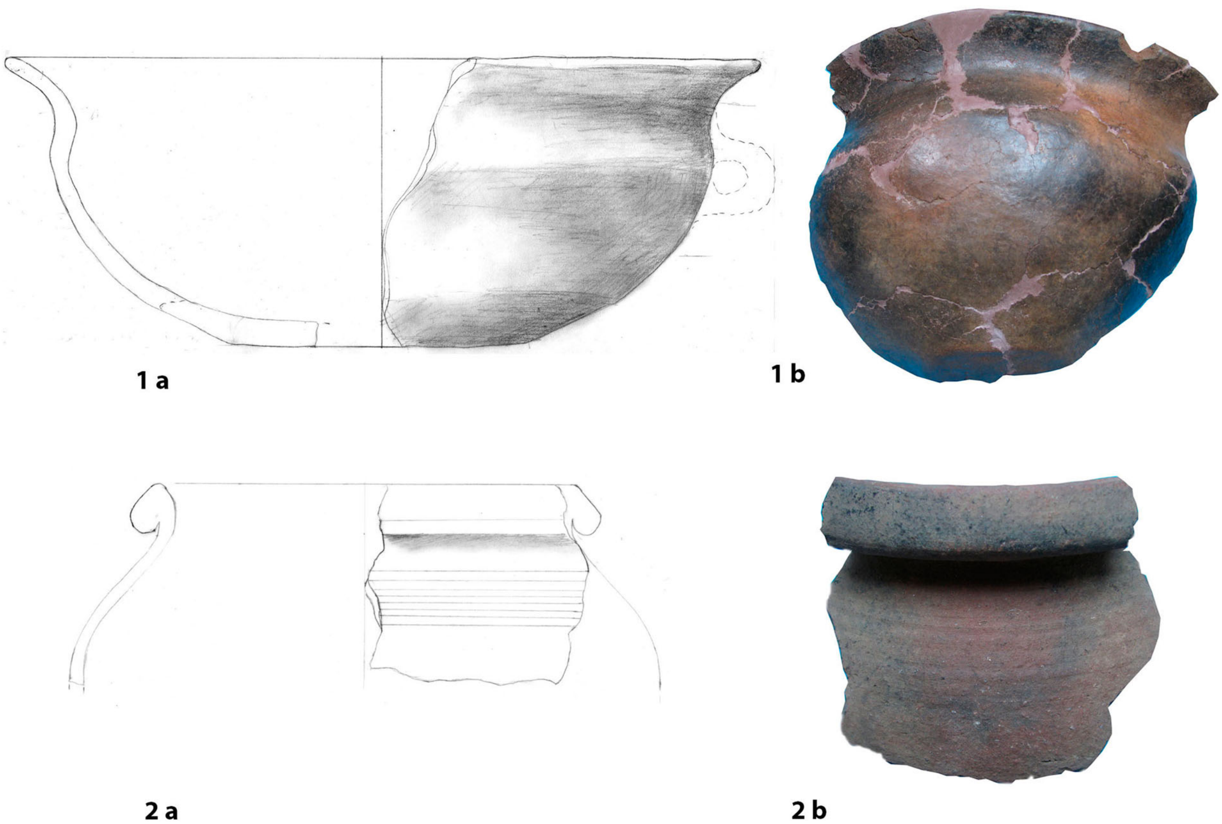

Figure 2. Example of analysed coarse wares from San Vincenzo, Stromboli: 1 Bronze Age *Impasto*, 2 historical Cooking ware; a. drawings by Paola Vertuani (scale 1:3); b. pictures.

critically, Williams demonstrated the unique situation regarding prehistoric pottery, including impasto, in the Aeolian Islands: there was respectively locally (ie Aeolian) made pottery containing (local) volcanic inclusions, locally made pottery using *imported* clay to which (local) volcanic material was added, and imported pottery with inclusions derived from plutonic and sedimentary rocks. This complex pattern of production and circulation is what makes Aeolian pottery so interesting and why it is important to know the origin of the pottery in the Aeolian Islands. Since we cannot thin section every sherd there is a real need for an alternative approach – pXRF. Williams' early studies were complemented with subsequent further work (Cazzella, et al., 1997; Jones, et al., 2014, 235; Levi & Williams, 2003; Williams & Levi, 2008). As a result, it is now clear that the Aeolian Archipelago pottery production sites are characterised by their volcanic tempers and those in Calabria and/or Sicily by their sedimentary and metamorphic clasts.

