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Between hearths and volcanic ash: The SU 13 palimpsest of the Oscurusciuto rock shelter (Ginosa e Southern Italy): Analytical and interpretative questions

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Abstract:

The Oscurusciuto rock shelter, located in the ravine of Ginosa (Taranto), is one of the key sites for the study of Neanderthal groups in Southern Italy. The rich stratigraphic sequence of the site, which is ascribable entirely to the Middle Palaeolithic, is rich in anthropic remains and combustion structures, attesting occupation by Neanderthals during MIS 3. This paper is focused on the study of Stratigraphic Unit (SU) 13, made up of a compact sandy sediment mixed with pyroclastic sediment derived from the underlying tephra level (SU 14). The latter has been identified as Monte Epomeo green tuff (dated Ar/Ar 55 ± 2 ka). The first stable human occupation of the shelter after tephra deposition is represented by unit
13. Our aim here is that of separating the Stratigraphic Unit into its main components so as to obtain a high temporal resolution on the activities which took place in this SU, and to reconstruct the individual events which formed the palimpsest. In order to fulfil these objectives, a multidisciplinary approach was needed through which data could be integrated from the microstratigraphy of the hearths; from the technological study of the lithic industries; from the individuation of the Raw Material Units (RMUs); from refitting and cojoining and from spatial analysis (GIS science/tool). The integration of these analytical methods reveals that SU 13 of the Oscurusciuto rock shelter was the product of a series of events ascribable to a short time span. This layer was formed by sediment aggradation and cementation (e.g., brecciation) processes. Human activities contributed to the sediment build up with the introduction of wood ash, lithic raw materials and bones. The results show the importance of using integrated research methods in order to identify short anthropic events within a palimpsest.

1. Introduction

The palimpsest problem in archaeology has become one of the main themes of scientific debate, due to the "flattening-effect" of an unknown number of individual events, with an unknown life span, into a single layer. Currently, the solution focuses on achieving a high resolution in the data analysis, in order to understand more accurately the cultural, social and economic dynamics in the archaeological context (quoting a few recent papers: Vaquero,2008; Bailey and Galanidou, 2009; Malinsky-Buller et al., 2011; Carbonell I Roura, 2012; de la Torre et al., 2012; Henry, 2012; Rosell et al., 2012; Machado et al., 2013; Mallol et al., 2013; Bisson et al., 2014). In these works, a new orientation in research is evident, emerging from the improvement of analytical techniques. Beyond the identification of single (short-term) occupational episodes, the "goal for future research is to transcend this descriptive label, as these may enclose diverse historical dynamics whose explanation can be sought by taking a close look into the specific activities performed and their role within a territorial context" (Machado et al., 2013: 2272).

This paper focuses on the "dissection" of a Middle Palaeolithic palimpsest (SU 13) from the Oscurusciuto rock shelter (Ginosa, Taranto, Southern Italy). In the context of the rich stratigraphic sequence of the Oscurusciuto rock shelter, SU 13 constitutes a privileged context for the setting up of an analytical protocol for palimpsest analyses. The crucial elements of SU 13 are its stratigraphic position (a sedimentological unit located between a dated sterile tephra level underneath and subsequent occupation levels), its extension (wider than the upper levels), the presence of hearths structures and a fairly low quantity of materials. This has made it easier to develop an integrated study aimed at understanding this palimpsest.

The main goal was to obtain a high temporal resolution of the activities recorded in this archaeological layer, in order to understand how those activities constitute a palimpsest. Furthermore, a second purpose was the identification of individual episodes of occupation, recognizable by the integrated study of material culture. These data may shed light on a research line which allows a different and innovative approach to dealing with the study of the economic and settlement strategies of Neanderthal groups.

A multidisciplinary approach has been necessary in order to fulfil our objectives. As a first analytical step, the level of integrity of the layer was verified through the study of the state of preservation of the anthropic remains and microstratigraphy of the hearths e and through the chisquared analysis of the faunal remains and lithic industry distribution. The following steps e the technological study of the lithic industry, the individuation of the RMUs, refittings and cojoints, and spatial analysis e have made it possible to individuate single activities which took place within the layer. From the integration of these methods it has been possible to obtain a complete view of the activities making up the palimpsest of this Stratigraphic Unit.

2. The Oscurusciuto rock shelter

The Oscurusciuto rock shelter is located in the ravine of Ginosa (TA), in southern Italy, at 235 m above sea level. The geomorphological background of this site favored both the presence of caves and shelters and the rich availability in loco of limestone and siliceous resources (such as quartz, quartzarenite, siliceous limestone, chert and jasper) contained in the form of pebbles within conglomerate terraces. Together with the presence of plateaux and coastal flood plains, areas suited for the grazing of herbivores a few kilometres from the site, this would have made the shelter a place of potential attraction for Neanderthal groups.

Excavations at the Oscurusciuto rock shelter began in 1998 and, up to now, nine Middle Palaeolithic occupation phases have been investigated, corresponding to the first 3 m of the

stratigraphy. All the levels are characterized by a great abundance of lithic and faunal remains. The discovery of a living floor (SU 15) is of particular importance. Still under exploration, this is sealed by tephra (SU 14) and is characterized by the presence of structures defined by stones. The current extension of the whole Oscurusciuto deposit is 60 m2, with a stratigraphy over 6 m deep, but the sequence is eroded, particularly in the upper strata (Fig. 1). The chronological limits, at present, are obtained by two dates: the first is a 14C date, referred to the bottom of SU 1, of 38,500 ± 900 BP e AMS, Beta 181165; cal. 42,724 ± 716 BP (Bronk Ramsev and Lee, 2013). The second derives from the identification of the tephra layer (SU 14) as Mount Epomeo green tuff, dated to about 55 ka BP (Allen et al., 2000). Therefore the upper part of the stratigraphic sequence refers to the final phase of the Middle Palaeolithic, an epoch close to that of the disappearance of Neanderthals in Southern Italy, which is presently a central topic of scientific debate (Higham et al., 2014). Regarding the lithic industry of the units so far excavated, the unipolar Levallois production system is predominant (Villa et al., 2009; Boscato et al., 2011; Ronchitelli et al., 2011). The faunal remains in the lower part of the analyzed deposit (SU 15 to SU 4), exclusively attributed to human activities, are characterized by high frequencies of Bos primigenius, which indicates a particular type of open environment and forest steppe, in association with Cervus elaphus, Dama dama, Capreolus capreolus, Equus ferus and rare appearances of Capra ibex and Rupicapra sp. Sporadic remains of carnivores: Panthera leo, and Canis lupus are present, too. The upper units refer to a more temperate and moist phase, since the number of cervids is higher (Boscato and Crezzini, 2012a). In the middle and lower part of the investigated stratigraphic sequence many combustion structures were found. In SU 13, SU 11 and SU 9 the hearths had two dimensional typologies: little (with diameters of about 20 cm) and larger (with around 50 cm in diameter). In these SUs most hearths were located along a belt separated from the rock shelter wall. In SU 7 a large hearth (2 m wide) was located in the NeW corner of the shelter (Boscato and Ronchitelli, 2008).

The Oscurusciuto rock shelter can be considered as a key site for the Palaeolithic peopling of Apulia and Lucania. This is because of its geographic position (between the eastern and western regions of southern Italy), its long stratigraphic sequence, the good preservation of structures with spatial organization and the large quantity of preserved remains.

The first permanent settlement of the site after the deposition of the Mt. Epomeo green tuff is recorded in Stratigraphic Unit 13, which is the subject of this paper (Fig. 2). This SU is characterized by the presence of hearths and by the activity of lithic knapping and butchering. SU 13 consists of compact sediment, created by the stirring of the underlying tephra (SU 14) and sand, with rare small pieces of calcarenite. On the other hand, the intensively anthropized upper Stratigraphic Unit shows a loamy sand matrix. The layer is a subhorizontal stratum with a weak slope. It is probably preserved for about 20 m2, but the excavated area amounts to about 11 m2. The median thickness is 10 cm, with a variability between 20 cm (in the outer part of the stratum) and 1 cm (in the inner part of the stratum, at the contact with the rock shelter wall). The lithic and faunal archaeological remains are distributed along the whole thickness of the layer, without any evident secondary separation levels.

In SU 13 ten hearths (Fig. 2) were identified: nine have a subcircular shape (about 20 cm in diameter). Only one, SU 12, (Fig. 2), placed on the erosional line, is bigger and probably it is made up by an overlapping of different hearths. Nine hearths were placed on the top portion of SU 13, whereas only SU 82 (Fig. 2) was within the layer. There is only one stratigraphic overlap between hearths: SU 84 and SU 83B are upon SU 83A (Fig. 2). No stratigraphic relationship is attested between SU 84 and SU 83B. SU 79 is an accumulation of ash found in the central part of the excavated area (Fig. 2).

Among the many Middle Palaeolithic sites of Apulia and Lucania, the long stratigraphic sequence of the Cavallo cave (the reference site for the whole of Southern Italy, located at about 120 km from

Oscurusciuto) shows Final Mousterian levels (MIS3) with faunal associations similar to those of Oscurusciuto (Sarti et al., 2000). An initial phase characterized by the diffusion of wooded grassland with a large presence of aurochs is recorded (FIIIe). This is followed by a temperate phase with a notable increase in fallow deer (FIIId- FIIIa) and by a third phase, the most recent one, with a more arid climate, with relatively abundant aurochs and horse (FII-FI). As in the Oscurusciuto, the degree of bone fragmentation at this site is also high (Boscato and Crezzini, 2012b). Levels FIIIe and FIIId of the Cavallo cave fall within the same chronological horizon as SU 13 at the Oscurusciuto (about 50,000 BP). Nonetheless, the production methods show differences alongside certain analogies. It is important to underline the sheer difference between the two sites as to the raw materials employed: pebbles at the Oscurusciuto and small slabs ("lastrine") at the Cavallo.

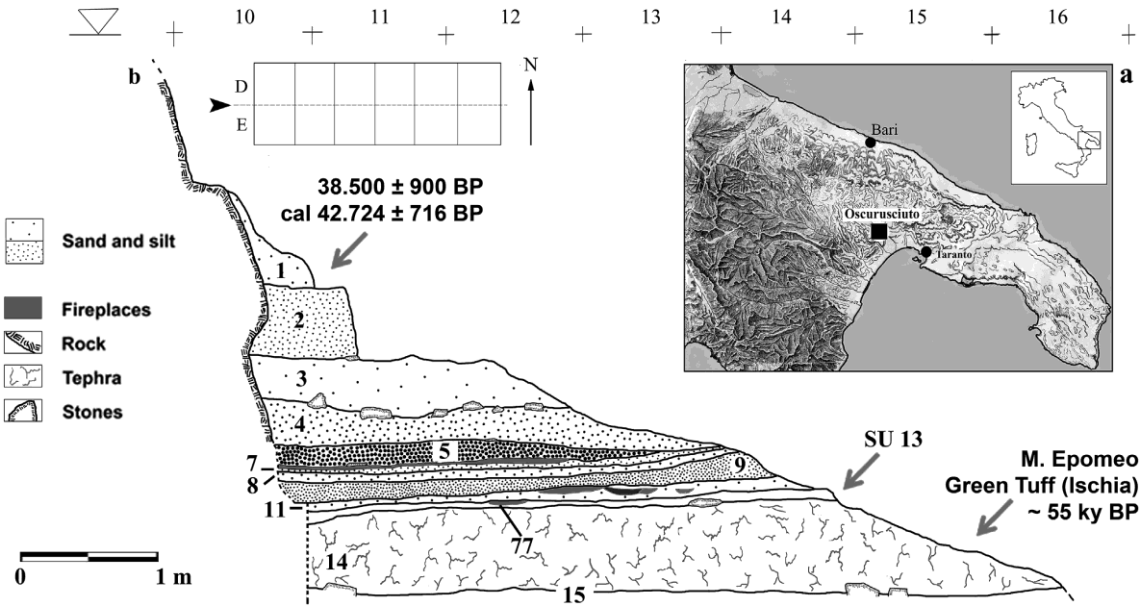


Fig. 1. Localization of the site (a) and stratigraphic sequence of the Oscurusciuto rock shelter (b). Relief P. Boscato, drawing A. Ronchitelli.

