Supplementary Information

Supplementary Information 1: Research history at Grotta del Cavallo

The Uluzzian was discovered and described for the first time in the 1960s by Prof. Palma di Cesnola of the University of Siena[6,61-64] at Grotta del Cavallo (Apulia, Nardó, Lecce). This cave contains a key stratigraphic sequence, including Mousterian (layers N-F), early Upper Paleolithic (layers E-D: Uluzzian), final Upper Paleolithic (layer B: Romanellian and Epi-romanellian), and Neolithic (layer A).

Research at Cavallo started in 1961 under the direction of Palma di Cesnola and was suspended in 1966. In the following years, the cave was visited by looters and the archaeological deposit was heavily damaged. In 1975, research was resumed to restore the cave infill and secure its entrance with a gate. From 1979, the excavation of the Uluzzian layers was continued by Prof. Paolo Gambassini who collaborated with Palma di Cesnola at Grotta del Cavallo from 1964 until 1986. Thereafter, research at Grotta del Cavallo has been carried out by Prof. Lucia Sarti who has excavated both the Mousterian and final Upper Paleolithic layers. Apart from the looters' activity, the central part of the cavity was affected by post-depositional disturbances consisting of erosive events, which caused the formation of a deep pit filled with reworked deposits down to the top of the Mousterian sequence. As the trench opened by Palma di Cesnola between 1963 and 1966 was partially disturbed by this pit (Supplementary Fig. 1), the undisturbed area was dug out separately from the pit to keep the archaeological materials distinct. In 1964, during the excavation of the north-western portion of the trench, Palma di Cesnola found two deciduous human teeth in the lowermost undisturbed Uluzzian deposit (layer EIII) (Supplementary Fig. 1). For a detailed description of the research history and a complete dissertation on the integrity of the Cavallo deposit see Moroni et al. (2018)[1].

The stratigraphic sequence of the Uluzzian deposit identified by Palma di Cesnola from 1963–1964 at Grotta del Cavallo was capped by layer C (maximum thickness 60 cm along the north-western side of Palma di Cesnola's trench). Layer C was further subdivided into CIa, CIb, and CII. The CII layer is composed of sterile, slightly cemented silvery gray sand, which is regularly laminated volcanic deposit attributed to the Y-5 eruption known as Campanian Ignimbrite[3]. Layer CII is followed (from the top downwards)[61,62] (Supplementary Fig. 1) by:

- layer D (maximum thickness 30 cm) is divided into subunits DIa (stalagmite crust), DIb and DII, all containing Upper Uluzzian assemblage;
- layer EI (maximum thickness 33 cm) composed of dark brown silty sand with several hearths; the Uluzzian assemblage in this layer is attributed to the Evolved Uluzzian; due to the absence of a clear-cut border between layers DII and EI, a 10 cm artificial transitional spit (E-D) was introduced during the 1964 excavations[1];
-layer EII (maximum thickness 10 cm), which was formed by the same silty sand as the previous layer, but is darker and includes a thick series of hearths (especially in the NW area of the trench); this layer is attributed to the Evolved Uluzzian;
-layer EIII (maximum thickness 20 cm), which was formed by dark brown silty sand and is characterized by thick stratified intact fireplaces; this layer represents the most ancient Uluzzian (Archaic Uluzzian) occurrence known to date;
- layer FI (maximum thickness 10 cm), which was formed by cemented reddish silty sand with Mousterian lithics, and is covered by a thin lens of greenish volcanic sand (Fa), which was very recently attributed to tephra Y-6 (Green Tuff of Pantelleria Island)[2].

Supplementary Information 2: Integrity of the Uluzzian deposit at Grotta del Cavallo and the makers of the Uluzzian

Integrity of the Uluzzian deposit

Since its discovery, the Uluzzian has been chronologically situated at the dawn of the Upper Paleolithic based on its stratigraphic position and some assumed similarities with the Châtelperronian (occurrence of curved backed tools, bone artifacts, ornaments). Due also to methodological limits of dental morphometric analysis, which prevented a clear taxonomic attribution of the two deciduous teeth from layer EIII[65,66], the Uluzzian has shared the same fate as the Châtelperronian technocomplex, which was first attributed to modern humans and then to Neanderthals after the discovery of Neanderthal human remains in the Châtelperronian contexts at Saint-Césaire and Arcy-sur-Cure[67,68].

However, in 2011, based on microtomographic image data and advanced morphometric analysis, the Cavallo teeth retrieved from the Uluzzian deposit were definitively attributed to *Homo sapiens* [26]. In the same year, dating of marine shells performed at the Oxford Radiocarbon Accelerator Unit indicated that the beginning of the Uluzzian at Grotta del Cavallo falls around 45,000 years ago[69] (layer EII-I 39,990 ± 340, 44,300–43,000 cal BP). More recent geological studies proved the accuracy of the radiometric dates by confirming the two tephra layers (Fa and CII) embedding the Uluzzian package at Cavallo: the former belongs to the Y-6 green tuff of Pantelleria dated at 45.5 ± 1.0 ka[2], while the latter to the Y-5 Campanian Ignimbrite (CI) at 39.85 ± 0.14 ka[2,3].

Despite the evidence reported in Palma di Cesnola's documentation, some scholars have disagreed with the renewed scenario and claim post-depositional disturbances of the archaeological deposit in which the human remains were found[25,70]. However, the integrity of the deposit of Grotta del Cavallo is supported by a recent contribution by Moroni *et al.*[1] re-examining Palma di Cesnola's and Gambassini's documentations (both fieldwork personal notes and publications). Ongoing archaeological excavations by Prof. Lucia Sarti and the above-mentioned study[2] by geologists and vulcanologists at Grotta del Cavallo have further confirmed the integrity of the Uluzzian succession (layer EIII-DI, of Palma di Cesnola stratigraphy):

"...layers E-D confidently represent the most continuous and possibly complete succession of deposits containing the Uluzzian techno-complex" (Zanchetta *et al.*, 2018, p. 68)[2].

General doubts of the assignment of the Uluzzian to modern humans are gradually being dispelled thanks to the ERC project (n. 724046, SUCCESS), which involves several Italian scholars who are experts in the Middle to Upper Paleolithic transition. An emblematic example is layers A4 and A3 of Grotta di Fumane, which were first been assigned to the Uluzzian. Owing to the assumed combination of Mousterian and Upper Paleolithic elements, Peresani and colleagues[71] suggested a local Middle Paleolithic origin of this technocomplex. However, further comparisons and exchanges of information within the ERC-SUCCESS research group, along with the discovery of a real Uluzzian deposit at Riparo del Broion, which is not far from Fumane and chronologically overlaps with layers A4–3 at this cave, prompted reconsideration of the assignment of layers A4 and A3 of Fumane[72]. Their investigation revealed that the layer A4 assemblage showed more consistent characteristics of Mousterian than Uluzzian; taphonomic revision of layer A3 is ongoing, owing to intrusive artifacts from the overlying Protoaurignacian.

