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# Grotta del Cavallo (Apulia – Southern Italy). The Uluzzian in the mirror

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**Summary -** *The Uluzzian techno-complex is commonly considered to be a "transitional industry" mostly on the basis of some inferred characteristics such as a chiefly flake-based production, a small amount of Upper Palaeolithic-like tools and a combination of Middle and Upper Palaeolithic elements both in the toolkit and in the technical systems. Following its discovery, the Uluzzian was identified as the Italian counterpart of the French Châtelperronian and attributed to Neandertals. However, a study issued in 2011 has established the modern character of the two deciduous teeth found in 1964 in the Uluzzian deposit of Grotta del Cavallo, fostering renewed interests to the Uluzzian culture, which real nature is almost unknown to the international scientific community. Here we provide preliminary results of the study on the lithic assemblage from the earliest Uluzzian layer and on backed pieces from the whole Uluzzian sequence of Grotta del Cavallo (Apulia, Italy), the type site of the Uluzzian. Moreover, besides a thorough review on the stratigraphy of Grotta del Cavallo (Supplementary Materials), we provide updated information on the human remains by presenting two unpublished teeth from the reworked deposit of the same cave. We conclude that the early Uluzzians demonstrate original technological behavior and innovations devoid of any features deriving or directly linked with the late Mousterian of Southern Italy. Therefore, the novelty nature of the Uluzzian techno-complex (with respect to the preceding Mousterian) complies with the recent reassessment of the two deciduous teeth from Grotta del Cavallo in suggesting an earliest migration of modern humans in southern Europe around 45,000 years ago.*

**Keywords -** *Uluzzian, Grotta del Cavallo, Bipolar technique, Backed pieces, Human remains.*

## Introduction

The Uluzzian has been assigned recently, along with a number of other techno-complexes (Châtelperronian, Szeletian, and Lincombian-Ranisian-Jerzmanowician), to the heterogeneous group of the so-called transitional assemblages (for a synthesis see Hublin, 2015 and references therein). These cultural entities cover a time span of ca. ten millennia (48 - 39 ka), corresponding in Europe to the Middle to Upper Palaeolithic transition, and display variable geographical distribution and techno-typological characteristics. One of the crucial points affecting this particular period is the scarcity and often the complete lack of human remains associated with the archaeological record (Churchill & Smith, 2000). It follows that in most cases, there is great uncertainty about the makers of these assemblages.

Presently the Uluzzian is represented in a small number of sites, all distributed in Peninsular Italy (Fig. 1) and Peloponnese in Greece. In Italy it occurs both in open-air (mostly surface) sites, where it is often mixed with materials from different periods, and in the stratigraphic sequences of a small number of cave sites. In this latter case, the Uluzzian layers always lay on top of a late Mousterian occupation with a sedimentological hiatus (erosion and/or sterile layer) in between and without interstratifications (Moroni *et al.*, 2013).

The story of this techno-complex starts in 1963 in the Uluzzo (Asphodel) Bay, at Grotta del Cavallo (Apulia) when, on July 10$^{th}$, in the course of the first excavation field season at this cave, Arturo Palma di Cesnola came across a curved backed tool crescent-like in shape. Due to the presence of curved backed artefacts and to its stratigraphic position, the newly-discovered assemblage was immediately identified as the Italian counterpart of the French Châtelperronian. Thus, after the discovery of Neandertal human remains at Arcy-sur-Cure and at Saint Césaire (Leroi-Gourhan & Leroi-Gourhan, 1964; Levêque & Vandermeersch, 1980), the Uluzzian was more or less formally considered as the product of Neandertals. Hence, the Uluzzian was interpreted over the years as evidence of the Neandertal trend towards the acquisition of cognitive skills analogous to those expressed by modern humans. This assumption was overturned by Benazzi *et al.* (2011), who were able to establish the modern nature of the two deciduous teeth (i.e. Cavallo B and Cavallo C) from the Uluzzian deposit of Grotta del Cavallo (squares E8 sectors I-II, E9 sector II, F8, F9 sectors II-III and G8; a detailed review on the integrity of the Uluzzian deposit containing the teeth is provided in the Supplementary Materials, thus confirming the attribution of the Uluzzian to modern humans), ultimately stimulating a renewed interest and passionate debate on the real nature of this poorly studied techno-complex (Zilhao *et al.*, 2015).

Indeed, the Uluzzian so far has been mainly analyzed and described from a typological viewpoint. To date, apart from the bone industry (d'Errico *et al.*, 2012), other aspects connected to behavioral modernity (i.e. the study of ornaments, anvils and pigments) have only been marginally tackled. The lack of a comprehensive picture of the Uluzzian diachronic and cultural evolution makes it difficult to detect the presence/absence of connections between this techno-complex and the preceding (and coeval) late Mousterian, and limits detailed investigations into possible relationships with European and non-European Initial Upper Palaeolithic/transitional assemblages. Two additional problems, inherent in the archaeological record, must be taken into account: 1) the Uluzzian is found in a small number of sites that are mostly single-phase sites; 2) the Uluzzian has often been described on the grounds of some characteristics occurring in sites in which the presence of the Uluzzian "proper" (that is the Uluzzian defined as such in the type site of Grotta del Cavallo) is questionable (Hublin, 2015; Peresani *et al.*, 2016).

Overall, such misinterpretations of the evidence have contributed to creating confusion around the character of this techno-complex.

Therefore, the present paper aims at clarifying the nature of this intriguing cultural entity in the context of the transitional scenario, including an inquiry on its relations to the late Mousterian in


***Fig. 1 - Locations of the Uluzzian findings in Italy. Star: Grotta del Cavallo. List of indicated sites: Porcari (1); San Leonardo (2); San Romano (3); Podere Colline (4); Val di Cava (5); Casa ai Pini (6); Salviano (7); Maroccone (8); Indicatore (9); Villa Ladronaia (10); Val Berretta (11); Poggio Calvello (12); Grotta la Fabbrica (13); Santa Lucia I (14); Colle Rotondo (15) (personal communication by M. Pennacchioni); Tornola (16); Atella (17); Grotta di Castelcivita (18); Foresta Umbra (19); Falce del Viaggio (20); Grotta della Cala (21); Torre Testa (22); Grotta del Cavallo (23); Grotta di Uluzzo (24); Grotta di Serra Cicora (25); Grotta Mario Bernardini (26); Grotta di Uluzzo C/Cosma (27); Grotta delle Veneri di Parabita (28); San Pietro a Maida (29); Grotta di Fumane (30). The question mark (?) for Grotta di Fumane points out that, based on our interpretation, the attribution of the layers A3 and A4 to the Uluzzian is questionable. Sea level 70 m below the present-day coastline (Benjamin* et *al., 2017). The colour version of this figure is available at the JASs website.***

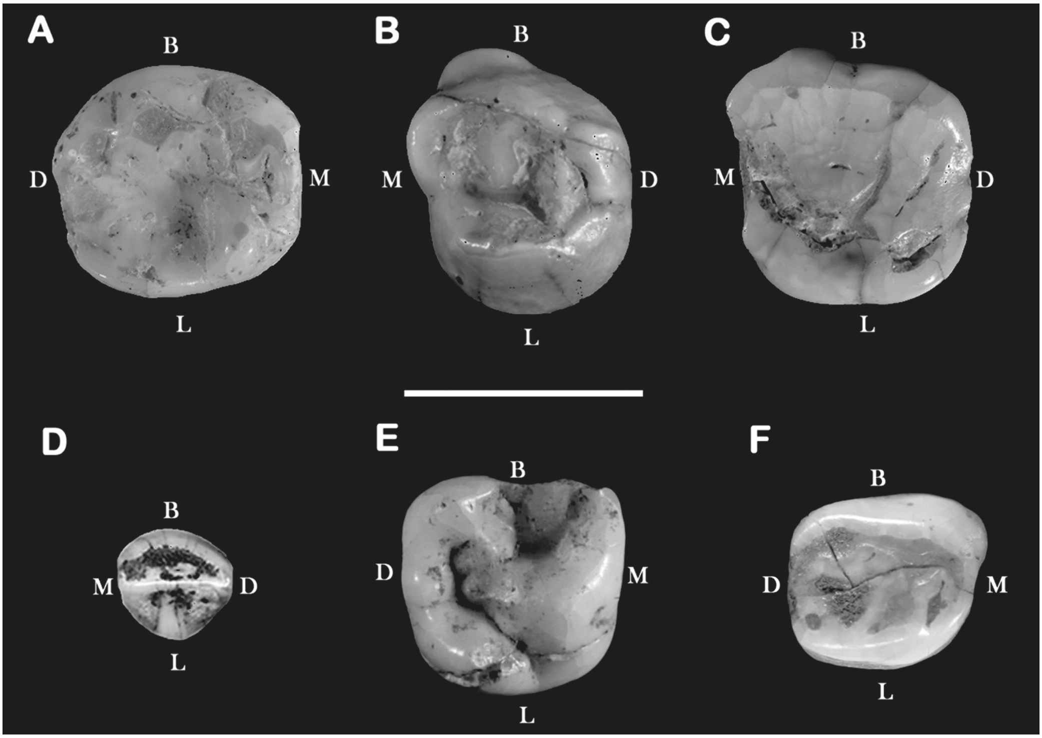


***Fig. 2 - Occlusal view of the deciduous teeth of Grotta del Cavallo. Cavallo A, Neandertal left dm$_2$ (A); Cavallo B, Homo sapiens left dm$^1$ (B); Cavallo C,* Homo sapiens *left dm$^2$ (C); Cavallo D, Neandertal right L$_1$ (D); Cavallo E,* Homo sapiens *right dm$^2$ (E); Cavallo F, Homo sapiens left dm$_1$ (F). B=buccal, D=distal, L=lingual, M=mesial. Scale bar, 1cm.***

Southern Italy. We focus on Grotta del Cavallo (the type site where the Uluzzian techno-complex has been defined), in particular on the lithic material from layer EIII (Palma di Cesnola's fieldworks 1963-1964) (Palma di Cesnola, 1965b, 1966b) and on the whole corpus of backed tools (layers EIII, EII-I, E-D and D) (excavations 1963-1986), as well as on the correlated behavioral implications. Finally, because there is uncertainty on the real number and taxonomic attribution of the human teeth from Grotta del Cavallo (Zihao *et al.*, 2015), here we provide the first taxonomic discrimination of two unpublished human teeth (Cavallo E and Cavallo F) and the morphological description of a specimen hereafter called tooth X, thus clarifying and completing the investigation of the human remains of Grotta del Cavallo (Fig. 2).

*Site presentation and research history*

Grotta del Cavallo, called also Grotta delle Giumente (Mares) or Uluzzo A, opens into the rocky coast of the Uluzzo Tower bay, around 15 m a.s.l. Its entrance, which is more than 5 m wide and about 2.5 m high, faces NW (Fig. 3). The cavity is formed by a single chamber roughly circular in shape, with a diameter of approximately 9 m. The vault is 3 m ca. above the present floor. In this cave, Palma di Cesnola identified a 7 m thick stratigraphic sequence of pivotal interest, encompassing a long time interval including the local Middle Palaeolithic (layers N-G), which closes with the late Mousterian (layer F), the subsequent Middle-to-Upper Palaeolithic transition (layers E, D), sealed at its top by a volcanic horizon (layer C), and, after a long chronological gap, the final Upper Palaeolithic (layer B Romanellian) and the Holocene occupations (layer A) (Palma di Cesnola, 1967). Two tephra layers (Fa below and C above) mark the stratigraphic and chronological boundaries of the Uluzzian. Layer Fa has recently been referred to tephra Y-6 (Green Tuff of Pantelleria Island dated to 45.5 ±10 ka; Zanchetta *et al.,* 2018); C has been identified as CI dated to 39.85 ± 0.14 ka; Giaccio *et al.*, 2017). Grotta del Cavallo is not only the site where the Uluzzian was recognized and described for the first time, but it currently remains the main site in which this techno-complex can be followed in its chrono-cultural evolution (a detailed description of the research history, the stratigraphy, the integrity of the deposit and the chronology of Grotta del Cavallo is provided in the Supplementary Materials).

Palma di Cesnola's investigations at this key cave started in 1961 and went on until 1966 (Palma di Cesnola, 1963, 1964, 1965a, 1966a). In 1963-64 field seasons a test trench was opened 2.5-3 x 3.5 m ca. wide (called principal trench) (Fig. 4). This trench was divided into sectors, which were excavated separately and were brought down to different depths. The Uluzzian layer E, which was divided into two main stratigraphic units (EIII and EII-I), was investigated over the whole area of the principal trench, reaching everywhere the late Mousterian layer F, only in 1964. In this season excavation into the Mousterian deposit was pushed down to layer I over an area 2 x 1 m wide. Subsequently (1965) the trench previously opened in the Mousterian deposit was enlarged and deepened down to more than 5 m. Most of the Uluzzian material published by Palma di Cesnola was thus recovered in 1964, as also the deciduous teeth Cavallo B and C were found in this year in the earliest (archaic) Uluzzian layer (EIII) (Palma di Cesnola & Messeri, 1967; Messeri & Palma di Cesnola, 1976; Churchill & Smith, 2000). Since the beginning of the research (1963), the cavity infill resulted to be affected by a major erosional event, which was initially identified by the excavator as an artificial pit Romanellian in age (see Supplementary Materials).

***Fig. 3 - Grotta del Cavallo in the Uluzzo bay (photo V. Spagnolo). The colour version of this figure is available at the JASs website.***

In 1966 the principal trench was further widened and the Mousterian series was explored down to the marine beach N (O in the more recent publications, see Romagnoli *et al.*, 2016). During this operation, other two human teeth, here named Cavallo E and F (Fig. 2), were found in the reworked deposit (the so-called "Romanellian pit"). Owing to the enlargement of the excavation surface the overlying layers, including the Uluzzian ones, were gone through again. In this year charcoal samples for dating were collected from the hearths found in EIII and EII (Palma di Cesnola, 1966a). Analyses were performed at the Istituto di Geochimica di Roma, but given that epoch's limited dating tools, it was only possible to obtain the *terminus ante quem* of >31000 BP (R-352) for the EII-I horizon (Palma di Cesnola, 1969).

In 1977, after a long interval (1967-76) in which the cave deposit was seriously damaged by looters, research at Grotta del Cavallo resumed. The following years (1978-1980) (Gambassini & Palma di Cesnola, 1979; Palma di Cesnola, 1979; Gambassini, 1980) were devoted to restoring the cave infill, by clearing the intact layers from looters' dumps. From 1979, Paolo Gambassini took over the responsibility of research at Grotta del Cavallo for the Uluzzian (Sarti, 1987-1988) and continued investigations until 1986. Gambassini's intervention encompassed squares

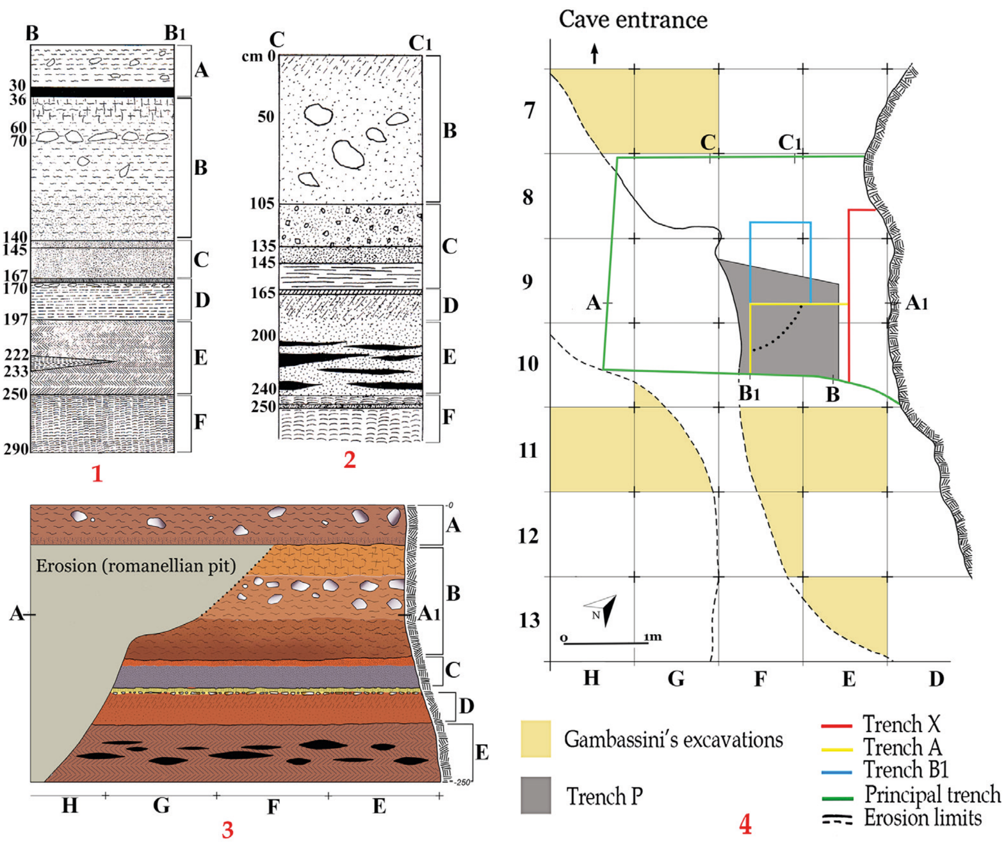


***Fig. 4 -Stratigraphic sequence and planimetry of Grotta del Cavallo. Schematic SE stratigraphic profile of trench P (fieldwork season 1963 modified after Palma di Cesnola 1963) (1); schematic NW stratigraphic profile of the Principal Trench (fieldwork season 1964 modified after Palma di Cesnola 1964) (2); schematic stratigraphic profile of the Principal Trench (Palma di Cesnola's excavations) with the pit due to the erosional event, reconstructed on the basis of published data and fieldwork notes (3); planimetry of the excavation area relating to 1961-1986 field seasons with trenches X, A, $B_1$, P, the Principal Trench and the squares excavated by P. Gambassini in the years from 1979 to 1986 (4). Trench X was opened as a test in 1961; trench A and $B_1$ were opened two days apart from each other at the beginning of the 1963 field season. The continuous line marks the boundary of the "pit" identified by Palma di Cesnola. The dotted line represents the erosion limits which have been reconstructed on the grounds of Gambassini's observations carried out in the years after 1979. The colour version of this figure is available at the JASs website.***

E11, E13, F11, F12, G5, G7, G10, G11, H7, H11 (Fig. 4, n. 4).

