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Archaeometric constraints on the architectural elements from the submerged installation discovered at the harbor of Lipari (Aeolian Archipelago, Italy)

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ABSTRACT

Submarine surveys, started in 2008 during the preliminary excavations preceding the construction of a new pier in the port of Lipari Island (Italy), brought to light the presence of large submerged remains, dated to the Roman age, in the base of typological features of the related pottery fragment styles. The archaeological discoveries included the find of structural elements - interpreted in the literature as part of a monumental building - located at the wharf terminal. Four of these structural elements, made up of volcanic rocks, which are now stored at the Lipari Museum, have been examined both from analytical and architectural points of view. To define the provenance of the rocks, petrographic and mineralogical investigations have been performed on the collected samples. The results obtained indicate that the rocks could be traced to the cordierite lava rocks outcropping at Fuardo Valley, in the SW area of the Lipari Island. The use of these rocks as building material was already attested for other artefacts found at Lipari and Messina (Sicily) and at Lamezia (Calabria), but no historical sources refer to any mining activities. However, the presence of working traces observable at Fuardo Valley and Pulera districts and the overall collected information suggest that the cordierite-lava flow was extensively used as stone quarry during historical times. From the stylistic point of view, the studied structural elements made with the Fuardo stone show architectural features that allowed defining them as column bases dating to the Roman Imperial age.

Keywords: Lipari Island; harbor installation; Roman age; petrography; SEM-EDX; Tyrrhenian Sea.

INTRODUCTION

In prehistory, and in the Greek, Roman and Medieval times, the Lipari Island represented an important node in the network of trade and commerce in the Mediterranean area. Lipari, the largest island of the Aeolian Volcanic Arc (South Tyrrhenian Sea), and the Lipara city played an important role overall for their abundance of natural resources, such as hydrothermal earths and alum, which were used for many applications during the Roman Republican and Imperial Age (Di Bella et al., 2018). During the Hellenistic age, Lipari's importance grew due to its geographically strategic position at the crossroad of the ancient maritime commercial trade between Italy, Sicily and Northern Africa, Greece and Anatolia (Orsi, 1929; Kapitan, 1958; Bernabò-Brea and Cavalier, 1985; Mastelloni, 2016; Mazza, 2016; Tusa, 2016; Anzidei et al., 2016; Marazzi, 2017; Spanu et al., 2018). The Island has been inhabited continuously since 5500 BC, as attested by the massive stratification on the Lipari Acropolis (Bernabò Brea and Cavalier, 1965; 1980).

Although the topography of ancient Lipari was quite known, because of years of studies and researches, the hypothetical reconstruction of the probable monumental buildings, which, as in all the Greek cities, would be placed in the urban centers, has never been proposed. The ancient harbor building installations of Lipari were rather unknown and studied, and the historical sources do not mention any harbor-related infrastructure. The installations were traditionally located on both sides of the city, at Marina Lunga or Sottomonastero (Tisseyre, 2010; De Guidi et al., 2015) and Marina Corta (Figure 1).

In 2008, during preliminary excavations preceding the construction of a new pier of the Island at Marina Lunga, near Sottomonastero (Figure 2), archaeological remains were casually discovered (Figure 1). Since then, this area has been subjected to archaeological excavations, carried out by a team of diving archaeologists of the Soprintendenza del Mare of Sicily, the local Archaeological Museum of Lipari, the University of Sassari, and the National Institute for Geophysics and Volcanology (INGV), for study and protection. The discovery shed light on the existence of a large submerged architectural structure considered a monumental edifice of an old coastal installation (De Guidi, 2015; Anzidei et al., 2016). In particular, the submarine excavations brought to light several structural and architectural elements of columns and many fragments of ceramic remains dated back to the III/II cent. BC (Tisseyre, 2010; Anzidei et al., 2016). Four of the recovered structural elements, which were interpreted as column bases, are now at the Lipari Museum.

Here, we focus our attention on these structural elements (Figure 2 a,b) in order to confirm the use of local cordierite-lava rocks from the Fuardo Valley (NW Lipari Island). To reach this aim, we carried out the archaeometric characterization of samples through the petrographic, mineralogical and chemical study approach. The analyses were performed by means of Optical Microscopy in transmitted polarized light (OM), Scanning Electron Microscopy with Energy Dispersive Spectroscopy Microanalysis (SEM-EDX), and X-ray Fluorescence (XRF). Afterwards, to better define the provenance attribution, the obtained data were compared with those of the literature on cordierite-bearing rocks from Lipari.

