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Archaeological and Anthropological Sciences

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Keywords: Neanderthals · Volcanos impact · Mt. Epomeo green tuff · Lithic technology · Sedimentology · Resilience · GIS

Abstract: The Oscurusciuto rock shelter (southern Italy) is crucial for the understanding of Neanderthals' subsistence and settlement strategies as it contains a ~ 6-m-thick reliable deposit made up of several Middle Palaeolithic levels. This paper focuses on level SU 14, a 60-cm-thick deposit of volcanic tephra containing traces of human occupation only in the few upper centimetres.

Geochemical and mineralogical features of SU 14 deposits allowed their correlation to the 'Mount Epomeo Green Tuff' eruption, which came from Ischia volcano and dated to ~ 55,000 years BP. The pyroclastic materials injected into the atmosphere caused an ash fall-out over a large part of southern Italy, resulting in the alteration of ecosystems.

Sedimentological data demonstrate that the formation of SU 14 is attributable to a short-term event. Moreover, the lithic behaviour indicates that Neanderthals used the shelter mainly to perform specific activities related to the first phases of the reduction sequence (i.e. selection and import of pebbles into the site, initialisation and production of the first generation of debitage objectives, and introduction of already finished tools). Consequently, the layer SU 14 raises questions regarding the impact of deposition of volcanic ash on human communities, offering the opportunity to investigate the settlement and techno- logical choices made by Neanderthals who were constrained by such an adverse environmental event.

Introduction

Volcanic eruptions are natural events which have affected human history, and have left marks on present and past soci- eties. Volcanic eruptions affect the Earth's ecosystems, not only near the volcano but also over large distances, due to tephra fall, earthquakes and tsunamis (e.g. Thorarinsson 1979; Blong 1984; Giaccio et al. 2008). In particular, the term 'tephra' indicates pyroclastic materials produced by the mag- matic fragmentation during explosive volcanic eruptions (sensu Thorarinsson 1957) which are injected into the atmo- sphere at different levels and dispersed over large areas (e.g. Sulpizio et al. 2008). Tephra deposits in prehistoric sites are helpful in order to solve chronological issues because (1) they can provide absolute dates, and (2) they were deposited in a short time-span over large areas and for this reason they make it possible to draw correlations between different archives.
Tephra' s impact on the ecosystems and human societies (Haeckel et al. 2001; Dale et al. 2005; Frogner Kockum et al. 2006; Riede 2008, 2016, 2017; Arnalds 2013) is well docu- mented for eruptions which have occurred in historical times (e.g. Driessen and Macdonald 2000; Eastwood et al. 2002; Di Vito et al. 2009). The magnitude of such an impact is related to several factors; among these, the most important are the volume and the mineralogical nature of erupted materials (cf. Narcisi and Vezzoli 1999; Hotes et al. 2006, 2010; Arnalds 2013; Allen and Huntley 2018). However, the effect of tephra deposition on prehistoric societies is still debated, and only a few occurrences are reported in literature (i.e. Riede 2008, 2016, 2017; Hatfield 2011; Hatfield et al. 2019). Understanding the impact of volcanism on prehistoric human communities is generally complex and requires a multifocal and multidisciplinary point of view, based on instances be- longing both to the natural and the social sciences (e.g. Cronin and Neall 2000; Bottema and Sarpaki 2003; Grattan 2006; Paton et al. 2008; Cashman and Giordano 2008; Oppenheimer et al. 2011; Chester et al. 2012; Riede 2016, 2017, 2019).
The aim of this paper is to present the exceptional archae- ological context preserved in the tephra deposit SU 14 of the Oscurusciuto rock shelter (Middle Palaeolithic, Apulia, south- ern Italy). In this SU, a Neanderthal occupation took place in the upper portion of the tephra deposition. Mineralogical and geochemical analyses provided in this study attest that this tephra layer is related to 'Mount Epomeo Green Tuff' event (dated at ~ 55,000 years BP). The tephra deposition was related to a catastrophic eruption that caused the collapse of the Ischia caldera (Orsi et al. 1991; Brown et al. 2008) and that injected into the atmosphere an enormous amount of pyroclastic materials, probably generating notable alterations of ecosys- tems (Allen and Huntley 2018). Based on the features men- tioned, layer SU 14 offers a unique opportunity to study the settlement, the technological and the hunting choices made by Neanderthal facing a strong environmental event and raises questions regarding the impact of tephra fall-out ashes on human communities living in the Oscurusciuto site.
In this framework, the specific objectives of the paper are
(1) to define the main features of the tephra deposits, including their chemical and mineralogical characterisation and the in- voked depositional mechanisms; (2) to define the technical behaviour of the occupants of the site; (3) to understand their hunting choices; and (4) to define the macro-traits of the or- ganisation of the settlement inside the rock shelter while it found itself under this particular condition.

The Oscurusciuto rock shelter and the SU 14

The Oscurusciuto rock shelter is one of the most important Middle Palaeolithic sites of southern Italy. The extension of the archaeological deposit is about 60 m2. The sedimentary succession is more than 6 m thick and it is composed of at least 27 stratigraphic levels with a sub-horizontal inclination. The site is located in the ravine of Ginosa (southern Italy, Apulia region) (Fig. 1). The bedrock of the ravine is made of Pleistocene calcarenite, known in literature by the formational name of 'Calcareniti di Gravina' (Boenzi et al. 1971). The site is situated at about 15 m from the present-day bottom of the ravine and at an elevation of about 235 m asl.

The upper 3 m of the sequence have been investigated (Fig. 1) since excavation began in 1998. Starting from the top of the sequence, SU 1 and SU 2 are the remnants of two levels almost totally destroyed by erosion. The top of the stratigraphic sequence (bottom of SU 1) is dated to 38,500 ± 900 BP, cal. 42,724 ± 716 BP Beta 181,165 (cal Ramsey and Lee 2013) (Boscato and Crezzini 2011). SUs 3 and 4 consist of silty sandstone, while the underlying layers SU 7 to SU 13 consist mainly of coarse-grained sand containing several hearths. SU 14 is a tephra deposition which sealed the living floor of SU 15.

All of the excavated levels are characterised by a great abundance of archaeological materials and evidence including lithic artefacts that show Levallois reduction sequence on lo- cal pebbles (Ranaldo 2005, 2017; Villa et al. 2009; Ronchitelli et al. 2011; Marciani 2013, 2018; Marciani et al. 2016, 2018), faunal remains (Boscato and Crezzini 2007, 2012; Boscato et al. 2011) and combustion structures (Boscato and Ronchitelli 2008, 2017). The site, with its rich record, docu- ments the different choices made by Neanderthals and their mode of settlement at the end of the Middle Palaeolithic (Spagnolo 2013, 2017; Spagnolo et al. 2016, 2019, 2020a).

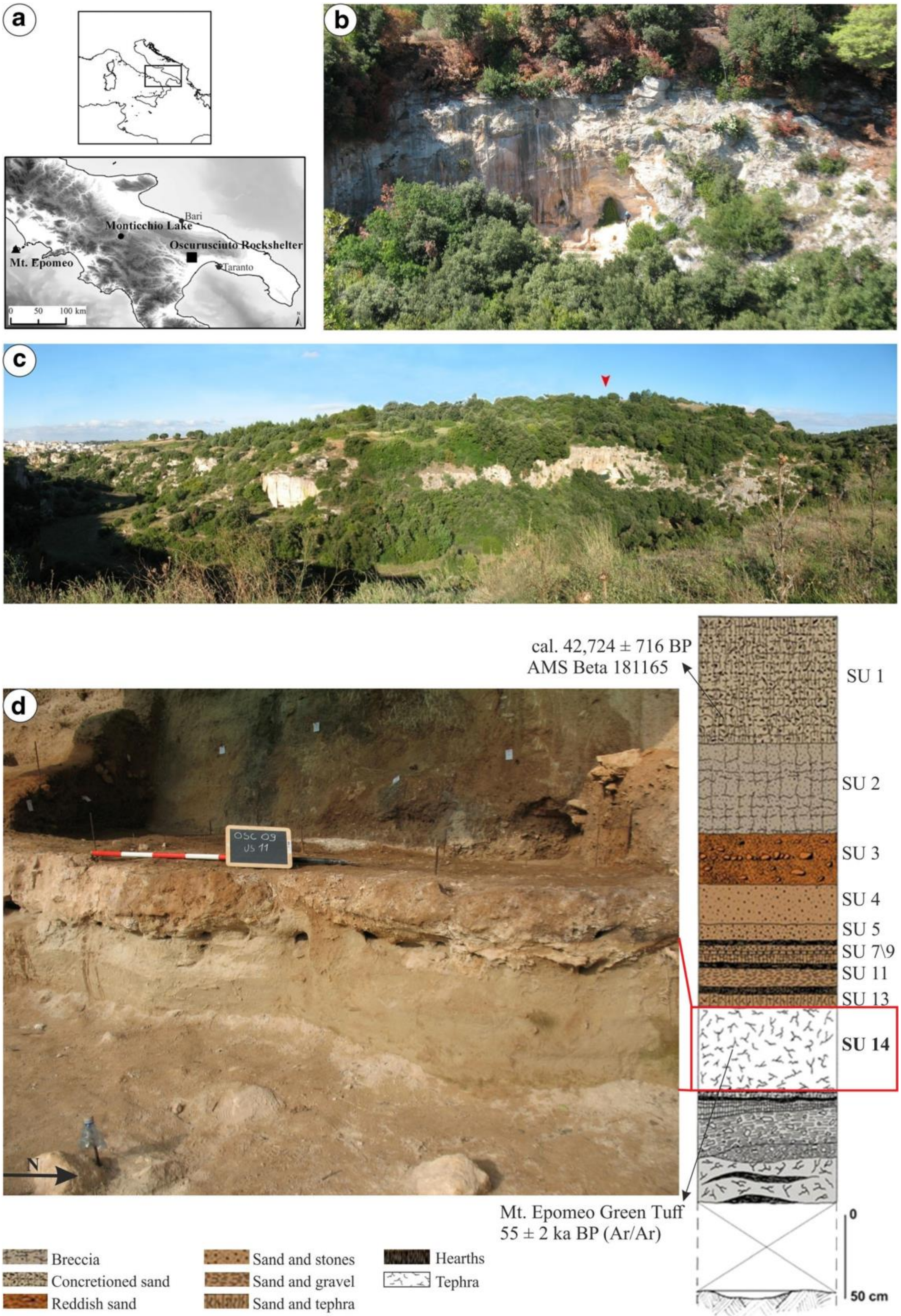


Fig. 1 a location of the site; b the rock shelter of Oscurusciuto; c panoramic view of the ravine of Ginosa; d west section of the archaeological deposit, stratigraphic sequence and

chronological references: bottom of SU 1 is dated to 38,500 ± 900 BP, cal. 42,724 ± 716 BP Beta 181,165 (cal Ramsey and Lee 2013); MEGT have been dated to 55 ± 2 ka, layer TM-19 in the Monticchio succession (Watts et al. 1996). Drawings and photo: P. Boscato; A. Ronchitelli

The excavation of SU 14 started in 2012 and lasted 2 years. SU 14 consists of pyroclastic light yellowish brown (2.5Y 6/4) sediments and is about 60 cm thick (Figs. 2 and 3). The layer is sub-horizontal with a slight northward dip. It is not possible to evaluate the original extension of the stratum because a portion of the deposit was eroded, thus the layer was excavat- ed on a total area of 11 m2 and, currently, it is still preserved in a stratigraphic baulk in the northern sector of the shelter and in the western and southern sectors which were not excavated. From an archaeological point of view, SU 14 is poorer in artefacts when compared with the other layers of the rock shelter which are exceptionally rich in archaeological finds. The collected archaeological materials were found in the up- per part of the layer, from the top of the level to approximately 15 cm below. Clear traces of anthropic structures have not been recognised.

Methods

Tephra EDS analysis

Energy-dispersive spectrometry (EDS) analyses of glass shards and glasses from micro-pumice fragments were per- formed at the Dipartimento di Scienze della Terra (University of Pisa), using an EDAX-DX micro-analyser mounted on a Philips SEM 515 (operating conditions—

Fig. 2 SU 14 during excavation, the tephra layer (photo P. Boscato)

20 kV acceleration voltage, 100 s live time counting, 200– 500 nm beam diameter, 2100–2400 shots per second, ZAF correction). The ZAF correction procedure does not include natural or synthetic standards for reference and requires anal- ysis normalisation at a given value (which is chosen at 100%). Analytical precision is 0.5% for abundances higher than 15 wt.%, 1% for abundances around 5 wt.%, 5% for abun- dances of 1 wt.% and less than 20% for abundances close to the detection limit (around 0.5 wt.%). Interlaboratory stan- dards include ALV981R23 (basalt), CFA47 (trachyte) and KE12 (pantellerite; Cioni et al. 1998; Supplementary Table S.1) samples. Some further comparisons of wave dis- persion spectroscopy (WDS) microprobe analyses carried out at GeoForschungsZentrum (GFZ, Potsdam, Germany) and at CAMPARIS service (CMP, Paris, France) on trachyte to rhy- olite glass shards are shown in Supplementary Table S.2, confirming the full comparability of EDS analyses from Pisa laboratory with respect to WDS data. Accuracy of measure- ment is around 1%, a value analogous to that obtained using WDS, as tested by Marianelli and Sbrana (1998). Comparison of EDS and WDS micro-analyses carried out on the same samples has shown differences of less than 1% for abundances greater than 0.5 wt.%. An accurate comparison of EDS data from DST-Pisa and CAMPARIS facilities at Paris VI can also be found in Caron et al. (2012).