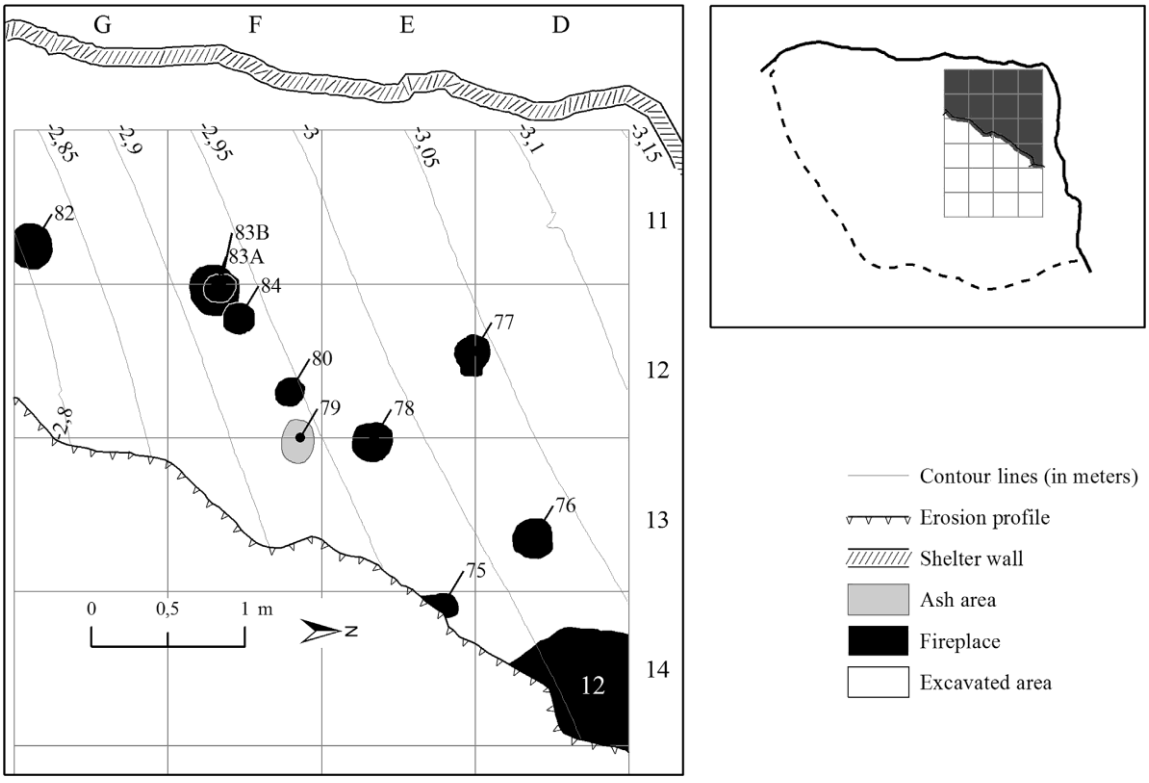


Fig. 2. Stratigraphic Unit 13, excavated area. Relief: P. Boscato, drawing: A. Ronchitelli, V. Spagnolo.

Whereas at the Oscurusciuto the most recurrent Levallois modalities are the unipolar and convergent ones, alongside a marginal presence of the volumetric method for the production of bladelets, at the Cavallo cave, the most frequent Levallois modalities are the centripetal and unibipolar ones, associated with a large volumetric production for the extraction of blade-bladelets, obtained through a different management of volumes (Carmignani, 2010, 2011).

3. Methods

The palimpsest analysis was aimed at an accurate reconstruction of the economic, social and cultural aspects as they emerge from the archaeological evidence. In order to achieve this objective, a multidisciplinary analytical protocol was conducted, comprising combustion features microstratigraphy, faunal analysis, lithic technological studies (including RMUs and lithic refitting/conjoin), and finally spatial studies.
The microstratigraphical study of the hearths was designed to individuate human activities associated with the management and combustion conditions of such features. The study of the fauna has led to the identification of the represented species, of the anatomical elements and their fragmentation conditions. The study of the lithic industry with the RMU method was set up in order to identify the minimum number of raw material units introduced in the site. The results of these studies were then fed into a GIS platform which was created for testing the state of preservation of the layer. This took into account the physical state of lithics, the microstratigraphy of hearths, the presence/absence of biotic alterations and the analysis of the density maps of microremains in relation to the morphology of the layer in order to verify whether the distribution of the various

categories of materials followed a given organization or was purely random (chi square test). This was done in order to obtain a high temporal resolution interpretation of the activities sequence which took place in SU 13 (spatial patterning of RMUs, distance between refittings, microstratigraphy of hearths).

3.1. Hearths: microstratigraphic analysis

Intact sediment blocks were collected from hearths SU 12, SU 77, SU 78, SU 80, SU 82, and SU 83. The blocks were embedded with polyester resin and processed into petrographic thin sections. The thin sections were analyzed by petrographic microscopy and Fourier transform infrared microspectrometry (m-FTIR) using a Thermo iN10 XM imaging FTIR microscope. Soil micromorphology descriptions were conducted following the criteria indicated in Stoops (2003). The integration of petrography, soil micromorphology and m-FTIR for the analysis of thin sections of intact archaeological deposits allows us to untangle the natural and cultural processes occurring in archaeological sites (Goldberg and Berna, 2010). In fact, the geogenic, biogenic, and anthropogenic components are best identified at the microscopic scale, as are the transport, deposition and diagenetic processes (Goldberg and Macphail, 2006). In particular, the micromorphological study of hearths and other combustion features allows for the identification of human activities associated with their management (e.g., pitting, fueling) and intentional and unintentional modifications such as ash removal and dumping, rake out, trampling and scuffing (Goldberg and Berna, 2010). By FTIR it is possible to identify and characterize the crystalline state of organic and inorganic phases composing bone (i.e., collagen and carbonate-hydroxyl apatite), soil (e.g., clay minerals, carbonates, sulphates, phosphates, nitrates) and wood ash (e.g., pyrogenic calcite, charcoal, and opaline phytoliths) (Weiner, 2010). Moreover, m-FTIR enables the estimation of temperature reached by bone, carbonates, and soil inclusions and consequently allows the reconstruction of combustion conditions of a given hearth (Berna and Goldberg, 2007; Berna et al., 2012). The microstratigraphic analyses at Oscurusciuto rock shelter were focused on the identification of soil microfabric units (Stoops, 2003) composing the overall matrix of SU 13 and the components of the different combustion features (i.e., SU 12, SU 77, SU 78, SU 80, SU 82 and SU 83) included in SU 13.

3.2. Faunal analysis

Faunal remains of SU 13 were divided into two qualitative classes (burned and unburned) and four dimensional classes (1e3 cm, 3e6 cm, 6e10 cm, >10 cm). Taxonomic data could only be recorded for a few remains, due to the high degree of fragmentation.

3.3. Lithic analysis: definition of a method to individuate more reliable RMUs

The study of lithic finds was based on the Raw Material Unit (RMU) approach (Roebroeks, 1988; Hall and Larson, 2004; Uthmeier, 2006; Vaquero, 2008; Romagnoli, 2012; Vaquero et al., 2012; White, 2012; Machado et al., 2013).
This approach permits the isolation of groups of lithic items pertinent to a single lithic unit\block, in this case pebbles. In this way it is possible to quantify the minimum number of raw materials brought into the site and to identify knapping, use and discard episodes and eventual importation or exportation of tools in order to have a clearer comprehension of the reduction sequence. A most effective result is obtained with an extensive programme of recognizing refittings and conjoins (Larson and Ingbar, 1992; Schurmans, 2007) as well as technological and spatial analysis of the

pieces integrating each RMU. An advantage of this method is the ability to identify the postdepositional translocation of lithic remains, which enhances correct detection of single human occupation episodes and different functional areas (Machado et al., 2013). The lithic finds were classified in five dimensional classes (1e50 mm2, 51e100 mm2, 101e150 mm2, 151e200 mm2, >200 mm2).
Different lithic groups (RMUs) were established, based on macroscopic traits of the lithic artifacts such as cortex color and thickness, texture, color, inclusions and opacity. A limitation on the application of this method is encountered when there are burnt, patinated or altered pieces, when there are tiny specimens or when the raw material is too homogeneous and impossible to separate. While RMU identification is currently a well consolidated practice in Paleolithic research, the subjectivity involved in their determination seems to be a problematic factor. For this reason a protocol was developed to evaluate the reliability of each RMU. At first, the indeterminable elements of the lithic assemblage were removed ("indeterminable" is defined as altered or tiny items smaller than 50 mm2). Then the remainder of the assemblage was divided into lithological categories according to the type and granulometry of the lithic raw material here defined: CL 1 fine grained jasper; CL 2 fine grained chert; CL 3 middle grained jasper; CL 4 middle grained chert; CL 5 middle grained siliceous limestone; CL 6 middle grained limestone; CL 7 coarse grained chert; CL 8 coarse grained siliceous limestone; CL 9 middle grained quartzarenite; CL 10 coarse grained quartzarenite; CL11 coarse grained limestone; CL 12 indeterminate. Consequently, based on macroscopic similarity within each lithological category, the RMUs were identified. The estimation of the reliability degree of the RMU (excellent, good or bad) was based on the evaluation of some parameters, each with its own numeric value: "Refitting Ratio", "Variability of Raw Material", "Uniqueness of Raw Material". The Refitting Ratio expressed the ratio between the number of conjoined or refitted items and the total quantity of elements in the RMU. The Variability of Raw Material represented the degree of internal variability in each single block of raw material (that can be homogeneous or inhomogeneous). The Uniqueness of Raw Material constituted the degree of inter-RMU variability, in other words the formal similarity between different RMUs (that can be unique or not unique). The level of reliability was calculated on the basis of the arithmetical sum of the above listed parameters (Marciani, 2013; Spagnolo, 2013).

3.4. Taphonomy and spatial analysis

The elaboration of spatial data was performed using ArcGIS® 10.2, with a specifically designed geodatabase (Spagnolo, 2013).
The preservation degree of SU 13 was tested. The considered parameters for this test included the state of a lithic's edges (fresh or floated), the microstratigraphy of hearths, the presence/ absence of biotic alterations, the chi-square test for the spatial pattern evaluation, the analysis of micro-flakes and micro- fragment accumulations in relation to the surface morphology of SU 13, the length of the refitting/conjoint lines and, finally, the spatial patterns of the RMUs (e.g. Dini and Moriconi, 2004: 52e57; Goldberg and Macphail, 2006: 42e84; Mallol et al., 2010, 2013; Drennan, 2009: 181e195; Stevenson, 1991; Bertran et al., 2012).
The chi-square test was performed in order to assess if the distribution modalities of the archaeological and faunal materials within the excavated area reflected a pattern of some kind or fell within a random statistical oscillation. The real distribution was compared with an expected distribution defined with the Poisson function (null hypothesis) corresponding to a random distribution with a 99.999% confidence interval. The test was performed in order to test the clustering rate of the lithic finds and faunal remains (Drennan, 2009: 181e195). Quadrants with an integrity level <88% were discarded in order not to distort the results of the test. As the test made

use of real quantities, it required quantitatively comparable sampled areas in order to be effective. This led us to exclude the quadrants which were too eroded as the material within them would be strongly underestimated in the test.

In some sectors, most artifacts were recovered by sieving (in particular all the lithics smaller than 200 mm2), so the only spatial reference known for these pieces is the quadrant (50 50 cm) of origin. The visualization of the lithic and faunal remains distribution pattern is allowed by adopting a random positioning strategy (ArcGIS® 10.2\Data management tools\Create random points) for the items recovered by sieving. For the other artifacts, the real coordinates were taken into consideration. In this manner, the realization of a micro-flake density map was also possible. The error in the randomly positioned points is negligible when the positioning cells (50 50 cm in this context) are smaller than the spatial phenomena under investigation. The scatters produced by lithic reduction activities are in the same dimensional module of the
excavation grid (Vidale, 1992: 158e160; Vaquero and Pasto`, 2001; Jones, 2008; Olausson, 2010; Bertran et al., 2012, 2015).

Starting from the distribution maps, the spatial patterns of the main categories of evidence (burned faunal remains, dimensional classes of unburned faunal remains, dimensional classes and technological categories of lithic finds and reliable RMUs with at least 10 items) were analyzed using Ripley's K function (Bevan and Conolly, 2006; Schwarz and Mount, 2006; Winter-Livneh et al., 2010). This tool was used in order to illustrate the relationship between the clustering or the dispersion of feature centroids and the neighborhood size changes (ArcGIS® 10.2\Spatial statistics tools\Multi-Distance Spatial Cluster Analysis). Density maps were also produced for these categories, using the kernel algorithm (with search radius at 0.25 m).

