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Abstract: Stratigraphic Unit 13 of Oscurusciuto Rockshelter (Ginosa, Taranto, Southern Italy) is a short Mousterian palimpsest representing the first stable occupation of the site soon after the deposition of a thick layer of tephra (Mt. Epomeo Green Tuff - Ischia datable around 55 kya BP). Different activities were identified by integrating the study of lithic finds, faunal remains, and the microarchaeology of combustion features. Additionally, geo-statistical analysis of these data has been carried out using a specifically designed geodatabase within a GIS platform.

Our results produced an articulated picture of this Neanderthal site as a tripartite location made of spatially segregated and integrated activity areas. A hearths' alignment (parallel to the rockshelter wall) divides the settled area into an inner and outer part. The inner part, between the hearths and the shelter wall, displays an abrupt rarefaction of the anthropic finds and was interpreted as a possible sleeping/ resting area. In the outer part, several multipurpose activity areas have been identified, mostly associated with the combustion features. The Northern sector of the settlement appears devoted particularly to lithic production (to a lesser degree, activities related with lithic tools use and faunal processing took place). In the Southern sector the main activities carried out represent more intensive production and use of lithic tools and the butchering and consumption of animal resources. Additionally, in this sector evidence of space maintenance behaviour (cleaning up of working areas and refuse dumping) has been attested.

1. Introduction

Neanderthal subsistence strategies and intra-site spatial man- agement are particularly significant themes in contemporary sci- entific debate. Theoretical approaches and analytical procedures have evolved in the broader development of spatial archaeology and activity areas studies (e.g. Bailey, 1981, 1983; 2007; Bertran and Texier, 1995, 1999; Bertran et al., 1997; Binford, 1978a, 1978b; 1981, 1983; 1986, 1987; 1996; Clarke, 1977; Gould, 1977; Hietala, 1984;Hietala and Stevens, 1977; Hodder and Orton, 1976; Kent, 1987; Kroll and Douglas Price, 1991; Leroi-Gourhan and Brezillon, 1966; Newcomer and Sieveking, 1980; Schiffer, 1972, 1975a; 1975b, 1976; 1983, 1987; Yellen, 1977). In these studies, a very important role is played by integrative and multidisciplinary research programs, which provide a complete and complex view of the archaeological record. The advances of the studies focused on Palaeolithic sites are interlaced with the theoretical debate on the Archaeology of Time and palimpsest problem (Bailey, 2007) and, simultaneously, with the development of new analytical tools and technologies. Impor- tantly, research aims within the discipline are moving from a find- focused approach to a context-focused one. In the last decades a great variety of works were carried out on Middle Palaeolithic sites with multidisciplinary approaches (e. g. Bargallo´ et al., 2016; Blasco et al., 2016; Boscato and Ronchitelli, 2008, 2017; Boscato et al., 2002; Carrancho et al., 2016; Cremaschi et al., 2002; de la Torre et al., 2012; Eixea et al., 2012; Gabucio et al., 2014, 2017; Gopher et al., 2016; Henry, 2003, 2012; Machado and Pe´rez, 2016; Machado et al., 2013; Mallol et al., 2013a, 2013b; Martìnez-Moreno et al., 2004, 2016; Modolo and Rosell, 2017; Neruda, 2017; Oron and Goren-Inbar, 2014; Ortiz Nieto-Ma´rquez and Baena Preysler, 2015, 2017; Ortiz Nieto-Ma´rquez et al., 2012; Peresani et al., 2011a; Polo- Díaz et al., 2016; Riel-Salvatore et al., 2013; Roebroeks and Villa, 2001; Romagnoli and Vaquero, 2016; Rosell et al., 2012a, 2012b; Sa´nchez-Hern´andez et al., 2014; San~udo et al., 2012, 2016; Serangeli et al., 2015; Spagnolo et al., 2016; Speth et al., 2012; Vallverdú et al., 2005, 2010, 2012; Vaquero, 2008; Vaquero and Pasto`, 2001; Vaquero et al., 2012a, 2012b, 2015; Vidal-Matutano, 2017; Vidal- Matutano et al., 2015; Villaverde et al., 2017). In order to achieve a more comprehensive understanding of Neanderthal social and economic strategies, their behaviour must be analysed with a high level of temporal resolution. Several kinds of activities (such as lithic production, faunal resources exploitation, use of fire, etc.) leave material traces that can be analysed from a spatial perspective through use of a variety of functional models of organized spaces, virtually reassembling the behavioural mosaic.

In rockshelters and caves, short palimpsests and living floors set on sterile levels have high informative potential regarding camp- site installation and functional space management. These kinds of sites are not common in archaeological literature and, so far, poorly studied with multidisciplinary approaches. Some representative examples from Southern Italy include Grotta del Cavallo (Apulia), Grotta Reali (Molise), Grotta Grande, and Riparo il Molare (Campania).

At Grotta del Cavallo (Nardo` e Lecce, Southern Italy) the bottom of the Mousterian sequence of the layer FIII (attributable to the MIS 3) lies on top of a sterile volcanic ash layer (Palma Di Cesnola, 1964, 1965; Zanchetta et al., 2018). During the most recent fieldwork season, several living floors were identified in this layer (Peretto et al., 2004). Faunal remains (Sarti et al., 2000) and lithic assem- blages (Carmignani, 2011) were studied, however, the spatial analysis of the layer FIII is currently incomplete (Fenu et al., 2002). Multidisciplinary studies were also carried out at the site of Grotta Reali. Lithic industries have been recorded from two Stratigraphic Units (dated to the final Mousterian) lying on sterile phytoclastic travertine. The lower Unit (SU 5) was entirely anthropogenic, while the upper (SU 2abc and a/b) was alternately frequented by humans and other carnivores (Coltorti et al., 2012; Lembo et al., 2012; Peretto, 2012; Rufo et al., 2012; Sala et al., 2012; Thun Hohenstein and Bertolini, 2012). Both the sites of Grotta Grande and Riparo il Molare (S. Giovanni a Piro e Salerno, Southern Italy) are attribut- able to the MIS 5. At trench F of Grotta Grande, layer 8 has been set on a marine conglomerate (layer 9), superimposed on a breccia with S. bubonius and Patella ferruginea (layer 10). Layer 8 exhibits evidence of a structured space with stones and stalactites align- ments (Peretto et al., 2004; Ronchitelli et al., 2011a). Riparo il Molare includes several thin anthropic layers separated by thick sterile clay layers, some of them with evidence of hearths and structured spaces. Here, each layer constitutes a living-floor or short palimpsest (Boscato and Ronchitelli, 2008; Boscato et al., 2002; Peretto et al., 2004).

Stratigraphic Unit (SU) 13 of the Oscurusciuto Rockshelter (Ginosa, Taranto, Southern Italy) provides an excellent reference context because it is a short palimpsest (Spagnolo et al., 2016) that lies on an almost sterile level of tephra (SU 14) recognized as the Mt. Epomeo Green Tuff of Ischia, datable around at 55 ka BP. For these reasons, SU 13 is particularly suitable for the application of analytical procedures aimed at achieving a wide overview of the activities carried out by a Neanderthal group and, consequently, to the identification of the spatial and functional aspects of the site. A possible parallelism with Oscurusciuto is the site of Abric Romaní (MIS 3), where many Stratigraphic Units are divided by sterile travertine layers (Bischoff et al., 1988; Vallverdú-Poch et al., 2012). The possibility for identification of occupational episodes in some of these levels, and the development of analytical protocols aimed to access high resolution temporal data allowed the recognition of the spatial structuration of a Palaeolithic settlement (Bargallo´ et al., 2016; Gabucio et al., 2014, 2017; Romagnoli and Vaquero, 2016; Rosell et al., 2012a; Vallverdú et al., 2005, 2010, 2012; Vaquero and Pasto`, 2001; Vaquero et al., 2001, 2012a, 2012b, 2015).

The purpose of this work is to understand the management of the site space and develop a functional interpretation of different areas on the basis of statistical differences in the distribution of the archaeological remains. A multidisciplinary approach was applied to achieve these objectives: as a first step, lithic finds (dimensional classes and technology), faunal remains (dimensional classes and burned/unburned state) and hearths (wood ash layers composition and preservation) were analysed. As a second step, data from these studies were integrated into a GIS platform and studied with visual and statistical methods. Using these techniques, a functional structure of the Mousterian settlement linked with SU 13 was reconstructed through identification of several interlaced activity areas.

2. The Oscurusciuto Rockshelter

Research at the Oscurusciuto Rockshelter site has been carried out by the Unita` di Ricerca Preistoria e Antropologia, Dipartimento di Scienze Fisiche, della Terra e dell’Ambiente, University of Siena, since 1998. The rockshelter opens in the Ginosa ravine, about 20 km NW from the coast, in a particularly friable Pleistocene calcarenite (Fig. 1a), at about 15 m from the current bottom of the ravine. Repeated collapses caused the progressive reduction of the shelter vault and the consequent erosion of part of the deposit.

Currently the whole stratigraphic series, about 6 m in depth, extends downwards, reaching a maximum area at the base of the deposit of about 60 m2. The stratigraphic series consists of layers of cemented sandy sediments in the upper part (SU 1 and SU 2 are truncated remains of the sediment infill close to the shelter wall), followed by a sequence of coarse sand and silt matrix units, compact and often hardened (SU 3 to SU 13), a thick tephra layer (SU 14) that covers a living floor (SU 15), and a sequence of sandy matrix units interlaced with localized vault shelter collapses and tephra layers (SU 16 to SU 27, currently unexcavated) (Fig. 1b). The excavated series (SU 1 to SU 15) is included in the first 3 m of stratigraphy and, chronologically, ranges between two dates in the final stage of the Middle Palaeolithic. The date of the lower part of SU 1 is 38.5 ± 0.9 ka BP e AMS, Beta 181165; cal. 42.724 ± 0.716 ka BP (for calibration see OxCal v4.2.4, Ramsey and Lee, 2013; Reimer et al., 2013). The second date is derived from the aforementioned tephra layer (SU 14), recognized as the Mt. Epomeo Green Tuff of Ischia (Spagnolo et al., 2016).

The identification of the same tuff in the lake sediment cores of Lago Grande di Monticchio (100 km North of Oscuruscuito rock- shelter) constitutes an excellent reference not only for the chronology of tephra deposition and SU 13 formation but also for the palaeoenvironmental framing of this context. The dates of the Mt. Epomeo Green Tuff fall to around 55 ka BP (Monticchio varvae chronology: 60.06 ± 3 ka BP, Wulf et al., 2012; 39 K/40Ar dates: 56 ± 4 ka BP, Gillot et al., 1982; 14C dates: 55 ± 3.5 ka BP, Perrotta et al., 2010; 40Ar/39Ar dates: 55 ± 2 ka BP, Watts et al., 1996; Tomlinson et al., 2014; Wulf, 2000). Pollen analysis of the Mon- ticchio's lake cores suggests a wooded steppe phase for this age (Allen et al., 2000; Watts et al., 1996). This is compatible with the earliest faunal-assemblage phase of the Oscurusciuto rockshelter after the tephra deposition (SU 13 to SU 8), which is characterized by absolute predominance of Bos primigenius, a typical wooded steppe-related species (Boscato, 2017; Boscato and Crezzini, 2012). Regarding the lithic industry in the post-tephra units (SU 13 to SU 1), a predominant use of unipolar and convergent Levallois concepts plus a marginal occurrence of additional debitages aimed at producing bladelets or flakes have been noted (Boscato et al., 2011; Marciani, 2013, 2018; Marciani et al., 2016; Ranaldo, 2005; Ranaldo et al., 2017; Ronchitelli et al., 2011b; Spagnolo et al., 2016; Villa et al., 2009).

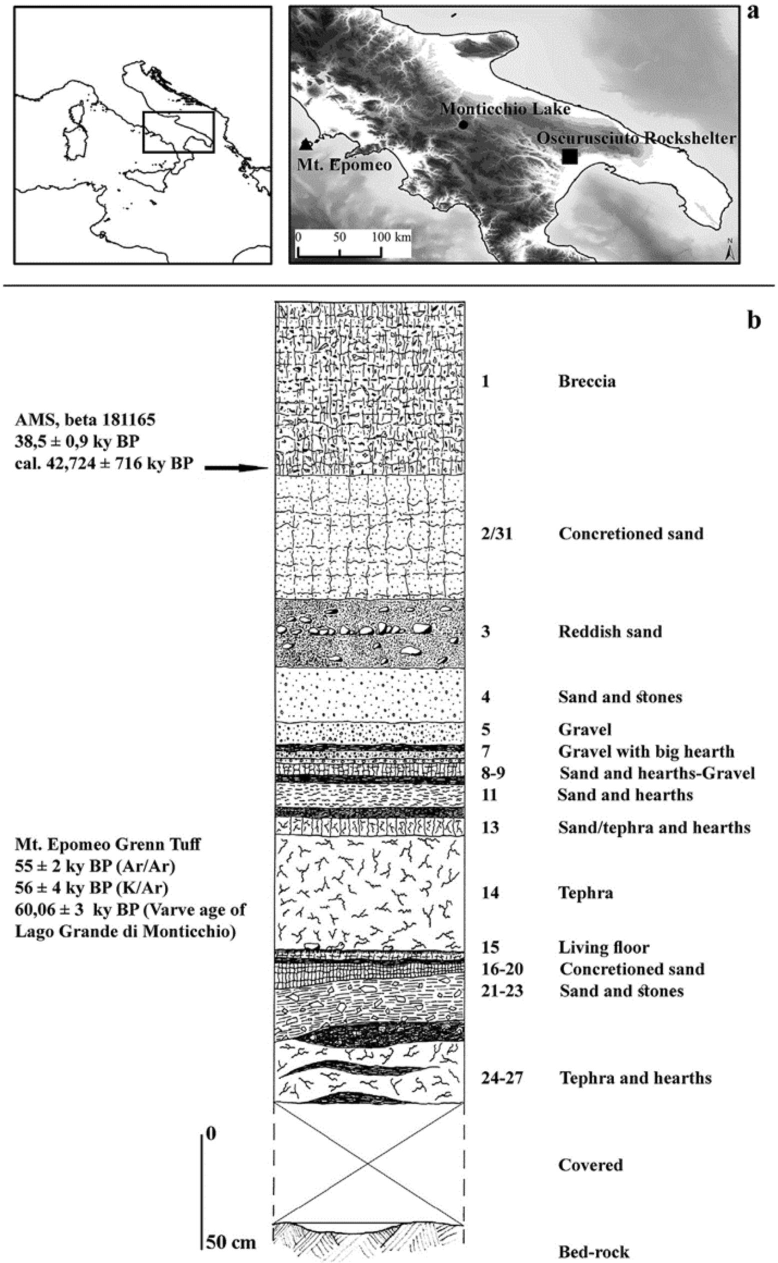

Fig. 1. (a) Geographic location of Oscurusciuto Rockshelter Site, Mt Epomeo volcano and Monticchio Lake; (b) stratigraphic sequence of the Oscurusciuto Rockshelter.