In recent years, papers have been issued on the chronology of the Uluzzian culture (Douka *et al.*, 2014) (see Supplementary Materials for details) and on its hypothetical origin (Moroni *et al.*, 2013). In addition, some very preliminary publications have been produced on the technological and functional characteristics of the Uluzzian of Grotta del Cavallo (De Stefani *et al.*, 2012; Klempererová, 2012; Ranaldo *et al.*, 2017). Finally, exhaustive studies have been performed on the faunal remains retrieved from layer EIII, spit 5 (Gambassini's excavations) (Boscato & Crezzini, 2012) and on the bone industry (d'Errico *et al.*, 2012).

## Materials and Methods

*Lithics*

The lithic sample from layer EIII housed at the University of Siena consists of 1089 pieces. These were studied from a technological viewpoint (Leroi-Gourhan, 1943, 1945; Crabtree, 1982; Barham, 1987; Geneste, 1991; Inizan *et al.*, 1999) with the aim of reconstructing, in this preliminary phase of the study, the main production processes carried out by the earliest Uluzzians and identifying distinctive attributes of their toolkit. As first step, artefacts were classed into five broad categories: cores, flakes (length/width < 2), blades (length/width ≥ 2), indeterminate pieces (fragmented, altered pieces etc.) and retouched pieces. A study on the cores was performed taking into consideration the origin and morphology of the blanks as well as the kind of volumetric concept and the exploitation system. The type and location of the striking platform, the characteristics of removals and the possible reasons why the core was discarded were further evaluated. Products were examined according to the extent and localization of cortical parts, their morphological attributes (profile, symmetry and cross-section), the characteristics of dorsal scars, butts, bulbs and ventral faces, in order to identify, as far as possible, the reduction sequence they belonged to. To identify bipolar products standard criteria borrowed from the literature were used (Barham, 1987; Knight, 1991; Guyodo & Marchand, 2005; Bradbury, 2010; Soriano *et al.*, 2010). Finally, the occurrence of retouch and of possible alteration features (chemical, post-depositional, thermal) was also taken into consideration. A raw material revision was performed on the lithic component obtained from siliceous lithotypes (mostly pebbles) along with a preliminary attempt of refitting which gave one successful result. In this case artefacts were sorted on the grounds of their macroscopic features such as colour and thickness of cortex, texture, colour, inclusions and opacity of the raw material.

A more detailed study was conducted on backed pieces. These were analysed on the basis of the procedures used in their manufacturing, the original blanks, their dimensions (maximum length, breadth and thickness were measured) and proportions (length/breadth and breadth/thickness have been considered), the backing process. The working edge (the one opposite the back) angle of each piece was also measured. The obtained data were intertwined in order to identify potentially recurring characters and to reconstruct, as far as possible, the techno-functional life of each artefact.

The traceological analysis on backed pieces was carried out by means of both the low power approach (LPA) (Tringham *et al.*,1974; Odell & Odell-Vereecken, 1980; Odell, 1981) and the high power approach (HPA) (Keeley, 1980; Plisson, 1985; Van Gijn, 2010). Traces were observed by means of a Hirox KH-7700 3D digital microscope using two different optics: a MX-G 5040Z body equipped with an AD-5040Lows and an AD-5040HS lens working at low magnification (20x-50x) used to observe the macro-traces (fractures, edge damage, diagnostic impact fractures) and a MXG-10C body and an OL-140II lens (140x-480x) used to analyze the micro use-wear (polishes, abrasions and striations). This instrument enables the generation of a 3D model of the observed surface through the overlapping of several planes (up to 120) taken at different focus levels, allowing versatile observation in three dimensions. A fully-focused image can be created from a small number of pictures facilitating observation of the used surfaces at high magnifications (Moretti *et al.*, 2015; Oxilia *et al.*, 2015; Arrighi *et al.*, 2016; Duches *et al.*, 2016).

*Human remains*

High-resolution micro-CT images of Cavallo E, Cavallo F and tooth X were obtained with a XAL-T microtomographic system (Institute of Clinical Physiology. Pisa. Italy) (Panetta *et al.*, 2012) using the following scan parameters 50 kV, 0.7 m A with a 2mm Al filters. Each tooth was scanned at the highest magnification factor (M=2.6) for ca. 45 min and a volumetric dataset has been then reconstructed with a cubic voxel size of 18.3 μm via cone-beam filtered back-projection with standard ramp filter applying corrections for ring artefacts and beam hardening. Attention has been paid on accurate geometrical calibration of the scanner prior to each scan session. The image stacks were segmented with a semiautomatic approach in Avizo 9.0 (Thermo Fisher Scientific) to reconstruct three-dimensional (3D) digital models of the teeth, which were then used for the morphological description of the external surface and the Enamel-Dentine Junction (EDJ) surface, and for morphometric analysis. Terminology for the morphological description follows Scott & Turner (1997). Non-metric traits were evaluated according to standards outlined by the Arizona State University Dental Anthropology System ASUDAS (Turner *et al.*, 1991). Occlusal wear stage was assessed based on Molnar (1971). Age of death for Cavallo E was estimated combining different observations such as stages of tooth formation dental eruption and root resorption using the sequences provided by Moorrees *et al.* (1963) and AlQahtani *et al.* (2010) for recent *Homo sapiens*. The Mesio-Distal (MD) and Bucco-Lingual (BL) crown diameters of Cavallo E and Cavallo F were compared with a sample of Neandertal (N) Upper Palaeolithic *H. sapiens* (UPHS) and Recent *H. sapiens* (RHS) teeth collected from the scientific literature (Foster *et al.*, 1969; Frayer, 1978; Tillier, 1979; Wolpoff, 1979; Madre-Dupouy, 1992; Tixier & Tillier, 1991; Bailey & Hublin, 2006; Toro-Moyano *et al.*, 2013). In addition to measuring the crown diameters, crown outline analysis was carried out on Cavallo E. Since the tooth is fractured buccally (see Fig. 5, A and morphological description below) several steps were required to obtain the shape variables.

First, it was not possible to exploit the orientation protocols based on the cervical line (i.e. Benazzi *et al.*, 2009, 2011). Therefore, the digital model of Cavallo E was imported in Geomagic Design x (3D Systems Software srl), virtually mirrored (i.e. to be compared to the sample by Bailey *et al.*, 2014, see below), oriented to maximize the occlusal surface area in superior view (xy-plane) and rotated around the z-axis so that the lingual side was parallel to the x-axis. The incomplete crown outline of Cavallo E was then projected onto the xy-plane (Fig. 5, A). Second, to reconstruct the outline without biasing the final outcome, two restorations were proposed based on the mean shape of the Upper Palaeolithic *Homo sapiens* (UPHS) and Neandertal samples used by Bailey *et al.* (2014) respectively (Fig. 5, B-C). Owing to the lack of real landmarks that can guide the deformation of the UPHS and Neandertal means onto the crown outline of Cavallo E, the means of the former groups were digitally translated and uniformly scaled onto the latter in Rhino 4.0 beta CAD environment (Robert McNeel and Associates, Seattle WA) until the best match was found. Then the portion of the mean outlines corresponding to the missing area was used to obtain two versions of a complete outline for Cavallo E: Cavallo E based on UPHS (i.e., Cav-E UPHS) and Cavallo E based on Neandertals (i.e., Cav-E N) (Fig. 5, D-E). Both versions were centered superimposing the centroids of their area within the comparative sample used by Bailey and colleagues (2014), represented by 24 pseudolandmarks obtained by equiangularly spaced radial vectors out of the centroid, and scaled to unit centroid size (Benazzi *et al.*, 2011; Benazzi *et al.*, 2012). Finally, the shape variables of Cav-E UPHS and Cav-E N were projected into the shape-space obtained from a Principal Component Analysis (PCA) of the comparative sample used by Bailey *et al.* (2014). The data was processed and analyzed through software routines written in R version 3.3.0 (R Core Team, 2016).

## Results

*New insights from the lithic assemblage of layer EIII*

The most common rock lithotype (approximately 80%) exploited by the Uluzzians of layer EIII is greyish laminated limestone showing different degrees of silicification. It was available from local Mesozoic outcrops (Palma di Cesnola, 1965b, pp. 36-38) as also attested for the Mousterian levels of the same site (Carmignani,

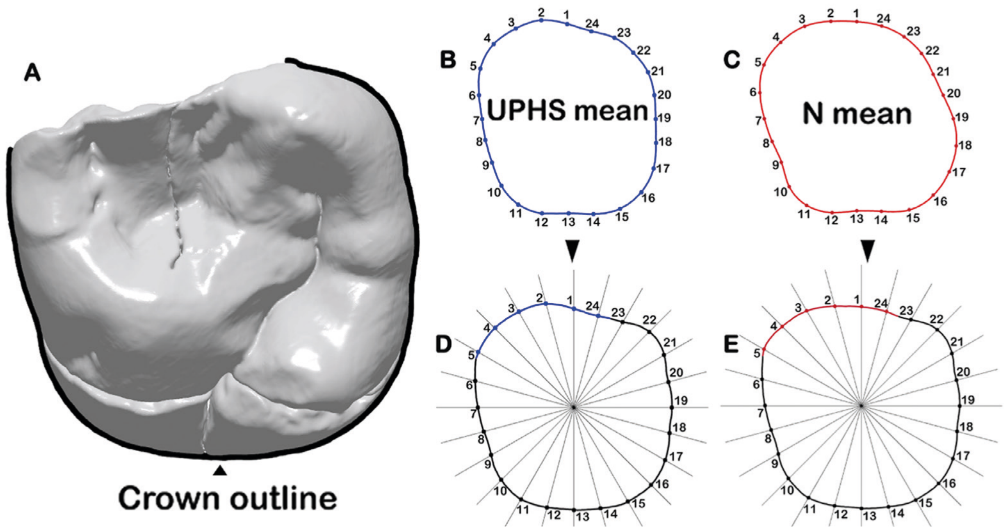


***Fig. 5 - The human remain Cavallo E. The incomplete crown outline of Cavallo E mirrored and projected onto the xy-plane (A); mean shape of the Upper Palaeolithic* Homo sapiens *(UPHS mean) crown outline samples (B); mean shape of the Neandertals (N mean) crown outline samples (C); the restoration of the crown outline shape of Cavallo E based on the mean shape of the Upper Palaeolithic* Homo sapiens *(UPHS) samples (D); the restoration of the crown outline shape of Cavallo E based on the mean shape of Neandertal (N) samples (E). The colour version of this figure is available at the JASs website.***

2010; Romagnoli *et al.*, 2016). Natural surfaces present on the artefacts show that this raw material was collected from primary outcrops as layers varying from approximately 50 mm to 5 mm in thickness. Such layers naturally cleave according to parallel planes. Thin layers are generally less silicified. Palma di Cesnola refers to thicker layers as "liste" (slabs), whereas he introduced the term "lastrina" to indicate thinner layers (15-5 mm) and cortical parts of more silicified thick layers or thin portions of them defined by cleavages (Palma di Cesnola, 1965b, p. 36). This raw material is often of poor quality and relatively difficult for knapping. Secondarily, a series of different siliceous raw materials are present which appear to have been mostly collected as small pebbles (as clearly indicated by cortex where present). They include fine-grained flint and radiolarite, medium to coarse grained flint, medium to coarse grained siliceous limestone and medium-grained quartzite.

Besides the use of debitage production, characteristic of the lithic assemblage from layer EIII is the considerable amount of lastrine (which constitute 76.8% of retouched pieces) (Tab. 1) directly employed as blanks for retouched tools, without any previous debitage modification. These two procedures are for two completely different purposes. End-scrapers and side-scrapers are above all on lastrina, while debitage is mostly associated with the production of blades and microlithic items in general.

Two techniques were employed in the knapping operations: direct freehand percussion (Crabtree, 1982, p. 82) and bipolar knapping on anvil, the latter largely predominant (67% of the whole sample) (Tab. 1). Cores are always of small size since their maximum dimension does not exceed 60 mm. However the occurrence of a number of large flakes from raw materials other than limestone slabs indicates that a minor part of the production was probably implemented elsewhere. In addition very rare unilateral crests and *tablettes* on fine-grained flint denote the sporadic use of more elaborated technological systems. Except for backed pieces, which are dealt

***Tab. 1 - Counts of layer EIII lithics (excavation seasons 1963 and 1964) currently housed at the University of Siena. Frequency distribution of the examined categories. Indeterminate blade and flake categories contain specimens which cannot be attributed to specific reduction systems.***

| LAYER EIII 1963-1964 | N | % |
|---|---|---|
| Bipolar core | 365 | - |
| Bipolar blade-bladelet | 74 | - |
| Bipolar flake-flakelet | 19 | - |
| **Tot. bipolar** | **458** | **67.0** |
| Freehand core | 33 | - |
| Freehand blade-bladelet | 28 | - |
| Freehand flake | 44 | |
| **Tot. freehand** | **105** | **15.4** |
| **Indet. blade-bladelet** | **23** | **3.4** |
| **Indet. flake-flakelet** | **44** | **6.4** |
| Total blade-bladelet | 125 | - |
| Total flake-flakelet | 107 | - |
| **Other** | **53** | **7.7** |
| Retouched artefact | 106 | - |
| **Tot. debitage** | **683** | **-** |
| **Tot. retouched on lastrina** | **357** | **-** |
| **Indeterminate on lastrina** | **36** | **-** |
| **Tot. retouched on thermal flake** | **13** | **-** |
| **Total assemblage** | **1089** | **-** |

with separately in the ensuing paragraph, formal tools on knapped blanks are not very numerous. These are mostly composed of side-scrapers (Fig. 6, ns. 13-17) and end-scrapers (Fig. 6, n. 6), as well as of some denticulates and a few (3 pieces) marginally backed small blades irregular in profile (unlike classic Dufour bladelets), two of which from bipolar reduction (Fig. 6, ns. 1-3). Among cores we also considered specimens bearing single or few short scaled test removals and a moderate quantity of unexploited slabs/lastrine showing adjustments of the edges, which are consistent with a sort of rough crest preparation.

In cores exploited by direct freehand percussion, debitage (Fig. 7, ns 3-6) is very simple as it encompasses none or only a minimal (presence of few partial crested items) preparation of the volume to be flaked. Striking platforms are generally natural. Save for some exceptions, knapping is unifacial (both unidirectional and bidirectional) and is carried out along the maximum dimension of the blank. Reduction sequences, aimed at the achievement of few blades (Fig. 7, ns. 1-2) or flakes per core, are brief and interrupted by hinged removals more often than not. A core shows an additional use as a hammerstone.

