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Climbing the time to see Neanderthal behaviour's continuity and discontinuity: SU 11 of the Oscurusciuto Rockshelter (Ginosa, Southern Italy)

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Abstract: The Oscurusciuto Rockshelter (Ginosa, Southern Italy) is a perfect sample-site for the reconstruction of multiple aspects of the last Neanderthals life. Different settlement strategies are attested in the excavated portion of the stratigraphic sequence, dated between ~ 55 and 43 ka BP. As a first goal, the reconstruction of the site spatial organization across the palimpsest SU 11 was achieved by a high-temporal-resolution approach (assisted by sedimentological analysis), integrating lithic technology, zooarchaeology and spatial analysis (by means of the GIS technology). As a second goal, a diachronic perspective was adopted by comparing results from SU 11 with the previously studied evidence from the underlying SU 13. Results were processed at a diachronic scale, highlighting similarities and differences related both to the type of activities carried out at the site and to their spatial management. This allowed us to recognize discontinuities and, especially, continuities of settlement dynamics, which can be related to phenomena of cultural transmission hinting to a "memory of places". Such results stimulate the debate not only on the necessity to study Middle Palaeolithic contexts at different temporal scales but also on the necessity to develop more refined multidisciplinary analytical protocols. The study of settlement dynamics at high-resolution scales allows to take advantage of the potentialities of contextual analysis i.e. the integration of results from different disciplines and data from the whole range of archaeological evidence in order to reconstruct solid behavioural models.

Keywords: Neanderthal behaviour . Settlement dynamics . Palimpsest . Lithic technology . Zooarchaeology . GIS

Introduction

The rich cultural legacy of Neanderthal, found in the Mousterian sequences of Eurasia, appears to be inexorably constrained in a kind of "Neanderthal Paradox": Neanderthals seem to be condemned to represent the shadow of Modern Humans (MH), in the form of a perfect alter ego, deprived of their own identity. This paradox is particularly evident when the crucial issue of the Neanderthal demise and of their replacement by MH is taken into account. Sometimes, the explanatory hy- potheses imply a preconceived idea of "modernity", which con- stitutes the borderline between the "Neanderthal behaviour" and the "Modern behaviour", implicitly creating the dichotomy "archaic" vs "modern" (Mellars and Stringer 1989; Mcbrearty and Brooks 2000). This approach, de facto, flattens the actual variety of the Neanderthal and MH cultural expressions to ide- alized concepts, where the Neanderthal (but also MH) becomes a mere imperfect replica of the idealized icon of the MH, im- plying a significant loss of past cultural diversity. A complex issue as human behaviour (or the reconstruction of Palaeolithic societies) cannot be inferred through wide-ranging generaliza- tions, i.e. the occurrence of a single evidence with an assump- tive symbolic meaning in the archaeological record (which by its nature is residual), without a contextual and multifocal anal- ysis of the whole range of data. In the scientific debate, the authentic meaning of the "Neanderthal behaviours" vs the "MH behaviours" and the evaluation of the actual reliability of these concepts represent a significant epistemological gap. The need for an in-depth knowledge of the "Neanderthal be- haviour" implies a Neanderthal re-evaluation in its own terms. In other words, a multidisciplinary, integrated and contextual approach is essential to recognize which diagnostic parameters can be used to isolate the range of behavioural diversity expressed by Neanderthals.

The current scientific research has achieved very high stan- dards, not only thanks to the development of cutting-edge ana- lytical tools and protocols but also thanks to an increasingly multidisciplinary approach and to the integration of results, which allow gaining a multifocal perspective. As a conse- quence, a real comprehensive approach to the study of the be- havioural variety of the Mousterian appears to be emerging in scientific praxis. However, a consolidation phase of the theo- retical and practical approaches is still needed. Spatial Archaeology (Clarke 1977), in this sense, constitutes the natural terrain in which the best convergence between multifocal per- spective, contextual archaeology (e.g. Carr 1991; Hodder and Hutson 2003) and behavioural approach (e.g. Leroi-Gourhan 1964; Newell 1987; Schiffer 1972, 1975a, 1975b) can be expressed. This pivotal role of Spatial Archaeology derives not only from the scientific background of the discipline and its multidisciplinary nature but also from the outstanding devel- opment of the GIS technology, to date perfectly integrated with the DataBase Management System and accurate 3D models (e.g. Conolly and Lake 2006; Dell'Unto 2014). Contextual and multivariate analysis, typical of the spatial approach, allow to frame data coming from different disciplines, endowing it with an increased epistemological value. However, the exact- ness of results is strictly linked both to the problem of archaeological visibility and to the need of a correct use of data. For this purpose, proper analytical procedures and, primarily, a concrete workflow (involving a taphonomic step, preventively to the "spatial-functional" one) are required. A contextual and spatial approach can, thus, help to formulate a more comprehensive and multi-scalar reconstruction of the Palaeolithic hunt- er-gatherers' economies, societies and behaviours.

A large sample of Neanderthal sites in Europe and the Near East has the potentialities to disclose high-resolution chronicles, in presence of good preservation of the contexts and of stratigraphic characteristics such as living-floors, other kind of short-term palimpsest and/or dissected palimpsests (e.g. Angelucci et al. 2018; Bargalló et al. 2016; Bataille 2006; Carrión and Walker 2019; Chacón et al. 2015; Clark 2015, 2017; Depaepe 2004; Fenu et al. 2002; Folgado and Brenet 2010; Gabucio et al. 2014, 2018; García-Moreno et al. 2016; Hayden 2012; Henry 2012; Jaubert et al. 2016; Leierer at al. 2019; Lembo et al. 2012; Machado and Pérez 2016; Machado et al. 2013, 2019; Martínez-Moreno et al. 2016; Mellars 1996; Modolo and Rosell 2017; Moreau and Locht 2017; Moroni et al. 2019; Neruda 2017; Ortiz Nieto-Márquez and Baena Preysler 2017; Peresani et al. 2011; Peretto et al. 2004; Plavšić 2015; Real et al. 2018; Romagnoli and Vaquero 2016; Ronchitelli et al. 2011; Sañudo et al. 2012, 2016; Spagnolo 2017; Speth and Tchernov 2001; Speth et al. 2012; Valensi et al. 2013; Vallverdú et al. 2010; Vaquero 2008; Vaquero et al. 2012; Wiśniewski et al. 2013, 2019). Nevertheless, only some of them are studied with a multidisciplinary and spatial approach. These sites are characterized by different chronological, geomorphological, paleoclimatic and contextual conditions. This means that a wide range of data can be collected on the diversity of Neanderthal behav- iour and adaptations. Prospectively, this can represent a new opportunity to compare Neanderthals and MH from a neutral viewpoint.

From this standpoint, the Oscurusciuto Rockshelter (Southern Italy) is a perfect sample-site. As the first point, the richness of its stratigraphic sequence and the differences and similarities in the macroscopic organizational patterns within each anthropogenic layer (e.g. Boscato and Ronchitelli 2017) allow pioneering studies to be carried out. As second point, the excavated part of the stratigraphic sequence of the site falls in the crucial phase between 55 and 40 ka BP, when the Neanderthal demise and the demographic replacement by MH occurred. In this period, the Italian peninsula was characterized by the presence of both Mousterian and Uluzzian techno-complexes. Moreover, the Oscurusciuto Rockshelter is located in a crossroad between two agglomerations of MIS 3 Palaeolithic sites: the cluster of Salento at South-East (e.g. Grotta del Cavallo, Grotta di Uluzzo C, Grotta di Uluzzo, Grotta di Serra Cicora A, Grotta Mario Bernardini and Grotta Romanelli), the group of Campanian sites at West (Grotta di Castelcivita, Riparo del Poggio and Grotta della Cala). The Mousterian of this area is characterized by a predominance of Levallois debitage used in a variety of methods. That is to say, at Oscurusciuto (Marciani et al. 2016, 2018; Ranaldo 2017; Marciani 2018), Poggio (Caramia and Gambassini 2006; Boscato et al. 2009), and Castelcivita (Gambassini 1997) the Levallois was utilized in recurrent unipolar and convergent modalities which, at the end of the reduction sequence, usually switched to a centripetal or preferential mode. At Romanelli, the Levallois sequence follows two dominant modalities: the centripetal and the unidirectional. At Bernardini and Uluzzo C (Spinapolice 2018), the recurrent centripetal Levallois predom- inates. These productions were aimed at producing both flakes, points and blades. The production of blades is found at Poggio (Caramia and Gambassini 2006), Castelcivita (Gambassini 1997), Oscurusciuto (Ranaldo 2017; Marciani 2018), Cavallo and Bernardini (Carmignani 2011). The discoid debitage is documented at Cavallo SU FII-FIIIa (Carmignani 2011) and Bernardini B1 (Carmignani 2011). At Oscurusciuto SUs 1–4 (Ranaldo 2017), Cavallo FIIIe-FIIIb (Carmignani 2010, 2011) and Bernardini B3 (Carmignani 2011) is also documented a unipolar volumetric debitage aiming at producing blades and sporadically bladelets; the latter are notably represented at Oscurusciuto SUs 11–15 (Marciani et al. 2016; Marciani 2018) and Cavallo (Carmignani 2010). A systematic produc- tion of scrapers, mostly side-scrapers is attested. In the same area, the Uluzzian techno-complex occurs in the Uluzzo Bay (Uluzzo C, Uluzzo, Serra Cicora, Bernardini) especially at Cavallo where it was defined (Palma di Cesnola 1964, 2004), at Castelcivita and Cala where it is also followed by the Protoaurignacian which seems to be absent in the region of Salento. From the technical point of view, the Uluzzian marks a sharp break with the former and partially coeval Mousterian techno-complex. At Uluzzo C (study ongoing), Cavallo (Moroni et al. 2013, 2018), Castelcivita (Gambassini 1997; study ongoing), Cala (De Stefani et al.

2012) the Levallois which has dominated the Mousterian in all its forms is absent, whereas the production is dominated by a unipolar volumetric debitage with a slight or none management of the striking plat- forms and lateral and distal convexities. There is a dominant use of the bipolar technique on anvil and flakes and blades of min- imal dimensions as primary objectives of debitage (Moroni et al. 2013, 2018; Marciani et al. 2019). The lunates, followed by end-scrapers, are the new retouched tools which characterize the Uluzzian. Such tools are very abundant at Cavallo during the evolved phase EII-I (Moroni et al. 2013, 2018; Sano et al. 2019) and less represented in the other Uluzzian sites Uluzzo C, Castelcivita, Cala.

The purpose of this work is to understand the spatial orga- nization of a sequence of Mousterian camp-sites recorded in the Stratigraphic Unit 11 of the Oscurusciuto Rockshelter and to compare results with the evidence from the underlying and already studied SU 13 (Marciani 2018; Marciani et al. 2016, 2018; Spagnolo 2017; Spagnolo et al. 2016, 2019), in order to gain a diachronic overview on the evolution of settlements dynamics within these palimpsests. The archaeological re- mains coming from the SU 11 were studied from a multidis- ciplinary and integrated perspective, with a behavioural ap- proach. More specifically, data coming from lithic finds (di- mensional classes and technology) and faunal remains (di- mensional classes and burned/unburned state) were analysed with statistical and geostatistical methods, also in relation to the presence and position of several hearths. Finally, a high- temporal-resolution and diachronic perspective were applied in order to follow the evolution of the camp-sites in the SUs 13-11 sequence, integrated to the sedimentological analysis of this sequence. This has made it possible to gain a deeper perspective on the historical processes that shaped the struc- ture of a Mousterian site at about 55 ka BP.

The site and the SU 11

The Oscurusciuto Rockshelter is located on the hydrological right of the ravine of Ginosa (Southern Italy), about 20 km NW from the current Ionian coast, opening in a friable Pleistocene calcarenite (Fig. 1a). Research have been ongoing since 1998 by the Research Unit Prehistory and Anthropology of the University of Siena (Department of Physical Sciences, Earth and Environment). The stratigraphic sequence extends down- wards (reaching about 60 m2 at the base) and is about 6 m deep. The excavated part of the deposit (SUs 1–15), about 3 m deep, is attributable to the final stage of the Middle Palaeolithic (Fig. 1b). This is shown by available dates deriving from the tephra SU 14 (identified with the Mt. Epomeo Green Tuff of Ischia, of about 55 ka BP) and by a 14C date of a burned bone from the base of the SU 1 (38.5 ± 0.9 ka BP e AMS, Beta-181165; cal. 42.724 ± 0.716 ka BP) (Higham et al. 2014).

The excavated portion of SU 11 (about 11 m2) is delimited to N, S and W by stratigraphic baulks, to E by an erosional line. It is a massive sandy Unit. Vertical gradients of the an- thropogenic signals are detected in SU 11. In particular, a 2– 3 cm thick sediment, locally characterized by a rarefaction or absence of anthropogenic evidence, was discontinuously in- terposed between the upper and the lower part of the layer, both rich in hearths and finds (Fig. S1). The boundary between SUs 11 and 13 is abrupt, due to their different sedimentolog- ical composition (SU 13 is a mixture of tephra and sandy sediment). The thickness of SU 11 is not homogeneous (Fig. S1), ranging between ~ 10–13 cm (in the northern part of the excavated area, subdivided into two spits) and ~ 20 cm (in the southern part of the excavated area, subdivided into three spits). Many hearths (made in sub-circular shallow pits with a flat bottom and a “bowl” shape section) and ash/charcoal patches were found in SU 11. The hearths differ in size: the smaller ones have an average diameter of about 25 cm, where- as that is 50 cm in the larger ones. To this regard, it seems comparatively interesting that among the ten hearths present in SU 13, only one corresponds to the larger size module of SU 11, while the other ones have a median diameter of 24 cm (Boscato and Ronchitelli 2017). Schematically, in the lower spits (SU 11/2 and 11/3) only small hearths were present (SUs 53A1, 53A2, 56, 61, 62, 63, 64, 65, 66, 68, 69, 70, 71, 72, 73), while in the upper spit (SU 11/1) both small (SUs 46, 49, 51, 59, 60, 67) and large (SUs 10, 44, 45, 47, 48, 50, 52, 53, 54, 55, 57, 58) hearths were recorded (Figs. 2, 3; Table S1).