Sedimentological analysis

The clastic sequence from SU 1 to SU 14 is investigated with bed-by-bed sedimentological logging and architecture line- drawings. The descriptive sedimentological terminology used is from Collinson et al. (2006), integrated with specific con- cepts for cave/shelter clastic sediments from Karkanas et al. (2007), Ghinassi et al. (2009), Martini (2011) and Martini et al. (2018).

Ten rock samples from bed SU 14 have been sampled for petrographic analysis (samples OS1 to 5 from the South sec- tion of the excavation, OS 6 and 7 from the West section and OS 8 to 10 from the North section). Samples have been con- solidated in the laboratory using epoxide resin and worked to obtain thin sections 30-μm thick. Thin sections have been observed using a polarised light petrographic microscope, in order to recognise the type of grains, the optical properties of mineral phases and the rock micro-texture.

Lithic technology

SU 14 yielded 3833 lithic artefacts. A technological analysis was carried out in order to gain comprehensive and compara- ble data regarding lithic production (Pelegrin et al. 1988; Geneste 1991a, b, 2010; Perlès 1991; Boëda 1994, 1995, 2013; Inizan et al. 1995). It includes the identification of sources of lithic raw material, as well as the description of

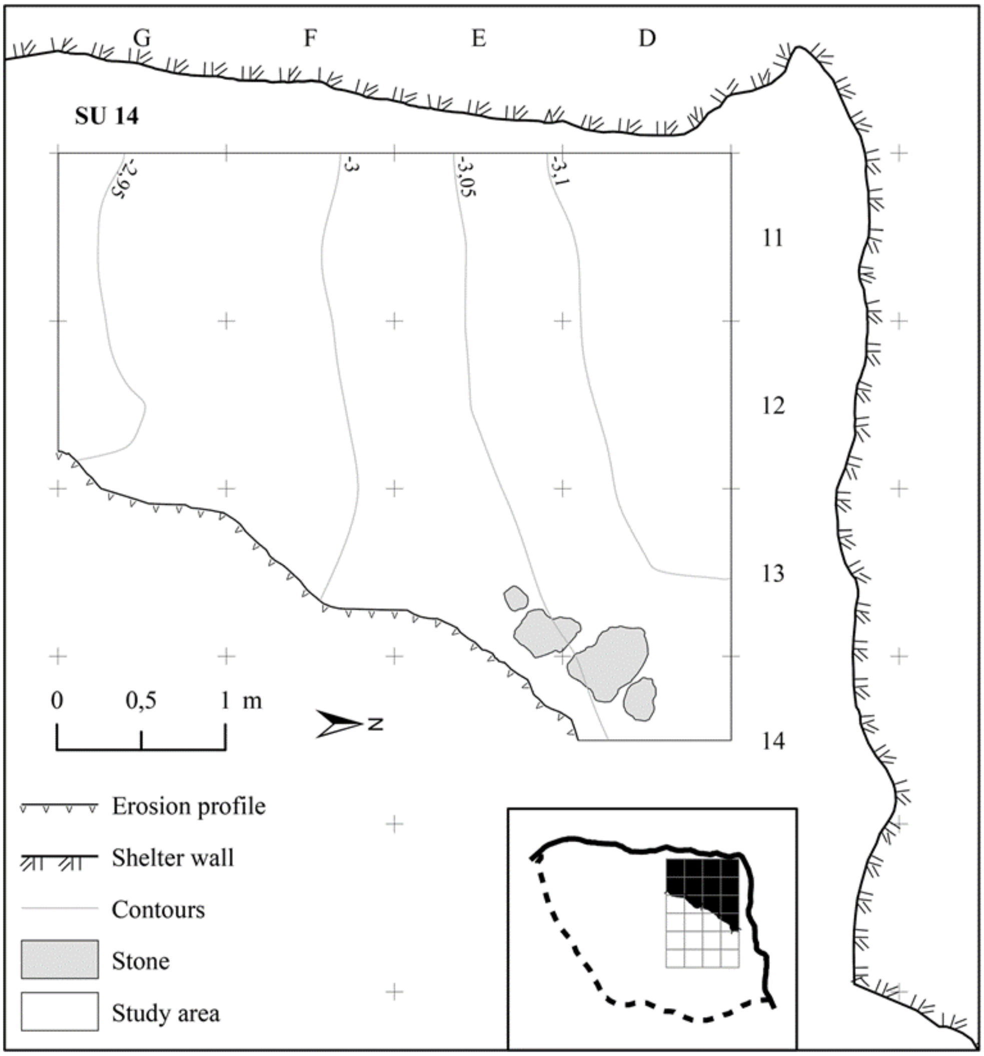


Fig. 3 Planimetry of SU 14 (mapping—P. Boscato; drawing—A. Ronchitelli, V.Spagnolo)

the dynamics of acquisition and exploitation of the lithic raw material. An attribute analysis of all the objects aimed at producing quantifiable statistical data was carried out. A qualita- tive analysis of cores and their extracted flakes has been per- formed in order to understand the volumetric concepts, methods, dynamics and objectives of the debitage. All these features were registered in a database specifically set up to suit the characteristics of the collection in question (Marciani 2013, 2018).

When looking at each item, the following traits were ob- served: raw material characteristics (lithotypes, granulometry, geological nature); dimensional class (DC), based on the area covered by each piece (Marciani 2013; Spagnolo 2013) (DC 1, 0–50 mm2; DC 2, 50–100 mm2; DC 3, 100–150 mm2; DC4, 150–200 mm2; DC 5, > 200 mm2). The items larger than the second DC were also measured according to their technolog- ical axis. When this was not possible, the longest measure- ment was conventionally regarded as the length. Then we considered the integrity of the item, the presence of combus- tion, mechanical or chemical alterations, and the presence of macro-traces (evaluation was made with the naked eye and with a magnifying glass). The typological class of retouched tools was indicated according to Laplace (1974). We consid- ered the following technological classes: flakes, cores, peb- bles, micro-flakes (integral flakes of the 1–2 DC), debris (fragmented or altered items of the 1–2–3 DC) and undeter- mined (fragmented or altered items

comprising only pieces of the 4–5 DC). We indicated the type of debitage according to Boëda (2013).
For each flake, we recorded the extension and position of cortex and the morphological features (morphology of the flake, symmetry (according to the technological axis), section shape, presence of flaking accidents). A diacritical analysis was employed in order to identify the chronological order of the scars and their role in the debitage process (Dauvois 1976; Inizan et al. 1995). Percussion attributes including the type of butt, the position of the impact point and the type of bulbs were also recorded. For each core, we considered the types and morphology of the raw block; its volumetric conception of exploitation (Boëda 2013); the hierarchy of surfaces;thestriking platform type (partial, peripheral), position and mode of organisation (one or several detachments, with or without abrasion, without any preparation) of the striking platform; and the diacritical analysis of scars (including number, direc- tion chronology and role of each scar) (Dauvois 1976; Inizan et al. 1995; Marciani 2013, 2018).

Faunal analysis

Faunal remains from SU 14 are scarce with only 648 speci- mens uncovered in the whole excavated area. Bone fragments were identified using the osteological reference collection at the University of Siena. Those fragments which were not identified according to taxonomy were ascribed to general anatomic categories (e.g. diaphysis, spongy bone, flat bone, etc.). Specimens were counted according to size (1–3 cm, 3– 6 cm, 6–10 cm, > 10 cm) and their burnt/unburnt condition was also recorded. Taphonomic analysis is biased in this layer by the presence of thin concretion layers on the bone surfaces.

Spatial pattern analysis

General distribution maps of lithic finds and faunal remains were produced. For this purpose, a preliminary exploration of spatial patterns (dispersed, random or clustered) was achieved by a combination of Spatial Autocorrelation (Global Moran's I method) and Getis–Ord General G statistics. Then, for a better visualisation of data, the kernel density estimation was calculated, powered by Ripley's K function, in order to check the best searching radius for the kernel density Analysis (Carrer 2017; Crezzini et al. 2016; Fletcher 2008; Garcea and Spagnolo 2018; Lancelotti et al. 2017; Moroni et al. 2019a, b; Romagnoli and Vaquero 2016; Spagnolo 2017; Spagnolo et al. 2016, 2019, 2020a, b, c; Thacher et al. 2017).

Results

Description and correlation of the tephra

The tephra layer is exposed across most of the archaeological excavation area and appears as a fine-grained greyish ash de- posit. SEM images of the tephra show that it contains aphyric glass shards and vesicular micro-pumice fragments in the size of 100–200 μm (Fig. 4).
Composition of glass is trachytic, with a narrow range of variability in the TAS diagram (Fig. 5), suggesting a Campanian origin. In particular, the alkali ratio close to 1 (Table 1) suggests an origin from Ischia island. Glasses from Pleistocene Ischia tephra layers are known for having a rather limited compositional variability (Tomlinson et al. 2014) making their individual recognition challenging. However, among the numerous Ischia tephra produced during the

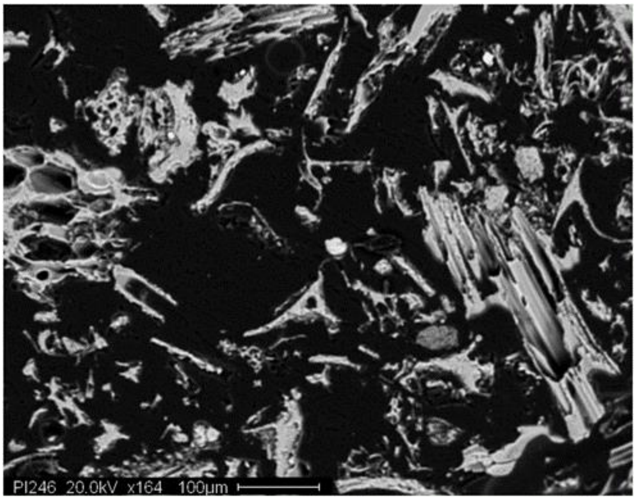


Fig. 4 Scanning electron microscope image of Oscurusciuto tephra, showing both aphyric glass shards and vesicular micro-pumice fragments

Pleistocene (e.g. Wulf et al. 2004; Brown et al. 2014; Tomlinson et al. 2014), the marine tephra Y-7, correlated to the large caldera forming Monte Epomeo Green Tuff (MEGT), is the most widespread. The chemical composition of Oscurusciuto tephra glass matches the Monticchio (TM-19; Wulf et al. 2004) and Fucino (TM-7; Giaccio et al. 2017) distal tephra layers, along with proximal MEGT data (Tomlinson et al. 2014). MEGT has been also recognised in San Gregorio Magno Basin (southern Italy; Munno and Petrosino 2007), in core PRAD1–2 (central Adriatic Sea; Bourne et al. 2010), in core MD01-2474G (southern Tyrrhenian Sea, Tamburrino et al. 2016) and in the Ionian Sea (cores RC9-191, M25/4-12, M25/4-13, V10-69, KC01B and 22M-60; Keller et al. 1978; Insinga et al. 2014), testifying for the large depositional area of ash related to the MEGT eruption Fig. 6. The distal deposits of MEGT have been dated to 55 ± 2 ka (layer TM-19 in the Monticchio succession; Watts et al. 1996) or to 56.1 ± 1.0 ka (layer TM-7 in Fucino basin; Giaccio et al. 2017). These ages are in agreement with those from proximal deposits of MEGT, dated to 56.5 ± 3.0 ka (Sbrana and Toccaceli 2011).

