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Grotta della Lea, a new Early Epigravettian site in southern Italy (Uluzzo Bay)

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ABSTRACT

Grotta della Lea, discovered in the 1970s, is located in the Municipality of Nardò (LE), southern Italy, and has been systematically investigated only in recent years. This cave remains an untouched environment, ideal for the application of modern analytical methodologies from the beginning of its excavation. Its unexplored status, combined with its proximity to other significant Palaeolithic sites such as Grotta del Cavallo and Grotta-Riparo di Uluzzo C, renders it a promising site for our understanding of the Palaeolithic in Italy.

Earliest results from the initial four years of investigations at Grotta della Lea brought to light both Upper Palaeolithic and Copper-Bronze Age human occupations. This paper is aimed at presenting Grotta della Lea for the first time, focusing on preliminary information about the site formation processes, the characteristics of the stratigraphic succession, and the establishment of both relative and absolute chronologies according to the initial results of a comprehensive AMS radiocarbon dating programme. Central to this research is also the analysis of pottery and lithic artefacts as well as the taphonomic and taxonomic assessment of macro mammal remains.

The study of the lithic industry from the Palaeolithic deposit highlighted the production of shouldered backed bladelets and points on high-quality chert, which are typologically and technologically indicative of an advanced phase of the Early Epigravettian. This attribution is corroborated by radiocarbon dating between 21,821–18,281 cal. BP, aligning with the timeline for the Early Epigravettian in Italy. In the Palaeolithic occupation, the large mammal association revealed an abundance of equids and large bovids, along with several carnivore, leporid, turtle and bird remains. Taphonomic analysis highlighted the occurrence of butchery marks, but also some carnivore activity.

1. Introduction

Grotta della Lea has recently been the object of systematic investigations, although it has been known since the 1970s, when it was discovered and first described by the Gruppo Speleologico Neretino (GSN). This cave, which opens on the plateau above Uluzzo Bay, within

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the municipality of Nardò (LE) (Moroni et al., 2022), holds a crucial position in the archaeological landscape, especially for the discovery in 2022 of one of the few well-dated *in situ* Early Epigravettian occupations presently available for the Italian Palaeolithic.

Uluzzo Bay is part of the broader bay of Porto Selvaggio, which has garnered national and international recognition for its archaeological importance since the 1960s. This recognition is due to the extensive range of prehistoric sites that cluster in a very restricted area (Valchera et al., 2011) and are still critically important for their significant contributions to the reconstruction of the evolution of both local and

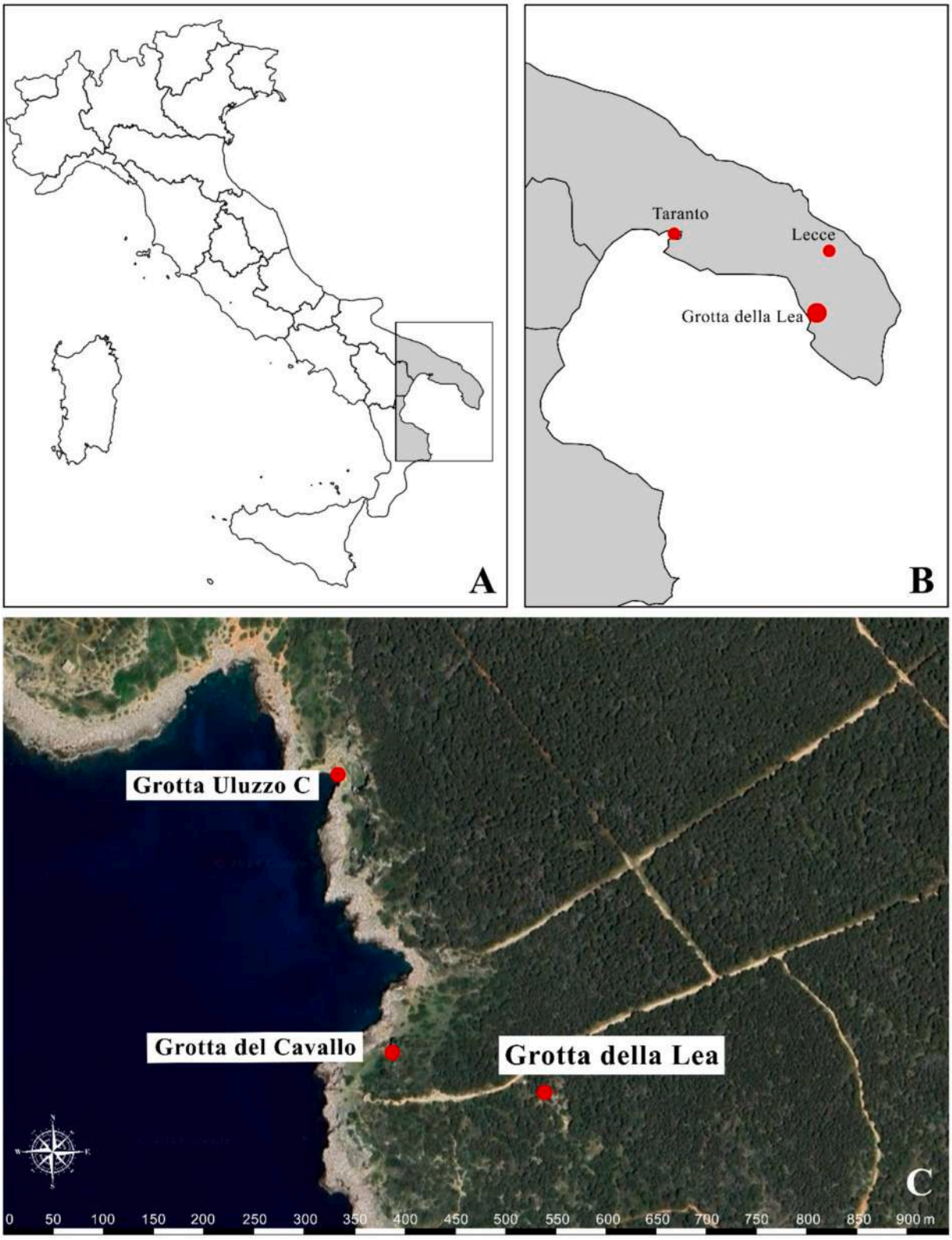

Fig. 1. A-B. Maps illustrating the position of Grotta della Lea in Italy and in Apulia; C. Aerial view of Uluzzo Bay with the position of Grotta della Lea and the nearby Grotta-Riparo di Uluzzo C and Grotta del Cavallo.

European Palaeolithic. This significance stems from the presence of internationally renowned cave sites such as Grotta del Cavallo (Moroni et al., 2018; Palma di Cesnola, 1963; Sano et al., 2019), Grotta-Riparo di Uluzzo C (Borzatti von Löwenstern, 1965; Silvestrini et al., 2022; Spinapolice et al., 2022; Seghi et al., 2024), Grotta Mario Bernardini (Borzatti von Löwenstern, 1970), and Grotta di Serra Cicora (Spennato, 1981). These sites have played a crucial role in archaeological research, yielding valuable discoveries that have shed light on the highly debated transition from the Middle to the Upper Palaeolithic (Arrighi et al., 2020; Badino et al., 2020; Marciani et al., 2020; Romandini et al., 2020), which is marked by the disappearance of the last Neanderthal populations and the advent of *Homo sapiens* in Europe. Among the discoveries, these sites have yielded pivotal stratigraphic successions and, from Grotta del Cavallo, two of the oldest documented fossils of *sapiens* in Europe (Benazzi et al., 2011).

Located just a few hundred meters from Grotta del Cavallo, Grotta della Lea provides an exceptional opportunity to further our understanding of the Palaeolithic in southern Italy. Beyond its proximity to key Palaeolithic sites, Grotta della Lea distinguishes itself as a unique and pristine site within the prehistoric landscape of the area of Porto Selvaggio (Fig. 1). Unlike many significant and renown prehistoric sites – the deposits of which were mostly excavated in the past – Grotta della Lea represents a fresh exploration. This allows for meticulous, controlled excavation techniques, combined with modern documentation methods and sample recovery from the outset.

This paper aims to present the preliminary research results from Grotta della Lea, providing a detailed description of the site and a comprehensive summary of the initial four years of excavation. The focus will be on reconstructing the cave's formation processes, examining the characteristics of the deposits, and exploring its stratigraphy and its relative and absolute chronologies. Additionally, the study will describe the Holocene and Upper Palaeolithic industries found thus far at the site, introduce taphonomic and faunal analyses, and present the first results of an extensive AMS radiocarbon dating programme.

2. The site: Grotta della Lea

2.1. Geomorphological and Geological outline

Grotta della Lea (40.1545833 N, 17.9625944E, 20 m a.s.l.) is located in the Natural Park of Porto Selvaggio and Paludi del Capitano, within the municipality of Nardò, in the Salento region. The cave developed in the Upper Cretaceous Altamura Formation (Fm.), a well-stratified muddy limestone bedrock. The cave entrance opens in correspondence with one of these bedding planes. Before the archaeological excavation, the cave entrance was almost filled with sediments, the most recent and surficial of which was composed of a heterogeneous mix of large debris and fine-grained materials, which were in places rich in organic matter (Fig. 2).

From the cave entrance, it is possible to access a wide and low chamber (approximately 30x25 m, with a north–south orientation). The morphology of the chamber suggests that bedding planes played a crucial role in driving the dissolution processes that led to the cave's formation. Before excavation, the chamber floor was composed of sediments with similar features to those observed close to the entrance, albeit with a reduced amount of rock debris.

2.2. Research history

Grotta della Lea was discovered and explored by the Gruppo Speleologico Neretino (GSN) in the 1970s (Fig. 3). The cavity is an area known as "Piana della Lea", from which it later derived its name. To access the cave, the GSN created a tunnel at the northern extremity of the cave entrance by displacing superficially collapsed rock blocks that were obstructing entry. During these initial explorations, a small test pit was conducted approximately three meters from the entrance, leading to the discovery of pottery fragments and burnt bones. Due to these findings, the cave was included in the regional registry of caves with archaeological significance (Catasto delle Grotte della Puglia, scheda PU_1679). These activities represent the only intervention at the site before the present systematic, authorized research.

In 2019, an inspection was carried out at the site to assess its archaeological potential. The research interest in unravelling the various phases of the Apulian Palaeolithic, including the Middle to Upper Palaeolithic transition, the site's proximity to Grotta del Cavallo, and its undisturbed nature, made Grotta della Lea an ideal candidate for methodical excavation activities.

Since 2020, a joint mission led by the Universities of Bologna and Siena has conducted research at the site. Initial investigations revealed that the large chamber that characterizes Grotta della Lea was almost completely filled with sediment, which almost sealed the entrance and interiorly reached on average 1 m from the ceiling. In addition, the cave's natural entrance was significantly obstructed by large limestone blocks derived from the collapse and retreating of the cave's original vault. These blocks were partially embedded within a recently formed soil (SU1) and were lying on the top of the underlying layer (SU2). Throughout 2020 and 2021, excavation activities at Grotta della Lea prioritised establishing a suitable access point to the cave interior. This involved the meticulous removal of recent soil layers and selected limestone blocks. The successful identification of an in situ Palaeolithic deposit in 2022 marked a significant achievement in this ongoing research programme.