As already repeatedly put forward by Palma di Cesnola (1989) and other authors involved in the study of the Uluzzian (Gambassini, 1997; Dini & Tozzi, 2012; Douka *et al.*, 2014; Peresani *et al.*, 2016 and references therein), a major feature marking the identity of this techno-complex is the overwhelming occurrence of artefacts displaying evidence of a particular stone knapping behavior, the bipolar flaking on anvil, and commonly classified as splintered pieces (the French *pièces esquillées* or *écaillées*). In its commonly accepted meaning, bipolar reduction can be described as a percussion technique in which lithic raw material is manually held on a mineral anvil and vertically or tangentially struck with a hammer (usually hard) (White, 1968; Crabtree, 1982; Barham, 1987; Knight, 1991; Shott, 1999; Soriano *et al.*, 2010; Duke & Pargeter, 2015). This entails obtaining relatively uncontrolled removals that vary in technological features. Moreover, contrary to the other debitage techniques, a single bipolar blow can concomitantly produce more than one product either from the same edge or from the two opposite ends (Soriano *et al.*, 2010; Vergès & Ollé, 2011; Duke & Pargeter, 2015). In several contexts bipolar reduction comes into play as an ancillary technique, either in cobble-splitting at the beginning of a reduction sequence or when the core becomes too small to be knapped otherwise. Its exclusive use on specific raw materials has also been noticed (Shott & Tostevin, 2015 and references therein). In our

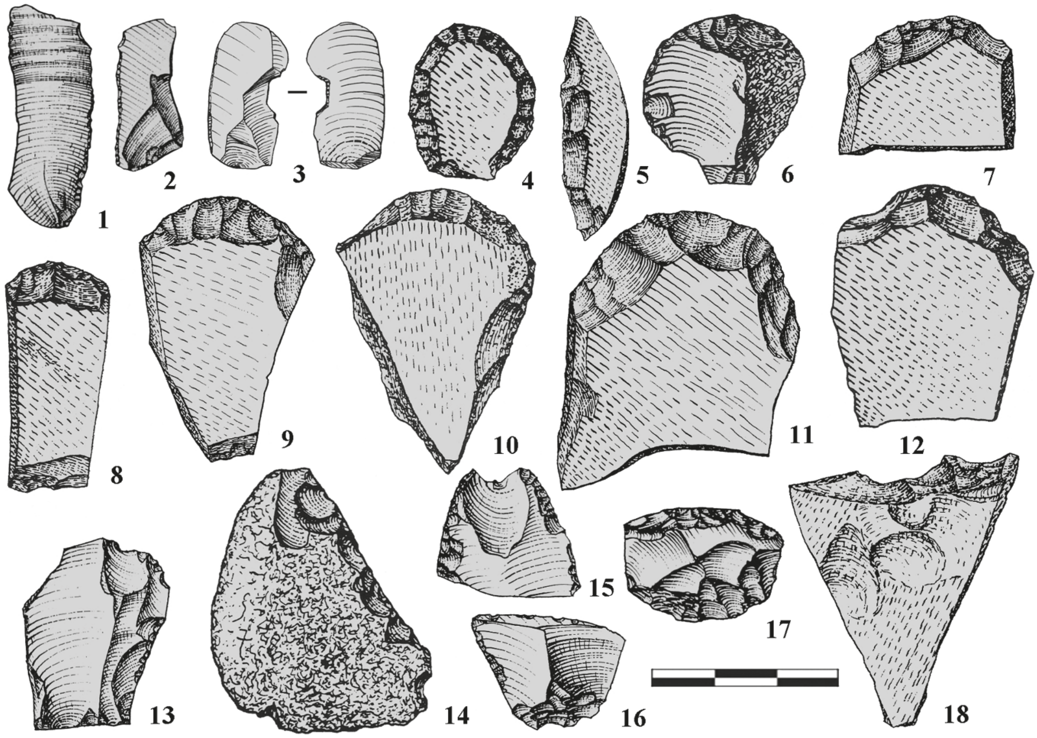


***Fig. 6 - Layer EIII. Retouched tools. Marginally backed small blades (ns. 1-3); pseudo-lunate on lastrina, characterized, unlike true lunates, by a fracture forming a curved back on the one side and by a retouched cutting edge on the other (n. 5); end-scrapers on lastrina (ns. 4, 7-12); end-scraper on flake (n. 6); scrapers on flake (ns. 13-17); denticulate on lastrina (n. 18). Modified after Palma di Cesnola, 1965b (ns. 1-2, 4-18). Tools 6, 8 and 9 are intentionally modified by splintering on the extremity opposed to the frontal edge.***

case there is no selection in the exploitation of different raw materials and direct freehand debitage and bipolar knapping appear to have been unrelated processes as, in both categories, several pieces display remnants of the original surfaces attesting the small size of the initial core mass.

Layer EIII yielded both specimens universally recognized as cores, and quadrilateral pieces, chisel-like in profile, which, in the literature, are often classified as tools (splintered pieces) on the grounds of their edge morphology and/or inferred function. Initial results of the study carried out on technological and morpho-metrical attributes of this bipolar component bear witness to the lack of a clear separation among differently-shaped artefacts. Conversely, these objects display, as shown below, recurring traits suggesting the possibility of a common technological pattern. While waiting for more in depth studies substantiated by a complete set of experimental tests and use-wear and residue analyses, we are inclined to interpret most of the bipolar evidence from layer EIII as cores belonging to reduction processes aimed at the production of blanks.

EIII bipolar flaking strategies are oriented towards the achievement of elongated products of small to hyper-micro-lithic dimensions. Fractions of slabs/lastrine, small pebbles and

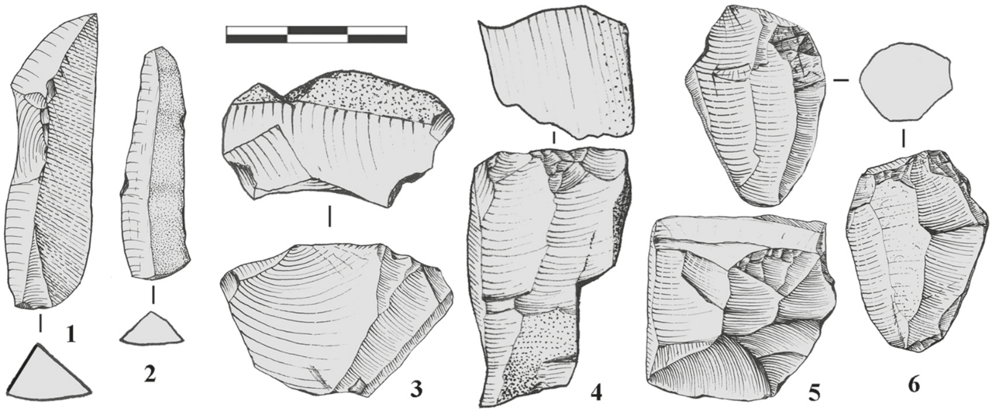


***Fig. 7 - Layer EIII. Cores and products. Cores (ns. 3-6) and products (ns. 1-2) from direct freehand percussion. Drawings by A. Moroni.***

flakes, the original ventral faces of which are, sometimes, still discernable, were indifferently exploited. Pebbles were first split into segments, resulting from an initial bipolar blow; each of these segments (Flenniken's "Split cobble cores" - 1981) was used independently as shown by a small refit between two cores stemming from the same pebble (Fig. 8, n. 8). Bipolar cores can be clustered into two main groups: 1) cores starting from elongated blank (Fig. 8, ns. 1, 2, 10). In the case of slabs these blanks are parallelepipeds with two cortical sides. Negative removals are represented, for the most part, by small blades, bladelets and micro bladelets. Intensive exploitation extended on both faces and sides can generate an elongated narrow morphology (resembling often a sort of small stick) showing at least one striking platform reduced to a point ogival in shape. Slabs used in this category of cores are thin and narrow as their width, which corresponds to the limestone layer thickness, only exceptionally exceeds 15 mm. The reduction process starts from the natural edge of the slab and always follows the direction of the layer surface.

2) cores starting from roughly square-shaped blanks (Fig. 8, ns. 5, 9, 15). In this case removals are both small blades/bladelets/micro bladelets and small flakes/flakelets/micro flakelets. Flakes always come from the plan faces of the core.

In both groups the spent cores, having, instead of the striking platform, one or two opposite ridges crushed and buttered by splintering, are numerous.

A minor part of bipolar cores display different evidence. Some quadrangular or triangular lastrine bear blade removals developing along the longest natural edges without invading the faces in plain view. Another system employs triangular fractions of slabs/lastrine to achieve elongated blanks using the triangle top as striking starting point. Finally, there are some cores, chiefly oriented towards blade production, showing few bipolar removals randomly distributed.

Interestingly, despite the "uncontrolled" character of bipolar reduction, conditions for the achievement of blades or, more in general, elongated products are provided by a standard exploitation *modus operandi* in which a key factor is the occurrence on the core of lateral steep edges naturally present (slabs and pebble segments) (Barham, 1987, p. 47, Fig. 8) or intentionally created (flakes). Plan removals tend to maintain this prerogative as they always develop parallel to these edges. Only at the very end of the process, in completely exhausted morphologies (usually of very small size), also lateral edges are invaded and obliterated by splintering. The entire process causes a progressive relatively proportional reduction of

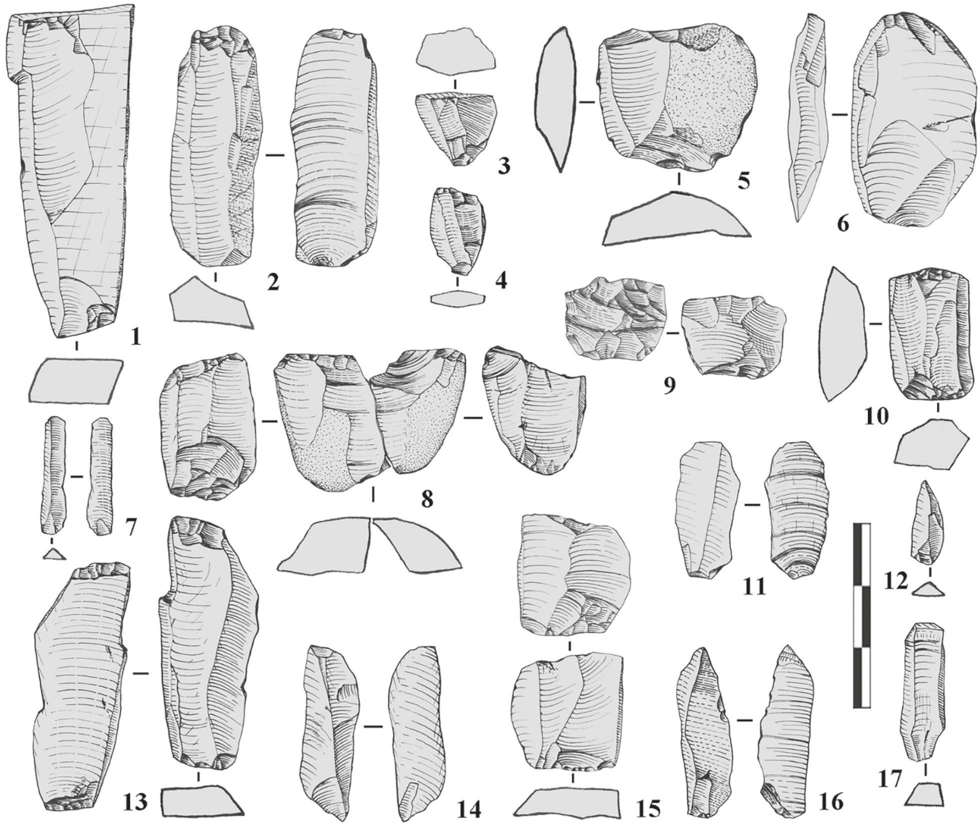


***Fig. 8 - Layer EIII. Bipolar cores and products. Bipolar cores (ns. 1-6, 8-10, 15) and products (ns. 7, 11-14, 16-17) from bipolar knapping. Refitting between two portions of a pebble which were individually exploited as cores after the splitting of the pebble (n. 8). Drawings by A. Moroni.***

the core which basically retains its original profile, although diminishing in size. Therefore, even if bipolar products are scarcely controlled in shape and thickness, the use of repeating patterns of technical expedients allowed prehistoric craftsmen to partially influence, if not predetermine, proportions of the wished products.

Although potentially more productive than hand-held cores (Hiscock, 2015), in the case under study, bipolar cores turned out to be unsuitable for extended reduction sequences owing to their intrinsic characteristics (primarily the already small size of blanks). This might account for their vast quantity in the EIII sample.

Given the lack of any former preparation of the core, the morphometric attributes of bipolar products are closely related to the potentialities inherent in the core blank natural morphology. Products resulting from bipolar reduction show (as in other authors' descriptions - Barham, 1987; Knight, 1991; Guyodo & Marchand, 2005; Bradbury, 2010; Soriano *et al.*, 2010) "sheared bulbs of percussion" (Barham, 1987, p. 48), butts shattered or reduced to a point or a line, and longitudinal profile of the ventral face generally rectilinear (Fig. 8, ns. 7, 11, 14, 16, 17). The ventral and the dorsal faces are not always easily distinguishable from each other; in addition the

***Tab. 2 - Counts of layer EIII artefacts on lastrina (excavation seasons 1963 and 1964) currently housed at the University of Siena.***

| LAYER EIII 1963-1964 | N | % |
|---|---|---|
| Front end-scrapers | 129 | |
| Nose end-scrapers | 22 | |
| Carenated end-scrapers | 6 | |
| End-scrapers fragments | 11 | |
| **Total end-scrapers** | **168** | **42.7** |
| Convex side-scrapers | 85 | |
| Straight side-scrapers | 38 | |
| Concave side-scrapers | 1 | |
| Side-scrapers fragments | 11 | |
| **Total side-scrapers** | **135** | **34.4** |
| **Denticulates** | **37** | **9.4** |
| **Pseudo-lunates** | **17** | **4.3** |
| **Indeterminate** | **36** | **9.2** |
| **Total** | **393** | |

ventral face of some products exhibits "very pronounced ripple marks" (Ahler & Christensen, 1983, p. 187, Figs. 6, n. 1 and 8, n. 11) corresponding to Binder's *face d'éclatement vibrée* (1987, p.182) which are due to the intensity of the strike and indicate a percussion angle of 90° (Guyodo & Marchand, 2005). Thick and quadrilateral in cross-section blades (Barham, 1987, p. 47, Fig. 8, C) are also present (Fig. 8, n. 17).

In layer EIII, specimens on lastrina represent 36.1% of the whole assemblage and 76.8% of retouched tools. Their use decreases from EIII to EII-I to D where they nearly disappear (Palma di Cesnola, 1965b, 1966b). This is a very particular system of making tools, induced by the characteristics of raw material, which is exclusive of the sites located in the same area of Grotta del Cavallo.

Tools were directly achieved from lastrine naturally fragmented or shaped by intentional breaking. Their 90° backed sides were then transformed by retouching them in order to obtain cutting edges. End-scrapers are the most numerous and characteristic tools (42.7%); they are mainly represented by specimens with semicircular fronts (Fig. 6, ns. 7-10) (Tab. 2). Only in 30 pieces does the retouch extend from the front to the adjacent edges (Fig. 6, n. 4). Even if end-scrapers are quite varied in size, they are all rather short (only 12 items display a more elongated profile) (Fig. 6, n. 8). It is also possible that this feature was deliberately pursued, since 18 pieces exhibit a clearly intentional shortening at the end opposite to the front (Fig. 6, n. 8).

Lateral fractures are generally sub-parallel with the exception of 20 specimens in which fractures converge to form a point opposite to the end-scraper (Fig. 6, n. 10). Some pieces with "flattened" fronts are in an intermediate position between end- and side-scrapers.

Within the rest of the assemblage (side-scrapers and denticulates) it is really difficult to identify which pieces are finished tools, fragments or by-products without having performed an appropriate experimental activity and a targeted technological study. However, we note, also amongst side-scrapers and denticulates, the occurrence of convergent fractures shaping the sides adjacent to the retouched edge (Fig. 6, n. 18). A noteworthy recurring type on lastrina, already described by Cesnola (Palma di Cesnola, 1966b, p. 58), is what we have provisionally labelled "pseudo-lunate" (Fig. 6, n. 5). This is indeed lunate-like in shape even if it is characterized, unlike true lunates, by a fracture forming a curved back on the one side and by a retouched cutting edge on the other.

Several pieces on lastrina retain residues of red pigment. The analysis of their localization integrated with a use-wear study will provide information about the possibility that tools on lastrina or some of them, were hafted.

*Backed pieces*

Crescent-shaped backed tools (also referred to as lunates or segments) are considered, together with the bipolar technique the hallmark of the Uluzzian (Fig. 9). Such tools actually occur in all the Italian assemblages belonging to this

***Tab. 3 - Dimensions (in mm) and length/breath and breath/thickness ratios (means ± standard deviation) by layer, calculated on backed pieces with complete length (Tot. 116), breath (Tot. 132) and thickness (Tot. 135).***

| LAYERS | LENGTH (mm) | BREATH (mm) | THICKNESS (mm) | LENGTH/ BREATH | BREATH/ THICKNESS |
|---|---|---|---|---|---|
| D | 26.5 ± 3.63 | 10.9 ± 2.17 | 4.29 ± 1.49 | 2.43 ± 0.49 | 2.81 ± 1.34 |
| | (n = 18) | (n = 20) | (n = 21) | (n = 18) | (n = 20) |
| E-D | 24.2 ± 4.75 | 11.07 ± 3.35 | 4.07 ± 1.28 | 2.31 ± 0.46 | 2.94 ± 1.11 |
| | (n = 25) | (n = 30) | (n =30) | (n = 25) | (n = 30) |
| EII-I | 25.13 ± 5.59 | 11.2 ± 2.64 | 4.1 ± 1.27 | 2.26 ± 0.48 | 2.86 ± 0.8 |
| | (n = 45) | (n = 51) | (n = 52) | (n = 45) | (n = 51) |
| EIII | 29.25 ± 5.76 | 14.74 ± 3.54 | 5.09 ± 1.94 | 2.01 ± 0.38 | 3.16 ± 0.99 |
| | (n = 28) | (n = 31) | (n = 32) | (n = 28) | (n = 31) |

techno-complex, but they are really numerous only at Grotta del Cavallo (Palma di Cesnola, 1982; Benini *et al.*, 1997; Gambassini, 1997). Palma di Cesnola's and Gambassini's excavations yielded more than 146 backed tools (considering both finished and *in fieri* objects -146 is the amount of specimens housed at the University of Siena), embodied for the greatest part by lunates. This allowed their quantitatively reliable study the preliminary results of which are presented herein.

