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The Uluzzian in the north of Italy. Insights around the new evidence at Riparo Broion.

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Abstract

In attempt to enlighten the debate on the Middle to Upper Palaeolithic transition, this work contributes new data from a yet unpublished site, Riparo Broion in the north-east of Italy. Studies confirm the presence of the Uluzzian technocomplex embedded in an archaeological sequence which includes Mousterian, Gravettian and Epigravettian. These layers have yielded finds of bone and lithic technology, shell beads, engraved portable art and the use of red mineral pigments, which make this archive a unique case for evaluating the implications of cultural dynamics in Northern Italy 44.0-42.4 ky BP. The diversity of the faunal assemblage recovered in layers 1f and 1g is representative of the different environments surrounding the site, with ungulates being targeted for hunting and consumption. The lithic assemblage records a high fragmentation rate due to the extensive use of the bipolar knapping technique, responsible for a large variety of splintered pieces and associated chips which also affected the backed pieces, lunates and end-scrapers. The features of the bone tools, as well as those of the marine and freshwater beads echo the technique used in the Uluzzian in the south of Italy, confirming the geographic spread of this technocomplex in the North-Adriatic region, as previously envisaged at Grotta Fumane. However, comparisons between these two sites stimulate a discussion around the possible driving forces responsible for the differences observed in technological, typological and structural lithic assemblages. A definitive scenario for the MP-UP transition in this region of Southern Europe is on-going and Riparo Broion is adding key contributions.

Key-words: Palaeolithic, Uluzzian, Radiocarbon dating, Bead, Rockshelter, Italy.

1. Introduction

Cultural change is one of the most investigated topics in palaeoanthropology, especially during the pivotal phase in human evolution represented by the Middle to Upper Palaeolithic in Western Eurasia. When and how early *Homo sapiens* replaced the native population, *Homo neanderthalensis*, is still far from being clarified, and the relations between these biological taxa and their respective material cultures is a subject of heated debate. Collected data on the

ecological, behavioral and cognitive spheres of these taxa, drive, at times, contested attributions of some specific expressions of past human diversity. Pieces of this intriguing puzzle have been unveiled in recent years from the cultural complex known as the Uluzzian, which spreads across the central Mediterranean rim from the Italian peninsula to the south of the Balkans (Palma di Cesnola 1989; 1993; Riel-Salvatore 2009; Ronchitelli et al. 2009; 2018; Moroni et al. 2013; 2018; Douka et al. 2014; Peresani 2014; Villa et al. 2018). Traditionally, the Uluzzian is characterized as a lithic and bone technocomplex that produces flakes and blades with pieces that are splintered or backed, crescent-shaped microliths, as well as endscrapers, bone tools and ornamental beads. At present, the Uluzzian is the oldest known cultural expression paleoanthropologically associated with Anatomically Modern Humans in Western Eurasia, as evidenced by the anatomical features of two deciduous teeth discovered in Grotta del Cavallo in Apulia (Benazzi et al. 2011). Along the Italian peninsula, the Uluzzian is currently best known by its stratigraphic position above the Mousterian in cave sedimentary sequences (Fig. 1). This has also been observed in northern Italian cave sites, which expanded its cultural borders from what was thought to be exclusively southern after the discovery of assemblages at Grotta Fumane (Peresani 2008; Peresani et al. 2016). There is a lack of comparable diagnostic evidence in many of the stratified sites along the Ligurian arch, where the final Mousterian persists until 40.5 ky (Higham et al. 2014; Riel-Salvatore and Negrino 2018) and along the southern and eastern margins of the Po Plain (Peresani 2011; Karavanić et al. 2018). This geographical space constrained from the Apennine, the Southern Alps, the Dinarids and the shallow Adriatic reach of MIS3 (van Andel et al. 2003), features high ecological diversity, and is of pivotal importance in influencing the possible human migratory routes and interactions between these biocultural worlds. This is relevant for further increasing the frame of the on-going debate regarding the makers of the Uluzzian (Moroni et al. 2013; Zilhão et al. 2015; Peresani et al. 2016), and the taxonomy of the evidence recognized at Fumane (Moroni et al. 2018; Benazzi et al. 2014; Villa et al. 2018). This calls for additional cultural and taphonomic data from the transitional sequence in question.

To disentangle the story of the first modern human arrivals and the last Neanderthals in this area and the role this may play, we present new evidence for the Uluzzian from a yet unpublished site, Riparo Broion, situated 60kms east of Fumane in the Berici Mounts. Studies at this site have confirmed the Uluzzian chronology, contributed new data on human ecology, bone technology, and, more significantly, shed light on lithic technology at this latitude with correlation to the extreme south of Italy. Other remains, such as worked marine shells and perforated freshwater shells, engraved portable art and materials with red pigmentation make Riparo Broion a unique case in the effort to evaluate the implications of cultural innovations in Northern Italy 43 ky years ago, offering a behavioural perspective on relations among different human groups.

2. Riparo Broion

2.1 Geographical and palaeocological setting

Riparo Broion lies in the Berici Mounts, a carbonatic karst plateau at the southern fringe of the Venetian pre-Alps in the Alpine foreland. This is a large alluvial plain that was formed initially during the Middle and Late Pleistocene by a number of major rivers, including the Po, the Adige and those of the Friulian-Venetian plain.

Figure 1. Sketch map showing the position of the sites in the Italian Peninsula mentioned in the text: (1) Grotta Rio Secco, (2) Grotta Fumane and Grotta Ghiacciaia, (3) Riparo Tagliente, (4) Riparo Broion, (5) Grotta La Fabbrica, (6) Grotta Fossellone, (7) Grotta Castelcivita, (8) Grotta La Cala, (9) Grotta Cavallo, Grotta Bernardini, Grotta Uluzzo. Sea level 70 m below the present-day coastline (courtesy by S. Ricci, University of Siena. Based on the global sea-level curve by Waelbrock et al. (2002), but lacking estimation of post-MIS3 sedimentary thickness and eustatic magnitude)

The Berici plateau extends over almost 200km^2 in the sub-alpine region (Fig. 2). It is isolated from other formations of similar constitution and morphology, like the Lessini Mountains located to the north-west, which are separated by a stretch of open plains formed by the Astico and other fluvial systems and which are bordered by the Brenta megafan in the south-east. The conical volcanic reliefs of the Euganean Hills are situated a further 10km to the east. The Berici is a landscape which has undergone karstic and fluvio-karstic processes, since at least the Middle Miocene, leading to the formation of sinkholes, dry valley systems and valley segments which evolved into large, closed basins (Sauro 2002). The plateau is bisected by two main valleys, the Val Liona and the Fimon Valleys which divide the plateau into two distinct zones. The eastern zone is a vast, articulated, tabular area which terminates abruptly at the alluvial plain along

its south-eastern side where several caves open onto the alluvial plain. The Riparo Broion is situated on this side along with many others, including the Grotta Maggiore and Grotta Minore di San Bernardino, Covolo di Trene and Grotta Paina. All of these sites have at some point yielded Middle and Upper Palaeolithic archaeological remains. The western zone of the Berici is a gentle landscape which conjoins with the alluvial plain. The highest peaks are located along the south-eastern margin and reach approximately 400m in elevation, with the highest, Mount Altissimo, reaching up to 444m above sea level.