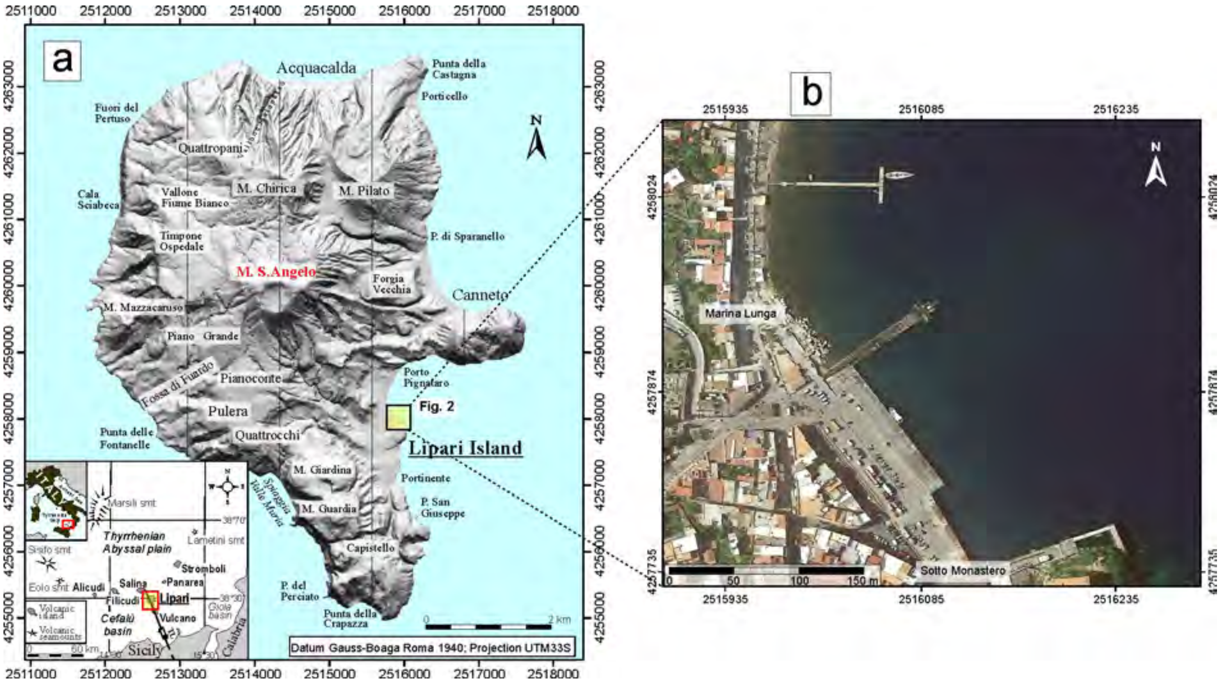

Figure 1. Sketch map of Lipari Island and location of the harbor installation.

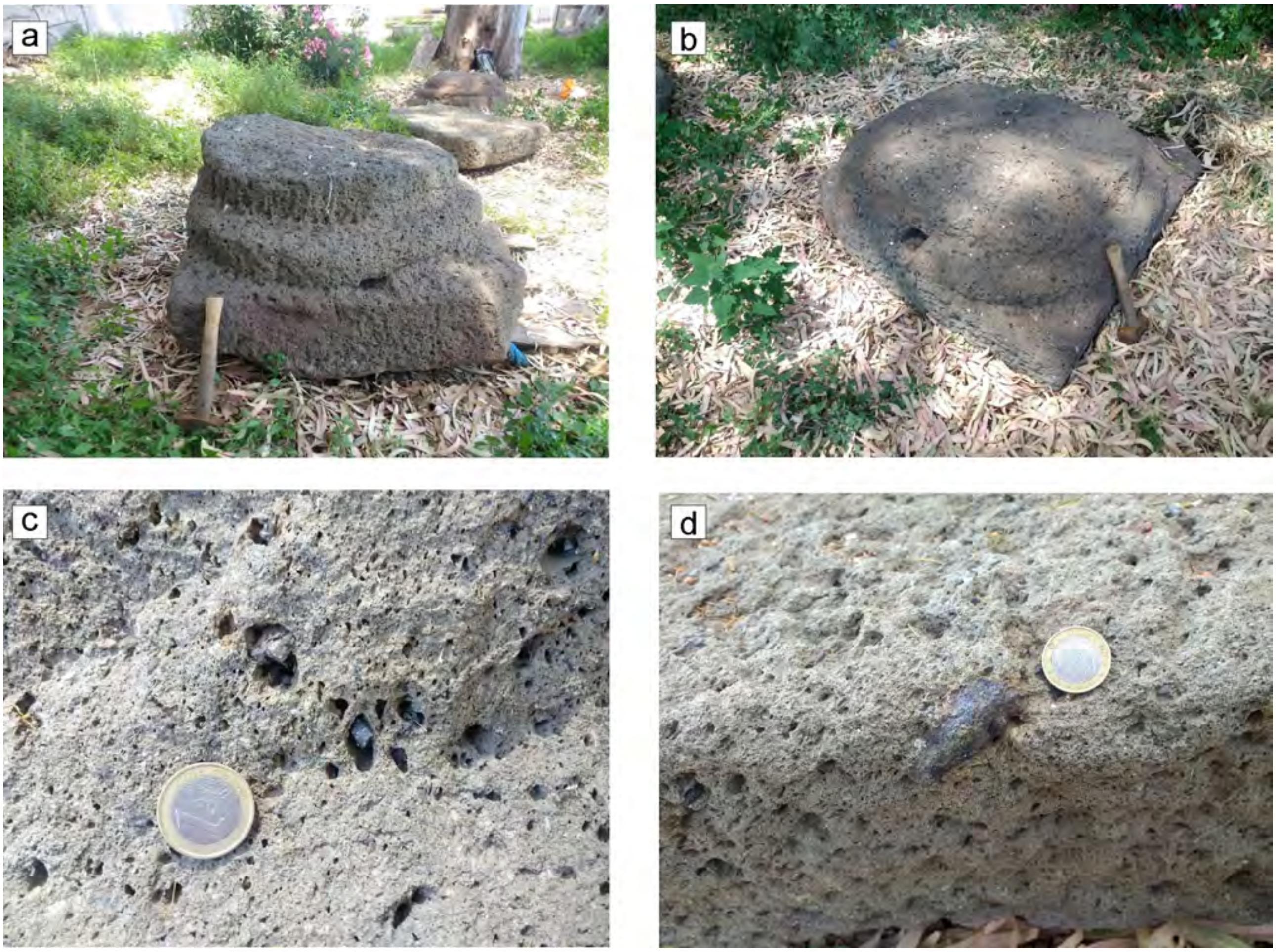

Figure 2. a-b) Images of two structural elements from the Lipari Harbor here studied, actually recovered at the Lipari Museum; c-d) particulars of the inclusions that characterize the building rocks.