Recently a petrographic study combined with micro-chemical analysis (by electron microprobe and ICP-MS) was carried out by Brunelli, et al. (2013) on 139 Middle Bronze Age (Capo Graziano *facies*) samples from various Aeolian Islands in order to further refine the above characterisation and to establish reliable reference groups of *Impasto* pottery based on temper. Capo Graziano vessels from different islands in the archipelago are not simply characterised by their tempers but also by their decoration in different patterns and styles (Levi, et al., 2014). According to the Brunelli, et al., (2013) study, it has been possible to subdivide the Aeolian Capo Graziano *Impasto* pots into four "Temper Compositional Reference units": AI, AIV, AVIII, AX.

The AX group is characterized primarily by lava clasts (50–70%) with abundant plagioclase and less clinopyroxene, orthopyroxene and hydrous phases as shown in Table 2. The AIV group is mainly characterized by mineral phases and lava clasts with very low to negligible glass content. Minerals are plagioclase, clinopyroxene and scarce orthopyroxene. Hydrous minerals are represented by euhedral brown hornblende and subordinate green hornblende and biotite. Temper in group AI is characteristically rich of colourless fresh volcanic glass fragments and pumice, and less plagioclase and pyroxene phyric lava clasts (basaltic andesite and andesite) with cryptomicrocrystalline groundmass. AVIII unit contains large and abundant grains (up to 2 mm) of plagioclase, clinopyroxene and orthopyroxene, along with some pyroxene-plagioclase glomerocrysts, which represent a distinct feature for the group.

The question addressed experimentally in this work is whether Aeolian vs. non Aeolian coarse wares can be differentiated easily and faster using a field-based technique like p-XRF. For the purposes of the present work, 50 *Impasto* and 12 Cooking ware sherds were specifically selected to be analysed both with p-XRF (a total of 62) and petrography (a total of 42). We present the results of petrographic analysis first, and then those of p-XRF analysis.

Petrographic analysis

42 out of the 62 sherds have been examined by petrographic analysis and the results are shown in Table 1. Five Fabric Groups have been defined and are summarised as follows:

- Volcanic Aeolian (Figure 3:1a, 1b)
- Granitic (Figure 3: 2a, 2b)
- Granitic +Micas (Figure 3: 3a)
- Micaschist (Figure 3: 4b)
- Siltstones (Figure 3: 5b)

The composition of volcanic temper of the Volcanic Aeolian Fabric is typical of the pottery made locally in

Table 1. Temper descriptions of the Fabrics of Stromboli coarse wares. The second column refers to Temper Compositional Reference Units discussed in Brunelli et al. (2013).

Fabric	Group	Suggested origin	Dominant 50–70%	Frequent 30–50%	Common 15–30%	Few 5–15%	Very few 2–5%	Rare 0.5–2%
Volcanic Aeolian	AX	Stromboli	lava clasts	plagioclase	ox, glass, pumice, clinopyroxenes	green hornblende	brown hornblende, orthopyroxenes	quartz, biotite, organic remains
	AIV	Stromboli or Filicudi	lava clasts	oxides, plagioclase	clynopyroxenes, glass		brown and green hornblende, orthopyroxene	olivine, pumice, quartz
	AI	Lipari	glass		plagioclase, oxides, clinopyroxenes	pumice	orthopyroxene	olivine
Granitic		Calabria?	quartz	K-feldspar	oxides, plagioclase, granitic rocks	mica	orthopyroxenes, hornblende	
Granitic +Micas		Calabria?	quartz mono/poli	hortoclase	plagioclase, biotite, mica	quartzshist	micashists	sandstones
Micaschist		Messina Strait area?	quartz	K-feldspar, micas, gneiss	oxides, plagioclase, grog	quartz scists	micascists, hornblende	
Siltstone		Sicily?	quartz	siltstones, grog, muscovite				

Table 2. R^2 values of the elements.