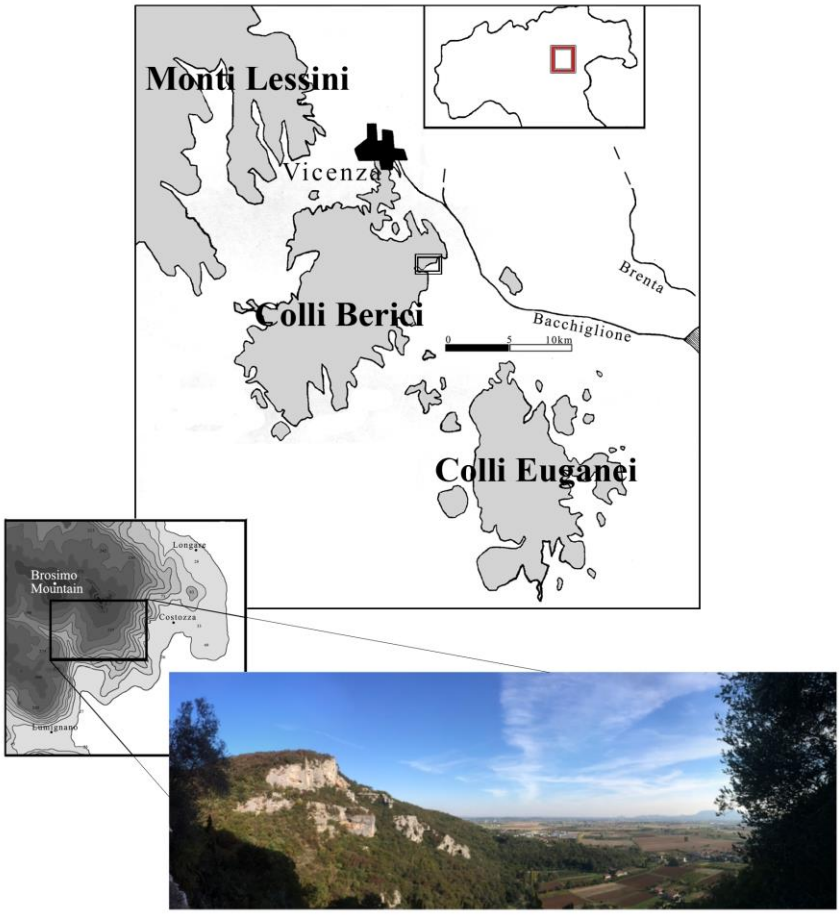

Figure 2. Top right: northern Italy with the location of the Berici Hills. Bottom: sketch map of the Berici plateau with location of Riparo Broion (45° 28' 55" Lat. north - 11° 35' 31" Long. est Greenwich)

Riparo Broion is located in the northern part of the Berici eastern slope, at 135m a.s.l., along a steep cliff face which connects the top of Mount Brosimo (327 m a.s.l.) to the plain (Fig. 2). The whole area up to and over the shelter has been at times artificially terraced for cultivation. The shelter, which is 10m long, 6m deep and 17 m high, was formed by a rock collapse along a major ENE-WSW oriented fault that developed from thermoclastic processes and chemical dissolution, which is comparable to other cavities in the area (Sauro 2002; Dal Lago and Mietto 2003). On the western side of the same cliff, two cavities are situated, one smaller named Grotta del Buso Doppio del Broion and another, deeper pit, called Grotta del Broion. Based on previous archeological investigation, both seem to have been used in the Palaeolithic (Peresani and Porraz 2004; Romandini et al. 2015). The slope around the shelter is characterized by escarpments and cliffs with remnants of collapsed sinkholes. Clayey slope-waste deposits can be found at the foot of Mount Brosimo, which develop into the marshes and swamps of the lowlands.

During the time span of 65ka from the Early to Middle Würm (MIS5a-d to MIS3), no signs of significant aggradation or fluvioglacial activity are recorded on the alluvial plain, which when combined with relatively low sedimentation rates

(Monegato et al. 2011) in both lacustrine and alluvial successions, indicates stability in the water table. Sea-level changes were minor and had very limited influence on alluvial sedimentation (Suríc and Juracić 2010; Monegato et al. 2011). Persistent afforestation with some temperate trees, notably *Tilia* and *Abies*, has been recorded from a pollen core taken at Lago di Fimon. These conditions seemingly persisted throughout the entire early and middle part of the last glaciation, with only moderate forest contractions during the early Dansgaard-Oescher climatic events (Pini et al. 2010). On the Friulian-Venetian alluvial plain, the pollen record of the Middle Würm period shows an episode of vegetation transition, including phases of contraction of open birch-conifer forests and expansion of xerophytic scrubs and steppe communities, that alternate with mixed conifer (*Pinus* and *Picea*) and *Betula* forests (Pini et al. 2009).

2.2 Archaeological excavation and current research

The shelter deposit was partially excavated in historical times, creating a trampled surface which was used for keeping sheeps and goats and as a store area for hay and wood. More recent destruction occurred in 1984 when unauthorized excavators removed sediment from the surface, creating an ensemble of pits and trenches that measures 14sqm by 2m deep from the present-day surface. The first archaeological excavations were carried out by Prof. Alberto Broglio from 1998 to 2008 and by two of us (M.P. and M.R.) in 2015, concluding with investigations on 20sqm extended area under the sheltered zone, bounded to north and west from the rock walls. A Pleistocene sequence with faunal remains, and Middle to Upper Palaeolithic cultural sequence (De Stefani et al. 2005) was uncovered. The bedrock has not yet been reached.

2.3 Sedimentary sequence

The deposit at Riparo Broion is made up of stones which largely prevail on the loamy fine fraction and carbonatic concretions. Of the stratigraphy which has been exposed, 16 units have been identified, which are planarly bedded (Fig. 3). The lowermost (13, 9, 7 and 4) contain Mousterian artifacts. Apparently, no evidence of anthropic activity has surfaced in units 2 and 3 in contrast with unit 1 where Upper Palaeolithic lithic assemblages have been recovered. Sediments are loose and partially reworked in a 30cm wide belt alongside the northern shelter wall which has been disturbed by marmot denning activity, and two pits excavated in historical times. Unit 1 has been split into seven subunits (layers), from 1g to 1a. Above an abrupt, not erosional, boundary with unit 2, layer 1g is a stony deposit discontinuously concreted, with a light gray loamy fraction and gravel that has been sorted by the activity of rodents of varying size. The upper boundary with layer 1f varies from regular to patchy due to the uneven microtopography produced by bioturbation, particularly along the northern wall. The upper boundary of layers 1f to 1e is at times so ephemeral as to make lithological distinction uncertain. The light brown loamy fraction is predominantly stony, consisting of sub-rounded middle-sized clasts. In addition, layer 1f has been affected by bioturbation and erosional processes in close proximity to the northern wall. Layers 1e and 1d, however, have clear upper boundaries. Stones are prevalent in the light brown loamy fraction. The lithic industry was attributed to the Gravettian (De Stefani et al. 2005). One further Gravettian assemblage has been yielded from layer 1c which has an abrupt upper boundary with 1b. This is a stony layer with a light brown loamy fraction, partially concreted and protected from bioturbation. At the top, stones are still prevalent in layers 1b and 1a, consisting of medium to large pebbles in a light brown loamy fraction. At the base, 1b and 1a have been attributed to the Early Epigravettian (Broglio et al. 2009) and are associated with backed points with shouldered points and a few leaf pieces. The upper boundary of 1a (1aα) is artificially truncated by the Pleistocene deposit made in historical times and coincides with the present-day trampling surface.