TRACES OF THE SUBMERGED LIPARI BUILDING STRUCTURE

Evidence from the underwater archaeological and topographic prospection performed between 2008 and 2013 by the Soprintendenza del Mare (2013), the Museum of Lipari, the University of Sassari, and the INGV proved that the submerged pier (about 140x60 m^2 extended) included the structural elements of columns lying on the flat walking surface that rest on the foundations. The documented sea level changes led to the disuse of this ancient harbor-related structure after around the 5th century AD, in agreement with the archaeological interpretations (Spanu et al., 2018). During the construction of the modern pier, in the sixties, other discoveries had already been made, in particular the right front foot, in bronze, of a statue (Mastelloni et al., 2016) of calculated height of about 2 m that L. Bernabo Brea hypothesized to have been destroyed during the Roman siege of Lipari in 252/1 BC, but that could be related to the attack and looting of Lipara and its Prytaneion by Agathocles in 304/3 BC (Diod. XX.101.1-3). Moreover, the rocky architectural elements were traced, based on their macroscopic features, to the stone quarry of “Fuardo” located on the west side of the island of Lipari, while two columns were photographed under the castle in a few meters of water. In this coastal area, probably from the Hellenistic times (3rd-2nd century BC), the presence of a structure with a colonnade, a portico or a monumental building was hypothesized. This structure was built with mixed construction techniques and included a paved area with large pseudoisodomic blocks used in the Lipari buildings during the Roman age.

Thirteen architectural elements were found in all, three extracted from the bucket and the other ten found in situ. Below these was a support surface with squared blocks of clear rocks (Anzidei et al., 2016). The structure closed in the N direction in a semi-circle, interpreted as the head of the pier. The construction of this pier probably corresponded with a phase of intense reconstruction of the Lipari city during the 3rd-2nd cent. BC. The ceramic materials found in the site (Tisseyre, 2010), representative of a production typical of the 3rd-2nd century BC, were fine-walled acromium artefacts, incised ceramics, fragments of amphorae with bifid handles, and bell black ceramics. The site was covered in alluvial clay and sediments 2 m deep. These sediments were detritus conveyed from behind the hills by the St. Lucia stream, which on entering Marina Lunga bay sealed the lower layers, preventing the classification of the site as a "port dump". If ever this landfill was active, it was certainly after the abandonment or destruction of the site, and in any case does not seem to have had an impact on the layers covered by the clay. Some squared blocks were also found in front of the site, and a small wall built in front of the head of pier, partially destroyed by the bucket, at a higher altitude attests to the resistance of the Lipari to the sinking of the pier (Tisseyre, 2010).

MATERIALS AND METHODS

Four fragments of the structural elements from the Lipari old harbor, provided by the Lipari Museum, were labeled port1÷port4. A small slice was cut from each fragment to produce a thin section for optical observations. The rest of the samples were cleaned in an ultrasonic bath, dried, crushed in a jaw crusher, and powdered in agate mill. The thin sections underwent petrographic and mineralogical analyses by OM and SEM-EDX. The powders were used to prepare powder pellets for the major and minor element determination by XRF analysis. All the analytical investigations were performed using instrumentations of the geochemical laboratory of the Messina University MIFT Department. The scanning electron microscope used was ESEM-FEI Inspect-S electron microscope, coupled with Oxford INCA PentaFETx3 EDX spectrometer - a Si(Li) detector, with a resolution of 137 eV at 5.9 keV (Mn Kα1), equipped with an ultra-thin window ATW2. The spectral data were acquired in EDX conditions at a working distance of 10 mm, with an acceleration voltage of 20 kV, counting time of 60 s, count per second of approximately 3000 (cps) with dead time below 30%. The results were processed by Oxford INCA Energy software. This software uses the XPP matrix correction scheme developed by Pouchou and Pichoir (1984).

The elemental composition was performed by XRF spectrometry using the WDXRF method, with a Bruker model S8 Tiger setup (Bruker, 2015 a,b; http://www.xrf.ethz.ch/xrf_instr_LOI.html). The excitation source was a tube of Rh at 4 kW. The power and the current intensity were varied according to the analyzed element and its quantity, in order to avoid detector saturation. The concentrations of the major and minor elements were calculated using the software package, GEO-QUANT M, which provides an accurate method for measuring 11 elements using more than 20 certified materials for calculating the calibration lines (Bruker 2015 a,b; http://www.xrf.ethz.ch/xrf_instr_LOI.html).

RESULTS OF PETROGRAPHY, MINERALOGY AND BULK CHEMISTRY ANALYSES

The macroscopic observation of the fragments revealed a porphyritic texture, with the presence of dark grey to black colored inclusions of different sizes immerged in a grey matrix (Figure 2 c,d). Some external portions of the remains showed particular altered areas, characterized by a reddish color. All the thin sections (Figure 3 a-f) had the same features, and were almost homogeneous in terms of textural features and mineralogical composition. They were highly porphyritic (P.I. of about 50 %) and seriate, with phenocrysts of plagioclase and pyroxene, set in a cryptocrystalline to vitrophiric groundmass composed of the same phases, with rare biotite plus oxides and glass. Abundant xenocrystic phases (including cordierite, garnet, andalusite, K-feldspar, sillimanite and quartz) were also observed. Specifically, xenoliths of metamorphic and gabbroic rocks were recognized (Figure 3 a-f).