The premise that the weak slope of the SU 13 surface was in itself a potentially important factor for context preservation was investigated. In particular we examined whether stream flow, overland flow, scuffage and/or trampling (Stevenson, 1991; Bertran et al., 2012, 2015) might have influenced the assemblage spatial configuration. For this purpose, the Dimensional Classes maps and, in particular, the micro-flake accumulations shapes were evaluated in relation to the contours line based on the Digital Elevation Model of SU 13 (Figs. 3 and 4).

In order to carry out the analysis of the refitting patterns, it was necessary to assess how far the inaccuracy of the random positioning could generate a misreading of the refitting/conjoint lines length pattern. There were three possible scenarios: 1) both the related artifact had known coordinates; 2) only one artifact in the pair had known coordinates; 3) both the related artifacts were randomly positioned. In the first case, the distance between the refitted elements was represented by the simple line, without error. In the second case, the error range evaluation was made measuring the minimum and maximum distances from the known point to the quadrant of the refitted artifact with unknown coordinates. In the last case, the minimum and maximum distances between the quadrants of the refitted artifact were calculated. The average values (between Max and min) were reported on a scatterplot graph with error bars (difference between Max and mean) (Fig. S1). RMU analysis is a powerful tool for dissecting palimpsests,
because of its potential capacity to achieve a high resolution view of activities carried out at the site (Vaquero, 2008, 2011; Lo´pezOrtega
et al., 2011; Machado et al., 2011, 2013; Carbonell I Roura, 2012; Vaquero et al., 2012). The spatial component of the RMU can help significantly in this analytical operation. For this reason some specific maps were produced for RMUs with at least 10 artifacts and good/excellent reliability degrees. In line with the results of Ripley's K function, vertical distributions of the aforementioned RMUs were grouped by spatial pattern and analyzed.

4. Results

4.1. SU 13 and hearths microstratigraphy

The micromorphological investigation of six (SU 12, SU 77, SU 78, SU 80, SU 82 and SU 83) of the ten excavated hearths revealed the presence of several micro-fabric units (mFUs) and sub-units (see Fig. 5, S2 and S3). These are:
mFU1 (Fig. 5a) e a fairly well preserved light tan volcanic tuff with characteristic needle and tubular glass crystals (Epomeo green tuff). mFU1 is the major component of the basal Stratigraphic Unit at the site (i.e., SU 14) and appears as cm-size aggregates (e.g., in SU 77 and SU 82, Fig. S3) and as burrow fill (e.g., SU 80, Fig. S3) in the micro-Stratigraphic Units forming the hearths.
mFU2 (Fig. 5b) e a slightly altered volcanic tuff with iron rich amorphous clay, found dispersed in the ground mass and coprecipitated with micrite in mm-size laminae and domains. mFU2 also contains variable amounts of quartz fine sand, micrite silt and sand, amorphous organic matter, plus subangular charred and uncharred bone fragments. mFU2 composes the bottom microStratigraphic Unit underlying SU 77 (Fig. S3).
mFU3 (Fig. 5c) e a colluvium supported by the mFU2 fine matrix and containing heterogeneous angular to rounded gravel, inclusive of local lithology (micritic and fossiliferous limestone, flowstone, etc.), exotic raw materials such as chalcedony chert and jasper (e.g., SU 78 e Fig. S2b), and fragments of charred and uncharred bone (Fig. S2b, S2c, and Fig. S3), coprolites (Fig. S2b), and charred and humified plant materials (Fig. S2c). mFU3 is the most common micro-fabric unit and represents the rock shelter basal deposit formed by the weathering of the underlying tephra and the colluviation of local rock and soil fragments with anthropogenic manuports (Fig. S2 and Fig. S3). mFU3 is diffusely cemented by micritic precipitate (Fig. 5c) and is found at the base of the hearths and also capping the wood ash layers in SU 12, SU 77, SU 78, SU 82, SU 83 (Fig. S2 and Fig. S3). mFU3a (Fig. S2b and Fig. S2c) is very similar in general composition and structure to mFU3, the only difference being that it is darker in color (dark brown). The darker color appears to be caused by a discoloration of the fine fraction possibly due to redox reaction of the iron compounds contained in the clay minerals and micrite due to the combustion of overlying fuel. mFU3a occurs in SUs 77, 78, 80, and 83 (Fig. S2 and Fig. S3). mFU3b (Fig. 5d) is very similar to mFU3 and mFU3a but shows a blackish brown color. The specific color of mFU3b appears to correlate to an increase in the abundance of partially decayed charcoal and micro-charcoal fragments with respect to mFU3 and 3a. mFU3b includes a microlayer of SU 12 (Fig. S3) and a burrow of SU 82 (Fig. S3).
mFU4 (Fig. S2) e light gray to blackish gray laminated micrite (Fig. S2b and Fig. S2c) with domains of oxalate pseudomorphs (i.e., “wood ash” e Fig. S2d), ashed and charred plant remains, and a few charcoal and bone fragments (calcined, charred, and uncharred). No grass phytoliths were observed in mFU4, thus it appears to be derived from the combustion of woody and brush plant tissues. mFU4 has been found in SU 78 (Fig. S2) and highly broken up and reworked (mFU4a) in SU 12, SU 80 and SU 83 (Fig. S3). In summary the six hearths appear to be composed of wood ash layers (mFU4 and mFU4a) overlying or mixing within not discolored and discolored substratum (i.e., SU 13) composed of mFU1, mFU2, and mFU3.

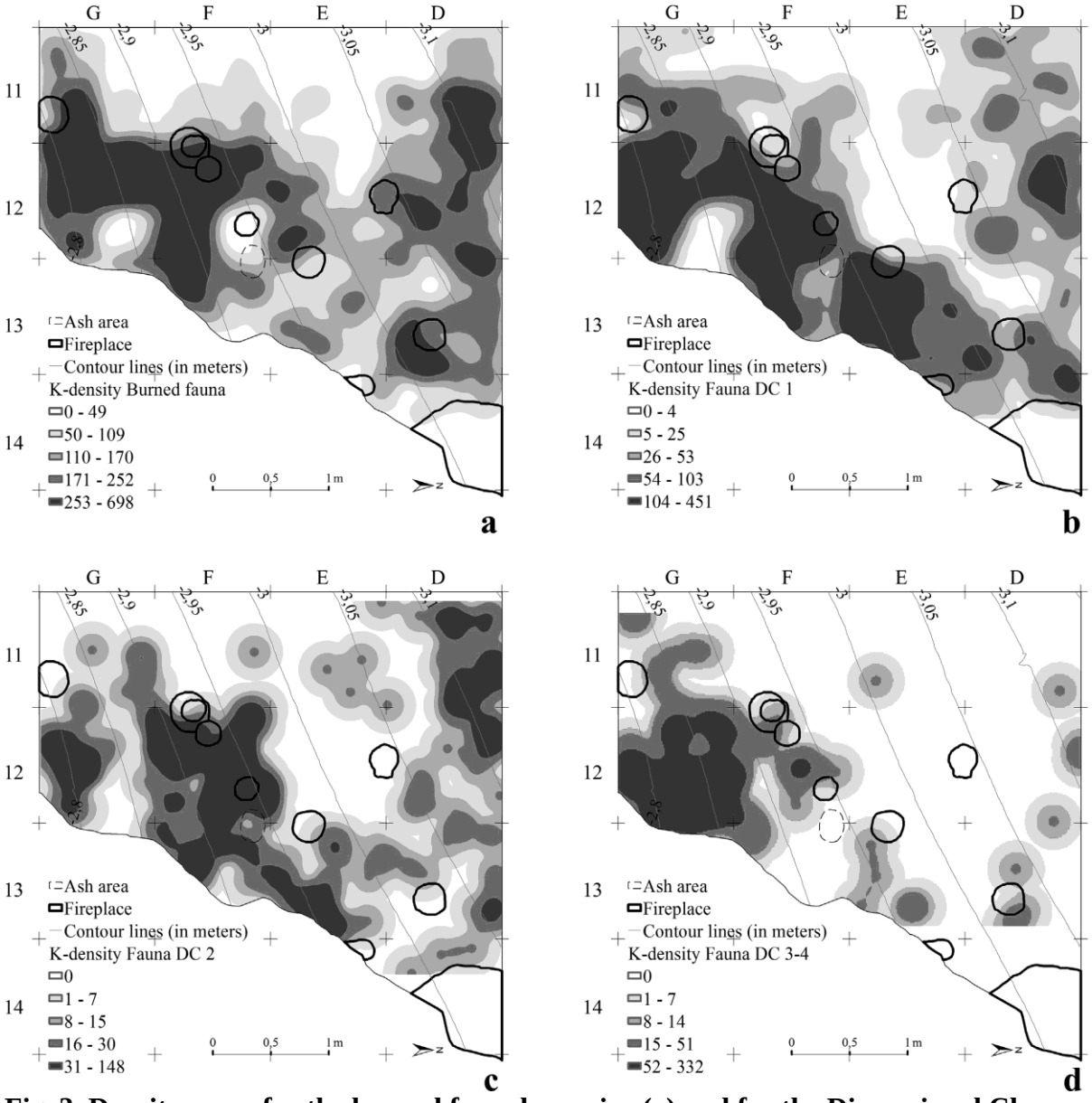


Fig. 3. Density maps for the burned faunal remains (a) and for the Dimensional Classes of the unburned faunal remains: DC 1 ¼ 1e3 cm (b), DC 2 ¼ 3e6 cm (c), DC 3e4 > 6 cm (d).