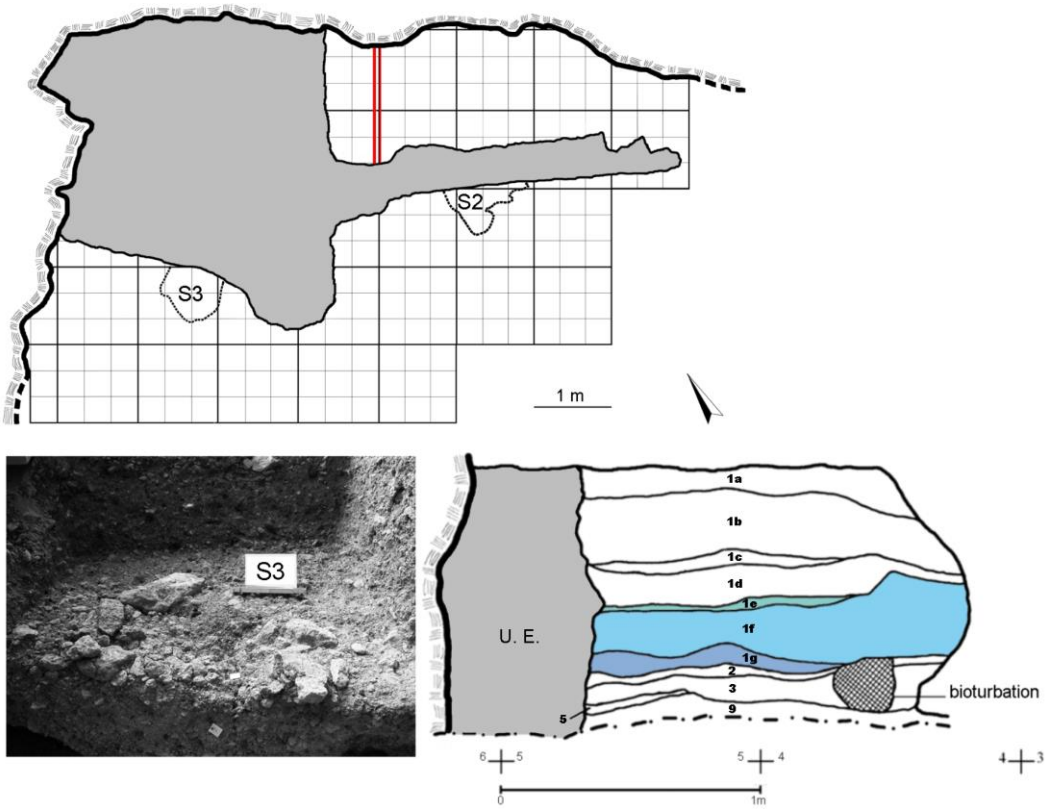

Figure 3. Top: plan of the excavated area with location of the hearths and the reference stratigraphic section (red line). Bottom left: hearth S3 in layer 1g seen from the north. Bottom right: sketch section of the upper deposit of the Riparo Broion (units from 1 to 7) exposed across squares AA4, AA5 and AA6 (numbers of the grid are reported in figure 4; drawing by G. Di Anastasio and N. Cappellozza)

2.4 Dwelling structures in layers 1g and 1f

Two hearths, S2 and S3, were discovered in layer 1g. S2 is positioned in the central area of the shelter in a shallow, 8cm deep and 50cm wide pit deliberately excavated in unit 2 and is dissected to the north by the unauthorized excavation. Tiny fragments of charred wood, chunks of burnt bones and thermally weathered flint artifacts mark the presence of this hearth. Any reddened horizon has been observed on the field.

Hearth S3 was discovered in the western sector (AB2-AC2-AC3), at the base of 1g. This 80cm diameter hearth is positioned in a 10cm deep, 50cm wide pit excavated in unit 2 and, like S2, is dissected to the north by the unauthorized excavation (Fig. 3). S3 is delineated by five carbonatic stones with the same lithology as the shelter walls. Loamy sediment with small fragments of charcoal also feature in this structure.

2.5 Chronometric data

A first set of Accelerator Mass Spectrometry (AMS) radiocarbon measurements was presented in a previous report (De Stefani et al. 2005), based on ABA treated charred wood and burnt bone samples taken from layers throughout the stratigraphic sequence, though primarily from layer 1g. Table 1 lists four dates from 1g, one from 1c, two from 1b and one from 1bα. During this preliminary phase, no samples were selected from layer 1f for radiocarbon dating due to lack of reliable materials. All these samples have diverse topographic provenience and none falls in the same square meter along the stratigraphic column, except UtC-13320 and UtC-13321. To avoid the risk of contamination by trampling and other perturbations, most of the samples were collected from the easternmost zone and only one from the southernmost zone, in an area untouched by illegal excavations and considered unaffected by post-depositional disturbance.

Material	Lab. code	Context	Square	Structure	14C Age
Charcoal	UtC-10504	1bα	A5f		27,960±300
Charcoal	UtC-13320	1b	A3g		28,460±260
Charcoal	UtC-10506	1b	B5i (S1)	S1	17,830±100
Charcoal	UtC-13321	1c	A3g		25,860±200
Burnt bone	UtC-11791	1g	B3e (S2)	S2	25,980±190
Charcoal	UtC-11790	1g	B3d (S2)	S2	32,100±400
Charcoal	UtC-12509	1g	AC2c (S3)	S3	31,700±400
Charcoal	UtC-11792	1g	B3a+b		30,480±300
Bone	OxA-35527	1g	AC1h		38,900±1000

Table 1. List of the radiocarbon dates

The dated charcoal samples from 1g were taken from hearths S2 and S3, as well as a third one in close proximity to the latter. Except for the burnt and fragmented bones selected from S2, the two dates from the hearths are chronologically consistent with each other. UtC-11792 by contrast does not overlap with these measurements, despite its broad chronological consistency. As expected, the date obtained from the burnt bone was unreliable due to low collagen content after standard treatment (Higham 2011). Layers 1c and above are younger in age and consistent with both their stratigraphic position with respect to 1g and their cultural attribution to the Gravettian. However, although UtC-10504 and UtC-13320 are statistically indistinguishable from each other, they are much older than UtC-10506, the youngest date of this set, despite its association to hearth S1. Values look highly dispersed due to the date of layer 1c, which falls in between the radiocarbon dataset of 1b and 1bα, thus defining an inverted shift with respect to stratigraphic order. The underlying cause of the chronometric inversion in the mid-Upper Palaeolithic record at Riparo Broion will be taken into consideration in future investigations.