With reference to the spatial organization of the site, the stratigraphic sequence is characterized by various management strategies adopted by Neanderthal groups.

- SU 13 is a short palimpsest with small hearths (Ø about 20e30 cm). Just one has middle dimensions (at least 80 cm wide). These hearths appear aligned along a NE-SW axis and

subdivide the settled space into an inner part (between hearths alignment and rockshelter wall) and an outer part.

- SU 11 is a palimpsest with a high density of hearths, attributable to two dimensional modules. The smaller one (Ø about 20e30 cm), similar in spatial patterns with the SU 13 hearths, are earlier than the middle ones (Ø about 50 cm). Also in this case, a NE-SW alignment seems to divide the settled space into an inner and outer part.

- SU 9 is a layer with two NE-SW alignments of middle-sized (Ø

about 50 cm) hearths.

- SU 8 is a layer without hearths.

- SU 7 is characterized by the presence of a very large hearth (at least 2 m wide) in the NW corner of the shelter.

- SU 4 is a layer characterized by the presence of a large amount of stones (both limestone and calcarenite) in the upper part of the layer. At least some of these stones (some of them imported) may be part of structures, although it is difficult to recognize a pattern due to the limited extension of the surface spared from the erosion (Boscato and Ronchitelli, 2008, 2017; Spagnolo, 2013, 2017).

2.1. Stratigraphic unit 13

As stated, SU 13 is a very interesting unit, both for its temporal meaning as short palimpsest and because deposited on an almost sterile tephra layer. The studied area is not the whole settled zone since the deposit is partially destroyed by the slope erosion (on the East edge) and the residual part of the layer is not completely excavated. The explored surface is 11 m2 and corresponds to the area enclosed between the Northern and the Western walls of the shelter (Fig. 2). SU 13 is composed of a mix of tephra and sandy sediment, with rare and fine calcarenite blocks deriving from the shelter wall. This unit represents the first stable reoccupation of the site by Neanderthals after the deposition of the thick tephra layer of SU 14. As shown in a previous work focused on the palimpsest dissection of this level (Spagnolo et al., 2016), the evidence of syn- and post-depositional disturbance appears relatively negligible. Some poorly preserved hearths and the scattered distribution patterns of the large lithic items and of some RMUs (Raw Material Units) suggest that trampling/scuffing phenomena may have partially altered some of the original spatial patterns. However, the absence of any linear gradient among the dimensional classes of faunal remains and lithic finds, the identification of several clustered RMU and the presence of very well-preserved hearths, suggests that the finds were found substantially in their original spatial distribution.

The thickness of SU 13 is fairly homogeneous (about 10 cm on average), however, local variations are present with respect to this trend. In G12 in particular the layer reaches almost 20 cm in thickness, while along the D11-F11 band the layer is thinner. Additionally, a light depression in F11 (especially in F11/III-IV) is present (Fig. 2; Fig. S1).

The lithic collection of this unit comprises 7504 items with fresh edges and a good state of preservation. The dominant raw materials are local pebbles of jasper and siliceous limestone, though pebbles of chert, quartz sandstone, and limestone are also present. The raw materials identified are commonly found in the sea-terraces and river deposits around the site (nowadays located between a few tens of meters to over 20 km away). The main production tech- niques associated with the debitage are unipolar and convergent recurrent Levallois aimed at producing flakes, backed flakes, and convergent flakes. A marginal presence of additional volumetric debitage aimed at producing bladelets was also identified (Marciani, 2013). The technical strategies of Neanderthals at SU 13 indicate fragmentation of the reduction processes, that is to say, lithic materials were imported and exported from the site at different stages of manufacturing, i.e. elements were introduced in the form of pebbles, as well as semi-finished items, and as finished tools. Moreover, it is also documented the export of items, espe- cially target objects, from the site (Marciani, 2013, 2018; Marciani et al., 2016; Marciani et al., 2018, in press). Pieces were intro- duced in the form of pebbles, as well as semi-finished items, and as finished tools (Marciani et al., 2016).

The faunal remains (2860 items) are highly fragmented (only 121 pieces are larger than 6 cm) and include mainly portions of long bone diaphyses. Only 6 items in the sample were taxonomically identified (one is attributable to Equus ferus and five to Bos pri- migenius). Behaviourally, the heavy fragmentation rate of the bones could be interpreted as marrow extraction activity. The presence of a thin layer of carbonate concretion on the surface of most bones hindered taphonomic analysis (Boscato and Crezzini, 2006, 2012; Spagnolo et al., 2016).

2.2. Combustion structures of SU 13

The remains of at least nine combustion features have been found associated with the SU 13 surface; eight (SU 75, SU 76, SU 77, SU 78, SU 80, SU 83A-B and SU 84) had diameters ranging from 20 to 34 cm while one (SU 12), dissected by the current erosional line had an estimated diameter of about 80 cm. A tenth feature (SU 82), also small, was found a few cm under the SU 13 surface. The hearths in SU 13 are all shallow pits with a flat bottom and a “bowl” shape section (Fig. S2; Fig. S3; Fig. S4). The combustion structures of this layer are distributed along a NE-SW oriented band, constituting a “boundary-feature”, which divides the settled area into an inner and outer sector. Only 3 hearths were superimposed (SU 83B and SU 84 partially intercepted the previous SU 83A); the others were completely isolated. Along with these structures, in the central part of the investigated area, a small concentration of sediment patches showing traces of ash (SU 79) has been identified and may be related to the nearby hearths (Fig. 2). Both the above mentioned stratigraphic overlapping and the hearths spacing can be read as a palimpsest-related evidence. The hearth-to-hearth spacing, indeed, derives, at least in part, from human anatomical constraints, that is to say it could be related to the space needed by someone sitting around a fire to carry out a series of tasks. As shown in some ethnographical and archaeological studies, this space can be encompassed within a radius of about 1.7e1.9 m. Theoretically, this implies the possibility of establishing relations of synchronicity between hearths (Henry, 2012). Despite the regularity of the hearth-spacing, however, the limited extension of the Oscurusciuto Rock shelter hinders a distance-derived chronological correlation of the hearths.

SU 12 e This combustion structure is partially destroyed by the slope erosion and covered by the unexcavated stratigraphic baulk against the shelter wall. For this reason, its actual shape and size are unknown. The hearth was set in an irregular shallow pit, at least 80 cm wide and 4 cm depth. It may in fact be a set of several shallow pit hearths, which are not distinguish- able through colour variations or by evidence of cutting in the substratum. At the bottom of the structure there are two slight depressions located side by side, which are probably the basal portions of two adjacent pits.

The brown filling shows darker areas, fragments of burnt bone, and small pieces of limestone (Fig. S2).

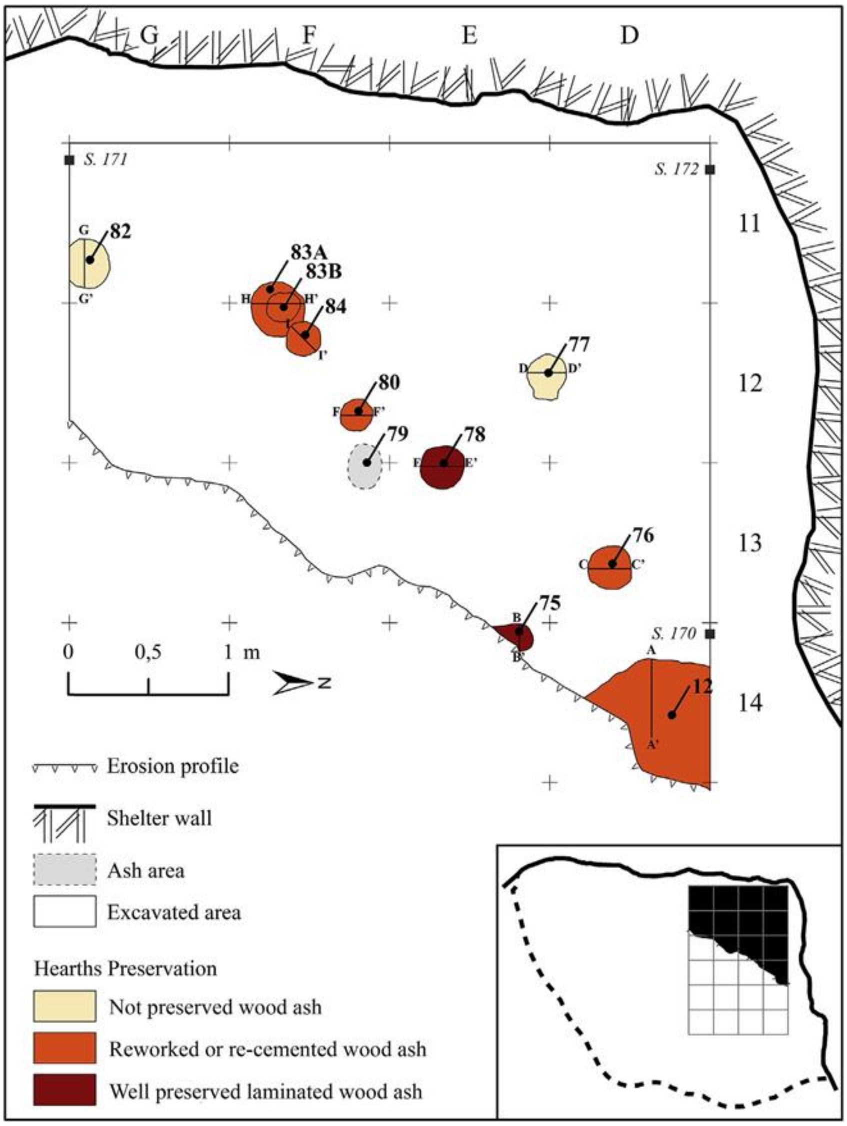

Fig. 2. Stratigraphic Unit 13, excavated area. Mapping: P. Boscato; drawing: A. Ronchitelli, V. Spagnolo.

SU 75 e This feature is a small hearth partially destroyed by the slope erosion. The recovered portion (22   17 cm) is character- ized by an ellipsoidal-shaped depression, roughly 3 cm in depth. The filling is composed by blackish sediment, covered by whitish cemented sediment just in the central part of the structure (Fig. S2).

SU 76 e This feature is a hearth set in a prepared circular-shaped depression (27 27 cm), 5 cm deep. A dark grey homogeneous sediment with sporadic finds and covered by whitish irregular- shaped concretion constitutes the filling of this structure (Fig. S2).

SU 77 e This feature is a hearth set in a 5 cm deep depression. On the base of its irregular shape, it could be assumed that it is made by two partially overlapped hearths, the larger one with a diameter of 24 cm, the second with a diameter of 8 cm. Patches of whitish cemented sediment were present on the top of the infilling (Fig. S2).

SU 78 e This is a hearth set in a circular-shaped depression (27 26 cm), 2 cm deep. The filling is dark brown with a thin whitish layer on the top (Fig. S3).

SU 79 e This is an ash area with a set of small strips of sediment (28 21 cm) showing combustion residues (pit evidences are not present). This sediment could be related to the emptying out of hearth (this may be correlated with a nearby hearth feature such as SU 78 or SU 80).

SU 80 e This is a small hearth set in a 3 cm deep depression. The structure (20 19 cm) is characterized by steep, almost vertical edges in the N-W transect. The filling (dark brown sediment, covered by whitish cemented sediment) contains sporadic finds (Fig. S3).

SU 82 e This is a small hearth set in a depression, it has been identified, unlike the previous ones, within SU 13 layer and not on its surface. Patches of dark sediment have been found on the top of this hearth, which likely refer to a modified upper part of the structure itself. This hearth is partially covered by the southern stratigraphic baulk, its diameter measures 30 cm and is 2 cm deep. The filling is dark brown not homogeneous sedi- ment (Fig. S3).

SU 83 e This is a pair of hearths set in overlapping pits. The larger (A), 34 33 cm wide and 3 cm deep in the preserved part, is cut off by the second (B), smaller (22 19 cm) and deeper (12 cm). This second hearth seem completely set within the previous structure and it is characterized by a darker and more homogeneous filling, covered by whitish and concreted sedi- ment (Fig. S4).

SU 84 e Due to the partially superimposition on SU 83A, this hearth represents the third combustion structure set in the same point of the shelter. However, it is not possible to deter- mine the succession between SU 84 and SU 83B. The SU 84 (21 21 cm) is the only one in this layer with an irregular pit walls, 7 cm deep. The filling is constituted by dark brown sedi- ment covered by a whitish and concreted one (Fig. S4).

3. Materials and methods

In this Stratigraphic Unit, a contextual approach (e.g. Bietti Sestieri, 1996; Carr, 1991; Hodder and Hutson, 2003) for the reconstruction of Neanderthal behaviour is applied from a spatial perspective to describe the organization of the settled area though the identification and interpretation of activity areas. Data collected by technological analysis of lithic finds, quantification and analysis of faunal remains (Marciani, 2013, 2018; Marciani et al., 2016; Spagnolo, 2013, 2017; Spagnolo et al., 2016) and soil micromor- phological study of hearths has been incorporated into a GIS plat- form with a specifically designed geo-database. The microarchaeological study (see Weiner, 2010) of the hearths was aimed at the reconstruction of behavioural aspects related with these structures. In order to achieve this objective, soil micromor- phology, Fourier transform infrared spectrometry (FTIR) and microspectrometry (m-FTIR) and phytolith analysis of the wood ash and underlain charred sediment layers were performed.

3.1. Microarchaeology analysis of combustion features

To gain information about the fuel composition, combustion condition and preservation state of the hearths, intact sediment blocks were collected from SU 12, SU 76, SU 77, SU 78, SU 80, SU 82, SU 83 A and SU 84. Additionally, intact blocks were collected from outside the combustion features in squares C14, (sample 170), G11 (sample 171) and C11 (sample 172) respectively (Fig. 2), to gain information on local activity, in situ human activities, and post- depositional processes. The intact blocks were embedded with polyester resin and processed into petrographic thin sections. The thin sections were analysed by petrographic microscopy (Olympus BX41) and soil micromorphology descriptions were conducted ac- cording to Stoops (2003). Loose sediment and thin sections were also analysed by FTIR and m-FTIR, using a Thermo iN10 XM imaging FTIR microscope respectively. FTIR analysis was specifically aimed at estimating the temperature reached by bone fragments (Berna, 2010, 2017; Berna et al., 2012) and by clay minerals contained in the substrate (Berna et al., 2007). Phytoliths were extracted from loose sediment sampled from the intact block before their embedding in polyester resin with a combination of two slightly modified protocols: wet oxidation and dry ashing (Albert and Weiner, 2001; Albert et al., 1999; Piperno, 2006; Zhao and Pearsall, 1998). The aim was to quantify the progressive loss of soluble minerals from the mineral and organic matrix. This com- bined process destroys calcium, phosphate, and organic com- pounds in order to isolate the biogenic silica through flotation in heavy liquid at a specific gravity of ~2.4 (Jones et al., 1963). Phytolith classification follows the criteria set by the International Code for Phytolith Nomenclature 1.0 (Madella et al., 2005). All samples were analysed and photographed at 400× magnification under differential interference contrast (D.I.C.) microscopy using Olympus BX53 and Stream Basic 1.8 image analysis software. Morphological features scrutinized were size, bi-dimensional outline, three- dimensional classification, and surface texture.