Plagioclase is mainly present in large to medium-sized zoned subheudral phenocrysts, which often show sieve-texture in the external mantle and rim areas. Both clino- and ortho-pyroxene crystals were found. Clinopyroxene is mainly present as large to medium-sized usually subheudral, rarely euhedral phenocrysts, which are often associated with plagioclase in glomeroporphiric aggregates. It is generally unzoned and frequently characterized by a crown of fine-grained orthopyroxene. Minor phenocrysts were partially resorbed, showing traces of reaction with the glassy matrix. Orthopyroxene mainly occurs as unzoned euhedral to skeletal microphenocrysts in the groundmass or in small crystals grown around clinopyroxene.

Cordierite is in general present as subheudral to heuedral, fractured and resorbed xenocrystals, and/or phenocrysts variably diffused in the samples or aggregate with the other phases in the metamorphic xenoliths. Microphenocrysts aggregates were grown around andalusite or garnet crystals. Most of the observed crystals, probably xenocrysts, were altered in pinite (yellow color //).

Garnets crystals show, in general, subheudral to heuedral morphologies, are variable in size, and contain biotite, sillimanite, quartz, ilmenite and cordierite inclusions. Many of the observed crystals were resorbed and show embayed outlines. SEM-EDX compositional data of

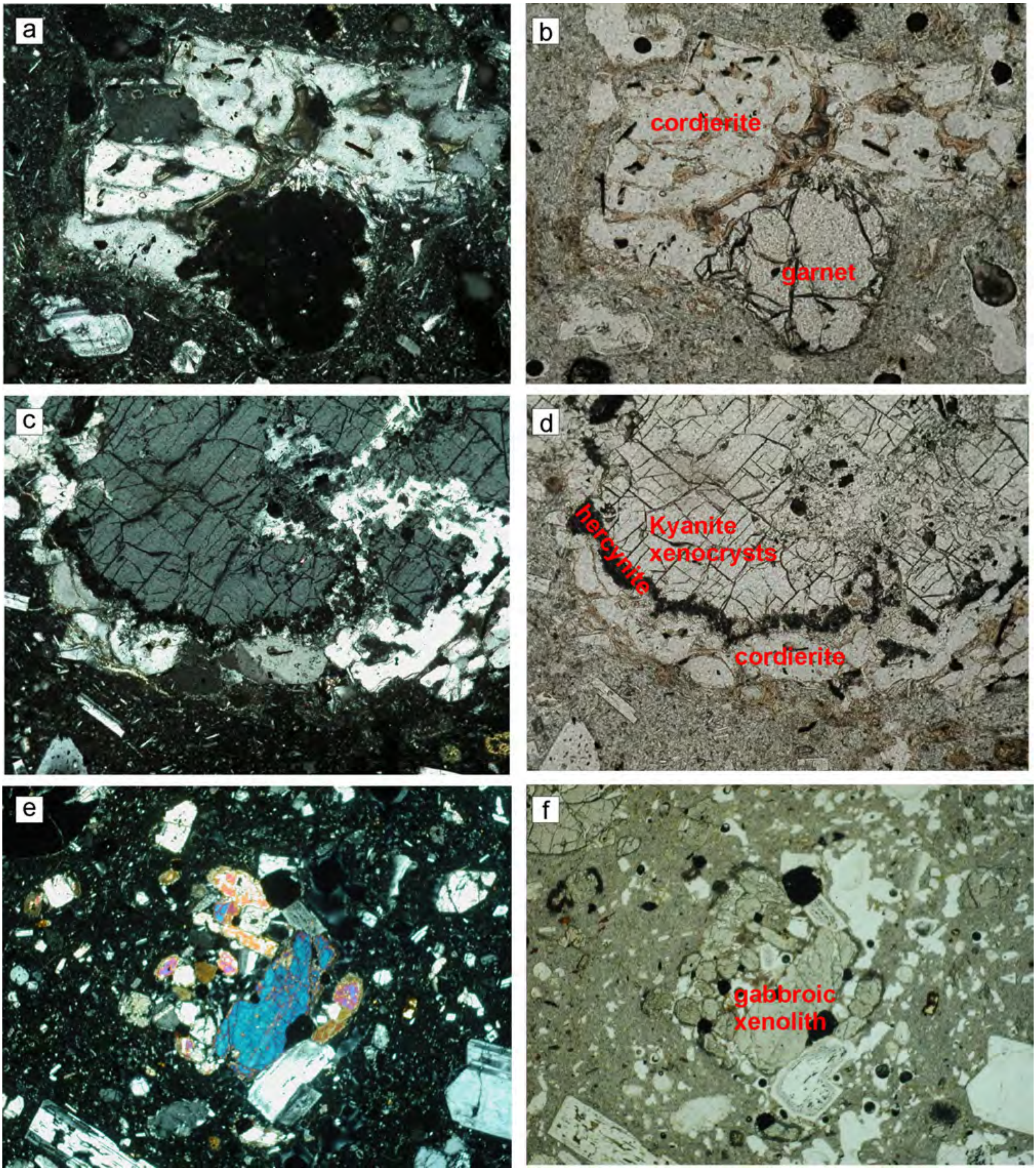

Figure 3. Photomicrographs (crossed and parallel nicols) showing representative petrographic features on thin sections of all the studied samples. a-b) Cordierite-garnet bearing xenolith in PL1 sample; c-d) Andalusite xenocrysts with a crown of a newly formed cordierite crystals in PL3 sample; e-f) Gabbroic xenolith in PL4 sample.

Table 1. Selected major elements composition of zoned and unzoned xenolithic garnet.