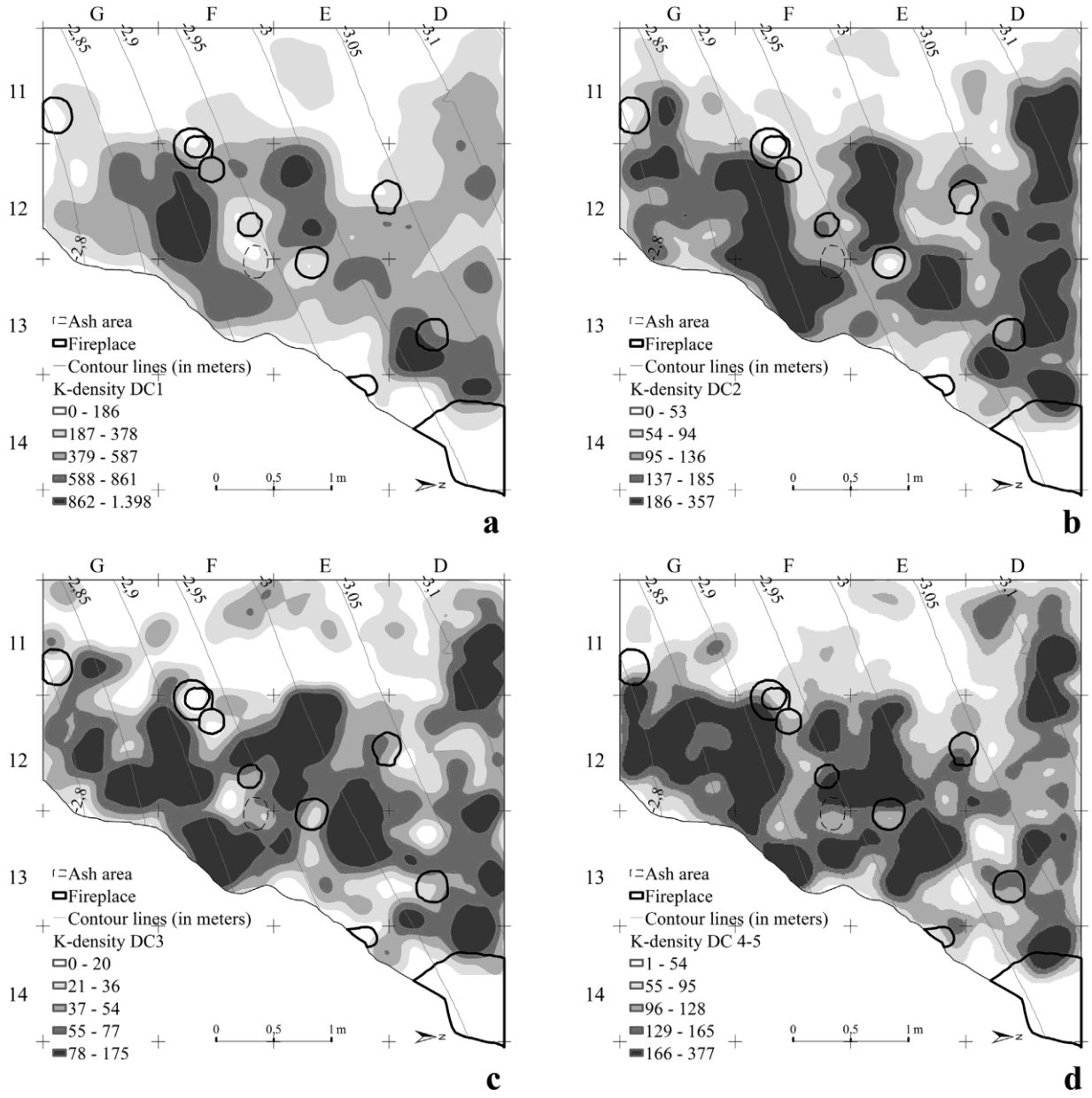
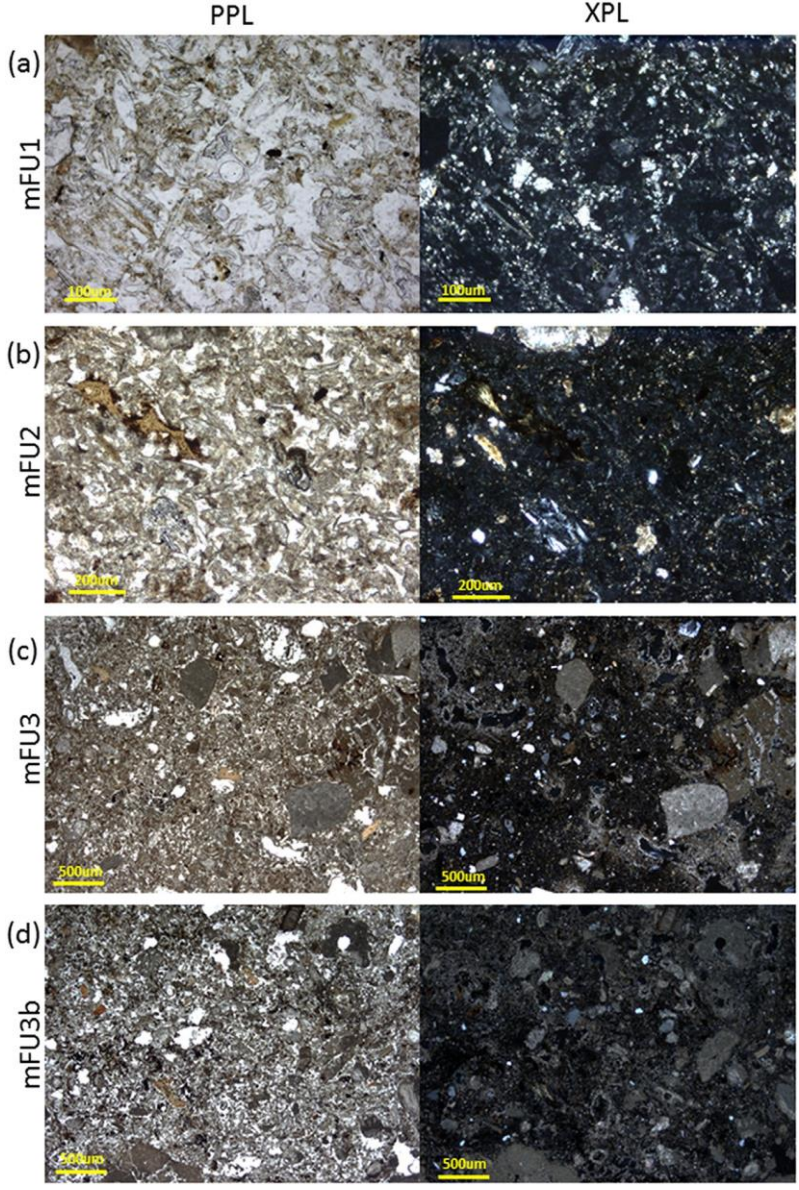


Fig. 4. Density maps the Dimensional Classes of lithic finds: a) 1e50 mm2; b) 50e100 mm2; c) 100e150 mm2; d) >150 mm2.

4.1.1. Syn and postdepositional processes

At the microscopic scale the deposits show evidence of intense syndepositional bioturbation. The diffuse intrapedal granular microstructure (Fig. 5c, d and Fig. S2c) suggests that the deposits were reworked by the trophic action of organisms such as earth worms and mites. Horizontal and vertical passage features, rhizo liths in particular, broken boundaries and deformation features (e.g., SU 77) are commonly observable in the thin sections (Fig. S2b and Fig. S3). Micromorphological analysis shows evidence of at least two major processes of deposit cementation by calcium car bonate (Fig. 5aed and Fig. S3): (1) a syndepositional formation of micritic calcite precipitating diffusely in the ground mass; (2) a postdepositional formation of microsparitic infillings, coatings and hypocoatings of chambers, vaugs and channels. Bioturbation and carbonation of the sediments disturbed and obliterated the microscopic spatial organization of the original constituents. The precipitation and crystallization of calcite associated with the alkalinity of the soil solution appears to have



particularly affected the preservation of the charcoal (e.g., in SU 80 e Fig. S3). On the other hand evidence of heavy trampling (human) is very limited. In fact most of the large flatlying objects observed in thin sections (Fig. S3) do not show sign of being trampled. This observation suggests that the physical impact on the site and the hearths by the human group occupying the shelter had limited effects at the microscopic scale.

Fig. 5. Representative photomicrographs in plane-(PPL) and cross-(XPL) polarised light of: (a) micro-fabric unit 1 (mFU1) from burrow in SU 80; (b) micro-fabric unit 2 (mFU2) from the bottom of SU 77; (c) micro-fabric unit 3 (mFU3) from the base of SU 80; (d) micro-fabric unit 3b (mFU3b) with abundant micro-fragments of charred plant materials from SU 12. Note in the XPL microphotographs the micritic cementation of the groundmass and the microsparitic coatings and hypo-coatings of voids and channels.

4.1.2. Hearths and palimpsest

Here we briefly report the results from the analysis of three hearths (SU 12, SU 78, and SU 83) that are most informative for the reconstruction of the palimpsest evolution of SU 13.

SU 12. The micromorphological analysis of sample OSC127 (Fig. S3) collected from SU 12 shows the presence of four microStratigraphic Units and several passage features (burrows). The top unit is composed of rock shelter deposit (mFU3) that caps a heavily reworked wood ash deposit

(mFU4a). The ashes appear to lie directly on top of a rock shelter stable surface revealed by the presence of flat-lying gravel size fragments of bone (m-FTIR heated < 500 ◦C) and chert (Fig. S3). The sediment underneath the reworked wood ash deposit is blackish brown and contains abundant amounts of weathered micro-charcoal (mFU3b e Fig. 5d). m-FTIR analysis also indicates that the associated fine fraction of the sediment did not reach temperatures above 500 ◦C. The portion of hearth SU 12 analyzed thus appears
to be the remains of reworked wood ash lying on the rock shelter surface (i.e. SU 13) above the remains of decomposing, partially uncombusted fuel from an older combustion event shallowly buried in SU 13.
SU 78. In the thin section prepared from sample OSC140 from SU 78, four superimposed microstratigraphic layers cut by several passage features are observable (Fig. S2). Here a 5 mm thick layer of fairly well-preserved laminated wood ash is overlying a sharp and irregular boundary of a shallow pit (Fig. S2c). The sediment underneath the wood ash layer is discolored but does not contain major quantities of charcoal nor does m-FTIR analysis show that it
was heated diffusely above 500 ◦C. It thus appears that the analyzed
portion of SU 78 is the remains of a hearth fueled on top of the SU 13 with a small amount of woody material that underwent complete combustion. The wood ash layer appears to be capped by more rock shelter deposits (i.e., SU 13), suggesting that this specific location was used very briefly, and possibly refueled a few times only.
SU 83. The thin section prepared from sample OSC146 shows that portions of hearth SU 83 are composed of two major microstratigraphic layers (Fig. S3). The top layer is composed of a ca. 1e2 cm thick heavily reworked wood ash deposit (mFU4a) containing partially calcined bone fragments (m-FTIR ¼ heated above 500 ◦C but below 800 ◦C). The boundary between the reworked wood ash layer and the underlying anthropogenic rock shelter deposit is sharp but extremely irregular. Moreover the shape of the boundary corresponding to the area sampled by the thin section is convex, suggesting that the hearth was not prepared in a pit. It thus appears that SU 83 was prepared on the irregular surface of the rock shelter (i.e., SU 13) and, with respect to the other hearths so far analyzed, it was fueled with a larger quantity of wood and other combustible materials and may have reached higher temperatures. A screening by m-FTIR of bone fragments (N 67) observed in the six available thin sections shows that only a small percentage (8%) reached temperatures above 700 ◦C, suggesting that burning of bone was mainly accidental or due to disposal in the fire and that bone was probably not used as fuel (The´ry-Parisot and Costamagno, 2005).

4.1.3. General consideration of site formation processes

The microstratigraphic analysis of the six hearths (i.e., SU 12, SU 77, SU 78, SU 80, SU 82 and SU 83) shows that all of them belong (as sub-Stratigraphic Units) to the same Stratigraphic Unit (i.e., SU 13) formed as a result of weathering of the underlying Mt. Epomeo green tuff and colluviation of geogenic and anthropogenic components. The geogenic components include rock fragments from the local lithostartigraphic column (micritic limestone, flowstone, calcarenite, and fossiliferous limestone) and soil aggregates formed above the ravine from the weathering of the Calcare di Altamura formation. The anthropogenic components include bone fragments (uncharred, charred, and partially calcined), charred wood (charcoal), angular chert fragments (de´bitage) and wood ash. The diffuse
character of the majority of the observed microstratigraphic boundaries and the lack of observable erosional unconformity strongly suggest that the depositional processes of the SU 13 at Oscurusciuto rock shelter were dominated by sediment aggradation and cementation (e.g., brecciation) processes. Human activities appear not to have contrasted with the sediment build up but rather to have contributed to it with the introduction of wood ash, lithic raw materials, and

bones.

4.2. Faunal analysis

From a total of 4660 skeletal elements collected, 4236 (90.1%) have a length between 1 and 3 cm. There are several fragments (n. 1935) with traces of combustion which are mostly constituted by small sized elements (1e3 cm: 95.2%). From the fillings of the combustion structures 88 bone fragments (all burned) were recovered; these have lengths between 1 and 6 cm (Table 1). Overall, the fragments larger than 6 cm number 121: they are mostly represented by portions of the diaphysis of long bones.

Table 1
Fauna dimensional classes.

	1e3 cm	3e6 cm	6e10 cm	>10 cm	TOT
SU 13	4236	303	110	11	4660

These highly fragmented samples permitted the taxonomic determination of only six remains: Equus ferus, a proximal epiphysis of metacarpal; Bos primigenius, two teeth (a molar and an incisor), a distal epiphysis of radiusulna, a fragment of a metacarpal diaphysis and a distal fragment of a first phalanx. The bones were covered by a thin layer of carbonate concretion that prevented taphonomic analysis of surfaces.
Such a strong rate of bone fragmentation, probably aimed at the extraction of marrow (Boscato and Crezzini, 2012a), is found across the whole area of the shelter investigated so far.
Regarding the palaeo-environmental reconstruction, SU 13 is part of a group of Stratigraphic Units belonging to the same climatic phase (SU 15 to SU 4), moderately temperate and arid, characterized by a large extension of wooded grassland. Within this phase, hunting by Neanderthals was almost exclusively directed towards ungulates and particularly towards aurochs (Boscato and Crezzini, 2012b).

4.3. Lithic assemblage

In the layer there are 7504 lithic items which all show a fresh state of preservation and it is possible to observe a high frequency of refitting within short distances. The most utilized raw materials were siliceous limestone, jasper and chert in their fine granulometry (Table 2). The starting blocks of raw material were oblong pebbles coming from secondary local sources. The main reduction sequence was the recurrent Levallois, unipolar and convergent, designed to produce elongated and convergent flakes. There was also present a marginal volumetric debitage for the production of bladelets. A total number of 279 RMUs were identified, made up of 1770 pieces and 56 refitting and conjoins sets formed of 134 pieces. Table S1 shows the description of some reliable and representative RMUs relevant for the understanding of the technological and spatial behavior identified at SU 13.

Table 2
Lithological classes.