Returning to layer 1g, the three dates so far ascertained fit their stratigraphic position and correlate both to their association with the hearths and to the square from which the samples originate. This therefore excludes contamination risks due to post-depositional disturbance. However, the 32.5-30.2 14C ky BP uncalibrated range does not match cultural attribution to either the Uluzzian layer 1g, regardless of the spatial distribution of the samples recovered from it, or by extension layer 1f, which should be younger in age based on its stratigraphic relationship to 1g. Highly dispersed radiocarbon dates younger than the securely dated Cambrian Ignimbrite tephra that seal several Middle Palaeolithic to Upper Palaeolithic sequences are known from sites throughout Italy and southeastern Europe (Giaccio et al. 2008). This inconsistency is due to various factors, including problems in removal of contamination before the radiocarbon measurement (Higham 2011; Higham et al. 2009). A similar occurrence was recorded at Grotta di Fumane, in the Uluzzian, where several radiocarbon determinations from level A3 produced a date range of 29-37 14C ky BP (Peresani et al. 2008; Higham et al. 2009), despite most of these dates being too young with respect to their stratigraphic relationships to the above Aurignacian layer, A2. Comparably to layer 1g at Riparo Broion, three pieces of charcoal collected from two hearths (SI and SII) and dumped material (SIV) in level A3 in Fumane range from 28.9-30.0 14C ky. In marked contradiction with these results, only LTL-1795A (37,828±430 14C BP) appeared to correspond with the A3 sequence (Higham et al. 2009). Further confirmation to support the reliability of this date came from bone samples taken from A4 and A3 (Douka et al. 2014).

Seeking chronometric consistency, one further specimen of the only two available anthropically modified large bone samples from Riparo Broion was submitted for dating, specifically a percussion cone produced from the deliberate smashing of an indeterminate mammal bone found in layer 1g, 1m south of hearth S3. Due to its dispersion and tiny

size, charred wood was not considered worth to be selected for dating. The radiocarbon date obtained from collagene ultrafiltration treatment consistently overlaps with the chronometric interval available for A3 at Fumane cave and Cavallo cave in the south of Italy (Douka et al. 2014; Zanchetta et al. 2018), thus supporting arguments for considering the position of Riparo Broion in the Uluzzian chronological range. Refinement of the chronology will be one of the focuses in ongoing programs.

3. Materials and methods

Zooarchaeological analysis of the bone assemblages yielded by layers 1e, 1f and 1g has been carried out on 37,390 faunal remains so far. Of these, 37,381 belong to mammals, 7 to birds and 2 to fish (Table 2). Brittle bones have been consolidated in the laboratory. All the remains have been counted, separating the burned and calcined bones from the unburned, and grouped by size (0-1cm, 1-2cm, 2-3cm, 3-4cm, 4-5cm, >5cm). They were then examined for taxonomical attribution at a family level, in instances when species or genus level could not be determined. Unidentified mammal bones were also grouped by size as follows: large (red deer, elk, megaceros, bison, auroch and bear), medium (alpine ibex, chamois, roe deer), and small (hare, marmot, beaver, mustelids, wild cat and fox).

Taxonomic and skeletal identification were based on two reference collections. The first is stored at Lazio Museum Pole at the National Prehistoric Ethnographic Museum "Luigi Pigorini" in the Bioarchaeology Section in Rome, while the second is in the Prehistoric and Anthropological Sciences Section at the University of Ferrara. Microscopic analyses of the bone surfaces were carried out using portable low-magnification lenses (10-20X) and Leica S6D Green Ough stereomicroscopes with 0.75-70X magnification range at the University of Ferrara. In specific cases, observation was also carried out using scanning electron microscopy at the Electronic Microscopy Laboratory in the Department of Life Sciences and Biotechnologies at the University of Ferrara. Digital photographs were taken with a Nikon Coolpix 4500 or Nikon D5100 camera and then processed with Adobe Photoshop 9.0, CS5.

In order to determine the nature of the surface bone alterations, and to distinguish human from animal traces, trampling abrasion, and modern mechanical modifications produced by excavation tools, reference was made to the well-established taphonomic literature (Binford 1981; Brain 1981; Potts and Shipman 1981; Shipman 1981; Shipman and Rose 1984; Blumenshine and Selvaggio 1988; Capaldo and Blumenshine 1994; Lyman 1994; Blumenshine 1995; Fisher 1995). The degree of combustion was evaluated employing the methodology developed by Stiner et al. (1995). Sex and age at death were determined to complete the dataset that would be used in reconstructing the strategies of exploitation of different species (Aitken 1974; Mariezkurrena 1983; Vigal and Machordom 1985; D'Errico and Vanhaeren 2002; Fiore and Tagliacozzo 2006). Measurements were taken following von den Driesch (1976). Given the small number of determined elements and the poor preservation of the bones, the minimum number of individuals estimate (MNI) is considered unreliable (Bökönyi 1970).

As concerns lithics, the analyses refer to all the material coming from layers 1f, 1g, and from the interfaces including the top of those levels. Level 1g is by far the richest, containing approximately the 80% of the whole assemblage.

However, the macro-unit, including layer 1f and the interface between 1f and 1g appear to be a homogeneous assemblage, clearly distinct from the upper and lower stratigraphic units (De Stefani et al. 2005). Given the very low number of findings in layer 1e, this material has been assembled with layer 1f. A section characterized by higher density of artifacts is located south of the unauthorized excavations: it is a wide ellipsoidal area expanded N/NW-S/SE, starting from the western wall and ending against southern artificial limits.