3. Methods

3.1. Excavation and stratigraphic description

Excavation was carried out following stratigraphic methods. The different layers/stratigraphic units (SUs) were numbered sequentially according to the directives of the Italian Ministry of Culture. Once the recent soil (SU1) was completely removed, a grid coordinate system was established, consisting of 1x1m squares identified by a letter and a number, further subdivided into 50x50 cm sectors named by Roman numerals (I, II, III, IV) in a clockwise direction. To enhance chronological resolution, each SU was excavated – when necessary – using 5 cm thick spits, following any discontinuities within the layers (e.g., living floors).

If visible, archaeological finds larger than 1 cm were recorded according to their three-dimensional spatial coordinates with a total station and assigned to the relative square, sector, layer, and spit. Additionally, the orientation and inclination of all items longer than 2.5 cm were recorded; items longer than 10 cm were recorded by three points to register their orientation. The exact position of items recorded by the total station was managed using the spatial analyst module in ArcMap, a GIS application developed by ESRI. Notable archaeological features and excavated surfaces were documented with photogrammetry.

Sediments – divided by square, sector, layer, and spit – were dry-sieved (1 mm mesh) in the field and brought to the lab, where the residue was further wet-sieved and screened with tweezers to avoid the loss of any small remains. All findings were stored in plastic bags according to their provenance. Sediment samples were taken for various analyses. Photographs and personal notebooks documented all excavation activities, and a comprehensive report was prepared for the Archaeological office.

3.2. Radiocarbon dating

Radiocarbon dating analyses were carried out by Accelerator Mass Spectrometry (AMS) at the Centre of Applied Physics, Dating and Diagnostics (CEDAD) of the University of Salento (Calcagnile et al. 2019). Following preliminary mechanical removal of macro-contaminants,

Fig. 2. Excavations at Grotta della Lea, showing the entrance of the cave as it was in 2020 at the beginning of excavation (above) and in 2023 after the discovery of the Early Epigravettian occupation (below), during which the distance between the floor and the ceiling was approximately 1.50–1.70 m.

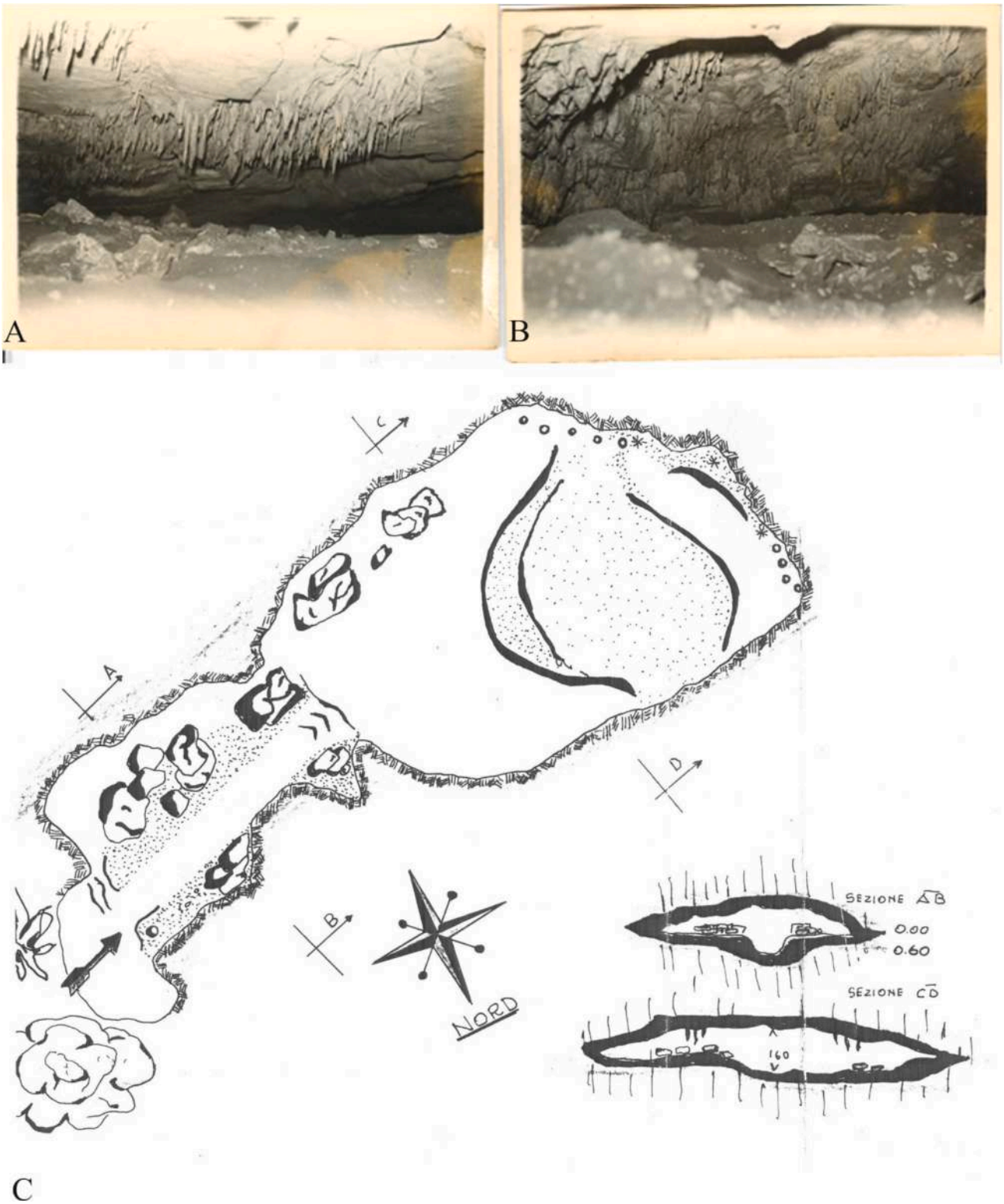

Fig. 3. A-B. First photographs of the interior of the cave (GSN, 1975). C. Plan of the cave made by the GSN in the 1970's (GSN, 1975). The sections (bottom right) clearly show the height of the cavity relative to the sediment before excavation.

collagen was extracted from bone samples and purified by following the Longin protocol (Longin, 1971; Quarta et al., 2004). Extracted collagen was dried and sealed under vacuum within quartz tubes together with copper oxide and silver wool. Subsequently, it was combusted into carbon dioxide at 900° C. The carbon dioxide released by the sample was then cryogenically purified and reduced to graphite by using pure hydrogen – as reducing agent – and silver powder – as catalyst (D'Elia et al., 2004). The resultant graphite was then pressed into the target holder of the AMS system, based on a 3 MV Tandetron accelerator (Mod. HVEE 4130 HC), and $^{14}C/^{12}C$ isotopic ratios were measured. Radiocarbon ages were then calculated after correcting for isotopic fractionation and processing background (Stuiver and Polach, 1977; Hajdas

et al., 2021). Conventional radiocarbon ages were then calibrated using the latest internationally accepted calibration curve for atmospheric data INTCAL20 (Reimer et al., 2020) and OxCal ver. 4.3 calibration software.

3.3. Ceramic finds

The excavation of SU1 and SU4 revealed evidence of human frequentation during the Holocene. Pottery sherds recovered during the 2020–2023 campaigns were subjected to detailed analysis, being counted and classified according to three main criteria: size, morphological attributes, and macroscopic composition of the paste. The fragments were thus sorted into three size categories: larger than 5 cm, between 5 cm and 3 cm, and smaller than 3 cm. The categorization of the fragments was then carried out according to their morphological attributes, which included body sherds, base, rim, and handle. Finally, the ceramic paste was macroscopically categorized into three different types of impasto: coarse, medium-fine, and fine.

3.4. Lithic artefacts

The study focused on the lithic materials recovered in the SUs 1 to 9. The methodology used to categorize each artefact included assigning an identification number, excavation year, excavation square, sector, SU and spit. For the analysis of raw materials, we classified lithotypes into categories such as chert, radiolarite, siliceous limestone, and limestone. We recorded their forms as either pebbles or blocks, observed the presence of patina and combustion traces, and evaluated the condition of the artefact's surface (fresh, worn, highly worn).

Morphometric data (length, width, and thickness) were recorded for items exceeding 100 mm^2 in area. These dimensions were measured along the artefact's technological axis when identifiable, otherwise, the longest dimension was designated as the length. The classification of each piece within the 100 mm^2 threshold, corresponding to Dimensional Class 2 as defined by Spagnolo et al. (2020a), was determined using a progressive template grid. The grid, representing different size thresholds, allowed for the assessment of each artefact's surface area based on whether it fit within the corresponding square. This classification supports spatial analysis by helping to identify potential activity areas and distinguishing material sorting processes from water flow. Cores were oriented by positioning the most used striking platform at the distal end and the primary debitage face – usually characterized by the most recent flake removals – as the main face. Measurements were taken according to this orientation or, when it was not possible, defaulted to using the longest measurement as the length.

The lithic artefacts were categorized based on technological classes as follows: Cores, Tools, Debitage products (encompassing all varieties of flakes, blades, and bladelets), Microflakes (flakes and flake fragments with an area smaller than 100 mm2), Debris (unidentifiable pieces with an area smaller than 100 mm2), Fragments (unidentifiable fragments, burned and altered pieces, all larger than 100 mm2), and Hammerstones. Debitage products were further classified according to their state of preservation as either complete or broken (with breaks identified as distal, lateral, mesial, proximal, distal-mesial, mesial-proximal, or composite), and by technological traits into cortical flakes, semi-cortical flakes, flakes (length/width ratio ranging from 0 to 2), blades (length/width ratio exceeding 2 – Inizan et al. (1995)), bladelets (referring to blades with a width $\leq$ 12 mm) (Tixier, 1963), and debordant flakes, backed blades or bladelets, crests, convergent blades or bladelets, management blades-bladelets-flakes (technical pieces used to manage the convexities of the core and rejuvenate the striking platform), and spalls (an elongated element detached from a lateral ridge of a flake-core). Tools that had been retouched were categorized according to Laplace's typology (1964), which includes criteria related to the mode, extent, direction, shape, outline, and location of the retouch.

3.5. Osteological remains

The zooarchaeological and taphonomic analyses were based on the faunal remains recovered during the 2020–2023 excavations, focusing on SUs 1 to 9. Modern and domestic faunal remains were considered as reworked materials and consequently were excluded from the analysis. All bone remains were counted and analyzed, including bone fragments $>$ 20 mm, morphologically identifiable remains $<$ 20 mm, and small unidentifiable bone elements $<$ 20 mm. Taxonomy was determined using the osteological comparative collection at the Laboratory of Osteoarchaeology and Palaeoanthropology – BONES Lab, at the Department of Cultural Heritage of the University of Bologna (Ravenna Campus, Italy) and several osteological atlases (Barone, 1976; Pales, 1981 among others).

Non-identified remains were grouped into four mammal-sized classes (Bunn, 1986), considering the weight of the most represented species: small mammal or size 2 (<20 kg), including lagomorphs and small carnivores; medium mammals or size 3 (20–100 kg) (i.e. *Rupicapra rupicapra*, *Ovis/Capra*); medium-large mammals or size 4 (100–300 kg) such as *Cervus elaphus*; large mammals or size 5 (>300 kg), which includes *Bos/Bison* sp. and *Equus* sp. When species determination was not possible, elements were identified to their genus level (*Equus* sp., *Bos/Bison* sp., *Ovis/Capra*). The assemblage was quantified by applying the following indices: Number of Remains (NR), Number of Identified Specimens (NISP), Minimum Number of Element (MNE) and Minimum Number of Individuals (MNI) (Binford, 1984; Grayson, 1984; Klein and Cruz-Uribe, 1984).