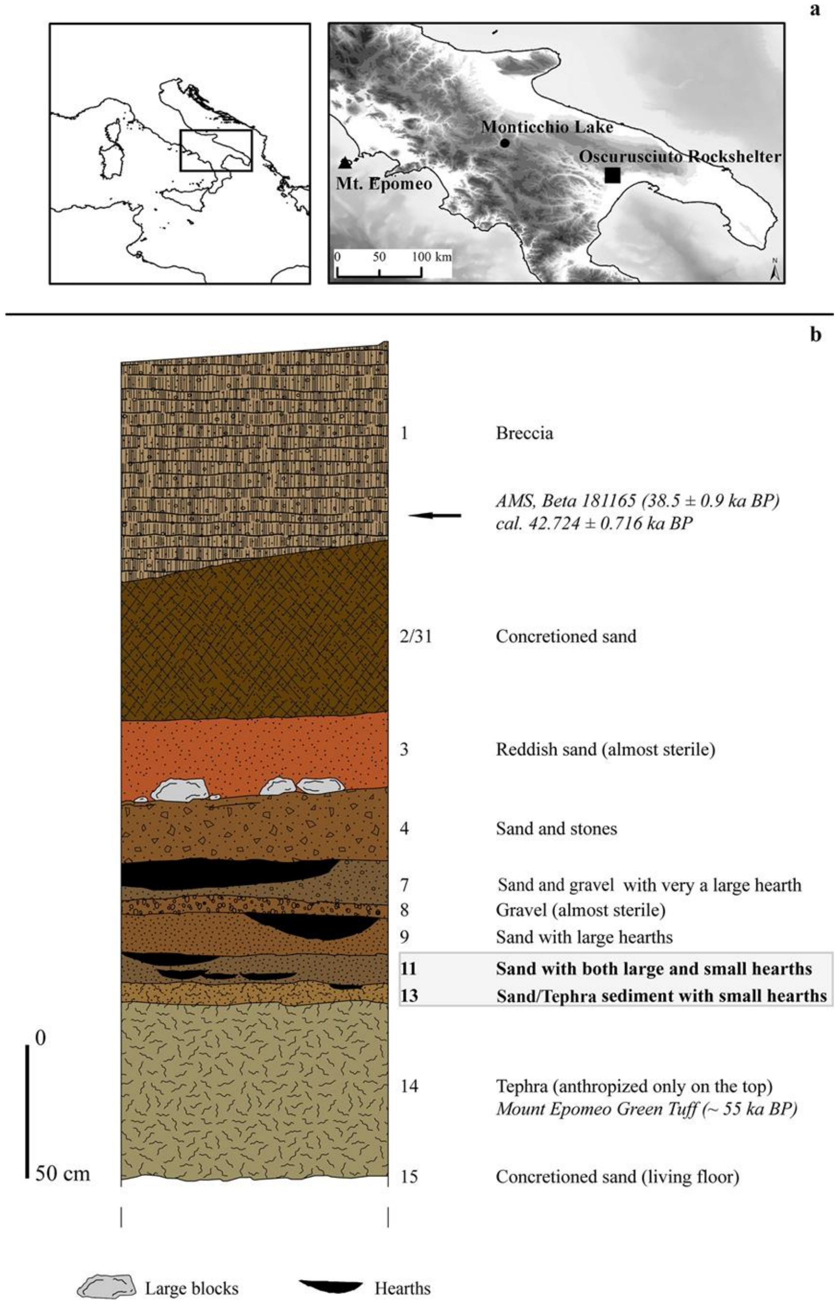

Fig. 1 Localization of the site (a); stratigraphic scheme of the currently excavated units

Material and methods

The approach applied in the study of SU 11 is mostly the same successfully tested for SU 13 (Marciani 2018; Marciani et al. 2016, 2018; Spagnolo 2017; Spagnolo et al. 2016, 2019), enriched by a diachronic perspective on the settlement dynamics.

Sedimentological analysis of SUs 13–11

The clastic sequence is investigated with bed-by-bed sedimento- logical logging and architecture line-drawings. The descriptive sedimentological terminology used is from Collinson et al. (2006), integrated with specific concepts for cave/shelter clastic sediments from Karkanas et al. (2007) and Martini (2011).

Palimpsest dissection of SU 11

Preliminarily to the study of materials, a dissecting of the SU 11 palimpsest was attempted, in order to gain a higher tempo- ral resolution for the reconstruction of the settlement dynam- ics. Differently, from SU 13 (a short-term palimpsest), SU 11 represents a long-term palimpsest. This fundamental differ- ence significantly affects the archaeological visibility of these sample layers: this was taken into account in order to calibrate the analytical process.

As the possible presence of two sublayers in SU 11 is sug- gested by excavation report ("The site and the SU 11"), the palimpsest dissection was carried out, in order to corroborate this subdivision and to verify the correlation between actual sublayers and excavation spits (made following, when possible, the vertical gradients of materials). For this purpose, the recog- nition of possible hiatuses between archaeo-stratigraphic sub- units was performed by items recovered with cartesian coordi- nates (both lithics and faunal remains), then the goodness of the association between excavation spits and actual archaeo- stratigraphic sub-units was statistically evaluated.

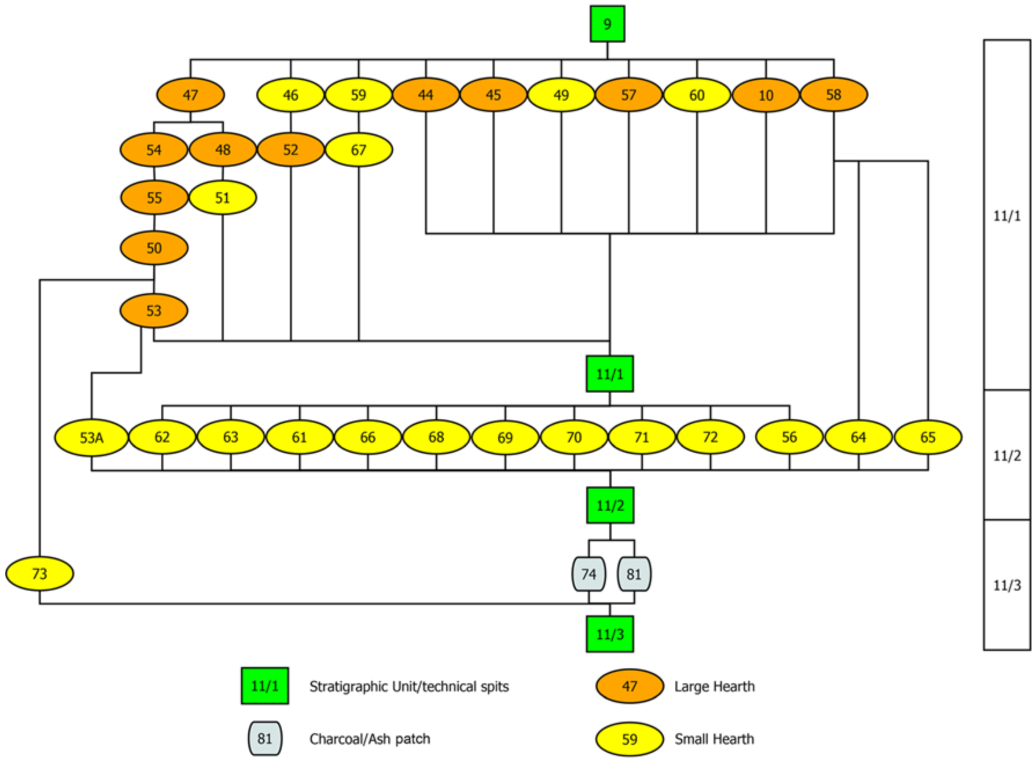

Fig. 2 Matrix of the stratigraphic relations among the hearths and charcoal/ash patches in Unit 11, with reference to their relative dimensional class

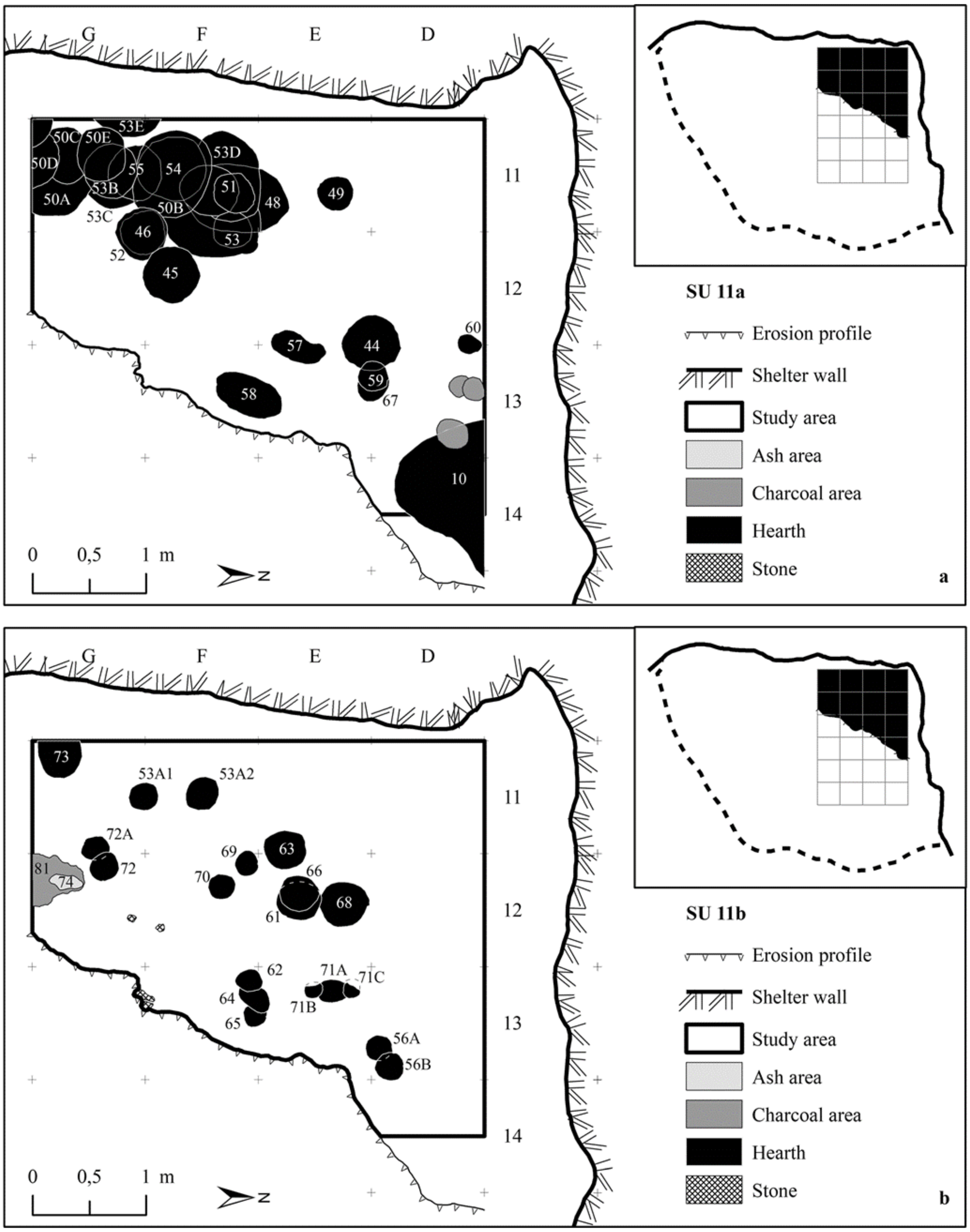

Fig. 3 General planimetries of SU 11, with relative distribution of the hearths in the upper (a) and in lower (b) parts of the unit

More specifically, in the SU 11, 1302 items were recovered with their cartesian coordinates (950 lithic finds and 352 faunal remains). These plotted pieces constitute a significant sam- ple to test the occurrence of hiatuses in the vertical distribution of archaeological finds (e.g. Adler et al. 2003; Anderson et al. 2018; Baena Preysler and Torres Navas 2019; Bargalló et al. 2016; Bunn et al. 1980; Canals et al. 2003; Chadelle 2000; Diez-Martín et al. 2014, 2017; Gravina et al. 2018; López-Ortega et al. 2017; Machado et al. 2013, 2019; Martínez- Moreno et al. 2004, 2010, 2016, Martínez-Moreno et al. 2019; Mora et al. 2018; Real et al. 2018; Sánchez-Romero et al. 2017; Sañudo et al.

2016; Vaquero 2008; Vaquero et al. 2015). The plotted finds, despite their relative high num- ber, do not constitute a dense enough cloud of points suitable to perform the vertical profiles analysis along 25 or 20 cm wide transects. Therefore, 50 cm wide transects were taken into account for this analysis, both with N-S (YZ axes) and W- E (XZ axes) orientation, covering the excavated area.

The internal coherence of the identified sub-units was tested in order to reduce the subjectivity of archaeo-stratigraphic inter- pretation, growing the overall reliability of the palimpsest dissec- tion. The analysis of the vertical distribution of plotted items was performed by frequency histograms (e.g. Brantingham et al. 2007; Canals et al. 2003; Chadelle 2000; Mackay et al. 2014; Surovell et al. 2005). The Y-axis of these histograms, reporting the elevation data, was set on bins' interval of 2 cm to magnify the reading of the distribution trends of findings. The histograms were systematically analysed for each 50 × 50 cm sector of the excavation grid in order to avoid the noise effect deriving from the slope bearing of the layers. A minor slope-related variance of elevation values (and then of overlapping noise), indeed, is ex- pected in the smaller spatial sample-unit than in the larger ones. The observed frequency distributions (e.g. continuous, bimodal, multimodal) were used to refine the identification of possible hiatuses in the vertical projections of plotted items and to report them in the extract of the SU 11 profiles.