Backed pieces are not evenly distributed amongst the three main stratigraphic partitions: their percentage is lower in EIII, increases in EII-I and decreases again in D (Palma di Cesnola, 1965b, 1966b) (34, 60, 30 and 22 pieces of the examined sample from layer EIII, layer EII-I, layer E-D and layer D respectively). This category contains several irregular and roughly retouched specimens, in addition to a greater part of more or less carefully made items, including rare quasi trapezoidal or triangular implements (which can be conceptually incorporated among lunates).

Evidence resulting from the analysis of their technological features attests that various kinds of blanks (bladelets, flakes and lastrine), obtained from different production systems, were used, on the condition that they had a sufficient degree of thickness. The production phase had, therefore, a subordinate role as tool shaping chiefly relied upon the transformation process (retouching) (see also Ranaldo *et al.*, 2017).

In the cases in which the original blanks (109 pieces) can be identified, these are more often blades (L/W ratio ≥ 2) (53%), especially in layers EII-I and D, represented by small, frequently thick, blades (maximum length > 20 ≤ 40 mm) and exceptionally by bladelets (maximum length ≤ 20 mm). The blade/flake ratio, globally 1.1, is in favour of flakes (0.6) in the lowest layer EIII (Tab. 3). Some blanks show clear features attesting their provenance from bipolar cores. The angle of the edge opposite the back ranges between 20° and 40° (Tab. 4).

In layer EIII some thermal flakes stemming from lastrina were used as blanks (Fig. 9, n. 3). It is possible that heating was an effective fracturing stratagem intentionally applied to this particular kind of raw material in order to quickly extract blanks.

For most of the lunates the back was obtained by reducing one of the longest edges of the blank (whether flake or blade) until reaching its maximum thickness (around the middle of the blank)

***Tab. 4 - Values of the working edge angles of backed pieces by layer.***

| WORKING EDGE ANGLE | EIII | | EII-I | | E-D | | D | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|
| | n | % | n | % | n | % | n | % | n | % |
| 20° | 8 | 24.2 | 14 | 26.9 | 9 | 30 | 4 | 23.5 | 35 | 26.5 |
| 30° | 14 | 42.4 | 25 | 48 | 14 | 46.6 | 8 | 47 | 61 | 46.2 |
| 40° | 11 | 33.3 | 12 | 23 | 7 | 23.3 | 5 | 29.4 | 35 | 26.5 |
| 50° | | | 1 | 1.9 | | | | | 1 | 0.7 |
| Total | 33 | | 52 | | 30 | | 17 | | 132 | |

(type A) (Fig. 9, ns. 1, 4-6). Usually, at the end of the backing process, the butt resulted in being entirely removed and only about 2/3 - 1/2 of the bulb was preserved. Some pieces with straight backs formed by retouch starting from the dorsal face are most probably to be considered unfinished specimens (Fig. 9, n. 2). Another system (type B) mainly attested from EII-I upwards, involves blanks formed by small blades often triangular in cross-section; only the ends were deeply modified by retouching, whereas the edge in between was slightly transformed or left unaltered (Fig. 9, ns. 7-8). Differently from Type A, none of the segments obtained in this last way show signs of impact damage.

Independently from the chosen procedure, the aim was to preserve as much cutting edge as possible, even at the expense of its regularity, and to make the back coincide with the thickest part of the blank. Therefore, the length of the cutting edge (which never presents any kind of intentional modification) corresponds, in most cases, to the original edge of the blank. The back thickness is highly variable (from 2 to 10 mm). The abrupt retouch was produced in many cases exclusively on the dorsal face (64 pieces), more rarely on the ventral one (15 pieces). Tools shaped using bipolar abrupt retouch alone are few (11 pieces), since this procedure was more often used only in the middle and proximal portions of the back, namely where the blank was thicker.

A possible use of backed pieces of Cavallo in composite implements is substantiated by the occurrence (on 28 items) of residues of red ochre often concentrated on or/and near the backed edges (Fig. 10, n. 4). However, although type B appears to be quite standardized, the majority of lunates display a certain degree of morphometric variability due to their size, profile and curvature of the backed side, especially during the early phase (EIII). What is not clear yet is whether these differences or some of these differences (and then which ones?) had a real practical value (with regard to their use in different devices or to their different positions in the same implement), as there are archaeological examples, like the case of the skeleton discovered with several backed microliths in a sand dune in Narrabeen (Sidney) (McDonald *et al.*, 2007; Fullagar *et al.*, 2009), where artefacts different in shape and size were probably hafted together.

The analysis of micro and macro use-wear traces of the Uluzzian lunates of Grotta del Cavallo has confirmed the functionally flexible nature of this specific tool (Fig. 10). Observations have been carried out on 40% of the sample, but the entire set of backed pieces has been examined in order to detect macro-fractures due to their possible use in hunting weapons. Sixty percent of the analysed items exhibit no use-wear traces or unclear traces. Up to now no experimental work has been directly conducted by the authors. Analytic results have been compared with data made available by current literature regarding this subject (Dockall, 1997; Pargeter, 2007; Lombard & Pargeter, 2008; Lombard & Phillipson, 2010; Yaroshevich *et al.*, 2010; Pargeter, 2013; Goldstein & Shaffer, 2016).

We are well aware of the risks connected to misinterpretations of impact scars when an archaeological study is not accompanied by a controlled experimental activity (Rots & Plisson, 2014). However, our main goal, in this preliminary phase, is to probe all the potentialities displayed by the Uluzzian lunates. Therefore we discuss herein only a general overview of fractures consistent with impact scars considered more diagnostic, postponing to a later project their final study, which will also include an experimental program. As similar fracture types are absent in the rest of the industry, we are inclined to refuse, at the time of writing, a taphonomic origin such as trampling. Specimens showing impact scars are thicker than the average, taking into consideration both the absolute value (mean 4.8 vs 3.8) and the width/thickness ratio (mean 2.3 vs 3); they also present a higher working edge angle (mean 33.6° vs 29°). Impact fractures are mostly of the burin-like type (Fig. 10, n. 1), often associated with spin-offs. To a lesser extent step terminating bending fractures (Fig. 10, ns. 2-3), also in this case associated with spin-off fractures have been detected.

Occasionally segments with impact burination or spin-off fractures exhibit semi-circular notches (Fig. 10, n. 4) on their cutting edges, consistent with those occurring on archaeological examples from Sibudu Cave and other Howiesons Poort South-African sites as well as with impact fractures experimentally reproduced (Lombard & Pargeter, 2008, pp. 25-28 and Fig. 6).

There are also specimens displaying bipolar scars, frequently associated with impact burination. These might be the result of an impact, as is the case of type a2m in Goldstein and Shaffer (Goldstein & Shaffer, 2016, Figs. 6 and 11). Microscopic linear impact traces were not observed on the analysed sample.

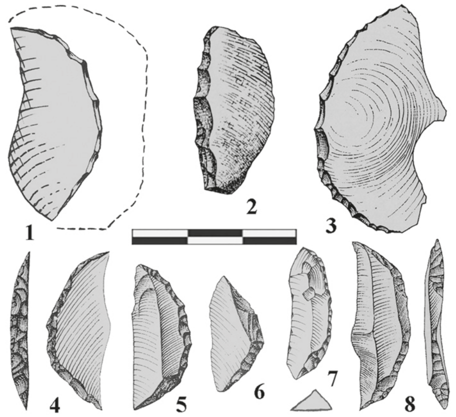


***Fig. 9 - Backed pieces. Schematic reconstruction of the most common method (type A) used in lunate manufacturing: the back was obtained by reducing one of the longest edges of the blank until reaching its maximum thickness (around the middle of the blank); usually, at the end of the backing process, the butt resulted in being entirely removed and only about 2/3-1/2 of the bulb was preserved (n. 1). Backed piece interpreted as an*** **in fieri** ***lunate from layer EIII (n. 2); lunate on thermal flake from layer EIII (n. 3); lunates (type A) from layer EII-I (ns. 4-6); lunates (type B) from layers EIII (n. 7) and DII (n. 8). Modified after Palma di Cesnola, 1963 (n. 8), 1965b (ns. 2-3), 1966b (ns. 4-6). Drawings by A. Moroni (ns. 1, 7).***

A different use as possible insets mounted in cutting implements is suggested by the use-wear traces occurring on the edge opposite the back of some pieces (Fig. 10, n. 5). Traces mostly consist of scars and edge rounding. Polishes are scarcely developed. These artefacts were used, above all, for cutting and scraping soft and semi-hard materials, at times detectable as vegetal material or animal tissue.

*The human and non-human remains*

Cavallo E. Upper right second deciduous molar (Rdm²), which lacks the mesiobuccal portion of the crown (thus affecting the integrity of the paracone) and most of both mesial and distal roots (Figs. 11, A and 5, A).

The tooth shows several fractures, which are clearly visible on the EDJ (Fig. 12, A). It is slightly

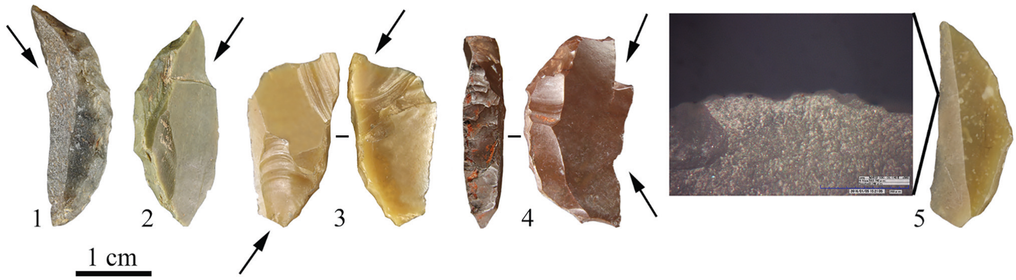


***Fig. 10 - Selection of backed pieces with impact scars and use-wear traces from Grotta del Cavallo. Burin-like fracture (n. 1); flute-like fracture with step termination (n. 2); flute-like fracture and step terminating fracture (n. 3); burin like fracture and impact notch (n. 4); polishes localized on the un-retouched edge interpreted as due to scraping vegetal material (n. 5). (Photos by Stefano Ricci). The colour version of this figure is available at the JASs website.***

worn (Molnar's stage 2). Despite the fractures and missing portions, four principal cusps, a Cusp 5 (ASUDAS grade 4), two mesial accessory tubercles (MAT), accessory crests, and a small depression near the protocone identifiable as Carabelli's trait (Grade 4), are still visible both on the external surface and on the EDJ (Fig. 12, A). The hypocone is relatively small, giving the crown a sub-square shape, as typically observed in modern human dm²s (see also crown outline analysis below) (Benazzi *et al.*, 2011; Bailey *et al.*, 2014). An interproximal facet is visible on the medial side (length=1.5 mm; height=1.2 mm). The lingual root is preserved, but still developing (equal to stage Rc of Moorrees *et al.*, 1963), which suggests an age at death between 2 and 3 years old, which is in agreement with the wear stage. The tooth crown has a MD diameter of 8.4 mm (minimum estimation due to interproximal wear), while the BL diameter ranges between 8.6 mm (crown outline reconstructed by Neandertal) and 8.8 mm (crown outline reconstructed by UP modern human). At the cervix the MD diameter is 6.6 mm. As shown in Tab. 5, the crown diameters of Cavallo E are small and fall (in particular for the BL crown diameter) in the RHS range of variability.

The two reconstructed crown outlines (Cav-E UPHS and Cav-E N) were projected into the shape-space PCA previously computed by Bailey and colleagues (2014) for Neandertal and *Homo sapiens* dm²s (Fig. 13). The two reconstructions plot nearby, illustrating that the reference used for reconstructing the missing mesiobuccal portion (either Upper Palaeolithic *Homo sapiens* or Neandertals) does not affect the final outcome. Most importantly, both outlines plot within the range of variability of RHS and UPHS, confirming that Cavallo E belongs to modern humans.

<u>Cavallo F.</u> Lower left first deciduous molar (Ldm$_1$) (Fig. 11, B) with a complete heavily worn crown (wear stage 5). Two large fractures, the first mesiodistally directed and the second departing from the previous one and directed bucco-distally, separate the crown in three main fragments, which are clearly visible on the EDJ (Fig. 12, B). The root is almost totally reabsorbed, thus suggesting an age of 11-12 years old. Due to the advanced stage of wear the cusps are not identifiable on the external surface, but on the EDJ the remnant of four cusps can be recognized (Fig. 12, B). From the occlusal view, the crown outline has an asymmetric shape in the mesio-buccal aspect due to the well-expressed tubercle of Zuckerkandl, a cervical tubercle at the mesiobuccal crown margin. Such asymmetry is usually observed in modern human dm$_1$s, which is generally different from the oval Neandertal dm$_1$s (Arnaud *et al.*, 2017). Both interproximal wear facets are visible, even though the mesial one is partially covered by deposit of calculus, ultimately suggesting the tooth was lost after the lower left deciduous canine. The tooth crown has a MD diameter of 8 mm (minimum estimation due to interproximal wear) and a BL diameter of 6.5 mm, while at the cervix the MD

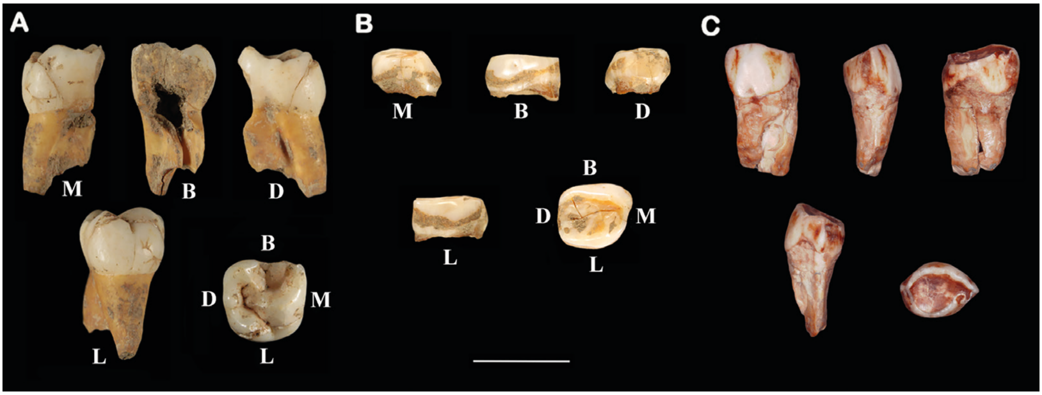


***Fig. 11 - Human remains from Grotta del Cavallo. The specimen Cavallo E (A); the specimen Cavallo F (B); the specimen tooth X (C). B=buccal, D=distal, L=lingual, M=mesial. Scale bar, 1cm. The colour version of this figure is available at the JASs website.***

diameter is 7.6 mm and the BL diameter is 5.5 mm. Overall, as shown in Table 5, the crown diameters are small and fall in the UPHS and RHS range of variability.

<u>Tooth X.</u> Heavily worn tooth retrieved from layer EIII, square G11 (Gambassini's excavations), of Grotta del Cavallo (Fig. 12, C). The irregular morphology of the tooth, with a crown mesiodistally elongated, a moderately convex buccal side and a single root buccolingually flattened, does not find any parallel in the human dentition, both deciduous and permanent. The advanced wear stage has removed all the morphological features on the external surface, even preventing the identification of the tooth class. A digital reconstruction of the EDJ and of the internal dental architecture (Fig. 14) shows that the pulp chamber is completely filled with secondary dentin, a process that in humans may be observed in permanent dentition. A cement layer covers parts of the crown (Fig. 14) as happens in hypsodont teeth, like in some ungulate species, and not in human ones.

The size is too small for a human permanent tooth, as the crown has a MD diameter of 8.1 mm and a BL diameter of 5.1 mm. Among the deciduous dentition, the BL diameter is comparable with the anterior deciduous teeth (Benazzi *et al.*, 2014; Benazzi *et al.*, 2015), while for the MD diameters the tooth is similar to the lower first deciduous molars (Arnaud *et al.*, 2017). However, lower first deciduous molars have two roots, which are not flatted buccolingually. To summarize, even though the taxonomic attribution of the specimen tooth X remains uncertain, based on the above mentioned considerations we exclude its attribution to humans.

## Discussion

In current studies the Uluzzian has been generally described as a lithic assemblage displaying a very limited presence of blades and chiefly oriented towards flake production. A small amount of Upper Palaeolithic-like tools (among which backed pieces) and a combination of Middle and Upper Palaeolithic items (even more than in the Châtelperronian) both in the toolkit and in the technical systems (discoid/centripetal cores) are also considered typical traits of this cultural entity (Hublin, 2015; Peresani *et al.*, 2016). Given the lack of exhaustive modern studies on the Uluzzian of Grotta del Cavallo, these assertions have been, in fact, mainly borrowed from Palma di Cesnola's publications.