Cultural assignment of the Uluzzian

Although the Uluzzian is considered as one of the so-called "transitional technocomplexes" from the Middle to Upper Paleolithic in Europe, we should no longer list the Uluzzian as a "transitional technocomplex". The Uluzzian shows neither techno-typological nor economic characteristics derived from the Mousterian tradition[1].

The main characteristics of the Uluzzian lithic industry are as follows:

- dominant use of a bipolar technique with systematic production of flakes and blades in very small dimensions;
- low technical investment at the production phase, with almost exclusive use of low-cost production systems, unlike the late Mousterian;
- occurrence of a new tool, as lunates;
- systematic production of short endscrapers.

Furthermore, Boscato and Crezzini[73] highlighted significant differences in the exploitation of ungulate carcasses between the Mousterian and Uluzzian in Southern Italy. In particular, Uluzzian assemblages are characterized by higher proportions of basipodial and acropodial bones, as well as fragments of epiphyses, suggesting that Uluzzian behavior is akin to the succeeding Upper Paleolithic assemblages (i.e., Aurignacian, Gravettian, and Epigravettian) of Southern Italy. By contrast, Mousterian contexts show lower proportions of the above-mentioned skeletal parts and spongy bone fragments among unidentified specimens.

In addition to the occurrence of formal bone tools[4], ornaments and coloring substances in the Uluzzian assemblages and the characteristics of lithic assemblages—such as the dominant use of bipolar technique and presence of lunate—show strong similarity with modern human assemblages in the South African Howiesons Poort (HP) and Eastern African HP-like Middle Stone Age technocomplexes[74-84]. One significant innovative and complex technology seen in the South African HP assemblages is mechanically delivered projectile weapons, which are considered 64,000 years old or older[24,84-87]. Hence, there are well-founded reasons to support that the roots of the Uluzzian—and therefore the roots of mechanically delivered projectile technology—should be traced to modern human cultures of the African continent[5].

Supplementary Information 3: Taphonomic analysis of bird remains

The anthropogenic modifications on the surface of bird bones retrieved from the Uluzzian deposit of Grotta di Castelcivita (Campania region), as well as their casts, were observed and analyzed at both macroscopic and microscopic levels[88]. The analyses were carried out with the aid of stereomicroscopes e Nikon SMZ 1000 and 8 e160X (Service Bioarchaeology, Museo delle Civiltà, Rome). For molding, we used silicon elastomers (Provil Novo) and developed high-resolution positive casts with epoxy resin (Araldite LY-554 and hardener Hy 956). The casts reproduce the details at resolutions as high as below 1 μm. Therefore, the observation of positivity of the transparent resin using a stereomicroscope allows us to obtain detailed images of the cut marks.

Cut marks on the wing bones of raptors and corvids are frequently found across several Middle and Upper Paleolithic sites[89-96]. It has already been noticed that the portion of the wing, including the distal humerus, the ulna, radius, carpometacarpus, and phalanges, cannot be an anatomical element simply discarded during butchering, due to the presence of recurrent cuts on the diaphyses of the humerus and ulna. Cut marks on these bones are more likely related to the collection of feathers (*e.g.* from the area of the ulnar diaphysis), while these traces are rarely associated with the consumption of birds.

In comparison to the Mousterian levels, the Uluzzian levels of Castelcivita reveal a notable increase in traces from the exploitation of avian carcasses, including cut marks, localized burning, peeling, *etc*. Cut marks found on the humerus of a Eurasian hobby (*Falco subbuteo*) (Supplementary Fig. 9), on the ulna of a Yellow-billed Chough (*Pyrrhocorax graculus)* (Supplementary Fig. 10), and on the ulna large-sized Accipitridae (probably a Eurasian griffon) suggest removal of feathers rather than meat, as these anatomical parts are almost completely meatless.

Supplementary Information 4: Zooarchaeological evidence

Most representative tooth samples from the late Mousterian (Layer F) and Uluzzian phases at Grotta del Cavallo belonged to the horse (*Equus ferus*). Since teeth are often broken, crown height was not considered as a parameter to establish age-at-death. To increase the sample as much as possible, only tooth type (deciduous or permanent) and presence or absence of wear were considered (Supplementary Table 4). Following this protocol, the late Mousterian sample comprises 15 specimens, 26.7% of which is deciduous or unworn permanent teeth. This percentage is higher in the Uluzzian samples (72.4 % in layer EIII, 29 specimens; 42.3% in layer EII-I, 71 specimens; 38.5% in layer D, 13 specimens).

Data from the late Mousterian of Grotta del Cavallo are reinforced by evidence from Riparo l'Oscurusciuto (Ginosa, Taranto), a rock shelter located about 100 km from Cavallo as the crow flies. L'Oscurusciuto yielded a late Mousterian sequence with a top (layer 1) dated to 42,724 ± 716 cal BP[97]. Faunal data from layer 2 (immediately below layer 1), characterized by low proportions of deciduous and unworn permanent teeth (15.6%, 32 specimens), indicate a low frequency of hunting younger horses.

The dominant stallion usually guards a home range during grazing and takes care of the group by leading it toward a safer place when danger approaches[27]. Given that the dominant stallion lives together with mares and younger horses, it would be challenging to hunt younger horses without a long-range and highly accurate projectile system. In this context, more intensive exploitation of younger horses in the Uluzzian assemblages may represent the use of mechanically delivered weapons. By contrast, the low percentages of younger horses in the Mousterian fauna may reflect selective hunting of isolated adult individuals or bachelor groups, possibly due to close-range hunting.

Supplementary Table 1 | Summary of results of use-wear analysis of Uluzzian backed pieces from Grotta del Cavallo.

Layer	*N*	Hunting	Hunting?	Cutting	Scraping	No clear use-wear
D	22	5 (22.7 %)	1 (4.5 %)	0 (0.0 %)	0 (0.0 %)	16 (72.7 %)
E-D (spit)	30	7 (23.3 %)	2 (6.7 %)	1 (5.0 %)	0 (0.0 %)	20 (66.7 %)
EII-I	60	12 (20.0 %)	5 (8.3 %)	3 (3.3 %)	3 (5.0 %)	37 (61.7 %)
EIII	34	2 (5.9 %)	3 (8.8 %)	0 (0.0 %)	0 (0.0 %)	29 (85.3 %)
Total	146	26 (17.8 %)	11 (7.5 %)	4 (2.7 %)	3 (2.1 %)	102 (69.9 %)

Supplementary Table 2 | Frequencies of the single DIF types and multiple DIF types of Uluzzian backed pieces from Grotta del Cavallo compared to those of the experimental samples (refs. 10, 11).