Animals' age at death was estimated by dental eruption and wear stage, as well as by bone fusion, following Silver (1969) Azorit (2011), Mariezkurrena (1983), Tomé and Vigne (2003), Couturier (1962), Habermehl (1992), Pflieger (1982) and Harris (1978). Once the age at death was determined, individuals were grouped into three age categories: Juv (Juvenile – light wear on deciduous teeth and erupted M1); SAd (sub-Adult – moderate wear on deciduous teeth and erupted M2) and Ad (Adult – all permanent teeth erupted with moderate to no wear). The sex was identified using the presence/absence of canines for *Equus* (male/female) and antlers for *Cervus elaphus* (male/female).

For the taphonomic analyses, specialised bibliography and taphonomic atlases were consulted (Behrensmeyer, 1978; Blumenschine et al., 1996; Fernandez-Jalvo and Andrews, 2016 among others). Evidence of anthropogenic modifications on the faunal remains includes cut marks (Binford, 1981; Lyman, 2008; Potts and Shipman, 1981; Shipman and Rose, 1983), intentional bone breakage (differentiating among fresh, dry or indeterminate fractures) and percussion marks (Galán et al., 2009; Sala et al., 2015; Vettese et al., 2020, 2017; Villa and Mahieu, 1991). Burnt damages were recorded following a modification of the criteria described by Stiner et al. (1995), and burnt bones were divided into different categories: charred (200–500° C, black/brown) and calcined (> 700 °C, grey – creamy yellow – bright ivory white).

Carnivore modifications were documented in the presence of tooth marks and various other marks related to chewing activity (Binford, 1981; Domínguez-Rodrigo and Barba, 2006; Domínguez-Rodrigo and Piqueras, 2003). Other post-depositional alterations included the presence/absence of root marks, modifications made by rodents, weathering, trampling, water dissolution, concretion, abrasion and manganese (Behrensmeyer, 1978; Fisher, 1995; Lyman, 1994; Shahack-Gross et al., 1997, among others). When necessary, microscopic analyses, measurements, and image captures were performed using a LEICA S9i digital stereo microscope.

The identification and attribution of human bones was conducted using dedicated bibliography and anatomical atlases (White and Folkens, 2005, France, 2009).

4. Results

4.1. Archaeological deposit and stratigraphic sequence

To access the cave's internal deposit, a large trench, named "Sondaggio Esterno" (External Area, hereafter EA) (Fig. 4), was opened outside the southern entrance.

Two different areas were chosen for the excavation. The first one, area A (hereafter A), is located close to the north wall of the cave, exactly where the GSN had conducted its first exploration in the 1970s. Its stratigraphy is complex due to wall proximity, resulting in downward-tilting layers and debris accumulation. The second area, Area B (hereafter B), is situated south of A, separated by a diaphragm (Fig. 4). Presently, B is the main focus of the systematic investigation and contains the *in situ* Early Epigravettian occupation.

Here, we describe of the excavated SUs based solely on field observations, as sedimentological and micromorphological studies are in progress. SU1 containing only Holocene materials (from the metal ages to very recent periods), was found throughout the excavation area (A, B and EA). SU2, containing Upper Palaeolithic materials, was present in B, EA and possibly in A. SU4, which exclusively yielded materials of the Metal ages, and SU6 (devoid of anthropogenic remains) were only

Fig. 4. A. Photograph indicating the three excavated areas. B. Orthophoto 3D plan of the base of the living floor/short-term palimpsest (SUs 7, 8, 9). C. magnification showing the deposition of fauna over the limestone blocks of SU9.

identified in A SU3, SU5, SU7, SU8, and SU9 were exclusively found in B (Figs. 4-5), where they formed an anthropogenic short-term palimpsest (according to the definition proposed by Spagnolo et al., 2020a, 2020b). In all investigated SUs, materials (lithics and bones) are never particularly numerous and charcoals are very rare, except for the so-called "carbonaceous layer" (see below).

The stratigraphic succession consists of the following SUs (from top to bottom) (Fig. 5):

External Area, Area A and Area B (Holocene finds – SU1, Epigravettian finds – SU2)

- **SU1** – Dark, loose sediment rich in organic remains, with sharp-edged limestone slabs and debris, pervaded by recent bioturbation, including stumps and roots of present-day pine trees. This SU was extensively reworked by bioturbation and was identified, throughout the excavation area, albeit with varying thicknesses. In the EA, SU1 was almost devoid of archaeological materials. However, inside the cave (areas A and B), it contained – alongside plastic, glass and remains of present-day animals – pottery fragments, lithics and human remains, mainly referred to the Metal Ages. In A, the lowermost part of SU1 yielded several vertically positioned sherds and some human remains. SU1 overlies SU2, separated by a sharp and irregular boundary, indicative of an erosional contact.
- **SU2** – Compact reddish-brown sandy sediment containing limestone clasts and debris, on top of which lay the base of most of the collapsed large blocks obstructing access to the cave. This SU notably

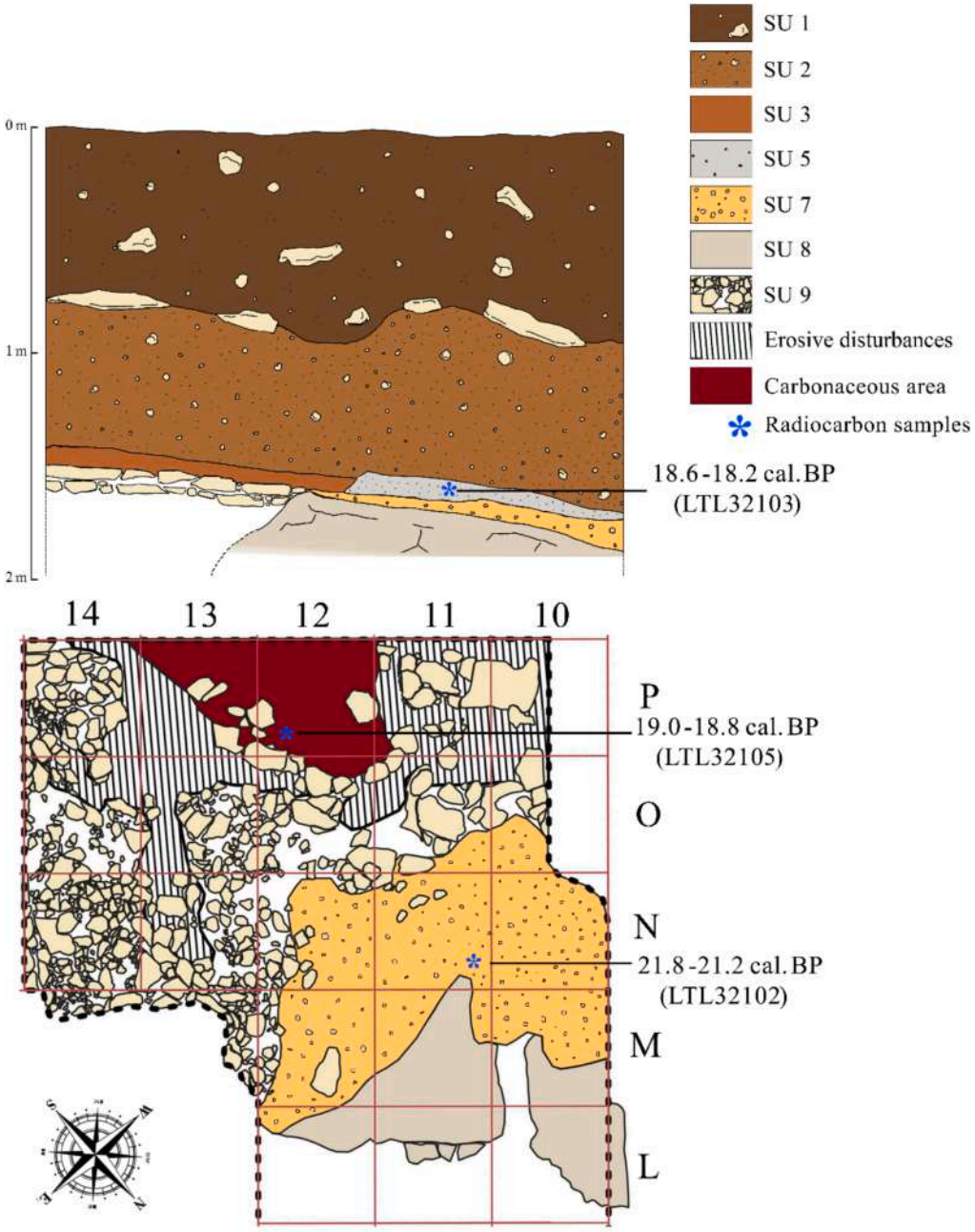

Fig. 5. Stratigraphic diagram of the deposit (above) and map of excavation area B (below) of Grotta della Lea, showing the different SUs and the provenience of the radiocarbon samples. The map represents the base of the Early Epigravettian living floor/short-term palimpsest (SUs 7, 8 and 9), as well as the "carbonaceous area" located below SU9. Stratigraphic units and radiometric dates are reported on the right.

decreased in thickness from the outside to the inside of the cave, where clasts and debris are lacking in some places. In the EA, the uppermost part of SU2 was sterile, while the lowermost part yielded Epigravettian lithic and faunal materials. These materials were distributed in ca 30–35 cm of thickness, with a higher concentration at the base of the SU. In A, a layer characterized by a reddish sandy sediment with few clasts was identified beneath SU6. This layer has been attributed to SU2 as it presents the same sedimentological characteristics.

Area A (Holocene finds)

- **SU4** – Located at the base of SU1, this layer is characterized by fine sandy sediment with some rock blocks (up to 10 cm) at its top. The layer is between 20 and 30 cm thick. The horizontal position of the artefacts at the interface between SU1 and SU4 suggests that this surface could have been frequented during the Metal Ages when the cave was possibly used as a burial site.
- **SU6** – A thick layer mainly formed by loose debris and limestone blocks, with a maximum thickness of 60 cm, discovered below SU4. At the base of this layer, in contact with compact sand containing small clasts (possibly corresponding to SU2), several well-fossilized intact bones were retrieved.