A Pearson correlation was performed to verify the as- sociation between excavation spits and archaeo- stratigraphic sub-units. Specifically, as first step, a reli- ability value for the archaeo-stratigraphic sub-units recog- nition was assigned to each 50 × 50 cm sector, based on the abovementioned vertical frequency distributions pat- terns. The reliability of sectors with clear bimodal distri- butions was considered "good", the one with multimodal or weakly bimodal distributions was considered "weak" and the one with continuous distribution was considered "bad". The last ones were excluded from the statistical test. Then, the Pearson correlation test was run comparing the distribution of findings by spits and sub-units.

Zooarchaeological analysis of SU 11

The faunal remains were identified using the osteological ref- erence collection at the University of Siena. Only fragmenta- tion rate, dimensional classes (1–3 cm, 3–6 cm, 6–10 cm, > 10 cm) and the burned/unburned state were considered for spatial analysis. No other taphonomic analyses were possible, due to the presence of a carbonate concretion layer on the surface of most of the bones.

Lithic technology analysis of SU 11

A technological analysis was carried out to gain comprehen- sive and comparable data regarding all the phases of lithic reduction sequences (Geneste 2010; Inizan et al. 1995; Pelegrin et al. 1988; Perlès 1991). To achieve this aim, every item was analysed separately i.e. all its features were regis- tered in an Access® database specifically set up to suit the peculiarities of the collection in question (for specification of the collected traits Marciani 2018). The technological analysis included the identification of the lithic raw material consider- ing its nature (pebble, slab, block), granulometry (fine, coarse) and type (chert, jasper, siliceous limestone, limestone and quartz sandstone). The presence and type of post- depositional alteration (chemical, mechanical or thermal) were evaluated.

Four technological classes were considered: flakes, cores, pebbles, debris (including fragmented un-orientable pieces, altered pieces and entire management flakes smaller than 150 mm2). Then a qualitative analysis of cores and flakes was performed to understand the volumetric concepts, dynam- ics and objectives of the debitage (Boëda 2013). For the com- plete flakes, the amount and localization of the cortex, the morphology, symmetry, profile and section shape, the number and orientation of dorsal scars, the type of butt and bulb and the position of the impact point were registered. Based on these technical features, the concept of debitage of the flakes was identified. Lastly, occurrences, type and localization of retouch were registered. For each core, the nature and shape of the raw block, its volumetric concept, the hierarchy of sur- faces, the type, location and kind of preparation of the striking platform, the number and direction of the negatives on the debitage surface and the possible reason for its abandonment were observed.

To integrate the technological data with the spatial analysis some lithic traits were selected, which are significant to infer a spatial behaviour, following Spagnolo et al. (2019). These cat- egories include micro-debris, cores (with the relative state of exploitation) and “tools”. The micro-debris is a sub-category of the technological class “debris” (including fragmented un- orientable pieces, altered pieces and entire flakes) defined by dimensional criterion. More specifically, all lithic artefacts were subdivided according to five Dimensional Classes (DC 1, 1–50 mm2; DC 2, 50–100 mm2; DC 3, 100–150 mm2; DC 4, 150–200 mm2; DC 5, > 200 mm2). The micro- debris represents the fraction of the debris included in the smallest Dimensional Class (put another way the produc- tion waste in DC 1, 1–50 mm2). The state of exploitation of the cores permits to classify cores according to the volume that remains to exploit, thus according to the concept of debitage present at the site (mostly Levallois and additional debitage) the initial, medial or final volume were consid- ered. Also, a macro class labelled as “tools” which included all retouched items and items with macro traces was creat- ed. On some items some macro traces at naked eyes or with a magnifying glass (based on the recurrence, order and reg- ularity of the scars) were identified. Random traces and scars or fracture with different patinas were considered as mechanical post-depositional alterations.

Spatial analysis of SU 11

The spatial analysis was performed by means of Past 3.14 (Hammer et al. 2001) and ArcMap® 10.6.1. The mixture analysis (based on the normal distribution model) was made to detect and discriminate possible modularity in the hearth- to-hearth distances, as suggested both by the visual analysis of the maps and by the evidence documented in the underlying SU 13. In agreement with the protocol applied for the study of SU 13 (Spagnolo 2017; Spagnolo et al. 2019), a set of data were identified as significant for the reconstruction of the spa- tial management of the site. These include: lithic micro-debris, lithic “tools”, cores (taking into account also their exploitation rate) and the faunal remains sorted by dimensional classes and physical state of the surface, namely unburned small speci- mens (1–6 cm), burned small specimens (1–6 cm) and large specimens (> 6 cm).

The spatial patterns (dispersed, random or clustered) and their statistical significance were preliminarily explored through the Ripley’s K function and the Spatial Autocorrelation (Global Moran’s I method) powered by Getis-Ord General G statistics. Then, the Kernel Density Analysis (setting the searching radius according to the results of the Ripley’s K function), the Hot Spot Analysis (Getis-Ord Gi* algorithm) were carried out and thematic maps were used to visualize the spatial patterns of the aforementioned catego- ries of findings. Finally, in order to achieve a more compre- hensive overview of the possible structuration of the space, a Ward's Cluster Analysis was performed (Carrer 2017; Crezzini et al. 2016; Fletcher 2008; Garcea and Spagnolo 2018; Lancelotti et al. 2017; Moroni et al. in press; Romagnoli and Vaquero 2016; Shennan 1997; Spagnolo 2017; Spagnolo et al. 2016, 2019; Thacher et al. 2017; Whallon 1984; Werdelin and Lewis 2013). Resulting patterns were macroscopically compared with the presence and posi- tion of the hearths in SU 11.

The input-data were adapted to the specific working-mode of the different analytical strategies here adopted both related to the Point Pattern Analysis (PPA) and to the Quadrat Count Method (QCM). The whole sample was taken into account without indexing of data for the PPA (e.g. Ripley's K function and Kernel Density Analysis) and the univariate QCM (e.g. Spatial Autocorrelation, Getis-Ord General G statistics, Hot Spot Analysis). The multivariate Ward's Cluster Analysis, conversely, was carried out discarding the not comparable spatial units of the excavation grid (scilicet 50 × 50 cm squares with an integrity level < 80%) and normalizing data by con- version into percentage indexes. This preliminary manage- ment of data is required to prevent under-/over-representations of some spatial patterns and, consequently, the misreading of the actual quantitative and relational distribution of the findings.

Results

Sedimentological framing of SUs 13-11

The Oscurusciuto Rockshelter's clastic sequence is more than 6 m thick (Fig. 4a). The sedimentological analysis presented in this work focuses on the stratigraphic fea- tures of SUs 13 and 11 (Fig. 4a, b). From a sedimen- tological point of view, the archaeological layer SU 13 corresponds to a single bed, while the archaeological layer SU 11 can be subdivided into two distinct beds labelled SU 11-upper and SU 11-lower (Fig. 4a).

SU 13 overlays SU 14 through a sharp erosional sur- face at place locally marked by the occurrence of col- lapsed blocks. In the west section, SU 13 displays a dome-shape, thus explaining lateral variations in thickness. The passage from SU 13 to the overlying SU 11-lower is marked by a relatively flat and slight-erosional surface (Fig. 4a). SU 13 is about 12 cm thick in present-day exposed sections, small thickness variations locally occur due to the scoured erosional surface at its base, but data collected during archaeological excavation indicate an al- most constant thickness for SU 13 in all the area. The bed is composed of coarse-grained sand with abundant silty- sized matrix and displays a crude plane-parallel lamination (Fig. 4b). Scattered granules, small pebbles and debris locally occur. At place, debris are made of tephra deriving from the erosion of the underlying SU 14.

The overlying SU 11-lower bed is about 9 cm thick and displays similar features to SU 13 bed, except for a lack of tephra debris and of the internal lamination (Fig. 4b). Consequently, the bed SU 11-lower is structureless.

Bed SU 11-upper overlies SU 11-lower through a slight erosional surface, it is about 12 cm thick and it is made of dominant granules/small pebbles in a sandy matrix. Pebbles scale is 14.5 cm long. b Sedimentary log of the investigated part of the succession. See a for the log trace are moderate to well rounded. The bed displays a crude finning-upward trend and lack of any sedimentary structure. Finally, SU 11-upper passes upward to SU 9 through a rela- tively high-relief erosional surface (Fig. 4a).

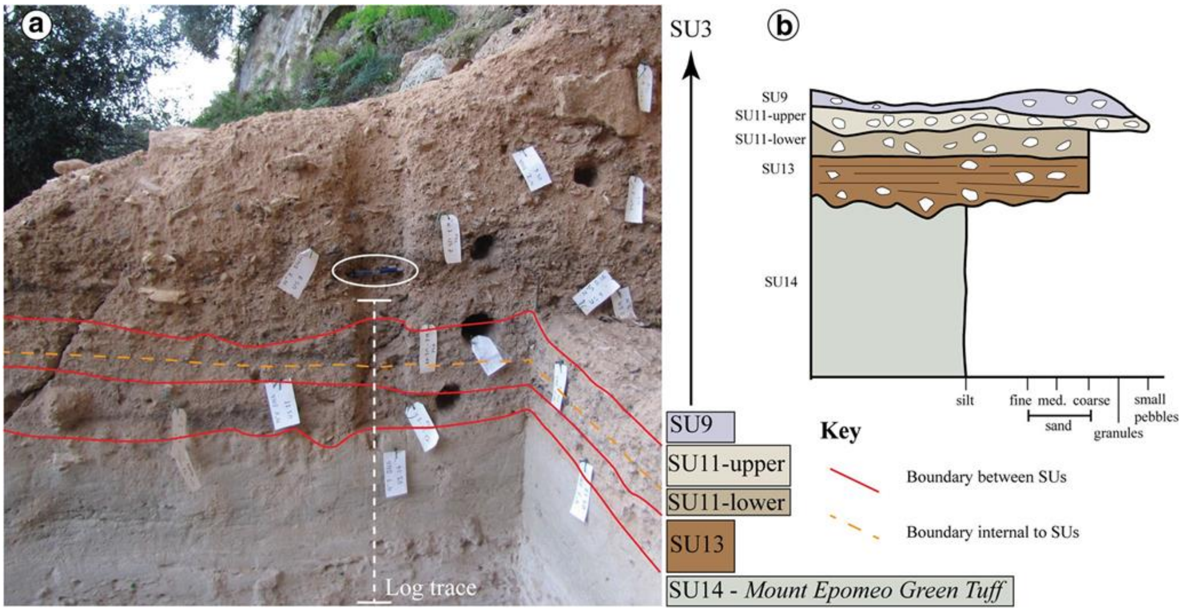

Fig. 4 a Panoramic view of the upper part of the Oscurusciuto Rockshelter clastic successions with highlighted the boundaries of the investigated stratigraphic units from the Southern section. Pencil for

Preservation state and archaeology of time of SU 11

The cross-sectional analyses of stratigraphic profiles, the car- tesian diagrams and vertical frequency histograms of plotted items remarked the sub-horizontal bedding of SU 11, charac- terized by a weak dip towards the NW corner of the shelter (Figs. 5 and 6; Figs. S1–S4). This evidence constitutes a po- tential conservative factor for the preservation of context in- tegrity from post-depositional tractive/gravitative distur- bances, that is macroscopically suggested by the fresh state of the lithic edges (with absence of double patinas), the quan- titative distribution by dimensional classes of lithics (“Lithic technology of SU 1 1 ”) a nd fa un al re mai n s (“Zooarchaeological evidence of SU 11”) (higher frequencies of small pieces on the large ones), the good preservation of some hearths (Table S1), the strong spatial correlation be- tween hearths and burned bones (Figs. 7 and 8; Figs. S6–S7) and the absence of large-scale erosional episodes or bioturbations on the preserved surface of SU 11.

The most relevant result of these analyses is the identification of at least one archaeo-stratigraphic hiatus, about 2–3 cm thick, discontinuously evident both by vertical distribution of finds and by the hearths patterns (vertical separation and sizing difference among the “lower” and the “upper” hearths). More specifically, a clear bimodal distribution pattern was returned by the plotted items analysis: a rarefaction/absence of materials, indeed, was highlighted in the whole excavated area, sandwiched between two high-density-finds sub-units of the SU 11 (Figs. 5–6; Figs. S2–S4). This hiatus perfectly fits with the separation layer be- tween the upper and the lower hearths, as shown by stratigraphic profiles (Fig. S1). This evidence allowed to dissect SU 11 into two sub-units: the upper one was named 11a and the lower one 11b. Moreover, the integration between sedimentological and archaeo-stratigraphic studies allowed to detect a significant cor- respondence between these archaeo-stratigraphic units and the geological beds ("Depositional processes and stratigraphy", Fig. S5). The Pearson correlation (Table 1), moreover, corroborates a very good correspondence between the archaeological spits and the actual achaeo-stratigraphic sub-units. The excavation grid, indeed, includes 48 sectors (50 × 50 cm wide), among these five were excluded from the analysis due to the low number of plot- ted items, nine returned a unimodal distribution pattern of eleva- tions (then they are considered badly reliable), nine returned weak bimodal or polymodal distributions (then they are consid- ered weakly reliable) and 29 returned a clear or very clear bi- modal patterns (then their reliability is considered good). The statistical test was run on the reliable sectors (good and weak sectors, N = 34), that constitutes a representative sample as it represents the 79% of the analysed sample (71% of overall sec- tors). With the correlation coefficients recognized ($R_{11/1-11a} = 0.95$, $p = 3.30E{-}18$; $R_{11/2–3-11b} = 0.86$, $p = 4.72E{-}11$), the positive correspondence between archaeological spits and archaeo- stratigraphic sub-units appear statistically highly significant (Table 1). The number of hearths and the presence of multi- stratified features are a significant evidence of the palimpsest magnitude, also giving information about anthropogenic post- depositional disturbances. As previously stated, all the hearths in SU 11 were not simple surface fireplace, but structured fea- tures, made in sub-circular shallow pits with a "bowl" shape section and flat bottom, usually 5 cm deep ("The site and the SU 11"; Table S1). In particular, the hearths SUs 50 and 53 (in the Southern part of the excavated area) are characterized by a complex stratigraphic sequence of pits: most of them (SU 50A-F and 53B-D) are related to sub-unit 11a, but at least two of them (SUs 53A1 and 53A2) are related to the lower sub-unit (SU 11b). This implies that, at least locally, a vertical dislocation of anthro- pogenic materials has to be expected. It is conceivable that, contextually to the formation of SU 11a, a moderate number of faunal and lithic findings coming from sub- unit 11b could have been unearthed by the Neanderthal digging activity during the making of some hearths in sub-unit 11a. In any case, possible under-representation (sub-unit 11b) and over-representation (sub-unit 11a) of the densities of findings in relation to the actual inten- sity of activities carried out during the formation of these sub-units can be considered not very extensive given the shallowness of the hearths' pits (Table S1).