Layer	Single DIF types						Multiple DIF types							Total
	a1	a2	a3	b1	b2	b3	a1m	a2m	b1m	b2m	cm	d1m	d2m	
Grotta del Cavallo	2	6	0	1	0	0	1	10	1	3	1	1	0	26
Experimental sample (ref. 10)														
Tip	6	4	2	1	3	3	2	2	2	3	1	2	2	33
Barb	2	4	2	1	3	20				1			3	36
Experimental sample (ref. 11)														
Tip	11	5	1	4	9	6	3	3	1	4	7	2	3	59
Barb	3	1		1		1	1		1		1			9

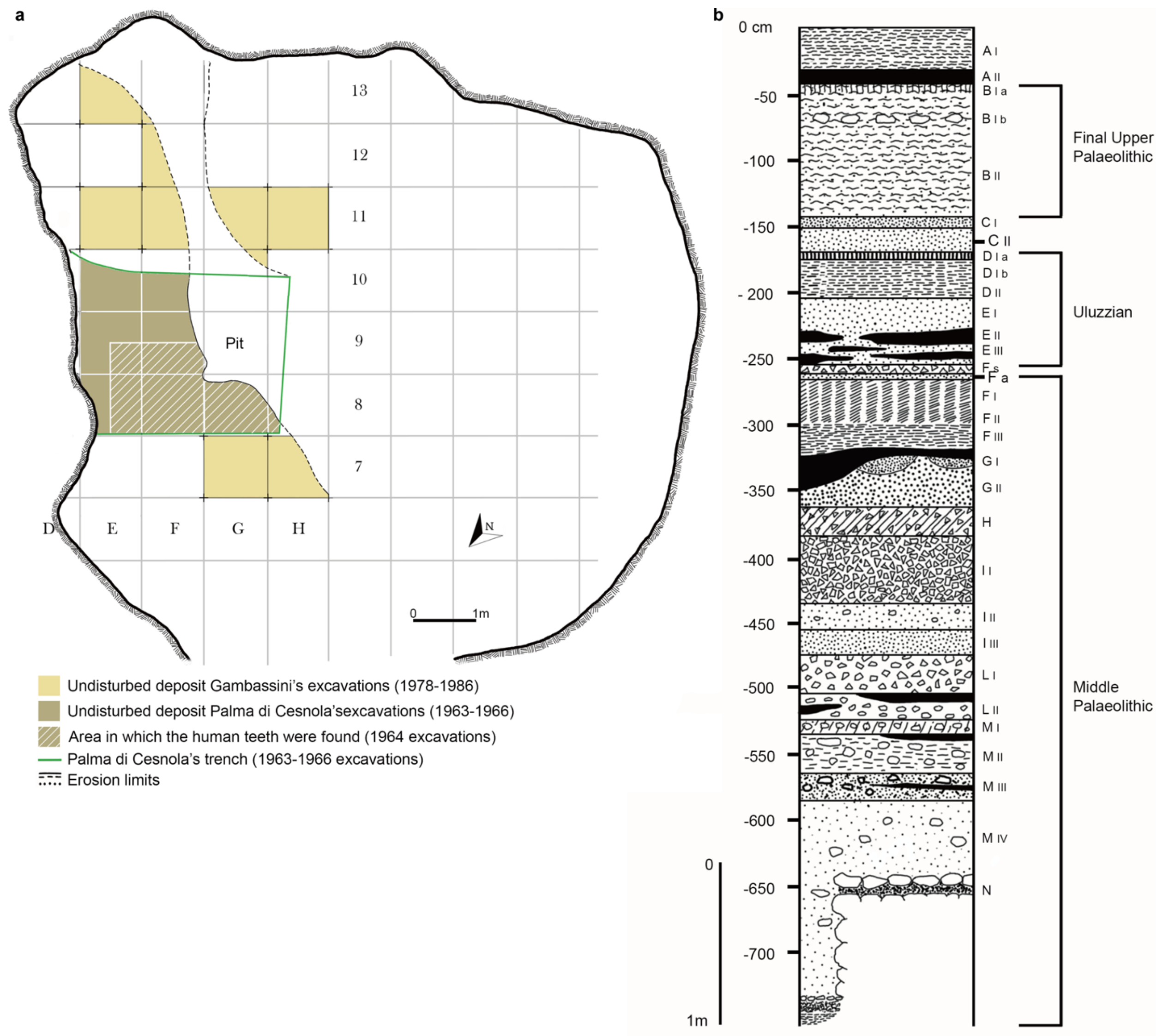
Supplementary Table 3 | Ratios of the length of flute- and burin-like fractures to that of the almost complete backed pieces.

Layer	< 10%	10-20 %	20-30 %	30-40 %	40-50 %	> 50 %
D		2	2	2		
E-D (spit)		1	3	1	1	3
EII-I	1	6	5	1	3	
EIII		1		1		1
Total	**1**	**10**	**10**	**5**	**4**	**4**

Supplementary Table 4 | Horse specimens from Grotta del Cavallo and Oscurusciuto according to layer, tooth type and wear.

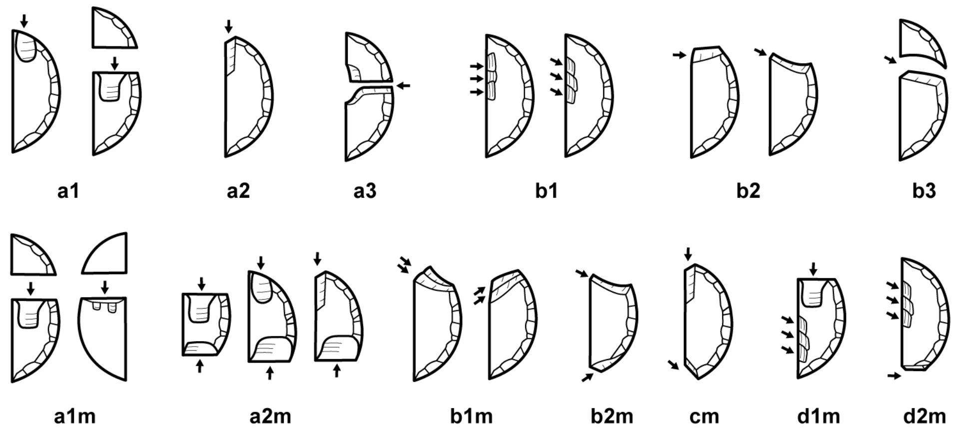
The Uluzzian materials were recovered from layers D, EII-I, and EIII at Grotta del Cavallo and Mousterian materials were found from layer F at Grotta del Cavallo and from layer 2 at Oscurusciuto.