Area B (Epigravettian in situ Occupation)

- **SU3** – Generally composed of sandy sediment without clasts and debris, it is a four to five-cm thick layer beneath SU2, this sediment is located over SU9 and is part of the Early Epigravettian short-term palimpsest as it incorporates several materials.
- **SU5** – Greyish sandy sediment with variable thickness between 10–1 cm, limited to squares L-N 10–12. It contains the Early Epigravettian living floor and lies directly on SU7. Archaeologically, it can be correlated with the materials lying on SU9 and the materials incorporated in SU3. The ^{14}C bone sample LTL32103, which produced the date 18,680–18,281 cal. BP (95,4%), was collected from this layer.
- **SU7** – A quite compact reddish yellow-ochre layer formed by a scarce sandy matrix and generally small, fragmented clasts with fresh edges, limited to squares L-N 10–12. It contains Epigravettian materials in its uppermost part (the rest is still to be excavated). This layer lies on the limestone blocks of SU8 and is also present in between. During fieldwork, the compactness of this sediment and especially its limited extent, strictly correlated with the emerging surface of SU8, led us to hypothesize that SU7 could have been subject to anthropogenic modifications, formed, at least in part, by sediments collected by the Early Epigravettian inhabitants to level the original natural floor of the cave. According to this assumption, SU7 might also include materials from more ancient human occupations. Ad hoc micromorphological analyses are planned to verify the formation process of this SU. Archaeologically, SU7 can be considered in phase with SU8 and SU9. The ^{14}C bone sample LTL32102, which produced the date 21,821–21,209 cal. BP (95,4%), was collected from this layer.
- **SU8** – Flat limestone blocks originated from the vault and situated at the cave entrance.
- **SU9** – Generally flat limestone small blocks juxtaposed to form a kind of "paving stone" area covered by part of SU3 (see above) and limited so far to squares N-O 12–14 and P14. SU9 appears to be in continuity with SU8 and SU7, constituting, together with these SUs, the base of the Early Epigravettian living floor/short-term palimpsest. In a restricted area towards the bottom of the cave, SU9 had been completely dismantled by erosive events. Once the reworked sediment was completely removed, a reddish sandy layer with charcoals, rare lithics, and faunal remains was brought to light. This layer (provisionally named "carbonaceous area", due to the presence of a continuous thin layer of charcoal), the exact stratigraphic position of which is still to be verified, stratigraphically clearly precedes the "paving stone" area. The ^{14}C charcoal sample LTL32105produced the date 19,089–18,800 cal. BP (95,4%), was collected in this zone

Except for SU1, no certain stratigraphic correlation has yet been established between A and B, nor is the stratigraphic lateral contact between the two areas known due to the diaphragm that still divides them. In addition, the formation processes and relationships between the same layers, especially in A, are yet to be more precisely defined due to the narrowness of the investigated area and its proximity to the cave wall.

4.2. Radiocarbon dating

Six samples, comprising two of charcoal and four bone fragments, were dated. However, only three samples yielded results: sample LTL32103 provided a calibrated date of 18,680–18,281 cal. BP (95.4 %); sample LTL32105 is dated to 19,089–18,800 cal. BP (95.4 %); and sample LTL32102 yielded a result of 21,821–21,209 cal. BP (95.4 %) (Table 1). Sample LTL32104 provided a low yield, resulting in unreliable measurements, while samples LTL32100 and LTL32101 could not be dated. To better contextualize each layer of the deposit, seven additional bone samples are currently under examination.

4.3. Holocene finds (SU1-SU4)

4.3.1. Ceramic materials

The research carried out during the first four excavation campaigns in and around the immediate area surrounding the entrance to Grotta della Lea yielded a total of 256 ceramic sherds. Most of the analyzed material came from the excavation of SU1 (5 from EA; 60 from A; 131 from B) and 14 from the uppermost part of SU4 (from A). The remaining material came from surveys conducted in the innermost area of the cave (46). The fragments analyzed are mostly body sherds of small/medium size (most not exceeding 5 cm) mainly of medium paste. Among the diagnostic materials are several medium-fine bowls (Fig. 6.1-2). Additionally, there is an elbow handle with a poorly developed upper section and straight profile (Fig. 6.6), a globular *olla* with a distinct neck (Fig. 6.3) and another with a conical stud applied below the rim (Fig. 6.4), as well as a fragment decorated with wolf's tooth pattern incision (Fig. 6.5).

4.3.2. Lithic materials

In SU1 of Area A, the most notable find is a polished, miniaturized greenstone axe with a trapezoidal shape, a sub-rectangular cross-section, and a straight cutting edge (Fig. 6.7). Additionally, a dozen patinated flaked chert artefacts were recovered from SU1 and SU4.

4.3.3. Faunal remains

4.3.3.1. SU1 – Area A. From this area, SU1 yielded 82 faunal remains, of which 58 (70.3 %) were identifiable to taxa (Table 2), predominantly small carnivores. Identified species include *Vulpes vulpes* (NISP% 29.3), *Meles meles* (5.1 %), and domestic animal species such as *Canis familiaris* (1.7 %), along with ungulates like *Bos/Bison* (8.6 %), *Ovis/Capra* (6.9 %), *Equus* sp. (3.4 %) and *Sus scrofa* (1.7 %). Leporids (15.5 %), birds (20.7 %) and turtles (5.1 %) were also recorded. This distribution highlights small-sized animals as the most abundant, while medium-sized and large animals are scarce. Only a minimum number of 30 elements (MNE) were quantified and a total of 13 MNI were estimated, with adults being predominant (Table 2).

The cortical surfaces of the remains are consistently well-visible, with 31.7 % indicating well-preserved cortical surfaces, while 13.4 % show no signs of taphonomic alteration. In SU1 of Area A, two bone remains were identified: one belonging to *Ovis/Capra* and one to

Table 1
AMS radiocarbon dating and calibration BP 95.4%, Curve Intcal20 (Reimer et al., 2020).

Sample ID (codice Lab datazioni)	SU/spit	square	material	C14 age BP	± Error	δ^{13}C ‰	±	δ^{15}N ‰	Data min	Data max
LTL32104	2, spit 2	P14II	charcoal	**12,186**	**85**	−31.8	0.6		–	–
LTL32105	"Carbonaceous area"	P12IV	charcoal	**15,651**	**75**	−28.3	0.4		**19,089**	**18,800**
LTL32103	5	N13	bone	**15,205**	**65**	−21.7	0.5		**18,680**	**18,281**
LTL32102	7 spit 1	N11III	bone	**17,727**	**65**	−22.6	0.3		**21,821**	**21,209**
LTL32100	7 spit 1	N10I	bone	**no date**						
LTL32101	9 top	N14II	bone	**no date**						

Leporidae, both displaying short and oblique cut marks. Only one indeterminate bone shows evidence of alteration by fire.

The most relevant post-depositional alterations observed are root marks and manganese staining, as detailed in Table 3, followed by carnivore marks. 19 remains exhibit mineral manganese coating, all categorized as Grade 1 (displaying a normal colouration of the bone surface with small, scattered dendrites in isolated areas). 17 remains display carnivore marks, including scores, pits, punctures and gnawing marks, observed on various animals such as birds, leporids, equids and bovids. Additionally, concretion, weathering, exfoliation and corrosion are present, albeit not to a significant extent (Table 3).

4.3.3.2. SU1 – Area B. In SU1 of Area B, 128 faunal remains were recovered, 81 (63.3 %) of which were identified to taxa. Carnivores are the most abundant animals, with *Vulpes vulpes* (NISP% 23.4), *Meles meles* (22.2 %), followed by domestic animals such as *Canis familiaris* (4.9 %) and *Felis catus* (1.2 %). Ungulates are represented by *Ovis/Capra* (16 %), *Equus* sp. (4.9 %), *Cervus elaphus* (2.5 %) and *Bos/Bison* (1.2 %). Additionally, leporid taxa (12.3 %), birds (7.4 %) and turtles (3.7 %) were also identified (Table 2). This distribution highlights small-sized animals as the most abundant, while medium-sized and large animals are represented to a lesser extent. A minimum number of 58 elements (MNE) were quantified and a total of 19 MNI were estimated, with adults and juvenile individuals being nearly equally represented (Table 2). The cortical surfaces of the remains consistently display good visibility, with 65.6 % indicating well-preserved cortical surfaces, while 6.2 % exhibit illegible surfaces as they are completely concreted.

Anthropogenic marks are identified only on one ungulate long bone (green fracture) and the femur of a small mammal, bearing short and oblique cut marks. Three indeterminate bones show evidence of alteration by fire.

Carnivore modifications are recorded on 16 remains, belonging to leporids, birds, small carnivores, and *Ovis/Capra*. The surface modifications include pits, scores, and gnawing.

Among the natural modifications, root marks were the most widespread post-depositional alterations, followed by rodent marks and trampling (Table 3). Manganese (grades 1 and 2), concretion, and weathering were also observed and documented (Table 3).

4.3.4. Human remains

In SU1 of A and B, three human remains were identified: a portion of a femur and two phalanges. These findings are consistent with the identification of few other human remains from the disturbed surface of the deposit in the inner part of the cave.

4.4. Epigravettian finds (SU2-SU3-SU5-SU7-SU8-SU9)

4.4.1. Lithic materials

4.4.1.1. SU2 – Area B + EA. A total of 191 lithic items were recovered (Table 4). A significant majority of the pieces (93.2 %) exhibit fresh edges, and in 43.5 % of cases the surface of the artefacts is characterized by a white patina. The presence of thermal alterations on some artefacts is rare (1.6 %). The edges of the artefacts show traces consistent with an intentional use in 14.7 % of cases, which could be promising for use-wear analysis. Fine-grained chert is the predominant raw material (86.9 %), followed by very low percentages of siliceous limestone (8.4 %) and radiolarite (3.7 %) (Table 5). A specific determination of the raw materials is necessary to make inferences about their sourcing and the mobility across the territory. However, high-quality fine-grained chert, which is the most commonly found raw material, is not documented in the outcrops near the cave (Spinapolice, 2012). This raw material might macroscopically be related to the Gargano area, indicating an exogenous supply.

Technologically, the industries are characterized by the production of bladelets and blades (Fig. 7), including both target objects and a few technical products, which, along with the presence of microflakes and debris, suggest that certain phases of the reduction sequence took place at the site (Table 6). However, the absence of cortical pieces, the scarcity of cores, and technical pieces indicate that the complete production process occurred elsewhere (in another part of the cave or a different location).

Regarding the retouched pieces, they constitute 21.9 % of the total and are mainly represented by bladelets and blades, which were the primary objectives of the debitage. The predominant mode of retouching is abrupt, utilized to manufacture backed bladelets and blades, and backed points. Noteworthy is the presence of pieces with a "cran" (French word to indicate the shouldered tool) (a shouldered-backed blade and two shouldered points) (Fig. 7). There are four truncations, a burin and two endscrapers. Other retouched pieces include points, side scrapers, and denticulates. Additionally, a mesial fragment of a bladelet with foliated retouch was observed (Table 7).

4.4.1.2. SUs 3, 5, 7 – Area B. A total of 218 lithic items were recovered (Table 4). The industry is characterized by fresh edges; and only few pieces show alterations due to fire (0.5 %). Fourteen (6.4 %) artefacts display macrotraces and 22.9 % exhibits patination. Almost the entire industry is made of chert (96.3 %), with the exception of a few pieces obtained on radiolarite and siliceous limestone (Table 5).

Despite the low quantity of pieces, the lithic assemblage from these layers still provides insight into the industry's characteristics. Technologically, the industry is marked by the production of bladelets. The high number of debris and microflakes suggests that some flaking activity, possibly including retouching, occurred on-site.