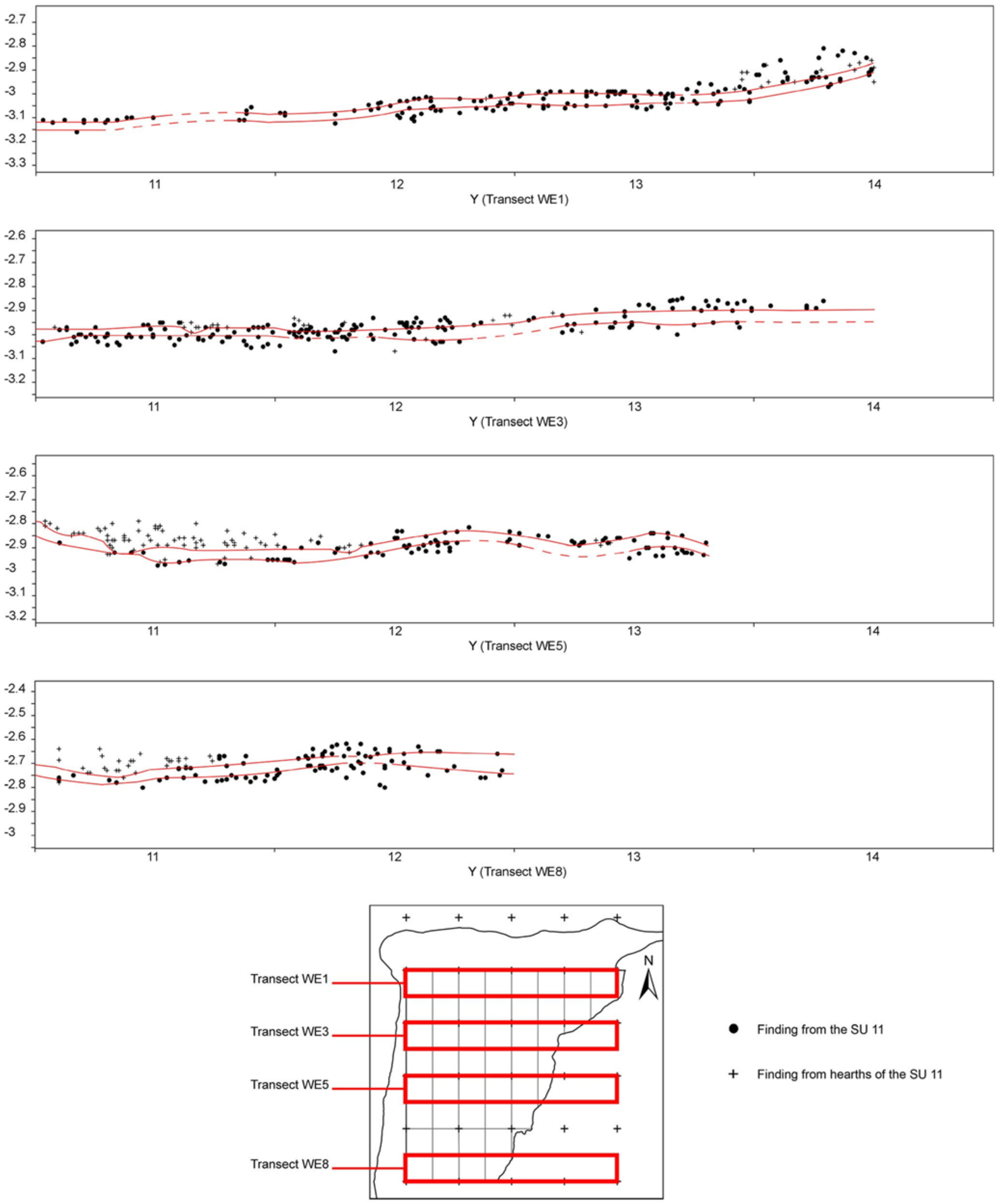

Fig. 5 Scatter-plot graphs of the findings with cartesian coordinates along the E-W transects. The transects relative to each graph are highlighted by a red rectangle

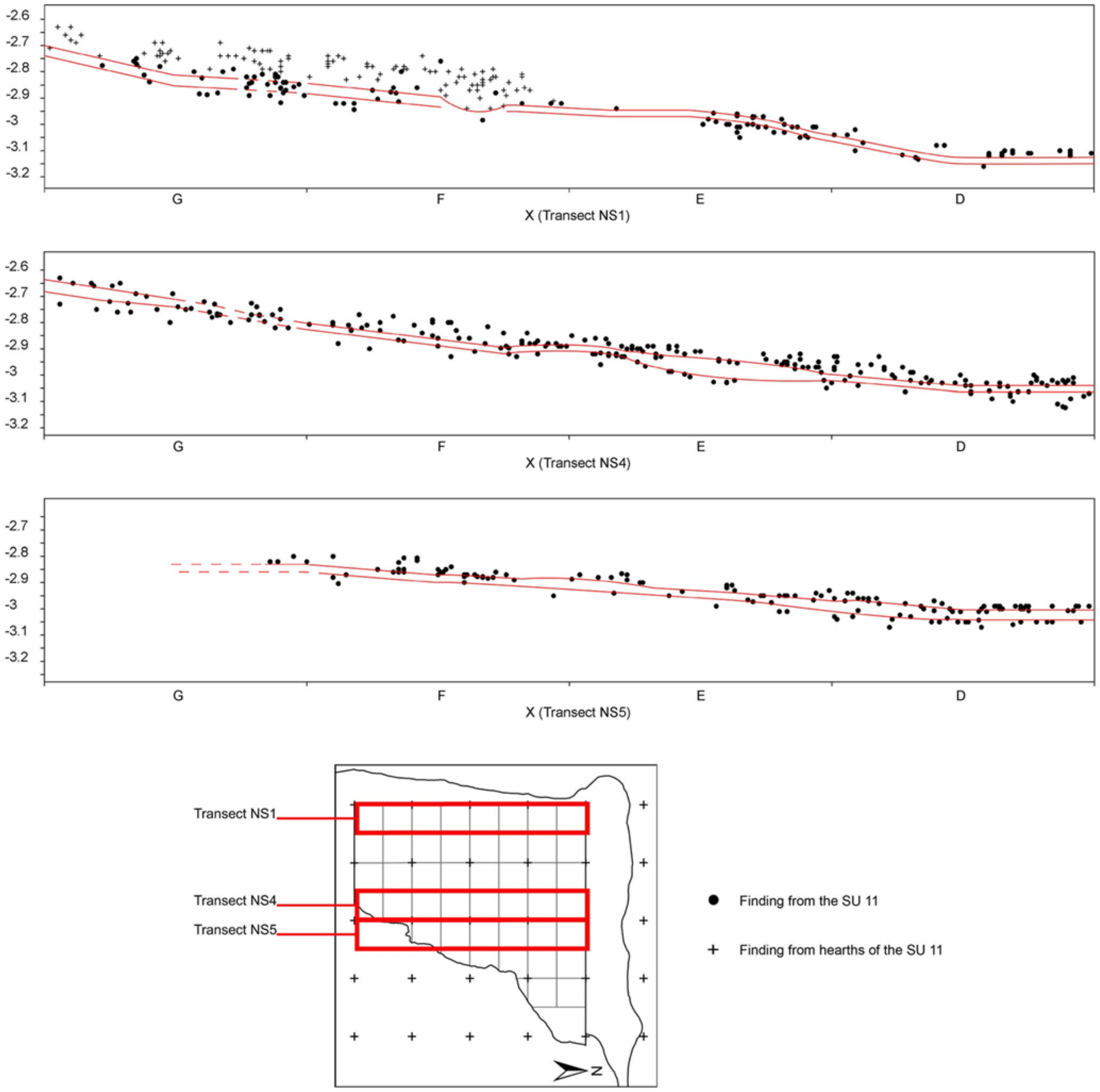

Fig. 6 Scatter-plot graphs of the findings with cartesian coordinates along the N-S transects. The transects relative to each graph are highlighted by a red rectangle

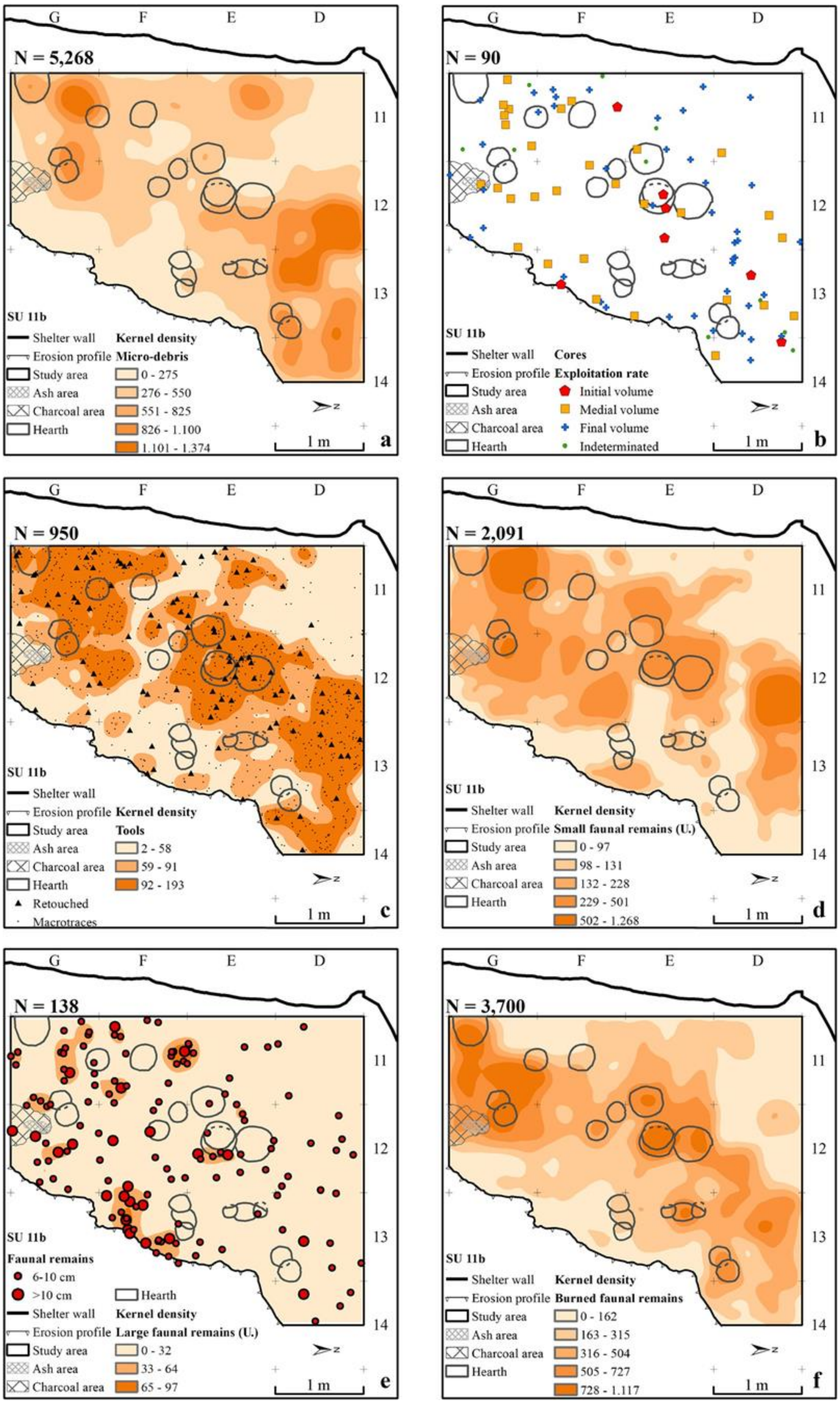

Fig. 7 Distribution of the analysed categories of findings in the lower sub-unit 11b. Kernel density map of the lithic micro-debris (a); distribution map of the cores with their exploitation rate (b); composite kernel density and distribution map of the lithic tools with differentiation be- tween retouched and items with macro-traces (c); kernel density map of the unburned small faunal remains (d); composite kernel density and distribution map of the large faunal remains with differentiation by Dimensional Classes (e); kernel density map of the burned faunal remains (f)

Zooarchaeological evidence of SU 11

The faunal remains (15,640 items) are highly fragmented: most of the pieces are smaller than 6 cm (15,264 items), only 376 items fall in the third and fourth dimensional classes (6– 10 cm; > 10 cm). Seventy-four remains were taxonomically identified, mainly by isolated teeth (Boscato 2017) (Tables S2–S3). Taxa are to be related mostly to steppe/ wooded grasslands (61 are attributable to Bos primigenius and 3 to Equus ferus), rather than to more vegetated environ- ments (5 Cervus elaphus, 3 Dama dama, 1 Capreolus capreolus, 1 Sus scrofa). The bulk of NISP (66.2%) is repre- sented by isolated teeth. Limb bones are mainly represented by diaphyseal fragments (18.9% of NISP), whilst epiphyses, with the exception of a fallow deer scapula, are only related to the distal portions of limbs (one distal metapodial and three phalanges). Noteworthy, in a sample of 5292 unidentified specimens from SU 11 only the 2.7% is represented by frag- ments of spongy tissues (Table S4). The lack of epiphyseal fragments, as well as of other spongy bones, is in line with the picture already described for the Mousterian from Apulia (Boscato and Crezzini 2007, 2012). The burned bones (9986 items) fall almost all in the first-dimensional class (1–3 cm) and constitute 64% of the sample (Tables S2–S3).