Raw material	Granulometry	N.	%
Jasper	Fine	1207	16.1
Chert	Fine	261	3.5
Jasper	Middle	80	1.1
Chert	Middle	314	4.2
Siliceous Limestone	Middle	1305	17.4
Limestone	Middle	37	0.5
Chert	Coarse	30	0.4
Siliceous Limestone	Coarse	51	0.7
Quartzarenite	Middle	137	1.8
Quartzarenite	Coarse	24	0.3
Limestone	Coarse	33	0.4
Indeterminate		4025	53.6
Total		7504	100.0

Despite the limitation due to the incompleteness of the excavated area, it was possible, thanks to the combination of technological analysis and study of the RMUs, to recognize the fragmentation of the reduction sequence. A large number of RMUs, consisting of one or a few elements of target products and retouched tools, leads us to hypothesize the import of finished objects (Fig. S4). RMUs with many items are few in number and represent simultaneously all the technological phases of the reduction sequence with a predominance of management e as attested by RMUs 1, 56, 137, 177 (Fig. S5, Fig. S6, Fig. S7, Fig. S8). In these cases the entire reduction sequence seems to have occurred at the site. It is just as interesting to note that most of the cores, often entirely exploited, form part of RMUs with few elements, leading us to the hypothesis of possible exports of target products (Fig. 6).

4.4. Taphonomy and spatial analysis

4.4.1. Taphonomy

The absence of mammals' burrows or of root imprints, the fresh state of the lithic edges and the virtual integrity of the hearths suggest a very good state of preservation of SU 13.
Other parameters allow us to reach the same conclusion. The chi-square test, used to assess the clustering degree of the archaeological remains gave the result of 1489.81. This value is rather higher than the expected one for a random distribution (127.32 at probability level 0.001). Therefore, a nonrandom spatial pattern can be asserted. Using Ripley's K function, different spatial patterns are found among the Dimensional Classes of the lithic finds: clustered for those smaller than 50 mm2, quite random for the items bigger than 50 mm2 (Fig. S9). Behind this configuration, a size-sorting effect due to water flow can be ruled out. A downslope increase in fine-grained debris is not found, and in particular the position and shape of the smallest lithic find accumulations are not conditioned by the surface morphology of SU 13 (Figs. 3 and 4). This data is consistent with the slope analysis of the SU 13 surface, that highlights a sub-horizontal layer with a weak slope (less than 5◦).

4.4.2. RMU

With regard to the refitting analysis a clear predominance of short distances is evident (Fig. S1). Usually these distances are shorter than 1.5 m.
In the lithic assemblage there are 30 RMUs with at least 10 items with a good or excellent degree of reliability. The Ripley's K-func- tion results from this sample (Fig. S10, Fig. S11, Fig. S12) indicate that almost 1/5 of these RMUs have a highly clustered pattern from a radius distance band of

between 0.5 and 0.6 m (RMUs: 1, 56, 137, 143, 193, 283) (Fig. 7 and Fig. 8). The agglomerations are concenrated around the hearths in the central part of the excavated area: only RMU 137 appears mainly focused on hearth SU 12 (or on SU 76), in the northern part of the excavated area. In the other cases random (RMUs: 9, 12, 31, 55, 64, 91, 132, 134, 146, 177, 197, 263, 264, 269, 279) (Figs. 7 and 8) and dispersed (RMUs: 53, 66, 96, 136, 139, 161, 255, 259, 280) patterns are recognizable. Nevertheless, by visual analysis, it is possible to get "disordered clusters", beside some random pattern. For example, in RMUs 12 and 177, both with a statistically random pattern, it is easy to recognize a lot of small agglomerates. The spatial organization of the technological phases of RMU 177, in particular, is very interesting: while the cortex removal, production flakes and indeterminate items are distributed in small agglomerates in the central and northern part of the excavated area, the target flakes are localized only in a small group around hearth SU 82, in the southern part of the excavated area (Fig. 8). Along with the high frequency of short refittings/conjoints, the presence of significant numbers of clustered patterns among the RMUs could be related to good preservation of the activity areas.

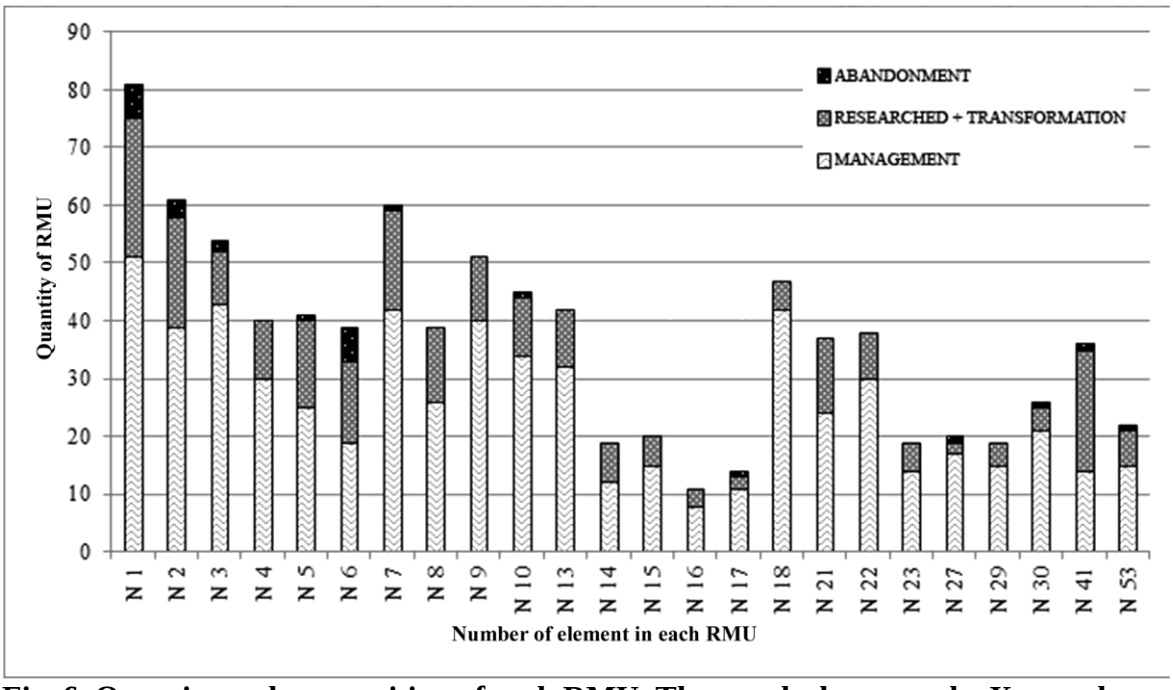


Fig. 6. Quantity and composition of each RMU. The graph shows on the X axes the number of objects for each RMU and on the Y axes the quantity of RMUs having the number of elements expressed on the X axes. The different patterning of the columns indicate, on the other hand, the technological composition of RMUs: abandonment, target þ transformation and management. These definitions refer to the technological phases of the reduction sequence of the lithic tools. "Abandonment" refers to cores, "researched" refers to all flakes which were the objective of production (in this case elongated, convergent and backed flakes as well as bladelets), "transformation" refers to retouched flakes. "Management" comprises all the flakes necessary to remove the cortex and to manage the technical knapping parameters needed for the production of target flakes.

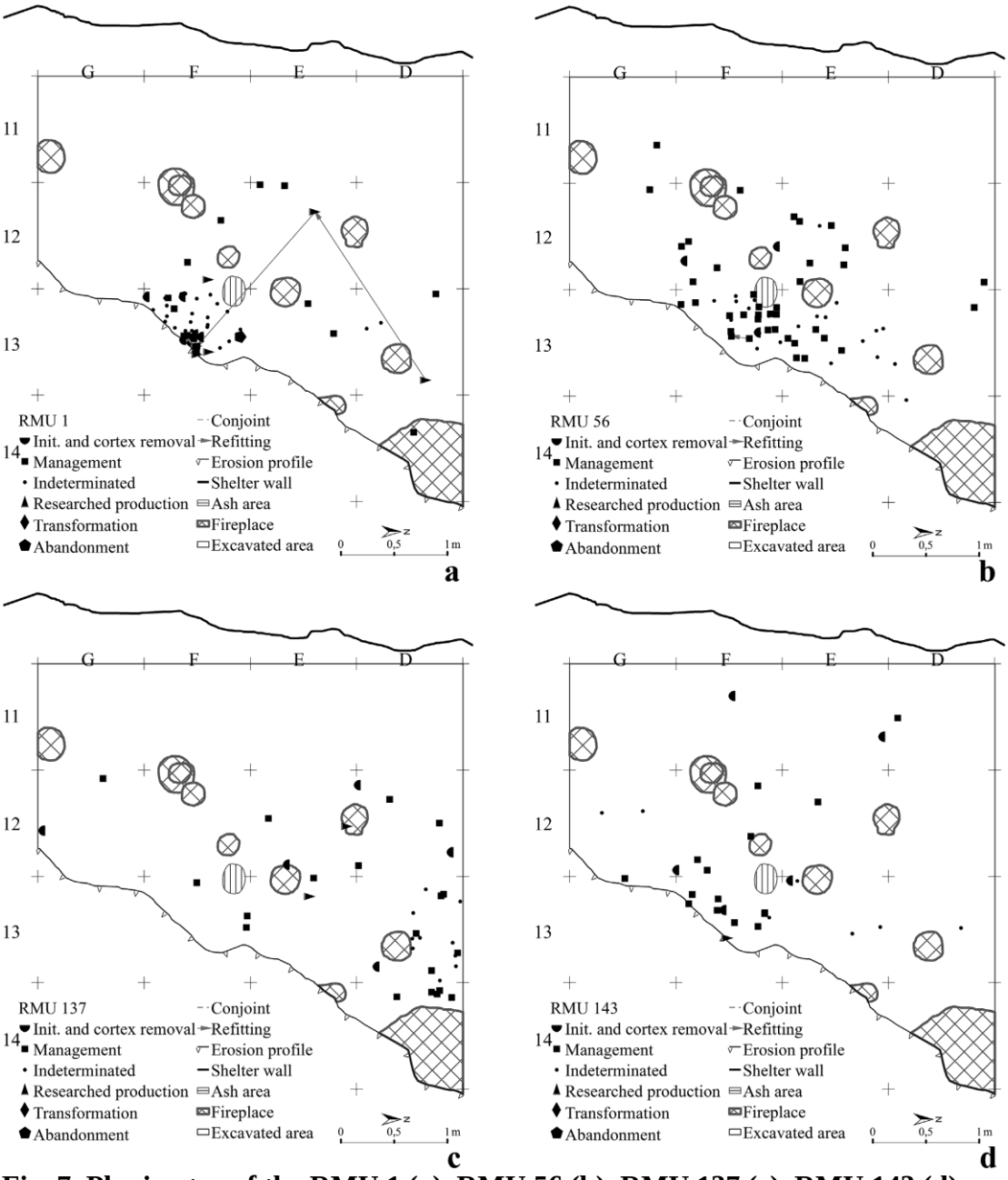


Fig. 7. Planimetry of the RMU 1 (a), RMU 56 (b), RMU 137 (c), RMU 143 (d).

The vertical distribution of the items in these RMUs was evaluated where at least 3 elements of each RMU had the actual coordinates recorded. On the profile NeS of the excavated area, the scatter-plot highlights a good coincidence between the lying plane of these RMUs and the altitude of SU 13 (Figs. 2 and 9).