Limiting our considerations to layer EIII, which represents, on the basis of the current

***Tab. 5 - Buccolingual (BL) and mesiodistal (MD) crown diameters (in mm) of Cavallo E (Rdm$^2$) and Cavallo F (Ldm$_1$) compared to a reference sample composed of Neandertals (N), Upper Paleolithic* H. sapiens *(UPHS), recent* H. sapiens *(RHS). m=mean; s=standard deviation. Number of individuals in brackets. [a][79]; [b][75]; [c][77-80]; [d][76]. CAV-E N: the specimen Cavallo E reconstructed by the Neandertal mean; CAV-E-UPHS: the specimen Cavallo E reconstructed by the Upper Paleolithic* H. sapiens *mean.***

| | RDM$^2$ | | LDM$_1$ | |
|---|---|---|---|---|
| | BL (MM) | MD (MM) | BL (MM) | MD (MM) |
| | M ± S (N) | M ± S (N) | M ± S (N) | M ± S (N) |
| Grotta del Cavallo | 8.6 (CAV -E N) -8.8(CAV-E UPHS) | 8.4 | 6.5 | 8 |
| N | 10.3 ± 0.4 (13)[a] | 9.22 ± 0.56 (13)[a] | 7.56 ± 0.47 (24)[c] | 8.83 ± 0.44 (24)[c] |
| UPHS | 10.5 ± 0.5 (15)[a] | 9.50 ± 0.62 (15)[a] | 7.23 ± 0.76 (11)[d] | 8.13 ± 0.75 (11)[d] |
| RHS European-male (UK)[b] | 9.38 ± 0.84 (50) | 9.42 ± 0.28 (50) | 7.03 ± 0.49 (50) | 8.16 ±0.49 (50) |
| RHS European-female(UK)[b] | 9.18 ± 0.49 (50) | 9.14 ± 0.14 (50) | 6.99 ± 0.63 (50) | 8.13 ± 1.27 (50) |

chronological data, the more archaic expression of the Uluzzian in peninsular Italy, the preliminary re-analysis of the lithic assemblage by means of an integrated technological approach paved the way for alternative interpretations of the available data. First of all, previous syntheses (including Moroni *et al.*, 2013) on the Uluzzian of Grotta del Cavallo never took into account (except for Riel-Salvatore, 2009, 2010) the role of bipolar reduction as the basic technical system in terms of blank production. As a consequence, there was an underestimation in the bulk of small-micro-hypermicro-lithic generally unmodified artefacts, often consisting of elongated items, and their presumably specific functions in the Uluzzian toolkit. An argument along similar lines can be made for the numerous tools on lastrina. This class of artefacts is the main cause for both the inferred similarities with the underlying Mousterian and the assumed flake-based character of the lithic set. Tools on lastrina are, most of the times flake-like in size and, in the past, they were classified as such. It should also be noted that, from the formerly applied typological perspective "flake-based" or "blade-based" definitions were above all concerned with the blanks used in the retouched component; these were considered the only desired products, while unretouched specimens were essentially relegated within discarded materials. In fact when we take into consideration the whole set of retouched and un-retouched debitage products of the examined sample from layer EIII (thus excluding tools on lastrina), the frequency of flakes and blades come out to be more or less equally proportioned (blades = 53.8%). The previous arguments provide a general picture of the earliest Uluzzians unlike the one commonly assumed. In particular one needs to question whether defining a lithic assemblage as "flake-based" or "blade-based" still makes sense, especially when we deal with post-Middle Palaeolithic cultural entities. In the Upper Palaeolithic lithic world not only flakes and blades alone had different techno-functional roles. The larger/smaller artefact dichotomy could be even more meaningful in that these two categories were most probably devoted to different activities (e.g. domestic/hunting activities) and were often produced by independent reduction processes. Differences in the frequency of each category are not necessarily due to cultural constraints; they can be connected to the functional role of the site under study and/or to the different spatial distribution of artefacts occurring inside the site itself, as well as to taphonomic reasons. The EIII lithic assemblage consists of both larger-size-tools, like end-scrapers and side-scrapers, most of which on lastrina, and smaller-size-tools (that include backed pieces) presumably used in composite devices. This understanding begs several questions concerning the range of possible implements involved, which can be only addressed using further methodological approaches (use-wear techno-functional residue) in addition to the techno-typological study.

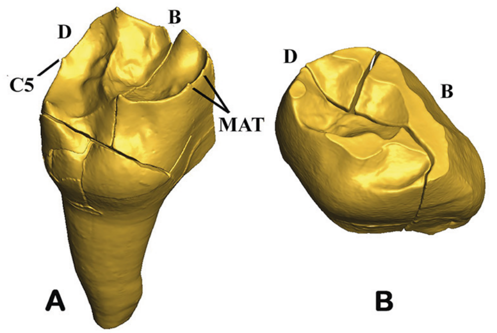


***Fig. 12 - The enamel-dentine junction (EDJ) of Cavallo E and Cavallo F. Digital reconstruction of the EDJ of the specimen Cavallo E (A): C5=Cusp 5, MAT=mesial accessory tubercles; digital reconstruction of the EDJ of the specimen Cavallo F (B): B=buccal, D=distal. The colour version of this figure is available at the JASs website.***

The functional status of bipolar artefacts is still an open question broadly debated among scholars (for a wider discussion on this topic see Shott, 1999; Le Brun-Ricalens, 2006; Shott & Tostevin, 2015). The problem revolves around whether pieces resulting from bipolar knapping were almost entirely more or less exhausted cores or whether they represented, instead, distinct functional categories. There are authors who agree with the former hypothesis (White, 1968; Barham, 1987; Knight, 1991; Goodyear, 1993; Shott, 1999; Mitchell, 2003), even if some admit the possibility that bipolar spent cores could be recycled as tools for a variety of tasks (Gambassini, 1970; Devriendt, 2011; Hiscock, 2015). According to others, core reduced pieces and splintered pieces are distinct categories aimed at distinct purposes and, despite them partially morphologically overlapping, they can be easily separated on the grounds of specific features (Hayden, 1980; Villa *et al.*, 2012).

Use-wear and residue analyses have emphasized the occurrence of traces on the edges (often the non-splintered ones) of splintered pieces due to the working of medium or hard materials (like wood and bone) (Devriendt, 2011; Klempererová, 2012; Langejans, 2012), demonstrating that these objects, whatever their origin, could have been used occasionally as tools.

The possible use of splintered items as intermediate pieces (wedges) for splitting or grooving wood, antler and bone has been put forward by many scholars (Chauchat *et al.*, 1985; Le Brun-Ricalens, 1989; Leblanc, 1992; Le Brun-Ricalens, 2006; Dini & Conforti, 2011; Villa *et al.*, 2012) and this hypothesis has also been the object of experimental tests (Dewez, 1985; Lucas & Hays, 2004; De la Peña & Vega, 2013). However experimental results on the efficiency of these objects as wedges are controversial (for an overview of this problem see Shott, 1999; Le Brun-Ricalens, 2006; Hiscock, 2015 and references therein). In lithic studies function and functioning constitute specific issues which may not have much to do with production processes and morphology, in that similar artefacts may have different uses (and vice versa) depending on their socio-cultural, chronological and geographical context. For these reasons each instance requires to be weighed individually (Lucas & Hays, 2004, p. 119). This is also the case of the splintered/bipolar phenomenon whose spatiotemporal diffusion (Vergès & Ollé, 2011 and references therein) does not allow for a generalization.

Despite its "R strategy" connotation, bipolar reduction proved to be an eclectic *modus operandi* which enables the knapper to obtain, with little effort small, elongated products particularly suitable to be hafted as they are scarcely curved and lacking in butts and bulbs. Additionally it has been efficiently demonstrated (Devriendt,

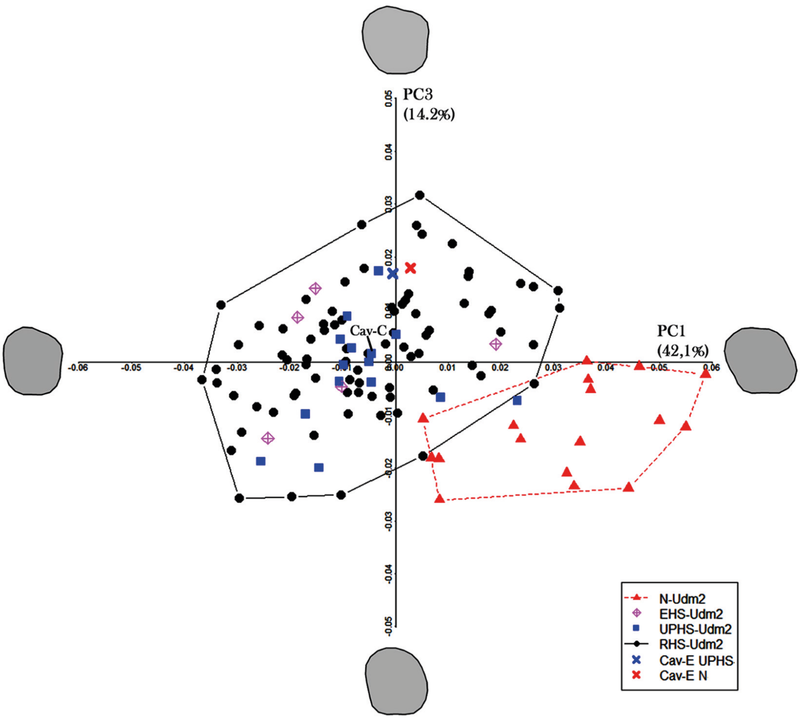


***Fig. 13 - Shape–space PCA plot of the two Rdm$^2$ crown outlines of Cavallo E restored by the Neandertal mean (Cav-E N) and the UPHS mean (Cav-E UPHS). The deformed mean crown outline in the direction of the PCA is drawn at the extremity of each axis. N-Udm$^2$=Neandertal; EHS-Udm$^2$=Early*** **Homo sapiens*****; UPHS-Udm$^2$=Upper Palaeolithic*** **Homo sapiens*****; RHS-Udm$^2$=Recent*** **Homo sapiens*****. The colour version of this figure is available at the JASs website.***

2011; Klempererová, 2012; Langejans, 2012) that exhausted cores (*alias* splintered pieces) were used for several activities. Our challenge is now to understand if we are dealing with something like an opportunistic recycling of few/ several pieces or with a planned *chaîne opératoire* resulting in the final achievement of specific tool morphologies. Whichever the answer is, further experimental and use-wear studies are needed to make this point clearer.

In general bipolar knapping is considered an "expedient" low-cost technique (Shott, 1989; Hiscock, 1996; Diez-Martin *et al.*, 2011; Mackay & Marwick, 2011; Morgan *et al.*, 2015) in that it can be a means of maximizing resources as it is the only effective method of making full use of small and/or unmanageable raw materials (Barham, 1987; Knight, 1991; Hiscock, 2015); as a consequence it can also represent a response to raw material shortage (Callahan, 1987). According to archaeological, ethnographic and experimental accounts (White, 1968; Chauchat *et al.*, 1985; Shott, 1989; Crovetto *et al.*, 1994; Le Brun-Ricalens, 2006; Riel-Salvatore, 2009 and references therein), bipolar "waste" products are suitable to be used "as is" for many purposes. In particular there is evidence of the use of unmodified small flakes as inserts in wood, bone and antler hafts (Monchot *et al.*, 2013; Knutsson *et al.*, 2015 and references therein). Very small flakes (mean length, width and thickness of 10.5 mm, 7.5 mm and 1.7 mm respectively) assembled in split wood handles are reported by Flenniken

(1981) from the Hoko River prehistoric site in Washington state. In Australia bipolar small flakes are mounted on composite knives and spear points (the so-called "death spears") with the aid of adhesives (Chauchat *et al.*, 1985) and in New Guinea similar artefacts occur in hafted implements (White, 1968). The possible use of unaltered bipolar inserts in cutting tools has also been confirmed by experimental and use-wear trace studies (Knutsson *et al.*, 2015). In other words, emerging evidence suggests the potential occurrence in the Uluzzian assemblages of a micro-lithic and unmodified tool component, hitherto not taken into consideration, which can be disclosed only by means of functional analyses.

The systematic exploitation of lastrine in a very singular way is symptomatic of a very low technical investment as it does not entail any action connected to debitage operations. We assume that this approach could be conceptually classified, like bipolar reduction, as an expedient procedure (in fact it could be defined as the expedient system *par exellence)* in the sense that it may represent an effective response to raw material constraints and to time and energy availability. Unlike bipolar technique, lastrine were exploited for the production of the larger size component of the industry, which was presumably devoted to specific tasks. The use of a number of thermoclastic elements, often from lastrina in the manufacturing of lunates (and of other tools) can probably be included in the same behavioural concept, either these specimens were intentionally obtained or only opportunistically used.

The pattern provided by backed pieces is, in some respects, different as their manufacture involves both the production and the transformation phases. Several projects focusing on use-wear traces, micro-residue and macro-fracture formation dynamics – many of which were conducted on African Howiesons Poort backed tools – have emphasized the concrete possibility that these objects were hafted, by means of the back as single or multiple inserts in composite implements (knives and weapons) (Dockall, 1997; Lombard, 2008; Lombard & Phillipson, 2010; Yaroshevich *et al.*, 2010; Pargeter, 2011, 2013;

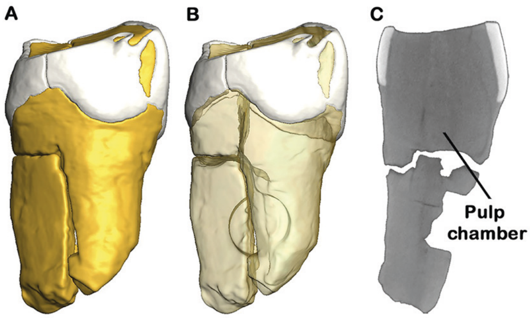


***Fig. 14 - The specimen tooth X. 3D digital model of the specimen tooth X (A): a cement layer covers parts of the crown; a digital transparent reconstruction of the specimen tooth X (B): in the internal dental architecture the pulp chamber is not visible; the hole in the root is where a sample was taken for DNA analysis; sagittal section of tooth X micro-CT (C): the pulp chamber is completely filled with secondary dentin. The colour version of this figure is available at the JASs website.***

Goldstein & Shaffer, 2016). Such an assumption is corroborated by ethnographic and archaeological instances (Clark, 1959; McDonald *et al.*, 2007; Lombard, 2008; Fullagar *et al.*, 2009; Lahr *et al.*, 2016 and references therein). In this perspective the lunate turns out to be a versatile tool which adapts to different multitask devices. The fact that each specimen is easily replaceable without any consequence for the rest of the implement is an advantage of this technology. Several pieces from Cavallo retain residues of red ochre often concentrated on or/and near the backed edges. Different applications of ochre, its antibacterial function and its effectiveness as an additive of wax and resin in adhesives, used to glue stone artefacts to hafts, have been discussed in numerous studies. In particular direct evidence of the use of ochre in adhesive compounds found on the back of geometric "microliths" has been reported for the South African MSA (Wadley, 2005; Lombard, 2006, 2007; Pargeter, 2007; Nishiaki *et al.*, 2008). At Grotta del Cavallo the occurrence of ochre spots particularly on the back of the segments is in accordance with the evidence resulting from use-wear analysis.

Our review of backed pieces from Grotta del Cavallo has contributed to highlighting the complexity inherent in the study of this particular tool-type. Although preliminary results from use-wear analysis foreshadow the occurrence of at least two broad categories of artefacts (the former aimed at arming hunting weapons and the second assembled in cutting or scraping implements), the general lack of standardization, which is also stressed by the use of different blanks (bladelets, flakes, and lastrine), constitutes an obstacle for the identification of more definite functional roles. In addition, another important aspect emerged: the heterogeneous composition of backed pieces which include artefacts at different stages of their techno-functional life (unfinished, not used, used, repaired and discarded) whose role in the whole sequence is not always clearly detectable. For now a constructive first step has been to provide evidence that the Uluzzian lunates could function successfully in composite tools, including weaponry.

Evidently the work to do is still long as it involves an array of analytical approaches combining techno-functional studies and comparative use-wear and residue analyses with experimental activity in order to reconstruct the techno-functional life of each artefact and to identify potentially recurring features pertaining to definite functional categories. A further question which must be deeply investigated is the relation existing between backed pieces and unmodified microlithic items and their respective functional roles as possible elements in composite devices.

For an understanding of the Uluzzian it is of paramount importance that we define the nature of its relationship with the underlying Mousterian. The latest Middle Palaeolithic of Grotta del Cavallo is represented by layer F which has been attributed to MIS3 (layer FII: 47.900-42.100 cal BP 95%) (Fabbri *et al.*, 2016). F contains three archaeological layers (FIII, FII, FI from bottom to top), among which FIII was further subdivided into sub-layers (FIIIe, FIIId, FIIIc, FIIIb, FIIIa). All the layers/sub-layers were clustered into three main units on techno-typological grounds (FIIIe-FIIId, FIIIc-FIIIb, FIIIa-FII-FI). If compared with the previous ones, the more recent unit (FIIIa-FII-FI) is characterized by the adoption of the discoid method (instead of the Levallois one), which dominates the production during the whole phase, and by the appearance of low percentages of bipolar items (a maximum of 11.6% in layer FI) (Carmignani, 2011; Romagnoli *et al.*, 2016). The use of lastrine reaches 2.8 % and 5.6 % in FII-I and FIIIa-d, respectively (Sarti, 1998-2000). In stratigraphic terms there is a sharp break between the earliest Uluzzian occupation (EIII) and the most recent Mousterians (Layers FII-I). This is documented by the presence of a thin volcanic sterile layer (Fa) (Palma di Cesnola, 1964) accompanied by a gap in sedimentation marked by dripping episodes (Gambassini's observations).

It should be of interest to note that a similar hiatus is also recorded in the other Uluzzian sites of peninsular Italy (Moroni *et al.*, 2013). To estimate this phenomenon scale studies and possibly age models on sediment aggradation will be carried out in the future.