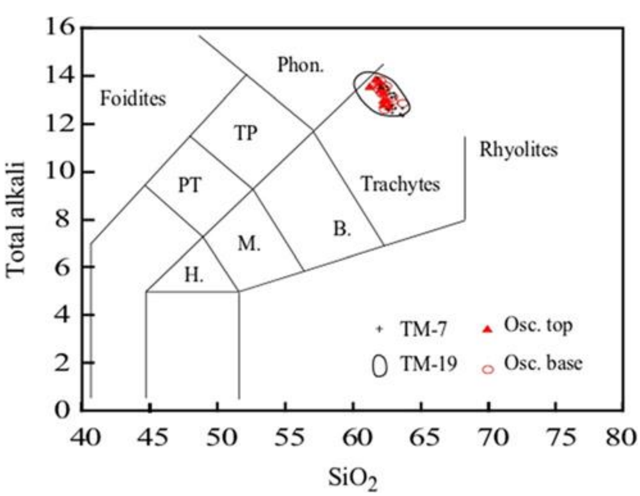


Fig. 5 Total alkali vs. silica (TAS) diagram showing the compositional variability of glass shards of two samples from Oscurusciuto tephra (base and top). Composition of tephra layer TM-19 from Monticchio succession (Wulf et al. 2004) and TM-7 from Fucino basin (Giaccio et

al. 2017) are shown for comparison

Oscurusciuto shelter top														
1	61.7	0.53	19.07	2.58	0.18	0.41	0.98	7	6.89	0	0.7	100	13.89	0.98
2	62.4	0.48	19.24	2.48	0.25	0.57	1.22	6.29	6.7	0	0.4	100	12.99	1.07
3	62.3	0.54	19.49	2.47	0.29	0.54	1	6.57	6.25	0	0.6	100	12.82	0.95
4	62.3	0.54	19.49	2.47	0.29	0.54	1	6.57	6.25	0	0.6	100	12.82	0.95
5	62.3	0.67	19.03	2.51	0.27	0.45	0.97	6.67	6.62	0	0.5	99.99	13.29	0.99
6	62	0.6	18.72	2.61	0.27	0.48	0.95	7.31	6.43	0	0.7	99.99	13.74	0.88
7	61.3	0.68	19.17	2.79	0.35	0.43	1.08	7.35	6.19	0	0.7	100	13.54	0.84
8	62.1	0.54	19.3	2.47	0.16	0.42	0.96	7.19	6.24	0	0.7	100	13.43	0.87
9	62.2	0.47	19.1	2.64	0.07	0.73	1.51	5.27	7.73	0	0.3	100	13	1.47
10	62.6	0.56	19.1	2.47	0.35	0.61	1.01	6.58	6.12	0	0.6	99.99	12.7	0.93
mean	62.10	0.56	19.17	2.55	0.25	0.52	1.07	6.68	6.54	0	0.56		13.22	0.99
sd	0.39	0.07	0.23	0.11	0.09	0.10	0.17	0.61	0.49	0	0.15		0.42	0.18
Oscurusciuto shelter base														
1	62.9	0.59	19.01	2.46	0.19	0.27	1.32	6.7	6.21	0	0.4	100	12.91	0.93
2	62.6	0.64	18.88	2.99	0.4	0.17	0.99	6.47	6.27	0	0.6	100	12.74	0.97
3	61.9	0.53	19.04	2.61	0.23	0.4	0.94	7.72	5.83	0	0.7	99.98	13.55	0.76
4	62.9	0.34	19.16	2.4	0.11	0.35	1.19	7.29	5.79	0	0.4	100	13.08	0.79
5	62.5	0.62	18.83	2.49	0.3	0.31	0.96	7.75	5.76	0	0.5	100	13.51	0.74
6	62	0.53	18.98	2.51	0.27	0.33	1	8.01	5.71	0	0.6	99.99	13.72	0.71
7	62.4	0.51	19.51	2.8	0.21	0.28	1.2	6.69	5.84	0	0.6	100	12.53	0.87
8	61.9	0.58	18.95	2.74	0.33	0.4	1.03	7.36	6.01	0	0.7	100	13.37	0.82
9	63.6	0.35	19.1	2.15	0	0.37	1.15	6.82	5.96	0	0.5	99.99	12.78	0.87
10	62.3	0.53	18.99	2.66	0.27	0.27	0.99	7.15	6.27	0	0.6	100	13.42	0.88
11	62	0.63	19.03	2.51	0.32	0.34	1.01	7.87	5.63	0	0.6	99.99	13.5	0.72
12	62.1	0.59	19.17	2.71	0.3	0.28	0.96	7.15	6.05	0	0.7	100	13.2	0.85
mean	62.42	0.54	19.05	2.59	0.24	0.31	1.06	7.25	5.94	0	0.59		13.19	0.83
sd	0.51	0.10	0.18	0.22	0.11	0.07	0.12	0.51	0.22	0	0.11		0.38	0.08

Table 1 Major element composition of glass from base and top of Oscurusciuto tephra

Sedimentological analysis

The Oscurusciuto rock shelter sequence is more than 6 m thick and, except for SU 14 bed, it is made almost exclusively of siliciclastic sediments (Fig. 1) ranging in size from small grav- el to silt, with the occasional occurrence of rock-fall debris/ blocks (sensu Ghinassi et al. 2009; Martini 2011). On the contrary, the approximately 60-cm-thick SU 14 bed is made almost exclusively of fine-grained pyroclastic sediments, as revealed by thin-section and SEM analyses (cf. 'Description and correlation of the tephra' section).

In detail, thin-section analysis of SU 14 reveals a substan- tially isotropic micro-texture and a clastic structure with a widespread presence of fine micritic matrix in all the analysed samples (Fig. 7a). Several grains of aphyric glass (about 50– 200 μm in size) and numerous crystals/crystal fragments are immersed in the micritic matrix (Fig. 7a, b). Crystals show a small size (50 μm on average) and often are characterised by shock deformations and fractures (Fig. 7b). Several mineral phases have been recognised; the most common of these is represented by feldspar, oxides and quartz, with subordinated pyroxenes and uncommon plagioclase and biotite. These min- erals are compatible with the trachytic composition of aphyric glass.

The sample OS5 (see Fig. 8b for its location within the bed) shows a peculiar clastic structure, characterised by the occurrence of skeletal grains of carbonatic shells and foraminifera (up to 300 μm in size) immersed in the micritic matrix (Fig. 7c, d), associated with rare small feldspar and quartz crystals (20–30 μm in size). A similar structure has been observed in the sample OS10

(collected in the North section, few centimetres below the top of SU 14 bed), where millimetric clasts consist of fine micritic matrix in turn containing small skeletal grains (up to 50 μm in size).
From a stratigraphic and sedimentological point of view, the archaeological layer SU 14 overlays bed SU 15 and they are in turn overlaid by bed SU 13 through a sharp erosional surface locally marked by the occurrence of collapsed blocks (Fig. 8a, b). The relief of such a surface is generally limited to a few centimetres (Fig. 8b).
Erosional surfaces can be recognised also within bed SU 14 and these allowed to subdivide the bed in sub-units labelled SU 14A to SU 14D in inverse stratigraphic order (i.e. from the top to the base of the strata; see Fig. 8b). The lower one in stratigraphic order, SU 14D, is 22-cm thick and displays a peculiar internal cross-stratification with an inclination that decreases moving from internal areas of the shelter (up to 4°–5° in the South section and 15° in the West section) to- wards the external sector, until it becomes sub-horizontal (i.e. downlap geometry, see Fig. 8b, c). A high-relief erosional surface, at place marked by post-depositional carbonate con- cretions, divides SU 14D from the overlying SU 14C bed (Fig. 8b). This bed displays a variable thickness (maximum 11 cm) due to the erosional nature of the lower bounding surface. Internally, it is generally structureless or displays a faint low-angle cross-stratification that only at place is well preserved and visible. The boundary between SU 14C and the overlying SU 14B is sub-horizontal and slight erosional fea- tures can be observed only at place. Bed SU 14B is about 12- cm thick and is composed by some bed-sets that internally display a low-angle cross-lamination laterally evolving to plane-parallel lamination (Fig. 8d, i.e. towards the external sector of the shelter), similarly to those observed in layer SU 14C. The stratigraphically higher bed SU 14A overlays SU 14B through a slight erosional surface with a maximum relief of a few centimetres. Bed SU 14A is about 22-cm thick and, similarly to SU14B, is composed by some bed-sets, some of these being structureless while others display a faint low-angle cross-lamination. Beds SU 14A and B are affected by post- depositional bioturbations represented by vertical burrows filled with coarse-grained sediments coming from the overly- ing siliciclastic sediments (Fig. 8c). The origin of such bur- rows is generally related to plant roots or to excavation by animals.

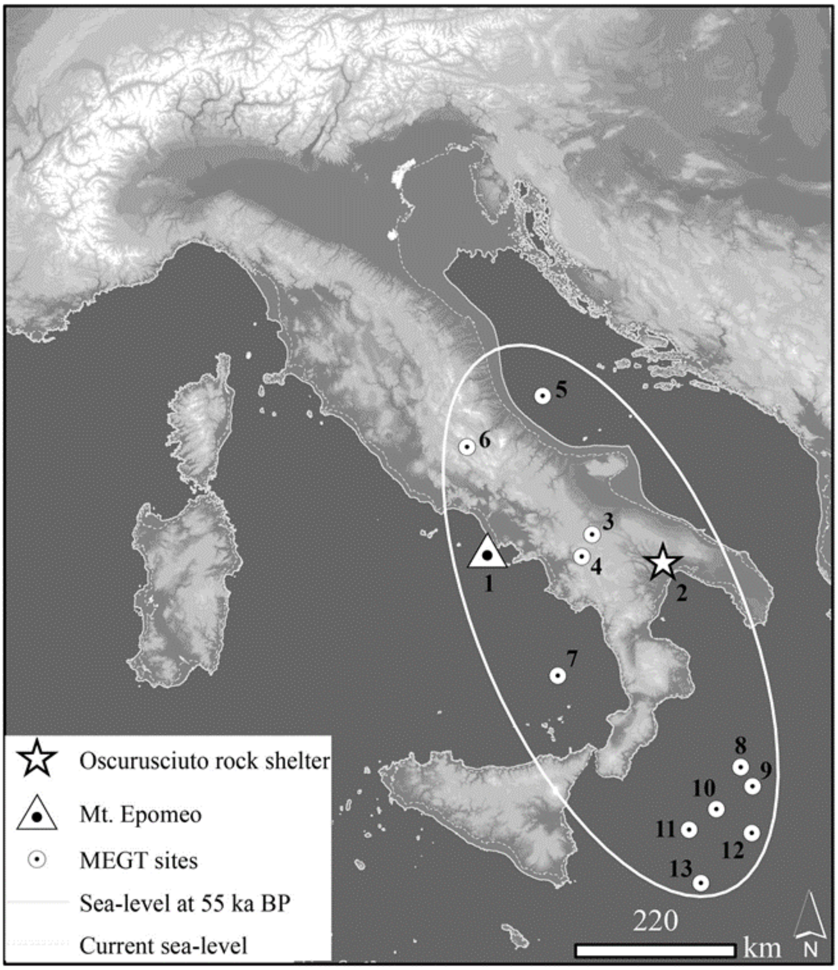


Fig. 6 Localisation on the map of the sites where the Mt. Epomeo Green Tuff was recorded: 1 Mt. Epomeo; 2 Oscurusciuto rock shelter; 3 Lago Grande di Monticchio; 4 San Gregorio Magno; 5 PRAD 1–2 (Adriatic sea-core); 6 Fucino; 7 MD01- 2474G (Tyrrhenian sea-core); 8 RC9-191 (Jonian sea-core); 9 M25/4-12 (Jonian sea-core); 10 M25/4-13 (Jonian sea-core); 11 V10-69 (Jonian sea-core); 12 KC01B (Jonian sea-core); 13 22M-60 (Jonian sea-core). The possible sea level at 55 ka BP is reported, according to Waelbroeck et al. (2002). Orography source: EU-DEM- ETRS89, European Environment Agency (resolution 30 m) (http:// www.eea.europa.eu/data-and- maps/data/eu-dem#tab-european- data). Bathymetry source: EMODnet (resolution 175 m) (http://www.emodnet- hydrography.eu/content/content. asp?menu=0040000_000000). Data processing: V. Spagnolo

