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Chapter 24

Aiding and abetting the archaeological enquiry: geochemical work-in-progress at the site of San Vincenzo, Stromboli, Aeolian Islands, Italy

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Abstract
This paper focuses on the site of San Vincenzo, Stromboli, Italy, and the use of the portable X-Ray Fluorescence analyser (p-XRF) in the field, as a fast and efficient means of geochemical data collection and processing, without the need to remove a sample. The purpose of the exercise is to aid the archaeological enquiry and to attempt to tie archaeological deposits and their chronology with the natural bedrock (i. e. scoriae and lapilli). We conclude that throughout the Bronze Age phase of the settlement the chemical make-up of the archaeological deposits is drawn largely from the lapilli-rich deposits which were formed after the end of the Neostromboli period, punctuated with those drawn from the scoriaceous lava that preceded the lapilli phase at the end of the same period. On the other hand, the post-BA deposits are geochemically different, pointing to new eruptive events. Our on-going work aims to systematically assess and compare the information that derives from each of the different disciplines involved – archaeology, geology, geochemistry and volcanology – in an attempt to reveal site formation processes and the anthropogenic activities within.

Keywords: *Bronze Age, formation process, Aeolian Islands, portable XRF*

Introduction

The use of archaeometric methods to investigate archaeological sequences and deposits has now a substantial tradition in archaeological practice (Milek 2012; Jones *et al*. 2010; Davidson *et al*. 2010). These studies, whilst frequent, have always played a supporting role in the interpretation as part of a suite of post-excavation methods studying archaeological and bioarchaeological materials and residues, instead of having a vital and dynamic role in the excavation process. It is unfortunately the case that the application of the majority of these methods still tends to be isolated to projects which can afford the investment in the equipment and laboratory assistance. Moreover, their apparent relevance to excavation has been under-valued since there tend to be significant time lapses between initial sampling and the integration of the results into the decision-making process of the excavation itself due to the requirement of most methods for analyses to take place in a controlled laboratory environment.

In this contribution, we outline how we have carried out on-site geochemical analyses to assist the excavation process. As excavation is on-going, this contribution can only focus on the methodological issues encountered to date, leaving the discussion of the complete analysis of the range of geoarchaeological, petrographic, geochemical and palaeoenvironmental analyses for a future fuller publication.

The site and its setting

The archaeological site of San Vincenzo (SV) is located on the central Mediterranean island of Stromboli (Fig. 1a). The Bronze Age (BA) village of San Vincenzo (Fig. 1b) belongs to the Capo Graziano *facies*, 21st-15th century BC according nearly 40 ^{14}C dates (Renzulli *et al*. 2013) The site was partially excavated in the 1980s (Cavalier 1981) and reopened by our team (Levi *et al*. 2011) in 2009. SV is located on a steep-sided plateau, in the northeast part of the island. The plateau is a large and uniform orographic unit, about 6 ha wide, at an altitude that varies from 40 to 100 m a.s.l. It is one of the few elevated and relatively flat areas of the island and it provides a remarkable visual control of an area that stretches from the Strait of Messina, in Sicily, to well beyond the promontory of Tropea, in Calabria. In short, its strategic position, at a high ground and at the north-east outpost of the Aeolian archipelago, ensured visual, if not also actual, control of the southern Tyrrhenian Sea.