The retouched pieces were predominantly on bladelets, with 16 out of 22 retouched pieces made on this type of blank. Once again, abrupt retouch emerges as the distinctive mode of retouching. This is utilized to create backed bladelets, backed blades, and backed points. Notably, 2 pieces with a cran are present, one shouldered backed blade and a tangled bladelet (double cran on the proximal portion of the bladelet)

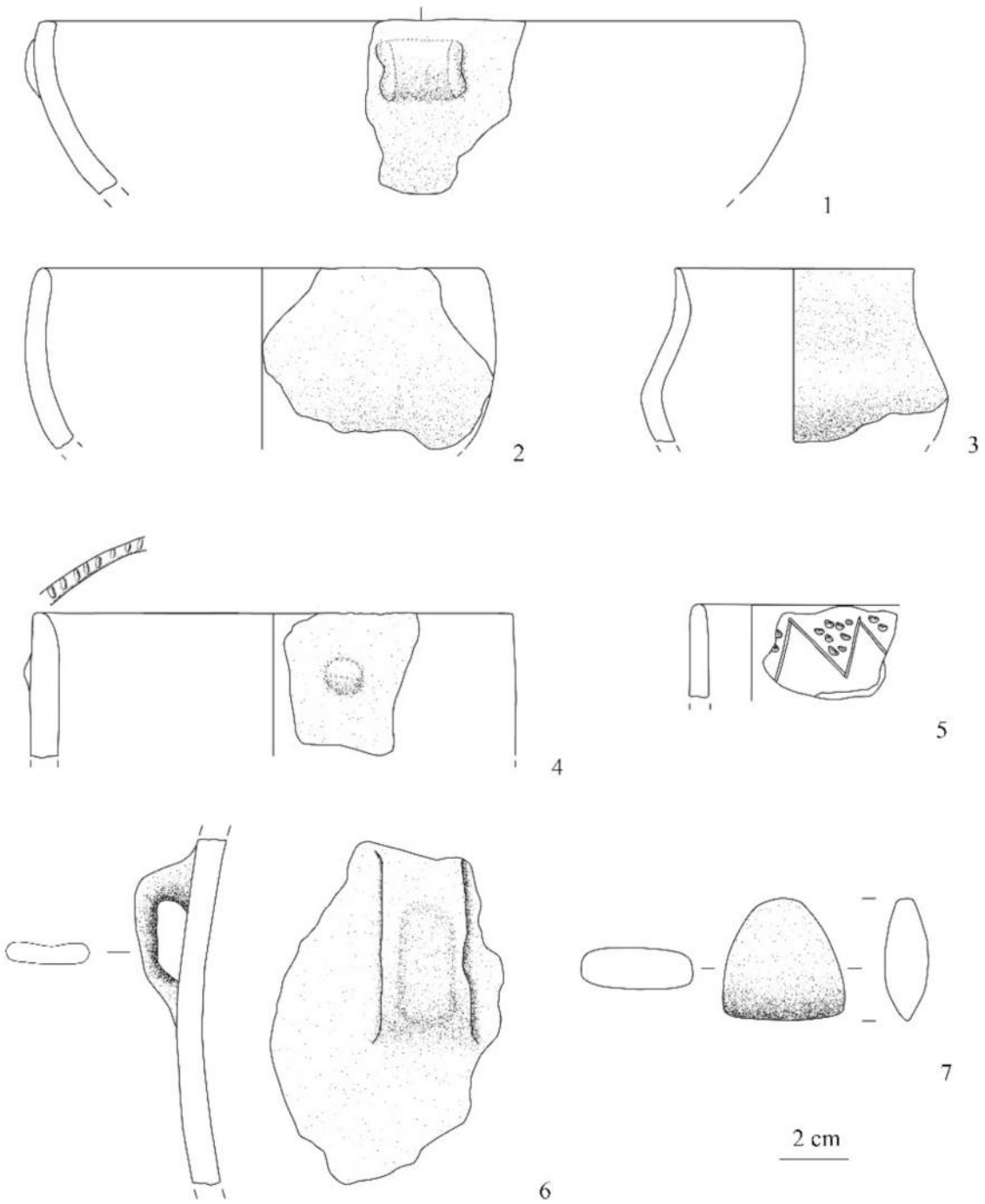

Fig. 6. Holocene materials from the upper stratigraphic units of Grotta della Lea: bowls (1–2); *olla* (3–4); decorated fragment (5); handle (6); greenstone axe (7).

(Fig. 7) (Table 7). Additionally, we report the presence of a fragment produced by bipolar reduction on anvil with retouch on the side. This tool in typology would be considered a scaled piece (Crémillieux, and Livache, 1976) with lateral retouch. This tool finds a comparison to the "Kostenki knives" described in the Epigravettian layers of Grotta Paglicci on the Gargano Promontory (Palma di Cesnola, 2003, p. 96, Figs. 2-3).

4.4.2. *Faunal remains*

4.4.2.1. SU2 – Area A. Only 8 bone remains were recovered from this SU in A (Table 2). Among these, 3 bone fragments were identified with uncertain attribution to *Equus/Bos/Bison* and one fragment of *Equus* sp., the remaining fragments belong to unidentified animals. Taphonomic alterations observed include manganese coating, root marks, concretion, and rodent marks (Table 3).

4.4.2.2. SU2 – Area B + EA. A total of 564 faunal remains were recovered from the SU in B + EA. Among these, 134 (23.7 %) were identified to taxa, 65 (11.1 %) were identified only to mammal body size, while the remaining 317 (56.2 %) were non-identifiable specimens. The taxonomic diversity in this SU is relatively high, although ungulates remain predominant. The taxa represented in this assemblage include *Equus* sp. (NISP% 48.5), *Bos/Bison* (5.9 %), *Cervus elaphus* (4.4 %), *Rupicapra rupicapra* (0.7 %), *Vulpes vulpes* (4.4 %) and *Meles meles* (3.7 %) (Table 2).

Table 2
Number of Identified Specimens (NISP), Minimum Number of Elements (MNE) and Minimum Number of Individuals (MNI) from Grotta della Lea, divided by area and SU of excavation. EA: external area; Juv: Juvenile; SAd: Subadult; Ad: Adult. H=Holocene finds; E = Epigravettian finds.

Area/SU		Taxon																												
		Equus sp.	*Bos/Bison* sp.	*Equus/Bos/Bison* sp.	*Rupicapra rupicapra*	*Ovis/Capra*	*Cervus elaphus*	*Sus scrofa*	**Tot. Ungulata**	*Canis familiaris*	*Vulpes vulpes*	*Meles meles*	*Mustela* sp.	*Felis catus*	**Tot. Carnivora**	Leporidae	Aves	Testudo sp	**Subtotal**	Ungulate unknown	Carnivore unknown	Mammal size 2	Mammal size 3	Mammal size 4	Mammal size 5	Unidentified	**Grand Total**	***Homo* sp.**
GLea-A/SU1-H																														
NISP		2	5			4		1	**12**	1	17	3	1		**22**	9	12	3	**58**	7	1	1	3			12	**82**	**1**
NISP%		3.4	8.6			6.9		1.7	**20.6**	1.7	29.3	5.1	1.7		**37.9**	15.5	20.7	5.1	**100**									
MNE		1	4			4		1	**10**	1	9	3			**13**	7			**30**								**30**	
MNI	Juv		1			1			**2**		1	1			**2**	1			**5**								**5**	
	SAd															1			**1**								**1**	
	Ad	1						1	**2**	1	2	1			**4**	1			**7**								**7**	
GLea-B/SU1-H																														
NISP		4	1			13	2		**20**	4	19	18		1	**42**	10	6	3	**81**	13		10	3	4		17	**128**	**2**
NISP%		4.9	1.2			16	2.5		**26.6**	4.9	23.4	22.2		1.2	**51.8**	12.3	7.4	3.7	**100**									
MNE		3	1			10	2		**16**	4	15	14		1	**34**	8			**58**								**58**	
MNI	Juv	1	1			2			**4**	1	2	2			**5**	1			**10**								**10**	
	Ad	1				1	1		**3**	1	2	1		1	**5**	1			**9**								**9**	
GLea-A/SU2-E																														
NISP		1		3					**4**										**4**	2					1	1	**8**	
NISP%		25		75					**100**										**100**									
MNE		1							**1**										**1**								**1**	
NISP	Ad	1							**1**										**1**								**1**	
GLea-B+EA/SU2-E																														
NISP		65	8	23	1		6		**103**		6	5			**11**	11	8	1	**134**	48	2	17	5	16	25	317	**564**	
NISP%		48.5	5.9	17.1	0.7		4.4		**76.8**		4.4	3.7			**8.2**	8.2	5.9	0.7	**100**									
MNE		23	4		1		5		**33**		4	4			**8**	9			**50**								**50**	
MNI	Juv	1	1						**2**			1			**1**	1			**4**								**4**	
	SAd	2							**2**										**2**								**2**	
	Ad	2	1		1		1		**5**		1	1			**2**	1			**8**								**8**	
GLea-B/SU3-E																														
NISP		2							**2**								1		**3**	2				1		1	**7**	
NISP%		66.6							**66.6**								33.3		**100**									
MNE		2							**2**										**2**								**2**	
MNI	Ad	1							**1**										**1**								**1**	
GLea-B/SU5-E																														
NISP		13	6	7			3		**29**			1			**1**	1		1	**32**	20	1		6	7	2	95	**163**	
NISP%		40.6	18.7	21.9			9.3		**90.6**			3.1			**3.1**	3.1		3.1	**100**									
MNE		9	3				1		**13**			1			**1**	1			**15**								**15**	
MNI	Juv	1							**1**										**1**								**1**	
	Ad	1	1				1		**3**			1			**1**	1			**5**								**5**	
GLea-B/SU7-E																														
NISP		3	1	1			1		**6**		1				**1**	1	1		**9**	13	1	6	2	2		252	**285**	
NISP%		33.3	11.1	11.1			11.1		**66.6**		11.1				**11.1**	11.1	11.1		**100**									
MNE		3	1				1		**5**		1				**1**	1			**7**								**7**	
MNI	Juv	1							**1**							1			**2**								**2**	
	Ad		1				1		**2**		1				**1**				**3**								**3**	
GLea-B/SU9-E																														
NISP		10	2	1			1		**14**										**14**	9					6	2	**31**	
NISP%		71.4	14.2	7.1			7.1		**100**										**100**									
MNE		7	2				1		**10**										**10**								**10**	
MNI	Juv	1							**1**										**1**								**1**	
	SAd		1						**1**										**1**								**1**	
	Ad	1					1		**2**										**2**								**2**	

Additionally, some remains of leporids (8.2 %), birds (5.9 %), and turtles (0.7 %) have also been identified. Due to the state of fragmentation of the assemblage, only a minimum number of 50 elements (MNE) were quantified, and a total of 16 MNI were estimated. The majority of these individuals are adults, followed by juveniles and subadults.

The surface legibility of the remains is generally good, with 26.2 % of total remains showing well-preserved cortical surfaces, while 11.2 % exhibit illegible surfaces due to complete concretion. Anthropogenic modifications, including butchering activities, deliberate breakage activities and thermoalterations, are documented (Table 3). Green fractures, characterized by curved, oblique and smooth edges, were observed in only 2.1 % of the total remains (Table 3). The identification of a percussion notch with an adhering flake (Fig. 8 C) and one bone exhibiting a single percussion impact and notch support the limited occurrence of fresh breakage. In general, fresh breakage marks were identified on medium/large ungulates. Cut marks were detected on only 6 remains, distributed among 4 shaft fragments of ungulates (Fig. 8 A), along with one rib and tibia of *Equus* sp. Modifications caused by fire concern 9.7 % of the remains.

Modifications caused by carnivores are also present. Pits, scores,

Table 3
Total Number of Remains (NR) and the percentage (NR%) of the anthropic and natural taphonomic alterations across the SUs of Grotta della Lea. H=Holocene finds; E = Epigravettian finds.