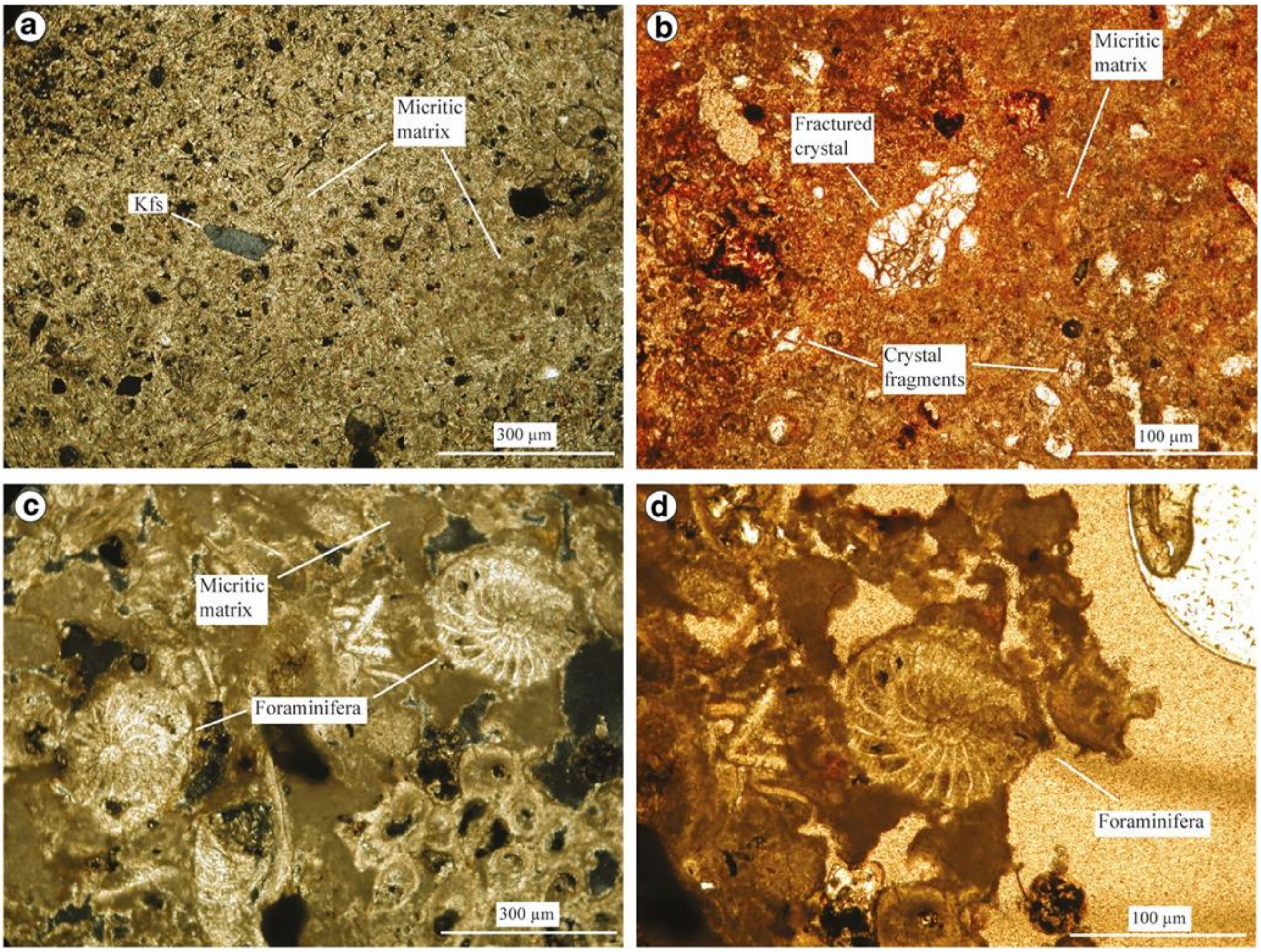


Fig. 7 Microphotographs of analysed thin sections. a Clastic structure characterised by the presence of fine micritic matrix and crystals (in detail a K-feldspar (Kfs) crystal). Sample OS7 (bed SU14 B, West Section), crossed nicols. b Quartz fractured crystals and crystal fragments immersed in the micritic matrix. Sample OS6 (bed SU 14A, West Section), plane-polarised light. c Foraminifera immersed in the micritic matrix. Sample OS5 (bed SU 14A, South Section), crossed nicols. d Detail of a well-preserved foraminifera. Sample OS5 (bed SU 14A, South Section), plane-polarised light

Lithic technology

Most of the archaeological material of SU 14 is concentrated in the stratigraphic sub-unit SU 14A. Few materials come from sub-unit SU 14B, while sub-units SU 14C and SU 14D are sterile. The collection contains 3833 lithic implements in an excellent state of preservation, with fresh edges and absence of any patina or mechanical post-depositional alter- ations. Thirty-five items are burned; however, no hearths have been found in the excavated portion of the layer, but the pres- ence of these burned items (together with 169 burnt faunal remains; see 'Faunal analysis' section, Table 8) suggest that there could be at least one hearth in an area which has not yet been excavated or not preserved. On the edges of 131 items, the presence of macro-traces was registered; however, a pro- grammatic traceological analysis to evaluate their use was not performed. A predominance of fine-grained material (96.4% of the collection) can be noted with a prevalence of jasper, followed by cherty limestone and chert plus a minor quantity of quartz sandstone and limestone (Table 2).

These raw mate- rials were introduced into the shelter in the form of small oblong and globular pebbles ranging in size between 2 and 5 cm (data coming from four unworked pebbles, two completely cortical flakes and one completely refitted item; cf. Marciani 2018).

Based on their technical features, the lithic materials of SU 14 were sorted into the following technological classes: cores, completely cortical flakes, semi-cortical flakes, management flakes, target flakes, hammerstones, micro-flakes and debris (Table 3). The data show a predominance of knapping waste (micro-flakes and debris) followed by management flakes and target and semi-cortical flakes. The main debitage concept is Levallois (74.6%) mostly featuring in its unidirectional and convergent forms and, sporadically, in the centripetal one (Table 4). In this assemblage, the first stage of initialisation and preparation of the convexities coincided with the selection of those raw blocks which already presented the natural con- vexities necessary to start the debitage, i.e. flat lenticular or oblong shape. Pebbles of jasper and cherty limestone were the preferred raw material for the Levallois. After the creation of a striking platform, usually with one, two or more strokes, the reduction proceeded with a unidirectional extraction of flakes, firstly two or three cortical flakes and finally one target product (usually a blade, either convergent or not) (Fig. 9). A centripetal re-initialisation of convexities before a last uni- directional target production is rarely documented (Fig. 10). Three Levallois cores are completely exploited, and one is abandoned at a half-complete stage of exploitation. It is inter- esting to observe the way in which this last stage of the reduction sequence was managed: in the case of the conver- gent Levallois, the core was abandoned due to hinged acci- dents (Fig. 9), whereas in the case shown in Fig. 10, the last reduction stage of the Levallois core was managed with a final additional unidirectional production.

Secondary debitage is an additional unidirectional debitage (12.1%) (Table 4) for which globular or oblong pebbles were two unidirectional production series, with no further prepara- tion of the striking platform or management of the convexities. The aims of this debitage were flakes or blades. It is possible to note three main structures of cores: (1) only one side of the block is exploited for the production (Figs. 11 and 13n); (2) two independent series of debitage occur, one on each side of the block; (3) one series of debitage exploits two sides of the core, taking advantage of the central rib of the debitage surface and the angle of the block (Figs. 12 and 13o). A predominance of pebbles of jasper, followed by cherty limestone, was used for a debitage that aimed at producing blades, whilst a pre- dominance of cherty limestone followed by jasper was used in the case of flake production. Thus, it is possible to note a certain degree of selection of raw material according to the type of desired target product.

There are 139 target objects in the assemblage (Figs. 13a–n and 14a, b): flakes, elongated flakes, blades, backed flakes and convergent flakes. The majority of these objects were pro- duced by the Levallois concept of debitage (92.8%). A spe- cific presentation of the morphological and technological at- tributes of each of these categories is presented in Table 5. Overall, the cortex is absent on 56.1% of the target objects, showing that these items were produced in an advanced stage of flaking when the cortex was already removed. The remain- ing 44.9% of the objects present cortex coverage, which there- fore indicates that the target items were made in an earlier stage of production. The location of the cortex on the dorsal surfaces of the flakes is quite variable in each category; how- ever, there is a clear dominance of cortex on the lateral back of the backed flakes. Given that the raw material is pebble, pro- ducing cortical backed flakes is a useful stratagem to manage the lateral and distal convexities of Levallois unidirectional debitage and at the same time obtain a functional tool: an item with a rectilinear cutting edge opposite to a thicker backed side. The direction of the scars is mostly unidirectional for all categories, except for the convergent flakes, whose trian- gular shape is obtained by three or more convergent removals (Figs. 13c, g and 14a, b). The target items are mostly symmet- rical, except for the backed items which are unsymmetrical. The shape of the transversal section of the objects is mostly trapezoidal as more than three removals are present on the dorsal surfaces. The butts are mostly flat, prepared (three or four removals) or facetted (five or more removals). The impact points are mostly central. Almost all pieces have a prominent bulb, which is an indication of the use of direct techniques with a hard hammerstone, typical of Levallois debitage (cf. Boëda 1995). Many items (41.7%) present macro-traces on their edges. The target flakes produced by additional debitage show only cortical or flat butts, according to the cortical and flat striking platform of the core from which they were detached. The metrical attributes indicate that at SU 14, the target objects have quite homogeneous dimensions: they are quite small and thin. The average length is 22.7 mm for flakes; between 32.1 and 36.75 mm for elongated flakes, blades and convergent flakes; and 40.8 mm for backed items. Overall, the average length of the target items ranges from approximately 20 to 40 mm, data which are in accordance with the average dimension of the imported pebbles (20–50 mm) and the cores (20–45 mm). However, it is notable that some items are out of this range due not only to their greater dimension (retouched tools with a length ranging from 54 to 79 mm) but also to their technological peculiarities, i.e. items in a very advanced stage of debitage, whose raw material holds different and unique characteristics in the context of the other materials produced at Oscurusciuto SU 14. This evidence leads us to hypothesise that these tools were not produced at the site but, on the con- trary, they were introduced as already finished objects.

Only a few pieces (21) have been retouched; these were target flakes, management flakes, semi-cortical flakes and un- determined fragments. There is a predominance of unilateral scrapers (Table 6).

Raw material	n.	%
Jasper	2140	55.8
Cherty limestone	1062	27.7
Chert	505	13.2
Limestone	70	1.8
Quartz sandstone	56	1.5
Total	3833	100.0

Table 2 Raw material

Technological classes	n.	%
Pebbles	4	0.7
Cores	13	2.1
Hammer stones	4	0.7
Completely cortical flakes	2	0.3
Semi-cortical flakes	108	17.6
Management flakes	343	56.0
Target flakes	139	22.7
Micro flakes and Debris	3220	[illegible]
Total	3833	100.0

Table 3 Technological classes (percentages are calculated without the micro-flakes and debris)

Concept-method	n.	%
Levallois	453	74.8
Unidirectional	*314*	
Convergent	*73*	
Centripetal	*2*	
Undetermined	*64*	
Additional Unidirectional	73	12.1
Indedermined	79	13.1
Total	605	100.0

Table 4 Concept method of debitage (flakes and cores)