In the western area (trenches 3, 4, 6, 7, see Fig. 2), it is possible to recognize two main building phases, marked by the use of two different terracing walls (the earlier – M – upslope, the later – L – downslope) and by the overlapping of the structures associated. Huts are generally circular with a hearth in their centre. The general topography organisation of the area appears to be complex with huge walls perpendicular to the terracing walls defining spaces. In the eastern area (trenches 1, 2, 5) a terrace-wall (Fig. 2, H) made of big stones sustains a large levelled area with various dwellings within. Hut 1, at the northernmost part of the area was destroyed by a channel (Sargassi) that cut across the structure and has affected the whole northern edge of the excavation area. The channel contains green glazed pottery dated to the 14^{th}-15^{th} century AD and is covered by a well-preserved, up to 10-15 cm thick, purplish to black layer of tephra. The origin of this layer is attributed to a Stromboli volcano paroxysm (see below) taking place during the 15^{th} century. This date is supported by three ^{14}C dated fragments of charcoal retrieved from the layers immediately below the ash fallout (Renzulli *et al*. 2013). Some authors suggested 1558 for this Stromboli paroxysm but this view is not strengthened by historical accounts (e.g. Tommaso Fazello 1558).

The sequence of the area arrives to the contemporary period, showing also Hellenistic and Roman evidence (Ferranti *et al*. 2015). The deposit forms a stratigraphy with a maximum depth of 2.5 m before reaching the bedrock. The stratigraphy is composed of medium to coarse sands showing any significant differences in particle size. The main macroscopic differences among layers is the colour which has been classified systematically giving some groups recurrent in all the investigated area (see Table 2).

Stromboli present-day volcanic activity

Stromboli, the northeastern-most island of the Aeolian Archipelago (Tyrrhenian Sea, southern Italy), is a stratovolcano that rises *ca*. 3 km from the seafloor, up to 924 m a.s.l.. It is famous for its persistent activity that began in the present form between the 3^{rd} and 7^{th} centuries AD (Rosi *et al*. 2000). Persistent 'normal' activity consists of rhythmic, short-lived, mildly energetic explosions that eject ash- to bomb-sized fragments to heights of a few hundred meters above the vents and mainly accumulating in the so-called 'crater terrace' located at about 750 m a.s.l. (Del Moro *et al*. 2013). The magma feeding this persistent activity is a crystal-rich degassed shoshonitic basalt (black scoriae) rising from the uppermost part of the plumbing system. Sporadic lava flows, having the same modal mineralogy and compositions of the scoriae, occur either from the summit craters or from eruptive fractures within the Sciara del Fuoco (SdF), a horseshoe-shaped structure on the NW side of the volcano that developed through a series of slope failures (Tibaldi 2001). The persistent normal activity of Stromboli is occasionally interrupted by sudden and highly energetic explosive events called Strombolian paroxysms (Mercalli 1881). During these paroxysms, driven by the rapid rise of deeper crystal-poor magma producing basaltic nearly a phyric golden pumices, meter-sized lithic blocks can reach distances up to several hundreds of meters from the active craters (Rosi *et al*. 2006; Renzulli *et al*. 2009).

Geology and bedrock of the excavation site

The emergent part of the Stromboli Island has been built in four main periods of activity during the last 100 kyr: Paleostromboli, Vancori, Neostromboli and Recent Stromboli, from oldest to youngest (Gillot and Keller 1993; Hornig-Kjarsgaard *et al*. 1993). The Bronze Age huts were built upon the volcanic products belonging to the Neostromboli period whose activity roughly ranges from 13 to 6 ka. The Neostromboli activity was mainly characterized by lava flows cropping out in the northeastern and southeastern sectors of the island and consists of basic to intermediate volcanic rocks (SiO_2 49-55 wt.%; MgO 2.50-6.25 wt.%) of the potassic series (KS; Francalanci *et al*. 1989). These lavas are variously porphyritic (10-30 vol.%), with a modal mineralogy represented by plagioclase + clinopyroxene + olivine ± leucite ± opaque minerals ± apatite. Biotite and alkali feldspars also appear as microphenocrysts in the groundmass of the most evolved terms (SiO_2 53-55 wt%; MgO 2.50-3.50 wt%).