Taxa	1e		1f		1g		TOTAL	
	Nisp	%	Nisp	%	Nisp	%	Nisp	%
Lepus sp.			2	*11.1*			2	*3.4*
Marmota marmota			1	*5.6*	2	*2.2*	3	*5.1*
Castor fiber			1	*5.6*			1	*1.7*
Total Rodentia			4		2		6	
Vulpes vulpes					4	*4.4*	4	*6.8*
Ursus spelaeus	2	*40.0*	3	*16.7*	16	*17.8*	21	*35.6*
Ursus sp.			2	*11.1*	11	*12.2*	13	*22*
Martes sp.					1	*1.1*	1	*1.7*
Felis silvestris					2	*2.2*	2	*3.4*
Felidae					1	*1.1*	1	*1.7*
Carnivora			2	*11.1*	4	*4.4*	6	*10.2*
Total Carnivora	2		7		39		48	
Sus scrofa					21	*23.3*	21	*35.6*
Capreolus capreolus			2	*11.1*	1	*1.1*	3	*5.1*
Cf. *Alces alces*					3	*3.3*	3	*5.1*
Alces/Megaloceros	1	*20.0*	1	*5.6*	7	*7.8*	9	*15.3*
Cf. *Megaloceros giganteus*					2	*2.2*	2	*3.4*
Cervus elaphus					5	*5.6*	5	*8.5*
Cervidae	1	*20.0*	1	*5.6*	2	*2.2*	4	*6.8*
Bison priscus					1	*1.1*	1	*1.7*
Cf. *Bos primigenius*					1	*1.1*	1	*1.7*
Bovidae					1	*1.1*	1	*1.7*
Capra ibex					1	*1.1*	1	*1.7*
Rupicapra rupicapra	1	*20.0*	2	*11.1*	1	*1.1*	4	*6.8*
Caprinae			1	*5.6*	3	*3.3*	4	*6.8*
Total Ungulata	3	*100.0*	7	*100.0*	49	*100.0*	59	*100.0*
Total Nisp	5	*0.3*	18	*0.5*	90	*0.3*	113	*0.3*
Mamm. Big size	4	*0.2*	10	*0.3*	97	*0.3*	111	*0.3*
Mamm. Medium size	5	*0.3*	23	*0.7*	106	*0.4*	134	*0.35*
Mamm. Small size			1		7		8	*0.02*
Undetermined	1790	*99.5*	3502	*99.0*	31723	*99.3*	37015	*99.0*
Tot. size mammals + undet.	1799	*99.7*	3536	*99.5*	31933	*99.7*	37268	*99.7*
Total mammals remains	1804		3554		32023		37381	*100.0*
Pisces			1		1		2	
Anas platyrhynchos			1		1		2	
Anas Cf. *crecca*					1		1	
Aves undet.	1		1		2		4	
Total *Aves*	1		2		4		7	
Total remains	1805		3557		32028		37390	

Table 2. Summary table of the analyzed mammals, fish and birds bone remains from sub-unit 1e-1f-1g, with Number and percentage of Identified Specimens (NISP)

After an initial screening of all the lithic material, further in-depth analysis focused on the most significant dimensional and/or technological classes: primarily, cores, tools and their by-products (retouched pieces, retouch and resharpening

flakes, splintered pieces, bladelets and scales from splintered pieces) have been taken into account. The rest of the material (flakes, cortical pieces, knapping mistakes, fragments) was considered for the technological analyses if it had a module (length plus width) equal to or greater than 3cm or its major axis was no smaller than 2cm. Finally, regarding lamellar products (intact or fragmented bladelets), these measurement limits were discarded, and instead every artifact was analyzed except for the smallest chunks and most fractured pieces.

These in-depth analyses resulted in the compilation of a database, structured on the base of 1,295 lithic implements deemed to have had a significant role in production. This included a report of all the data required for morpho-technical, diacritic, and morphometric analyses. The conceptual and analytical approach applied to the technological analysis of the knapped stone tools was based on Inizan et al. (1995). Morpho-technical analyses used technological and morphological criteria for understanding the role and the position of each flake along the reduction sequence specifically for each flaking method. Particular attention was given to the intersection or the consequential development of the different knapping methods on the same blanks: some finished pieces were in fact recycled and exploited with bipolar knapping, destroying the previous tool but giving a new and different life to the blank. Morphometric data (length, width and thickness) were taken following the morphological axis of the flake, with attention to the cortical products, the end-products and the cores. Technological descriptions of both the major and minor lithic productions, together with the key typological features of the retouched blanks, are given in the paragraphs below.

The conservation degree of the material, which is not always optimal, has partially precluded the analysis: there are some rare surface alterations caused by water percolation or heating activities, but primarily, widespread fragmentation is present, largely related to split fractures due to exploitation by bipolar knapping. The tables of composition refer to the minimum number of flakes (MNF), with estimations based on complete specimens. For fragmentary pieces, the proximal-mesial part of bipolar knapping by-products (chips/flakes and spalls/bladelets) were counted, because the butt is often crushed and the only distal part is rarely satisfactory for the identification for these classes of artifacts. On other flakes and bladelets the MNF is assured by cross-checking the raw material, the blank techno-typology and the preserved portion; among these fragments there are currently no refitted elements except for a retouched blade.

The technological approach permitted us to distinguish and isolate, at first, the products obtained with bipolar knapping from those derived from direct percussion. To discern lamellar *débitage* and bladelets from splintered pieces the following attributes were recorded: butt type and preservation, accentuation and section of percussion waves, ventral bending, blank thickness and regularity. The cores were analyzed giving particular attention to three-dimensional measurements; surface hierarchization and exploitation; rotation and displacement of the core-face units; degree of preparation of striking platforms; origin and direction of the last detachments; intensity of utilization and possible causes of abandonment. Given the high number of by-products, the bipolar reduction sequences have been further investigated through replication with a stepwise experimental testing method. This allowed the identification of gestures, the consequences of the actions, aims and technical expedients included in this particular knapping technique. The experimental production of splintered pieces using a percussion angle of 90° was also useful for recognizing a number of features in artifacts found in the archaeological record. These include typical features and stigmata (scaled and burin-like spalls, butt cracking and shattering, sheared bulb of percussion, split fracture, pronounced and disarmonic ripple marks), as well as the inference of the length of use of these tools, which was likely very short based on the fast and inevitable exhaustion of those seen. Finally, retouched tools where analyzed in their original blank (where determinable) and type, direction and extension of retouch. Special interest was also given to recycled and converted tools.

4. Results of studies on layers 1f-1g

4.1 Zooarchaeological analyses

Due to the large volume of fragmented remains, taxonomic and anatomical identification of the bone assemblage was problematic. A total of 34,549 fragments measure less than 2 cm (92.4% of the total) and among these, 31,479 (84.2%), are less than 1 cm (Table 2). Such fragmentation can be ascribed to anthropogenic activity, here recorded by evidence of butchery and the possible use of bone as fuel for the hearths. Of the over 37,000 remains examined, it has been possible to recover 113 elements to the species or family levels (0.3% of the total) (Table 2). For an additional 253 fragments (0.7% of total), determination was limited to the size class of the animal. Of those that were identified, there were 7 bird bones, including two mallards (*Anas platyrhynchos*) and one teal (*Anas* cf. *crecca*) (Gurioli et al. 2006), and two fish vertebrae, presumably belonging to a pike (*Esox lucius*). Mammals are represented by rodents, carnivores and ungulates with the most prevalent findings being teeth and short limb bones. The only three marmot remains (*Marmota marmota*) come from an ancient den excavated in layers 1a and 1b which extends to 1g in AA1+0 sq. in the external area of the shelter. Beaver (*Castor fiber*) is also reported, while the lagomorph family is represented only by the hare (*Lepus* sp.), being attributed to two elements. Cave bear (*Ursus spelaeus*) is the most common species among carnivores with 21 remains (35.6%) including teeth, metapodials and phalanges. In 1g this species represents 17.8% of the assemblage with 16 elements. Generally, the bear is the most dominant at Riparo Broion if the 13 remains attributed to the genus (*Ursus* sp.) are included. In layer 1g, fox (*Vulpes vulpes*) is represented by teeth and an assortment of other bones, mustelids by a single element assigned to *Martes* sp., as well as felines by two teeth (0.9%) belonging to the wild cat (*Felis silvestris*).