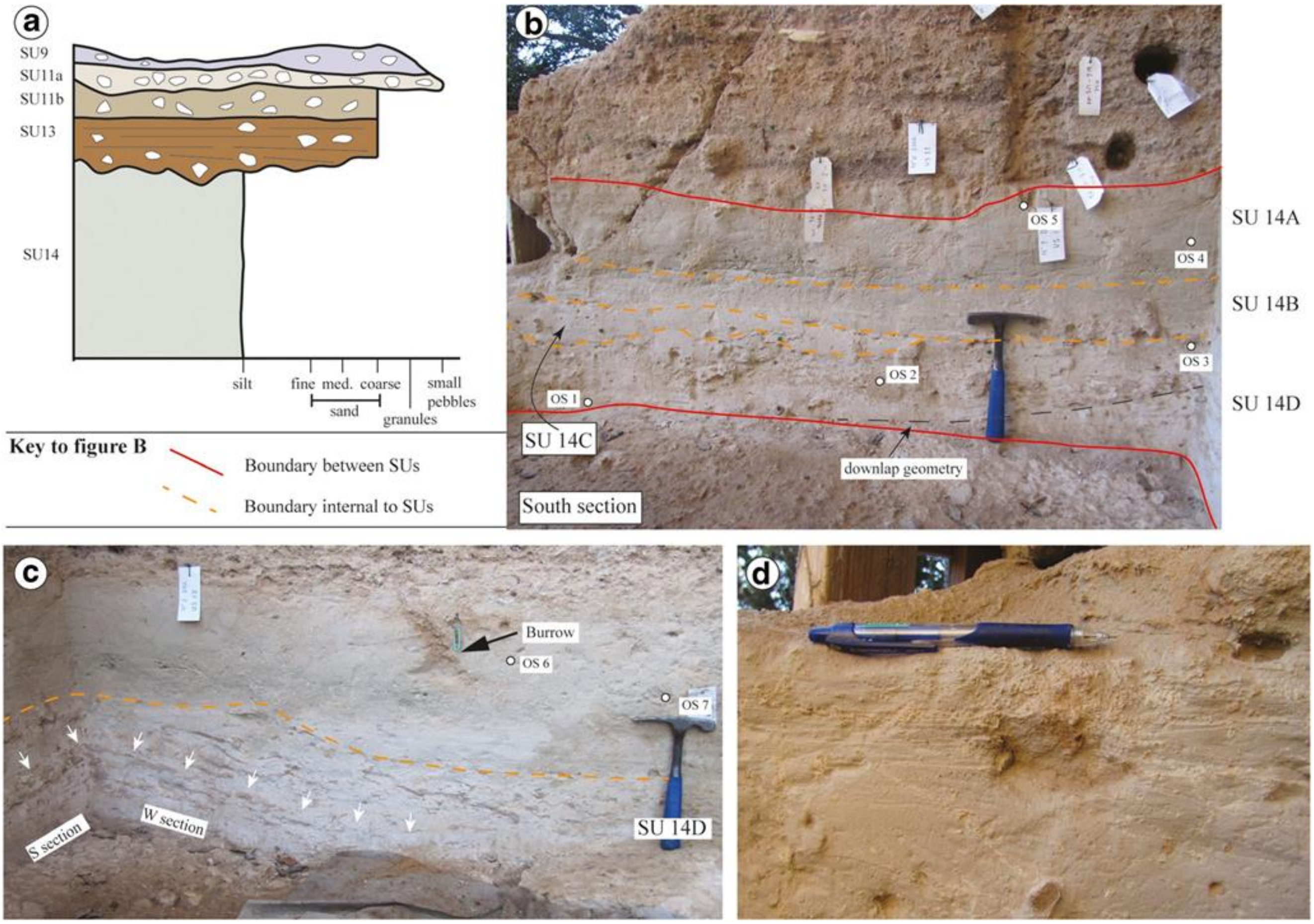
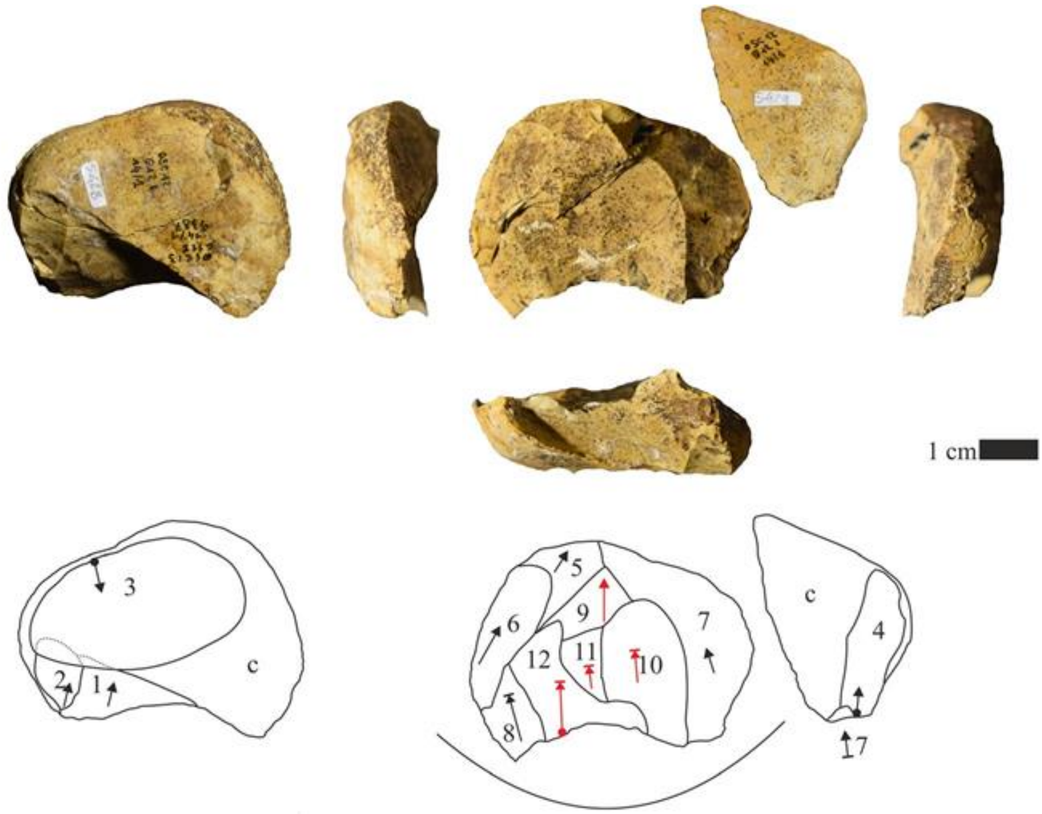
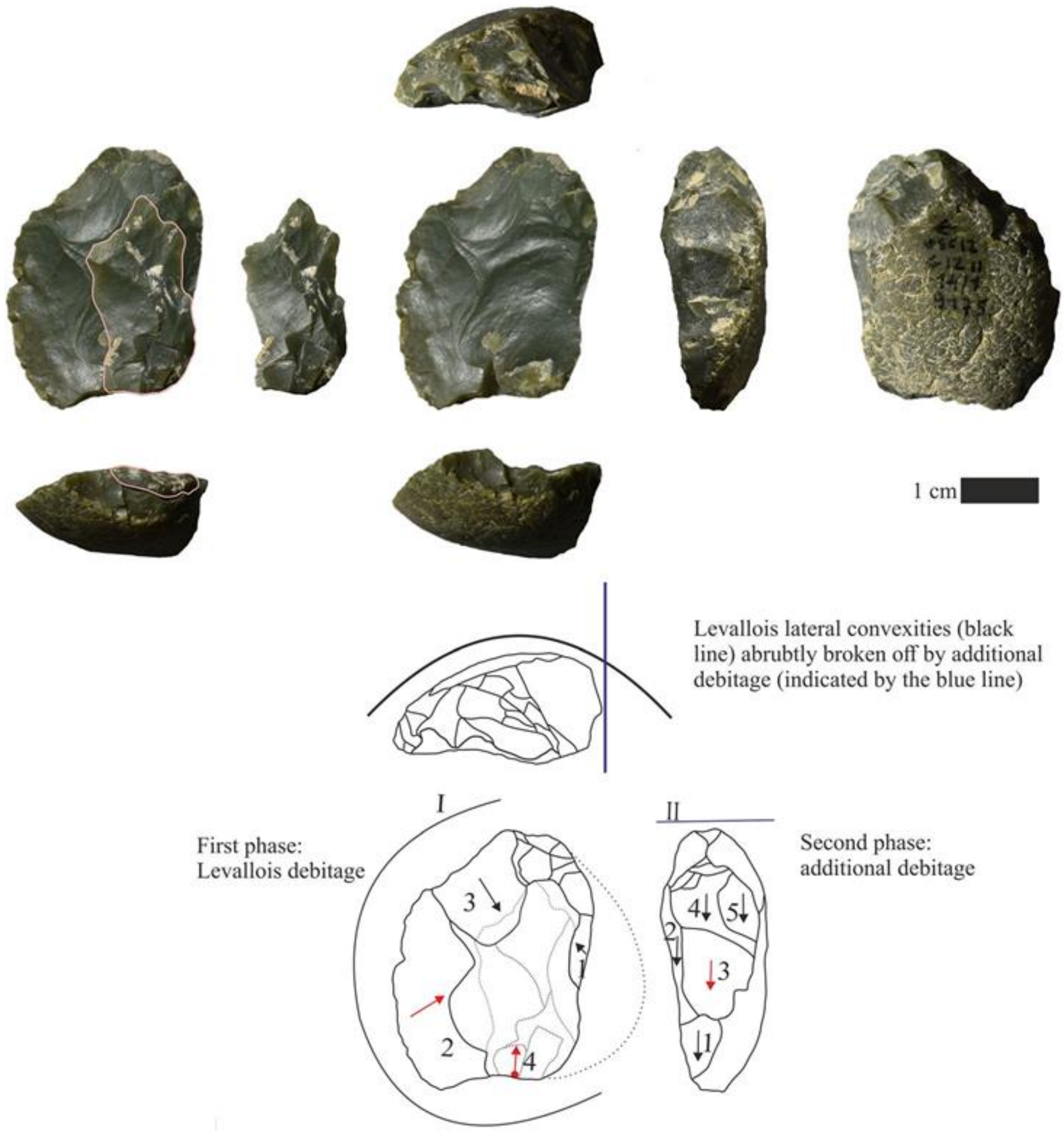


Fig. 8 a Sedimentary log of SU 14 bed and overlying beds. b Line- drawing of the South section with reported the collected samples for petrographic analysis (hammer for scale is 28.5 cm high), SU14A where the human occupation took place. c Detail of the corner between West and South sections. White arrows indicate the cross-stratification that becomes sub-horizontal moving towards the external sector of the sections. d Plane-parallel lamination observable in bed SU 14B in the external sector of the South section (pencil for scale is 14.5 cm long)



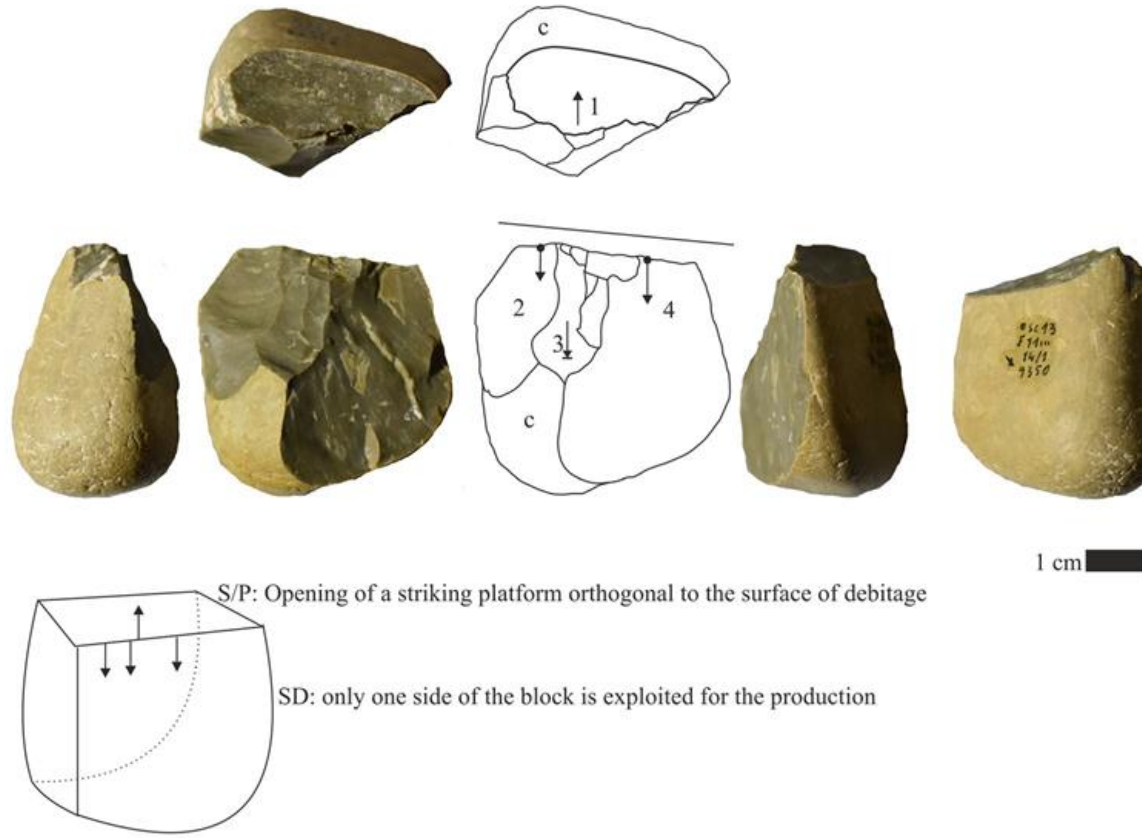
Selection	Pebble.
Striking platform	Semi-peripheral, prepared with small removals.
Production	1, 2, 3 = Opening of the debitage surface, interception of inner fragmentation plane of the pebble. The pebble was turned onto the other side and a recurrent convergent levallois reduction took place. 4, 5, 6, 7, 8 = decortication and convexities management. 9 = researched production, convergent flake. 10 = researched production, flake. 11, 12 = hinged accidents which led to the abandonment of the core.
Target object	Flakes and convergent flakes.

Fig. 9 Diacritical analysis of a convergent Levallois core



Selection	Pebble.
Striking platform	I: Peripheral, prepared with several removals. II: Orthogonal to the debitage surface, prepared with several removals.
Production	First phase- Centripetal levallois, after the preparation of the striking platform (I), a production of 3 flakes (1, 2, 3), and a target flake (4) took place. Second phase- After the levallois production, the convexities of levallois were abruptly broken off by the opening of a distal striking platform on the right side of the core. Subsequently a series of elongated supports were realised.
Target object	Flakes and blades.