Taphonomic alterations	Area/SU															
	GLea-A/SU1-H		GLea-B/SU1-H		GLea-A/SU2-E		GLea-B + EA/SU2-E		Glea-B/SU3-E		Glea-B/SU5-E		Glea-B/SU7-E		Glea-B/SU9-E	
	NR	NR%	NR	NR%	NR	NR%	NR	NR%	NR	NR%	NR	NR%	NR	NR%	NR	NR%
Anthropic modification																
Green fracture			1	0.7			12	2.1			1	0.6	2	0.7	1	3.2
Percussion marks							2	0.3			1	0.6				
Cut marks	2	2.4	1	0.7			6	1			2	1.2				
Thermoalterations	1	1.2	3	2.3			55	9.7			57	34.9	59	20.7		
Natural modification																
Carnivore marks	17	20.9	16	12.5			8	1.4			2	1.2			1	3.2
Rodents marks			17	13.2	1	12.5	10	1.7			1	0.6				
Trampling			3	2.3			3	0.5			1	0.6				
Weathering	4	4.9	11	8.6			28	4.9	1	14.2	4	2.4	1	0.3	1	3.2
Exfoliation	2	2.4					17	3	2	28.5	2	1.2	4	1.4	2	6.4
Corrosion	1	1.2					8	1.4								
Water dissolution							2	0.3								
Concretions	8	9.8	21	16.4	2	25	192	34	6	85.7	60	36.8	14	4.9	17	54.8
Root marks	27	33.3	20	15.6	3	37.5	100	17.7	4	57.1	14	8.5	7	2.4	15	48.3
Manganese staining	19	23.4	34	26.5	6	75	142	25.1	1	14.2	28	17.1	12	4.2	22	70.9

Table 4
Totality of the lithic pieces retrieved from Grotta della Lea, classified according to the technological class of the material and divided by area and SU of excavation. EA: external area. H=Holocene finds; E = Epigravettian finds.

Area/SU	SU1	SU2	SU3	SU4	SU5	SU7	section	Total	%
	H	E	E	H	E	E	H		
Glea-A	**5**			**2**				**7**	**1,6**
Debitage	3			1				4	0,9
Axehead	1							1	0,2
Tool	1			1				2	0,5
Glea-B	**5**	**171**	**23**		**34**	**161**	**13**	**407**	**93,6**
Debitage	5	35	2		8	19	4	73	16,8
Tool		35	6		4	12	1	58	13,3
Microflake		28	6		4	45	5	88	20,2
Debris		67	8		18	85	3	181	41,6
Fragment		5	1					6	1,4
Hammerstone		1						1	0,2
Glea-EA	**1**	**20**						**21**	**4,8**
Debitage	1	13						14	3,2
Tool		7						7	1,6
Total	**11**	**191**	**23**	**2**	**34**	**161**	**13**	**435**	**100,0**

Table 5
Total number (N.) and relative percentage (%) of lithic pieces divided according to the lithotype within each Epigravettian SU.

Lithotype/SU	SU2		SU3		SU5		SU7		Total	
	N.	%	N.	%	N.	%	N.	%	N.	%
Chert	166	86,9	20	87,0	32	94,1	158	98,1	376	91,9
Siliceous limestone	16	8,4	3	13,0	1	2,9			20	4,9
Radiolarite	7	3,7			1	2,9	3	1,9	11	2,7
Limestone	1	0,5							1	0,2
Indet	1	0,5							1	0,2
Total	**191**	100,0	**23**	100,0	**34**	100,0	**161**	100,0	409	100,0

gnawing and crenulated edges were identified on 8 remains belonging to *Equus* sp., leporids and small carnivores.

Among the natural modifications, concretion, black manganese oxide dendrites (stages 1 and 2) and root action are the most widespread post-depositional alterations (Table 3). Other biostratinomic and diagenetic alterations, such as rodent marks, trampling, weathering, exfoliation and water dissolution also appear in the assemblage (Table 3).

4.4.2.3. SUs 3, 5, 7 and 9 – Area B. SU3 exhibits a notable scarcity of faunal remains. Nonetheless, we identified 2 remains of *Equus* sp., 1 bird, 2 ungulates, 1 mammal size-category 4, and 1 unidentified bone (Table 2). Taphonomic alterations observed include concretion, root action, exfoliation, black manganese oxide dendrites and weathering (Table 3).

SU5 yielded a total of 163 bone remains, with 32 (19.6 %) identified to taxa, 15 (9.2 %) only to mammal body size, while the majority of the assemblage, 95 (58.3 %), consisted of non-identifiable specimens. Ungulates dominate the assemblage, represented by *Equus* sp. (NISP% 40.6), *Equus/Bos/Bison* (21.9 %), *Bos/Bison* (18.7 %) and *Cervus elaphus* (9.3). Other identified taxa include *Meles meles*, leporid and turtle, each represented by only one specimen (Table 2). Only a minimum number of

Fig. 7. Lithic materials from the Epigravettian occupation (SUs 2, 3, 5, 7) of Grotta della Lea: total backed points (1–2-3–4-12–23); backed bladelets (5–6); shouldered blades (7–8-10); tangled bladelet (9); fragmented backed pieces (11–19); long end scraper (13); unretouched blades (14–15); truncated blade (16); partial backed blade (17); burin (18); marginal backed bladelet (20); elongated side scraper (21); denticulated scraper on blade (22); point (24).

Table 6
Total number (N.) and relative percentage (%) of pieces divided according to technological category and subcategory within each Epigravettian layer. The number of retouched pieces is indicated in parentheses.

Techno categories	SU2		SU3		SU5		SU7		Total	
	N.	%	N.	%	N.	%	N.	%	N.	%
blade	**25(11)**	13,1	**1**	4,3	**1**	2,9	**4(3)**	2,5	**31**	7,6
backed blade	1(1)	0,5		0,0		0,0		0,0	1(1)	0,2
blade	17(10)	8,9	1	4,3		0,0	3(3)	1,9	21(13)	5,1
convergent blade	2	1,0		0,0		0,0		0,0	2	0,5
crested blade	1	0,5		0,0		0,0		0,0	1	0,2
management blade	4	2,1		0,0	1	2,9	1	0,6	6	1,5
bladelet	**35(23)**	18,3	**5(4)**	21,7	**5(4)**	14,7	**15(8)**	9,3	**60**	14,7
backed bladelet	1	0,5		0,0		0,0		0,0	1	0,2
bladelet	27(21)	14,1	4(4)	17,4	5(4)	14,7	14(8)	8,7	50(37)	12,2
partial crested bladelet	1(1)	0,5		0,0		0,0		0,0	1(1)	0,2
convergent bladelet	1(1)	0,5		0,0		0,0		0,0	1	0,2
management bladelet	2	1,0	1	4,3		0,0	1	0,6	4	1,0
flake	**19(1)**	9,9	**2(1)**	8,7	**5**	14,7	**11(1)**	6,8	**37**	9,0
flake	16(1)	8,4	2(1)	8,7	5	14,7	10(1)	6,2	33(3)	8,1
management flake	2	1,0		0,0		0,0	1	0,6	3	0,7
spall	**5**	2,6		0,0		0,0		0,0	**5**	1,2
fragment	**14(6)**	7,3	**2(1)**	8,7	**1**	2,9	**1**	0,6	**18(7)**	4,4
microflake	**28**	14,7	**6**	26,1	**4**	11,8	**45**	28,0	**83**	20,3
debris	**68(1)**	35,6	**7**	30,4	**18**	52,9	**85**	52,8	**178(1)**	43,5
hammerstone	**1**	0,5		0,0		0,0		0,0	**1**	0,2
Total	**191(42)**	100,0	**23(6)**	100,0	**34(4)**	100,0	**161(12)**	100,0	**409(64)**	100,0

Table 7
Typology of retouched tools with Epigravettian SUs.

Retouched tools' typology	SU2	SU3	SU5	SU7	Total
LD1_marginal backed blade	1				1
LD2_backed blade	4				4
LD3-LD4_shouldered backed blade	1	1		1	3
LD4/PD5_shouldered backed blade or point	1				1
LD6_tangled blade				1	1
PD2_partial backed point	2				2
PD4_total backed point	2		2	2	6
PD5_shouldered backed point	1				1
fLD/PD_fragment of backed blade/ point	14	3	2	3	22
Total of backed implements	***26***	***4***	***4***	***7***	***41***
T2_normal truncation	1				1
T3_oblique truncation	3				3
A2_flake with abrupt retouch				1	1
B1_burin				1	1
B6_burin on distal truncation	1				1
F_fragment of foliated tool	1				1
G2_elongated end scraper with lateral retouch	1				1
G4_short end scraper with lateral retouch	1			1	2
D1_notch				1	1
D2_denticulate	2				2
P2_point	1				1
L1_elongated side scraper with marginal retouch	1			1	2
L2_elongated side scraper	1				1
R2_side scarper	3	1			4
E1_scaled piece + R2 side scraper "Kostenki knife"		1			1
Total of common tools	***16***	***2***		***5***	***23***
Total	**42**	**6**	**4**	**12**	**64**

15 elements (MNE) were quantified and a total of 6 MNI was estimated, with adults being predominant (Table 2).

The legibility of the remains' surfaces is generally good, with 27.6 % displaying well-preserved cortical surfaces, while 9.8 % exhibit illegible surfaces, completely concreted. Anthropogenic alterations, such as butchering activities, deliberate breakage, and thermoalterations, are recorded (Table 3). Green fractures, characterized by curved, oblique, and smooth edges, as well as percussion marks, were observed in only 2 remains (Table 3). Longitudinal cut marks were noted on two shafts of long bones from medium/large ungulates. Fire-induced modifications affect 34.9 % of the total remains, displaying various burning categories ranging from brown to white colouration. These alterations were identified on unidentified, flat, and spongy bones of indeterminate animals. Carnivore marks are very rare in this SU. Among the natural modifications, concretion, black manganese oxide dendrites (grades 1 and 2), and root action were the most prevalent post-depositional alterations (Table 3). Other biostratinomic and diagenetic alterations, such as weathering, exfoliation, and rodent marks, are also documented, albeit to a lesser extent (Table 3).

In SU7, 285 bone remains were recovered. Although this represents a notable number of remains, approximately 88.4 % could not be identified to taxa or size, and thus classified as unidentified remains. The NISP at this level is very low, 9 (3.1 %), resulting in a MNE of 7 and a MNI of 5, comprising three adults and two young individuals (Table 2). The identified taxa include *Equus* sp. with 3 remains, as well as *Bos/Bison*, *Equus/Bos/Bison*, *Cervus elaphus*, *Vulpes vulpes*, Leporid, and bird, each represented by only one specimen.

As indicated in Table 3, 20.7 % of the total remains display evidence of burning. Similar to SU3, these alterations were identified on indeterminate bones. Biostratinomic and diagenetic alterations, such as concretion, manganese, root action, weathering and exfoliation, are also documented.

Only 31 remains were recovered from SU9, 14 (45.1 %) of which were identified to taxa. The identified taxa include *Equus* sp. (NISP% 71.4), *Bos/Bison* (14.2 %), *Equus/Bos/Bison* and *Cervus elaphus* (both 7.1 %). Only a minimum number of 10 elements (MNE) were quantified and a total of 4 MNI were estimated, with adults being predominant (Table 2).

Anthropogenic modifications are extremely scarce, represented only by a fresh fracture on a long bone of an ungulate. Carnivore traces are also scarcely represented, with only one humerus of *Equus* sp. showing gnawing marks on the distal epiphysis (Fig. 8 D). Among the biostratinomic and diagenetic alterations, black manganese oxide dendrites (grades 1), concretion and root action are the most prevalent post-depositional alterations. Other natural alterations, such as weathering and exfoliation, are also documented (Table 3).