At the end of the Neostromboli period a phreatomagmatic eruption took place, driven by a lateral collapse of the northwestern sectors of the volcano, which outlined the 'Sciara del Fuoco' scarp. This explosive eruption gave rise to a yellow, accretionary lapilli-rich pyroclastic deposit well known as the 'Secche di Lazzaro Pyroclastics' (Bertagnini and Landi 1996; Renzulli and Santi 1997). The terrace upon which the Bronze Age village was built is mainly represented by a scoriaceous lava flow belonging to the last phase of activity of Neostromboli (biotite-bearing; porphyritic index of 10-15 vol.%) which can be classified on a chemical basis as a K-basaltic trachyandesite (i.e. shoshonite; Total Alkali-Silica diagram) with SiO_2 *ca*. 53.25 wt.% and Na_2O + K_2O *ca*. 7.0 wt.%. Preliminary palaeomagnetic dating of the volcanic bedrocks in the excavation site gives an age of 6200 BP (Speranza *et al*. 2012) which is well constrained by the fact the 'Secche di Lazzaro Pyroclastics', locally covering the scoriaceous lavas without any erosional surface or palaeosol, is considered to have erupted at ≤ 6000 BP (Speranza *et al*. 2008). Local bedrocks were used in handcraft: the microchemical–petrographic analysis of pottery has been used to define the 'Temper Compositional Reference Units' from distinct Aeolian production centres and identify provenance and circulation networks (Brunelli *et al.* 2013).

As will be discussed below, there is plenty of evidence for both lapilli (see for example context 66, Table 1) and scoriae (solid bedrock) (context 517, Table 1) on site, underlying hut structures or associated with them; there are also plenty of loose 'rocks', ie scoriae blocks scattered about the site. Bedrock in the form of lapilli or scoriae has been analysed with the p-XRF in an attempt to identify archaeological 'soil' deposits which carry the same chemical signature as the bedrock.

About p-XRF

The methodological approach developed over the last four years of excavation at SV is that of embedding scientific techniques of analyses *both* within the excavation process and at the post-excavation phase. This is a practice that is rarely undertaken either in the context of Mediterranean archaeology or beyond for a number of reasons, cost of labour and equipment being the defining one. Yet the site of SV represented from the start a real challenge and the potential of addressing fundamental issues such as, for example, how different disciplines which 'come together' at the archaeological trench can seamlessly blend their methodological approaches and work with, and benefit from, each other's data sets. Therefore, a two-tier approach was developed based around (a) the provision of geochemical data from archaeological and natural stratigraphic deposits on site and *while* the excavation is ongoing and (b) the sampling of these deposits for sediment analysis (including organic content, magnetic susceptibility, granulometry and geochemistry) as well as micromorphology and palynology at the *post-excavation* stage. p-XRF was the instrument of choice for the *during the excavation* phase.

The p-XRF is an extremely versatile instrument which provides chemical analysis for a large number of elements with atomic weight from Al (Z=13) to Uranium (Z=92) and with particular emphasis on metallic elements. A Niton X3Lt-GOLDD was used with a 50kV Ag X-ray tube, 80MHz real time digital signal processing and two processors for computation and data storage respectively. The Niton p-XRF operated in the Test All Geo (TAG) mode and uses four filters to cover light and heavy elements. Irradiation was set for a total of 90 seconds. There is no 'sample' preparation *per se*; the XRF beam points at the section face and a reading /analysis is taken over a prescribed length of time. Three spot analyses are taken within each archaeological context. At the end of the working period the data were downloaded from the instrument NDT file to an excel file, and a mean of the three readings was calculated. The data were subsequently inserted in the IBM SPSS-21 statistics package for Principal Component Analysis (PCA). The first two factors were plotted as scatter plots (see Fig. 4). The aim is to identify groups of contexts and, once these have been identified, to colour-code them, prior to 'reinserting' them within the stratigraphic record as given in Fig. 2 or within the section drawing (see Fig. 3 and Table 2).

When using the p-XRF for intra-site comparisons no effort is made to optimise parameters and to account for issues such as matrix inhomogeneities and variations in surface topography. These issues are dealt with in a sequel to this work, on soils samples analysed in the lab; compositional variations within each context, and on an element by element basis, will be scrutinised and the data compared with ICP-derived data from a selected number of contexts.