	Fe	*Ti*	*K*	*Ca*	*Al*	*Si*	*Mn*				
R^2 value	0,82	0,97	0,99	0,99	0,51	0,92	0,53				
	Zr	*Sr*	*Rb*	*Th*	*Pb*	*Zn*	*Cu*	*Cr*	*V*	*Ba*	*Nb*
R^2 value	0,97	0,92	0,99	0,98	0,89	0,78	0,98	0,73	0,83	0,30	0,76

the Aeolian Archipelago. This consists of three of the groups – AX, AIV and AI – previously identified by Brunelli, et al. (2013) and previously mentioned. The remaining fabrics (Granitic, Granitic+Micas, Micaschists and Siltstones) are characterised primarily by quartz (dominant phase) and are indicative of imported pottery (Calabria, Messina Strait area, or Sicily) due to the presence of minerals and rock fragments totally absent in the Aeolian Islands. The relative proportions of AX, AIV and A1 at SanVincenzo are 25%, 39%, 27% respectively with the remainder comprising AVIII (9%) which is the fabric exclusively produced in Filicudi and Lipari and is not attested in our dataset. Table 2 summarises the petrographic data and gives the suggested origin of each fabric.

Regarding this point, the results evidence a local production in the single island, but also show an active intra-archipelago exchange network.

p-XRF analysis

During the last decade portable XRF (p-XRF) has revolutionised archaeological materials science and by extension archaeological fieldwork on account of its ability: a) to examine most archaeological inorganic materials (lithics, metals, glass, ceramics, pigments, and soils) and b) to bring technical analysis into the field (Shackley, 2011). Progress has been made in applying pXRF to the sourcing of ceramics, especially fine wares (eg. Jones & Campbell, 2016), but, unsurprisingly, it lacks the resolving power that techniques of destructive analysis can give. Although current concerns are rightly centred on defining p-XRF's limitations in the characterisation of ceramics (eg. Aimers, et al., 2012; Hunt & Speakman, 2015), pXRF has a role to play in the determination of origin so long as appropriately simple questions are asked of the data.

The present study, along with that at San Vincenzo on soils (Di Renzoni, et al., 2016), employed a NitonX3Lt-GOLDD instrument was a 50kVAgX-raytube, 80 MHz real-time digital signal processing and two processors for computation and data storage respectively. The instrument has three calibration modes suited to ceramic and soil analysis (TestAllGeo, Soils, Mining), of which the TestAllGeo (TAG) mode was chosen. Analysis time was set at 90 seconds and three measurements were taken on different spots on a cleaned, sawn surface of the sherd, prepared with a circular saw. The concentration of each of the twenty-five measured elements were averaged. Accuracy and precision were calculated by analysing six international standards GSP-2, AGV-2, DNC-1a, BCR-2, NIST2780 and NIST2709 and Edinburgh Standard Clay (this standard is described by Jones, et al., 2014, 527) and plotting the measured values against the certified values. The equation of a straight line was produced in Microsoft excel. From the regression analysis (calculation of the R^2 value) it was possible to ascertain the accuracy of measurement for each element. As shown in Table 2, not all elements were acceptable for the creation of bi-variate and multivariate PCA s using IBM-SPSS v. 21.

The Impasto and cooking wares have a coarse, heterogeneous fabric characterized by tempers of volcanic rocks (basalt and andesitic lava clast), intrusive rocks (granitic rocks), metamorphic rocks (mica-schists) and sedimentary rocks (siltstones), as described above. The Cr and the Na contents are the best markers of the local volcanic groups (Brunelli, et al., 2013). The other types of rocks (intrusive, metamorphic and sedimentary) have similar mineral constituent (mainly quartz) and the difference between the lithologies is mainly due to the presence and the composition of the micas. Of the elements - Al, Cr, Mn, K and Mg - that can best discriminate between these lithologies, p-XRF cannot determine Mg and Cr only semi-quantitatively.

Results

Table 2 presents the results of the regression analysis (R^2) Element determinations were deemed satisfactory if the R^2 value is >0.8. From Table 2 it is observed that Al, Mn, Ba, should not be considered when carrying out Principal Component Analysis (PCA) and that Cr, Zn and Nb should be accepted as semi-quantitative. In this way the dataset prepared for PCA was reduced to the thirteen elements shown in Table 3.