Wild boar (*Sus scrofa*) is the most common ungulate found in layer 1g (21 remains, 35.6%), with fragmentary radii, metacarpals, metatarsals, first and second phalanges and only one complete third phalanx; some teeth being deciduous. The chamois (*Rupicapra rupicapra*) is represented by a total of 4 bones (6.8%), identified as phalanges (first, second and third) and one tooth. Only one ibex (*Capra ibex*) bone is present in 1g. Cervids are represented by 19 bones of large individuals, most likely the giant deer (*Megaloceros giganteus*), elk (Cfr. *Alces alces*) or red deer (*Cervus elaphus*). Of these, five bones in layer 1g have been determined as a metatarsal and the third phalanx of a giant deer, and a metacarpal, a humerus and the first phalanx of an elk. Red deer is represented by five bones (8.4%), including teeth and elements of the appendicular skeleton. In layers 1f and 1g, three teeth belonging to roe deer (*Capreolus capreolus*) have been identified, equal to 5.1% of the determinable faunal assemblage. Finally, three bovid bones (5.1%) have been counted. One is the fragmented ulna of a bison (*Bison priscus*), one is the second phalanx of an auroch (*Bos primigenius*), and the third stands undeterminable to the species level.

The diversity of this faunal assemblage is an expression of the different environments surrounding Riparo Broion. Alongside the presence of marmot, hare, chamois, ibex, bison and possibly aurochs, the number of red deer and roe deer bones as well as the abundance of wild boar indicate the existence of woodland with humid zones in the alluvial plain which extended east of Mount Brosimo.

The faunal assemblage has been subjected to several natural post-depositional events that altered the bone structure, density, morphology and surface color. Four agents contributed to this thanatocoenosis: humans, carnivores, burrowing rodents and various physical-mechanical agents.

The anthropogenic traces can be inferred by the butchering of carcasses and combustion (Table 3). Striations associated with disarticulation and the removal of muscular mass have been observed on long shafts of medium and large mammals (Fig. 4 (3)), including what is likely to be an elk. The humerus shaft in proximity to the distal epiphysis of

presumed elk, preserves parallel longitudinal scrapings created after the removal of the periosteum; a percussion notch identified by its signature cone is still partially connected (Fig. 4 (4)). Additional remains are large mammal notched shafts and at least five percussion cones (Fig. 4 (2)). None of the bones examined shows marks ascribable to deliberate splitting produced using flakes and splintered pieces like wedges. All the faunal remains that were anthropically modified were located in close proximity to the S3 hearth (Fig. 4 (1)). Additional evidence of anthropogenic activity is provided by several burnt and calcified bones, the majority being smaller than 1 cm (NR 18,464 equal to 49.3% of the total). There were few bones found in hearths S2 and S3 and the ratio between burnt and unburnt remains the same when compared to the outer area.

	1e		1f		1g		TOTAL	
	NR	*%*	NR	*%*	NR	*%*	NR	*%*
Total remains	1805	*100.0*	3557	*100.0*	32028	*100.0*	37390	*100.0*
Total with natural alterations	1252	*69.4*	1986	*55.8*	21733	*67.9*	24971	*66.8*
Burned and calcined remains	948	*52.5*	1626	*45.7*	15890	*49.6*	18464	*49.3*
Burned remains	930	*98.1*	1465	*90.1*	13200	*83.1*	15595	*84.5*
Calcined remains	18	*1.9*	161	*9.9*	2690	*16.9*	2869	*15.5*
Cut marks	1		3		12		16	
Percussion cones			1		4		5	
Percussion marks			3		3		6	

Table 3. Number and percentage of bone mammals remains (RN) with natural alterations and traces of human activity

There are a few traces of carnivores, usually represented by marks on long shafts and by some digested bones. In addition to these modifications, some long shafts found in layer 1f have had their edges gnawed on by rodents. Other natural phenomena include carbonate incrustations, especially in the central excavated area; surface corrosion from roots; and frost damage such as weathering, cracks and exfoliation.

4.2. Lithic assemblages

4.2.1. Chert provenance

Riparo Broion is a singular example of where lithic economy has been studied in marginal contexts devoid of raw lithic material. Indexes of techno-economic behaviour in this region during the Middle Palaeolithic reveal how humans used lithic resources according to a site's geographic location and function (Bertola and Peresani 2000; Porraz and Peresani 2006; Peresani et al. 2015). Chert supply conditions range from excellent in the Mount Lessini area to the west of the Berici plateau Mountain Range, to areas almost or totally devoid of lithic sources within the critical 5km range. The relationship between lithic suitability and other critical resources is subtle, as the Berici sites are located at an intermediate position to regions that normally offer more favorable conditions for subsistence and lithic production.

Two different areas for provisioning of chert blocks and decimetric nodules have been identified. The first one located south-east and closer to the shelter (5-10 km), where there is limited exposure of Cretaceous limestone, occur along the foot of the eastern scarp of the Berici hills and in small isolated hills between the Berici and Euganean hills. These small reliefs are elevated at 70-100m a.s.l. and are the relict surface of a plane, possibly Miocene in age (Sauro 2002).