Lithic technology of SU 11

The lithic sample of SU 11 includes 31,030 items (the SU 13 consists of 7504 items). The recovered objects are mostly in an excellent state of preservation, with fresh edges and well- preserved macro-traces (visible even to the naked eye), double patina is absent. According to results of the palimpsest dissec- tion, the technological analysis was carried out considering the distribution of lithics among the sub-units 11b and 11a.

The supply of raw material is strictly local, the pebbles of cherty limestone, jasper, chert and quartz sandstone were found in the secondary formation of the marine and fluvial terrace deposits near the site. The most common raw material in the examined levels (SUs 13, 11b and 11a) is cherty lime-stone (46.7%) followed by jasper (33%). We note a selection of raw material depending on the concept of debitage: i.e. the additional volumetric debitage is mainly performed on chert and jasper followed by cherty limestone. Moreover, there is a concept-oriented selection of the shape of the block depending on which kind of reduction sequence was performed. That is to say, oblong and lenticular pebbles for the Levallois and fragment or angular pebbles for the other reduction sequences. The vast majority of the items in the two sub-Units in question are all included in the smallest dimensional classes (DC1 and DC2), documenting a flaking activity in situ (Table S5). The lithic complexes were produced by debitage: besides a great quantity of debris, the presence of raw pebbles, hammerstone and cores is attested together with a predomi- nance of flakes and few retouched items (mainly side scraper). All of the technological classes show a similar percentage in every Unit except for the class of retouched tools which are progressively more represented in 11a and 11b (Table S6).

The majority of cores in both sub-unit are in a very ad- vanced state of exploitation (exploited volume 11a: 58 items and 11b: 30 items); followed by medium (11a: 19 items and 11b: 32 items) and initial state (11a: 6 items and 11b: 6 items). Both sub-units of SU 11 show a dominance of

Levallois in all of its recurrent modalities (i.e. unipolar, convergent, cen- tripetal) followed by various other additional debitages (i.e. a volumetric unidirectional sequence aimed at producing flakes, blades or bladelets with a management of the striking platform and few managements of the lateral and distal convexities). In these cases, each block is used for one or more sequence of reduction used independently by each other. A sporadic ap- pearance of discoid and kombewa production is also attested (Table 2). In both sub-units of SU 11 an increase in the variety of the additional reduction concepts can be seen (i.e. unidirec- tional cores for producing flakes: unidirectional cores aiming at producing blades or bladelets; cores producing techno-typo Levallois points (Boëda 2013; Marciani 2018)), together with a switch from one concept to another (i.e. from Levallois to additional). Furthermore, some exploited cores were later retouched (Marciani 2018).

The spatial patterns of SU 11

As in SU 13, the presence and localization of the hearths in SU 11 is an essential feature of the spatial structure of the site, dividing it into two sectors: the inner one (between the hearths alignments and the Rockshelter wall) and the outer one (be- tween the hearths and the ravine bottom) (Boscato and Ronchitelli 2017).

Beyond the macroscopic similarity of the spatial organiza- tion, some differences can be recognized among the hearth patterns of SU 11. More specifically, the lower sub-unit (11b) is characterized by small hearths (some of them stratigraphically overlapped) aligned along a SW-NE axis and arranged in 3 small clusters of 5, 6 and 8 features respec- tively (from SW to NE). The dimensional ranges of these hearths appear relatively standardized (standard deviation of the diameters 7.3 cm), with a median diameter of 26 cm (first quartile, Q1 24 cm; third quartile, Q3 33.5 cm) (Table 3).

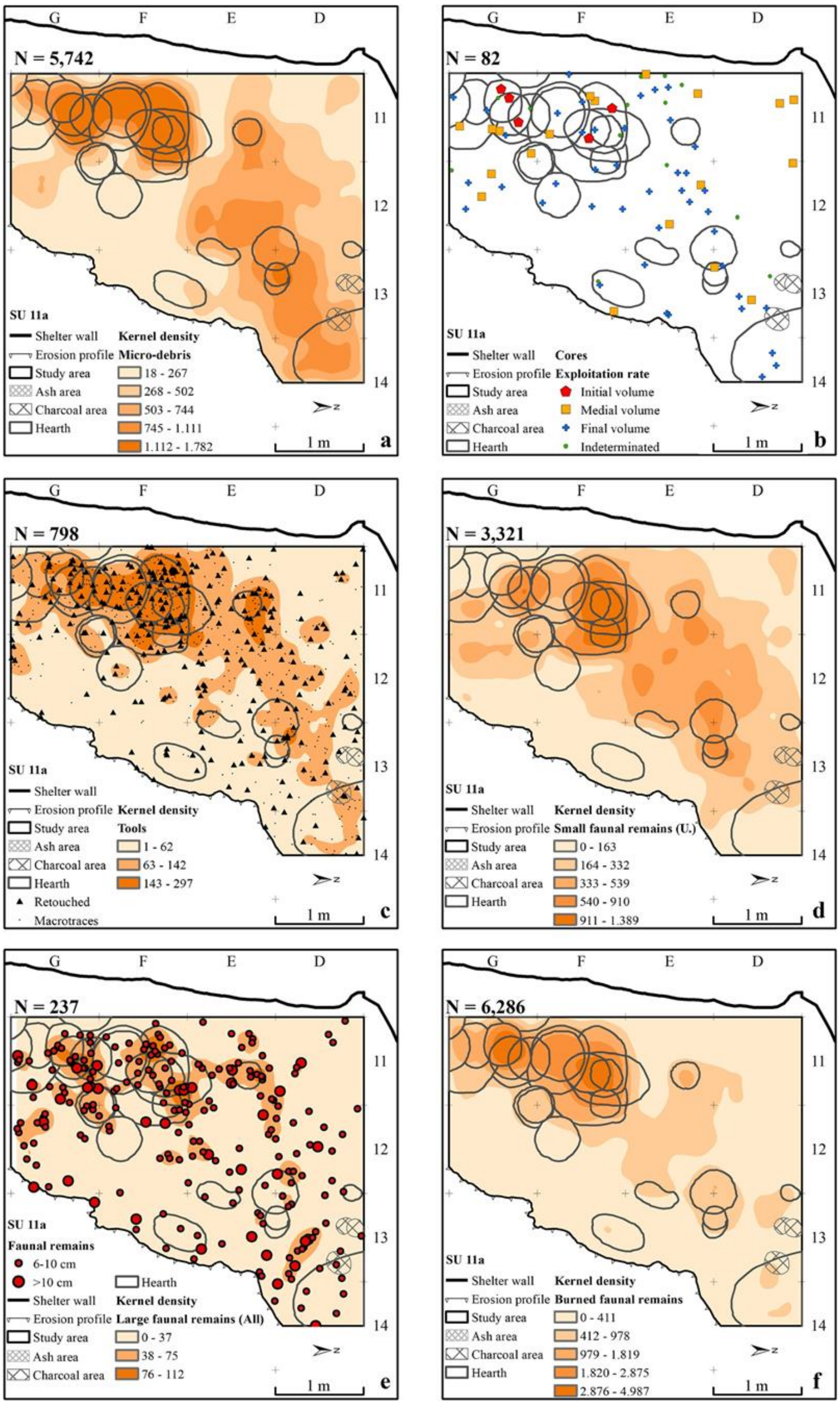

Fig. 8 Distribution of the analysed categories of findings in the upper sub-unit 11a. Kernel density map of the lithic micro-debris (a); distribution map of the cores with their exploitation rate (b); composite kernel density and distribution map of the lithic tools with differentiation be- tween retouched and items with macro-traces (c); kernel density map of the unburned small faunal remains (d); composite kernel density and distribution map of the large faunal remains with differentiation by Dimensional Classes (e); kernel density map of the burned faunal remains (f)

Modular distances can be detected among these combustion features, apparently based on a polymodal distribution model. As shown also by the mixture analysis, the “inter-cluster” distances range from about 2 ± 0.4 m to 3 ± 0.2 m, respective- ly (Fig. S6b; Fig. 3b).

The hearths in the upper sub-unit (SU 11a) are grouped into two-dimensional classes: the smaller ones appear more ho- mogenous (standard deviation of the diameters 6 cm, CV: 0.19), while a slightly larger variability is reflected among the larger ones (standard deviation of the diameters 23.4 cm, CV: 0.36). The smaller hearths tend to exhibit a median diam- eter of 33 cm (Q1 29.5 cm, Q3 35.5 cm), and the larger ones have a median diameter of 54 cm (Q1 49 cm, Q3 73.5 cm) (Table 3). Their spatial pattern appears clearly clustered: a high concentration of 21 features (mostly stratigraphically o- verlapped) is located in the SW sector of the excavated area, the other ones (seven) are in the NE sector. Moreover, in the latter sector, SU 10 represents a mass of un-disentangled hearths, perhaps similar to the multi-stratified hearths SUs 50 and 53. Due to the massive palimpsest effect, a hearth-to- hearth distance pattern in sub-unit 11a is not so clear. Both the visual and the mixture analysis of the distances between the “SW cluster” and the “NE cluster” suggest an increase in the distance modules for the inter-cluster range, characterized by two peaks at about 2.8 and 4.4 m, respectively, which can be directly related to the hearth-size increase (Fig. S6a; Fig. 3a). Statistically significant clustered patterns are given by the Spatial Autocorrelation Global Moran’s and the Getis-Ord General G statistics among the different categories of findings of SU 11 dataset, with the exception of the cores (from both sub-units) and the unburned small faunal remains from sub- unit 11b, whose z-scores values appear quite similar to a ran- dom distribution. Comparatively, sub-unit 11a shows a greater clustering rate and spatial overlapping than the 11b (Tables 4, 5, 6 and 7). The Hot Spot Analyses of each sub-unit show a macroscopic spatial correspondence between the patterns of the categories of findings, with some minor relative differ-ences. The main hot-spots in sub-unit 11b are positioned in the NE and in the SW edges of the excavated area, while two cold-spots are detected in the NW corner of the shelter and along the eastern limit of the excavated area. A significant overlapping of hot-spots can be noted in the southern part of the excavated area in sub-unit 11a (related to the high concen- tration of hearths). As in the lower sub-unit, the cold-spots are mainly located along the eastern limit of the excavated area and in the NW corner of the shelter (Fig. S7-S8).

	11/1	11/2–3	11a	11b
11/1		0.82559	**3.30E−18**	0.021187
11/2–3	0.04		0.30319	**4.72E−11**
11a	**0.95**	0.18		0.017505
11b	0.39	**0.86**	0.40	

Table 1 Correlation table of the archaeological spits and archaeo- stratigraphic sub-units identified in SU 11. Data in bold are statistically significant

Concept	SU 13		SU 11b		SU 11a			
	N	%	*N*	%	*N*	%	Total	Total%
Levallois	592	96.6	2103	92.2	3251	94.3	5946	93.8
Additional	21	3.4	162	7.1	153	4.4	336	5.3
Kombewa	0	0.0	11	0.5	36	1.0	47	0.7
Discoid	0	0.0	5	0.2	7	0.2	12	0.2
Total without indet.	**613**		**2281**		**3447**		**6341**	
Indeterminable	6890		11,324		13,978		32,192	
Total	**7504**		**13,605**		**17,425**		**38,534**	

Table 2 Concept of debitage from SUs 13 to 11a. Data in bold represents the tatal values

More in detail, the Ripley's K function confirms this scenar- io, highlighting different clustering radius: within 0.4–0.7 m for tools and slightly smaller (0.3–0.6 m) for micro-debris and fau- nal remains (included the small faunal remains from the sub-unit 11b). On average, the 0.5 m diameter seems to be the main dimensional trend of the findings' agglomerations (Fig. S9). Kernel density analyses, therefore, were made taking into ac- count the Ripley's K results and setting the searching radius at 0.25 m. The resulting density maps allow to detail the picture obtained by previous analyses. Compared to the Rockshelter setting, the main concentrations of findings appear spatially re- lated to the hearths, being usually positioned along the side of the hearths towards the back wall of the shelter (that is to say in the "inner sector" of the shelter). For each sub-unit, the spatial patterns of the analysed categories do not differ significantly between each other, highlighting a relative overlapping of the main high-density areas (this appears particularly evident in the upper sub-unit). In particular, in sub-unit 11b, the patterns of micro-debris, lithic tools, unburned and burned small faunal remains covary according to a common model with small- scale dislocations. The large faunal remains and the cores, in- stead, seem to follow a different logic: both these categories of findings are marginally distributed along the borders of the high- density areas of the small unburned faunal remains and of the micro-debris, respectively. Noteworthy, further pattern differ- ences are detectable in the ensemble of cores if the exploitation rate is taken into account. The still usable cores are typically scattered in the outer side of the hearths alignment, and the exhausted ones appear relatively grouped immediately to the inner side, forming a sort of arc alignment (with two main con- centration in the SW and in the NE zones respectively) (Fig. 7a– f). In sub-unit 11a, the spatial overlapping of micro-debris, lithic tools, unburned and burned small faunal remains is more evi- dent (with a major clustering in the SW area of the excavation, corresponding to the main concentration of hearths). The large faunal remains and the cores seem to be distributed in a slightly marginal position with respect to the high-density areas of small faunal remains and micro-debris. Specifically, while the usable cores are mainly clustered in the SW area (spatially overlapped to the main hearths and micro-debris concentration), the exhausted cores are arranged in the northern part of the excavated area, along a SSW-NNE alignment (similar to the one recognized in lower sub-unit 11b) (Fig. 8a–f).