The Sr-Zr plot (Figure 4) shows a clear distinction between the Aeolian *Impasto* and the other classes. This is furthermore observed in the multivariate view (Figure 5a) but it is not possible to separate the Granitic from the Granitic+Micas *Impasto*. A similar situation occurs for the Cooking wares, with the volcanic Aeolian examples standing apart from the non-local fabrics. It is significant that the discriminatory elements – Zr, Sr, Th and Nb – are among those expected geochemically to differ between volcanic and non-volcanic environments.

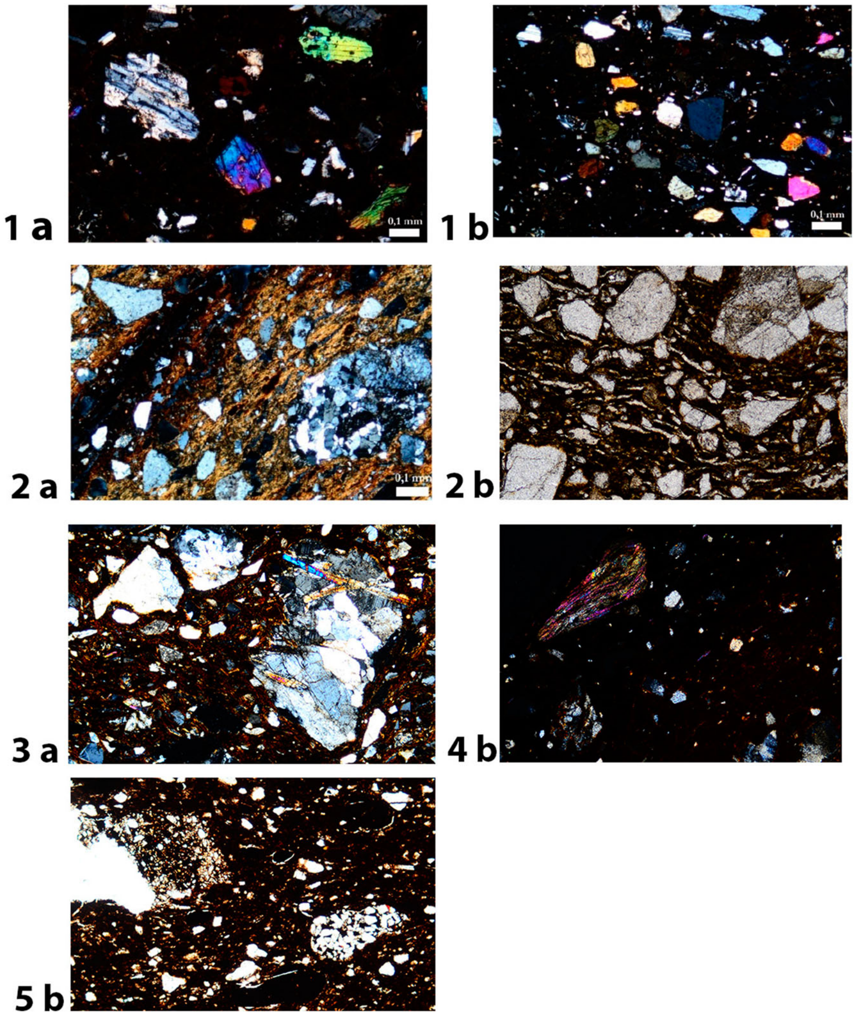

Figure 3. Photomicrographs of the Stromboli's coarse ware Fabrics (XP: cross polars; PPL: parallel polars; a: *Impasto* pottery; b: Cooking wares): 1.a Volcanic Aeolian (XP); 1.b Volcanic Aeolian (XP); 2.a Granitic (XP); 2.b Granitic (PPL); 3.a Granitic +Micas (XP); 4.b Micaschist (XP); 5.b Siltstones (PPL).

Regarding the volcanic Aeolian Fabric, the Temper Units typical of each island (Table 2) are not clearly distinguished by p-XRF.