Site	Layer	Deciduous cheek teeth	Permanent unworn cheek teeth	Permanent worn cheek teeth	Deciduous incisors	Permanent unworn incisors	Permanent worn incisors	Total
Cavallo	D	4	0	7	1	0	1	13
Cavallo	EII-I	10	11	36	4	5	5	71
Cavallo	EIII	10	3	8	6	2	0	29
Cavallo	F	2	1	9	1	0	2	15
Oscurusciuto	2	2	3	26	0	0	1	32



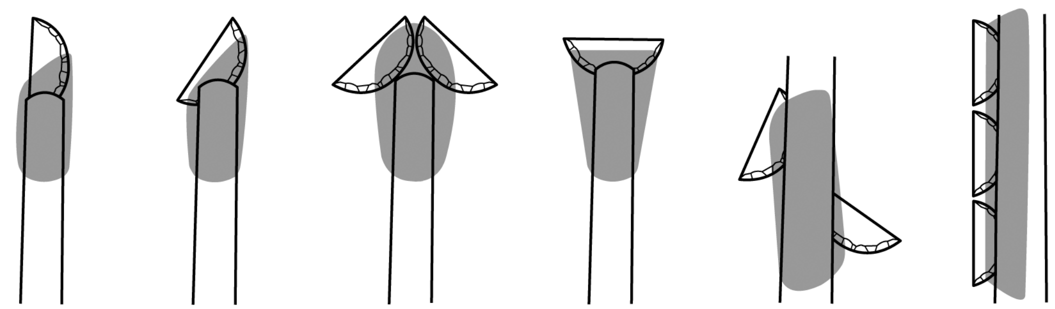
Supplementary Fig. 1 | Planimetry (a) and schematic stratigraphic sequence (b) of Grotta del Cavallo.

The excavation area related to the 1 963–1986 field seasons is shown in the planimetry with the trench excavated by A. Palma di Cesnola between 1963 and 1966, and the squares excavated by P. Gambassini in the years from 1979 to 1986. The continuous line marks the boundary of the "erosive event" 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 (ref. 1). The two deciduous teeth were found in the undisturbed deposit of the lowermost Uluzzian layer (EIII) from the area filled with oblique lines. The stratigraphic sequence is modified from Palma di Cesnola (2001) (ref. 98). Tephra layers Fa and CII have been correlated to Y-6 dated at 45.5 ± 1.0 ka (ref. 2) and Y-5 (Campanian Ignimbrite) dated at 39.85 ± 0.14 ka (refs. 2, 3).



Supplementary Fig. 2 | Single (a1, a2, a3, b1, b2, b3) and multiple (a1m, a2m, b1m, b2m, b2m, cm, d1m, d2m) DIF types.

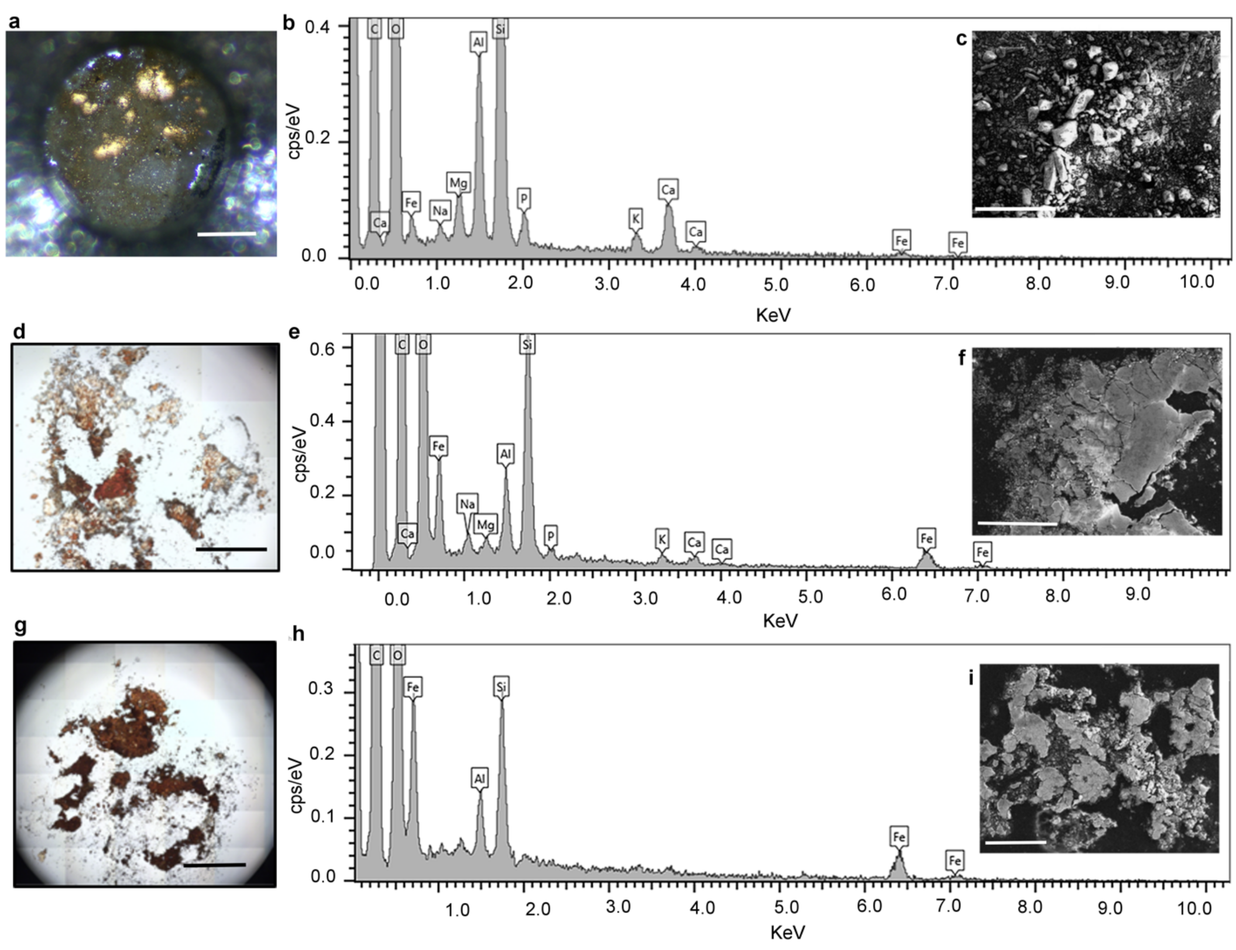
(**a1**) Flute-like or transverse fracture from steep angle. (**a2**) Burin-like fracture from steep angle. (**a3**) Burin-like fracture from backed side. (**b1**) Lateral fractures or crushing from sharp edge. (**b2**) Burin-like fracture on tip from oblique angle. (**b3**) Burin-like fracture from sharp edge. (**a1m**) Transverse fracture from steep angle with spin-offs. (**a2m**) Flute-like, burin-like, or transverse fractures from bidirectional steep angle. (**b1m**) Multiple burin-like fractures on tip from oblique angle. (**b2m**) Burin-like fractures on both tips from oblique angles. (**cm**) Combination of burin-like fractures from different angles. (**d1m**, **d2m**) Combination of lateral fractures (crushing) with transverse or burin-like fracture. After Yaroshevich *et al.* (2010) (ref. 10) and Goldstein & Shaffer (2017) (ref. 11).