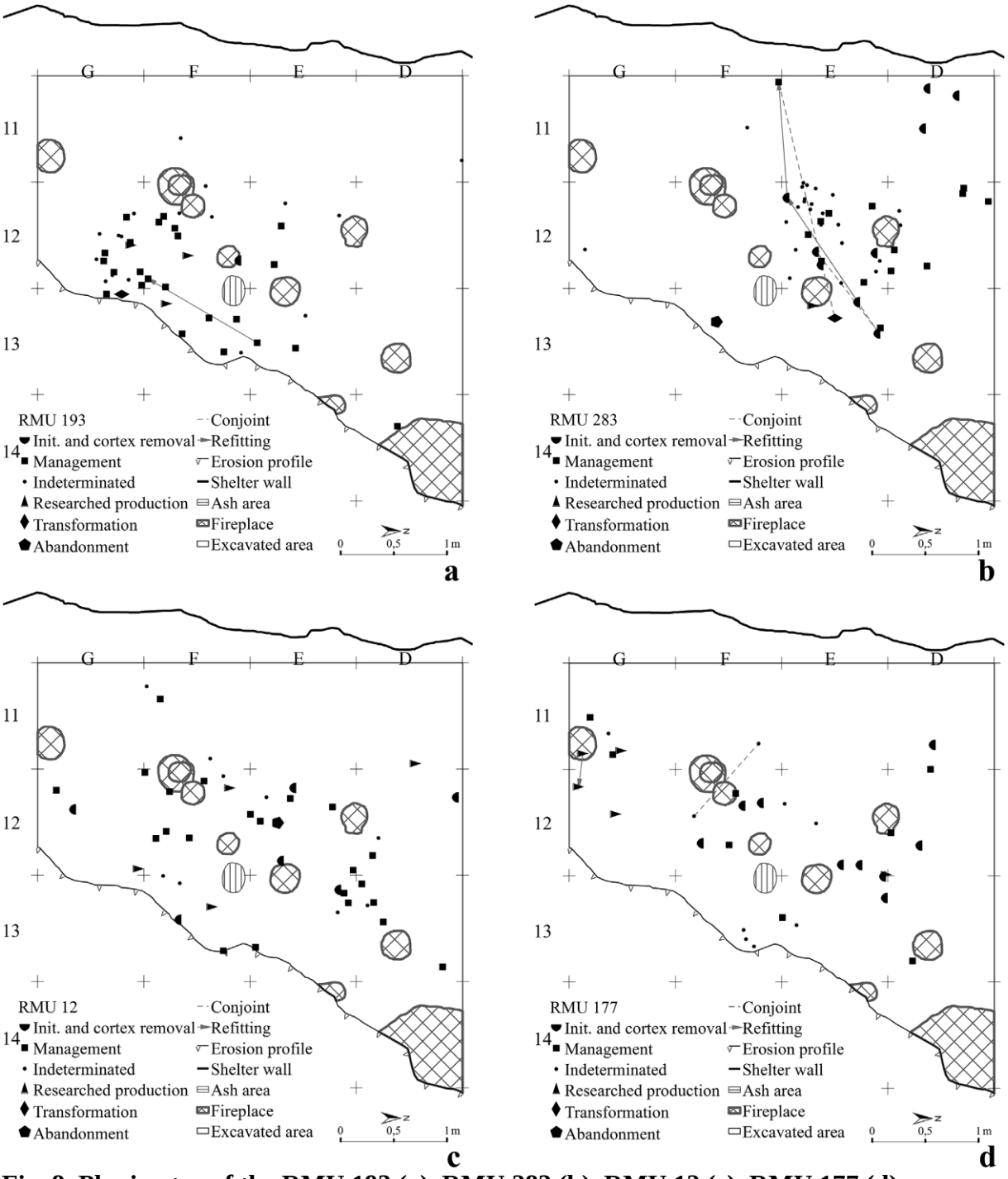


Fig. 8. Planimetry of the RMU 193 (a), RMU 283 (b), RMU 12 (c), RMU 177 (d).

Another interesting point derived from the RMU analysis consists in the relationship between the spatial pattern, the number of items for RMU and their technological composition. In order to analyse further, two technological macro-categories were created: the first one consisting of the

“tools” (target products, retouched tools and items with macro-traces) and the second of the production “waste” (initialization and cortex removal flakes, management flakes and indeterminate). Due to the complete exploitation of their volume, the few cores were included in the second category. As shown by the scatter-plot graph, there is a clear difference in the RMUs' dimension and technological composition compared with their spatial pattern. The clustered RMUs have a large number of items and a strong representation of production waste in relation to tools. On the contrary, the dispersed RMUs have few items and tend to exhibit an overrepresentation of tools instead of waste. The random patterned RMUs, as expected, show some mixed characters (Fig. 10).

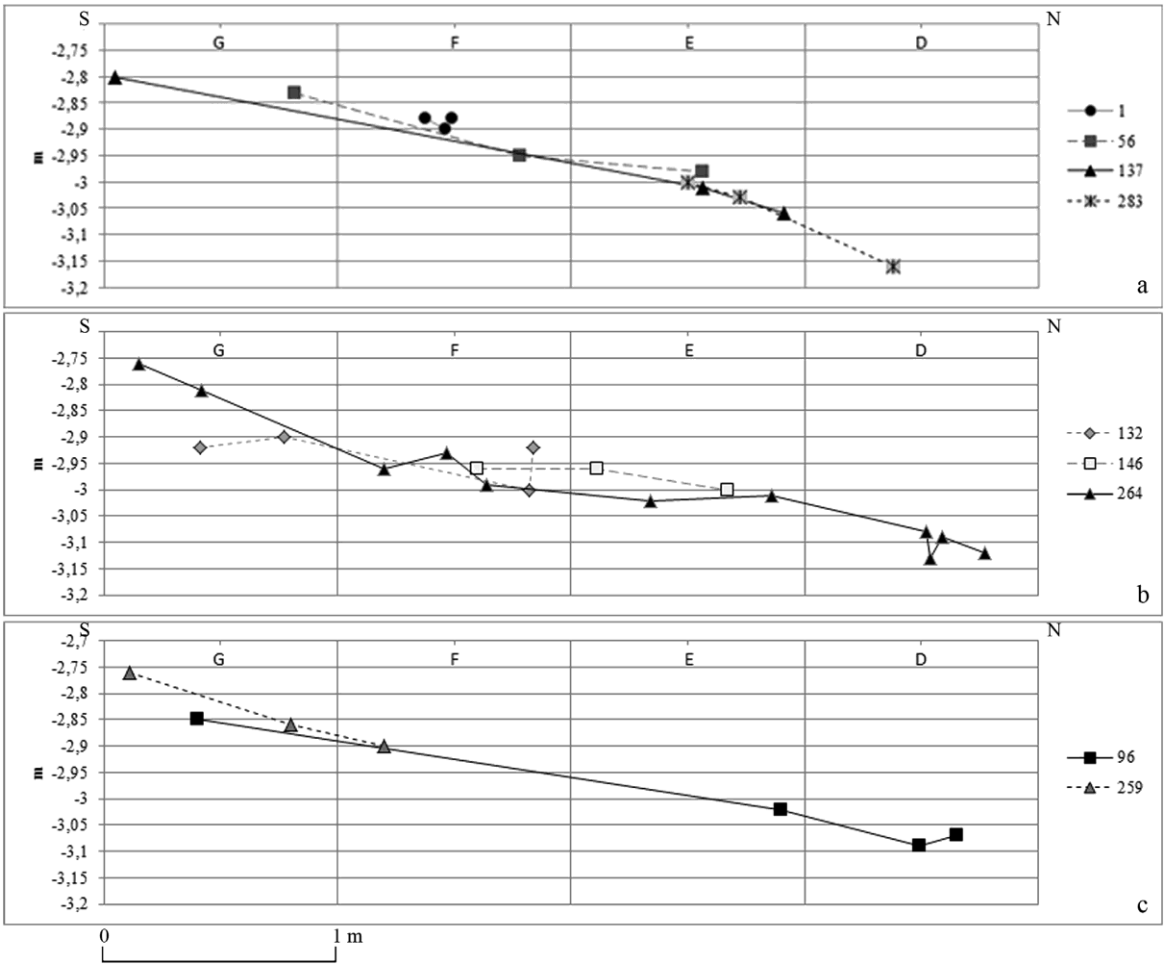


Fig. 9. Vertical distribution on the NeS profile of the items in the clustered RMU (a), random RMU (b), dispersed RMU (c).

4.4.3. Spatial organization

Through the analysis of the density maps of lithic and faunal remains, a clear distinction between the inner part of the rock shelter and the outer is recognizable. The area enclosed between the rock shelter wall and the hearths' alignment (about 4 m2 including the small unexcavated stratigraphic baulk against the wall) is characterized by the almost total absence of lithic finds and faunal remains. The other area (about 8 m2), delimited at North and South by unexcavated stratigraphic baulks, is interrupted by the erosion front (in the eastern part). In this area, the presence of the

hearth and the massive amount of anthropic remains, well-structured in some distinct agglomerates, is the distinctive feature (Figs. 3 and 4).
Computation of the distances between the hearths (from the respective centroids) highlight a significant recurrence of median values around 1.63 m: the same distance between the rock shelter wall and the hearths nearest to each other (1.3e1.6 m). A recurrent pattern related to the hearths consists in the distance from their centroids to the nearest accumulations of lithic finds smaller than 50 mm2 and faunal remains smaller than 3 cm, which is 70 cm.

5. Discussion

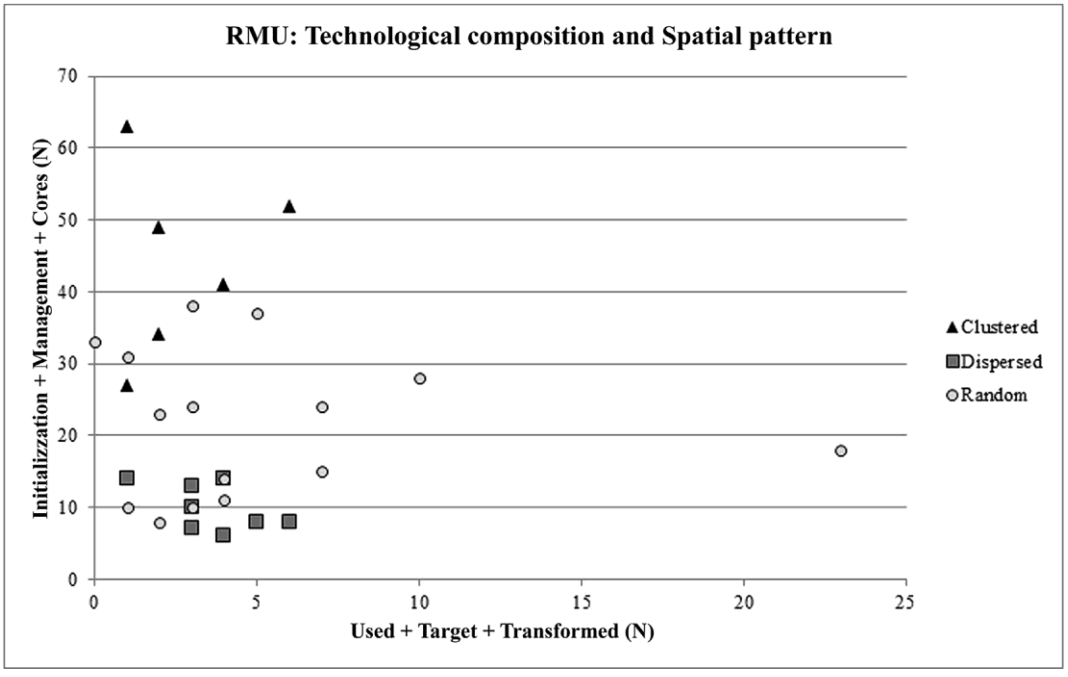


Fig. 10. Technological composition of the different spatial patterns of RMUs.

With its material culture, ecofacts, and hearth feature SU 13 is an interesting context for studying the settlement and economic strategies of the Neanderthals in Oscurusciuto rock shelter. Microstratigraphic investigation suggests that a series of hearths were lit on the surface of the local deposit composed of weathering Epomeo tuff and colluviated degrading local limestone. The absence of large scale burrows and carnivore activities, erosion or flooding, and the general integrity of the hearths resulting from one or a few combustion episodes enable the recognition of the exceptional state of preservation of the layer. The in loco availability of subsistence sources (hunting prey) and of knappable raw materials contributed to the attractiveness of the site. The lithic industry is dominated by convergent and unipolar levallois production. This was designed to obtain convergent and backed long flakes, whereas the volumetric production of bladelets was marginal. The fragmentation of the reduction sequences and the
on-site absence of some phases of the cha^ine op´eratoire suggests
that these activities were carried out elsewhere, entailing a certain mobility of the Neanderthal population of the Oscurusciuto. The mobility of the hunters is also attested by faunal remains: the lack of vertebrae and ribs in the shelter points suggests the dismembering of carcasses at killing sites and the transportation to the shelter of the limbs and crania of the killed animals.
The patterns observed in the spatial distribution of lithic and faunal remains are clearly not random,

and they mainly reflect the outcome of anthropogenic activities. Zones of Organized Activity (Allue´ et al., 1993) are clearly recognizable on the basis of the strong recurrence of the same spacefunctional modules. In SU 13 the strong recurrence of hearth dimensional modules allows the identification of quite defined spatial patterns. These hearths constitute an alignment that acts as a “barrier” and divides the deposit into an internal part (enclosed within the alignment and the wall of the shelter) and an outer part including the hearths (incomplete as partially removed by erosion slope). This pattern is further emphasized by the distribution of lithic and faunal remains. The density gradients of various analyzed categories bring out a clear distinction between the inner area (characterized by an almost complete absence of findings) and external area (with a high density of artifacts). Moreover, in the external area, an additional configuration (discernible thanks to the density maps) shows a different organization of the northern half of the outside area compared to the southern half (Figs. 3 and 4).