Conclusions and Future Work

This exploratory study has highlighted that field based p-XRF analysis can provide good separation between the imported (non-Aeolian) vessels from the locally made ones. It cannot differentiate between different groups of non-Aeolian wares. This limitation is associated with the technique's inability to determine geochemically critical elements such as Na and Mg, its low level of accuracy for some elements, Cr being one of them. This element together with Na provided the best markers for the more finely resolved fabric distinctions made as a result of Brunelli *et al* electron micro probe analysis.

Furthermore, regarding the non-Aeolian Fabrics – Granitic, Granitic+Micas, Mica schist and Siltstone – the ability to discriminate them chemically has been undermined by their relatively similar mineralogical composition based mainly on quartz). What differences exist between the lithologies of these fabrics lie in the micas which in turn are governed chemically mainly by elements that, as already mentioned, p-XRF either cannot determine or determines with low confidence. Adopting one of the p-XRF's other calibration modes would not have alleviated this problem.

The message from this study is clear. p-XRF's role in characterising coarse wares such as *Impasto* and Cooking wares begins after their fabrics have been defined, either macroscopically or petrographically, p-XRF's considerable attributes then come into play providing in the field rapid analyses of the cut (sawn) surface of large numbers of sherds; this can be viewed as a 'screening' procedure generating chemical data which is scrutinised in the light of the fabric classification to make useful, if broadly based statements about identity, for instance precisely those elucidated in this study – volcanic vs. non-volcanic or local vs. non-local. The chemical classification should not be expected to be amenable to a more detailed level of interpretation, paralleling the outcome of the other p-XRF

Table 3. p-XRF data major and minor element concentrations (in ppm) in the 62 sherds analysed.