Fig. 10 Diacritical analysis of the final stage of a centripetal Levallois core plus a last additional activity performed on the side of the core: a unidirectional debitage performed on the side of the core

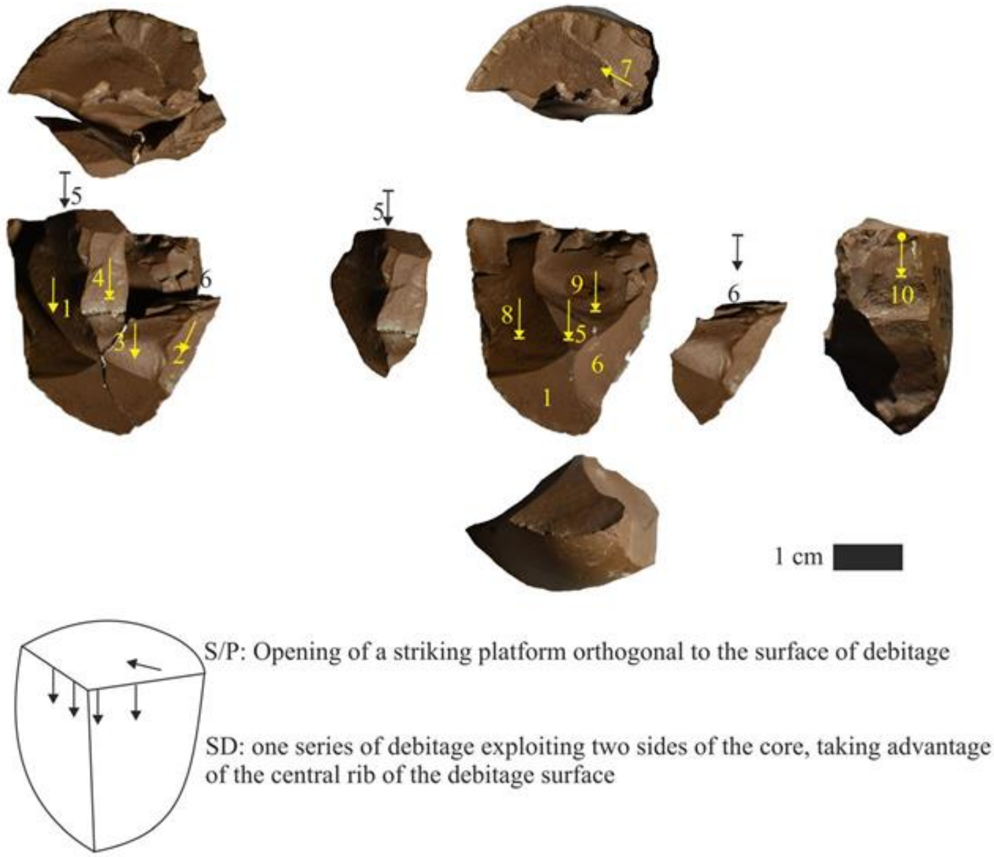


Selection	Pebble.
Striking platform	Orthogonal to the surface of debitage, opened with one stroke 1.
Production	2, 3, 4 = initialisation, decortication. 3 is a hinged accident 4 intercepts an inner fragmentation plane of the pebble. Consequently the pebble was abandoned.

Fig. 11 Diacritical analysis of an additional core: unidirectional series of removals striked from a striking platform orthogonal to the debitage surface

Faunal analysis

Only three specimens were identified according to species. They all belong to aurochs (Bos primigenius) and in particular to three individuals (two left lower third premolars and one right lower third deciduous). The identified specimens all come from the same square (E13). Among all other specimens (n = 645), which are unidentified, two diaphysis fragments belong to a small-size ungulate (e.g. a Caprinae or a small Cervidae), thus representing an additional individual. The bulk of the bone assemblage consists of small fragments (82.9% of remains fall in the category 1–3 cm, Table 7). From an anatomic point of view, most specimens are frag- ments of compact bone tissue (80.6%, 2.6% of which identified as diaphysis), whilst the 18.5% is represented by spongy bone fragments. Only one flat bone and two uniden- tified tooth fragments were detected. Even if no hearths were found in SU 14, 26.1% of bone specimens show heat-induced alterations. Spongy fragments look to be more burnt than others (Table 8), but the absence of calcined specimens (only carbonisation was detected) makes it difficult to infer about a possible use of bones as fuel.



Selection	Pebble.
Striking platform	Orthogonal to the surface of debitage, opened with one stroke.
Production	Two production series with the same idea/objective and stroke sequence. The first sequence produced the removals 1, 2, 3, 4, 5, 6, utilising an orthogonal striking platform, 4, 5 are hinged accidents. 7 re-opening of the striking platform, production of the flakes 8, 9. 10 being a hinged accident, which led to abandonment of the core.

Fig. 12 Refitting set and core of an additional debitage

Spatial evidence

The exploration of the spatial patterns highlights significant clustered patterns both among the overall set of the lithic finds and of the faunal remains. In general, according to the Spatial Autocorrelation, there are less than 1% and 5% likelihood, for lithic finds and faunal remains respectively, that the clustered patterns evidenced could be the result of random chance (Table 9). This scenario is also confirmed by the Getis–Ord General G statistics, highlighting significantly high clustered patterns both for lithic finds and the faunal remains (Table 9). As shown by the Hot Spot Analyses, the spatial patterns of lithic and faunal remains appear quite similar: both the hot and cold spots of these general categories of findings appear rela- tively overlapped (Fig. 15). Ripley’s K function gave significant evidence of clustering rates between 0.3 and 0.8 m (for the lithics) and between 0.3 and 0.5 m (for the faunal remains) (Fig. 16). Based on this evidence, the 0.5 search radius was used for the kernel density maps that magnify the resolution of spatial patterns yielded by previous analyses (Fig. 17).

Discussion

Origin and depositional mechanisms of SU 14 layer

The sedimentary structures recognised in bed SU 14 show that the strata deposited in a framework of aeolian transportation, in which the volcanic ash was transported by wind from the surrounding areas into the shelter where sediments accumu- lated. In detail, the pervasive low-angle lamination/ stratification passing to sub-horizontal laminations towards the more external sectors of the shelter suggest that the de- posits resemble a dune leaning against the bedrock of the rock shelter, with the apex in the SW internal margin of the shelter. The lack of a basal level showing normal-grading and faint plane-parallel lamination suggests that fall-out-related de- posits did not occur. The origin of the erosional surfaces that separate sub-units SU 14A to SU 14D is unclear, but it is likely that they originated both for autocyclic mechanisms of the aeolian deposition and/or for localised and ephemeral sur- face water runoff.

The petrographic analysis of samples collected in bed SU 14 provides helpful information to understand the time inter- val in which the bed accumulated. Indeed, the tephra layer is interbedded within a thick siliciclastic succession in which sediments accumulated mainly due to infiltration and rockfall processes (sensu Bosch and White 2004; Martini 2011; Iacoviello and Martini 2012, 2013). Rockfall processes are also promoted by the severe weathering that affects the poorly consolidated calcarenite of the bedrock. Such a process is still active as documented by the thin calcarenite powder that ac- cumulates over the protective cover of the site every year (i.e.from one excavation to the next). Obviously, pyroclastic ash fall-out and subsequent aeolian transport did not influence the magnitude of infiltration and rockfall processes inside the shelter environment. Therefore, if the tephra accumulated over a relatively large time span (i.e. years), one would expect to find a mixture of pyroclastic ash, siliclastic clasts and granules with lithological affinity with the host rock. In actual fact, siliclastic clasts were never recognised and clasts with an af- finity with the bedrock have been recognised only occasion- ally in samples OS5 and OS10, the first collected at the top of the bed and the second collected within sub-unit SU 14A, 5 cm under the top of the bed. This evidence suggests that the deposition of the overall tephra bed was extremely fast, as much as to prevent the mixing of materials of different origin that occurred only in the upper few centimetres of the bed.

Target object	Flakes		Long flakes		Blade		Convergent f.		Backed f.		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Total	28	20.1	44	31.7	17	12.2	15	10.8	35	25.2	139	100.0
Quantity of cortex on dorsal surface												
0	23	82.1	30	68.2	11	64.7	12	80.0	2	5.7	78	56.1
0-25	4	14.3	10	22.7	3	17.6	3	20.0	24	68.6	44	31.7
25-50			4	9.1	3	17.6			6	17.1	13	9.4
>50	1	3.6							3	8.6	4	2.9
Cortex location												
Back			3	6.8	2	11.8	1	6.7	32	91.4	38	27.3
Distal	1	3.6	8	18.2	3	17.6	2	13.3	1	2.9	15	10.8
Mesial-lateral	4	14.3	3	6.8	1	5.9					8	5.8
Absent	23	82.1	30	68.2	11	64.7	12	80.0	2	5.7	78	56.1
Scar direction												
Unidirectional	21	75.0	35	79.5	16	94.1	3	20.0	33	94.3	108	77.7
Convergent	5	17.9	8	18.2			12	80.0	1	2.9	26	18.7
Orthogonal			1	2.3	1	5.9			1	2.9	3	2.2
Centripetal	1	3.6									1	0.7
Ventral	1	3.6									1	0.7
Scar number												
One	2	7.1	1	2.3					9	25.7	12	8.6
Two	8	28.6	12	27.3	4	23.5	2	13.3	13	37.1	39	28.1
Three	7	25.0	14	31.8	7	41.2	5	33.3	8	22.9	41	29.5
Four	5	17.9	10	22.7	2	11.8	5	33.3	3	8.6	25	18.0
> Five	6	21.4	7	15.9	4	23.5	3	20.0	2	5.7	22	15.8
Morphology (only integer)	12		27		12		12		16		79	
Oval	1	8.3	7	25.9	2	16.7			5	31.3	15	19.0
Trapeze	11	91.7	20	74.1	8	66.7	2	16.7	9	56.3	50	63.3
Triangular					2	16.7	10	83.8	2	12.5	14	17.7
Symmetric (only integer)	12	100.0	23	85.2	11	91.7	10	83.3	6	37.5	62	78.5
Section shape												
Trapeze	19	67.9	26	59.1	5		10	66.7	23	65.7	83	59.7
Triangle	9	32.1	18	40.9	12		5	33.3	12	34.3	56	40.3
Butt												
Absent	6	21.4	8	18.2	2	11.8	3	20.0	8	22.9	27	19.4
Cortical	1	3.6	2	4.5	1	5.9					4	2.9
Flat	6	21.4	12	27.3	6	35.3	2	13.3	14	40.0	40	28.8
Dhiedral	1	3.6	1	2.3	1	5.9	3	20.0	3	8.6	9	6.5
Prepared	6	21.4	8	18.2	4	23.5	3	20.0	5	14.3	26	18.7
Faccetted	7	25.0	7	15.9			4	26.7	3	8.6	21	15.1
Linear			6	13.6	3	17.6			1	2.9	10	7.2
Point-shaped	1	3.6							1	2.9	2	1.4
Impact point												
Absent	6	21.4	8	18.2	2	11.8	3	20.0	8	22.9	27	19.4
Central	21	75.0	31	70.5	10	58.8	11	73.3	13	37.1	86	61.9
Lateral	1	3.6	5	11.4	5	29.4	1	6.7	14	40.0	26	18.7
Bulb												
Absent	6	21.4	8	18.2	2	11.8	3	20.0	8	22.9	27	19.4

Target object	Flakes		Long flakes		Blade		Convergent f.		Backed f.		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Prominent	21	75.0	29	65.9	10	58.8	11	73.3	23	65.7	94	67.6
Not prominent	1	3.6	7	15.9	5	29.4	1	6.7	4	11.4	18	12.9
Presence macro traces	10	35.7	20	45.5	10	58.8	9	60.0	9	25.7	58	41.7
Concept od debitage												
Levallois	27	96.4	43	97.7	13	76.5	15	100.0	31	88.6	129	92.8
Additional	1	3.6	1	2.3	4	23.5			4	11.4	10	7.2
Metric attributes (only integer items)	12	42.8	27	61.4	12	70.6	12	80.0	16	45.7	79	56.8
	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average		
Length	14-31	22.75	13-66	32.1	18-54	34.4	20-79	36.75	22-64	40.8		
Width	17-30	24.2	10-43	23	5-24	14.56	14-38	23.4	11-29	21.3		
Thikness	4-9	5.6	2-18	6.1	2-8	4.7	4-8	5	3-13	6.2		

Table 5 **Morphological and technological attributes of target flakes (the percentages are calculated on the total of each category; note the morphology, symmetry and metric attributes evaluation and percentage are made only on integer items)**

Fig. 13 Products of Levallois and unidirectional additional debitage. a–h Levallois debitage—a: blade; b: backed elongated flakes; c, g: convergent flakes; d, e, f, h: flakes. i–o: unidirectional additional debitage—i, l, m: flakes; n: refitting set including a core and a flake; o: refitting set including a core and 2 flakes (cf. Fig. 12). In the unidirectional additional debitage, please note the flat butt, which corresponds to a flat striking platform, 90° angle between the surface of debitage and the striking surface. On the contrary, the Levallois flakes present prepared or facetted butts, indicating a careful preparation of the striking platform with an angle of detachment of the flakes that is less than 60°