SV archaeological deposits are represented here by their context number; they originate from a number of trenches (2, 3 and 5) and associated sections (see Table 1). Trench 2 contains sections 126, 178 and 169; Trench 3 contains sections 167, 168 and 170, and Trench 5 the sections 244, 259, 260 and 261. The relative position of these trenches with respect to each other is shown in Fig. 3. Archaeological contexts within a section are presented in a sequence starting from the actual ground surface (201/301) and moving progressively downwards to the bedrock, in both a horizontal and vertical way. It is worth noting that these trenches are not necessarily contiguous and are located on a slope. Therefore the correlation between the different stratigraphic contexts is of crucial importance to understanding the relationship between the trenches and the nature of the deposits themselves.

Results

A total of 41 samples have been analysed and their mean composition was inserted in the IBM-SPSS-21 package and presented as a scatter plot (see Fig. 4). Three main groups have been identified (Fig. 4), together with a set of outliers (see description in Fig. 4) and with the possibility of a fourth group (IIa).

Table 2 combines context number, colour of context, chronology, geochemical data and archaeological interpretation. There are two types of natural bedrock: the scoriaceous lava and the lapilli. Lapilli form the most predominant group (II) while the scoriaceous lava can be of different composition (I, II and outlier). The BA layers belong to both groups I and II. Only one sample belonging to a later deposit is in Group II.

Group III is characteristic of contexts formed after the end of the prehistoric village from Hellenistic to Middle Age (including the filling of the Sargassi channel). Group IIa, between II and III (see Fig. 4), contains samples of different chronologies. In groups IIa and III several grey and light yellow or light brown contexts are classified.

Among the outliers we underline the presence of the Tefra context (207), an *in situ* outcrop of an explosive episode dated to the late Middle Ages.

Conclusions

The p-XRF analyses of the San Vincenzo, Stromboli deposits suggest the presence of three chemically distinct groups (I, II and III). The chemical signature of the Bronze Age deposits is represented by groups I and II and is characterized by the two types of bedrock, namely the scoriaceous lava and the lapilli, dated to 6200 BP and 6000 BP respectively. We can therefore infer that the stratigraphy of the BA village is directly derived from the redeposition of deposits with either one of these signatures. Interestingly, the colour of deposits has been a useful parameter for their classification while on site since the majority of the BA layers are either yellow or brown.

The post-BA deposits have a chemical signature that is represented by group III. An intriguing hypothesis is that those layers, which are characterized by a new series of colours (grey or light yellow) might be derived from a new explosive activity whose beginning is dated between the 3rd and 7th centuries AD (Rosi *et al*. 2000). Analysis of additional deposits is in progress in order to investigate how much Stromboli volcano activity, which begins in the 3rd-7th centuries and continues today, affected the formation process in the site. The other known explosive activity is dated to *ca*. 1500 AD (Renzulli *et al.* 2013) and is clearly reflected in context 207 (tephra layer) which forms an outlier in our dataset.

Our p-XRF derived data show that the chemical signature at the San Vincenzo settlement is mainly related to the volcanic rocks emerging out of the different eruptive activities. The nature of the sediments have been consistently problematic. There appears to be a uniformity of particle size distribution across the site - medium to coarse sand - without clear and well-separated solid surfaces resulting in considerable homogeneity between the layers.

It is clear from Table 2 that in ascribing function to each context, the three chemically distinct groups cannot provide the level of detail provided by stratigraphy in association with material evidence. However when ambiguities arise as was the case with contexts 541, 350 and 255=253 then it was possible to confidently ascribe activities to early (BA) or later (post-BA) activities.