Finally, statistically significant low-density areas are recog- nized and they appear to spatially coincide both between sub- unit 11b and 11a. The most evident is located along the SE edge of the excavated area, another one occupies the NW corner of the shelter (Figs. S7–S8; Figs. 7 and 8).

These results are well summarized by the Ward's cluster analysis as well. In the lower sub-unit (11b), despite the rela- tively low cophenetic correlation value (c = 0.5814), the good- ness of the obtained dendrogram seems to be suggested by the spatial coherence of the five clusters recognized. Specific find- ings associations correspond to each cluster. Specifically, clus- ter 1 is characterized mainly by high values of small unburned faunal remains, micro-debris and lithic tools, cluster 2 by totally exploited cores and micro-debris, cluster 3 by a very low den- sity of materials (with absence of cores), cluster 4 by a middle- low occurrence of all the categories (with higher concentration of burned bones) and cluster 5 by a higher incidence of large faunal remains (Fig. S10; Table S7). In the upper sub-unit (11a), the cophenetic correlation value is higher but still not optimal (c = 0.7632), attesting, alongside the spatial coherence of the clusters, a better goodness of the dendrogram. Clusters 1 and 2 are very similar, characterized by high frequencies of all the categories of findings (cluster 1 is substantially differentiated by a higher quantity of small unburned faunal remains) and strictly related to the mass of hearths in the SW part of the studied area. Cluster 3 differs from the aforementioned ones for a higher occurrence of exhausted cores opposed to a minor (but still high) frequency of findings. Cluster 4 exhibits a very low den- sity of findings. Clusters 5 and 6 are very similar (middle-low occurrence of remains) and differentiated by a relatively higher representation of the micro-debris in cluster 5 (Fig. S11; Table S8).

SU 13 (s)	Ø (cm)	SU 13 (l)	Ø (cm)	SU 11b	Ø (cm)	SU 11a (s)	Ø (cm)	SU 11a (l)	Ø (cm)
SU 80	20	SU 12	80	SU 71C	15	SU 60	22	SU 52	46
SU 84	21			SU 71B	16	SU 59	27	SU 53B	47
SU 75	22			SU 65	21	SU 49	32	SU 50E	48
SU 83B	22			SU 69	23	SU 67	33	SU 57	48
SU 77	24			SU 56A	24	SU 53	34	SU 45	49
SU 76	27			SU 62	24	SU 51	37	SU 55	49
SU 78	27			SU 70	24	SU 46	40	SU 44	51
SU 82	30			SU 53A1	26			SU 50C	51
SU 83A	34			SU 56B	26			SU 47	52
				SU 71A	26			SU 50D	54
				SU 72	26			SU 53E	60
				SU 72A	26			SU 54	60
				SU 64	29			SU 58	64
				SU 53A2	33			SU 53C	67
				SU 66	34			SU 50B	80
				SU 63	36			SU 53D	80
				SU 61	38			SU 53	87
				SU 73	39			SU 48	90
				SU 68	41			SU 10	141
N	**9**	*N*	**1**	*N*	**19**	*N*	**7**	*N*	**19**
Mean	**25.2**			Mean	**27.7**	Mean	**32.1**	Mean	**64.4**
σ	**4.7**			σ	**7.3**	σ	**6**	σ	**23.4**
CV	**0.2**			CV	**0.3**	CV	**0.2**	CV	**0.4**
I quart	**22**			I quart	**24**	I quart	**29.5**	I quart	**49**
Median	**24**			Median	**26**	Median	**33**	Median	**54**
III quart	**27**			III quart	**33.5**	III quart	**35.5**	III quart	**73.5**

Table 3 Overview of the dimensional classes of the hearths in SUs 13 to 11a. The descriptive statistics (mean, standard deviation, coefficient of variation, I quartile, median and III quartile) are reported in bold

Global Moran's I Summary—SU 11b	Number	Moran's Index	Expected Index	Variance	*z*-score	*p* value
Micro-debris	5268	0.276623	− 0.021277	0.005328	**4.081128**	0.000045
Cores	90	0.026949	− 0.021277	0.005644	0.641904	0.520935
Tools	950	0.288529	− 0.021277	0.005606	**4.137759**	0.000035
Small faunal remains	2091	0.039092	− 0.021277	0.004229	0.928353	0.353225
Large faunal remains	139	0.147244	− 0.021277	0.005369	**2.299909**	0.021453
Burned remains	3700	0.311047	− 0.021277	0.005648	**4.421758**	0.000010

Table 4 Global Moran's I summary of the analysed categories of findings from sub unit 11b. Statistically significant data are reported in bold

Discussion: diachronic perspectivism on the settlement evidence from SUs 13, 11b and 11a

The stratigraphic continuity of the palimpsests sampled for this study constitutes a good reference to explore Neanderthal behaviour from a middle-to-long range time- scale. In other terms, the evolution of the settlement dynamics from SUs 13-11 can be included and understood in light of time perspectivism (Bailey 2007). The combination between high-temporal resolution and diachronic perspective allows to gain a deeper view of the historical processes developed in this continuous Mousterian settling sequence, as observed in each recognized anthropogenic Unit.

Depositional processes and stratigraphy

Sedimentological features of SUs 13 and 11-lower are similar and this indicates that the two beds were deposited by similar depositional processes. These features suggest that sedimen- tation occurred mainly due to infiltration processes, namely sediments derived from surficial soils and pre-existing de- posits infiltrated through fractures and/or joints into the shelter (Bosch and White 2004; Martini 2011; Iacoviello and Martini 2012, 2013). Small debris and granules with lithological af- finity with the host rock, could be settled by rockfall process- es. The occurring of a crude plane-parallel lamination in SU 13 suggests that the deposition of this layer was only partially perturbed by human trampling and digging, while the struc- tureless nature of the overlying SU 11-lower could be indica- tive of a major human influence during deposition (e.g. Karkanas et al. 2007; Martini et al. 2018). The slight- erosional boundary that separates the two investigated beds suggests that deposition of the two layers occurred almost in continuity i.e. without any relevant time interval dominated by erosional processes.

The bed SU 11-upper is as structureless as SU 11-lower but it is made of coarser sediments, indicating a grain size increase of the clastic sedimentary inputs. This is generally related to the spatial expansion of pre-existing fractures and joints and/ or to new points of sediments input, as suggested by the oc- currence of moderately- to well- rounded pebbles that are lacking in older strata. Similarly, to SU 11-lower, the lack of any sedimentary structure could be indicative of human influ- ence during deposition. The marked erosional boundary at the top of SU 11-upper bed points to the occurrence of an erosion- al phase after the deposition of the bed and before the deposi- tion of bed SU 9, with the subsequent erosion of a part of the sedimentary record that can be estimated as having amounted to some centimetres.

High-low clustering report—SU 11b	Number	Observed general G	Expected general G	Variance	z-score	p value
Micro-debris	5268	0.165765	0.132979	0.000140	**2.766442**	0.005667
Cores	90	0.142929	0.132979	0.000182	0.736997	0.461124
Tools	950	0.157277	0.132979	0.000069	**2.924017**	0.003455
Small faunal remains	2091	0.150478	0.132979	0.000327	0.967313	0.333388
Large faunal remains	139	0.157510	0.132979	0.000141	**2.067418**	0.038695
Burned remains	3700	0.179150	0.132979	0.000117	**4.265811**	0.000020

Table 5 High-low clustering report (Getis-Ord General G statistics) of the analysed categories of findings from the sub-unit 11b. Statistically significant data are reported in bold

Global Moran's I summary—SU 11a	Number	Moran's Index	Expected Index	Variance	*z*-score	*p* value
Micro-debris	5742	0.255226	−0.021277	0.005372	**3.772678**	0.000162
Cores	82	0.122341	−0.021277	0.005366	**1.960552**	0.049931
Tools	798	0.474321	−0.021277	0.005116	**6.929048**	0.000000
Small faunal remains	3231	0.334255	−0.021277	0.004552	**5.269365**	0.000000
Large faunal remains	237	0.192405	−0.021277	0.005498	**2.881734**	0.003955
Burned remains	6286	0.419161	−0.021277	0.004898	**6.293534**	0.000000

Table 6 Global Moran's I summary of the analysed categories of findings from the SU 11a sub-unit 11a. Statistically significant data are reported in bold

Beyond the sedimentological meaning of these beds, a cor- relation between geological and archaeological units can be performed. Currently, the correlation is possible in the south- ern section of the shelter, where the sedimentary log was col- lected and the SU 11 bed shows a present-day total thickness of 21 cm (SU 11-lower, 9 cm; SU 11-upper, 12 cm). Here, archaeological and GIS data highlight that the overall thick- ness of SU 11 is about 22 cm, with the interval of rarefaction of artefacts (that separates archaeological layers SU 11a and b) comprised between − 12 and − 8 cm from the top of SU 11 (Fig. S5). Considering that small thickness differences be- tween archaeological data and present-day thickness measur- able in the exposed section are possible for several reasons (e.g. different original thickness of beds, erosional processes associated with beds boundary), these data highlight a perfect correlation between geological bed SU 11-lower with archae- ological layer SU 11b and of bed SU 11-upper with SU 11a. The interval of rarefaction falls at the base of the geological unit SU 11-upper. Unit SU 11 displays marked differences in thickness both in its archaeological and sedimentological constituents, depending on the different excavation areas. These are imputable to various causes at the present state not completely investigated, including for example the different amount of sediment erosion connected with erosional bound- aries of beds, the differential accumulation of materials related to human activity and/or the differential syn-depositional ac- cumulation of clastic sediments in different sectors of the shelter connected with the location of sediments entry-points.

The palimpsest unravelling

In details, the frame arising from the palimpsest dissection highlights the different temporal meaning of the selected pa- limpsests: SU 13 is a short-term palimpsest (Spagnolo et al. 2016), while SU 11 is a long-term one. This essential differ- ence significantly affects the archaeological visibility of these Units and requires a different approach in their study. The strong spatial structuration of SU 13, indeed, is the product of a limited number of long-term and close in time settling episodes (apparently no more than three, if the hearth patterns are taken into account), as also suggested by sedimentological analysis. Therefore, a direct/isomorphic correspondence was detected between spatial patterns and activity areas (and consequently social structure of the Neanderthal camp-site) (Spagnolo et al. 2019). These premises allowed for a high- resolution screening and contextualization of other behaviour- al components mirrored in the lithic technology, as the tech- nical traditions, the import/production/export of lithic imple- ments and the techno-functional studies (Marciani 2018; Marciani et al. 2016, 2018; Spagnolo 2017).

High-low clustering report—SU 11a	Number	Observed general G	Expected general G	Variance	*z*-score	*p* value
Micro-debris	5742	0.176310	0.132979	0.000161	**3.410134**	0.000649
Cores	82	0.155549	0.132979	0.000237	1.466985	0.142380
Tools	798	0.194391	0.132979	0.000145	**5.104041**	0.000000
Small faunal remains	3231	0.200902	0.132979	0.000140	**5.730689**	0.000000
Large faunal remains	237	0.174249	0.132979	0.000125	**3.691949**	0.000223
Burned remains	6286	0.239239	0.132979	0.000414	**5.221831**	0.000000

Table 7 High-low clustering report (Getis-Ord General G statistics) of the analysed categories of findings from the sub-unit 11a. Statistically significant data are reported in bold

The spatial structure behind SU 11 derives from its nature of spatial palimpsest (sensu Bailey 2007). In other terms, an unknown sum of settling episodes (probably numerous) took place at the site following a similar scheme but with small- scale spatial dislocations. These seem to have taken place in accordance with an apparently linear progression between two main settlement configurations. This implies that the possibil- ity of a correct reading of the settlement systems evolution in this Unit is subject to the accuracy of the preventive palimp- sest disentangling because a correct and reliable behavioural approach is possible only starting from smaller time units. This purpose was reasonably reached by the cross-sectional analyses both of the stratigraphic profiles, of the frequency histograms of findings per 50 × 50 cm sector and of the Cartesian diagrams of the plotted items (and reinforced by the sedimentological evidence). The identified sub-units (SUs 11b and 11a) are palimpsests themselves, however, their lower inner spatial variances (as highlighted by the hearths and archaeological material patterns) suggest that they repre- sent the product of reiterate and homogeneous settling strate- gies even if in a sequence of tangled settling episodes. The related data can, therefore, be considered relatively reliable for the purpose of the spatial-functional analysis.

The site-structure identification

The spatial patterns in SUs 13, 11b and 11a, as a whole, allow to individuate interesting analogies and differences. The dia- lectic relationships and the “relative” chronological positions between them could be considered as a clue to infer the long- term dynamics of the settlement strategies.

In the first place, the lithic production in SUs 13, 11b and 11a is characterized by a manifest continuity, as suggested by the use of local raw material and by the predominance of Levallois concept. On this basis, we could relate the lithic material of SUs 13, 11b and 11a to a same technical tradition. However, the difference in the technological structure of the Units could be interpreted on the bases of the type of occupa- tion for each unit. In the two sub-units of SU 11 we note: the presence of cores reused several times in various reduction sequences; cores with two productional lives (first Levallois and subsequently additional); a change in the state of the in- strument: from core to retouched tool; and a progressively higher number of retouched items. These are all behaviours which indicate a correspondence between the space of the site and the source of raw material, that is to say, the lithic material discarded in the site is subsequently reprocessed. These activ- ities are indicators of a prolonged use of the lithic materials, and consequently of some reiterated and close in time occupations.

In the second place, an evident gradual evolution is recog- nizable in the size of the hearths from these Units, from the smallest in SU 13 (median diameter of 24 cm) to the biggest in SU 11a (median diameter of 54 cm) (Table 3).