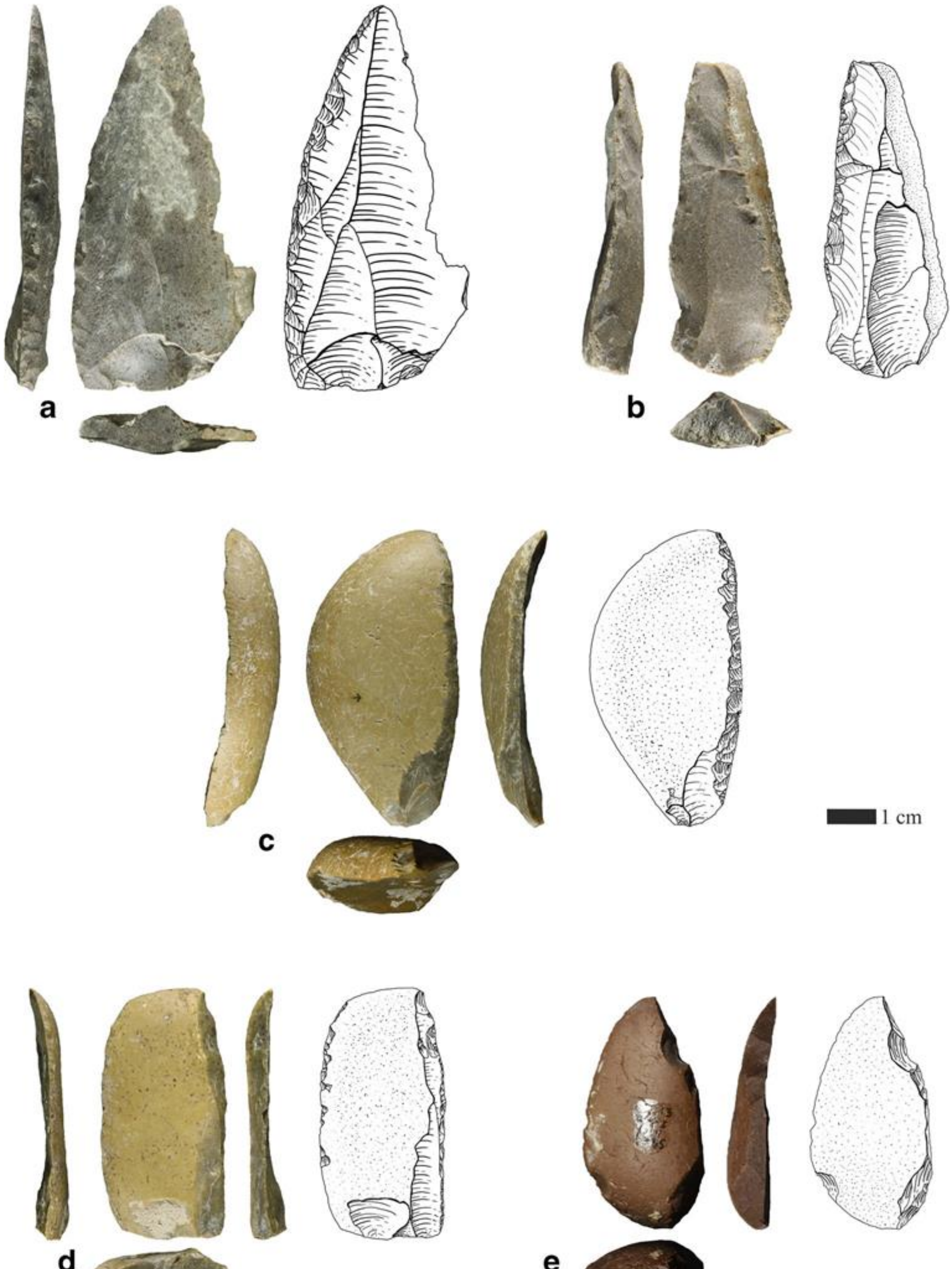


Fig. 14 Retouched tools a–e: side scrapers. To note, the support upon which each tool was made—a: Levallois convergent flakes; b: Levallois convergent flakes with a lateral cortical side; c–e: cortical flakes

Technical, hunting and settlement strategy into the tephra layer SU 14A

Knapping activity in situ was identified in SU 14. This was carried out by introducing raw blocks into the site (oblong and globular pebbles) which subsequently underwent both Levallois and additional unidirectional debitage. The Levallois cores were exploited until depletion, whereas the additional ones were abandoned after one or two series of production. The objectives of the debitage are flakes, elongat- ed flakes, blades, convergent flakes and backed flakes, mostly produced by the unidirectional and convergent Levallois (Fig. 13).

The formation of the lithic assemblage of SU 14 is made up of several fragmented reduction sequences: as well as the ac- tivity of knapping in situ, there is also evidence of the impor- tation of already finished tools into the site. The activity of knapping in situ is documented by the presence of several technological categories made of the same raw material, and the great quantity of debris and micro-flakes. Moreover, the fact that 52.5% of the flakes show cortex coverage indicates that the first stage of initialisation and cortical removal with the production of a first generation of target objects took place in SU 14. The introduction to the site of already finished tools is demonstrated by the presence of several single items: retouched tools or target flakes made on a specific raw mate- rial, which are oversized compared to the dimension of the imported pebbles, and whose reduction sequence of produc- tion is absent (Fig. 14a, b). This evidence points to the idea that these finished tools were imported to the shelter as part of a toolkit.

The activity of transformation by retouch occurs on both target pieces and on management and cortical flakes (Fig. 14c–e). The most common retouched tools are scrapers (lateral or bilateral). Unlike SU 11 (Marciani 2018) and SU 13 (Marciani 2013; Marciani et al. 2016), SU 14 is the only level where most of the retouched items (12 specimens) were made from management flakes, cortical flakes or fragments, i.e. items which require less investment in their crafting. They seem to point to a more expedient behaviour, the creation of tools compelled by a necessity. Moreover, evidence of recycling or reusing activities is absent. This absence can be explained by the peculiar nature of this occupation, SU 14A was placed on a sterile level of tephra and, consequently, the materials of the previous occupations were buried beneath sediments and thus would not have been available to the Neanderthals when they returned to the site. To sum up, the lithic behaviour indicates that Neanderthals used the rock shelter to perform activities of knapping in situ mostly related to the first phases of the reduction of pebbles, namely their decortication and the production of the first generations of debitage objectives. Moreover, it was possible to note the import of already finished tools.

Zooarchaeological data are too scarce to allow us to infer about the possible effects of volcanic eruption on the faunal communities in the area at issue. Nevertheless, the presence of aurochs (the most abundant mammal taxon, at least consider- ing the minimum number of individuals) is in line with data from the uppermost layers (Boscato 2017; Boscato and Crezzini 2007, 2012; Spagnolo et al. 2016, 2019, 2020a). Despite the low number of identified specimens, the faunal assemblage from SU 14 reveals some interesting aspects: the presence of at least three aurochs individuals and one small- sized ungulate should represent a quite high potential biomass transported at site if compared to the hypothesised brief occu- pation. In relation to this apparent contradiction, it has to be highlighted that the total amount of bone fragments (most of them smaller than 3 cm) detected in the layer is much lower than the quantity that would be expected considering the butchery and marrow/fat extraction of complete carcasses. The sample seems to have originated from the exploitation of few anatomical elements (few limb bones and some mandibles). The absence of specimens clearly belonging to epiphyseal portions, together with a scarcity of spongy fragments among unidentified remains, is in line with the evidence from other layers of the site and, more in general, with the picture emerged from the study of other Late Mousterian contexts in Apulia

(Boscato 2017; Boscato and Crezzini 2007, 2012).

SU 14 shows a unique settlement identity, i.e. a fast occupation that occurred during or immediately after the tephra fall-out, when the volcanic ash was in the landscape and aeolian transport was still active. Significant clustered patterns of lithic and faunal remains with a relatively overlapped distribution are recorded. In the excavated portion of the deposit, the absence of evident features which could indicate the existence of stone structures or hearths is notable. The site seems to represent an occupation in a sedimentary context of very fast deposition. In this scenario, the rock shelter was devoted to developing some specific activities: the opening of pebbles and production of first generations of target objects and the exploitation of specific faunal anatomical elements.

Typology\ Technological category	Unilateral scrapers	Unilateral scrapers +point	Bilateral scrapers +point	Bilateral scrapers	Transversal scrapers	End scrapers	Undetermined	Total
Target flakes	1	1	1	0	2	0	4	9
Semi-cortical flakes	3	0	0	0	0	1	0	4
Management flakes	2	0	0	1	0	1	1	5
Undetermined	1	0	0	0	0	0	2	3
Total	7	1	1	1	2	2	7	21

Table 6 Retouched recurrences

	1-3 cm	3-6 cm	6-10 cm	>10 cm	Σ	%
Tooth	3	2	0	0	5	0.8
Compact bone	425	74	6	0	505	77.9
Diaphysis	0	7	9	1	17	2.6
Flat bone	0	1	0	0	1	0.2
Spongy bone	109	10	0	1	120	18.5
Σ	537	94	15	2	648	
%	82.9	14.5	2.3	0.3		

Table 7 Specimens counted according to anatomy and size

	burnt	unburnt	Σ
Tooth	0	5	5
Compact bone	121	384	505
Diaphysis	0	17	17
Flat bone	0	1	1
Spongy bone	48	72	120
Σ	169	479	648
%	26.1	73.9	

Table 8 Burnt fragments according to anatomy

SU 14 in the context of the entire Oscurusciuto sequence

The Oscurusciuto site is characterised by several levels of occupation that are palimpsests with a great abundance of both faunal and lithic materials. The lithic technological behaviours at Oscurusciuto are characterised by a high degree of continu- ity in utilised raw material (which comes from local sources), in the choice of fine-grained lithotypes and in the selection of certain shapes of small pebbles according to the chosen debitage. The debitage is mainly Levallois in all the excavated portion, present in all its variety. In SU 1, SU 4 and SU 8 (still only partially studied), the unidirectional Levallois plus pref- erential and centripetal modality (mostly used at the end of the reduction sequence) can be seen (Ranaldo et al. 2017). In SU 11, the Levallois is documented in all its recurrent types (uni- polar, convergent and centripetal) (Marciani 2018; Spagnolo et al. 2020a). The unidirectional and convergent Levallois are dominant in all the lower levels (SU 13, SU 14) (Marciani 2013, 2018; Marciani et al. 2016, 2018). Another interesting feature to note is the marginal presence of other types of debitages. In SU 1 and SU 4, a blade/bladelets volumetric

Global Moran's I Summary - SU 14	*Number*	*Moran's Index*	*Expected Index*	*Variance*	*z-score*	*p-value*
Lithic finds	3.833	0.420618	-0.021277	0.005388	6,020,007	0.000000
Faunal remains	648	0.000301	-0.021277	0.005434	2,061,257	0.039279
High-Low Clustering Report - SU 14	*Number*	*Observed General G*	*Expected General G*	*Variance*	*z-score*	*p-value*
Lithic finds	3.833	0.212039	0.132979	0.000156	6,323,788	0.000000
Faunal remains	648	0.173675	0.132979	0.000127	3,614,030	0.000301

Table 9 Results of the Spatial Autocorrelation (Global Moran's I) and Getis–Ord General G statistics

Considering the level from a settlement point of view, moving from top to bottom of the sequence, the upper layers (SU 1 to SU 4) show an extremely high density of materials and possibly some structures (Boscato et al. 2004, 2011; Ranaldo et al. 2017). Level SU 7 is characterised by a large hearth in the corner of the rock shelter (at least 2 m wide) (Boscato and Ronchitelli 2008). SU 8 is characterised by fewer materials and the absence of hearths and struc- tures. SU 9, SU 11 and SU 13 are palimpsests as document- ed by the abundance of materials and by the recognised alignment of hearths that divides the space of the rock shel- ter into an outer and an inner portion (cf. Marciani et al. 2016, 2018; Spagnolo et al. 2016, 2019; Boscato and Ronchitelli 2017).