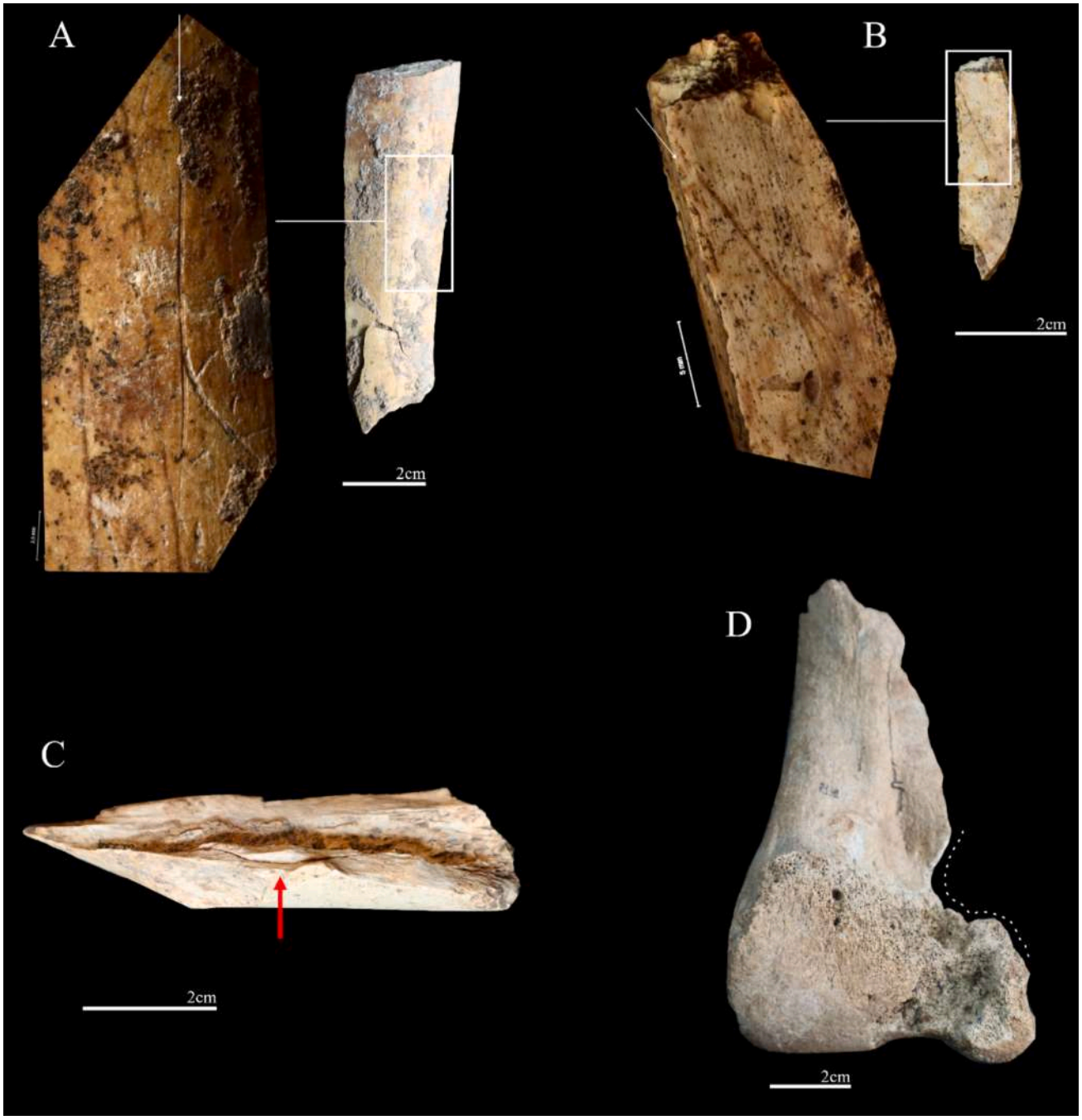

Fig. 8. A. Diaphysis of an indeterminate ungulate, displaying a longitudinal cut mark; B. Indeterminate bone with a short cut mark; C. Diaphysis of an indeterminate ungulate, featuring a notch and an adhering flake; D. Left humerus of *Equus* sp. with gnawing marks on the distal epiphysis.

5. Discussion and Conclusion

5.1. Insights from the Holocene and Early Epigravettian Contexts of Grotta della Lea

Our recent excavation and research at Grotta della Lea have revealed a well-defined stratigraphy containing Epigravettian and Holocene human frequentations, with promising underlying deposits still awaiting excavation.

The upper deposit includes SU1, which spans the Holocene and contains a mix of recent materials alongside artefacts from the Copper and Bronze Ages, as well as remains of domesticated animals including *Canis familiaris* and *Felis catus*. Specifically, the medium-fine bowls (Fig. 6.1-2) have good parallels in various tombs of the tumuli of Salve and at Grotta di San Biagio at Ostuni (Aprile et al., 2018: 27, Fig. 6.4,:30, Fig. 10.1;:37, Fig. 20.1,:37, Fig. 20.1; Coppola et al., 2011: 107, Fig. 4.7). Additionally, the elbow handle (Fig. 6.6), the globular *olla* with a distinct neck (Fig. 6.3) and the other with a conical stud applied below the rim (Fig. 6.4) show comparisons with materials from Grotta di San Biagio at Ostuni, referable to an initial phase of the Eneolithic (Del Fattore, 2008–2009, type 15; Coppola et al., 2011, pp. 110, Fig. 4.2,4,11). All this material can be dated to a not-advanced moment of the Copper Age. Finally, the fragment decorated with wolf's tooth pattern incision (Fig. 6.5) is attributed to a more recent phase, finding comparisons with materials attributable to an early moment of the Middle Bronze Age found at the neighboring sites of Cozzo Marziotta

and Porto Perone (Cocchi Genick et al., 1993: 180, Fig. 4.37). The polished, miniaturized greenstone axe with a trapezoidal shape likely belongs to the early Copper Age period or it is potentially earlier as it also shows parallels with artefacts from the nearby Neolithic settlement of Serra Cicora (Dell'Anna, 2011: 115, Fig. 59.2). The other flaked lithic materials do not exhibit particularly diagnostic traits and can be referred to both Copper and early Bronze Ages.

SU2 comprises Early Epigravettian artefacts and seals a structured living floor/short-term palimpsest consisting of SUs 3, 5,7, 8 and 9. The lithic industry from these SUs is primarily characterised by the utilisation of exogenous high-quality, fine-grained chert as the main raw material. Technologically, the industry focuses on the production of blades and bladelets, employing crested pieces and the management of convexities, along with the rejuvenation of the striking platform for the production of blade-bladelets. Typically, the target products undergo retouching, with a significant majority featuring abrupt retouching. A significant characteristic is the presence of shouldered pieces, including shouldered points, shouldered blades, and bladelets, along with a tangled bladelet. A minimal quantity of end scrapers and burins has been observed, in roughly equal numbers. There is a rarity of large backed tools and a marginal presence of side scrapers (both on blade and flake). Geometric forms are notably absent. Backed implements constitute over 64.1 % of the retouched pieces in the assemblage. While no study on impact-fractures has been conducted, it is noteworthy that some backed tools exhibit fractures at their tips, typically retaining only the base. These observations are promising for future use-wear analysis of the collection and for the definition of the site's function.

The study remains preliminary, and further excavation and the retrieval of additional materials are needed to clarify the production process and to further detail the characteristics of the assemblage. Nevertheless, the presence of very distinctive lithic tools, especially backed tools, has allowed for the attribution of the Palaeolithic horizon encompassing SUs 3, 5, 7, 8 and 9 to the "early Epigravettian with crans (or shouldered pieces)" (Palma di Cesnola, 1993), namely an advanced stage of the Early Epigravettian. Importantly, this evidence seems to be connected with an intentional arrangement of the living area, exploiting the original natural floor of the cave formed by a rocky pavement represented by SUs 8 and 9. The cultural attribution to the Early Epigravettian (between 23,950–21,950 years BP and 19,450–18,950 years BP Conforti, 2020, Tomasso 2014) aligns well with the radiocarbon date obtained from SU5 (18,680–18,281 cal. BP – 95,4%). The date from SU7 (21,821–21,209 cal. BP – 95,4%) also falls within the known range for the Italian Early Epigravettian, but it is at least 2,500 years more ancient than that from SU5. This discrepancy is even more peculiar when one considers the date yielded by the "carbonaceous area" (19,089–18,800 cal. BP – 95,4%), which, at the present state of research, results to be stratigraphically positioned under SUs 7 and 9, and therefore chronologically earlier. Based on observations carried out during fieldwork, the pronounced difference in radiocarbon chronology between SU7 and SU5 does not seem to be due to diagenetic phenomena or hiatuses created by erosive events. Although further dating and verification of potential issues related to diagenesis are advised, for the time being, based on the stratigraphic evidence, we think that such discrepancy might lie in the potential anthropogenic modifications of SU7, which might contain materials that could belong to a more ancient deposit. These episodes become more apparent when multiple dates are obtained for the layers, helping to clarify the intricate processes of sedimentation and re-sedimentation in the complex cave deposits influenced by anthropogenic activity (see also Hunt et al., 2015). Micromorphological analyses and the continuation of excavations will allow us to shed further light on this issue.

Preliminary results from the faunal spectrum of units SU3, 5, 7, 8 and 9 provide insights into the prey predominantly hunted at Grotta della Lea, which consisted mainly of large and medium-sized ungulates, with a clear prevalence of equids and large bovids, while red deer remains are relatively scarce. During the Late Pleistocene, two wild equids (*Equus* sp.) inhabited this region (Borzatti von Lowerstern and Magaldi, 1966; Boscato and Crezzini, 2012; Boschin et al., 2018; Petronio et al., 2007), namely the larger *Equus ferus* and the smaller, much rarer *Equus hydruntinus*. However, distinguishing between these species is challenging due to poor preservation and the significant presence of concretions affecting the occlusal surface of many molars.

In terms of ecological context, this faunal assemblage reflects exploitation of different habitats, with taxa typical of open environments such as open steppe-grassland (i.e., equids and large bovids) and woodland (red deer). Concerning carnivores, the presence of red fox and European badger is suited to a forested landscape. Based on taphonomic data, anthropogenic modifications such as percussion marks and cut marks have been identified on long bones of ungulates. Carnivore marks are relatively scarce, suggesting that the assemblage is primarily of anthropogenic origin, occasionally disturbed by biological agents other than humans.

5.2. *Exploring the Early Epigravettian in Italy*

The Epigravettian, a widespread phenomenon spanning from southeastern France to Armenia (e.g., Naudinot et al., 2014; Fasser et al., 2024), represents one of the last expressions of the Upper Palaeolithic, succeeding the Gravettian. It emerged almost simultaneously across regions, between 26,000 and 24,000 cal. BP (Lengyel et al., 2021; Ruiz-Redondo et al., 2022; Fasser et al., 2024), and ended variably, around 15,000 years ago, with evidence of its persistence in the Mediterranean region until the end of the Pleistocene (11,600 cal. BP) (Naudinot et al., 2014; Demidenko 2021; Ruiz-Redondo et al., 2022; Fasser et al., 2024).