Furthermore, Units 13, 11b and 11a are characterized by the presence of regular-spaced hearths, aligned along sub-par- allel/diagonal patterns in relation to the shelter wall (Fig. 3; Fig. S6). A possible module of 2.6–3m can be detected taking into account the distances between the hearths in SU 13 with a similar preservation state and, consequently, interpretable as possibly “synchronous”. This module perfectly fits with the “inter-cluster” ranges detected in sub-unit 11b (2 and 3 m). In sub-unit 11a, parallel to the growth in hearths’ size, the “inter- cluster” hearth distance modules seem to deploy to higher values, 2.8 and 4.4 m, respectively. On the one hand, the limited extension of the sheltered area behind the drip-line (probably not very far from the preserved extension of the deposit of SUs 13–11) could be considered as a constraining factor that limited the space free for the combustion features. On the other hand, the strong recurrence of very similar hearth-spacing patterns and alignments has to be connected to specific behavioural choices and not to a merely random pattern. The patterns recognized in SUs 13, 11b and 11a are consistent with the average distance values observed in many archaeological and ethno-archaeological sites for strictly contemporaneous inter-fires distance and explained as a body-size dependent variable (Binford 1983; Galanidou 1997; Gamble 1986; Henry 2012).

Moreover, the relative position of the hearths in relation to the shelter wall involves a spatial partition between an "inner place" and an "outer place" of the camp-site. This dichotomy is also supported by more or less sharp density gradients of findings (Figs. 7 and 8; Figs. S7–S8), but some differences are suggested between Units 13, 11b and 11a. In SU 13 a spatially segregated area, characterized by significantly low densities of findings and "bounded" between the shelter wall and some regularly spaced hearth was clearly identified, and it was interpreted as a possible sleeping/resting area (Spagnolo et al. 2019). A comparable spatial structure seems to emerge also in sub-unit 11b and, perhaps, in 11a, consisting in the low-density areas enclosed between the hearths and the NW corner of the shelter (comparatively less evident than the one in SU 13). This arrangement of sub-units 11b and 11a could be referred to the possible use of this sector of the shelter as sleeping/resting area by the Neanderthal hunter-gatherers, similarly to SU 13 (Figs. 9, 10, 11), nevertheless, this inter- pretation is more difficult here, due to the massive palimpsest- effect of SU 11 (particularly for the SU 11a). Several Middle Palaeolithic contexts (both open-air and rockshelter/caves) yielded evidence of possible sleeping/resting areas. In Western Europe, possible cases are reported in Spain, in levels M, N and O of Abric Romaní (Gabucio et al. 2018; Hayden 2012; Vallverdú et al. 2010) and in France, in level VIII of Grotte Vaufrey (Mellars 1996), in UA 2 of Grotte du Lazaret (de Lumley et al. 2018) and at the open-air site of La Folie (Clark 2015, 2017). In Eastern Europe and the Near East, similar arrangements are described in layer 3 of Velika Balanica Cave in Serbia (Plavšić 2015), in layer 4 of Molodova I in Ukraine (Hayden 2012) and in floors I-III of Tor Faraj in Jordan (Hayden 2012; Henry 2012).

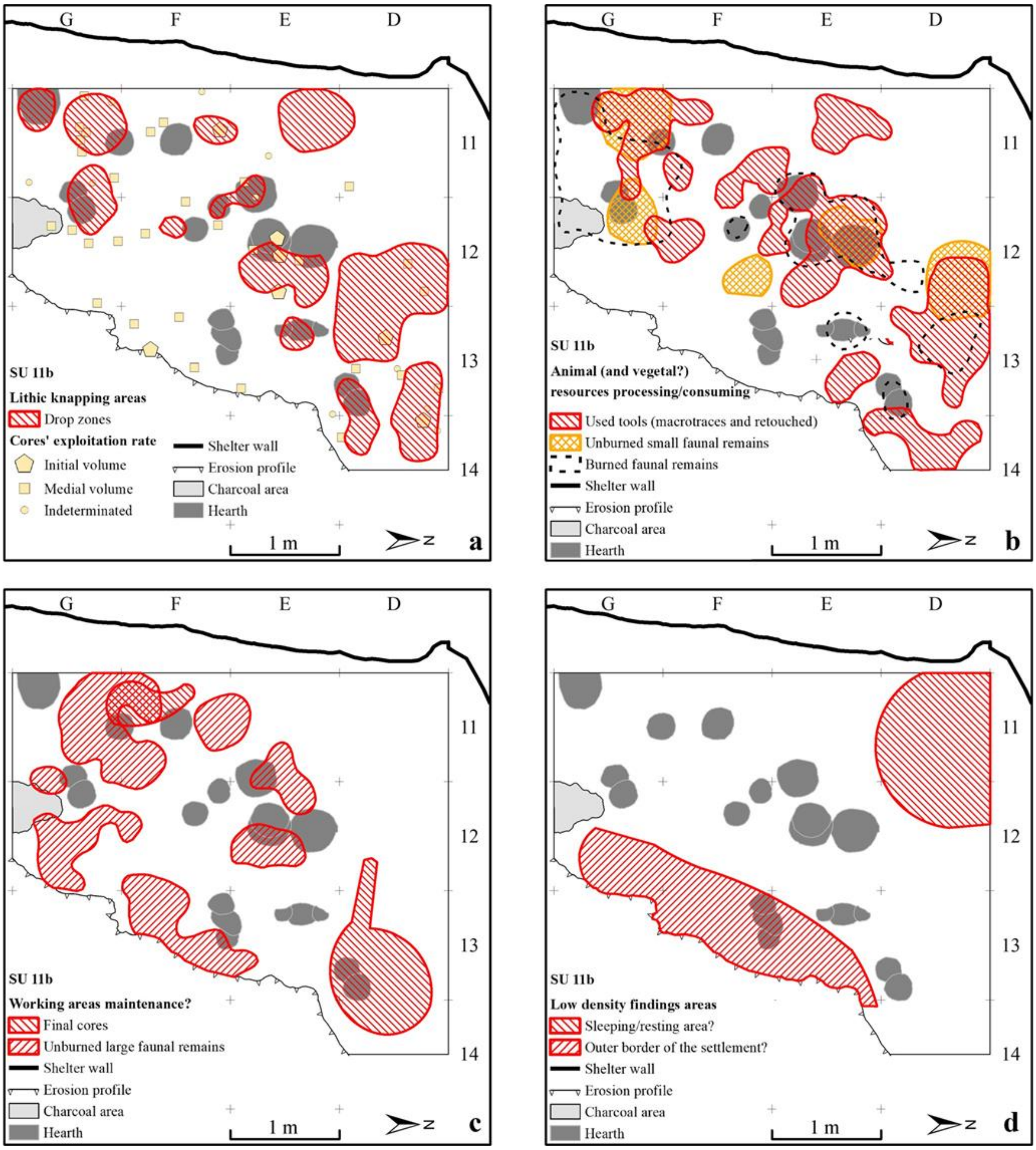

Fig. 9 Activity areas identified in the sub-unit 11b. Main lithic knapping areas (a); possible processing/consuming areas of faunal (and vegetal?) resources (b); possible evidence of working areas maintenance (c); possible sleeping/resting area and possible limits of the settled area (d)

The low-density area along the SE edge of the excavated area, both in SU 11a and 11b, could represent an actual bound- ary of the Neanderthal camp (e.g. the peripheral band or the limit between different occupation areas), as suggested both by its possible correspondence with the drip line and, in particular, by the presence of cores and large faunal remains (that could indicate a possible toss-zones). The hypotheses of additional sleeping/resting areas and/or of organic beddings (e.g. animal skins/mats) removed after the camp abandonment and/or of structures realized with organic materials producing a barrier-effect (e.g. tents or windbreakers) seems less parsimonious, thus less plausible. Nevertheless, the interpretation of this sector of the site is more problematic, due to the in- complete record of the camp caused by slope erosion.

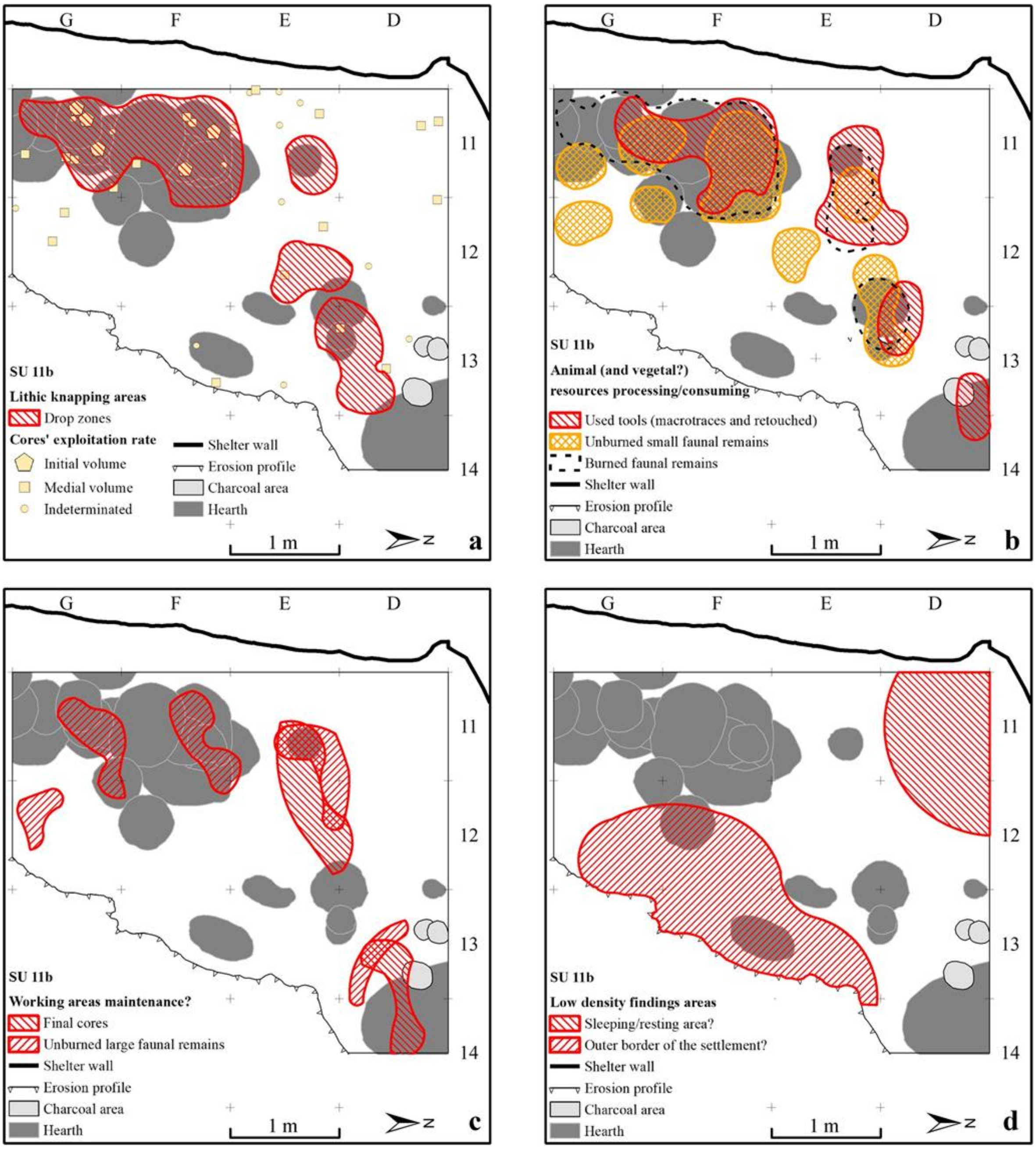

Fig. 10 Activity areas identified in the sub-unit 11a. Main lithic knapping areas (a); possible processing/consuming areas of faunal (and vegetal?) resources (b); possible evidence of working areas maintenance (c); possible sleeping/resting area and possible limits of the settled area (d)

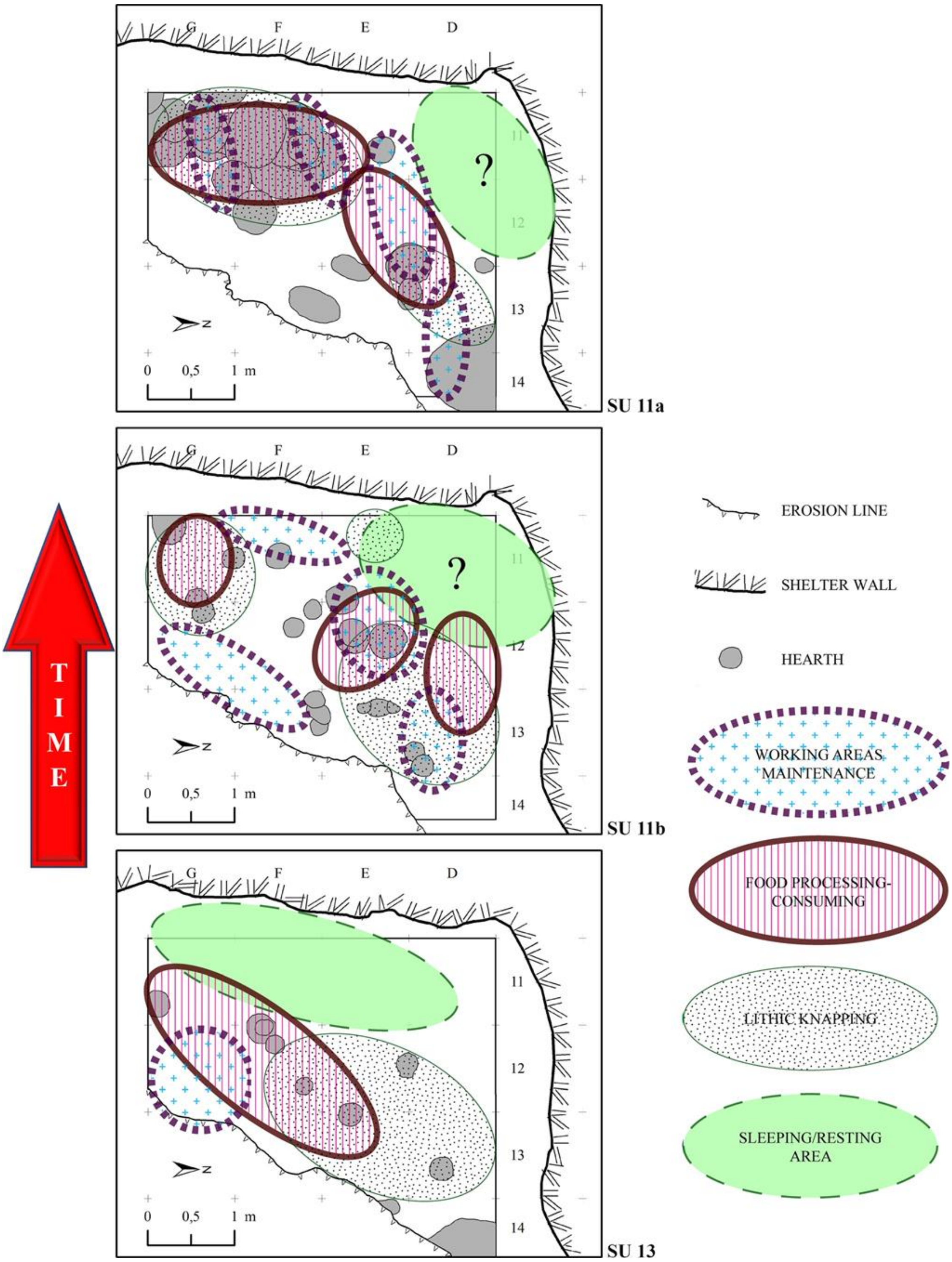

Fig. 11 General synthesis of the settlement structure evolution from SUs 13 to 11a