Despite their specificities, all the levels of Oscurusciuto (studied by means of an integrated approach) may be interpreted as relatively long-stay settlements where various domestic activities took place. In particular, SU 13 and SU 11 are two palimpsests whose occupation consists of settlements where each occupation is at least partly superimposed on the previous one (Marciani et al. 2016, 2018; Spagnolo et al. 2016, 2019, 2020a). This means that at least a part of the materials from the previous settlement was probably still vis- ible when the Neanderthals returned to the site. However, SU 14 is an exception in regard to what can be observed before and after the tephra event. The occupation of SU 14 took place in a deposit of tephra which had formed with a fast rate of deposition. This event permits us to isolate this Neanderthal occupation from what happened before (3-m thick of occupation of Oscurusciuto which are still to be excavated) and what happened after the tephra deposition. There is a sterile amount of tephra between the Neanderthal occupation of the

SU 14 and the subsequent re-occupation of the site documented by the SU 13, ‘the first recolonization of the site after the dust’ (Spagnolo et al. 2016).
In particular, the archaeological level SU 14 shows specific features: (1) from a stratigraphic point of view, this occupation occurs at the top of a sterile deposit; (2) the total number of lithic items (3833) and the number of retouched tools (21) are the lowest of the studied sequence; (3) many cores are aban- doned in a non-final phase of exploitation; (4) no recycling or reuse activities are attested; (5) only few faunal anatomical elements have been found; (6) structures indicating a more persistent use of the space (i.e. hearths and/or permanent structures) are lacking in the excavated area. These features together with the extremely fast deposition of tephra deposits indicate a shorter occupation in a sedimentary context of fast sedimentation.
Whilst it is not easy to establish the precise times and modes of the settlement in SU 14, this occupation raises interesting points in the debate on short occupation/ palimpsests and it deserves a specific analysis, which is ongoing. However, as the research stands now it is already possible to say that when the Neanderthals arrived at the rock shelter the floor was definitely made of fine-grained tephra deposits and not of remnants of previous occupa- tions. This is extremely interesting and gives rise to three further observations:

(a) The thick fine-grained tephra deposits (SU 14) not only document a drastic change in the physiography of the rockshelter but also suggest an important change in the environmental conditions in the surrounding landscape due to the pyroclastic fall-out. Despite this probably less hospitable setting, Neanderthals did not abandon the ter- ritory, testifying their resilience to an unusual geological hazard. In addition, this data could also indicate a return to the same place, despite the presence of about 50 cm of tephra inside the shelter. A kind of ‘memory of place’ or ‘attractiveness of place’ is preserved among these Neanderthals leading them back to this shelter for thou- sands of years, as shown by the superposition of occupa- tion levels along the sequence, and this did not fail to happen even after the tephra (Spagnolo et al. 2019, 2020a).
(b) When Neanderthals returned to the shelter after the py- roclastic fall-out, they did not have access to the lithic and faunal materials from the previous occupation (as they were buried beneath tephra deposits), unlike the other levels where there was always access to the mate- rial of the level beneath. Consequently, in SU 14 they did not have the possibility to recycle the earlier materials (for example in order to continue exploiting a core or reuse an abandoned tool, etc.), whilst the re-using of older materials was a common practice documented in the other levels of the site (Marciani 2018), attesting not only the residential use of the shelter but also its use as a source of ‘raw material’.
(c) Finally, the particularity of SU 14 opens new perspec- tives on the role played by the sedimentation rate in the framework of the construction of the archaeological re- cord. In fact, the exceptional preservation of SU 14 was possible due to the high sedimentation rates experienced during its deposition because probably if there had been a low sedimentation rate, these brief occupations would have been mixed with previous and subsequent settle- ments, which would have resulted in the creation of palimpsests.

In conclusion, the difference between SU 14 and the other occupation phases can be explained in a twofold way: on the one hand, SU 14 is an event which represents the capacity of adaptation to a peculiar environmental condition; on the other hand, the change in sedimentation rate (slow vs. fast) did not make the formation of a palimpsest possible, thus isolating the evidence of specific activities carried out at the site during a single occupation.

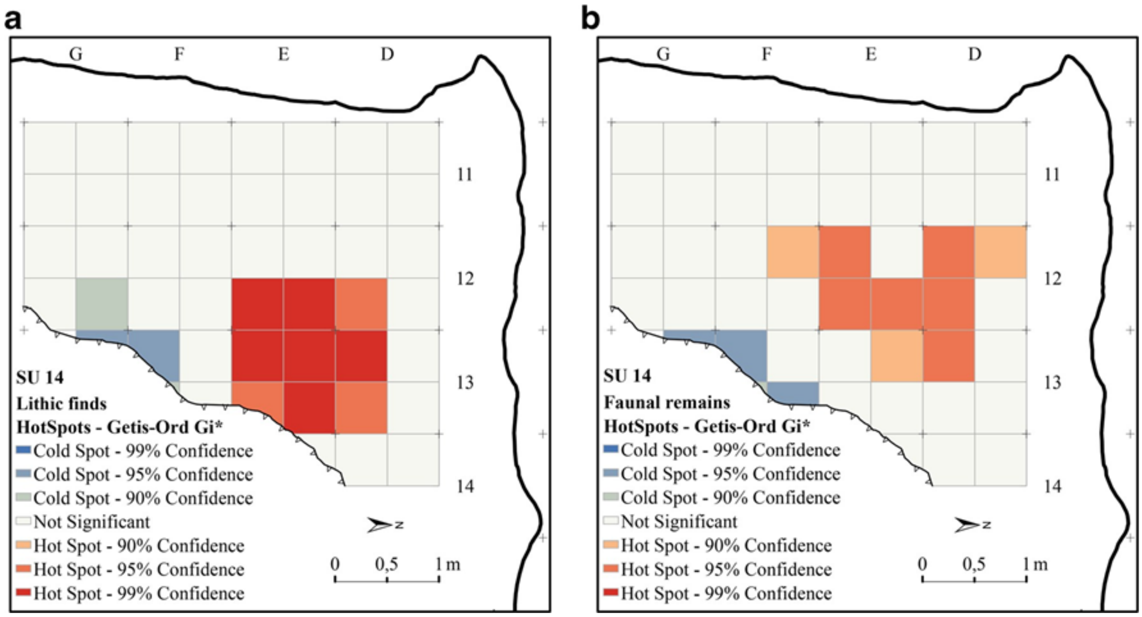


Fig. 15 Hot Spot Analyses results for the lithic finds (a) and the faunal remains (b), respectively

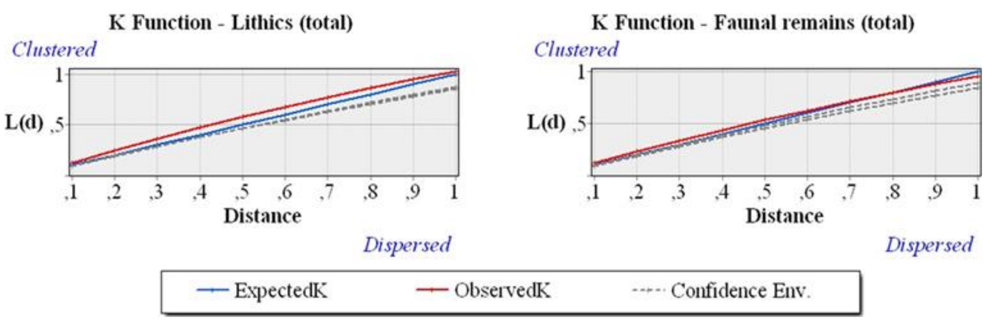


Fig. 16 Ripley's K function results for lithic finds and faunal remains, respectively

Conclusion

The identification of the SU 14 ashes, as a product relatable to the tephra of 'Mount Epomeo Green Tuff' dated at ~ 55,000 years BP, gives a reliable chronological boundary to the Oscurusciuto sequence, thus allowing us to insert this rock shelter into the context of Middle Palaeolithic sites that have a consistent and well-dated stratigraphic sequence.

Prehistoric sites containing evidence of Neanderthal occu- pation are widespread in Eurasia and typically consist of pa- limpsests in which different occupational phases are mixed and/or superimposed. From this point view, the archaeological layer SU 14 of the Oscurusciuto rock shelter offers a great opportunity to investigate the feature of a short occupation by Neanderthals which occurred on a sterile deposit of tephra. The sedimentological evidence, combined with the results of the spatial analysis, suggests that the human evidence from SU 14 is attributable to an occupation that occurred during the fast deposition of secondary volcanic ashes within the shelter.

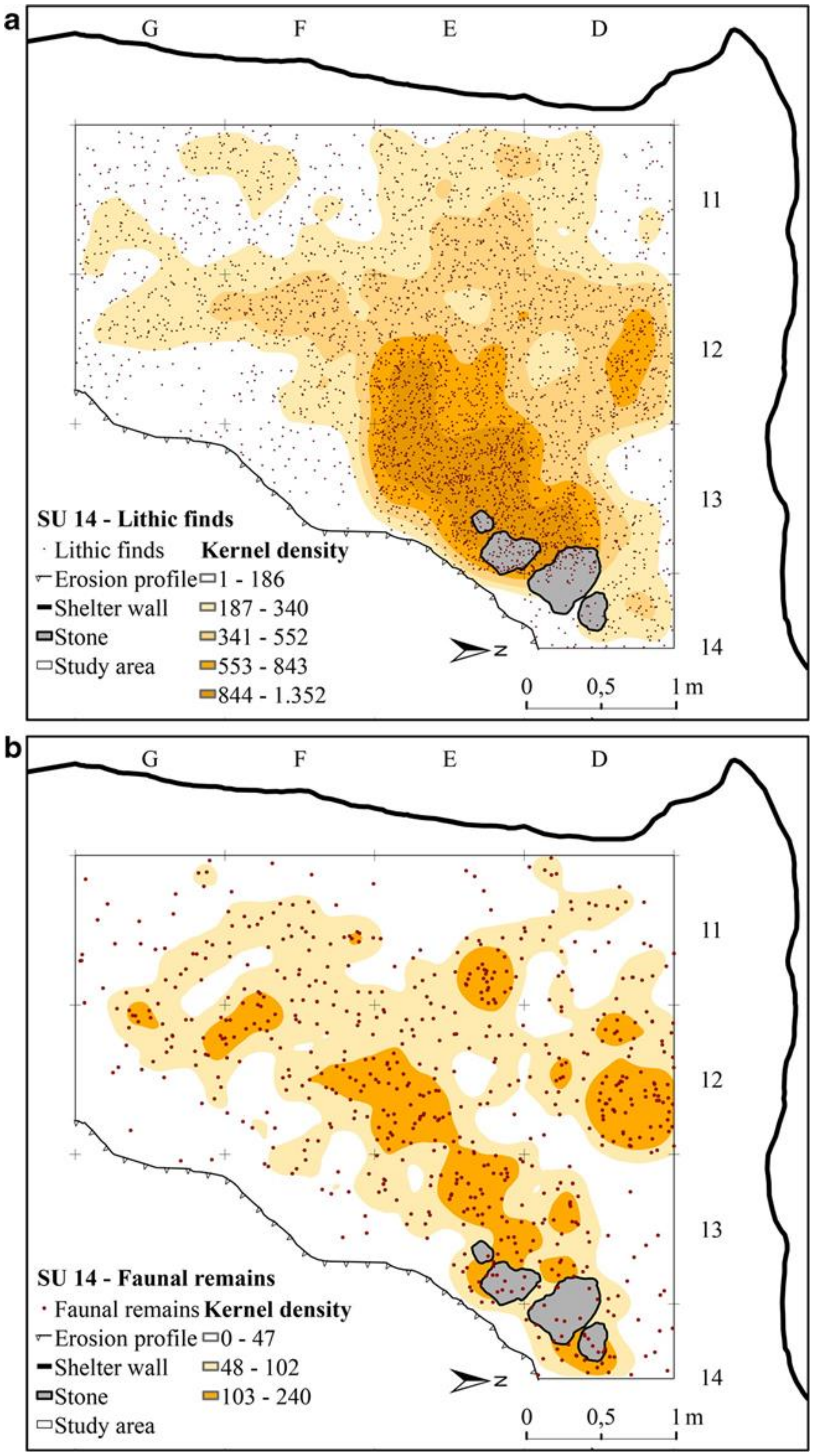


Fig. 17 Kernel density maps of the lithic finds (a) and the faunal remains (b), respectively

The effect of the Mount Epomeo Green Tuff event on the occupants of Oscurusciuto seems to have given an expedite character to their actions, possibly affecting the amount of 'time' spent and the quantity/sort of activity performed in the rockshelter. The tephra event does not represent a caesura in the occupation of the site; indeed, Neanderthal came back to the shelter whilst the tephra was falling (SU 14) and soon after its complete deposition (SU 13). The faunal data are too scarce to show an effect on the biome surrounding the ravine. The lithic behaviour shows a specific goal-oriented use of the shelter, which was utilised to perform activities related to the opening of the pebbles, the production of first generations of target objectives and the introduction of already finished tools.

To sum up, the SU 14 of Oscurusciuto rockshelter demon- strates the resilience of Neanderthal populations who, despite being constrained by a severe environmental hazard, contin- ued to use the rockshelter, retaining certain habits which were common in other levels (such as the use of local raw material, the Levallois debitage and the hunting strategies), but chang- ing the mode of using the shelter, not as a stable residential site but as a faster occupation used to perform specific activities.

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Authors' contribution

G.M. conceptualised the paper and studied the lithic industry as part of her PhD, in collaboration with her tutor D.A.; A.R., P.B. and F.B. are the research and excavation coordinators. V.S. performed the spatial analyses; I.M. the geological, sedimentological and stratigraphic analysis of the succession; A.C. performed the petrographic study of the thin sections; R.S. performed the tephra geochemical analysis and F.B. and P.B. analysed the faunal remains. All the authors collabo-rated in writing, reviewing and editing the paper.

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