Sample	Zoned garnet					Unzoned garnet				
Domain	rim	int	core	int	rim	rim	int	core	int	rim
%										
SiO_2	36.26	36.72	36.50	36.42	36.82	37.34	37.40	37.37	37.81	37.22
Al_2O_3	20.82	20.80	21.27	21.09	21.50	20.31	20.66	20.43	20.67	20.17
TiO_2	0.13	0.03	0.06	0.03	0.18	0.09	0.08	0.14	0.13	0.12
FeO	33.94	30.27	28.17	30.69	30.39	31.63	31.78	31.62	31.35	31.73
MnO	2.35	7.66	9.06	7.61	2.57	2.15	2.16	2.30	2.26	2.22
MgO	3.76	2.35	2.13	2.75	5.61	5.82	5.97	5.95	5.82	5.98
CaO	1.70	1.29	1.44	1.24	1.63	1.52	1.49	1.56	1.55	1.53
Tot	98.96	99.12	98.63	99.83	98.70	98.86	99.54	99.37	99.59	99.97
			O = 12					O = 12		
Cations										
Si	2.94	2.99	2.99	2.95	2.98	2.99	2.97	2.98	3.00	2.98
Al^{IV}	0.06	0.00	0.007	0.05	0.02	0.01	0.03	0.02	0.00	0.02
Tot	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Al^{VI}	1.93	2.00	2.05	1.96	1.94	1.91	1.90	1.89	1.94	1.88
Ti	0.01	0.001	0.004	0.00	0.01	0.01	0.00	0.01	0.01	0.007
Tot	1.93	2.00	2.00	1.96	1.95	1.91	1.90	1.90	1.94	1.88
Fe^{2+}	2.30	2.06	2.06	2.08	2.06	2.12	2.11	2.11	2.08	2.12
Mn	0.16	0.53	0.53	0.52	0.18	0.15	0.15	0.15	0.15	0.15
Mg	0.46	0.29	0.29	0.33	0.68	0.69	0.71	0.71	0.69	0.71
Ca	0.15	0.11	0.11	0.11	0.14	0.13	0.13	0.13	0.13	0.13
Tot	4.39	3.00	3.00	3.04	3.05	3.08	3.08	3.09	3.05	3.11
End members %										
Alm	75.09	69.00	65.52	68.38	67.40	68.57	68.32	67.92	68.15	68.08
Sps	5.27	17.68	20.86	21.34	5.78	4.72	4.70	5.00	4.98	4.82
Prp	14.83	9.55	8.65	8.83	22.18	22.49	22.88	22.79	22.56	22.87
Grs	4.41	3.67	4.02	4.11	4.09	3.93	3.85	3.86	3.89	3.82

garnets are reported in Table 1. All the analyzed garnets show almandine-rich composition (Alm=65-75%). In particular, two types of mineralogical patterns have been observed for all the analyzed garnets. The first type (Table 1) is zoned and characterized by variable spessartine (Sps=1 to 20%) and pyrope (Prp=3 to 30%) and low grossular (Grs=3 to 5%). The second type is unzoned (Table 1) and shows, instead, almost constant values of the end-members (Sps ~5%; Prp ~23%; Grs ~4%).

Andalusite occurs in large xenocrysts, frequently characterized by a cleavage of ~90° angles on the crystal basal section, and shows high relief. Commonly, these xenocrysts include elongated crystals of sillimanite and in some cases are surrounded by cordierite and hercynite crystals.

The chemical data on the major and some trace elements are listed in Table 2. On the basis of the TAS (Na_2O+K_2O vs SiO_2) classification diagram reported in Figure 4, the studied samples show high-K calcalkaline affinity and fall under the andesite field. On this diagram, the compositional data in the literature of the cordierite-lavas from Monte S. Angelo are also plotted for comparison.

DISCUSSION

The mineralogical and petrographic features, besides the chemical composition, agree with the data in the

Table 2. XRF data of major (wt %) and some trace (ppm) elements analyzed for the studied structural elements for the Lipari harbor.

Sample	Port1	Port2	Port3	Port4
%				
SiO_2	58.02	57.37	57.93	58.36
$Al2O_3$	15.28	16.58	15.01	14.7
FeO_{tot}	8.97	8.88	9.57	8.74
MnO	0.14	0.15	0.15	0.11
MgO	4.51	4.42	4.56	4.19
CaO	3.78	3.73	4.01	4.08
Na_2O	2.01	2.12	2.21	2.02
K_2O	3.49	3.33	2.99	3.31
TiO_2	0.63	0.61	0.55	0.64
P_2O_5	0.21	0.23	0.28	0.24
LOI*	2.92	3.02	2.32	3.58
Tot	99.96	100.44	99.58	99.97
ppm				
Ba	563	582	631	605
Ce	104	98	97	103
Co	14	16	15	15
Cr	61	57	41	53
La	50	48	46	48
Nb	15	11	12	13
Ni	28	32	25	24
Rb	155	144	126	118
Sr	440	428	480	474
Th	17	18	15	14
V	135	136	128	140
Y	27	26	27	29
Zr	186	179	172	181

*Loss on ignition (LOI) at 1050 °C for at least 1 hour.

literature of the cordierite-lava from Monte S. Angelo (Forni et al., 2013; Di Martino et al., 2011) and allowed constraining the provenance of the rock used to build the structural elements from the Lipari Roman harbor.