a b c d e f

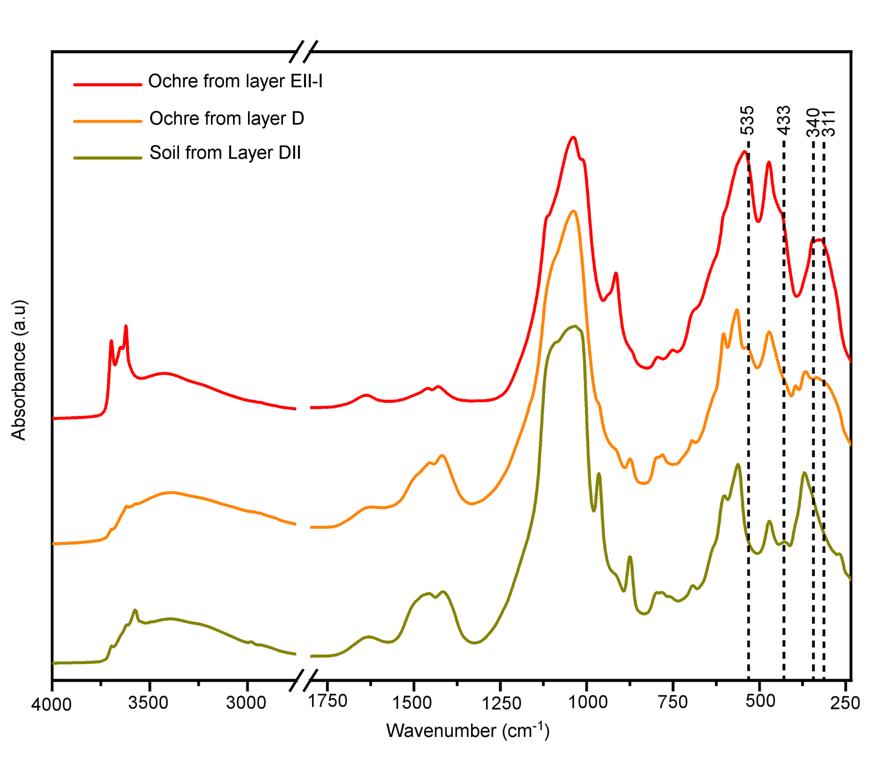
Supplementary Fig. 3 | Possible hafting modes of Uluzzian backed pieces based on the distribution of residues and reconstruction of Goldstein & Shaffer (2017) (ref. 11).

(**a**) Straight/oblique (<30°), (**b)** oblique (>30°), (**c**) double oblique, (**d**) transverse, (**e**) oblique barb, and (**f**) straight barb.



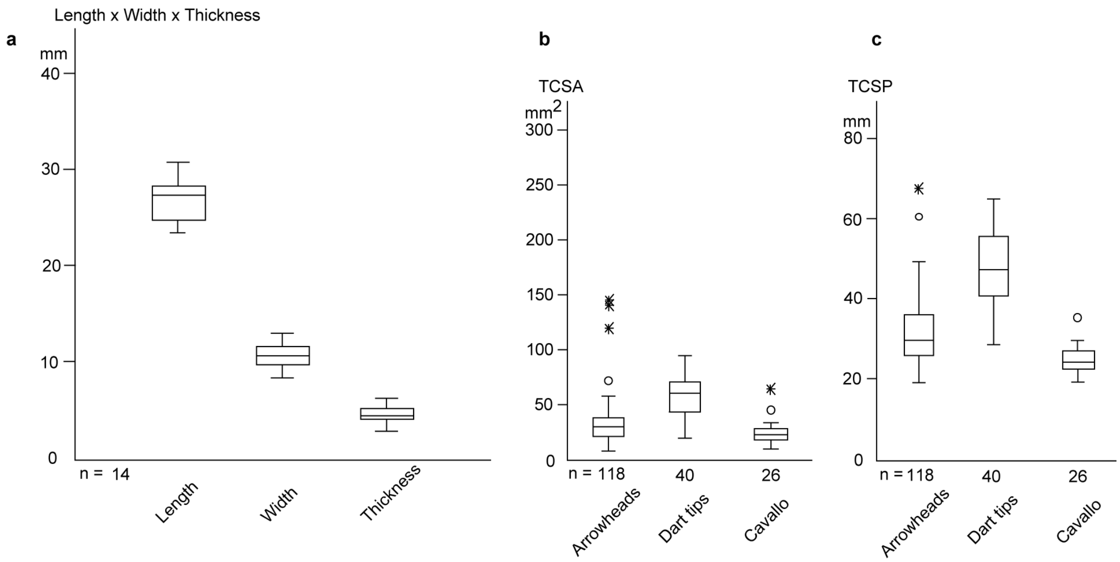
Supplementary Fig. 4 | SEM/EDX spectra of the soil sample and two Uluzzian backed pieces from Grotta del Cavallo.

Optical images of the closed diamond compression cell (scale bars: 500 µm), SEM/EDX spectrum and SEM image (scale bar 250 µm) of the soil sample from layer D (**a, b, c**), optical images of the open diamond compression cell (scale bars 500 µm), SEM/EDX spectrum and SEM image (scale bar 100 µm) of the sample #106 from spit E-D (**d, e, f**) and optical images of the open diamond compression cell (scale bars 500 µm), SEM/EDX spectrum and SEM image (scale bar 100 µm) of the sample #1 from layer EII-I (**g, h, i**).