It is significant that spatial patterns differ according to specific categories of data. Regarding dimensional classes, for example, opposite patterns are observed between lithic and fauna. While lithic finds tend to be clustered in the smaller dimensional classes (with configurations of random type in the remaining ones), the faunal remains show a pattern strongly clustered in major size classes, while the smaller classes and the burnt remains are more likely to show a random distribution. Likewise, among the lithic technological classes, only cores and retouched pieces have a clustered distribution as to a minor extent do the used tools. This evidence is the result of overlapping different events, which are classifiable in the palimpsest model: a modular repetition of the same pattern of use of the space are flanked by partial dislocation spaces which, at least in part, allow the identification of individual activity.

Thanks to the RMU technique it is possible to get a high temporal resolution, clearly identifying not only individual events, but also the temporal meaning of some spatial patterns. Indeed the analysis of RMUs revealed a rather complex scenario, not only according to the technological composition of the lithic assemblage, but also regarding the sequences of activity identified at the site.

Taking into account the spatial distribution patterns of the reliable RMU with at least 10 items, it is possible to recognize three distinct spatial patterns: clustered, random and dispersed. Also a different technological composition corresponds to this spatial distribution of the RMUs. On the basis of these two elements it is possible to individuate a different temporal value to the three spatial patterns: the clustered pattern corresponds to a final subphase of occupation; the random pattern to an intermediate sub- phase and the dispersed pattern to an initial subphase of the occupation.

The RMUs with few elements, a high frequency of tools (compared to waste) and more dispersed spatial patterns, from a temporal point of view, can be interpreted as the product of a rather long time between the production of the object and their burial. This means that such materials having been exposed longer to voluntary (activity areas maintenance, selection of tools used outside of the production areas) and involuntary (trampling, scuffing) factors of translocation are more dispersed on the surface of the layer. This category of scattered RMUs indicates an initial moment of the individual phase of occupation. A possible behavioral explanation of the technological composition and spatial patterns of these RMU could consist in the fact that, while waste was more easily dispersed (for both involuntary and voluntary factors), the tools would be maintained because of their major technical investment and their essential utility in daily occupations.

The RMUs with a high number of elements and a technological composition consisting of only a few tools and concentrated spatial patterns may indicate a short interval of time between production and burial, suggesting the final events before abandonment of the site. Hardly surprisingly is the low number of target products related to these RMUs, since some of them may have been removed at the time of departure (exports). In terms of space, the first product of flaking activity is the

dropzone, a rather compact agglomeration consisting basically of production waste (e.g. Binford, 1983; Stevenson, 1991; Vidale, 1992: 158e175; Vaquero
and Pasto`, 2001; Jones, 2008; Olausson, 2010; Bertran et al., 2012,
2015; Henry, 2012). While the cores (especially if still exploitable) may remain spatially correlated with the dropzone, the set of tools could also be moved to a working area different from the one for flaking (Fig. 11).

The remaining RMUs with random patterns (or semi-clustered), as suggested by all technological and spatial parameters, in temporal terms could be intermediate moments between the initial and final occupation.
One aspect which is worth noting concerns the distribution of structures in SU 13. The combustion structures are concentrated in the top part of the layer, except for hearth SU 82, which is found inside the unit, set within a small pit which partially cuts into the underlying SU 14. It is thus possible to infer an initial sporadic frequentation followed by a more stable occupation with the setting up of aligned hearths. In this regard it is particularly significant that the RMUs with concentrated patterns gravitate around the central area of the site (only one seems to have as its focus the hearth SU 12, in the north). This could suggest a strong chronological proximity between these RMUs, which could then all refer to the same end event rather than an event of settlement. Also significant is RMU 177, with a random spatial pattern, since an original decomposed drop-zone is clearly distinguishable (made up almost exclusively of waste) in the central part of the excavated area and a small accumulation composed almost exclusively of target objects is seen around the hearth SU 82 (the first combustion structure set in the layer).

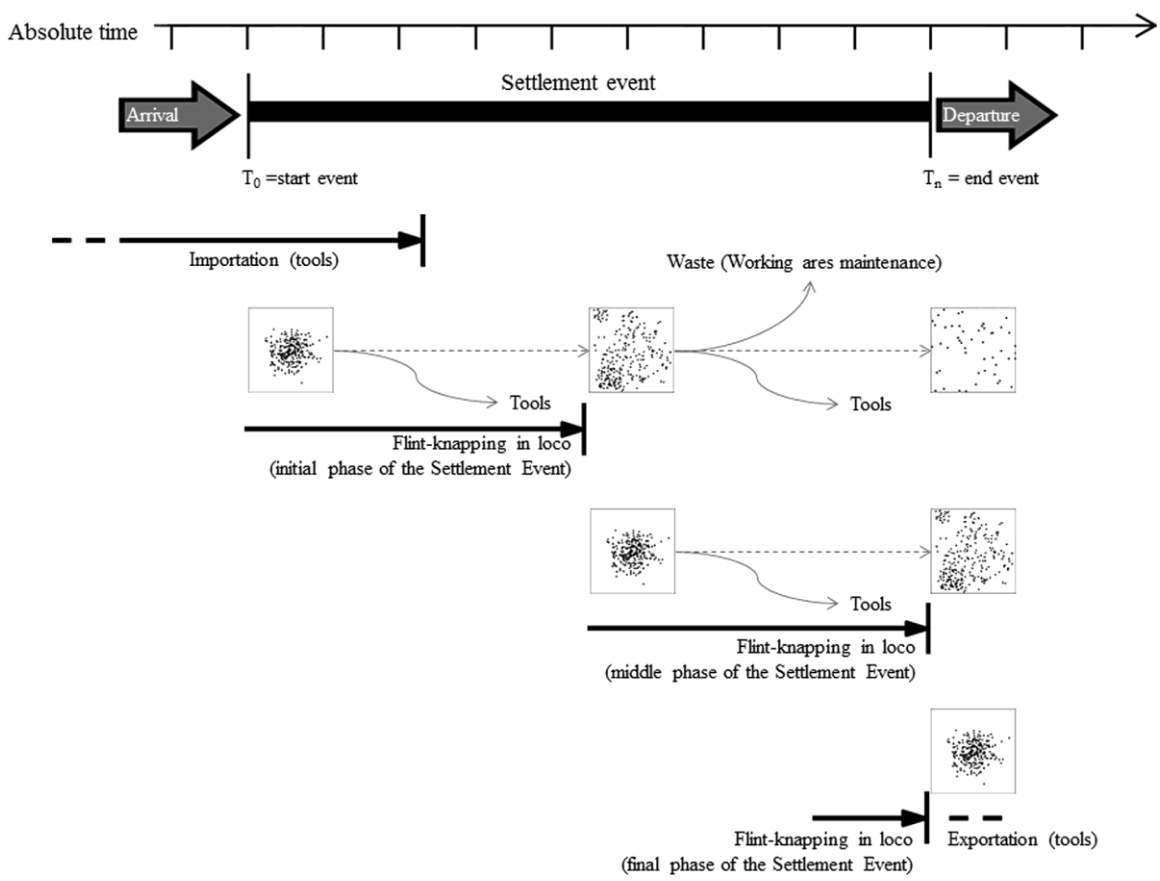


Fig. 11. Possible temporal meaning of the spatial pattern of the RMUs.The image shows the spatial configuration of the technological composition of RMUs within the site in relation to the length of the occupational event. An 'occupational event' is meant as the elapsed time between the arrival and departure of a human group, indicated by different activities of finished stone tool importation (importation tools) and the introduction of knappable raw materials, recognizable through the RMU analysis. The different spatial distribution of RMUs (clustered, random, dispersed), as it can be recognized at the site, can be put in relation to the time elapsed between the introduction of the RMUs and the abandonment of the site.

6. Conclusion

Finally, a series of clues lead us to interpret SU 13 as the product of a series of individual events referable to a rather short period, which presumably could be ascribed to the same human group. The spatial data of the RMUs seems to suggest the existence of brief events during a single phase of occupation, which can be seen by the gravitation of almost all concentrated RMUs in the same area. The presence of a stratigraphic overlap of two hearths and the hearth SU 82 (built before the other combustion structures) suggests a succession of at least two events separated in time, but not necessarily of an alternation between phases of occupation and phases of abandonment. The alternation of two events is also suggested by the distribution of hearths within the SU, where they all concentrate in the top part of the layer (except for hearth SU 82). But the vertical distribution of artifacts and the recurrence of the same spatial patterns does not seem to justify the hypothesis of a possible sequence of occupation events interspersed with phases of abandonment.
In conclusion, SU 13 can almost certainly be assessed as a short palimpsest (i.e. the product of a set of events taking place in a small period of time). As the research stands now, it remains difficult to define which kind of occupation is reflected by this short palimpsest. Both the hypothesis of at least two (if not most) occupational events being separated by brief hiatuses, and the hypothesis of a single settlement event seem equally plausible.
Having realized the validity of this integrated method of analysis it is our intention to carry on with the study of the other levels of the site so as to have a diachronic vision of the occupation modalities and of the organization of the living space by the Neanderthal populations of the Ginosa ravine.

Author contribution

Annamaria Ronchitelli is the coordinator of the research with Paolo Boscato. The study of the lithic industry is part of Giulia Marciani's Masters thesis. The spatial analyses are based on Vincenzo Spagnolo's Masters thesis. Both of them were supervised by Daniele Aureli and Filomena Ranaldo. The micro morphological study of the hearths was undertaken by Francesco Berna.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.quaint.2015.11.046.

References

- Allen, J.R.M., Watts, W.A., Huntley, B., 2000. Weichselian palynostratigraphy, palaeovegetation and palaeoenvironments; the record from Lago Grande di Monticchio, southern Italy. Quaternary International 73/74, 91e110.
- Allue´, E., Burjachs, F., C`aceres, I., Carbonell, E., Castro, Z., Cebri`a, A., Esteban, M.,
- Giralt, S., Jover, A., Lorenzo, C., Masquera, M., Olle´, A., Pasto`, I., Perales, C., Prats, J.M., Rodrìguez, J.P., Rossell, J., Sala, R., Valverdù, J., Vaquero, M., Verge´s, J.M., Zaragoza, J., 1993. Abric Romani, level H. A synchronous inter- pretation of an occupation of hunters and gatherers in the Upper Pleistocene. Revista d'Arqueologia, Prehisto`ria i Histo`ria Antiga 6, 5e30.
- Bailey, G.N., Galanidou, N., 2009. Caves, palimpsests and dwelling spaces: examples from the Upper Palaeolithic of South-East Europe. World Archaeology 41, 215e241.
- Berna, F., Goldberg, P., 2007. Assessing Paleolithic pyrotechnology and associated hominin behavior in Israel. Israel Journal of Earth Science 56, 107e121.
- Berna, F., Goldberg, P., Horwitz, L.K., Brink, J., Holt, S., Bamford, M., Chazan, M., 2012. Microstratigraphic evidence of in situ fire in the Acheulean strata of Wonder- werk Cave, Northern Cape province, South Africa. Proceedings of the National Academy of Science 109 (20), E1215eE1220.
- Bertran, P., Lenoble, A., Todisco, D., Desrosiers, P.M., Sørensen, M., 2012. Particle size distribution of lithic assemblages and taphonomy of Palaeolithic sites. Journal of Archaeological Science 39, 3148e3166.
- Bertran, P., Beauval, C., Boulogne, S., Brenet, M., Costamagno, S., Feuillet, Th, Laroulandie, V., Lenoble, A., Malaurent, Ph, Mallye, J.B., 2015. Experimental archaeology in a mid-latitude periglacial context: insight into site formation and taphonomic processes. Journal of Archaeological Science 57, 283e301.
- Bevan, A., Conolly, J., 2006. Multiscalar approaches to settlement pattern analysis. In: Lock, G., Molyneaux, B.L. (Eds.), Confronting Scale in Archaeology: Issues of Theory and Practice. Springer, New York, pp. 217e234.
- Binford, L.R., 1983. In pursuit of the past. Decoding the Archaeological Record. Thames & Hudson Ltd, London.
- Bisson, M.S., Nowell, A., Cordova, C., Poupart, M., Ames, Ch, 2014. Dissecting pa- limpsests in a Late Lower and Middle Paleolithic flint acquisition site on the Madaba Plateau, Jordan. Quaternary International 331, 74e94.
- Boscato, P., Gambassini, P., Ranaldo, F., Ronchitelli, A., 2011. Management of Paleo-environmental resources and exploitation of raw materials at the Middle Paleolithic Site of Oscurusciuto (Ginosa, Southern Italy): units 1 and 4. In: Conard, N.J., Richter, J. (Eds.),

Neanderthal Lifeways, Subsistence and Technology. One Hundred Fifty Years of Neanderthal Study. Springer, New York, pp. 87e96. Boscato, P., Crezzini, J., 2012a. Il deposito musteriano del Riparo l'Oscurusciuto (Ginosa e TA): la fauna a grandi mammiferi delle UUSS 1÷9. In: De Grossi Mazzorin, J., Sacca`, D., Tozzi, C. (Eds.), Atti del 6◦ Convegno Nazionale di Archeozoologia (Orecchiella, San Romano in Garfagnana e Lucca, 21-24 maggio 2009), pp. 25e32.