The cordierite-bearing lavas (CBL) cropping out at Lipari in the Aeolian Arc represent one of the most exotic lithologies associated with orogenic volcanism in Italy and worldwide (Di Martino et al., 2011). In the evolutionary history of the volcanic activity of the Lipari island, the so-called third period (datable around 140.000 years ago) was responsible for the emplacement of peculiar lava flows from the eruptive centre of Monte S. Angelo, currently visible in the outcrops in the south-eastern area of the Island. This lava flow was 3 km long and 20 m thick and covered the south-western area of Monte S. Angelo. These rocks show several colors from dark brown to dark grey and have a bulk andesitic composition with a rhyodacitic groundmass (Barberi et al., 1974). They are characterized by the peculiar presence of metapelitic xenoliths, coming from the metamorphic basement placed under the Aeolian Volcanic Arc (Peccerillo, 2013), which are assimilated and brought to the surface by the rising magma.

The cordierite-bearing lavas (CBL) cropping out at Lipari were classified as high-K andesites (Barberi et al., 1974) or rhyodacites (Honnorez and Keller, 1968; Pichler, 1980) on the basis of the groundmass composition, but the bulk rock chemistry is andesitic. These rocks show peculiar petrographic features given by the coexistence of typical igneous minerals, such as zoned plagioclase, clinopyroxene, and orthopyroxene, along with (a) metapelitic and gabbroic xenoliths (up to 20-30%); (b) euhedral to subhedral xenocrysts of cordierite, andalusite and garnet; (c) a heterogeneous groundmass with rhyolitic-rhyodacitic composition (Barker, 1987; Crisci et al., 1991; Esperanca et al., 1992; Di Martino et al., 2011), which perfectly fit the features of the studied rocks. On the TAS classification diagram (Figure 4), the studied samples fall in the same andesitic field of "cordierite-lavas" from Monte S. Angelo (Di Martino et al., 2011) reported for comparison.

From the petrographic and mineralogical point of view, the main distinctive feature of the Monte S. Angelo

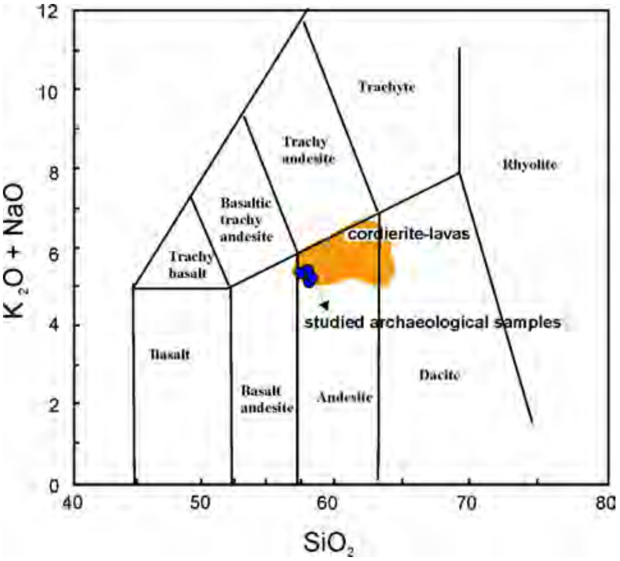

Figure 4. TAS classification diagram on which the composition of the studied samples and data from the literature (Di Martino et al., 2011) on the cordierite-lava from Lipari has been plotted for comparison.

cordierite-lavas is the presence of metamorphic and gabbroic xenoliths that make them easily identifiable. Two distinct groups of xenoliths have been recognized by Barker (1987). The former constitutes 10% of the lava volume and is composed of gneisses and granulites with various quantities and combinations of cordierite, garnet, andalusite, sillimanite and hercynite. These metamorphic xenoliths represent partially disaggregated fragments of metapelites typical of the Calabria-Peloritani Arc that constitute the basement under the Lipari Island (Honnorez and Keller, 1968; Schenk, 1984). The latter, which makes up 25% of the lava, contains orthopyroxene, clinopyroxene, plagioclase and magnetite, and derives from gabbro rocks (Barker, 1987; Peccerillo, 2013). These both types of xenoliths have been found in the studied samples from the Lipari harbor. In Figure 5, the analogy between the main characterizing xenolithic metamorphic minerals (garnet, cordierite and andalusite) and the gabbroic ones for samples of both the Lipari harbor and cordierite-lava from Monte S. Angelo is given. The presence of cordierite and garnet in the andesites from Monte S. Angelo makes these rocks distinguishable within all the volcanic series of the Aeolian Arc. In this regard, mineralogical features of the marker metamorphic minerals such as garnet can be used as a discriminating factor to define provenance attribution of the studied archaeological samples (Figure 5). Comparison of the mineralogical data of the here analyzed garnets and the ones in the literature (Di Martino et al., 2011) relative to the cordierite-lavas of Monte S. Angelo has been carried out with the aim of verifying similarity. As for the cordierite lava from Monte S. Angelo, we have found two different types of garnets, zoned and unzoned. The results of the comparison shown in the ternary (Fe+Mg)-Ca-Mn and Fe-Mg-(Ca+Mn) discrimination diagrams (Figure 6 a-b) clearly reveal the mineralogical affinity between the garnets in the studied samples from the Lipari harbor and those analyzed in the literature for cordierite-lava from Monte S. Angelo.