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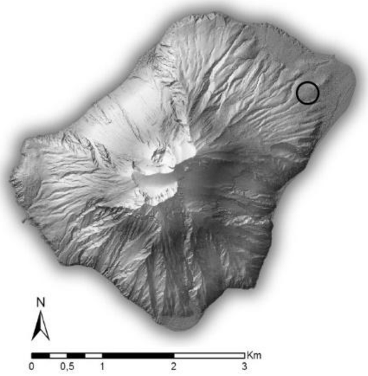

Fig. 1a (left). The Aeolian Archipelago in the framework of the southern Tyrrhenian Sea.
Fig.1b (right). San Vincenzo is marked with a circle on the digital map of Stromboli island.

Table 1. List of the samples according to trenches, sections and contexts (Stratigraphic Units –SU).

W Area	**TRENCH 3**	**SECTION 167**	**SECTION 168**	**SECTION 170**	**SECTION 262**	**SECTION 263**
		SU 301	SU 301	SU 301	SU 327	SU 351
		SU 323	SU 302	SU 302	SU 393/343	SU 384
		SU 314	SU 303	SU 310	SU 394	SU 377
		SU 340	SU 304	SU 303		
		SU 313	SU 350	SU 304		
			SU 379	SU 379		
			SU 382	SU 353/352		
E Area	**TRENC 5**	**SECTION 244**	**SECTION 259**	**SECTION 260**	**SECTION 261**	**BEDROCKS**
		SU 538	SU 551	SU 541	SU 548	SU 66 (trench 1)
		SU 570	SU 552	SU 566	SU 566	SU 517
		SU 568	SU 562	SU 585	SU 584	SU 578
		SU 558	SU 562 base		SU 585	
		SU 569	SU 563			
		SU 537	SU 576			
		SU 575	SU 548			
		SU 562	SU 579			
		SU 576	SU 580			
		SU 565	SU 566			
		SU 573	SU 573			
		SU 574	SU 588			
		SU 578				
		SU 577				
		SU 585				
	TRENCH 2	**SECTION 126**	**SECTION 169**	**SECTION 178**		
		SU 224	SU 201-202	295		
		SU 225	SU 2019	297		
		SU 279	SU 207	255/253		
			SU 2022	254		
				260		
				256		

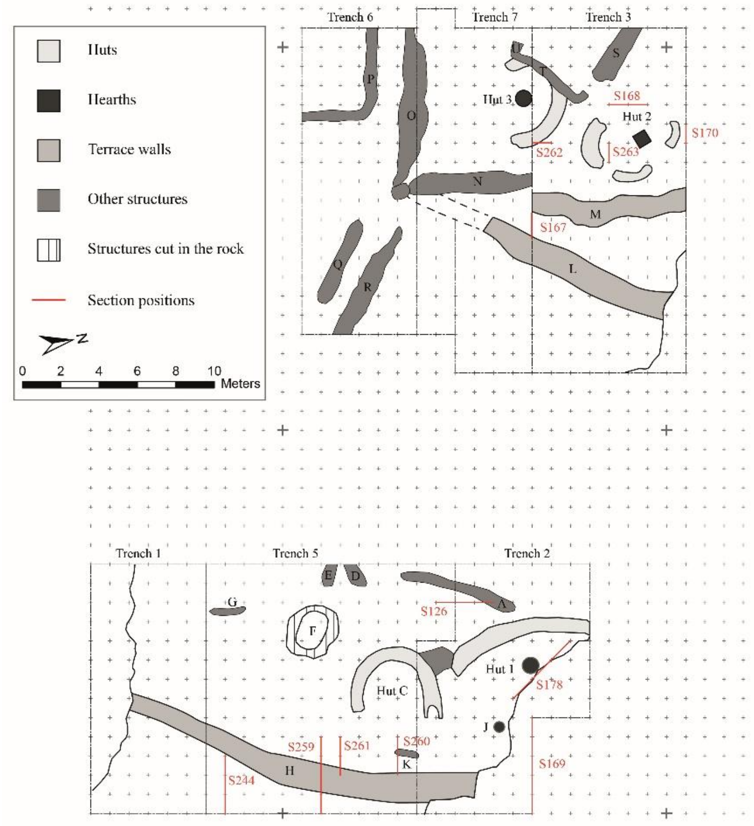

Fig. 2. Plan of excavated areas with stone structures outlining huts and terrace-walls, and the sections within the various trenches as discussed in the text.