3.2. Spatial analysis

The elaboration of spatial distribution of the archaeological re- cord was performed using ArcGIS® 10.3, into a specifically designed geodatabase (Spagnolo, 2013, 2017; Spagnolo et al., 2016). SU 13 was analysed to identify the spatial structuration of the Neander- thal camp, as preserved in the excavated area, both through Point Pattern Analysis and through Quadrat Count Method.

To perform the spatial analysis, data have been selected based on their meaningfulness in terms of behavioural and spatial “visi- bility values”. The behavioural value of the finds depends on their role in the behavioural chain (Schiffer, 1972, 1975a, 1975b, 1976). The concept of spatial visibility is expressed in terms of corre- spondence between the spatial structuration of the behavioural meanings of finds and the recognisability of actual activity areas. Based on the preservation rates of activity areas, it is possible to list three main grades of visibility:

1 Direct correspondence between the actual activity areas and the spatial distribution of their correlated finds. In this scenario, all the finds related with a specific kind of activity are spatially linked to the area(s) where this activity took place.

2 Isomorphic correspondence between the actual activity areas and the spatial distribution of their correlated finds. In this scenario, the activity area(s) suffered a partial but relatively low alteration because of synchronic voluntary actions (e. g. cleaning up of the activity area) of synchronic involuntary actions (e. g. trampling/scuffing, digging, …) and/or of post-depositional actions. In this case, only a part of the overall finds related with a specific kind of activity is

spatially linked to the area(s) where this activity took place. So, to correctly detect the activity areas a preliminary "disturbed" data removal is required.

3 No correspondence between the actual activity areas and the spatial distribution of their correlated finds. In this scenario, the integrity of the activity area(s) is severely compromised because of synchronic voluntary actions (e. g. waste removing from the activity area) of synchronic involuntary actions (e. g. trampling/ scuffing, digging) and/or of post-depositional actions. In this case, is not possible to recognize the spatial organization of the site.

These visibility grades depend on a set of parameters, which involve the "Otherness of the Past" (Hodder and Orton, 1976), the taphonomy of the site, the ambiguity of archaeological record (Binford, 1987), the residuality of archaeological context (Schiffer, 1972), the intensity of archaeological signal left by activities per- formed in the site and the magnitude of the palimpsest effect.

Referring to the short palimpsest of SU 13 of Oscurusciuto Rockshelter, technological study of the lithics and analysis of faunal remains show that activities related to lithic knapping, possible use of lithic tools, and meat processing and consuming took place in situ. Concerning the lithic knapping activity, some reduction se- quences have been entirety performed in the site, as testified by RMUs (Raw Material Units) with all the technological phases rep- resented. However, in the set of lithics, clear trampling/scuffing phenomena can be argued, as shown both by the dispersed spatial pattern of several RMUs and by the clustering rate decrement of finds increasing the dimensional classes. From a spatial point of view, in the lithic set (Table 1), sorted by Dimensional Classes (DC1: 1e50 mm2, DC2: 51e100 mm2, DC3: 101e150 mm2, DC4: 151e200 mm2, DC5: >200 mm2), only the smallest pieces (DC1) have exhibited a moderately clustered pattern. This category, here defined as "micro-debris", includes small flakes and fragments associated with lithic production (Marciani, 2013; 2018; Marciani et al., 2016; Spagnolo, 2013, 2017; Spagnolo et al., 2016). Thus, for the purpose of spatial analysis, it is assumed that the micro-debris represents a more reliable correlate for detecting knapping activity areas than the larger production waste. This hypothesis is consis- tent with data from experimental flint-knapping and well- preserved Palaeolithic knapping areas. Statistically, a complete reduction sequence assemblage makes up a very high percentage of debris (small flakes and indeterminate fragments). Moreover, in absence of extensive water-flow processes (as inferred by the SU 13 analysis), the objects in the smallest size classes tend to be quickly buried. For this reason they do not suffer significant horizontal displacements, in contrast to the largest elements, more prone to be trampled/scuffed or to be removed by cleaning up activities (Ahler, 1989; Andrewsky, 2004; Baumler and Davis, 2004; Benito-Calvo et al., 2011; Bertran et al., 2012; Bowers et al., 1983; Bradbury, 2007, 2011; Bradbury et al., 2011; Brown, 2001; Carr and Bradbury, 2004; Gifford-Gonzalez et al., 1985; Healan, 1995; Henry et al., 1976; Hilton, 2003; Knell, 2004; Kvamme, 1997; Larson, 2004; Lin et al., 2016; Maíllo Ferna´ndez, 1998; Metcalfe and Heath, 1990; Nielsen, 1991; Patterson, 1982; Patterson and Sollberger, 1978; Rasic, 2004; Roebroeks, 1988; Root, 2004; Schiffer, 1983; Shott, 1994, 2004; Stevenson, 1985, 1991; Vaquero, 2012; Vaquero et al., 2012a, 2012b).

The presence of several retouched tools and items (mainly target objects) with possible macro-traces (individuated by naked eyes) lead to hypothesize the presence of activity related with the use of lithic tools in the level. A combined study of techno- functional and use-wear approaches (Aureli et al., 2015, 2016; Boe€da et al., 2015; Bonilauri, 2010) to the target objects dataset is currently ongoing. Preliminary results on the Levallois target products (flakes, convergent flakes and backed flakes) have confirmed that some of them were used for performing several types of activities (Marciani et al., 2018, in press). In this paper a macro-category named “used tools” (including retouched tools and items with possible macro-traces) has been created to identify possible areas related to the use of stone tools.

The cores can play a double role from a functional point of view: they can represent a raw material reserve (if they have a still usable volume) or they can be considered waste (if the active volume is completely exhausted). The cores of SU 13 have been included in the spatial analysis taking into account their exploitation rate (Initial, Medial or Final volume).

Compared to the lithic finds, an inverse tendency is recognizable among the Dimensional Classes of faunal remains, in view of generally clustered patterns, the largest bones are more clustered than the smallest ones. The only available data for the spatial analysis of faunal remains include the surfaces aspect (burnt or unburned) and the dimensional classes (DC1: 1e3 cm, DC2: 3e6 cm, DC3: 6e10 cm, DC4: >10 cm). Given the results of spatial patterns analysis (Spagnolo, 2013, 2017; Spagnolo et al., 2016), the Dimensional Classes with a significantly similar spatial pattern have been merged, creating two macro-categories: small faunal remains (<6 cm) and large faunal remains (>6 cm). The unburned faunal remains are grouped in these two distinct sets by dimen- sional class, due to the clearly different patterns, while almost all the burnt faunal remains are smaller than 6 cm, so this category has been analysed without dimensional distinctions (Table 1).

In summary, the categories selected for the spatial analysis include micro-debris, cores (including the exploitation rate), used tools, burnt faunal remains, small unburned faunal remains and large unburned faunal remains. These data have been studied both with several Point Pattern Methods (taking into account the point- files of the geodatabase associated with each find as a unique ID) and with Quadrat Count Method (taking into account the quanti- fication tables based on the content of each quadrant 50 50 cm). Concerning the Point Pattern Methods, the analysis carried out include Ripley's K function, Kernel Density and Ring and Sector Analysis. Regarding the Quadrat Count Method, a Hierarchic Cluster Analysis (Ward's Method) has been performed.

TECHNOLOGICAL PHASES	DC1	DC2	DC3	DC4-5	FAUNAL REMAINS	DC1-2	DC3-4
Acquisition	0	0	0	8	Unburned faunal remains	804	121
Initializzation/cortex removal	0	5	28	244			
Management	1394	734	248	514	Burnt faunal remains	1935	0
Target production	0	18	24	300			
Transformation	0	3	1	30			
Abandonment	0	1	1	31	**TOT**	**2739**	**121**
Indeterminated	2.842	652	226	200			
TOT	**4236**	**1413**	**528**	**1327**			

Table 1: Quantifications of lithic finds and faunal remains by Dimensional Classes.

Ripley's K function has been carried out to verify the variations of the clustering/dispersion rate incrementing distance of items among the aforementioned categories. This analytical tool (Arc-Map® 10.3\Spatial statistics tools\Multi-Distance Spatial Cluster Analysis) is sensitive to study-area variations. Consequently, this field has been set on the actual extension of excavated area (Study area Method\User_provided_study_area_feature_class). The 99 permutation-based confidence envelopes have been calculated to more accurately evaluate the result (Bevan and Conolly, 2006; Schwarz and Mount, 2006; Spagnolo, 2017; Spagnolo et al., 2016; Winter-Livneh et al., 2010). Kernel density maps (with search radius at 0.25 or 0.5 m, according with the results of Ripley's K cluster analysis) have been realized for a better visual rendering of finds distribution (Conolly and Lake, 2006: 175e177; Spagnolo, 2017; Spagnolo et al., 2016). The relationships between the hearths and the areas with high density of behaviourally- significant finds have been investigated by Ring and Sector Anal- ysis (powered by the preliminary analysis of density maps) (Boekschoten and Stapert, 1996; Cavulli, 2008; Henry, 2012; Stapert, 1989, 1990; Stapert and Johansen, 1997). To perform the Ring and Sector Analysis, multiple rings have been created (Arc-Map® 10.3\Analysis tools\Proximity\Multiple Ring Buffer), setting the buffering distance on 10 cm bands, to cover a radius of 1.2 m from the hearth centre (a greater distance would be unreliable due to the small excavated area and the short distances between the hearths). The rings have been clipped into eight sectors (45◦ wide), oriented as cardinal directions (N-NE, E-NE, E-SE, S-SE, S-SW, W- SW, W-NW and N-NW). The counting of finds for each ring/sector has been performed directly into ArcMap® 10.3 by the join data tool (ArcMap® 10.3\Open attribute table\Table options\Joins and rela- tes\Join\Join data from another layer based on spatial location).

Finally, the resulting absolute values have been transformed into area-related density values (Spagnolo, 2017). Furthermore, a hierarchic cluster analysis of agglomerative type (with Past 3.14) has been performed, using the Ward's Method with the aforementioned categories. The Ward's Method has been used because it has the advantage of offering group elements charac- terized by the highest level of homogeneity, minimizing the total variance within each cluster (Shennan, 1997: 241e258; Whallon, 1984). In order to use comparable spatial units, data have been referred to excavation grid (50 50 cm), discarding quadrants with an integrity level of <80% to avoid distortion of analysis results. In addition, to prevent a magnet-effect of several overrepresented findings, quantitative data in each category field have been normalized by conversion into percentage values (Spagnolo, 2017).

4. Results

4.1. Combustion feature microarchaeology

Here, the analysis of the microscopic ash and charred substrate layers are reported, focusing on information relevant to fuel composition, combustion conditions, potential function, and pres- ervation state of the hearths.

SU 12. The soil micromorphological analysis of intact block sample 127 from combustion feature SU 12 shows a ca. 2 cm thick heavily reworked and recemented wood ash layer (Fig. 3). The wood ash layer contains plant pseudomorphs, angular chert, and charred bone fragments. FTIR analysis indicates that charred bone fragments analysed were not heated above 500 ◦C (Fig. S5). The wood ash layer, lying directly on top of the blackish brown rockshelter sediment, contains abundant amounts of weathered micro-charcoal. m-FTIR analysis of the clay fraction indicates that the sediment did not reach a temperature above 500 ◦C (Fig. S5). It thus appears that SU 12 is the remains of an 80 cm wide hearth, whose ash layer has been slightly mechan- ically disturbed (i.e., raked or trampled) and recemented. No evidence of multiple fuel loads has been observed in sample 127; however, due to the thickness of the wood ash layer, this appears possible.

SU 75. Soil micromorphology analysis shows, in intact block sample 125 from SU 75, a very well preserved 0.5 cm thick layer of laminated wood ash interlaminated by micritic calcite infill- ing containing tephra needles (Fig. 3; Fig. 4e). Wood ash laminae contain well preserved fragments of ashed and charred woody parts (Fig. 4e). Leaf and grass phytoliths were also extracted from this layer (Fig. S6a-d). No bone fragments have been observed in this sample. The laminated ashes lie on a ca. 0.75 cm thick layer of local rock shelter sediment interlaminated by mm thick micritic laminae (Fig. 3). The origin and significance of this layer is not clear. Underneath a 0.25 cm thick layer containing charred and humified plant material is evident. It is important to note that in SU 75 the wood ash and other microstratigraphic layers appear exceptionally well preserved. It thus appears that SU 75 is the remains of a small hearth that was refuelled several times with wood, leaves, and grasses in the same spot in short intervals.

SU 76. In intact block sample 137 the top 1.5 cm thick wood ash layer appears to be reworked and cemented by dusty micrite (Fig. 3). It contains rounded gravel-size sandstone pebbles and charred and uncharred angular bone fragments. The underlain charred sediment is locally cemented by micritic calcite cement (i.e., brecciated). It thus appears that SU 76 is a partially disturbed hearth that was recemented by locally dripping water.

SU 77. No layer of preserved wood ash has been observed in intact block sample 129 (Fig. 3). The top 3.0 cm thick layer is discoloured (possibly charred) rockshelter sediment containing charred bone fragments and heat-altered limestone fragments. Phytoliths of grasses and leaves were found in this layer mixed with diatoms (Figs. S6hel). It also appears that, locally, the calcite cementation of the sediment has undergone dissolution. It thus appears that SU 77 is the remains of the substratum of a combustion feature whose wood ash has been removed by anthropogenic and taphonomic processes.