- Boscato, P., Crezzini, J., 2012b. Middle-Upper Palaeolithic transition in Southern Italy: Uluzzian macromammals from Grotta del Cavallo (Apulia). Quaternary International 252, 90e98.
- Boscato, P., Ronchitelli, A., 2008. Strutture di combustione in depositi del Paleolitico medio del Sud Italia. Proceedings XVII Congress of the Italian Anthropological Association, Cagliari, 26e29 september 2007. International Journal of Anthro- pology 218e225 special issue.
- Bronk Ramsev, C., Lee, S., 2013. Recent and planned developments of the program OxCal. Radiocarbon 55, 720e730.
- Carbonell I Roura, E. (Ed.), 2012. High Resolution Archaeology and Neanderthal Behavior Time and Space in Level J of Abric Romaní (Capellades, Spain). Springer, Dordretch.
- Carmignani, L., 2010. L'industria litica del livello F IIIE di Grotta del Cavallo (Nardo`, Lecce). Osservazioni su una produzione lamino e lamellare in un contesto del Musteriano Finale. In: Origini XXXII, Nuova serie IV.
- Carmignani, L., 2011. Le ultime espressioni del Musteriano nell'Italia del sud-est. Variabilita` tecnologiche e comportamenti tecno-economici in un contesto peninsulare. I casi studio di Grotta del Cavallo e Grotta Mario Bernardini. Nardo` (Lecce). Ph.D. Thesis, Universita` degli Studi di Siena, Italy.
- de la Torre, I., Martínez-Moreno, J., Mora, R., 2012. When bones are not enough: lithic refits and occupation dynamics in the Middle Palaeolithic Level 10 of Roca dels Bous (Catalonia, Spain). In: Seetah, K., Gravina, B. (Eds.), Bones for Tools e Tools for Bones: the Interplay between Objects and Objectives. McDonald Institute for Archaeological Research, Cambridge, pp. 13e23.
- Dini, M., Moriconi, M., 2004. I nuclei dell'US 1 del sito epigravettiano di La Greppia II (Parco dell'Orecchiella e Lucca). Analisi tecno-tipologica e distribuzione spa- ziale. Preistoria Alpina 40, 45e62.
- Drennan, R.D., 2009. Statistics for archaeologists. A Commonsense Approach. Springer, New York.
- Goldberg, P., Berna, F., 2010. Micromorphology and context. Quaternary Interna- tional 214, 56e62.
- Goldberg, P., Macphail, R.I., 2006. Practical and Theoretical Geoarchaeology. Black- well Publishing, Malden-Oxford-Carlton.
- Hall, C.T., Larson, M.L. (Eds.), 2004. Aggregate Analysis in Chipped Stone. University of Utah Press, Salt Lake City.
- Henry, D., 2012. The palimpsest problem, hearth pattern analysis, and Middle Paleolithic site structure. Quaternary International 247, 246e266.
- Higham, T.F.G., Douka, K., Wood, R., Bronk Ramsey, C., Brock, F., Basell, L., Camps, M., Arrizabalaga, A., Baena, J., Barroso-Ruíz, C., Bergman, C., Boitard, C., Boscato, P., Caparro´s, M., Conard, N.J., Draily, C., Froment, A., Galv´an, B., Gambassini, P., Garcia-Moreno, A., Grimaldi, S., Haesaerts, P., Holt, B., Iriarte-Chiapusso, M.-J., Jelinek, A., Jorda´Pardo, J.F., Maíllo-Fern´andez, J.-M., Marom, A., Maroto, J., Mene´ndez, M., Metz, L., Morin, E., Moroni, A., Negrino, F., Panagopoulou, E., Peresani, M., Pirson, S., de la Rasilla, M., Riel-

Salvatore, J., Ronchitelli, A., Santamaria, D., Semal, P., Slimak, L., Soler, J., Soler, N., Villaluenga, A., Pinhasi, R., Jacobi, R., 2014. The timing and spatio-temporal patterning of Neanderthal disappearance. Nature 512, 306e309.

- Jones, B.D., 2008. The simple and the complex: two Middle Archaic small Upland Lithic Sites in North Stonington, Connecticut. In: Rieth, C.B. (Ed.), Current Ap- proaches to the Analysis and Interpretation of Small Lithic Sites in the North- east, New York State Museum Bulletin Series, New York.
- Larson, M.L., Ingbar, E.E., 1992. Perspectives on refitting: critique and supplemen- tary approach. BAR International Series 578, 151e161.
- Lo´pez-Ortega, E., Rodríguez, X.P., Vaquero, M., 2011. Lithic refitting and movement
- connections: the NW area of level TD10-1 at the Gran Dolina site (Sierra de Atapuerca, Burgos, Spain). Journal of Archaeological Science 38, 3112e3121.
- Machado, J., Herna´ndez, C.M., Galv´an, B., 2011. Contribucio´n teo´rico-metodolo´gica al an´alisis histo´rico de palimpsestos arqueolo´gicos a partir de la produccio´n lítica. Un ejemplo de aplicacio´n para el Paleolítico medio en el yacimiento de El Salt (Alcoy, Alicante). Recerques del Museu D'Alcoi 20, 33e46.
- Machado, J., Hern´andez, C.M., Mallol, C., Galva´n, B., 2013. Lithic production, site formation and Middle Palaeolithic palimpsest analysis: in search of human occupation episodes at Abric del Pastor Stratigraphic Unit IV (Alicante, Spain). Journal of Archaeological Science 40, 2254e2273.
- Malinsky-Buller, A., Hovers, E., Marder, O., 2011. Making time: ‘Living floors’, ‘pa- limpsests’ and site formation processes e a perspective from the open-air Lower Paleolithic site of Revadim Quarry, Israel. Journal of Anthropological Science 30, 89e101.
- Mallol, C., Cabanes, D., Baena, J., 2010. Microstratigraphy and diagenesis at the upper Pleistocene site of Esquilleu Cave (Cantabria, Spain). Quaternary Inter- national 214, 70e81.
- Mallol, C., Herna´ndez, C.M., Cabanes, D., Sistiaga, A., Machado, J., Rodríguez, A´.,
- Pe´rez, L., Galva´n, B., 2013. The black layer of Middle Palaeolithic combustion structures. Interpretation and archaeostratigraphic implications. Journal of Archaeological Science 40, 2515e2537.
- Marciani, G., 2013. The Lithic Assemblage of the US 13 at the Middle Paleolithic Site of Oscurusciuto (Ginosa, Taranto, Southern Italy): Technological Studies. MA Thesis Erasmus Mundus, Instituto Polite´cnico de Tomar, Portugal. Universidade de Tr´as-os-Montes e Alto Douro, Portugal.
- Olausson, D., 2010. Experimental Flintknapping replication. A valuable method of archaeological analysis. In: Nami, H.G. (Ed.), Experiments and Interpretation of Traditional Technologies: Essays in Honor of Erret Callahan. Ediciones De Arqueologia Contemporanea, Buenos Aires, pp. 37e56.
- Roebroeks, W., 1988. From find scatters to early hominid behavior: a study of middle palaeolithic riverside settlements at Maastricht-Belve´de`re (The Netherlands). Ph.D. Thesis. University of Leiden, Leiden.
- Romagnoli, F., 2012. Risorse litiche e comportamento tecnico dei Neandertaliani: variabilit`a culturale e adattamento all'ambiente nel Salento. Grotta del Cavallo,
- Strati L-N e Grotta Mario Bernardini, Strato D. Ph.D. Thesis, Universita` di Fire- nze, Italy. Universitat Rovira i Virgili, Spain.
- Ronchitelli, A., Freguglia, M., Longo, L., Moroni Lanfredini, A., Ranaldo, F., 2011. Studio tecno-funzionale dei supporti a morfologia triangolare dell'US 8 del Riparo l'Oscurusciuto (Ginosa e Taranto). Rivista di Scienze Preistoriche LXI, 5e20.

- Rosell, J., Blasco, R., Fernandez-Lazo, C., Vaquero, M., Carbonell I Roura, E., 2012. Connecting areas: faunal refits as a diagnostic element to identify synchronicity in the Abric Romaní archaeological assemblages. Quaternary International 252, 56e67.
- Sarti, L., Boscato, P., Lo Monaco, M., 2000. Il Musteriano finale di Grotta del Cavallo nel Salento: studio preliminare. Origini XXII, 45e109.
- Schurmans, U., 2007. Refitting in the Old and New World. BAR International Series 1596 (7), 7e23.
- Schwarz, K.R., Mount, J., 2006. Integrating spatial statistics into archaeological data modeling. In: Mehrer, M.W., Wescott, K.L. (Eds.), GIS and Archaeological Site Location Modeling. Taylor and Francis, New-York, pp. 167e189.
- Spagnolo, V., 2013. Analisi spaziale di un contesto musteriano: Riparo L'Oscu- rusciuto (Ginosa e TA). MA Thesis. Universita` del Salento, Lecce, Italy.
- Stevenson, M.G., 1991. Beyond the formation of hearth-associated artifact assem- blages. In: Kroll, E.M., Douglas Price, T. (Eds.), The Interpretation of Archaeo- logical Spatial Patterning. Springer, New York-London, pp. 269e299.
- Stoops, G., 2003. Guidelines for Analysis and Description of Soil and Regolith Thin Sections. Soil Science Society of America, Madison WI, p. 184.
- The´ry-Parisot, I., Costamagno, S., 2005. Proprie´te´s combustibles des ossements.
- Donne´es expe´rimentales et re´flexions arche´ologiques sur leur emploi dans les sites pale´olithiques. Gallia Pre´histoire 47, 235e254.
- Uthmeier, Th, 2006. Stone tools, horses and cognition: transformation of lithic raw materials at the Middle Paleolithic open air Kill and Butchering Site of Kabazi II, Level III/1. In: Jürgen Richter, V.C., Uthmeier, Th (Eds.), Kabazi II: the 70000 Years since the Last Interglacial. University of Cologne, Cologne, pp. 253e269.
- Vaquero, M., 2008. The history of stones: behavioural inferences and temporal resolution of an archaeological assemblage from the Middle Palaeolithic. Jour- nal of Archaeological Science 35, 3178e3185.
- Vaquero, M., 2011. New perspectives on recycling of lithic resources using refitting and spatial data. Quarta€r 58, 113e130.
- Vaquero, M., Pasto`, I., 2001. The definition of spatial units in Middle Palaeolithic sites: the hearth-related assemblages. Journal of Archaeological Science 28, 1209e1220.
- Vaquero, M., Chaco´n, M.G., Cuartero, F., García-Anto´n, M.D., Go´mez de Soler, B., Martínez, K., 2012. Time and space in the formation of lithic assemblages: the example of Abric Romaní Level J. Quaternary International 247, 162e181.
- Vidale, M., 1992. Produzione artigianale protostorica. Etnoarcheologia e archeologia. ISIAO, Padova.
- Villa, P., Boscato, P., Ranaldo, F., Ronchitelli, A., 2009. Stone tools for the hunt: points with impact scars from a Middle Paleolithic site in southern Italy. Journal of Archaeological Science 36, 850e859.
- Weiner, S., 2010. Microarchaeology, beyond the Visible Archaeological Record. Cambridge University Press, Cambridge MA, pp. 275e319.
- White, B., 2012. Minimum analytical nodules and lithic activities at site W2, Hunter Valley, New South Wales. Australian Archaeology 75, 25e36.
- Winter-Livneh, R., Svoray, T., Gilead, I., 2010. Settlement patterns, social complexity and agricultural strategies during the Chalcolithic period in the Northern Negev, Israel. Journal of Archaeological Science 37, 284e294.