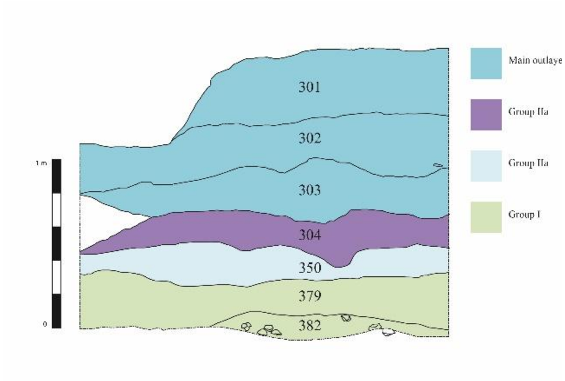

Fig. 3. Section 168 with p-XRF grouping.

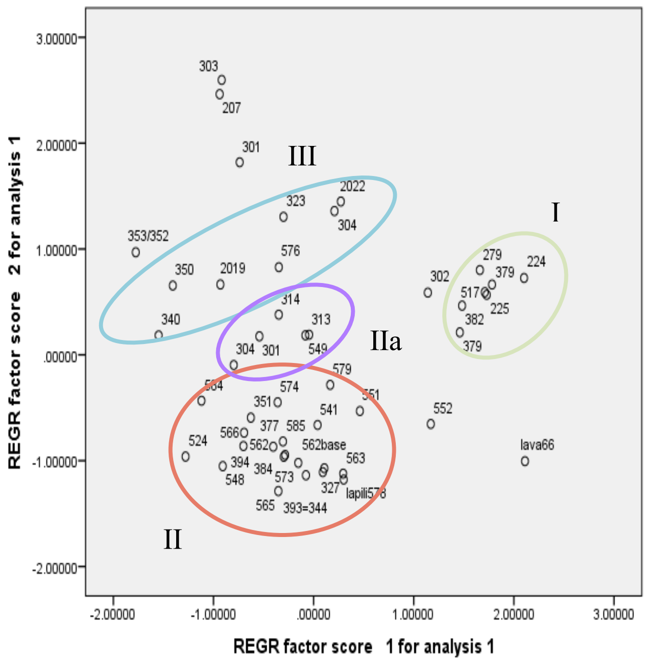

Fig. 4. PC1: variance = 43%; PC1= K, Al, Ti, Ca; PC2: variance = 31%; PC2= Fe, Si

Group I: contexts 224/225/279/ of section 126 are chemically similar to 382 in section 168; also to 379 which occurs in two sections i.e. 168 and 170. Section 126 and associated contexts in other sections are consistently emerging as chemically distinct from the rest of the contexts (group colour = green, Table 2).

Group II: the contexts within sections 263 and 262 are homogeneous and chemically similar to the lapilli 578. There are many contexts across the site within trenches 5 and 3 that are of the same chemical composition (group colour = bright pink, Table 2).

Group IIa: Some contexts in section 167 (314 and 313) and across sections 168(304), 260 (524) and 261 (584) may form a chemical group of their own (group colour = purple, Table 2). However they may also be considered as possible outliers to the main group II.

Group III: Some contexts in section 169 (2019 and 2022) are chemically similar to some contexts in section 167 (323 and 340) and also chemically similar with some contexts in 168 (350) (group colour =light blue, Table 2).

Main outliers: These contexts do not all necessarily belong to the same chemical group. They are simply not similar to any of the other groups.