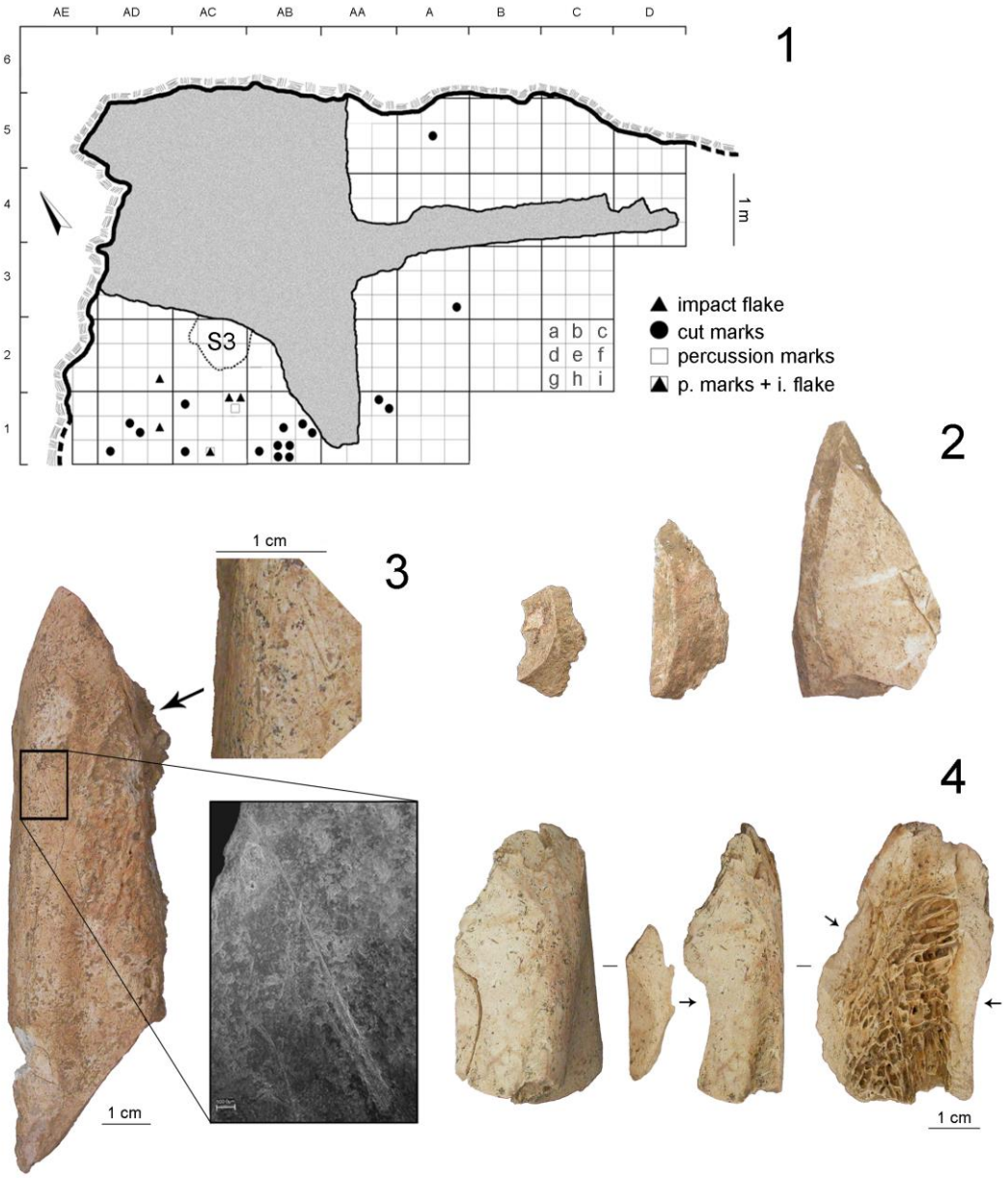

Figure 4. (1) Distribution pattern of anthropically modified faunal remains in layers 1f and 1g, showing concentrations in the proximity of hearth S3. (2) Percussion cones. (3) SEM and stereomicroscope micrographs of a large ungulate diaphysis with cut-marks produced during defleshing. (4) Possible elk (Cf. *Alces alces*) humerus. Note the longitudinal parallel scrapes related to the removal of the periosteum and a percussion mark with its cone still in place

The second one is located west of the shelter, in the central-southern part of the Mount Lessini area, at a much greater distance (35-40 km). The chert of the Berici-Euganei area is best represented on the site. The Biancone/Maiolica and Scaglia Variegata Alpina (SVA; lower and middle Cretaceous) lithotypes occur the most frequently despite their present-day exposures still visible in limited areas of the Euganei while the widespread Scaglia Rossa (upper Cretaceous) have been less exploited. They tend to be medium to poor quality due to intense fissuration, incipient cracking, partial silicization, with voids and large saccharoidal asperities. The Mount Lessini (ML) chert group is represented almost exclusively by the grey to dark Maiolica types that characterize the middle-upper part of this formation. The other cherts are the yellow/greenish and black types of the Scaglia Variegata (middle Cretaceous), grey

Eocene and to dark grey Oolitic-Giurassic varieties. The assemblage from layers 1f-1g is comparable with the distribution of exposures in the central-southern part of the Mount Lessini area (Bertola 2001).

4.2.2. Main techno-typological features

The lithic assemblage of layers 1f and 1g amounts to 1295 pieces, of which 56 (4.3%) are considered indetermined because of thermal alterations or thick and extended concretions on their surfaces (Table 4). Lithic artifacts show fresh surfaces over all faces and retouched edges, although natural modifications ranging from the marginal to the invasive of the unmodified and retouched edges affect less than 1% of the total assemblage.

The assemblage records a high fragmentation rate: fractures affect more or less two thirds of the total number of pieces; as a consequence, sizes are generally very small with length reaching 20mm on average - 20.8 for the undamaged artifacts. The marked prevalence in number of the products created by bipolar knapping could be the major cause of this high fragmentation rate and small dimensions.

4.2.3. The splintered pieces

The small flakes and bladelets that originated from the exploitation of splintered pieces (SP; Shott 1999) represent a substantial part of the assemblage, accounting for roughly 42.0%. Including also the reduced blanks, products and by-products play a majoritarian role counting over two thirds of the determined assemblage (67.6%).

The SP tools/cores are the blanks on which the bipolar percussion was applied on an anvil. These implements develop clearly distinguishable technological and morphological features in a very short time, making identification possible also for the underexploited blanks. The main attributes correspond to those defined and described in the last century and recently specified through technological approaches assisted by experimental protocols (Tixier 1963; Crabtree 1982; Knight 1991; Lucas and Hays 2004; Le Brun-Ricalens 2006; de la Peña 2015): presence of scaled and sometimes invasive detachments on opposite ends, usually bifacial; the negatives have well marked and punctuated percussion waves, and the edges from which detachments fall away are irregular and crushed from direct and rebound impacts. These implements are manufactured on different types of blanks, with thickness ranging from 2 to 19mm, enough to make possible the detachment of flat flakes and bladelets from the wide face, and bladelets with narrow, thick or quadrilateral cross-section from the side. SP were made also on previously retouched blanks (n=34, 12%). This evidence highlights the high demand of raw material for bipolar production, in addition to the high versatility and applicability of this knapping technique to a wide morpho-dimensional range of blanks.

The SP have been distributed in groups defined on the base of morphological and technical features, which can reflect subsequent stages of reduction. Unfortunately, in most cases, the intense exploitation hinders the reconstruction of the initial shape and dimensions of the splintered blanks. Many of these, however, had to be thick flakes, although sometimes thin flakes and bladelets were used, as well as small blocks or plaques. Regardless of initial blank morphology, the first stage of splintering was based on the following specific rules: exploiting the major axis through striking on a flat surface (the butt, a cortical side, a pre-existing sharp fracture, etc.) opposed to the convergent/dihedral portion positioned on the anvil (Fig. 5, nos. 4, 6, 8). This latter arrangement was essential in order to control the impact point of the knockback and the general predetermination of the detached piece. 65 SP belongs to this group, representing 22.1% of the whole SP assemblage.