Others archeological finds made with the Fuardo Valley stone are known at Lipari Island. Some of these artefacts are: 1) the over 2700 tombs dated to the ancient Greek and Roman ages (Figure 7a), found during the archaeological excavations carried out at Lipari, in C. da Diana (Orsi, 1929; Bernabò-Brea and Cavalier, 1998; Bernabò-Brea et al., 2001); b) the large basin of fountains and the masonry structures in the sector of 4th-3rd century BC of the S. Calogero thermal complex in the western side of the Lipari Island (Figure 7 b,c; Bernabò Brea and Cavalier, 2003); c) the Doric decorations (5 fragments of friezes, two of which are inserted in the walls; 18 small columns and 1 column fragment; 7 capitals) of Hellenistic age (second half of 4th, 3rd-2nd cent. BC), related to housing, funerary or monumental buildings of the Acropolis (Mastelloni, 2017; Fuduli, 2018). The use of two distinct lithologies (Monte Rosa and Monte S. Angelo) as building stones at Lipari was attested for by the construction of several artefacts (e.g. sarcophagi, funerary stones, architectural elements, walls) (Figure 7a) and edifices during both the ancient Greek and Roman ages (Mastelloni and Martinelli, 2015). A first type of rocks refers to the so-called violet "latitandesite" from Monte Rosa (central-eastern area of Lipari Island), while a second type refers to the Fuardo stone, here investigated, from the lava flow emplaced at Monte S. Angelo (south-eastern area of Lipari Island).

At the time of the emplacement, the Monte S. Angelo lava flow was divided into the Fuardo and Pulera branches, which were separated from each other by the deep depression of the Fuardo Valley (Figure 7d). Here, traces of working and extraction activities are still evident. The area of the Pulera district must have been in use for a long time, even up to the Middle Ages, as is evident from the large processing waste dump that extends into the cliffs below. In the district of Pulera (Pianoconte Village), there are some remains of an extraction site of stone used during the ancient Greek and Roman times for buildings and obtaining the slabs for sarcophagi and stelai. Moreover, rock boulders and an unfinished rock column showing traces of cuts and grooves made using the wooden wedge method are still visible in the area (Mastelloni and Martinelli, 2015).

Surveys carried out throughout the Fuardo Valley (Figure 7d), along the road towards the modern S. Calogero Thermae, showed the presence of lava blocks (Figure 7e) with chisel marks. The processed blocks observed on the in situ volcanic outcrops and along the road probably represent the remains related to the ancient quarry dumps (Triscari et al., 2005).

Archaeological features and sizes (an average diameter of 1 m and height of 0.5 m) of the studied structural elements, obtained from the submerged harbor structure of Lipari Island made with the Fuardo stone, allowed their classification as bases of columns typical of the ancient Greek and Roman ages (Anzidei et al., 2016). Despite the fact that the molded blocks are not architecturally related to each other, we can speculate that when the structure was operational they formed the base of a colonnade with a plinth. In any case, the information currently available does not allow us to determine whether the hypothetical colonnade was part of a temple or a public building. This structure at Lipari was built on a low elevation facing the sea, as in other ancient Roman cities and/or islands along the coasts of the Mediterranean (e.g. at Sabratha and Leptis Magna in Libya or at Baia in the Phlaegrean Fields, Italy, as described in Lambeck et al., 2010; Anzidei et al., 2016).