SU 78. In sample 140 a 5 mm thick layer of fairly well-preserved laminated wood ash is overlying with an abrupt and wavy dis- coloured (possibly charred) rockshelter sediment containing numerous fragments of charred bone but no charcoal (Fig. 3). m- FTIR analysis shows that the clay mineral components of the discoloured layer were heated diffusely above 500 ◦C. It thus appears that SU 78 is the remains of a hearth in a shallow basin refuelled several times with woody plant material that under- went complete combustion. It is interesting to note that chert debitage fragments are found in the wood ash layer (Fig. 4aeb). SU 80. In sample 136 no wood ash layer is observable (Fig. 3). The top 1 cm thick whitish beige layer is, in fact, brecciated (by microsparite cement) rockshelter sediment containing charred bone fragments (Fig. 4ced) and degraded charcoal. The 2 cm thick dark brown layer underneath appears to be discoloured rockshelter sediment containing microscopic fragments of charred and degraded plant material. SU 80 thus appears to be the remains of the substrate of a small hearth.

SU 82. Similarly to sample 129 from SU 77, no layer of preserved wood ash has been observed in intact block sample 143 from SU 82 (Fig. 3). The top 2 cm thick layer is discoloured (possibly charred) rockshelter sediment containing gravel-size charred coprolite and limestone fragments and a few sand size charred bone fragments. It thus appears that SU 82 is the remains of an in situ combustion feature, whose wood ash was locally removed.

SU 83 A. In sample 146 the top 2 cm-thick whitish beige layer is composed of heavily reworked and recemented laminated wood ash containing charred and partially calcined bone fragments (Fig. 3). The temperature reached by some bone fragments is estimated by m-FTIR to be above 500 ◦C but below 800 ◦C. The fine fraction of the underlying rock shelter deposit is dis- coloured (dark brown) and contains rounded pebbles and angular charred bone and charcoal fragments. It thus appears that SU 83 was a small hearth fuelled with wood and other combustible material that may have reached higher tempera- tures than other hearths.

SU 84. The top 2 cm-thick layer of Sample 149 is composed of wood as fragments mixed and cemented with local rock shelter sediment (Fig. 3). This layer contains ashed plant material and angular charred bone fragments. Similarly to the ash layer of SU 75, grass phytoliths were also extracted from this layer (Figs. S6eeg) but not parenchyma phytoliths. The underlying charred substrate contains chert artefacts, charred bone frag- ments, and degraded charcoal. It appears less cemented than the overlaying ashy layer.

SU 13. The sediments a few cm NW of hearth SU 12 (sample 170) are characterized by a ca. 2 cm thick weathered tephra containing micritic limestone sub-rounded coarse sand and heavily frag- mented bone and teeth residues (Fig. 5). The entire top 2 cm layer appears to be recemented by calcite. The sediment (sample 171) 50 cm W of hearth SU 82 is characterized by 5 cm thick colluvium containing debitage of various lithology (shale, chert, limestone), mixed in weathered tephra and micritic matrix (Fig. 5). Terra rossa aggregates and coarse sand size bone fragments are also dispersed in the matrix suggesting that in this area of the rock shelter resi- dues from stone tool making and bone processing accumulated on top of the tephra together with debris dropping from the rock- shelter wall and roof. The sediments from an area adjacent to the rockshelter wall (sample 172) are characterized by a sharp contact between the underlying weathering Mt. Epomeo Tephra and a terra rossa colluvium containing large fragments of uncharred and charred bone, chert debitage, and limestone fragments (Fig. 5). The surface of the tephra does not appear to be significantly compacted, nor were evidence of plant fibres observed. On the other hand, no residue deriving from stone tool making, bone or plant processing, or fire making were observed.

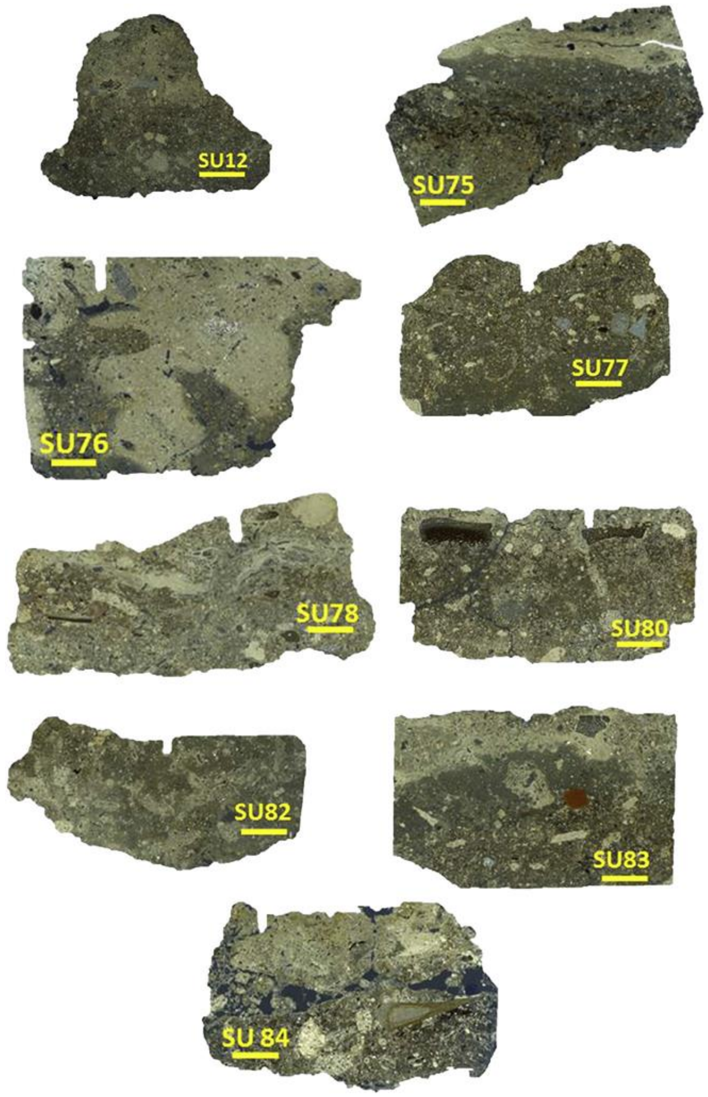

Fig. 3. Cut-outs of cross-polarized scans of petrographic thin sections prepared from intact sediment blocks of combustion features within SU 13. Scale bar ¼ 1 cm.

4.1.1. General observations

In all samples the observed thickness of the laminated wood ash layer does not surpass ca. 2 cm. The lamination of the wood ash layers suggest that several fuel loads were used. The sub-cm thickness of the laminae suggests that the fuel loads used to fuel the fire were exiguous. The limited number of observable laminae (7 in SU 75 and 4 in SU 78), similarly, suggests that the hearths were refuelled frequently but with small charges. The data thus hints at short-lived hearths. Abundant charcoal fragments (although highly degraded), ashed plant remains, and wood ash rhombs suggest that wood was the main fuel used. Grass and leaves phytoliths are also found in the ashes suggesting that grasses and leaves entered the fire too. Unfortunately, it is currently not possible to determine if grass and leaves entered the fire accidentally or intentionally. In fact, grass and leaves phytoliths are also found dispersed in the sediment surrounding the hearths, suggesting that grass and leaves fragments were mixed in the substratum by natural and/or anthropogenic processes.

Bone fragments have been found in the wood ash layers of the majority of hearths analysed (SU 12, SU 75, SU 76, SU 80, SU 83, SU 84). The screening by m-FTIR of 67 bone fragments observed in the thin sections of SU 12, SU 77, SU 78, SU 80, SU 82, and SU 83 shows that only 8% reached temperature above 700 ◦C. According to The´ry-Parisot and Costamagno (2005) this distribution suggests that bone was probably not used as fuel but entered the fire accidentally or due to disposal. Nevertheless, the data suggest that bone processing may have occurred around the hearths while they were lit.

In the well preserved laminated wood ash layers of SU 12, SU 76 and SU 78, angular fragments of chert artefacts have been observed, suggesting that flint knapping may have taken place around these 3 hearths while the fire was lit. Organic residues, charcoal, and other charred material appear extremely degraded and therefore any observation on plant anat- omy and identification are grossly hampered. The best-preserved hearths are SU 75 and SU 78 with laminated ashes still observable in situ. In SU 80 and SU 83 the ashes appear to be in situ but heavily recemented. Wood ash reworked with local soil has been observed in SU 12, SU 76, and SU 84. In SU 77 and SU 82 no in situ preserved ashes were observed in thin section (Fig. 2).

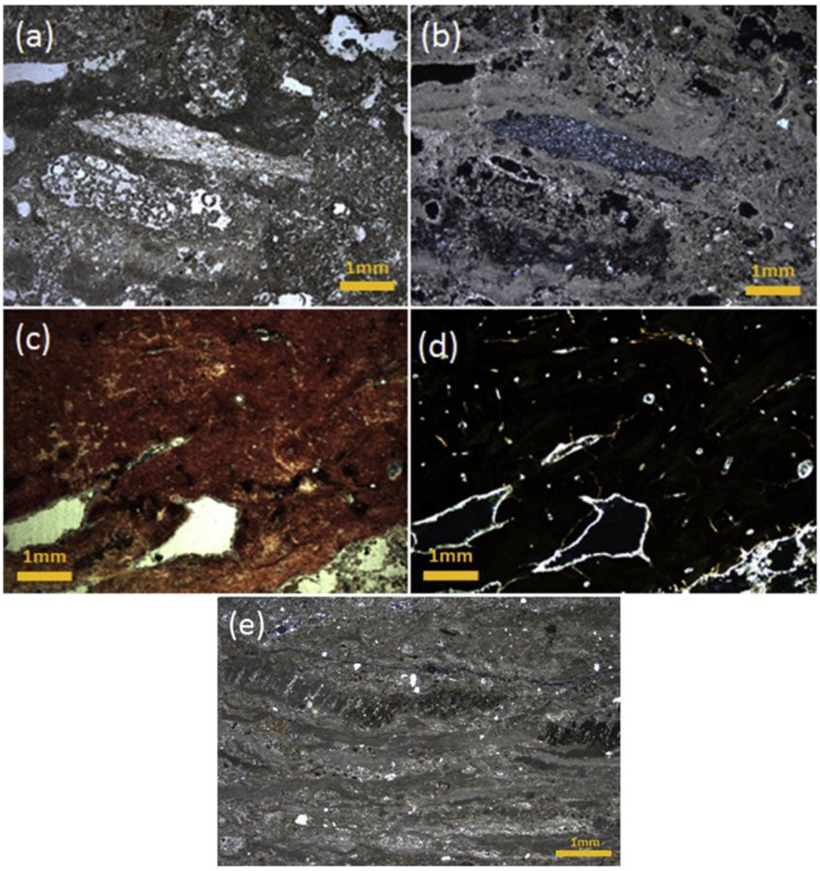

Fig. 4. Chert and Charred Bone Micrographs: a) and b) Micrographs of chert fragment (debitage) in laminated wood ash layer from SU 78. c) and d) Micrographs of fragment of charred bone in the wood ash of SU 80. e) Cross-polarized light micrograph of laminated wood ash with charcoal and ashed plant material from SU 75 (sample 125). Scale bar ¼ 1 mm.

Fig. 5. Control Sample Thin Sections. Cut-outs of cross-polarized scans of petrographic thin sections prepared from intact sediment blocks of three control samples within SU 13. Scale bar ¼ 1 cm.

4.2. Taphonomy and spatial data

Several factors of SU 13's taphonomy and spatial data, including the absence of biotic macro-alterations, the fresh aspect of the lithic cutting edges, the hearths' preservation, the high value of the chi- square test, and the presence of several clustered RMUs highlight the good preservation of Unit. These parameters also emphasise the non-random nature of the distribution pattern of finds. Further- more, no correlation has been found between the dimensional classes of lithic finds and faunal remains and the surface morphology of SU 13, therefore a water flow effect can be ruled out. In other words, the spatial configuration of these materials can be mainly (if not exclusively) understood as the product of human activity. Possible unintentional displacement processes (scuffing/ trampling) are suggested by the presence of scattered RMUs and by the general decrease of clustering rate of lithic finds incrementing size (Spagnolo, 2017; Spagnolo et al., 2016).

Within the excavated area (11 m2), both the hearths' alignment and the density find gradients (Fig. 6) denote an anthropic orga- nization of the space in at least two main sectors; referred to as the inner and outer parts.

1) Inner part: sector between the hearths alignment (NE-SW) and the rockshelter wall (W). The characteristic feature is the lower frequency of lithic finds and faunal remains compared to the outer part. The extension is about 4 m2 (5 m2 including the unexcavated area against the wall).

2) Outer part: sector between the hearths and the erosion front. It is characterized by the presence of hearths and by a massive number of lithic finds and faunal remains. The outer part of the deposit has been partially destroyed by the slope erosion. Two unexcavated stratigraphic baulks at the Northern and Southern edges of anthropic deposition have been left. The extension here analysed (saved from slope erosion) corresponds at about at 7 m2.

In this small area, the density variations in the feature distribution suggest a further articulation of the space into distinct zones (Fig. 6). Results of the cluster analysis with the Ward's Method are consistent with this suggestion (Fig. 7). Indeed, 5 “individual en- tities” have been identified (at distance measure 16), significantly corresponding to the zones recognizable through the visual analysis of density maps. The cophenetic correlation value (c 0.8163) highlights the quality of the dendrogram obtained by this cluster analysis (Spagnolo, 2017).

As shown by results of the preliminary Ripley's K function analysis and by density maps, it is possible to distinguish different spatial patterning among the dataset features here presented. A relatively low clustered pattern (ranging between 0.2 and 0.6 m of radius) has been found in the set of micro-debris (N 4236), with several small agglomerates related with the hearths SU 82, SU 83, SU 84, SU 78, SU 77, SU 76 and SU 12. As shown by density maps and Ring and Sector Analysis (RSA), it is usually possible to relate each hearth to just one of these agglomerates. Moreover, the micro- debris density variations along the ring profiles obtained by RSA highlight a continuous localization of the hearth-side density peaks between 0 and 0.79 m from the hearth centre (0e0.66 m if the hearth border is taken into account). Usually, the band with high- density peaks is abruptly followed by a band with low density of finds. Not all the micro-debris accumulations take place directly in association with a hearth, shown by several clustered RMU (Spagnolo et al., 2016) and by density maps. A strong spatial cor- relation between micro-debris and the refittnig/conjoint set has also been observed. The main accumulations of micro-debris occur in clusters 5, 4 and 2 (Fig. 6; Fig. 7; Fig. 8; Fig. S7; Fig. S8; Tab. S1). Despite the higher confidence envelopes of the Ripley's K analysis and the spatial pattern of cores (N 33), results clustered. The highest clustering rate appears within the band 0.3e0.7 m. This pattern became more evident when the exploitation rate was taken into account: while the scarce cores with a still usable volume are scattered in the northern part of the excavated area, the completely exploited cores are mainly clustered at the SE edge, apparently not associated with any combustion structure. The main accumulation of cores (totally exploited) appears in cluster 2 identified by the Ward's method. This area corresponds with the thickest part of SU 13 (Fig. S1; Fig. 6; Fig. 7; Fig. 8).