Table 2. p-XRF geochemical groups, date, colour and archaeological interpretation of the contexts.

p-XRF-group	Dating	Colour	Context interpretation based on stratigraphy and material evidence	Context no	Trench no	Section no
I	6200 BP	yellow	**Bedrock - Scoriaceous lava**	517	5	
I	Bronze Age	brown	**Living surface**: Hut 2	382	3	168
I	Bronze Age	grey	**Living surface:** close to wall A	279	2	126
I	Bronze Age	yellow	**Wall**: matrix between stones of wall A	225	2	126
I	Bronze Age	yellow	**Colluvium/Artificial filling:** overlapping the collapse of Hut 2	379	3	168
I	Bronze Age	yellow	**Colluvium/Artificial filling:** overlapping the collapse of Hut 2	379	3	170
I	Bronze Age	grey	**Colluvium/Artificial filling:** overlapping the collapse of Hut 1	224	2	126
II	6200 BP	yellow	**Bedrock - Scoriaceous lava**	585	5	260
II	6000 BP	yellow	**Bedrock - Lapilli**	524	5	260
II	6000 BP	yellow	**Bedrock - Lapilli**	584	5	261
II	6000 BP	yellow	**Bedrock - Lapilli**	394	3	262
II	6000 BP	yellow	**Bedrock - Lapilli**	377	3	263
II	6000 BP	yellow	**Bedrock -Lapilli**	578	5	
II	Bronze Age	grey	**Living surface** under the walls of Hut 2	393/343	3	262
II	Bronze Age	yellow	**Living surface** of Hut 2	384	3	263
II	Bronze Age	brown	**Living surface**: under wall H	579	5	259
II	Bronze Age	yellow	**Living surface**: under wall H	548	5	261
II	Bronze Age	brown	**Living surface**: under wall H, Hut C and wall K	566	5	261
II	Bronze Age	brown	**Living surface**: outside wall H	562+56 2 base	5	259
II	Bronze Age	brown	**Living surface**: outside wall H	563	5	259
II	Bronze Age	yellow	**Collapse** of the walls of Hut 2	351	3	263
II	Bronze Age	brown	**Collapse** of the walls of structure K	541	5	260
II	Bronze Age	yellow	**Filling:** overlapping the collapse of Hut 2	327	3	262
II	Hellenistic/Roman	light yellow	**Colluvium/Artificial filling**	551	5	259
IIa	Bronze Age	yellow	**Wall**: matrix between stones of wall M	313	3	167
IIa	Bronze Age	brown	**Artificial filling** following the collapse of wall M and preceding wall L	314	3	167
IIa	Hellenistic/Roman	grey	**Agricultural level?**	304	3	168
IIa	Hellenistic/Roman	grey	**Agricultural level?**	549	5	259
IIa	Contemporary	dark grey	**Agricultural level**	301	3	167
III	Bronze Age	brown	**Wall**: matrix between stones of wall L	340	3	167
III	Hellenistic/Roman	light brown	**Agricultural level?**	350	3	168
III	Hellenistic/Roman	light yellow	**Agricultural level?**	576	5	244
III	Hellenistic/Roman	brown	**Agricultural level?**	323	3	167
III	Late Medieval	grey	**Filling** of the channel Sargassi	2022	2	169
III	Late Medieval	grey	**Layer -** covering the tefra of the channel Sargassi	2019	2	169
outlier	6200 BP	brown	**Bedrock - below hearth of Hut 1**	255/253	2	178
outlier	6200 BP	yellow	**Bedrock - Scoriaceous lava**	66	1	
outlier	Hellenistic/Roman	light yellow	**Agricultural level?**	552	5	259
outlier	Medieval	light yellow	**Agricultural level?**	303	3	168
outlier	XV century AD	pink	**Tefra:** on the top of channel Sargassi	207	2	169
otlier	Contemporary	dark grey	**Agricultural level**	302	3	168
outlier	Contemporary	dark grey	**Agricultural level**	301	3	168