From the archaeological features of the column bases

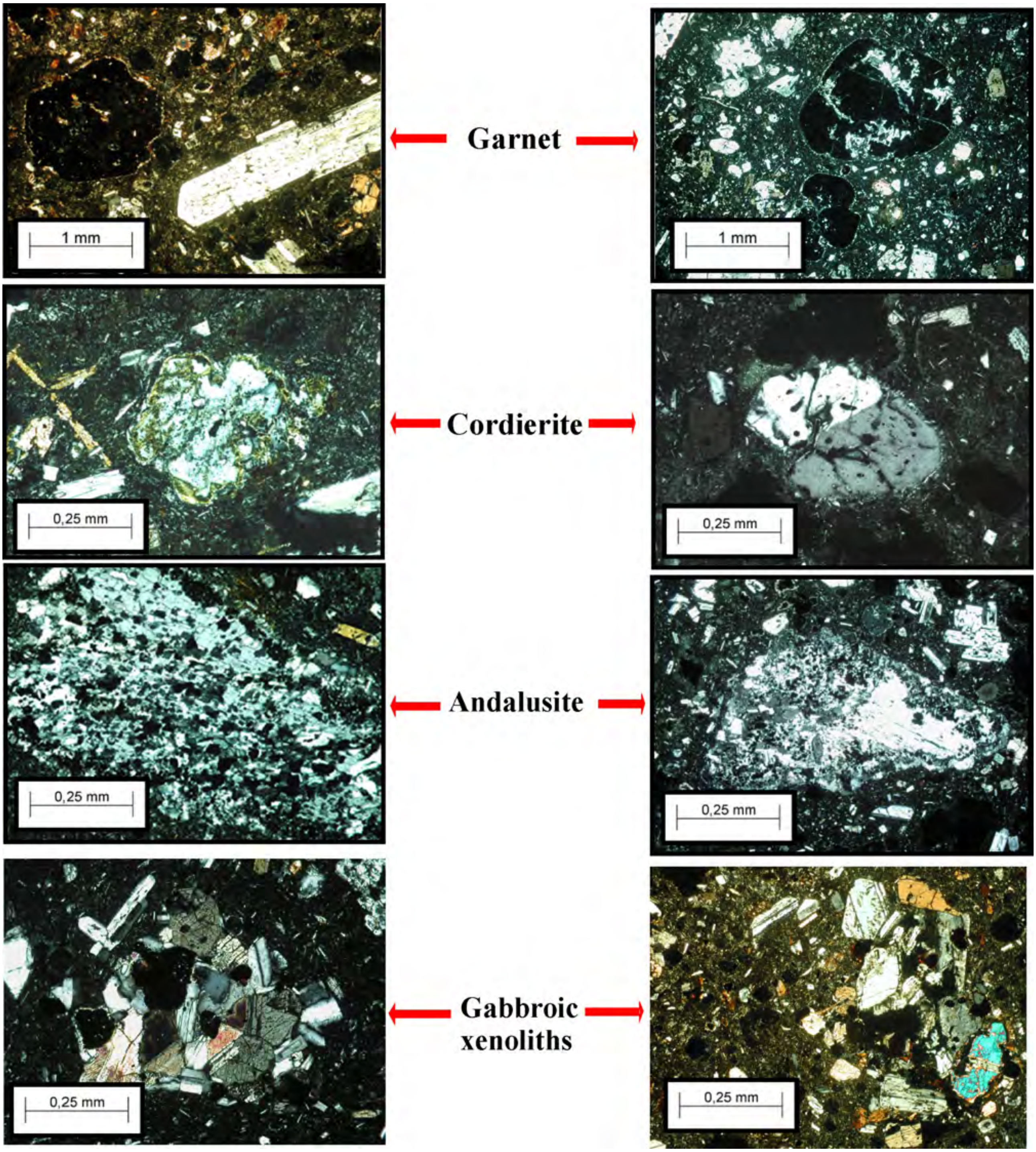

Figure 5. Comparison between photomicrographs (crossed nicols) of the studied samples and the cordierite-lava from Lipari Island.

and the type of pottery included in the archaeological layers, the considered maritime structure can be dated to between the Republican and the Imperial ages, i.e. from the 2nd century BC-1st century AD (Anzidei et al., 2016). In that time, this pier was completely exposed, since the sea was at a lower level than today and the coast of Lipari was different from today (Lambeck et al., 2010; Lambeck and Purcell, 2005; Anzidei et al., 2016).

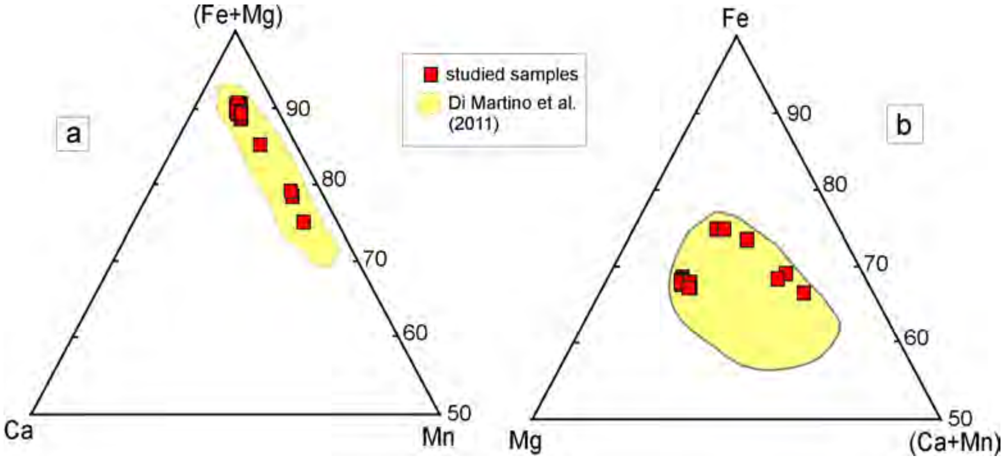

Figure 6. a) (Fe+Mg)-Ca-Mn and b) Fe-Mg-(Ca+Mn) ternary classification diagrams for comparison of the data on garnets analyzed in the studied samples with the data in the literature on garnets by Di Martino et al. (2010).

Figure 7. Examples of artefacts build with the cordierite-lava from Monte S. Angelo: a) Sarcophagi (5th-3rd cent. BC) recovered in the garden of Lipari museum; b) Fountain with basin for ritual and therapeutic immersion (created in the Hellenistic period and modified in the Roman imperial period) at the S. Calogero Thermae; c) Dry stone wall of a tank at the S. Calogero Thermae; d) Mountain side view of Fuardo Valley; e) Current remains of the quarry landfill related to the extraction activities of lava blocks used to build sarcophagi, located along the Lipari road directed to the S. Calogero Thermae (Lipari Island).

CONCLUSIONS

The studied architectural elements from the Lipari harbor-related structure were built using raw cordierite-lava rocks, called “Fuardo stone”, produced by the Monte S. Angelo volcano outcropping in the Fuardo Valley, Lipari. The studied samples were high-K andesites, containing abundant metamorphic and gabbroic xenoliths, and the cordierite lavas from Monte S. Angelo. Besides all the observed textural and compositional affinities, the analogy with CBL is particularly strengthened by the mineralogical features of garnets. Comparison with artefacts from Necropolis of all times and different archaeological sites, dated to 6th-3rd cent. BC and built with the same type of rock, demonstrates the utilization of this stone as a local building resource for a long historical period. Moreover, the archaeological evidences, such as the processing remains found in the proximity of the C.da Fuardo area, attest that a production workshop probably existed in the area (Triscari et al., 2005; Mastelloni and Martinelli, 2015).

The studied architectural elements show stylistic similarities with the structural elements, dating back to the 2nd cent. BC, of harbors of the Roman Imperial age in other ancient Roman cities along the coasts of the Mediterranean. The use of the Fuardo rocks to make artefacts at Lipari, as well as on the mainland of Messina and Calabria, testifies that the city walls and sarcophagi were made with the same type of rocks. However, since artefacts made with Fuardo stone have been found in Messina and S. Eufemia, where good building stones were available, the choice to import them from Lipari must have been inspired by non-utilitarian evaluations.

In our opinion, the results here reported represent a small, but important piece necessary to improve the knowledge on the use and exploitation of natural resources at Lipari in times past.

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