As mentioned above, among the major features which are still commonly considered typical of the Uluzzian there is the occurrence of "clear" elements of Mousterian tradition. Yet, even Palma di Cesnola, despite his firm belief in a local evolution of the Uluzzian, had, indeed, to admit the difficulty in finding a direct ancestor of this techno-complex within the Middle Palaeolithic evidence of Southern Italy (Palma di Cesnola, 1993, p. 114). Also in the years immediately following the discovery of the Uluzzian, the "filiation hypothesis" was only generically approached by Cesnola as it rested ultimately on the so called "archaic" features of the EIII lithic assemblage, especially due to convex and transverse scrapers mainly on lastrina, that he considered reminiscent of the types occurring in layer F.

Based on an updated reading, compelling evidence suggests that a radical behavioral change took place at Grotta del Cavallo between the late Mousterian and the earliest Uluzzian. This change is reflected by several factors operating in concert. Layers FII-I and EIII share similar ungulate associations, which are dominated by aurochs, red deer and horse, possibly attesting to the same cool arid climatic phase characterized by the widespread occurrence of grassland and forest steppe (Boscato & Crezzini, 2012; Moroni *et al.*, 2013). Nevertheless, these two assemblages exhibit clearly distinct modalities in the exploitation of skeletal parts. In FII-I postcranial bone associations are typical of the Middle Palaeolithic assemblages found in the Apulia region: abundance of diaphisys fragments of long bones and little to no presence of epiphyses and carpal and tarsal bones, as well as of phalanges and sesamoids. The faunal sample from layer EIII, spit 5 of Grotta del Cavallo (Gambassini's excavations) revealed, on the contrary, an exploitation pattern wholly in line with the Upper Palaeolithic record, with numerous fragmented phalanges and epiphyses and much higher percentages of carpal and tarsal bones (Boscato & Crezzini, 2012).

Contrary to what is generally thought neither the production processes nor the toolkit of layer EIII display any evident link with the Mousterian. Moreover, the frequency and variety of Upper Paleolithic types is important as proved by the number of end-scrapers (22.3%) (Palma di Cesnola, 1965b, 1966b) and backed pieces. Such values are incompatible with any Middle Palaeolithic Italian industry (Palma di Cesnola, 1996, 2001a). The use of lastrine, which represents a prominent part of the earliest Uluzzian technical attitude, was marginal in FII-I. The same can be noted for the blade component, which is completely absent in FIIIa, FII and FI (conversely it is attested in FIIIe and FIIId) (Carmignani, 2011). Finally, and perhaps most importantly, the sharp break in blank production, which is based in layer EIII, almost exclusively on expedient systems (bipolar, on lastrina and on thermal flake), despite the fact that there were no significant changes in the use of raw material with respect to the latest Mousterians. It has been correctly observed (Donnart *et al.*, 2009) that bipolar flaking is indeed a technique not a method as the term "method refers to any carefully thought out sequence of interrelated actions, each of which is carried out according to one or more techniques" (Inizan *et al.*, 1999, p. 30). From a conceptual standpoint this fact places bipolar reduction, as well as the other expedient strategies (namely the use of lastrine and thermal flakes) in an antithetical position to highly predetermined methods such as the Levallois and the discoid ones. As has already been argued (Ranaldo *et al.*, 2017), this entails a very low technical investment in terms of time and energy dedicated to blank production by the Uluzzians (unlike the Mousterian).

In sum, the use of low-cost production strategies could be defined as the "leitmotiv" of the Uluzzian for this trend is also characteristic, with all due changes, of the evolved and the final phases of this techno-complex both at Grotta del Cavallo and in the other Uluzzian sites of Central-Southern Italy. Our challenge is now detecting what this implies in behavioral terms. Bipolar stone-working is considered by many to be an expedient technique for conserving time and/or energy, (Jeske, 1992; Mitchell, 2000; Diez-Martin *et al.*, 2011), which comes into play under particular subsistence (energy gathering) circumstances and specific constraints according to a delicate and complex balancing between costs and benefits (Jeske, 1992; Mackay & Marwick, 2011; Eren *et al.*, 2013). Both the systematic use of lastrine and the occasional exploitation of thermal flakes are part of the same energetic-efficiency scheme. In behavioral terms this choice acquires, therefore, a broader significance involving the socio-economic context, given that it allowed prehistoric people to preserve their own time and energy budget not only during knapping operations, but also in the procurement (pursuit and transport) of more suitable lithotypes – thus diminishing risks due to long periods away from the campsite – as well as in the apprenticeship time dedicated to young artisans. A further purely speculative hypothesis put forward by some (Stapert, 2007; Sternke & Sørensen, 2009) is that the use of bipolar technique could have been a matter of different skills and age connected, for instance, to children training – or even a matter of gender (for a wider discussion see Devriendt, 2011 and references therein). A similar pattern would be most likely expected in contexts where other production systems prevail and bipolar reduction is attested to a lesser degree. Conversely, when the use of expedient technologies embodies the very essence of the lithic production being so rooted, as is the case in the Uluzzian, in the socio-economic tissue of a human group, more holistic explanations must be taken into account. It has been demonstrated, for instance, that bipolar knapping is not always exclusively connected to the use of small and/or intractable raw materials and, vice versa, small and/or poor quality raw materials appear to be not always associated with this technique (Guyodo & Marchand, 2005). The adoption of such a method can, thus, foreshadow also reasons which are beyond simple material costs or time/environmental constraints. In the case of layer EIII the abundance of slabs/lastrine with natural striking platforms and ridges should have encouraged the use of freehand direct percussion. The overwhelming occurrence of bipolar technique leads us to suppose that also some persisting tradition might have had its weight in this technological choice. In the last analysis an interplay among different factors operating in concert (availability and quality of raw materials, territory expertise, socio-economic requirements and cultural tradition) is the most probable explanation for the Uluzzian technological behavior of layer EIII.

Bipolar flaking has been reported in several MSA complexes of eastern-southern Africa and is considered a typical trait of the LSA of these regions (for a wider dissertation see De la Peña, 2015 and references therein). At Mumba Rockshelter in Tanzania Eren *et al.* (2013) tried to explain the considerable use of bipolar reduction in Bed V (which dates between 56.9±4.8 and 49.1±4.3 ka cal BP) by analyzing several factors which could have stimulated an increased territoriality, namely "the resource defence strategy in which foragers occupy certain areas more or less exclusively by means of repulsion through overt defence or through social interactions" (Eren *et al.*, 2013, p. 253). An increase in territoriality (i.e. reduced mobility) can occur as an adaptive response to an array of factors like climatic changes (Hiscock *et al.*, 2011), population increase, competition among groups in terms of resource procurement and limited territory-expertise. In Eren *et al.*'s opinion (2013), this phenomenon might have triggered a spectrum of possible effects among which are increase in time costs and subsistence risks, as well as an improvement of the toolkit by developing more portable easily repairable implements and weapons. As the main characteristics of a weapon must be efficiency and reliability, these required a certain amount of energy and time for composite tool manufacture (tool design, hafts, clues, ballistics etc.). The only way, therefore, to save time was the shortening of the production phase by introducing least-cost technological systems.

A similar model might also fit the Uluzzian of Southern Italy as this techno-complex developed during a period of climatic variability (Boscato & Crezzini, 2012; Tagliacozzo *et al.*, 2013; Douka *et al.*, 2014) and demographic changes in a geographic area populated by behaviorally different human groups, possibly coexisting in the same territories for a reasonable time span (about 3000 years) (Higham *et al.*, 2014). Although it is highly speculative it could be mentioned that in the area of Grotta del Cavallo, several sites (Grotta di Uluzzo, Grotta-Riparo di Uluzzo C, Grotta di Serra Cicora, Grotta Mario Bernardini) (Palma di Cesnola, 2001b) are concentrated in a very restricted territory which could have represented a sort of enclave.

Some final remarks are concerned with a paper recently issued on the site of Grotta di Fumane in Veneto (Peresani *et al.*, 2016). This cave deposit yielded an archaeological sequence spanning from the late Middle Palaeolithic to the early Upper Palaeolithic. Layers A4 - A3, which are interstratified between a Levallois Mousterian (layers A6-A5) and the Proto-Aurignacian (layers A2-A1), are thought to be emblematic of the Early Uluzzian in Northern Italy and of its connection with the final Mousterian. Layer A5 occupation took place prior to 43.6-43.0 ka cal BP while the arrival of the first Aurignacians (layer A2) dates after 41.2 - 40.4 ka cal BP (Higham *et al.*, 2009; Peresani *et al.*, 2016). The assemblages from layers A4-A3 both contain a clearly Mousterian component (less abundant in A3) and are characterized by reduction strategies primarily oriented towards the production of flakes, denoting a significant divergence from the underlying Levallois blade complex (layers A6-A5). In layer A4 there is still a predominance of the Levallois method, although the unipolar modality (typical of layers A6-A5) was replaced by the centripetal one. Bipolar technique makes its appearance in this layer (3.8% considering both cores and products). Blade/bladelets and blade cores have a very subordinate role (3.8% of the total assemblage).

In layer A3 recurrent centripetal flaking characterized by a low degree of predetermination is the most exploited technical procedure. Bipolar reduction is here slightly more important (7.4%) than in layer A4 as is the blade/bladelet component (6.0%). Among tools a single end-scraper on cortical flake marginally retouched is also reported (Peresani *et al.*, 2016, Fig. 9, n. 6). Based on what has emerged from the revision of layer EIII, it is evident that Fumane exhibits a really different pattern. Leaving aside the evidence displayed by the A4-A3 strongly Mousterian imprint (which is absent in layer EIII), it should be emphasized that the roles of bipolar reduction and of laminar volumetric exploitation are always substantially marginal. Actually the incidence of bipolar and laminar items at Fumane is patently closer to the variability reported for some latest Mousterian contexts of Southern Italy. For instance, bipolar reduction makes its emergence in layer F of Grotta del Cavallo with frequencies reaching as high as 11.6% in FI; a blade-bladelet volumetric system is significantly present in sub-layer FIIIe of the same cave (Carmignani, 2010) and is attested in other Middle Palaeolithic sites of Peninsular Italy (Marciani *et al.*, 2016; Peresani *et al.*, 2016; Spagnolo *et al.*, 2016). Thus, the following assertion that: "The splintered pieces are the key element that characterizes the more pronounced shift in the transition from the final Mousterian unit A5-A6 to the Uluzzian layer A4, although these are very scarce compared to all other tool types and are associated with a tool kit still traditionally Mousterian" (Peresani *et al.*, 2016, p. 51) is correct. However, it does not demonstrate that layer A4 is not Mousterian and, least of all, that it may be Uluzzian. Likewise, the occurrence of often roughly-made end-scrapers and, more in general, of sporadic leptolithic-like tools is not unusual in the Italian final Middle Palaeolithic (Palma di Cesnola, 2001a). We report, for instance, the few end-scrapers attested in layer FIII at Grotta del Cavallo (Palma di Cesnola, 1964, p. 34 and Fig. 5, ns. 8-10; Palma di Cesnola, 1965a, p. 298; Sarti *et al.*, 1998-2000, p. 69) and the specimens from SU1 of Riparo L'Oscurusciuto (Boscato *et al.*, 2011, p. 94).

Judging from figures and descriptions (Peresani *et al.*, 2016, Fig. 5, ns. 1-5 and Fig. 9, ns. 1-5 and pp. 44-45 and 48) backed pieces recovered in layers A4-A3 seem to display atypical characteristics related both to their general morphology (proportions, profile irregularity, back delineation and morphology) and to the fashion in which they were manufactured (blank type, backing procedure), relative to their Uluzzian counterparts. As a matter of fact, the presence of backed pieces has sporadically been reported in late Mousterian contexts. Both the straight and curved variants are attested in a few surface sites in Tuscany, where Palma di Cesnola, pursuing his idea of continuity with the latest Mousterian, had identified a possible cradle for the Uluzzian (Palma di Cesnola, 1993, p. 114). The occurrence of backed artefacts in late Middle Palaeolithic assemblages is not an Italian feature alone; well-known is the case of the Mousterian of Acheulean tradition type B considered by Peyrony (1948) and by Bordes (1954-1955) the ancestor of the Châtelperronian because of its typical backed-knives; this theory challenged by Bordes & Teyssandier (2011), has been recently re-proposed by Ruebens *et al.* (2015) and Roussel *et al.* (2016). All things considered we could argue that Fumane does not look like an Uluzzian complex or, at least, it does not look like a "Classic" Uluzzian complex in that it is sufficiently divergent from the picture reconstructed at Grotta del Cavallo, which remains, at any rate, the eponymous site. Whether it is worth preserving this "purist" vision or, otherwise, enlarging the Uluzzian concept to a broader spectrum of distinctive traits, will be an integral part of scientific debate in projects devoted to the study of the Uluzzian in the near future.

## Conclusions

Based on a careful revision of Palma di Cesnola's unpublished field notes and publications as well as on Gambassini's observations (see supplementary materials) there are no valid reasons for casting doubts on the integrity of the deposit of Grotta del Cavallo (*contra* Zilhão *et al.*, 2015) in which the two modern human deciduous teeth (Cavallo B and Cavallo C) were retrieved. Post-depositional disturbances, especially the so-called "Romanellian pit", were identified and separately investigated by Cesnola at the beginning of his excavations at Cavallo in 1963. Cavallo B and Cavallo C were recovered in 1964 in layer EIII from an undisturbed deposit during the excavation of the NW part of the test trench opened by Cesnola. This is confirmed by one of us (P. G.) who took part in the excavation at Cavallo (Palma di Cesnola, 1964, p. 23). In addition there is clear evidence that Cavallo B was found at the base of the earliest Uluzzian hearth.

Concomitantly this contribution has been devoted to a preliminary reassessment of the Uluzzian of Grotta del Cavallo, examined from a behavioral perspective, mainly resting, in this phase of the research, on the initial results provided by the technological study of the lithic assemblage from the earliest Uluzzian occupation (layer EIII), and by the analyses of backed pieces from the whole sequence. Owing to various elements, the Uluzzian of layer EIII can be depicted as a true "Upper Palaeolithic" assemblage devoid of any features displaying a possible connection with the preceding (and coeval) late Mousterian of Southern Italy. The lithic industry from layer EIII is characterized by an important mostly un-retouched small blade/bladelet component derived mainly from bipolar reduction. Among formal tools, end-scrapers and backed elements (including three marginally backed small blades), which are mainly composed of lunates, have a key role. However, the most distinctive feature is the vast use of low-cost production strategies, especially exemplified by bipolar technique, but also consisting of the direct use of "lastrine" and thermal flakes, which allowed the knappers to significantly reduce time dedicated to debitage activities. This concept appears to be strongly rooted in the Uluzzian technology because it persists during the evolved and the final Uluzzian at Grotta del Cavallo, and it is a recurring trait of the other Uluzzian sites on the Italian Peninsula, as highlighted by other authors (Palma di Cesnola, 1965b, 1966b; Gambassini, 1997). The use of bipolar technique as the main production system entails that an important part of the Uluzzian toolkit might be composed of micro-artefacts presumably used "as is" in composite devices. This behavior has no parallel in the European record of the period at issue and embodies a well-defined *caesura* with the Mousterian world of Southern Italy (Palma di Cesnola, 1996, 2001a) where the production phase appears to be, in terms of lithics, the most challenging technical investment.

In the light of these observations we question the attribution of the Uluzzian, or at least of the classic facies of this techno-complex identified in the eponymous site, to the group of the transitional assemblages. This label implies the idea that "these industries display some Middle Palaeolithic reminiscence…" and/or that they "resulted… from a local evolution of the late MP groups" (Hublin, 2015, p. 198).

The systematic use of expedient production strategies in the lithic assemblage of layer EIII led us to assume that the Uluzzians might have developed a reduced residential mobility as a means of resource-defence under particular environmental and demographic conditions in which different human groups could occupy the same territories. This notion may account for the exploitation of essentially local lithic raw materials and for the occurrence of several sites in a very restricted geographic area.

The backed segment is a tool of original morphology typical (along with bipolar technique) of the Uluzzian, which does not display parallels in other archaic Upper Palaeolithic complexes of Europe. In a previous paper (Moroni *et al.*, 2013) some of us (A.M., P.B. and A.R.) had argued for an African origin of the Uluzzian also basing it on the occurrence of these tools and on their specific attributes. Recently published studies (Bader *et al.*, 2015; De la Peña, 2015) have highlighted that bipolar technique (generally associated with segments) is broadly widespread in South Africa/eastern Africa MSA and MSA/LSA transitional assemblages and is considered a distinctive trait of the African LSA. A weak point of the Uluzzian "out of Africa" hypothesis is the wide geographic lacuna existing along the assumed dispersal routes between the nearest area of African evidence and the Uluzzian sites in Europe. We are well aware that this is an essential still unsolved question. Nevertheless the Uluzzian shares with the African complexes, and in particular with Mumba Rockshelter's so-called transitional assemblage from Bed V (which dates between 56.9±4.8 and 49.1±4.3 ka cal BP) undeniable behavioural similarities. These are not easy to justify under a simple convergence pattern. To date, the notion of an African cradle for the Uluzzian remains, in the opinion of some of us (A.M. P.B. and A.R.), the most parsimonious hypothesis accounting for the sudden emergence of a techno-complex endowed with such specific characteristics.