Sample	Ware	Shape	Fabric	Si	K	Ca	Ti	Fe	Cu	Pb	Rb	Sr	Zr	Nb	Th	V
14	*impasto*	decorated carinated cup	Aeolian	8,5	1,3	1,4	0,3	3,9	488	127	108	205	147	17	17	216
18	*impasto*	carinated cup with handle	Aeolian	9,4	1,3	2,2	0,4	4,3	432	18	105	202	153	15	8	278
28	*impasto*	decorated carinated cup	Aeolian	11,4	1,9	1,8	0,3	3,6	256	33	124	221	151	16	17	203
45	*impasto*	jug	Aeolian	12,6	1,9	2,0	0,4	4,3	367	18	101	202	122	14	12	286
84	*impasto*	jug	Aeolian	11,4	1,3	1,1	0,4	4,5	444	357	101	184	156	17	9	221
89	*impasto*	handle of closed shape	Aeolian	9,9	1,3	1,2	0,4	4,2	355	25	94	180	152	15	7	197
106	*impasto*	bowl	Aeolian	11,5	1,8	1,9	0,3	3,8	352	72	125	205	187	16	15	197
132	*impasto*	bowl	Aeolian	1,9	1	1,4	0,3	4,0	219	9	90	183	166	15	10	188
140	*impasto*	decorated fragment	Aeolian	12	2,2	1,6	0,4	4,1	191	97	149	204	170	16	11	162
154	*impasto*	decorated fragment of open shape	Aeolian	3,6	1,5	1,6	0,4	4,9	100	47	108	197	167	16	10	244
155	*impasto*	jug with applied rib	Aeolian	4,5	1,3	2,0	0,3	3,2	340	78	96	194	128	13	9	122
158	*impasto*	jug	Aeolian	5	0,9	1,0	0,3	3,9	395	25	72	176	90	10	2	167
165	*impasto*	carinated cup	Aeolian	10,8	1,1	2,0	0,4	3,7	134	9	103	197	165	16	8	217
175	*impasto*	decorated fragment	Aeolian	11,8	1,5	2,2	0,3	3,6	403	33	93	197	116	12	7	166
178	*impasto*	carinated cup with handle	Aeolian	2,9	1	1,8	0,2	3,3	133	67	77	243	127	13	7	119
187	*impasto*	jar	Aeolian	4,8	1,4	1,6	0,3	3,2	191	49	91	187	142	14	9	171
192	*impasto*	carinated cup	Aeolian	11,6	1,5	2,3	0,4	3,9	119	16	107	212	152	16	10	201
196	*impasto*	fragment of lid or support	Aeolian	11,6	1,6	1,6	0,3	3,3	237	113	103	197	187	15	8	205
203	*impasto*	handle	Aeolian	12,9	1,4	1,6	0,3	3,3	190	99	89	196	145	16	12	230
210	*impasto*	decorated fragment	Aeolian	3,9	1	1,9	0,3	3,7	213	57	82	197	142	14	9	173
216	*impasto*	carinated cup with handle	Aeolian	9,1	1,3	2,1	0,3	3,5	224	10	105	213	112	14	11	266
224	*impasto*	carinated cup	Aeolian	13,3	2,2	1,9	0,4	3,9	86	77	167	214	152	17	13	201
235	*impasto*	carinated cup	Aeolian	11,5	1,5	1,7	0,4	3,5	337	116	112	196	157	16	10	221
251	*impasto*	bowl	Aeolian	11,6	1,6	1,5	0,3	4,7	219	9	117	203	104	13	5	217
254	*impasto*	bottom of undefined pot	Aeolian	12,2	1,4	2,3	0,3	3,9	174	9	107	225	135	17	18	176
255	*impasto*	jug	Aeolian	11,1	1,7	2,2	0,4	4,4	156	14	112	230	127	17	14	221
268	*impasto*	cup	Aeolian	12,3	1,2	1,1	0,5	4,4	215	30	118	174	235	21	11	247
278	*impasto*	shoulder of jug	Aeolian	10,8	1,4	2,3	0,4	4,8	120	9	99	229	129	16	16	200
280	*impasto*	bowl	Aeolian	8,9	1	1,4	0,3	4,4	334	9	103	187	192	15	9	158
301	*impasto*	handle of closed shape	Aeolian	11,6	1,4	1,7	0,3	3,8	363	17	103	212	137	16	14	256
302	*impasto*	decorated fragment of open shape	Aeolian	9,1	1,4	1,9	0,4	3,7	134	75	96	201	155	16	9	265
304	*impasto*	pedestrial cup	Aeolian	13,4	2	1,9	0,3	3,3	101	14	122	199	153	13	8	157
336	*impasto*	carinated cup	Aeolian	10,9	1,8	2,1	0,3	4,2	190	12	162	215	143	17	15	237
366	*impasto*	decorated fragment	Aeolian	13,5	1,7	1,8	0,3	3,7	225	16	115	210	131	14	9	198
399	*impasto*	decorated fragment of open shape	Aeolian	11,4	1,1	1,4	0,3	3,8	372	26	171	193	203	10	10	224
424	*impasto*	cup	Aeolian	14,8	1,4	1,2	0,3	3,7	287	14	123	202	128	13	12	217
539	*impasto*	jug	Aeolian	12,7	1,0	1,3	0,3	3,3	284	22	97	187	124	14	10	117
540	*impasto*	jug	Aeolian	8,1	2,2	1,4	0,3	3,0	43	78	174	191	365	34	28	160
573	*impasto*	bowl	Aeolian	5	2,5	1,6	0,3	3,3	47	72	154	194	486	53	22	168
594	*impasto*	cup/bowl	Granitic	5,4	1,5	0,9	0,4	2,9	339	59	107	171	222	22	14	163
601	*impasto*	jug	Granitic	11,3	1,5	1,2	0,3	2,3	135	36	104	171	191	16	9	128
613	*impasto*	decorated fragment	Granitic	13	1,9	0,8	0,4	2,4	159	43	145	166	282	18	13	106
626	*impasto*	jug	Granitic	13,8	2,2	0,9	0,3	4,0	118	59	219	167	190	23	14	181
630	*impasto*	miniaturistic jug	Granitic	12,3	1,9	1,1	0,4	3,5	155	63	131	168	251	21	14	167
644	*impasto*	decorated fragment of open shape	Granitic	11,5	1,6	1,2	0,3	2,6	100	24	113	173	201	16	12	149
650	*impasto*	decorated fragment of open shape	Granitic	11,9	1,4	1,0	0,5	3,1	153	42	100	169	238	23	18	273
668	*impasto*	closed shape	Granitic	13,4	1,8	1,1	0,3	3,3	50	44	121	169	199	15	9	131
673	*impasto*	decorated fragment of open shape	Granitic	11,9	1,7	1,0	0,3	2,1	52	30	147	162	181	14	8	146
675	*impasto*	decorated fragment of open shape	Granitic	13,4	2,3	1,1	0,3	2,5	41	19	130	168	214	16	10	96
677	*impasto*	decorated fragment of closed shape	Granitic	4,3	3,3	0,7	0,2	2,3	11	99	200	173	393	28	32	181
1117	cooking pot	lid or plate	Granitic	5,2	1,4	0,8	0,4	2,8	78	45	94	168	282	17	6	99
1119	cooking pot	lid or plate	Granitic	5,5	1,3	2,4	0,6	3,7	25	34	52	171	308	20	2	142
1130	cooking pot	lid or plate	Granitic +Micas	12,4	1,7	1,0	0,4	2,9	166	36	141	170	204	16	9	122
1132	cooking pot	cooking pot	Granitic +Micas	41,5	1,4	1,1	0,3	2,5	160	49	91	170	193	16	7	167
1152	cooking pot	cooking pot	Granitic +Micas	10,6	1,8	1,1	0,5	4,5	54	53	128	167	231	21	15	195
1153	cooking pot	cooking pot	Micaschist	4	1,9	0,9	0,3	2,1	60	69	115	177	244	18	12	154
1159	cooking pot	cooking pot	Micaschist	4,3	2,4	1,0	0,4	4,5	71	68	107	167	210	20	10	208
1160	cooking pot	fragment of pot	Micaschist	4	2,2	1,0	0,5	5,0	111	64	118	170	202	19	9	183
1168	cooking pot	cooking pot	Micaschist	4,5	1,7	1,1	0,4	2,5	56	60	95	175	268	19	10	166
1171	cooking pot	lid or plate	Micaschist	4,3	1,9	1,0	0,5	4,1	125	74	124	174	229	19	11	234
1423	cooking pot	cooking pot with handle	Siltstone	6,5	1,7	0,7	0,4	3,4	34	40	65	173	631	20	8	65
2669	cooking pot	cooking pot	Siltstone	3,8	1,7	0,5	0,3	2,6	19	48	132	158	157	16	8	182