The Italian Epigravettian was first formalised by G. Laplace who divided it into three main chronological phases based on the typological variability of lithic tools: Early, Evolved, and Final Epigravettian (Laplace, 1964a, 1964b; 1997). Subsequent research has led to revise this framework (Bietti, 1990; Palma di Cesnola, 1993; Broglio, 1997; Montoya, 2008; Tomasso, 2017), even though a unified and formalised division for the entire Italian peninsula remains elusive, reflecting the pronounced regional diversity of the period and the methodological variability among studies (Fasser et al., 2024).

The primary distinction lies in the regional classification of the Epigravettian. The three-phase model proposed by Laplace – Early, Evolved, and Final – is still used by authors dealing with southern Italy (Martini et al., 2007; Ricci et al., 2019). Conversely, in northern and central Italy, the Epigravettian has typically been divided into two phases: Early and Late. The two-phase model was initially suggested by Broglio (1997), essentially based on palaeoenvironmental changes. The same subdivision was later re-proposed by Tomasso (2017), taking into consideration techno-economic factors, with a boundary between the Early and the Late Epigravettian at about 16 ka cal. BP. Recently, based on Bayesian models, the transition between the Early and the Late Epigravettian is positioned at about 17.6–17.1 ka cal. BP (Ruiz-Redondo et al., 2022; Fasser et al. 2024). Advances in technological and techno-economic studies have significantly improved our understanding of the previous typological subdivisions of the Epigravettian, particularly focusing on the Late Epigravettian (as it is widely spread throughout the peninsula) and further clarifying the distinct characteristics and significance of each phase within the Late Epigravettian (Montoya, 2008; Tomasso, 2014; 2017; Conforti, 2020). This process has not yet been fully applied to the Early Epigravettian, which is still mainly known through typological studies.

The model proposed by Laplace was further refined by Palma di Cesnola (1983), who identified three distinct subphases within the Early Epigravettian: the initial Early Epigravettian, the Early Epigravettian with foliate tools, and the Early Epigravettian with crans (shouldered tools). These taxonomic classifications provided a foundational chrono-cultural framework for guiding archaeological research and identifying broad temporal trends. However, these should not be viewed as fixed cultural categories but rather as flexible tools for interpreting the

Epigravettian chrono-technical context (Laplace, 1964a, 1964b; 1997; Palma di Cesnola, 1993).

The lithic assemblage from SUs 3, 5, 7, 8, and 9 of Grotta della Lea is defined by the predominant use of high-quality, fine-grained exogenous chert for blade and bladelet production. Notable features include abrupt retouching on a significant portion of the tool kit and the presence of shouldered tools, such as shouldered points, blades, and bladelets, as well as a tanged bladelet. These techno-typological characteristics, combined with the results of radiocarbon dating between 21,821–18,281 cal. BP, allowed us to attribute the assemblage of SUs 3, 5, 7, 8 and 9 of Grotta della Lea to the Early Epigravettian phase characterised by shouldered tools/ crans (*sensu* Palma di Cesnola 1983). To date, Grotta della Lea is the only site in the area to have yielded Early Epigravettian remains *in situ*, as the only other clue of an Early Epigravettian presence in the Uluzzo Bay comes from the reworked deposits of Grotta del Cavallo (Zilhão et al., 2015).

In Puglia, a few sites preserve undisturbed evidence of the Early Epigravettian with shouldered tools, which are coherently dated (Table 9). These sites include: Taurisano (spits 23–6) (Palma di Cesnola, Bietti, 1983), Riparo C delle Cipolliane (layer 4) (Laplace, 1964b, 1966; Gambassini, 1970), Fondo Focone (Cancellieri, 2006; Bietti, Cancellieri, 2007), Grotta Paglicci (layers 16–12) (Mezzena, Palma di Cesnola, 1967), and Grotta delle Mura (layer G) (Cornaggia Castiglioni and Palma di Cesnola, 1964; Laplace 1964b, 1966).

While demonstrating similar techno-typological features, particularly in the production of bladelets, backed tools, and shouldered pieces, the assemblages from these sites also reflect some specificities. Grotta Paglicci provides a well-documented, stratified sequence illustrating the *in situ* evolution of this subphase of the Epigravettian, highlighting changes in the proportion of backed tools and shouldered pieces across layers. In layers 16–15, backed tools and shouldered pieces dominate, with only rare backed truncated tools and a few foliated tools. In layers 14–12, backed tools and shouldered pieces become less prominent, while backed truncated tools increase. Foliated tools persist in layer 14 but disappear entirely in the upper layers (Palma di Cesnola, 1993). Grotta Paglicci serves as a reference point for other sites in Puglia. At Taurisano 23–6, a high concentration of shouldered and backed pieces exhibits typological similarities with Grotta Paglicci's layers 16–15. Riparo delle Cipolliane 4 and Grotta delle Mura G align more closely with Grotta Paglicci's layers 14–12 (Gambassini, 1970; Palma di Cesnola, 1993).

In Salento, Cipolliane 4 and the upper layers of Taurisano, in addition to the prevalence of backed bladelets, display also a number of foliated pieces associated with a prevalence of endscrapers (Palma di Cesnola, 1993). Fondo Focone, which is comparable to Cipolliane 4, yielded rare large-backed tools and significant quantities of abruptly retouched bladelets, points and truncated bladelets. Another interesting aspect that Fondo Focone shares with Cipolliane 4 is the use of the bipolar technique on anvil and the presence of a large quantity of exogenous chert, which suggests extensive mobility and possibly wide-ranging networks of contacts among Epigravettian people (Gambassini, 1970; Cancellieri, 2006; Bietti & Cancellieri, 2007). Typological evidence suggests a close relationship between Grotta della Lea and all the aforementioned sites. However, the current reliance on typological analyses for understanding these lithic assemblages limits the scope of their definition. In depth studies on technological choices and raw material usage could provide valuable insights, providing a more comprehensive basis for comparison and enabling a clearer characterization of the label 'Early Epigravettian with crans'.

This paper presented an overview of the discoveries at Grotta della Lea, highlighting their pivotal role in advancing our understanding of the Early Epigravettian in southern Italy and their potential to refine existing chrono-cultural frameworks. While the current findings establish a valuable foundation, future excavations and further studies—particularly focusing on spatial distribution, techno-economic practices, and sedimentological analyses—will be crucial for gaining deeper insights into the behavioural and adaptive strategies of this period. Such investigations will also provide a more comprehensive understanding of behavioural patterns and the similarities and differences among sites, ultimately contributing to the clarification of the complex dynamics that shaped the Epigravettian in this region.

Table 9
Calibrated radiocarbon dating (95.4%) (INTCAL20 Reimer et al., 2020 and OxCal ver. 4.3 calibration software) of sites with Early Epigravettian characterised by shouldered tools (crans) in Puglia.

Site-Level-SU-spits	C14 age BP and error	Calibrated age BP 95.4 %	Lab code	Material	Reference
Taurisano, B 23–6, spits 6–9	16050 ± 160	19626–18909		charcoal	Palma di Cesnola, Bietti, 1983
Taurisano, B 23–6, spits 10–12	15600 ± 120	19136–18686		charcoal	Palma di Cesnola, Bietti, 1983
Taurisano, B 23–6, spits 18–22	16000 ± 150	19620–18915		charcoal	Palma di Cesnola, Bietti, 1983
Fondo Focone, Pozzo Zecca III-IV	13870 ± 110	17112–16438	R-272	charcoal	Alessio et al., 1967; Palma di Cesnola et al., 1983
Fondo Focone, Pozzo Zecca I-II	14170 ± 170	17833–16766	R-271	charcoal	Alessio et al., 1967; Palma di Cesnola et al., 1983
Grotta Paglicci, layer 12A	15950 ± 350	20238–18385	GrN-14316	charcoal	Boschin et al. 2018
Grotta Paglicci, layer 12C	15730 ± 330	19843–18289	GrN-14317	charcoal	Boschin et al. 2018
Grotta Paglicci, layer 13A	15480 ± 150	19091–18301	GrN-14318	charcoal	Boschin et al. 2018
Grotta Paglicci, layer 13B	16310 ± 350	20524–18907	GrN-14319	charcoal	Boschin et al. 2018
Grotta Paglicci, layer 13C	15990 ± 160	19772–18898	GRN-14320	charcoal	Boschin et al. 2018
Grotta Paglicci, layer 13D	16030 ± 190	19833–18924	GRN-14321	charcoal	Boschin et al. 2018
Grotta Paglicci, layer 14B	15600 ± 200	19408–18319	UtC		Boschin et al. 2018
Grotta Paglicci, layer 14B	15930 ± 200	19797–18824	GrN-14322	charcoal	Boschin et al. 2018
Grotta Paglicci, layer 15	17100 ± 300	21671–19880	UtC		Boschin et al. 2018
Grotta Paglicci, layer 15A	15570 ± 160	19225–18324	GrN-14323	charcoal	Boschin et al. 2018
Grotta Paglicci, layer 15B	16260 ± 160	20064–19195	GrN-14324	charcoal	Boschin et al. 2018
Grotta Paglicci, layers 16	17200 ± 300	21759–20071	UtC		Boschin et al. 2018
Grotta Paglicci, layer 16A 3–1	16690 ± 150	20531–19638	GrN-14325	charcoal	Boschin et al. 2018
Grotta Paglicci, layer 16B 3	16450 ± 190	20385–19448	GrN-14326	charcoal	Boschin et al. 2018
Grotta Paglicci, layer 16b3	16970 ± 150	20875–20150	GrN-14870		Boschin et al. 2018
Grotta Paglicci, layer 16B5	16750 ± 150	20608–19842	GrN-14871		Boschin et al. 2018
Grotta Paglicci, layer 16b7	16480 ± 150	20295–19539	GrN-14872		Boschin et al. 2018
Grotta Paglicci, layer 16c2	16850 ± 150	20767–19966	GrN-14873		Boschin et al. 2018
Grotta delle Mura, G	15860 ± 80	19392–18933	Beta 171353	charcoal	Calattini Marconi 2003
Grotta della Lea, "Carbonaceous area"	15651 ± 75	19089–18800	LTL32105	charcoal	this paper
Grotta della Lea, SU5	15205 ± 65	18680–18281	LTL32103	bone	this paper
Grotta della Lea, SU7 tg 1	17727 ± 65	21821–21209	LTL32102	bone	this paper

CRediT authorship contribution statement

Giulia Marciani: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Antonino Vazzana:** Writing – review & editing, Visualization, Investigation, Conceptualization. **Owen Alexander Higgins:** Writing – review & editing, Investigation, Data curation, Conceptualization. **Ivan Martini:** Writing – review & editing, Investigation, Formal analysis. **Gabriele Terlato:** Writing – review & editing, Writing – original draft, Formal analysis, Data curation. **Simone Severi:** Writing – review & editing, Writing – original draft, Visualization, Investigation, Formal analysis, Data curation. **Sara Silvestrini:** Writing – review & editing, Data curation. **Matteo Romandini:** Writing – review & editing, Data curation. **Gruppo Speleologico Neretino:** Writing – review & editing, Investigation. **Francesco Berna:** Writing – review & editing, Data curation. **Francesco Iacono:** Writing – review & editing, Data curation. **Lucio Calcagnile:** Writing – review & editing, Data curation. **Gianluca Quarta:** Writing – review & editing, Formal analysis, Data curation. **Adriana Moroni:** Writing – review & editing, Validation, Supervision, Investigation, Funding acquisition, Data curation, Conceptualization. **Stefano Benazzi:** Writing – review & editing, Supervision, Investigation, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

Data will be made available on request.

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