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## Author contributions

P.G., A.M. and A.R. article design and research history. P.B., F.B. and J.C. collaboration in the study of tooth X. S.S. raw materials. A.M., A.R., D.A., G.M., F.R. and V.S. lithic artefacts. S.A. use-wear analysis. S.B., G.C., S.R., S.E.B. and D.P. human remains. K.D. chronology. G.C., A.M. and S.R. figures and illustrations.

## References

Ahler S.A. & Christensen R.C. 1983. *A Pilot Study of Knife River Flint Procurement and Reduction at Site 32DU508, A Quarry and Workshop Location in Dunn County, North Dakota*. Department of Anthropology and Archaeology, University of North Dakota. Contribution No. 186.

AlQahtani S.J., Hector M.P. & Liversidge H.M. 2010. Brief communication: the London atlas of human tooth development and eruption. *Am. J. Phys. Anthropol.*, 142: 481-490.

Arnaud J., Benazzi S., Romandini M., Livraghi A., Panetta D., Salvadori P. *et al.* 2017. A Neandertal deciduous human molar with incipient carious infection from the Middle Palaeolithic De Nadale cave, Italy. *Am. J. Phys. Anthropol.*, 162: 370-376.

Arrighi S., Bazzanella M., Boschin F. & Wierer U. 2016. How to make and use a bone "Spatula". An experimental program based on the Mesolithic osseous assemblage of Galgenbühel/Dos de la Forca (Salurn/Salorno, BZ, Italy). *Quatern. Int.*, 423: 143-165.

Bader G.D., Will M. & Conard N.J. 2015. The lithic technology of Holley Shelter, Kwazulu-Natal, and its place within the MSA of Southern Africa. *S. Afr. Archaeol. Bull.*, 70 : 149-165.

Bailey S.E. & Hublin J-J. 2006. Dental remains from the Grotte du Renne at Arcy-sur-Cure (Yonne). *J. Hum. Evol.*, 50: 485-508.

Bailey S.E., Benazzi S., Souday C., Astorino C., Paul K. & Hublin J-J. 2014. Taxonomic differences in deciduous upper second molar crown outlines of *Homo sapiens*, *Homo neanderthalensis*, and *Homo erectus*. *J. Hum. Evol.*, 72: 1-9.

Barham L.S. 1987. The Bipolar Technique in Southern Africa: A Replication Experiment. *S. Afr. Archaeol. Bull.*, 42: 45-50.

Benazzi S., Bailey S.E., Peresani M., Mannino M.A., Romandini M., Richards M.P. *et al.* 2014. Middle Paleolithic and Uluzzian human remains from Fumane Cave, Italy. *J. Hum. Evol.*, 70: 61-68.

Benazzi S., Douka K., Fornai C., Bauer C.C., Kullmer O., Svoboda J.J. *et al.* 2011. Early dispersal of modern humans in Europe and implications for Neanderthal behaviour. *Nature,* 479: 525-528.

Benazzi S., Fantini M., De Crescenzio F., Persiani F. & Gruppioni G. 2009. Improving the spatial orientation of human teeth using a virtual 3D approach. *J. Hum. Evol.*, 56: 286-293.

Benazzi S., Fornai C., Buti L., Toussaint M., Mallegni F., Ricci S. *et al.* 2012. Cervical and crown outline analysis of worn Neanderthal and modern human lower second deciduous molars. *Am. J. Phys. Anthropol.*, 149: 537-546.

Benazzi S., Slon S., Talamo S., Negrino F., Peresani M., Bailey S.E. *et al.* 2015. The Makers of the Protoaurignacian and Implications for Neandertal Extinction. *Science*, 348: 793-796.

Benini A., Boscato P. & Gambassini P. 1997. Grotta della Cala (Salerno): industrie litiche e faune uluzziane e aurignaziane. *Rivista Scienze Preistoriche*, 48: 37-95.

Benjamin J., Rovere A., Fontana A., Furlani S., Vacchi M., Inglis R.H. *et al.* 2017. Late Quaternary sea-level changes and early human societies in the central and eastern Mediterranean Basin: An interdisciplinary review. *Quatern. Int.*, 449: 29-57.

Binder D. 1987. *Le Néolithique ancien provençal, typologie et technologie des outillages lithiques*. XXIVe suppl. á Gallia Préhistoire, Ėd. du CNRS, Paris.

Bordes F. 1954-1955. Les gisements du Pech de l'Azé (Dordogne). 1. Le Moustérien de tradition acheuléenne. *L'Anthropologie*, 58: 401-431; 59: 1-38.

Bordes J.G. & Teyssandier N. 2011. The Upper Paleolithic nature of the Châtelperronian in South- Western France: Archeostratigraphic and lithic evidence. *Quatern. Int.*, 246: 382-388.

Boscato P. & Crezzini J. 2012. Middle-Upper Palaeolithic transition in Southern Italy: Uluzzian macromammals from Grotta del Cavallo (Apulia). *Quatern. Int.*, 252: 90-98.

Boscato P., Gambassini P., Ranaldo F. & Ronchitelli A. 2011. Management of Palaeoenvironmental Resources and Raw materials Exploitation at the Middle Palaeolithic Site of Oscurusciuto (Ginosa, TA, Southern Italy): Units 1 and 4. In N.J. Conard & J. Richter (eds): *Neanderthal Lifeways, Subsistence and Technology - One Hundred Fifty Years of Neanderthal Study*, pp. 87-98. Springer, Berlin/Heidelberg.

Bradbury A.P. 2010. Bipolar reduction experiments and the examination of middle archaic bipolar technologies in West-Central Illinois. *N. Am. Archaeol.*, 31: 67-116.

Callahan E. 1987. *An evaluation of the lithic technology in Middle Sweden during the Mesolithic and Neolithic.* Aun 8, Societas Archaeologica Upsaliensis, Uppsala.

Carmignani L. 2010. L'industria litica del livello FIIIe di Grotta del Cavallo (Nardò, Lecce). Osservazioni su una produzione lamino-lamellare in un contesto del Musteriano finale. *Origini,* 32: 7-26.

Carmignani L. 2011. *Le ultime espressioni del Musteriano nell'Italia del sud-est. Variabilità tecnologiche e comportamenti tecno-economici in un contesto peninsulare. I casi studio di Grotta del Cavallo e Grotta Mario Bernardini. Nardò (Lecce).* Ph.D. Dissertation, Università degli Studi di Siena.

Chauchat C., Normand C., Raynal J.P. & Santamaria R. 1985. Le retour de la pièce esquillée. *Bull. Soc. Préhist. Fr.*, 82: 35-41.

Churchill S.E. & Smith F.H. 2000. Makers of the early Aurignacian of Europe. *Am. J. Phys. Anthropol. Suppl.*, 31: 61-115.

Clark D.J. 1959. *The prehistory of Southern Africa*. Penguin, London.

Crabtree D.E. 1982. An Introduction to Flintworking. *Occasional Papers of the Idaho Museum of Natural History*, 28: 1-57.

Crovetto C., Ferrari M., Peretto C., Longo L. & Vianello F. 1994. The Carinated Denticulates from the Paleolithic Site of Isernia La Pineta (Molise, Central Italy): Tools or Flaking Waste? The Results of the 1993. Lithic Experiments. *Hum. Evol.*, 9: 175-207.

d'Errico F., Borgia V. & Ronchitelli A. 2012. Uluzzian bone technology and its implications for the origin of behavioural modernity. *Quatern. Int.*, 259: 59-71.

De la Peña P. 2015. Refining our understanding of Howiesons Poort lithic technology: the evidence from Grey Rocky Layer in Sibudu Cave (KwaZulu-Natal, South Africa). *PLoS One*, 10: 434-451.

De la Peña P. & Vega L.G. 2013. Bipolar knapping in Gravettian occupations at El Palomar Rockshelter (Yeste, Southeastern Spain). *J. Anthropol. Res.*, 69: 33-64.

De Stefani M., Dini M., Klempererová H., Peresani M., Ranaldo F. & Ronchitelli A. *et al.* 2012. Continuity and replacement in flake production across the Middle-Upper Palaeolithic transition: a view over the Italian Peninsula. In A. Pastoors & M. Peresani (eds): *Flakes not Blades: The Role of Flake Production at the Onset of the Upper Palaeolithic in Europe*, pp. 135-151. Wissenschaftliche Schriftendes Neanderthal Museums, 5, Mettmann.

Devriendt I. 2011. Bipolar Pieces. A Question of Function, Raw Material Availability, or Skill? A Case Study of the Neolithic Sites at Swifterbant (The Netherlands). *Lithic Technology*, 36: 177-188.

Dewez M. 1985. Le pièces esquillées dans le Paléolithique Supérieur de Belgique. *Bull. Soc. Préhist. Fr.*, 82: 131-133.

Diez-Martin F., Sánchez-Yustos P., Dominguez-Rodrigo M. & Prendergast M. 2011. An experimental study of bipolar and freehand knapping of Naibor Soit Quartzn from Olduvai Gorge (Tanzania). *Am. Antiq.*, 76: 690-708.

Dini M. & Conforti J. 2011. Lo sfruttamento del quarzo nel Musteriano, Uluzziano e Aurignaziano di Grotta La Fabbrica (Grosseto, Italia). *Rivista Scienze Preistoriche*, 61: 21-38.

Dini M. & Tozzi C. 2012. La transizione Paleolitico medio - Paleolitico superiore nella grotta La Fabbrica (Grosseto – Toscana). *Atti della Società Toscana di Scienze Naturali, Memorie, Serie A*, 117-119: 17-25.

Dockall J.E. 1997. Wear Traces and Projectile Impact: A Review of the Experimental and Archaeological Evidence. *J. Field Archaeol.*, 24: 321-331.

Donnart K., Naudinot N. & Le Clézio L. 2009. Approche expérimentale du débitage bipolaire sur enclume: caractérisation des produits et analyse des outils de production. *Bull. Soc. Préhist. Fr.*, 106: 517-533.

Douka K., Higham T.F.G., Wood R., Boscato P., Gambassini P., Karkanas T. *et al.* 2014. On the chronology of the Uluzzian. *J. Hum. Evol.*, 68: 1-13.

Duches R., Nannini N., Romandini M., Boschin F., Crezzini J. & Peresani M. 2016. Identification of Late Epigravettian hunting injuries: Descriptive and 3D analysis of experimental projectile impact marks on bone. *J. Archaeol. Sci.*, 66: 88-102.

Duke I. & Pargeter J. 2015. Weaving simple solutions to complex problems: an experimental study of skill in bipolar cobble-splitting. *Lithic Technology*, 40: 349-365.

Eren M.I., Diez-Martin F. & Dominguez-Rodrigo M. 2013. An empirical test of the relative frequency of bipolar reduction in Beds VI, V, and III at Mumba Rockshelter, Tanzania: implications for the East African Middle to Late Stone Age transition. *J. Archaeol. Sci.*, 40: 248-256.

Fabbri P.F., Panetta D., Sarti L., Martini F., Salvadori P.A., Caramella D. *et al.* 2016. Middle Paleolithic human deciduous incisor from Grotta del Cavallo, Italy. *Am. J. Phys. Anthropol.*, 161: 506-512.

Flenniken J.J. 1981. *Replicative systems analysis: a model applied to the vein quartz artifacts from the Hoko River site.* Washington State University Laboratory of Anthropology, Reports of Investigations No. 59, Pullman.

Foster T.D., Hamilton M.C. & Lavelle C.L.B. 1969. Dentition and dental arch dimensions in British children at the age of to 3 years. *Arch. Oral Biol.*, 14: 1031-1040.

Frayer D.W. 1978. *The evolution of the dentition in Upper Paleolithic and Mesolithic Europe*. University of Kansas.

Fullagar R., McDonald J., Field J. & Donlon D. 2009. Deadly weapons: backed microliths from Narrabeen, New South Wales. In M. Haslam, G. Robertson, A. Crowther, S. Nugent & L. Kirkwood (eds): *Archaeological Science under a Microscope Studies in Residue and ancient DNA Analysis in*

*Honour of Thomas H. Loy*, *Terra Australis*, 30 pp. 258-270. ANU E Press, Canberra.

Gambassini P. 1970. Risultati della campagna di scavi 1964 nel Riparo C delle Cipolliane (Lecce). *Rivista Scienze Preistoriche*, 25: 127-181.

Gambassini P. 1980. Grotta del Cavallo (Nardò, Prov. di Lecce). *Rivista Scienze Preistoriche*, 35: 372.

Gambassini P. (ed) 1997. *Il Paleolitico di Castelcivita: culture e ambiente*. Electa, Napoli.

Gambassini P. & Palma di Cesnola A. 1979. Grotta del Cavallo (Nardò, Prov. Di Lecce). *Rivista Scienze Preistoriche*, 34: 288-289.

Geneste J.M. 1991. Systèmes techniques de production lithique: variations techno-économiques dans les processus de réalisation des outillages paléolithiques. *Techniques & Culture*, 17-18: 1- 35.

Giaccio B., Hajdas I., Isaia R., Deino A. & Nomade S. 2017. High–precision 14C and 40Ar/39Ar dating of the Campanian Ignimbrite (Y-5) reconciles the time-scales of climatic-cultural processes at 40ka. *Sci. Rep.*, 7: 45940.

Goldstein S.T. & Shaffer C.M. 2016. Experimental and archaeological investigations of backed microlith function among Mid-to-Late Holocene herders in southwestern Kenya. *Archaeol. Anthropol. Sci.*, 2016: 1-22.

Goodyear A.C. 1993. Tool kit entropy and bipolar reduction: A study of interassemblage lithic variability among Paleo-Indian sites in the Northeastern United States. *N. Am. Archaeol.*, 14: 1- 24.

Guyodo J.N. & Marchand G. 2005. La percussion bipolaire sur enclume dans l'Ouest de la France de la fin du Paléolithique au Chalcolithique: une lecture économique et sociale. *Bull. Soc. Préhist. Fr.*, 102: 539-549.

Hayden B. 1980. Confusion in the bipolar world: bashed pebbles and splintered pieces. *Lithic Technology*, 9: 2-7.

Higham T.F.G., Douka K., Wood R., Bronk Ramsey C., Brock F., Basell L. *et al.* 2014. The timing and spatio-temporal patterning of Neanderthal disappearance. *Nature*, 512: 306-309.

Higham T, Brock F., Peresani M., Broglio A., Wood R. & Douka K. 2009. Problems with radiocarbon dating the Middle to Upper Palaeolithic transition in Italy. *Quaternary Sci. Rev.*, 28: 1257-1267.

Hiscock P. 1996. Mobility and technology in the Kakadu coastal wetlands. *Bull. Indo Pac. Pre. HI*, 15: 151-157.

Hiscock P. 2015. Making it small in the Palaeolithic: bipolar stoneworking, miniature artefacts and models of core recycling. *World Archaeol.*, 47: 158-169.

Hiscock P., Clarkson C. & Mackay A. 2011. Big debates over little tools: ongoing disputes over microliths on three continents. *World Archaeol.*, 43: 653-664.

Hublin J-J. 2015. The modern human colonization of western Eurasia: when and where? *Quaternary Sci. Rev.*, 118: 194-210.

Inizan M.L., Reduron-Ballinger M. & Roche H. 1999. *Technology and terminology of knapped stone: followed by a multilingual vocabulary arabic, english, french, german, greek, italian, portuguese, spanish*. Vol. 5. Cercle de Recherches et d'Etudes Préhistoriques.

Jeske R. 1992. Energetic efficiency and lithic technology: an Upper Mississippian example. *Am. Antiquity*, 57: 467-481.

Keeley L.H. 1980. *Experimental Determination of Stone Tool Uses: a Microwear Analysis*. University of Chicago Press, Chicago and London.

Klempererová H. 2012. *Functional analysis applied to the lithic assemblage of the final Middle Paleolithic and beginning of the Upper Paleolithic with the aim to reconstruct behaviour of ancient human groups.* Ph.D. Dissertation, University of Siena.

Knight J. 1991. Technological Analysis of the Anvil (Bipolar) Technique. *Lithics*, 12: 57-87.

Knutsson H., Knutsson K., Taipale N., Tallavaara M. & Darmark K. 2015. How shattered flakes were used: Micro-wear analysis of quartz flake fragments. *J. Archaeol. Sci. Rep.*, 2: 517-531.

Lahr M.M., Rivera F., Power R.K., Mounier A., Copsey B., Crivellaro F. *et al.* 2016. Inter-group violence among early Holocene hunter-gatherers of West Turkana, Kenya. *Nature*, 529: 394-398.

Langejans G.H.J. 2012. Middle Stone Age pièces esquillées from Sibudu Cave, South Africa: an initial micro-residue study. *J. Archaeol. Sci.*, 39: 1694-1704.

Le Brun-Ricalens F. 1989. Contribution à l'étude des pièces esquillées: la présence de percuteurs à "Cupules". *Bull. Soc. Préhist. Fr.*, 867: 196-201.

Le Brun-Ricalens F. 2006. Les pièces esquillées: état des connaissances après un siècle de Reconnaissance. *PALEO*, 18: 95-114.

Leblanc R. 1992. Wedges, pièces esquillées, bipolar cores, and other things: an alternative to Shott's view of bipolar industries. *N. Am. Archaeol.*, 13: 1-14.

Leroi-Gourhan A. 1943. *Évolution et techniques, I.* Milieu et technique. Albin Michel, Paris.

Leroi-Gourhan A. 1945. *L'homme et la matière, II.* Milieu et technique. Albin Michel, Paris.