A very low clustering rate (within the band 0.3e0.5 m of radius) characterizes the pattern of used tools (N 238). Main accumula- tions seem related to hearths, but they are hardly attributable to specific combustion structures due to wider scattering of pieces with respect to other categories of finds (possible relations could be identified with hearths SU 82, SU 83, SU 84, and SU 76, within the band 0e0.92 m from the fire centre). The distribution of used tools seems to be associated with clusters 2, 4, 5 (partially with cluster 1) of the Ward's method (Fig. 6; Fig. 7; Fig. 8; Fig. S9; Fig. S10; Tab. S1). With regard to faunal remains, the burnt pieces (N 1935), practically all smaller than 3 cm, show a relatively clustered pattern, ranging between 0.2 and 0.6 m in radius. The main con- centration is located in the SE part of the excavated area (in part correlated with the hearths SU 82, SU 83 and SU 84), while smaller clusters are located in the North side of the excavated area, in correspondence with several hearths (SU 76, SU 77, SU 78) and close to the northern stratigraphic baulk. Likewise, the hearth- related micro-debris accumulations, the density maps, and the RSA emphasise the presence of one cluster for each hearth. Looking at the Ring profiles, the lower peaks tend to fall at 0.64 m from the hearth centre (0.54 m considering the hearth border). The accu- mulations of burnt faunal remains are mainly related to clusters 5 and 4, and partially with cluster 2 (Fig. 6; Fig. 7; Fig. 8; Fig. S8; Fig. S9; Tab. S1).

The unburned small faunal remains (N 804) are highly clus- tered (within a radius of 0.1e0.7 m), forming small agglomerates. They are mainly located along the hearths' alignment, specifically on the “external” side of several hearths (SU 82, SU 83, SU 84, SU 80, SU 78), close to hearths SU 12 and to the northern stratigraphic baulk. Looking at the Ring profile, the main peaks are enclosed between 0 and 0.93 m from the hearth centre (0e0.77 m consid- ering the hearth border). This category of finds appears signifi- cantly related to clusters 2 and 5 of the Ward's method (Fig. 6; Fig. 7; Fig. 8; Fig. S9; Tab. S1).

The spatial pattern of the set of unburned large faunal remains (N 121) appears very highly clustered. Almost all the pieces are concentred in the SE edge of the excavated area and are not associated with hearths. The larger bone concentration area corresponds with cluster 1 (and in part with cluster 2) identified through the Ward's method. The area related to this accumulation comprises the thickest segment of SU 13, as observed for the totally depleted core localization (Fig. 6; Fig. 7; Fig. 8).

Finally, cluster 3 includes all the quadrants characterized by a low or very low density of findings, mainly enclosed between the shelter wall (where a slight depression is located) and the hearths' alignment. This sector measures 3.7 m2 but can reach a 5 m2 surface if the small unexcavated stratigraphic baulk in the western side of the site is included (Fig. 6; Fig. 7; Fig. S1). Another interesting aspect is the apparent modularity observed in the hearths' distances. A bimodal distribution model both in the hearth-to-rockshelter-wall and in the hearth-to-hearth distances sets is evident. Regarding the hearth-to-rockshelter-wall distances, the two peaks fall at 1.5 ± 0.1 m (SU 77, SU 82, SU 83A-B, SU 84) and 2.8 ± 0.7 m (SU 12, SU 75, SU 76, SU 78, SU 80); a very similar pattern is recognizable among the hearth-to-hearth distances (1.4 ± 0.2 m and 2.4 ± 0.3 m) (Table 2) (Spagnolo, 2017).

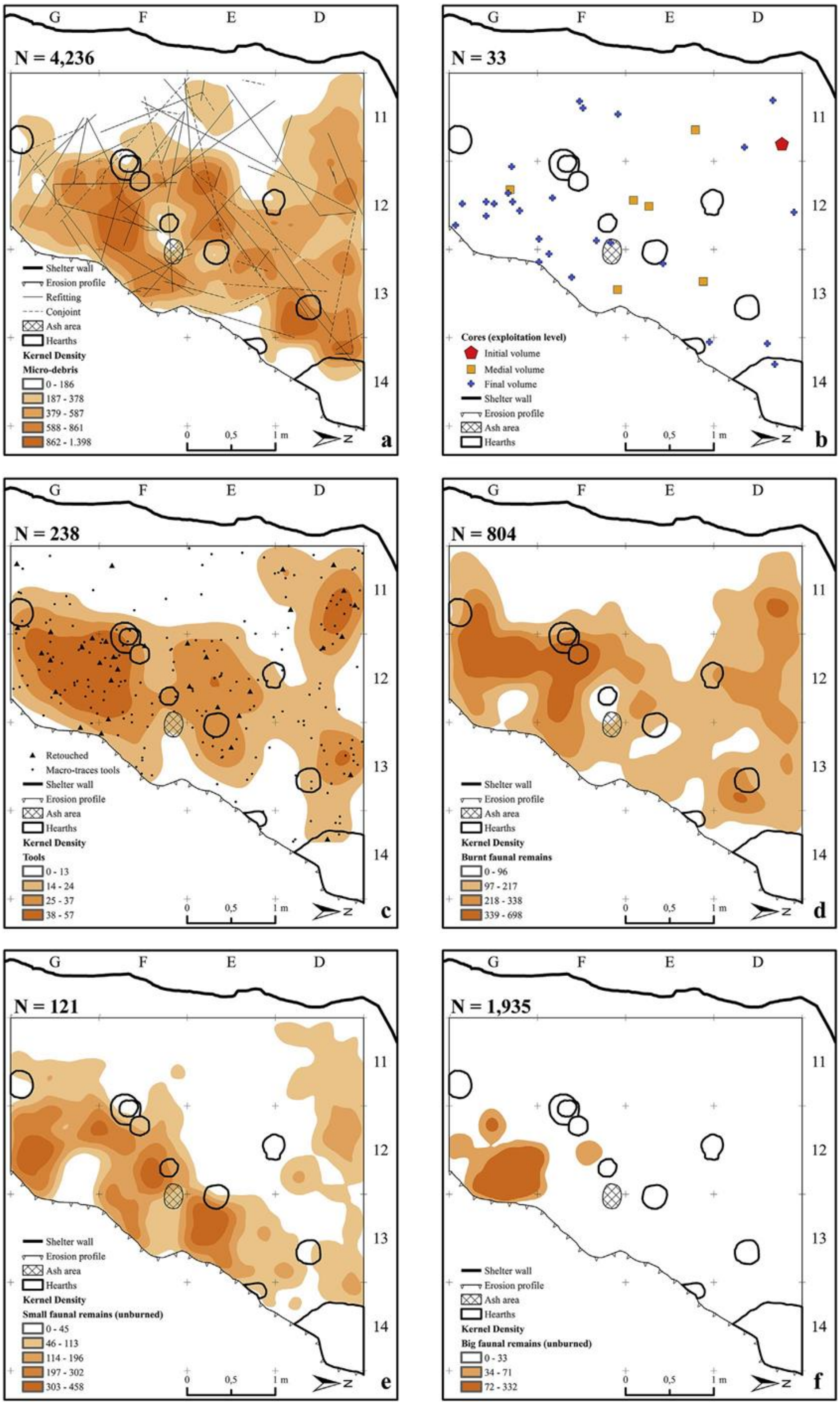

Fig. 6. Density and distribution maps of main categories analysed: a) micro-debris; b) cores (along with the exploitation level); c) used tools (with characterization of retouched and macro-traces); d) unburned small faunal remains; e) unburned large faunal remains; f) burnt faunal remains.

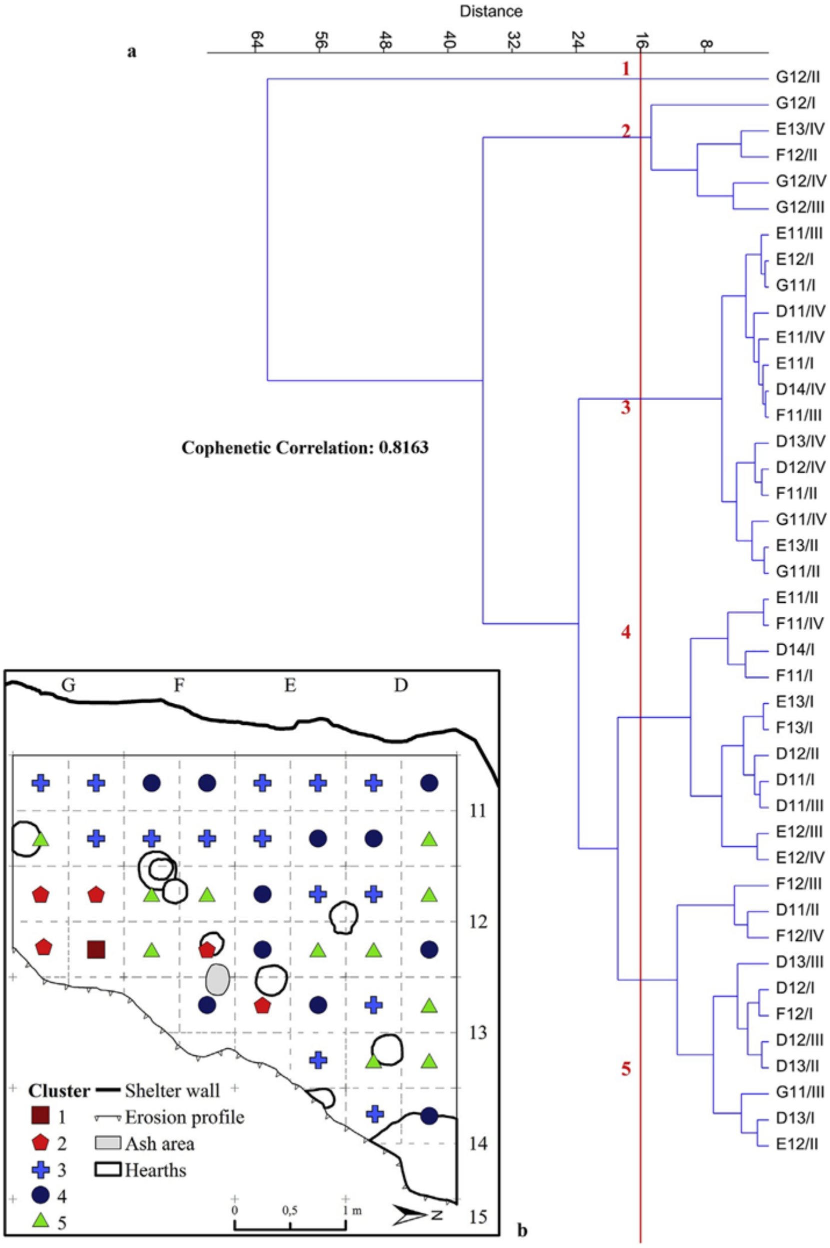

Fig. 7. Cluster analysis (Ward's method) results: a) dendrogram; b) choice of the distance level; a) spatial visualization of results.

5. Discussion

The results of these analyses provide an articulated picture of the human organization of settlement at Stratigraphic Unit 13 of the Oscurusciuto Rockshelter. From a behavioural point of view, the activities carried out in situ, as shown by lithic and faunal results, include flint-knapping, use of lithic tools, faunal resource process- ing and consuming (including bone fracturing aimed at marrow extraction). Moreover, this context can be considered a well pre- served “short palimpsest”; that is, the formation of the layer can be framed into a relatively short time-span. Thus, it can be associated with a limited number of human occupations, presumably attrib- utable to the same human group (Marciani et al., 2016; Spagnolo et al., 2016). This makes SU 13 a unique context for analysis aimed at the reconstruction of strategies adopted by Neanderthal groups to organize and manage a settlement.

The microarchaeological analysis of the combustion features investigated suggests that most probably all of them derived from short lived fires fuelled by woody parts of plants, though grass and leaf phytoliths were also found in the ashes of SU 75 and SU 84 as well as in control sediment underneath SU 77 (Fig. S6). Further research is needed to fully understand the nature of grasses and leaves in the pyrotechnological activity of the site. One hypothesis is that grasses could have been used as kindling material. The best- preserved feature, SU 75, shows evidence of several fuel loads in the form of distinct wood ash laminae. Additionally, it appears that faunal resource processing may have occurred around the majority of the hearths. The thin sections, finally, show evidence of flint knapping activity just around hearths SU 12, SU 76, and SU 78. Microarchaeological analysis suggests that besides being used as source of light, warmth and protection, meat and bone processing as well as stone tool activities may have taken place around these hearths. To date, no compelling observations have been made regarding potential fire-starting techniques, such as the use of py- rite or marcasite.