Finally, density patterns of archaeological findings and the cluster analysis allow to identify a different kind of activity areas, almost systematically related to hearths and partially overlapped. The "delimitation" and interpretation of these areas is easier in SU 13 (the short-term palimpsest) than in 11b and 11a, where the more intensive palimpsest-effect re- duces the archaeological visibility. Significantly, this seems to be mirrored also by cluster analysis: both the higher diversity index of the identified clusters and the cophenetic correlation of the SU 13 (Spagnolo et al. 2019:

Fig. 7) describe a more structured picture than the evidence from sub-units 11b and 11a (characterized by a lower inter-cluster variance and cophenetic correlation).

The density gradients of micro-debris are the best proxy to detect flint-knapping activity areas, when, as in this case, in- tensive post-depositional tractive disturbances can be ruled out. In this perspective, the spatial relation between some of the main micro-debris aggregates and the cores seems mean- ingful. Specifically, a clear dichotomy was recognized in re- lation to the cores' exploitation rate in SU 13: the few still usable cores are functionally related to the knapping areas of the Northern part of the excavated area, while the exhausted ones are clustered in a marginal area of the settlement where large faunal remains are also found (a waste dump) (Spagnolo et al. 2019: Fig. 6a–b). The picture which can be drawn from sub-units 11b and 11a appears more complex, due to less archaeological visibility. Macroscopically, in the sub-unit 11b, the cores seem mainly scattered along the borders of the main knapping areas with a subtle difference in position- ing related to their relative exploitation rate: the still usable cores are mainly placed along the "outer side" of the hearths' alignment, whereas the exhausted ones are immediately along the "inner side". The reason for this pattern could be a man- agement of the knapping areas which can be considered as a reflection of the double functional nature of the cores. This "peripheral" localization of the cores in relation to the knap- ping areas, on the one hand, could have been useful to keep the cores intended as a reserve of raw material (the still usable ones) within reach, on the other hand, it could be a by-product of the primary cleaning up of the working areas (the final volume cores), by the lateral pushing of production waste (e.g. Binford 1983; Clark 2017; O'Connell 1987; Stevenson 1991). A similar pattern (but more evident) comes from upper sub-unit 11a, where the usable cores are clearly clustered around the main micro-debris concentration, while the exhausted ones follow a similar pattern to that observed in sub-unit 11b. The recurrent correlation between the micro- debris and the still usable cores could suggest a possible func- tional identity, indicating a storing behaviour, with the cores conceived as a raw material reserve close to the lithic- knapping areas (Figs. 9, 10, 11).

The dynamics of faunal resources exploitation, as observed also in other sites, has a spatially fragmented character and seems to be organized into two main moments. It can be as- sumed that the first step was carried out directly on the killing sites and was aimed to the selective transportation of specific anatomical parts of the preys, as suggested by the systematic under-representation/absence of some skeletal districts in the camp-sites. The second butchery step (slaughtering, marrow extraction, spongy-bone processing and meat cooking/con- suming) was made in the residential camps (Boscato and Crezzini 2007). In Units 13, 11b and 11a of the Oscurusciuto Rockshelter, this step tends to take place around the hearths, according to the hearth-related activity areas mod- el (e.g. Bataille 2006; Gabucio et al. 2014, 2018; Henry 2012; Lembo et al. 2012; Modolo and Rosell 2017; Moreau and Locht 2017; Real et al. 2018; Spagnolo et al. 2019; Speth and Tchernov 2001; Speth et al. 2012; Valensi et al. 2013), as suggested by the spatial co-varying of lithic tools, small faunal remains and burned bones. This spatial overlapping suggests that at least some of the lithic tools could be involved in butchery activity. Nevertheless, other possible activities re- lated to the lithic implements (e.g. presence of hunting weapons, vegetal resourced processing, skin scraping, …) cannot be ruled out. Subsequent and systematic techno-func- tional/traceological analyses could help to deepen the spatial reading of these contexts (Figs. 9, 10, 11).

Another interesting behavioural aspect seems to be sug- gested by the spatial patterns of the large faunal remains and exhausted cores (as partially described above). In SU 13, both these categories were clearly clustered and spatially segregat- ed in a marginal area of the settlement (a possible heap), representing a clear evidence of preventive maintenance of the working areas. Significantly, this kind of behaviour along- side the presence of discrete activity areas (well highlighted by spatial and cluster analyses) is a clue of the long-term nature of the occupations in SU 13 (Spagnolo et al. 2019). As observed in ethno-archaeological studies, the hunter-gatherers site structure is primarily a function of the anticipated duration of stay at the camp and only secondarily of the actual length of the occupation. Therefore, spatial structure is "preventive- ly" established at the arrival of the hunter-gatherers at the sites (Galanidou 1997; Kent 1987, 1991). Articulated spatial struc- tures with both multipurpose and spatially segregated activity areas and/or curated features tend thus to occur in relation to planned long-term camping. At the contrary, when the planned depth of occupation is short the evidence of structured behaviours appears decisively less evident and less curated. The actual duration of the camp acts secondarily, incrementing the archaeological signal (and so the visibility) of the site structure. In this scenario, the palimpsest-effect deriving from several discrete occupations plays a decisive role in the ar- chaeological visibility preservation, due to the entropy deriv- ing from the overlapping of many camps. The evidence from sub-units 11b and 11a recalls some organizational aspects ob- served in the SU 13: the presence of a moderately similar spatial articulation of the camp is suggested by the hearths' pattern and by the hypothesised presence and interrelation of both multipurpose and segregated activity areas (also shown by cluster analysis). More specific aspects of these occupa- tions in SU 11, nevertheless, are obscure. Put it another way, despite the palimpsest effect magnitude, a similar settlement strategy could be identified in Units 13, 11b and 11a. In par- ticular, in sub-units 11b and 11a, the peripheral distribution of exhausted cores and large faunal remains along the borders of the main micro-debris and unburned small faunal remains aggregates resembles the spatial outcomes of peripheral pushing-out behaviours of wastes from the activity areas (e.g. Binford 1983; Clark 2017; O'Connell 1987; Stevenson 1991). Such a pattern represents a form of working areas maintenance (Figs. 9, 10, 11). The Mousterian contexts in which this type of evidence has been unequivocally highlight- ed are quite rare (e.g. Bataille 2006; Clark 2017; Gabucio et al. 2018; Henry 2012; Speth and Tchernov 2001; Speth et al. 2012; Valensi et al. 2013; Vaquero et al. 2012). Other possible clues of prolonged occupation derive from some lithic tech- nology observations, as the reprocessing of items from the site and the progressive increase of the retouched items in the lithic sample.

Diachronic reading

To sum up, a similar general model of space management produced a redundant structure in SUs 13, 11b and 11a. However, small-scale variations are recognizable along this sequence. The reasons for the changes can be related with the time component (spatial palimpsest) as the strict chrono- logical relation between the sampled SUs and the relative homogeneity of the environmental conditions in and around the site allow to rule out that these changes are conditioned by purely environmental factors. The overlapping of several long-term Mousterian residential camps that took place con- textually to the formation of SUs 13–11 seems to be framed in the continuum of the cyclical mobility patterns adopted by Neanderthals of the Oscurusciuto Rockshelter. Thus, a deeper analysis of these contexts is expected to shed new light on the Mousterian settlement and mobility strategies. As a conse- quence of these results and of their deep-time quality, an in- triguing hypothesis can be advanced. Behind the dichotomy between the statics and dynamics of Neanderthal occupations in SUs 13–11 of the Oscurusciuto Rockshelter, one of the quiet motors of history could be identified: the dialectic rela- tion between the collective memory of Group and the deep- time (Bailey and Galanidou 2009; Galanidou 2000; Ichikawa et al. 2011; Lovis and Donahue 2011; Whallon 2011). On one hand, the reiteration of the same spatial patterns and the struc- tural identity of the lithic production suggest that the same Neanderthal group, possibly also over different generations, could be responsible for the settling episodes reflected in these layers. On the other hand, the palimpsest character of the SUs 13 and 11 stresses the importance of the deep-time-related phenomena (as the generational replacement of individuals in the Group, the possible interaction/alternation between different groups, the local micro-variations of the environmental conditions, …). These phenomena, across the multiple (and unknown) settling episodes accrued in the formation of SUs 13–11, could have contributed to the accumulation of small- scale difference and variations in a general common settlement pattern characterized by a gradual progression. The over- all identity of the settling scheme seems to point in this direction together with the gradual transformation of the hearth sizes, the relative lateral “moving” of the possible sleeping/ resting areas in the “inner place” of the shelter and the persistence of the lithic production systems tradition (Fig. 11). The historical memory of places, that appears to be reflected by settlement dynamics of the SUs 13–11, is a key factor in the cyclicity of the mobility strategies among hunter-gatherers, in particular when crucial resources are involved (e.g. Binford 1980; Kelly 2013). In this sense, the Oscurusciuto Rockshelter could represent an attractive-point in the Palaeolithic land- scapes of Southernmost Italy, both for the presence of a shel- tered area in a ravine (with possible vegetal and hydrographic supplies and preys) and, especially, for the rich presence of very good quality raw materials. These characteristics could have contributed to turn this site into a placemark of the cognitive map of the Neanderthal Groups that lived in the Lucanian-Apulian region, in Southern Italy.

Conclusions

The Oscurusciuto Rockshelter is a key-point for the history of the last Neanderthals in Italy. The rich stratigraphic sequence, the characteristics of the anthropogenic materials and the pres- ence of both latent and evident structures make the site partic- ularly suitable for the reconstruction of multiple aspects of Neanderthal behaviour. The multifocal analyses performed in the contexts studied so far led to impressive results and, prospectively, new significant data will arise as the research at the site proceeds.

In this paper, multidisciplinary analyses were performed, focused on the Time and Spatial Archaeology approach, aiming to a diachronic reconstruction of the settlement dy- namics history along a relatively “brief” stratigraphic se- quence, deposited in the same paleoenvironmental context. The palimpsest nature of the layers here sampled (SUs 13 and 11), and their stratigraphic continuity allow for the recog- nition of multiple settling episodes, that can be enucleated in 3 main Units: SUs 13, 11b and 11a. In other terms, the short- term palimpsest echoed in SU 13 is in itself a reliable sample to be used in a behavioural approach, while a preliminary palimpsest dissection was required to understand SU 11.

In these Units, an interesting picture is given by the spatial- functional analysis which makes it possible to identify various inter-connected activity areas and hearths, making up the main feature of space structuring. This functional articulation of the camps can be linked both to the cultural and social roots of the Neanderthal groups that contributed to the formation of these archaeo-stratigraphic Units and to the actual nature of these Mousterian camp-sites.

The presence both of multipurpose hearth-related activity areas and “special” segregated activity areas (as the possible sleeping/resting areas and the secondary-refuse disposal areas) together with the clear site-structuration suggest a long-term nature of the occupations overlapped in SUs 13–11. From a diachronic perspective, the sequence of these long-term Mousterian camps took place within the framework of the continuous Neanderthals cyclical mobility. The gradual small-scale variations accumulated in the spatial patterns se- quence are a time-average consequence of the spatial palimp- sest spanning from SU 13 to SU 11a. Among the strongest evidence of these continuities, it is worth reminding the per- manency of the same general settling scheme, the gradual size-growing of the hearths, the hearths alignments rotation from a sub-parallel to a diagonal orientation in relation to the shelter wall enclosing an “inner place”, the persistence of a possible sleeping area in this “inner” part of the shelter and the continuity of the lithic production. The dichotomy between these small-scale variations and the general identity of the site structure seems to suggest the fascinating idea of a sort of historical memory of places handed down during the camp cyclical transfers. Namely, we could be looking at the material representation of the dialectic relationship between the collec- tive memory of Group and deep-time. In light of the mobility strategy adopted, the historical memory of places repre- sents a key factor for the hunter-gatherer's survival, in particular when the crucial resources are not homoge- neously distributed in the territory. In this sense, the Oscurusciuto Rockshelter could have represented a very important placemark in the cognitive map of a number of Neanderthal Groups of Southern Italy.

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Author contribution

Annamaria Ronchitelli is the research coordinator with Paolo Boscato and Francesco Boschin. Giulia Marciani in collabo- ration with Daniele Aureli studied the lithic industry. Ivan Martini per- formed the geoarchaeological analysis. Francesco Boschin and Paolo Boscato analysed the faunal remains. Vincenzo Spagnolo conceptualized the paper and performed the palimpsest dissecting and the spatial analy- ses. All the authors collaborated in writing reviewing and editing the final version of the paper.

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