Leroi-Gourhan Ar. & Leroi-Gourhan An. 1964. Chronologie des grottes d'Arcy-sur-Cure (Yonne). *Gallia Préhist.*, 7: 1-64.

Lévêque F. &Vandermeersch B. 1980. Découverte de restes humains dans un niveau castelperronien à Saint-Césaire (Charente-Maritime). *C. R. Seances Acad. Sci. D*, 291: 187-189.

Lombard M. 2006. Direct evidence for the use of ochre in the hafting technology of Middle Stone Age tools from Sibudu Cave. *South. Afr. Humanit.*, 18: 57-67.

Lombard M. 2007. The gripping nature of ochre: The association of ochre with Howiesons Poort adhesives and Later Stone Age mastics from South Africa. *J. Hum. Evol.*, 53: 406-419.

Lombard M. 2008. Finding resolution for the Howiesons Poort through the microscope: micro-residue analysis of segments from Sibudu Cave, South Africa. *J. Archaeol. Sci.*, 35: 26-41.

Lombard M. & Pargeter J. 2008. Hunting with Howiesons Poort segments: pilot experimental study and the functional interpretation of archaeological tools. *J. Archaeol. Sci.*, 35: 2523-2531.

Lombard M. & Phillipson L. 2010. Indications of bow and stone-tipped arrow use 64 000 years ago in KwaZulu-Natal, South Africa. *Antiquity*, 84: 635-648.

Lucas G. & Hays M.A. 2004. Les pièces esquillées du site paléolithique du Flageolet I (Dordogne): outils ou nucléus? In P. Bodu & C. Constantin (eds): *Approches fonctionnelles en préhistoire*, pp. 107-120. Actes du XXVe Congrès Préhistorique de France, Nanterre.

Mackay A. & Marwick B. 2011. Costs and benefits in technological decision making under variable conditions: examples from the late Pleistocene of southern Africa. In B. Marwick & A. Mackay (eds): *Keeping Your Edge: Recent Approaches to the Organisation of Stone Artifact Technology*, pp. 119-134. British Archaeological Reports, Archaeopress, Oxford.

Madre-Dupouy M. 1992. *L'enfant du Roc de Marsal. Etude analytique et comparative*. Cahiers de Paléoanthropologie, Editions du CNRS, Paris.

Marciani G., Spagnolo V., Aureli D., Ranaldo F., Boscato P. & Ronchitelli A. 2016. Middle Palaeolithic technical behaviour: Material import-export and Levallois production at the SU 13 1644 of Oscurusciuto rock shelter, Southern Italy. *Journal of Lithic Studies*, 3, https://doi.org/10.2218/jls.v3i2.1414.

McDonald J.J., Donlon D., Field J.H., Fullagar R.L.K., Coltrain J.B., Mitchell P. *et al.* 2007. The first archaeological evidence for death by spearing in Australia. *Antiquity*, 81: 877-885.

Messeri P. & Palma di Cesnola A. 1976. Contemporaneità di Paleantropi e Fanerantropi sulle caste dell'Italia Meridionale. *Zephyrus*, 36-37: 7-29.

Mitchell P.J. 2000. The organization of Later Stone Age lithic technology in the Caledon Valley, Southern Africa. *Afr. Archaeol. Rev.*, 17: 141-176.

Mitchell P.J. 2003. *The Archaeology of Southern Africa*. Cambridge University Press, Cambridge.

Molnar S. 1971. Human tooth wear, tooth function and cultural variability. *Am. J. Phys. Anthropol.*, 34: 175-189.

Monchot H., Houmard C., Dionne M.M., Desrosier P.M. & Gendron D. 2013. The modus operandi of walrus exploitation during the Palaeoeskimo period at the Tayara site, Arctic Canada. *Anthropozoologica*, 48: 15-36.

Moorrees C.F.A., Fanning E.A. & Hunt E.E. Jr. 1963. Formation and resorption of three deciduous teeth in children. *Am. J. Phys. Anthropol.*, 21: 205-213.

Moretti E., Arrighi S., Boschin F., Crezzini J., Aureli D. & Ronchitelli A. 2015. Using 3D Microscopy to Analyze Experimental Cut Marks on Animal Bones Produced with Different Stone Tools. *Ethnobiology Letters*, 6: 14-22.

Morgan B., Eren M.I., Khreisheh N., Hill G., Bradley B., Jennings T. *et al.* 2015. Clovis Bipolar Lithic Reduction at Paleo Crossing, Ohio: A Reinterpretation Based on the Examination of Experimental Replications. In J. Thomas & S. Ashley (eds): *Clovis: Current Perspectives on Technology, Chronology, and Adaptations*, pp. 121-143. Texas A&M Press, College Station.

Moroni A., Boscato P. & Ronchitelli A. 2013. What roots for the Uluzzian? Modern behaviour in Central-Southern Italy and hypotheses on AMH dispersal routes. *Quatern. Int.*, 316: 27-44.

Nishiaki Y., Nakata H., Yoneda M., Kondo O., Tanno K., Kanjo Y. *et al.* 2008. The 2006-2007 Season's Investigations at Dederiyeh Cave, Afrin, Syria. *Bulletin of Kochi University of Technology*, 5: 9-23.

Odell G.H. 1981. The mechanics of use-breakage of stone tools: some testable hypotheses. *J. Field Archaeol.*, 8: 197-209.

Odell G.H. & Odell-Vereecken F. 1980. Verifying the Reliability of lithic use-wear assessments by 'Blind tests': the low-power approach. *J. Field Archaeol.*, 7: 87-120.

Oxilia G., Peresani M., Romandini M., Matteucci C., Debono Spiteri C., Henry A.G. *et al.* 2015. Earliest evidence of dental caries manipulation in the Late Upper Palaeolithic. *Nature Scientific Reports*, 5, Article number: 12150.

Palma di Cesnola A. 1963. Prima campagna di scavi nella Grotta del Cavallo presso Santa Caterina (Lecce). *Rivista Scienze Preistoriche*, 18: 41-74.

Palma di Cesnola A. 1964. Seconda campagna di scavi nella Grotta del Cavallo presso Santa Caterina (Lecce). *Rivista Scienze Preistoriche*, 19: 23-39.

Palma di Cesnola A. 1965a. Notizie preliminari sulla terza campagna di scavi nella Grotta del Cavallo (Lecce). *Rivista Scienze Preistoriche*, 20: 291-302.

Palma di Cesnola A. 1965b. Il Paleolitico superiore arcaico (facies uluzziana) della Grotta del Cavallo, Lecce. *Rivista Scienze Preistoriche*, 20: 33-62.

Palma di Cesnola A. 1966a. Gli scavi nella Grotta del Cavallo (Lecce) durante il 1966. *Rivista Scienze Preistoriche*, 21: 289-301.

Palma di Cesnola A. 1966b. Il Paleolitico superiore arcaico (Facies uluzziana) della Grotta del Cavallo (Continuazione), Lecce. *Rivista Scienze Preistoriche*, 21: 3-59.

Palma di Cesnola A. 1967. Il Paleolitico della Puglia. *Memorie del Museo Civico di Storia Naturale di Verona*, 15: 1-84.

Palma di Cesnola A. 1969. Datazione dell'Uluzziano col metodo del C14. *Rivista Scienze Preistoriche*, 24: 341-348.

Palma di Cesnola A. 1979. Grotta del Cavallo (Nardò, Prov. Di Lecce). *Rivista Scienze Preistoriche*, 34: 288.

Palma di Cesnola A. 1982. L'Uluzzien et ses rapports avec le Protoaurignacien en Italie. *Eraul*, 13: 271-288.

Palma di Cesnola A. 1989. L'Uluzzien: faciès italien du Leptolithique archaïque. *L'Anthropologie*, 93: 783-811.

Palma di Cesnola A. 1993. *Il Paleolitico superiore in Italia*. Garlatti e Razzai Editori, Firenze.

Palma di Cesnola A. 1996. *Le Paléolithique inférieur et moyen en Italie*. Série "Préhistoire d'Europe", 1, Jérôme Millon, Grenoble.

Palma di Cesnola A. 2001a. *Il Paleolitico inferiore e medio in Italia*. Millenni, 3, Firenze.

Palma di Cesnola A. 2001b. *Le Paléolithique supérieur en Italie*. Série "Préhistoire d'Europe", 9, Jérôme Millon, Grenoble.

Palma di Cesnola A. & Messeri P. 1967. Quatre dents humaines paléolithiques trouvées dans des cavernes de l'Italie méridionale. *L'Anthropologie*, 71: 249-262.

Panetta D., Belcari N., Del Guerra A., Bartolomei A. & Salvadori P.A. 2012. Analysis of image sharpness reproducibility on a novel engineered micro-CT scanner with variable geometry and embedded recalibration software. *Phys. Medica*, 28: 166-173.

Pargeter J. 2007. Howiesons Poort segments as hunting weapons: experiments with replicated projectiles. *S. Afr. Archaeol. Bull.*, 62: 147-153.

Pargeter J. 2011. Assessing the macrofracture method for identifying Stone Age hunting weaponry. *J. Archaeol. Sci.*, 38: 2882- 2888.

Pargeter J. 2013. Rock type variability and impact fracture formation: working towards a more robust macrofracture method. *J. Archaeol. Sci.*, 40: 4056-4065.

Peresani M., Cristiani E. & Romandini M. 2016. The Uluzzian technology of Grotta di Fumane and its implication for reconstructing cultural dynamics in the Middle-Upper Palaeolithic transition of Western Eurasia. *J. Hum. Evol.*, 9: 36-56.

Peyrony D. 1948. Le Périgordien, l'Aurignacien et le Solutréen d'après les dernières fouilles. *Bull. Soc. Préhist. Fr.*, 45: 305-328.

Plisson H. 1985. *Étude fonctionnelle d'outillages lithiques préhistoriques par l'analyse des micro-usures: recherche méthodologique et archéologique.* Dissertation, Université de Paris I, Paris.

R Core Team 2016. *R: A Language and Environment for Statistical Computing*.

Ranaldo F., Klempererová H. & Ronchitelli A. 2017. Evoluzione dei sistemi tecnici nell'Uluzziano di Grotta del Cavallo (Nardò-LE). In F. Radina (ed): *Preistoria e Protostoria della Puglia*, pp. 61-67. Studi di Preistoria e Protostoria, 4, Firenze.

Riel-Salvatore J. 2009. What Is a 'Transitional' Industry? The Uluzzian of Southern Italy as a Case Study. In M. Camps & P. Chauhan (eds): *A Sourcebook of Paleolithic Transition*, pp. 377-396. Springer.

Riel-Salvatore J. 2010. A niche construction perspective on the Middle-Upper Paleolithic Transition in Italy. *J. Archaeol. Method Th.*, 17: 323-355.

Romagnoli F., Trenti F., Nannini L., Carmignani L., Ricci G., Lo Vetro D. *et al.* 2016. Raw-Material Procurement and Productive Sequences in the Palaeolithic of Southern Italy: the Tyrrhenian and Ionian Areas. An Integrated Approach to the Reconstruction of Human Behaviour. In A. Tomasso, D. Binder, G. Martino, G. Porraz, P. Simon & N. Naudinot (eds): *Ressources Litiques, Productions et Transferts entre Alpes et Méditerranée*, pp. 185-205. Séances de la SPF, Nice, mars 2013, Société Préhistorique Française, Paris.

Rots V. & Plisson H. 2014. Projectiles and the abuse of the use-wear method in a search for impact. *J. Archaeol. Sci.*, 48: 154-165.

Roussel M., Soressi M. & Hublin J-J. 2016. The Châtelperronian conundrum: Blade and bladelet lithic technologies from Quinçay, France. *J. Hum. Evol.*, 95: 13-32.

Ruebens K., McPherron S. & Hublin J-J. 2015. On the local Mousterian origin of the Châtelperronian: Integrating typo-technological, chronostratigraphic and contextual data. *J. Hum. Evol.*, 86: 55-91.

Sarti L. 1987-1988. Grotta del Cavallo (Prov. di Lecce). *Rivista Scienze Preistoriche*, 41: 385-386.

Sarti L., Boscato P. & Lo Monaco M. 1998-2000. Il Musteriano finale di Grotta del Cavallo nel Salento: studio preliminare. *Origini*, 22: 45-109.

Scott G.R. & Turner C.G. 1997. *II. The anthropology of modern human teeth. Dental morphology and its variation in recent human populations.* University Press, Cambridge.

Shott M.J. 1989. Bipolar industries: ethnographic evidence and archaeological implications. *N. Am. Archaeol.*, 10: 1-24.

Shott M.J. 1999. On bipolar reduction and splintered pieces. *N. Am. Archaeol.*, 20: 217-238.

Shott M.J. & Tostevin G. 2015. Diversity under the bipolar umbrella. *Lithic Technology*, 40: 377-384.

Soriano S., Robert A. & Huysecom É. 2010. Percussion bipolaire sur enclume: choix ou contrainte? L'exemple du Paléolithique d'Ounjougou (Pays dogon, Mali). In V. Mourre & M. Jarry (eds): *Entre le marteau et l'enclume - La percussion directe au percuteur dur et la diversité de ses modalités d'application*, pp. 123-132. PALEO. Numéro spécial.

Spagnolo V., Marciani G., Aureli D., Berna F., Boscato P., Ranaldo F. *et al.* 2016. Between hearths and volcanic ash: The SU 13 palimpsest of the Oscurusciuto rock shelter (Ginosa - Southern Italy): analytical and interpretative questions. *Quatern. Int,* 417: 105-121.

Stapert D. 2007. Neanderthal children and their flints. *PalArch's Journal of Archaeology of Northwest Europe*, 1: 16-38.

Sternke F. & Sørensen M. 2009. The identification of children's flintknapping products in Mesolithic Scandinavia. In S.B. McCartan, R. Schulting, G. Warren & P. Woodman (eds): *Mesolithic Horizons*, pp. 722-729. Oxbow Books, Oxford.

Tagliacozzo A., Romandini M., Fiore I., Gala M. & Peresani M. 2013. Animal Exploitation Strategies during the Uluzzian at Grotta di Fumane (Verona, Italy). In J.L. Clark & J.D. Speth (eds): *Zooarchaeology and Modern Human Origins: Human Hunting Behavior during the Later Pleistocene*, *Vertebrate Paleobiology and Paleoanthropology*, pp. 129-150. Springer, Dordrecht.

Tillier A.M. 1979. Restes crâniens de l'enfant moustérien homo 4 de Qafzeh (Israël), la mandibule et les maxillaires. *Paléorient*, 5: 67-85.

Tixier J. & Tillier A.M. 1991. Une molaire d'enfant aurignacien a Ksar'Aqil (Liban) Mt. Carmel, Israël. *Paléorient*, 17: 89-93.

Toro-Moyano I., Martínez-Navarro B., Agustí J., Souday C., Bermúdez de Castro J.M., Martinún-Torres M. *et al.* 2013. The oldest human fossil in Europe dated to ca. 1.4 Ma at Orce (Spain). *J. Hum. Evol.*, 65: 1-9.

Tringham R., Cooper G., Odell G., Voytek B. & Whitman A. 1974. Experimentation in the formation of edge damage: a new approach to lithic analysis. *J. Field Archaeol.*, 1: 171-196.

Turner C.G., Nichol C.R. & Scott G.R. 1991. Scoring procedures for key morphological traits of the permanent dentition: the Arizona State University dental anthropology system. *Advances in dental anthropology*, 24: 13-31.

Van Gijn A. 2010. *Flint in Focus. Lithic Biographies in the Neolithic and Bronze Age*. Sidestone Press, Leiden.

Vergès J.M. & Ollé A. 2011. Technical microwear and residues in identifying bipolar knapping on an anvil: experimental data. *J. Archaeol. Sci.*, 38: 1016-1025.

Villa P., Soriano S., Tsanova T., Degano I., Higham T.F.G, d'Errico F. *et al*. 2012. Border Cave and the beginning of the Later Stone Age in South Africa. *Proc. Natl. Acad. Sci. USA*, 109: 13208-13213.

Wadley L. 2005. Putting ochre to the test: replication studies of adhesives that may have been used for hafting tools in the Middle Stone Age. *J. Hum. Evol.*, 49: 587-601.

White J.P. 1968. Fabricators, Outils écaillés or Scalar Cores? Reprinted from Mankind. *Aust. J. Anthropol.*, 6: 658-666.

Wolpoff M.H. 1979. The Krapina dental remains. *Am. J. Phys. Anthropol.*, 50: 67-114.

Yaroshevich A., Kaufman D., Nuzhnyy D., Bar-Yosef O. & Mina Weinstein-Evron M. 2010. Design and performance of microlith implemented projectiles during the Middle and the Late Epipaleolithic of the Levant: experimental and archaeological evidence. *J. Archaeol. Sci.*, 37: 368-388.

Zanchetta G., Giaccio B., Bini M. & Sarti L. 2018. Tephrostratigraphy of Grotta del Cavallo, Southern Italy: Insights on the chronology of Middle to Upper Palaeolithic transition in the Mediterranean. *Quaternary Sci. Rev.*, 182: 65-77.

Zilhão J., Banks W.E., d'Errico F. & Gioia P. 2015. Analysis of site formation and assemblage integrity does not support attribution of the Uluzzian to Modern Humans at Grotta del Cavallo. *PLoS One*, 10: 131-181.

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