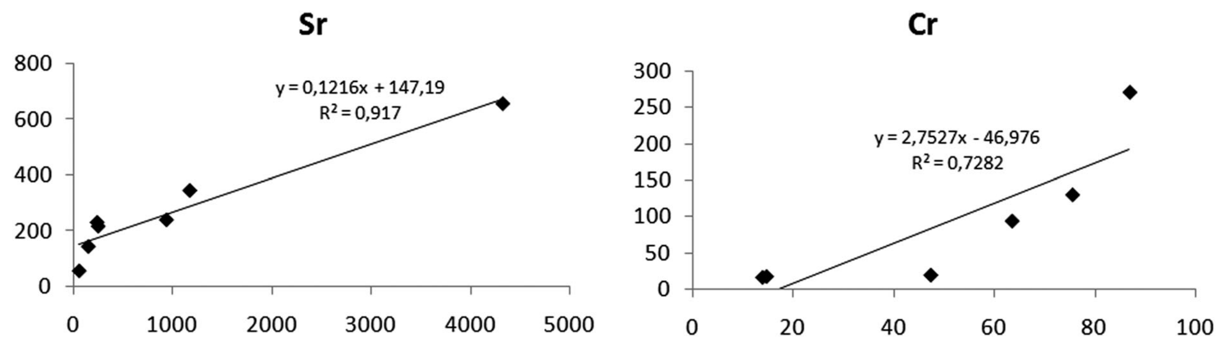

Figure 4. The binary plot of Sr and Zr contents (in ppm) in *Impasto* and Cooking pots.