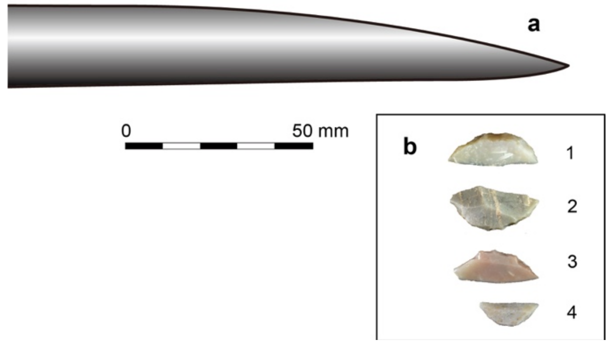
Supplementary Fig. 5 | Infrared spectra in the FIR-MIR spectral range of ochre samples from layers EII-I and D (red and orange lines, respectively) and soil sample from layer DII (olive line).

The absorption bands due to iron oxide are highlighted by dotted lines and their relative frequencies.



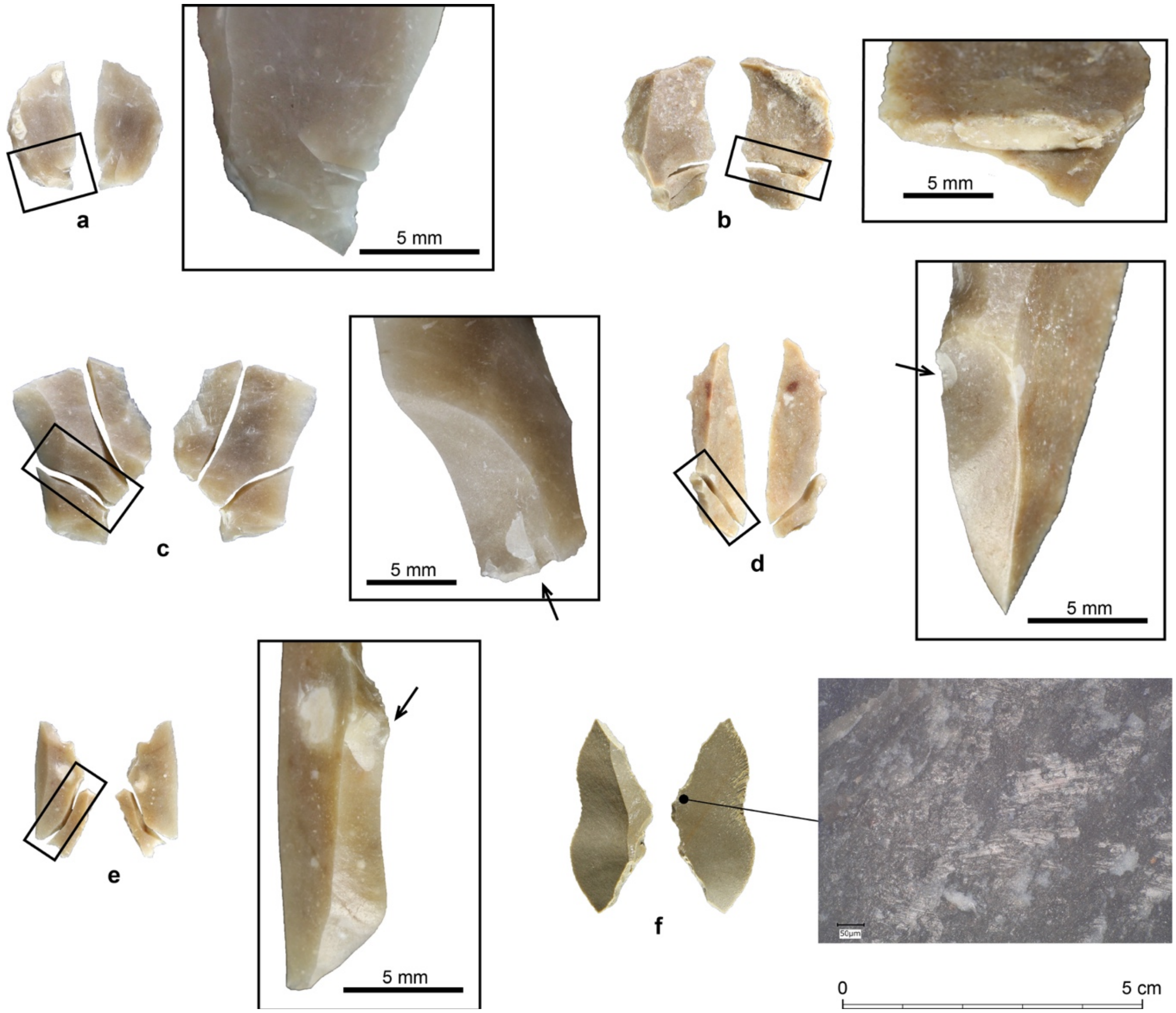
Supplementary Fig. 6 | Boxplots of length, width, and thickness of complete or almost complete backed pieces from Grotta del Cavallo (a) and boxplots of TCSA and TCSP values for backed pieces with DIFs from Grotta del Cavallo (b), compared to those of the North American ethnographic arrowheads and dart tips (c) (refs. 12, 13).

Median; box limits, upper and lower quartiles; whiskers, 1.5x interquartile range; points, outliers; asterisks, extreme outliers.