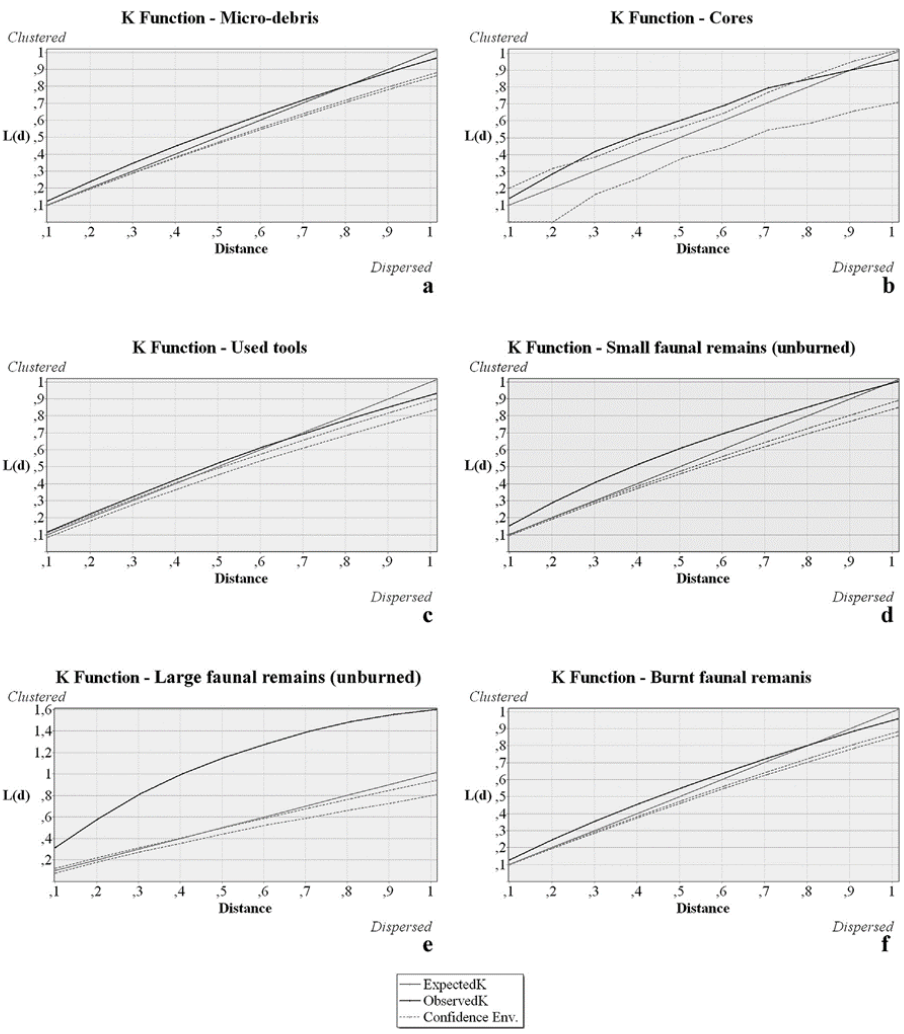

Fig. 8. Ripley K Analysis: a) micro-debris; b) cores; c) used tools; d) unburned small faunal remains; e) unburned large faunal remains; f) burnt faunal remains.

a								b	
Hearth-hearth (class 1)	m	Hearth-hearth (class 2)	m	Hearth-hearth (class 3)	m	Hearth-hearth (class 4)	m	Hearth-wall	m
83A-83B	0,0	12–76	1,0	76–80	1,9	12–84	3,3	**Class 1**	
83B-84	0,2	12–75	1,1	80–82	1,9	12–83B	3,5	82-Wall	1,4
83A-84	0,3	75–78	1,2	12–78	2,1	12–83A	3,5	83B-Wall	1,5
80–48	0,6	78–84	1,2	12–77	2,2	75–82	3,5	83A-Wall	1,5
78–80	0,6	82–83A	1,2	75–84	2,3	76–82	3,8	84-Wall	1,6
75–76	0,7	77–80	1,2	76–84	2,4	12–82	4,6	77-Wall	1,7
80–83B	0,8	76–78	1,2	75–83B	2,5			**Mean**	**1,5**
80–83A	0,8	82–83B	1,2	75–83A	2,5			**σ**	**0,1**
77–78	0,9	76–77	1,3	78–82	2,6				
		78–83B	1,4	76–83B	2,6			**Class 2**	
		82–84	1,4	76–83A	2,6			80-Wall	2,0
		78-83a	1,4	12–80	2,7			78-Wall	2,3
		77–84	1,5	77–82	2,9			76-Wall	2,8
		75–77	1,6					75-Wall	3,3
		77–83B	1,7					12-Wall	3,7
		75–80	1,7					**Mean**	**2,8**
		77–83A	1,7					**σ**	**0,7**
Mean	**0,5**	**Mean**	**1,4**	**Mean**	**2,4**	**Mean**	**3,7**		
σ	**0,3**	**σ**	**0,2**	**σ**	**0,3**	**σ**	**0,5**		

Table 2: Hearths-to-hearths and hearths-to-shelter-wall distances summary.

The spatial analysis has allowed the identification of a subdivi- sion of settled areas in small sectors that may correspond to Zones of Organized Activity (Allue´ et al., 1993). The recurrence of specific sets of findings can provide insight into the possible functional designation of those sectors.

In SU 13, the existence of a dichotomy between the inner part of the shelter and the outer part can be clearly identified. This is supported by both the sharp density gradients in the areal distri- bution of findings and the hearths' alignment (sub-parallel to the shelter wall, with regular distances). The abrupt density variations between the inner part (with a lower frequency of lithics and faunal remains) and the outer part (with high density of findings) could be explained through the following inferences:

- Existence of a “vertical barrier” between inner part and outer part.
- External localization of activities that produced refuses.
- Presence of animal skins, mats or other covering on the floor of the inner part, removed after the abandonment of the camp-site by Neanderthals.

The sharp density variations of lithic finds and faunal remains in Palaeolithic settlements, has been explained by the barrier-effect hypothesis that invokes the existence of latent structures (Gelhausen et al., 2004; Leesch and Bullinger, 2012; Leroi-Gourhan and Brezillon, 1966; Moseler, 2011; Nigst and Antl-Weiser, 2011; Stapert, 1989, 1990; Stapert and Johansen, 1997; Wenzel, 2011). However, in SU 13 there is no evidence to support the hypothesis of structures built in elevation between the shelter wall and the hearths alignment. Therefore, a possible barrier-effect can be ruled out. Other hypotheses appear more plausible and are not self- excluding. The spatial arrangement of SU 13 could be related to the use of a sector of the shelter's inner part as a sleeping/resting area. Despite the elusive character of the sleeping areas in the Palaeolithic record and the wide cultural variability of these fea- tures (with consequential differences in formal results), as reported in ethnoarchaeological literature, several recurrent parameters can help to identify them. In rockshelter contexts, according to data in ethnoarchaeology, the most protected locations (e.g. areas against the walls) tend to be preferred and well-bounded by aligned and regular-spaced hearths (often relatively small in size). Skins or vegetal mat beddings can be placed or between the hearths, as at Big Elephant Shelter, NW settlement, South West Africa (Binford, 1996; Clark and Walton, 1962; Galanidou, 2000; Henry, 2003; Henry et al., 2004; Wadley, 1976, 1977) or in the space left between the rockshelter wall and the hearths alignment, as at Gatecliff Shelter, Arizona (Henry, 2003; Henry et al., 2004; Thomas et al., 1983), at De Hangen Cave, South West Africa (Binford, 1996; Henry, 2003; Henry et al., 2004; Parkington and Mills, 1991; Parkington and Poggenpoel, 1971), at Bendiyagalge Shelter, Sri Lanka (Binford, 1996; Henry, 2003; Henry et al., 2004; Seligmann and Seligmann, 1911) and at Yungubalibanda Shelter 6, Australia (Galanidou, 2000; Henry, 2003; Henry et al., 2004; Nicholson and Cane, 1991). In this set of sample sites, the constant and similar values observed among the hearth-to-hearth distances (average 1.7 m) and among the hearth-to-shelter-wall distances (average 1.6 m) is explained as a body-size dependent variable (Table 3; Tab. S2). Lastly, the sleeping and resting areas are kept clean as evi- denced by refuse heaps produced in nearby activity areas (Binford, 1983, 1987, 1996).

Close analogies with the rockshelter patterns can be found in some open-air sites characterized by the presence of brush wind- break, as in many Australian camps. In these sites, an alignment of regular-spaced hearths (average 1.9 m) is arranged parallel to the windbreak (at a mean distance of 1.7 m) (Table 3; Tab. S3). Vegetal mat beddings are placed between the hearths, as at Nabulabanda Camps 1, 3, 7, 11, Australia (Nicholson and Cane, 1991), at Sandover River Alyawara men's camp, Australia (Binford, 1986), at Gurlanda B Alyawara conjugal camp, Australia (Binford, 1986, 1987), at Tawara ngura placed at approximately 45 km SW of Warburton Mission, Australia (Binford, 1983; Gould, 1977) and at the Mrabri Camps 1, 4, Thailand (Binford, 1983; Velder, 1963). Even in these cases, the sleeping areas are kept clean by limiting production to nearby ac- tivity areas (Binford, 1983, 1987).

In summary, according to the ethnographic model, the typical parameters of a sleeping/resting area in a rockshelter should be the presence of a spatially segregated sector from other activity areas (with a low density of lithic and bones), the localization of this area close to the shelter wall, the presence of an approximately equi- distant hearth alignment that acts as a boundary for this area on its “external” border (at mean distances of 1.7 m both hearth-to- hearth and hearth-to-wall), and the possible presence of skins or vegetal mat beddings traces. In order to avoid a misreading of the context, the evaluation of all parameters is required. Indeed, as shown by the Gurlanda B Alyawara conjugal camp (Australia), the simple presence of beddings related with fireplace alignment par- allel to a brush windbreak and without the spatial analysis of other finds, would have led to overestimation of the extent of the sleeping area (and therefore the number of occupants), as well as to overlooking domestic activity areas related with peripheral cooking (and not sleeping) hearths (Binford, 1986, 1987). Interesting, also, is the relationship between the sleeping area dimensions, the hearth spacing, and the number of inhabitants, since these are body-size dependent measures. As calculated on the basis of observations among a large number of hunter-gatherer groups, a bedding-space ranging between 1 and 1.7 m2 is required by an adult man. This means that, based on the sleeping area surface, it is possible to estimate the number of occupants in the site (Binford, 1983; Gamble, 1986).

	Site	Site surface	Sleeping area surface	N. hearths	Hearths' diameters	Distances hearth-hearth	Distances hearth-shelter wall
Ethnoarchaeological – Holocene rockshelters	Big Elephant Shelter, NW	65 m^2	~9 m^2	3	44 ± 9 cm	3.1 m, 4.2 m	1.4 ± 0.1 m
	Gatecliff Shelter, Horizon 9	50 m^2	~8 m^2	6	56 ± 19 cm	1.5 ± 0.3 m 2.7 ± 0.1 m	2.6 ± 0.6 m
	Gatecliff Shelter, Horizon 2	52 m^2	~8 m^2	?	?	?	?
	De Hangen Cave	37 m^2	~18 m^2	3	59 ± 11 cm	4.6 m, 1.7 m	1 ± 0.1 m
	Bendiyagalge Shelter	22 m^2	~5 m^2	7 (5s)	38 ± 3 cm (s)	1 ± 0.2 m (s)	1.3 ± 0.2 m (s)
	Yungubalibanda Shelter 6	25 m^2	~8 m^2	4 (3s)	65 ± 4 cm (s)	1.6 ± 0.4 m	1.5 ± 0.5 m (s)
	Mean values (± σ)	**42 ± 16 m^2**	**9 ± 4 m^2**	**4 ± 1**	**52 ± 11 cm**	**1.7 ± 0.7 m**	**1.6 ± 0.6 m**
Ethnoarchaeological open-air	Nabulabanda – Camp 1	?	1.4 m^2	3 (2s)	57 ± 4 cm (s)	1.7 m (s)	1.8 ± 0.1 m (s)
	Nabulabanda – Camp 3	?	4.4 m^2	4	51 ± 23 cm	1.5 ± 0.1 m	2.7 ± 0.8 m
	Nabulabanda – Camp 7	?	3 m^2	4 (1s)	24 ± 2 cm (s)	2.2 ± 0.2 m	1.5 ± 0.4 m
	Nabulabanda – Camp 11	?	4.9 m^2	7 (4s)	30 ± 1 cm	2 ± 0.1 m (s)	/
	Sandover River men's camp	~150 m^2	5.8 m^2	5	57 ± 3 cm	1.7 m	1.5 ± 0.3 m
	Gurlanda B conjugal camp	~210 m^2	3.7 m^2	5 (1s)	55 cm (s)	2 ± 0.8 m	0.9 ± 0.5 m
	Tawara ngura, Warburton Mission (Australia)	?	5.4 m^2	5	30 ± 1 cm	1.7 ± 0.5 m	/
	Mrabri Camp 1	?	13.1 m^2	5	?	3 ± 1.7 m	/
	Mrabri Camp 4	?	9.7 m^2	7	?	1.8 ± 0.1 m	/
	Mean values (± σ)	**/**	**6 ± 4 m^2**	**4 ± 2**	**43 ± 14 cm**	**1.9 ± 0.4 m**	**1.7 ± 0.6 m**
Palaeolithic rockshelter/cave and open-air sites	Grotte Vaufrey, level VIII	90 m^2 (ex.)		2	?	~6 m	~2.5 m
	Grotte du Lazaret, level 5	38 m^2 (str.)	~9.5 m^2	2	~100 cm	~3.5 m	~0.9 m
	La Folie	207 m^2	~17 m^2	1	/	/	/
	OSCURUSCIUTO,SU 13	11 m^2 (ex.)	~5 m^2	10	24 ± 3 cm –80 cm	1.4 ± 0.2 m 2.4 ± 0.3 m	1.5 ± 0.1 m; 2.8 ± 0.7 m
	Tor Faraj, Floors I-III	67 m^2 (ex.)	~8 m^2	19	66 ± 20 cm	2.6 ± 1.2 m 3.9 ± 2.1 m	1.1 ± 0.43m; 3.1 ± 0.3 m
	Abric Romaní, Level N	75 m^2	~12 m^2	19	79 ± 20 cm (s)	~1.3 m (s)	0.6 ± 0.3 m (s)
	Molodova I, layer 4	42 m^2	~21 m^2	15	53 ± 12 cm –80 cm	1.5 ± 0.3 m	
	Abri Pataud, level 11	31 m^2 (ex.)	~5 m^2	7	77 ± 12 cm	1.2 ± 0.1 m 2.4 ± 0.3 m	1.5 ± 0.4 m;
	Abri Pataud, level 3	72 m^2 (ex.)	~10 m^2	5	93 ± 19 cm	1.9 ± 0.1 m 3.8 ± 0.1 m	1.4 ± 0.2 m
	Ohalo II, hut 1 – floor III	14 m^2	~8.6 m^2	1	~100 cm	/	1.5 m
	Mean values (± σ)	**63 ± 52 m^2**	**11 ± 5 m^2**	**10 ± 7**	**76 ± 29 cm**	**2.7 ± 1.4 m**	**1.4 ± 0.6 m**

Table 3: Sleeping areas analysis summary (ethno-archaeological and Palaeolithic samples).

Possible sleeping/resting areas in Palaeolithic contexts have been recorded. Two French caves, Grotte Vaufrey (Acheulean level VIII, 234 ± 45 ka BP) (Hernandez et al., 2014; Mellars, 1996; Rigaud and Geneste, 1988) and Grotte du Lazaret (archaic Mousterian level 5, ~130e150 ka BP) (Mellars, 1996), could be the most ancient sites in Europe. Other sites are framed in late Mousterian phase, both in open-air and rockshelter contexts. Among the open-air sites it is possible to cite La Folie, France, 57.7 ± 2.4 ka BP (Bourguignon et al., 2002, 2006; Clark, 2015) and Molodova I layer 4, Ukraine, > 44 ka BP (Gamble, 1986; Hayden, 2012). Mousterian sleeping areas in rockshelter sites are advised at Tor Faraj, floors I-III, Jordan, 55.1 ± 5.6 ka BP (Hayden, 2012; Henry, 1998, 2003; 2012; Henry et al., 2004) and Abric Romaní, levels M, N and O, Spain, ~55 ka BP (Gabucio et al., 2017; Hayden, 2012; Vallverdú et al., 2010). In the Upper Palaeolithic frame, sleeping areas are also mentioned at the Aurignacian level 11 of Abri Pataud (38.7 ± 0.3 cal ka BP) (Binford, 1983; Chiotti et al., 2003; Higham et al., 2011; Marquer et al., 2010), at the Gravettian level 3 of the same rockshelter (29.3 ± 0.7cal. ka BP) (Binford, 1983; Gamble, 1986; Marquer et al., 2010; Nespoulet, 2000) and at the Israeli hut 1 of Ohalo II (~23 ka BP) (Nadel et al., 2004).