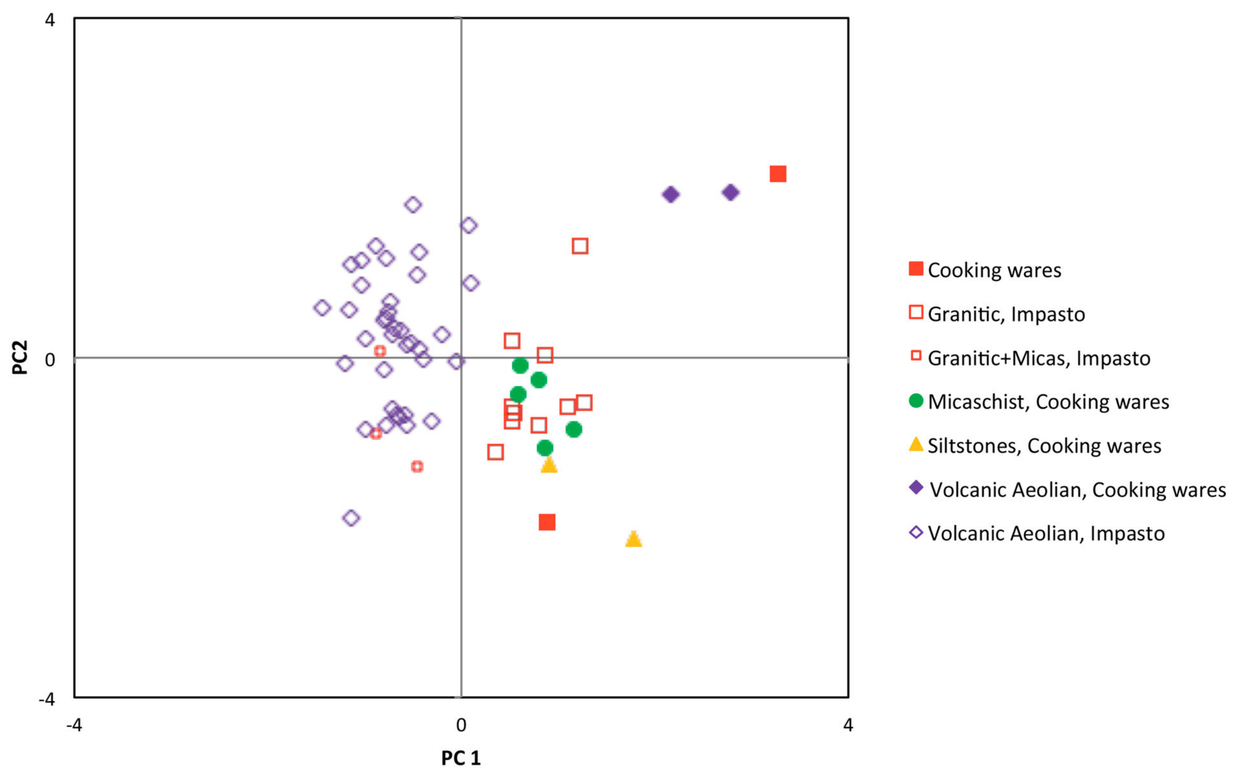

Figure 5. Plot of PC1 vs PC2 distinguishing the volcanic Aeolian *Impasto* (open blue diamonds) from the Granitic *Impasto* (open red squares) and the rest of the Fabrics. Variability along PC1 is 30.3% with Zr and Nb showing the greater anticorrelation with Ca and Cu. Variability along PC2 is 18% with Th and Rb showing the greater anticorrelation with Ti.

investigation at San Vincenzo on soils from different excavated contexts (Di Renzoni, et al., 2016). For sure, there is room for the analytical protocol to be refined beyond that described in the present study in order to improve accuracy, to allow additional elements to be included in the data set and to calibrate with respect to the corresponding data obtained by destructive analysis such as benchtop WDXRF (Jones & Campbell, in press).

We suggest that p-XRF should not be habitually compared to ICP/NAA and repeatedly be found wanting in its inability to cover all elements and /or display equivalent levels of accuracy for all elements. At the same time p-XRF should not develop a 'scatter gun' reputation, generating one-off data which cannot be reused or can only be used for internal – in-house – purposes. It is time to look boldly at its greatest attribute, that is, that of non-destructive, in situ, analysis aimed at analysing large quantities of sherds; equally important is our ability to formulate appropriate questions that it can answer, satisfactorily and conclusively. In the case of impasto ware there is already a good understanding of the origin and production of these wares; so the need now is to process large quantities of newly excavated material, and to assess whether they are imported or not. This study has shown that this type of assessment (local vs non local) is indeed feasible and effective. Coarse wares are amongst the most common fabrics found in many archaeological sites so the implication of the results of this study goes beyond the remit of our work on Stromboli.

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