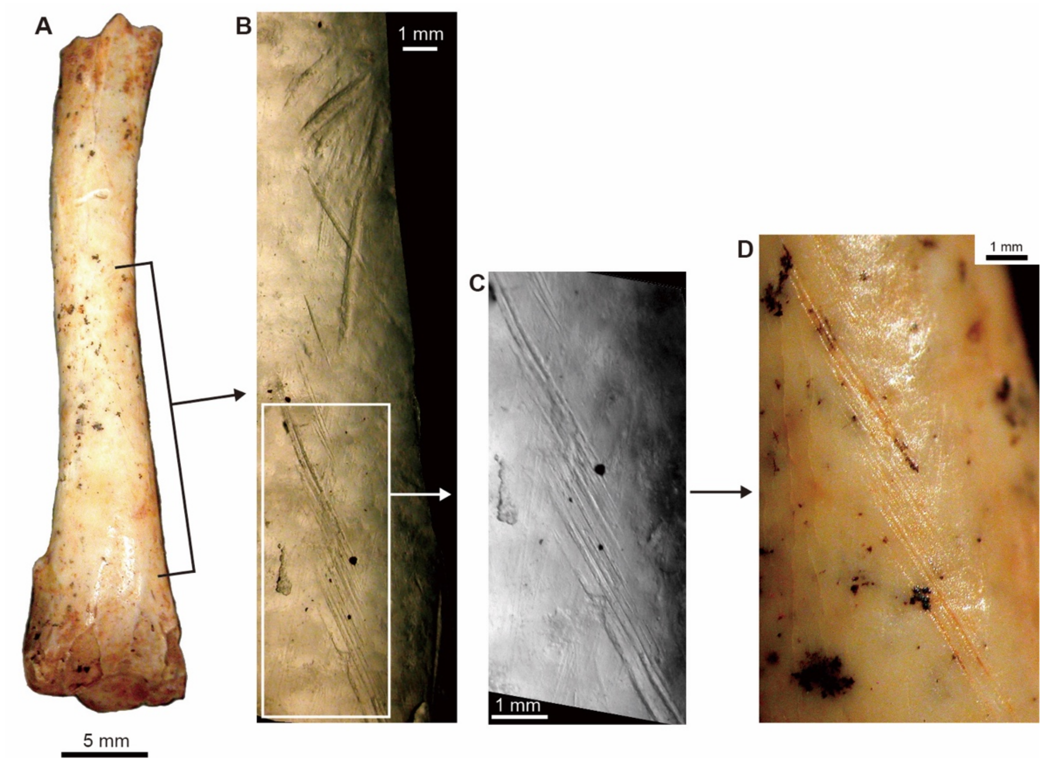
Supplementary Fig. 7 | Tip of a Schöningen spear (a) and representative Uluzzian backed pieces from Grotta del Cavallo (b).

(**a**) Spear II from Schöningen 13 II-4, reproduced after Thieme (1996) (ref. 99). The length is 230 cm and the maximum diameter is 37 mm.



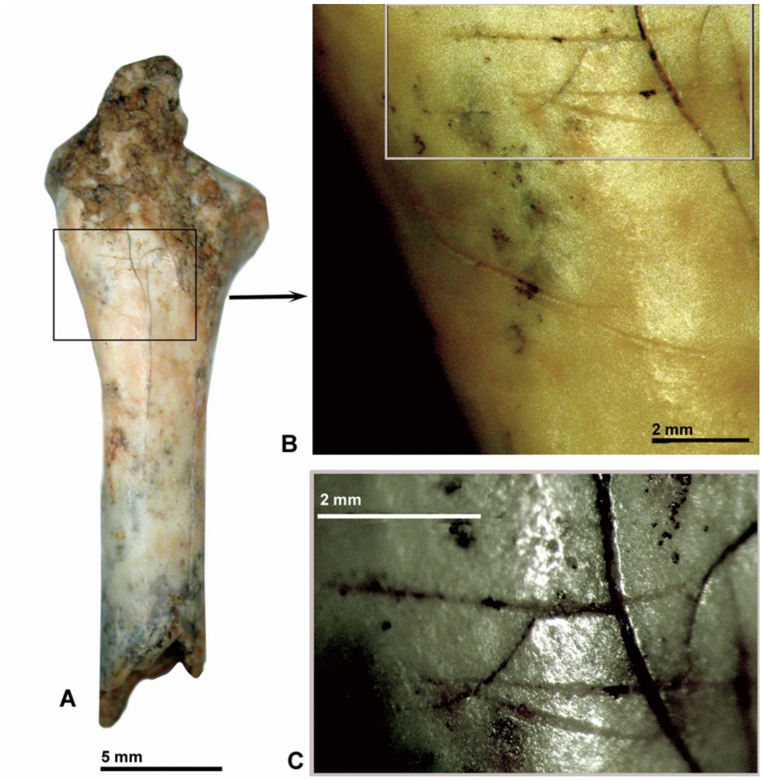
Supplementary Fig. 8 | Broken experimental replicas of Uluzzian backed pieces.

(**a**) Small bending fracture resembling a burin-like fracture. Such small burin-like and flute-like fractures can occur due to trampling as well and are difficult to distinguish from impact fractures. (**b**) Snap fracture with a finial. This type is considered as a non-diagnostic impact fracture. (**c–d**) Pseudo-burin-like fractures with a negative blub of percussion from the retouched side. (**e**) Pseudo-burin-like fracture with bending initiation from the retouched side (back). (**f**) Linear polishes due to retouching by a stone hammer. Arrows show the position of the negative bulb of percussion and the direction of the fracture progression. Impact fractures usually start from an end of the specimen without a negative bulb of percussion (bending initiation). Based on the presence of a negative bulb of percussion and the position of the fracture initiation, (**c–d**) can be distinguished from DIFs. (**e**) can also occur due to impact; hence, if a bending fracture starts from the retouched side, it should not be included as a DIF. (**f**) comprises short linear polishes with different directions from each other. Therefore, it is possible to distinguish linear polishes from a hammer percussion from MLITs characterized by long, stripe-like linear polishes running parallel.



Supplementary Fig. 9 | Humerus of Eurasian hobby (*Falco subbuteo*) showing traces of scraping (Castelcivita, Salerno).

The humerus lacks the proximal end and was fractured when it was still fresh. The distal end shows two surface gaps at the *sulcus scapulotricipitalis* and *processus flexorius*, probably due to tearing of ligaments during the disarticulation of the humerus from the ulna (**A**). Numerous oblique striae are distributed across the diaphysis on the caudal face (**B**). The striae on the proximal end are deep and intermediate in length, with different orientations, indicating cutting or engraving. In contrast, the striae on the medium-distal diaphysis are arranged in parallel bundles and are thin, superficial, straight, uniform, and closed (**C, D**). (**B, C**) are cast in Araldite, and (**D**) is the original surface. Such traces are probably not a result of butchery, as the portion in which these traces were found yields only small amounts of meat and the position and orientation of cut marks differ from those typically seen in butchery. Instead, these particular marks are due to scraping action, probably for the removal of feathers.



Supplementary Fig. 10 | Proximal ulna of Yellow-billed Chough (*Pyrrhocorax graculus*).
A number of cut marks attributed to disarticulation or skinning beneath the olecranon (**A**). The orientation of the striae suggests these were caused while detaching the wing portion with primary and secondary remiges (**B, C**).

Supplementary References

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

62. Palma di Cesnola, A. Seconda campagna di scavi nella Grotta del Cavallo presso Santa Caterina (Lecce). *Rivista Scienze Preistoriche* **19,** 23–29 (1964).

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

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

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

66. Churchill, S. E. & Smith, F. H. Makers of the early Aurignacian of Europe. *American Journal of Physical Anthropology* **113,** 61–115 (2000).