In the abovementioned archaeological sample, the dimensions of possible sleeping areas appear comparable with the ethno- graphic analogy, as well as the hearth-to-hearth and hearth-to-rockshelter-wall distances. However, a significant difference is recognizable in the number of combustion structures (average 4 in ethnographical samples, 10 in the Palaeolithic sample, with wider intra-variability). This difference can be related in part to the palimpsest effect, suggesting that the higher number of hearths reflects an overlapping of several occupations. The actual number and size of the strictly contemporary sleeping fires and the spacing between them can vary in relation to several factors, such as the climate, the size of the shelter, the number of occupants, the number and arrangement of the beddings, the body posture of people, the lifespan of the occupation, and/or the palimpsest effect (Binford, 1983, 1986; 1987; Galanidou, 2000; Gamble, 1986; Gould, 1971; Hayden, 2012; Henry, 1998, 2012; Nicholson and Cane, 1991; Vallverdú et al., 2010) (Table 3; Tab. S4).

Although no evidence of vegetal beddings has been identified by the thin sections of the samples 171 and 172, the hypothesized sleeping/resting area of SU 13 corresponds with the inner sector of the shelter identified by cluster 3 of the Ward's Method. Limited to the excavated surface, it has an area of 3.7 m2 (this area becomes 5 m2 including the small stratigraphic baulk against the shelter wall). Nevertheless, it is not possible to define the actual surface of this activity area in its Southern edge due to the presence of a stratigraphic baulk. Moreover, its position corresponds partially with the small depressed zone against the shelter wall shown by cross-sections along the squares D11-F11 (Fig. S1; Fig. 7; Fig. 9). In the intact sediment samples from this area analysed by soil micromorphology, the contact of the weathered Mt Epomeo tephra (Fig. 5) and the overlaying deposit has been identified. No evidence of degraded fibrous plant material nor sediment compaction (i.e., platy microstructure) were observed. Therefore, there is currently no evidence of bedding made out of plant materials or intensive trampling in this area of the rockshelter. However, at least in sample 172, the absence of evidence related to lithic knapping, faunal/vegetal resources processing, and/or fire management seems to support the hypothesis that this corner of the rockshelter was used to rest. The scant presence of these activities in sample 171 could to be a product of the palimpsest effect.

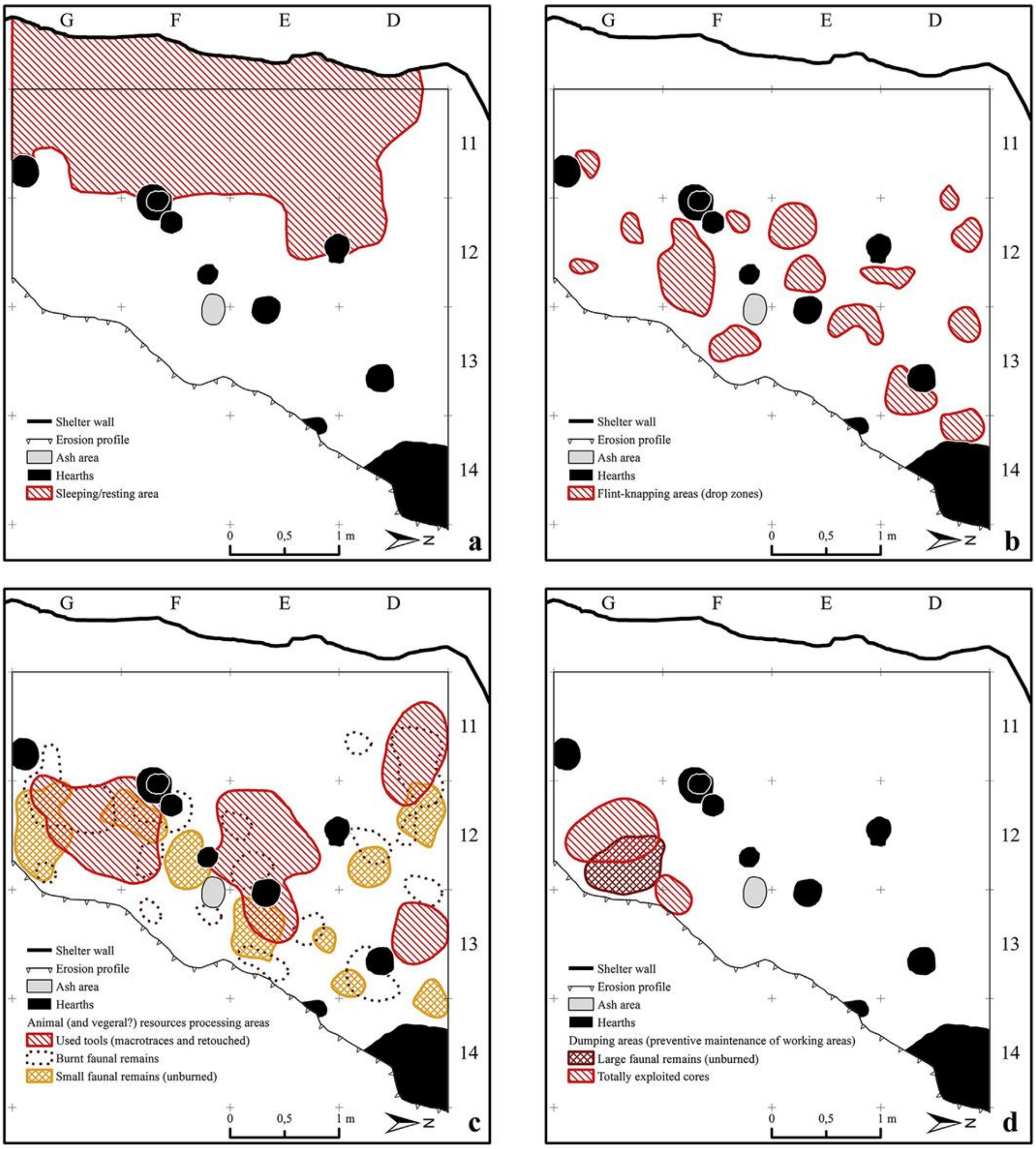

Fig. 9. Map of the hypothesized activity areas: a) sleeping/resting area; b) lithic knapping/tools maintenance; c) faunal resource processing/consuming and lithic tools use; d) working/living areas cleaning up/maintenance and refuse dumping.

Moreover, the presence of hearths and their spatial relations in the excavated area constitute a clear evidence of structuration of the living space by Neanderthal hunter-gatherers. Hearths in SU 13 (almost all circular/sub-circular and 20e30 cm wide) show modular and recurrent distances. Considering the hearth-to- rockshelter-wall distances, two main classes have been recog- nized: 1.5 ± 0.1 m (SU 77, SU 82, SU 83A-B, SU 84) and 2.8 ± 0.7 m (SU 12, SU 75, SU 76, SU 78, SU 80). Similar classes have been identified among the hearth-to-hearth distances (1.4 ± 0.2 m and 2.4 ± 0.3 m) (Fig. 2; Table 2). These data fit perfectly with the sleeping areas model, as inferred from the ethnoarchaeological sample. Nevertheless, at least in part, this evidence must be related to the palimpsest effect (Spagnolo et al., 2016), meaning that it is not possible to establish the true temporal relationship between the combustion structures. This limit derives also from the extent of excavation, which does not represent the entire Mousterian camp. From this point of view, the different state of preservation of hearths recorded by thin sections supports the palimpsest-effect hypothesis. Based on the lithic find and faunal remains density gradients and the Ring and Sector Analysis, the module of 1.5 m observed in the hearth-to-rockshelter-wall distances (moreover characterized by a lower standard error) can be argued to be attributable to the sleeping/resting area delimitation. Indeed, a robust spatial overlapping can be recognized among the sharp density variations and the aligned hearths closest to the shelter wall (Fig. 6).

With regard to hearth-to-hearth distances, it is not possible to establish any close temporal relationships between the hearths (i.e., if the “short module” or the “long module” has to be considered noise due to palimpsest effect). Based on the distances observed between the features with a similar state of preservations (and consequently with a possible temporal proximity), the features with no layer of preserved wood ash and those with a heavily reworked wood ash layer seem to be included in the “long module” (ca. 2.9 m). In other words, even if it were possible to hypothesize a relative temporal proximity between the hearths with a similar state of preservation (in this case spaced about 2.9 m), it is not possible to establish among them a very high temporal relation- ship. Indeed, the small size of the area enclosed in the shelter is a strong constraint factor that limits the features' allocation freedom, preventing a reliable inference of a possible “simultaneity” or strictly “contemporaneity” relationship among the combustion structures. Another factor that can contribute to a scant reading of temporal relations between the hearths derives from their mo- dality of use (single use vs multiple use). In this context, at least the best-preserved combustion structures (SU 75 and SU 78) and probably the SU 12 seem to be refuelled frequently with exiguous fuel loads, as suggested by thickness or by number of the laminae. The sectors identified by clusters 2, 4 and 5 (and by density maps and RSA) are configured as multi-purpose activity areas (or domestic areas). The RSA highlighted a significant recurrence of agglomeration of several categories of findings closely linked with hearths. Looking at the ring profiles, the hearth-side peaks can be considered accumulations produced by hearth-related activities, and the subsequent low-density-zones (occurring on average at 0.8 m far from the hearth centre or 0.7 m from the its border) can be considered the possible sitting/squatting areas of Neanderthals. Possible second peaks after the low-density-zones are considered noise because of the small size of the site (Fig. 6; Fig. S9; Fig. S8; Fig. S10).

The spatial arrangement of hearth-related activity areas is common in the ethno-archaeological literature (Bartram et al., 1991; Binford, 1983; Fisher and Strickland, 1991; O'Connell et al., 1991). Referring to the Middle Palaeolithic, this kind of spatial or- ganization of activities around a fire is widely documented. Some examples include the Spanish sites of Bolomor Cave (~150/121 ka BP) (San~udo Die, 2008), Abric del Pastor (~>75 ± 10 ka BP) (Machado et al., 2013; Vidal-Matutano et al., 2015), Abric Romaní (~70e40 ka BP) (Allue´ et al., 1993; Gabucio et al., 2014, 2017; Modolo and Rosell, 2017; Romagnoli and Vaquero, 2016; Rosell et al., 2012a, 2012b; San~udo et al., 2012; Vaquero and Pasto`, 2001; Vaquero et al., 2001, 2012a, 2012b, 2015), El Salt (52.3 ± 4.6 ka BP) (Vidal-Matutano, 2017), Abrigo de la Quebrada (~>50.8/ 43.93 ka BP) (Eixea et al., 2012, 2013; Villaverde et al., 2017), Roca dels Bous (~>47e38 ka BP) (Benito-Calvo et al., 2009; Martìnez- Moreno et al., 2004, 2016), and El Can~averal (~34e33 ka BP) (Ortiz Nieto-Ma´rquez and Baena Preysler, 2015, 2017). Similar ob- servations are advised at the French sites of Grotte XV/Grotte Vaufrey (234 ± 45 ka BP) (Hernandez et al., 2014; Rigaud and Simek, 1991) and La Folie (57.7 ± 2.4 ka BP) (Bourguignon et al., 2002, 2006; Clark, 2015). In Italy, hearth-related activity areas are documented at Riparo del Molare (MIS 5) (Boscato and Ronchitelli, 2008), Grotta Fumane (44.8e42.2 ka cal. BP) (Cremaschi et al., 2002; Peresani et al., 2011a, 2011b; Romandini, 2012), Riparo Bombrini (~44 ka BP) (Riel-

Salvatore et al., 2013), Grotta Reali (between 40.04 ± 0.59 ka and 36.62 ± 0.26 ka BP uncalibrated) (Lembo et al., 2012), Riparo L'Oscurusciuto (Boscato and Ronchitelli, 2008, 2017; Spagnolo, 2013, 2017; Spagnolo et al., 2016) and Grotta del Cavallo (~> 43 ka BP) (Fenu et al., 2002). Finally, in the Near East, sites include Kebara cave, Israel (60 ± 3.5 ka BP) (Speth and Tchernov, 2001; Speth et al., 2012), Tor Faraj, Jordan (55.1 ± 5.6 ka BP) (Henry, 1998, 2003; 2012; Henry et al., 2004) and Quneitra, Syria (~54 ka BP) (Oron and Goren-Inbar, 2014).

The multidisciplinary approach adopted for the study of SU 13 at the Oscurusciuto Rockshelter allowed a deeper recognition of the spatial organization of the Neanderthal camp, leading to more ac- curate identification of different kinds of activity areas. The spatial correlate of knapping activity is the drop zone (Binford, 1983). As shown by experimental flint-knapping (Aubry et al., 2008; Barton and Bergman, 1982; Behm, 1983; Bertran et al., 2015; Bowers et al., 1983; Brown, 2001; Hilton, 2003; Kvamme, 1997; Newcomer and Sieveking, 1980; Olausson, 2010; Stevenson, 1991) and well preserved Palaeolithic knapping areas (Austin et al., 1999; Cancellieri, 2015; Jones, 2008; Roebroeks, 1988; Vallin et al., 2001; Vaquero and Pasto`, 2001), the typical drop zones associated with an individual knapping session tend to be charac- teristically sub-circular areas, with diameters in the order of 50 cm, containing high concentrations of lithic flakes and debris (small flakes and indeterminate fragments). The last category constitutes the most representative part of the lithic assemblage associated with the production phase.