67. Leroi-Gourhan, A. & Leroi-Gourhan, A. Chronologie des grottes d'Arcy-sur-Cure (Yonne). *Gallia Préhistoire* **7,** 1–64 (1964).

68. Leveque, F. & Vandermeersch, B. Découverte de restes humains dans un niveau castelperronien à Saint-Césaire (Charente-Maritime). *C. R. Acad. Sci. Paris* **291,** 187–189 (1980).

69. Douka, K. *et al.* On the chronology of the Uluzzian. *Journal of Human Evolution* **68,** 1–13 (2014).

70. Banks, W. E., d'Errico, F. & Zilhão, J. Human–climate interaction during the Early Upper Paleolithic: testing the hypothesis of an adaptive shift between the Proto-Aurignacian and the Early Aurignacian. *Journal of Human Evolution* **64,** 39–55 (2013).

71. Peresani, M., Cristiani, E. & Romandini, M. The Uluzzian technology of Grotta di Fumane and its implication for reconstructing cultural dynamics in the Middle–Upper Palaeolithic transition of Western Eurasia. *Journal of Human Evolution* **91,** 36–56 (2016).

72. Peresani, M., Bertola, S., Delpiano, D., Benazzi, S. & Romandini, M. The Uluzzian in the north of Italy: insights around the new evidence at Riparo Broion. *Archaeol Anthropol Sci* **39,** 1–34 (2019).

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

74. Ambrose, S. H. Chronology of the Later Stone Age and food production in East Africa. *Journal of Archaeological Science* **25,** 377–392 (1998).

75. Ambrose, S. H. in *Thinking Small Global Perspectives on Microlithization* (eds. Elston, R. G. & Kuhn, S. L.) 9–29 (Thinking Small: Global Perspectives on Microlithization, 2002).

76. McBrearty, S. & Brooks, A. S. The revolution that wasn't: a new interpretation of the origin of modern human behavior. *Journal of Human Evolution* **39,** 453–563 (2000).

77. Pleurdeau, D. Human technical behavior in the African Middle Stone Age: the lithic assemblage of Porc-Epic Cave (Dire Dawa, Ethiopia). *Afr Archaeol Rev* **22,** 177–197 (2006).

78. Soriano, S., Villa, P. & Wadley, L. Blade technology and tool forms in the Middle Stone Age of South Africa: the Howiesons Poort and post-Howiesons Poort at Rose Cottage Cave. *Journal of Archaeological Science* **34,** 681–703 (2007).

79. Villa, P., Soriano, S., Teyssandier, N. & Wurz, S. The Howiesons Poort and MSA III at Klasies River main site, Cave 1A. *Journal of Archaeological Science* **37,** 630–655 (2010).

80. Brandt, S. A. *et al.* Early MIS 3 occupation of Mochena Borago Rockshelter, Southwest Ethiopian Highlands: implications for Late Pleistocene archaeology, paleoenvironments and modern human dispersals. *Quaternary International* **274,** 38–54 (2012).

81. Gliganic, L. A., Jacobs, Z., Roberts, R. G., Domínguez-Rodrigo, M. & Mabulla, A. Z. P. New ages for Middle and Later Stone Age deposits at Mumba rockshelter, Tanzania: optically stimulated luminescence dating of quartz and feldspar grains. *Journal of Human Evolution* **62,** 533–547 (2012).

82. Eren, M. I., Diez-Martín, F. & Domínguez-Rodrigo, M. 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. *Journal of Archaeological Science* **40,** 248–256 (2013).

83. la Peña, de, P. 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 (2015).

84. la Peña, de, P., Taipale, N., Wadley, L. & Rots, V. A techno-functional perspective on quartz micro-notches in Sibudu's Howiesons Poort indicates the use of barbs in hunting technology. *Journal of Archaeological Science* **93,** 166–195 (2018).

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

86. Lombard, M. Quartz-tipped arrows older than 60 ka: further use-trace evidence from Sibudu, KwaZulu-Natal, South Africa. *Journal of Archaeological Science* **38,** 1918–1930 (2011).

87. Lombard, M. & Wadley, L. in *Multidisciplinary Approaches to the Study of Stone Age Weaponry* (eds. Iovita, R. & Sano, K.) 273–286 (Springer, 2016).

88. Gala, M., Fiore, I. & Tagliacozzo, A. in *Palaeolithic Italy. Advanced studies on early human adaptations in the Apennine* (eds. Borgia, V. & Cristina, E.) 187–217 (Sidestone Press, 2018).

89. Cassoli, P. F. & Tagliacozzo, A. Butchering and cooking of birds in the palaeolithic site of Grotta Romanelli (Italy). *Int. J. Osteoarchaeol.* **7,** 303–320 (1997).

90. Laroulandie, V. Alpine chough Pyrrhocorax graculus from Pleistocene sites between Pyrenees and Alps: natural versus cultural assemblages. *Groningen Archaeological Studies* **12,** 219–232 (2008).

91. Peresani, M., Fiore, I., Gala, M., Romandini, M. & Tagliacozzo, A. Late Neandertals and the intentional removal of feathers as evidenced from bird bone taphonomy at Fumane Cave 44 ky B.P., Italy. *Proceedings of the National Academy of Sciences* **108,** 3888–3893 (2011).

92. Mathieson, I. *et al.* The genomic history of southeastern Europe. *Nature* **555,** 197–203 (2018).

93. Finlayson, C. *et al.* Birds of a feather: Neanderthal exploitation of raptors and corvids. *PLoS ONE* **7,** e45927 (2012).

94. Finlayson, S. & Finlayson, C. The birdmen of the Pleistocene: On the relationship between Neanderthals and scavenging birds. *Quaternary International* **421,** 78–84 (2016).

95. Fiore, I. *et al.* From feathers to food: reconstructing the complete exploitation of avifaunal resources by Neanderthals at Fumane cave, unit A9. *Quaternary International* **421,** 134–153 (2016).

96. Romandini, M. *et al.* Neanderthal scraping and manual handling of raptors wing bones: evidence from Fumane Cave. Experimental activities and comparison. *Quaternary International* **421,** 154–172 (2016).

97. Spagnolo, V. *et al.* Neanderthal activity and resting areas from stratigraphic unit 13 at the Middle Palaeolithic site of Oscurusciuto (Ginosa - Taranto, Southern Italy). *Quaternary Science Reviews* 1–25 (2018).

98. Palma di Cesnola, A. *Le Paléolithique supérieur en Italie*. (Jérôme Millon, 2001).

99. Thieme, H. Altpaläolithische Wurfspeere aus Schöningen, Niedersachsen: ein Vorbericht. *Archäologisches Korrespondenzblatt* **26,** 377–393 (1996).