The taphonomic analysis of SU 13 at Oscurusciuto demonstrated a good state of the layer's preservation as well as the absence of a size-sorting effect among the lithic finds and faunal remains due to water-flow processes. It is therefore possible to assert that the small clusters of micro-debris identified by spatial analysis could be considered primary accumulations formed in several preferential areas as result of reiterate production and/or transformation of lithic artefacts (drop-zones). In essence, the spatial correspondence between the RMUs with a clustered pattern (1, 56, 137, 193, 283) and their actual drop-zones is confirmed by the relatively high presence of micro-debris attributable to the same RMU. On the other hand, as shown by geostatistical analysis, the evidence of random/scattered spatial patterns, both among the lithics larger than 50 mm2 and among several RMU, clearly suggests that tram- pling/scuffing processes produced a wider dispersion of larger lithics compared to the micro-debris (Spagnolo et al., 2016). In agreement with archaeological literature (Ahler, 1989; Andrewsky, 2004; Baumler and Davis, 2004; Benito-Calvo et al., 2011; Bertran et al., 2012; Bowers et al., 1983; Bradbury, 2007, 2011; Bradbury et al., 2011; Brown, 2001; Carr and Bradbury, 2004; Gifford- Gonzalez et al., 1985; Healan, 1995; Henry et al., 1976; Hilton, 2003; Knell, 2004; Kvamme, 1997; Larson, 2004; Lin et al., 2016; Maíllo Fernandez, 1998; Metcalfe and Heath, 1990; Nielsen, 1991; Patterson, 1982; Patterson and Sollberger, 1978; Rasic, 2004; Roebroeks, 1988; Root, 2004; Schiffer, 1983; Shott, 1994, 2004; Stevenson, 1985, 1991; Vaquero, 2012; Vaquero et al., 2012b), in the context of SU 13 of Oscurusciuto Rockshelter, the micro-debris should be considered the most reliable correlate for the identifi- cation of drop-zones. These drop zones, as shown by RSA and by hearth thin sections, tend to be related to hearths; however, the correlation of each knapping area with a specific hearth is not al- ways possible because of the size of the site. As shown by Ward's cluster analysis, the main drop zones are identified by cluster 5 and partially with clusters 2 and 4 (Fig. 7; Fig. 9).

The specialized areas for the processing/transformation of ani- mal and/or vegetal materials is inferred by the presence of clus- tered areas with lithic tools (both flakes with macro-traces and retouched), supported by the co-occurrence of high densities of faunal remains, possibly with evident cut-marks (Bartram et al., 1991; Binford, 1983; Keeley, 1991). A number of Middle Palaeolithic contexts can be identified where activity areas related with faunal resources processing/

consuming are documented, at some of the aforementioned sites (as Kebara Cave, Tor Faraj, Grotta di Fumane, Riparo Bombrini, Grotta Reali and Abric Romaní), at K˚ulna Cave, in the Czech Republic (~50 ka BP) (Neruda, 2017) and at the French sites of Grotte du Lazaret (~160 ka BP) (Valensi et al., 2013) and Hermies (~70e65 ka BP) (Vallin et al., 2001). At SU 13 of Oscurusciuto Rockshelter, several concentrations of small faunal remains have been found. The main accumulations, corresponding to cluster 2 and partially to cluster 5 (Ward's Method), are strictly associated with some com- bustion structures (SU 82, SU 83, SU 84, SU 80 and SU 78) and they may reflect areas of bone fracturing aimed at marrow extraction. The main concentrations of used tools, on the other hand, are not strictly related to those accumulations of small bones; a partial co-occurrence can be argued in the southern part of the excavated area. The pattern of used tools (primarily associated with the clusters 2, 4, and 5) seems more comparable to the pattern of burnt faunal remains. This evidence could suggest that activity related to some butchery phases of carcass portions (and/or with vegetal resources processing) and with meat cooking and consuming have taken place in these sectors, generically interpreted as “processing/ transformation areas” and strongly related to hearths. The corre- lation between meat-processing/consuming and hearths is other- wise suggested by highly recurrent presence of burnt bones in the ash layers of some hearths (Fig. 7; Fig. 9).

Along the SE edge of the excavated area, a particular concentration of finds has been highlighted both by Ward's cluster analysis (cluster 1 and, partially, cluster 2) and by density maps, as completely different with respect to other areas. This area corre- sponds with the maximum thickness band of the layer (Fig. S1) and is characterized by the co-occurrence of a massive concentration of cores and larger bones. In this sense, the difference between the cores' spatial pattern and their exploitation rate is remarkable. While the few cores with usable volume (interpreted as raw ma- terial reserves) are scattered in the northern part of the excavated area (in correspondence with knapping areas), the majority of cores are completely exploited (interpreted as waste) and clustered into a small area (well overlapped with the large bones cluster). In SU 13, this strong concentration of “waste” into a marginal area and its segregation from other activity areas suggests that possible main- tenance activities were carried out by Neanderthals (Fig. 7; Fig. 9). It can be argued that this kind of activity (cleaning of work areas and accumulation of elements in refuse areas) can be recognized through the presence of heterogenous “refuse” aggregates, con-sisting of production waste (as heavily exploited cores or large flakes) and/or large faunal remain (>6 cm) concentrations, possibly confined in marginal areas rather than in areas devoted to debitage, processing/consuming of food, and other social or individual ac- tivities (e. g. Bartram et al., 1991; Binford, 1983, 1987; Gargett and Hayden, 1991; O'Connell, 1987; O'Connell et al., 1991; Schiffer, 1972, 1983, 1987; Stevenson, 1991; Thomas et al., 1983:431e433; Vaquero, 2012).

Similar behaviours are reported in archaeological literature but appear quite scant in Neanderthal sites. At the Acheulean archae- ostratigraphic unit 25 of Grotte du Lazaret (France, ~160 ka BP), where a well-defined spatial organization of activity areas has been found, several segregated large circular heaps made of a very abundant food waste have been interpreted as working space maintenance and cleaning. Also in this site, slaughtering activity areas are characterized by higher density of small-size faunal re- mains (contrasting with the larger dimensions and the higher density of findings in the heaps), also associated with lithic tools. The relationship between these different functional areas is also emphasised by bone refittings (Valensi et al., 2013). At several levels of Abric Romaní (Spain, 70e40 ka BP), possible floor cleaning behaviour was observed based on both the faunal remains and lithic finds spatial analysis, attributable to different strategies. The first strategy is based on the distinction between the inner area of the rockshelter (devoted to domestic activities, as flint-knapping, food processing and consuming) and the outer area (that exhibits scatters and accumulations of refuse). This dichotomy is consistent with the exogenous cave model, specifically elaborated for caves and shelters by Thomas (1983:431e433) on the drop zone/toss zone model of Binford (1978b, 1983). The main indicator of this behaviour is an evident size-sorting of finds not related with natural tractive processes, where the largest pieces tend to be tossed into the outer area from inner activity areas. In this case the largest pieces are relatively more scattered than the smallest ones, which are more tightly clustered. A second strategy can involve an intentional transport of refuse from the activity areas(s) to a dumping area, in agreement with the Binford's (1978b, 1983) preventive maintenance model. The product of this behaviour is a dump characterized by bigger wastes (in relation with the activity areas) and/or unex- pected evidences, as high percentages of burnt elements in areas without fireplaces. Finally, the presence of hearths in the camp suggests the disposal of organic residues by fire, probably in order to avoid unpleasant smell that might attract other predators (e. g. Gabucio et al., 2014, 2017; Martínez et al., 2005; San~udo et al., 2012; Vaquero et al., 2001, 2012b, 2015). At occupation X of Kebara Cave (Israel, 60 ± 3.5 ka BP), a similar dichotomy was identified between a central “domestic zone” on the one hand and the presence of several “pit-structures” and a peripheral midden or disposal zone on the other. The floor cleaning behaviour has been suggested ac- cording to their different content in terms of faunal remains and lithic finds. In the “domestic zone”, the presence of small-sized bones with very abundant microscopic-scale fragments is notable, suggesting that activities related with bone fracturing were carried out there. In the dumping area, instead, a higher density of large bones and large-sized lithic wastes (as cores and cortical and management flakes) was observed. Based on these signals, periodical deliberate tossing/sweeping away of the larger waste from the working areas to the dumping area has been inferred. Moreover, this reading may suggest the presence of “pit- structures”, interpreted as possible trash-filled pits (Speth and Tchernov, 2001; Speth et al., 2012). A possible dumping zone, finally, was described at Tor Faraj (Jordan, 55.1 ± 5.6 ka BP), in the external part of the rockshelter. Here, parameters adopted to identify this as a refuse area (inferencing living areas maintenance behaviours) include the relative absence of small debris, the pres- ence of mixed lithic production waste (mostly large in size), the scarce presence of tools, the presence of fire-altered pieces and absence of hearths. Moreover, a large amount of woody plant phytoliths, in correspondence with this area (along the rockfall), were interpreted as a brush windbreak/fuel depot (Henry, 2003, 2012; Henry et al., 2004).

The scarcity of attestations of living area cleaning behaviours in Eurasian Middle Palaeolithic contexts may be linked on the one hand to difficulties in identifying unequivocal evidence (e. g., distinguish a secondary accumulation due to dumping/sweeping away behaviour from a secondary accumulation formed by tram- pling, palimpsest effect and/or other natural or unintentional pro- cesses, in particular in presence of long-lasting palimpsests). On the other hand, the same settlement strategies adopted by Neander- thals (including mobility strategy, time-span of the occupations, site typology) can help make such evidence less readable or absent in the archaeological record. It was argued, for instance, that the occurrence probability of cleaning behaviours is lower in the short-term occupations than in the long-term ones. Thus, traces of pre- ventative maintenance of the activity areas in a Palaeolithic site, together with other data, can be a useful tool to infer settlement strategies and camp function (Bartram et al., 1991; Binford, 1983; O'Connell, 1987; Stevenson, 1991; Vaquero, 2012; Vaquero et al.,

2015).

6. Conclusion

In the frame of Late Mousterian of Italy, the Oscurusciuto Rockshelter represents a very important deposit. The wide array of cultural adaptation (in terms of lithic production systems, faunal resources exploitation, and spatial organization of the camps) of the Neanderthal groups that occupied the site constitutes a wealth of data with the potential to shed light on Neanderthal settlement strategies in Southern Italy.

In the stratigraphic sequence, SU 13 represents the first stable re-occupation of the site after the deposition of the almost sterile tephra layer (SU 14). This peculiar stratigraphic position, the limited thickness of SU 13, and its temporal meaning as a “short palimp- sest” contribute to the unit's high informative potential. This short palimpsest allows the focalizing of a limited “event” in the occupation history of the deposit.

Spatial analysis of SU 13 allowed for the identification of different activity areas. At a macroscopic scale, a strong dichotomy in the settled area management is made evident by the overlapping between the sharp density gradients of finds and the hearths' alignment. A possible sleeping area (characterized by a low fre- quency of finds) is located against the Rockshelter wall and bordered by an alignment of regular-spaced small hearths. This constitutes an interesting finding, since there are few such reports in the Palaeolithic literature due to the ephemeral nature of sleeping/resting areas. The presence of a sleeping area in the Oscurusciuto Rockshelter is intriguing, since it allows estimation of the possible demographic size of the Neanderthal group (perhaps relatively small) that occupied the site. Curiously, however, most of the Palaeolithic comparisons fall into the Mousterian framework (mostly in MIS 3).

From a behavioural point of view, as attested by ethno- archaeological and Palaeolithic examples, hearths constitute the focus of different kinds of activities. The SU 13 record allowed the recognition of several hearth-related activity areas, located in the “outer part” of the Rockshelter. Based on the lithic and faunal re- mains analysis, two types of economic activities have been identi- fied: lithic knapping and faunal resource processing/consuming. Evidence for lithic knapping in situ is demonstrated by the presence of micro-debris accumulations. As part of faunal resource exploi- tation, the carcass processing phases attested at the site suggest breaking of bones aimed at marrow extraction and meat cooking/ consuming. Both these activities are associated with hearths, as testified by small burnt and unburned bone distribution. The presence of lithic tools around the hearths suggests possible butchery or other activities. As of yet, the taphonomic analysis of the faunal sample has not been performed, due to the carbonate concretion that covers the bones. The spatial study of the lithic tools analysed by the techno-functional and use-wear analysis (Marciani et al., 2018, in press) is in progress and could provide specifications regarding the type of activity performed with these objects. Finally, the presence of a “refuse” aggregate (consisting of lithic production waste, almost all the completely exploited cores and the largest bones) segregated into a “marginal” area (with respect to other activity areas) was identified. This evidence can be read as a dumping area produced by preventive maintenance behaviour (i.e. sweeping away/cleaning of the working floors and dumping/ accumulation of refuses in specifically dedicated and segregated areas). This constitutes an exceptionally important discovery, both to address the near absence of attestations of this kind of behaviour in the Neanderthal settlements, and for interpretive consequences related to the Neanderthal settlement strategies.

The redundancy of several spatial patterns and the palimpsest dissection support the hypothesis of the formation of SU 13 by one hunter group, as previously suggested (Spagnolo et al., 2016). The evidence of an articulated management strategy of the camp (with spatially segregated activity areas organized into three functional sectors, at least, as suggested by spatial and cluster analysis) sug- gests a complex behaviour, and not an “opportunistic” or “auto- matic” management of sites. Moreover, the presence of living area maintenance may offer clues to explain the time-span of the occupation, since this kind of behaviour usually appears associated with relatively long-term camping. The evidence of a complex structuring of the site, constitutes a new important tile in the reconstruction of Neandertal behavioural mosaic. The similarity of some Neandertal sites settlement strategies with the ones observed in “modern” contexts, indeed, requires a reconsideration on the very parameters that are conventionally used to distinguish be- tween “Neandertal” and “modern human” behaviour. The Nean- dertal hunter-gatherers adopted complex and variegated settlement strategies, showing not only good adaptations to a wide range of environments, but also different cultural expressions. This complexity, well mirrored also in the camp structuring identified in the SU 13 of the Oscurusciuto Rock shelter, emerges in the recent studies of different Mousterian sites. The concept of behaviour, applied to Palaeolithic societies, derives from the global set of in- formation retrieved from the archaeological record, which, by its very nature, is strongly residual and ambiguous. The problem of the “archaeological visibility” of the Neandertal behaviour can only be approached through a contextual perspective, observing the Ne- andertals “in their own terms”.

This study provides significant contributions to the knowledge of the social and economic organization of the last Neanderthals in Southern Italy. Thanks to the integrated method adopted and the combination of the hearths' micromorphology, lithic technology, zooarchaeology, and spatial analysis of SU 13, different kinds of activity areas have been identified. These results emphasise the importance of high resolution temporal studies of the other levels of the site with a multidisciplinary approach. The protocol and approach used successfully for SU 13 Mousterian levels at Oscu- rusciuto rockshelter, can be developed into a broader research project on the Neandertal settlement patterns (Spagnolo, 2017), can represent a model for further studies aimed at high-resolution reconstruction of the spatial behaviour of Palaeolithic hunter- gatherers.

Author contribution

Annamaria Ronchitelli is the research coordinator along with Paolo Boscato and Francesco Boschin, who carried out the archae- ozoological study. The study of the lithic industry was realized by Giulia Marciani in collaboration with Daniele Aureli. The micro- archaeology study on the hearths was made by Francesco Berna with the support of Ginevra Toniello and Fernando Astudillo. The spatial analyses were realized by Vincenzo Spagnolo. All the au- thors collaborated in the editing of this paper.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.quascirev.2018.06.024.

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