Group	Subgroup	1f		1g		Total	
		NR	%	NR	%	NR	%
	SP with two opposed wedges	15		95		110	
	SP with wedge opposed to a flat end	6		59		65	
	SP with more than one axis	6		31		37	
	SP made on retouched tool	3		31		34	
	Fragmented/not determinable	6		42		48	
Tot. Splintered Pieces (SP)		36	*22.2*	258	*22.8*	294	*22.7*
	SP Flakes and flake fragments	48		336		384	
	SP Bladelets and burin spalls	14		146		160	
Total SP by-products		62	*38.3*	482	*42.5*	544	*42.0*
	Backed knives	1 (+2)		10 (+3)		11 (+ 5)	
	Fragments with abrupt retouch	3 (+1)		27 (+10)		30 (+ 11)	
	End-Scrapers	1		4 (+1)		5 (+ 1)	
	Retouched blades	1		1		2	
	Side-Scrapers/Denticulates	\		3 (+4)		3 (+ 4)	
	Other/Fragments	1		9 (+13)		10 (+ 13)	
Total retouched tools		7 (+3)	*4.3*	54 (+31)	*4.7*	61 (+ 34)	*4.7*
Resharpening/retouch flakes		3	*1.9*	12	*1.1*	15	*1.2*
	Cortical bladelets	2		9		11	
	Bladelets	1		8		9	
	Fragmented or hinged bladelets	3		38		41	
	Core-tables	\		6		6	
Total free-hand bladelets assemblage		6	*3.7*	61	*5.4*	67	*5.2*
Kombewa-type flakes		2	*1.2*	25	*2.2*	27	*2.1*
	Centripetal flakes	\		5		5	
	Core edge removal flakes	1		4		5	
	Naturally backed flakes	4		1		5	
Total flake assemblage		5	*3.1*	10	*0.9*	15	*1.2*
Technical management flakes		3	*1.9*	8	*0.7*	11	*0.8*
	Free-hand bladelet cores	\		3		3	
	Flake cores/Other	1		3		4	
	Cores on flakes	\		1		1	
Total other cores		1	*0.6*	7	*0.6*	8	*0.6*
	Cortical flakes	7		24		31	
	Fragments with cortex	4		30		34	
	Undifferentiated flakes	6		48		54	
	Fragments	12		42		54	
	Knapping mistakes	4		18		22	
	Reparatory flakes	\		2		2	
	Undeterminate	4		52		56	
Total Other		37	*22.8*	216	*19.1*	253	*19.5*
TOTAL		162	*100.0*	1133	*100.0*	1295	*100.0*

Table 4. Composition of the lithic assemblages of layers 1f and 1g. The number of the retouched artifacts fragmented due to splintering is reported between brackets

This exploitation quickly dismantles the striking platform, producing scaled flakes and bladelets and reshaping it into a wedge, thus opposed to the first one along the same axis (Fig. 5, nos. 2, 5). This practice can lead to different products in function of the initial shape of the blank and the type of the by-products; the production can switch to bladelets, developing on the sides of the SP and converting its shape into a stick; alternatively, the SP thickness could be exploited mainly on wide fronts, for detaching thin and rough flakes (Fig. 6). Of the total number of SP, those discarded at the stage of two wedges opposed make up the majority (n=110, 37.4%).

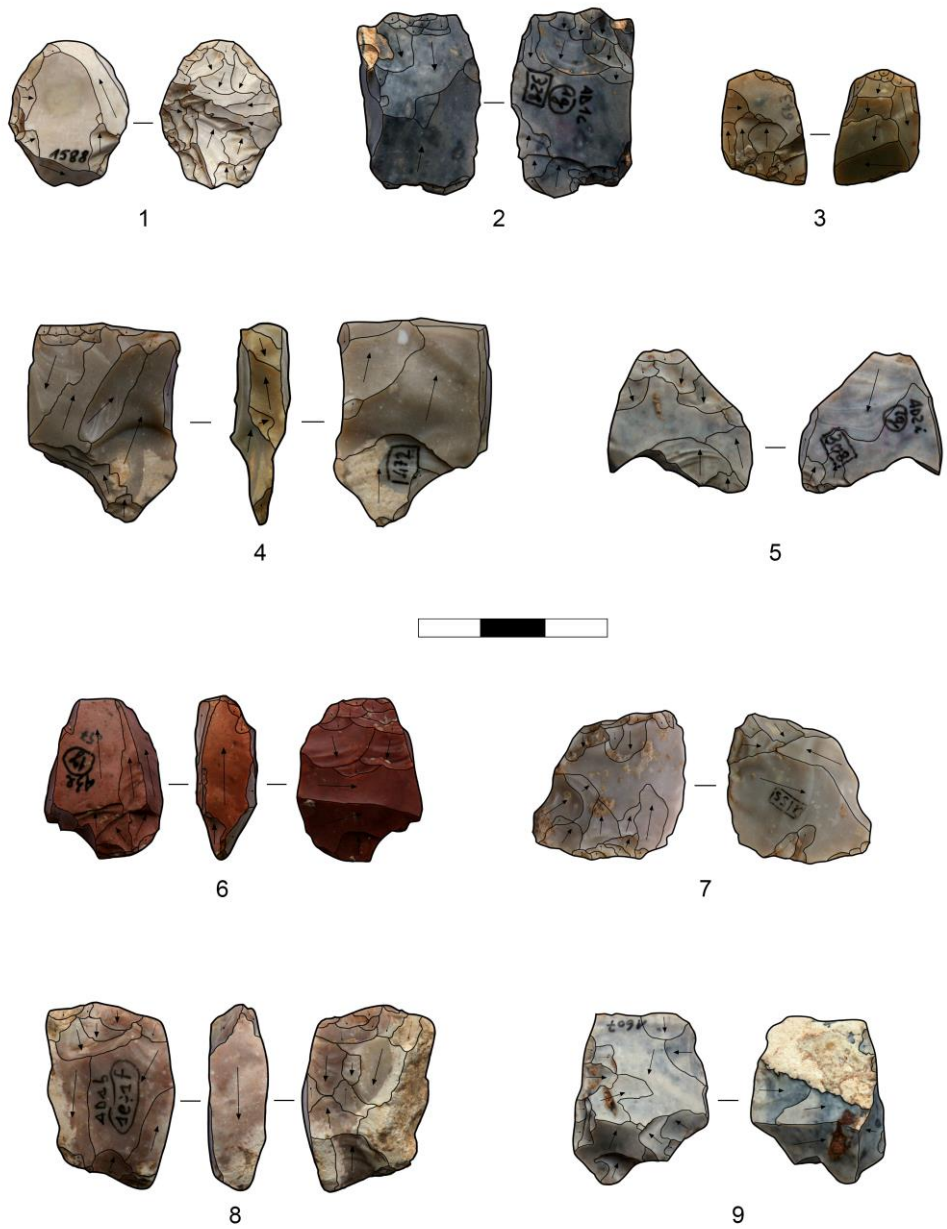

Figure 5. Splintered pieces from layers 1f-1g. (2, 5) SP showing two opposite wedges on the same axis. (1, 3, 7, 9) SP exhibiting many exploited axes across the profiles, mainly orthogonal. (4, 6, 8) SP which exhibit a possible wedge (which leaned on the anvil) opposed to a flat end (struck part), and the production of bladelets on the narrowest blank surface

At this point, if the SP volume supports a further stage of production despite whether the striking platform looks irretrievably damaged or the piece has been much reduced along the main axis, exploitation shifted along another axis, often positioned orthogonal to the previous one (Fig. 5, nos. 1,3,7,9). The blank rotation of the SP ensured that a final reduction stage could be possible before complete exhaustion. When SP exploitation is along two (or more) axis it numbers at 37, 12.6% of the total SP.

All the SP types appear to have been discarded at a similar degree of exhaustion; when they reach 18 to 28 mm in length on the main axis, most of them are no longer exploitable for producing blanks. The typometrical values highlight that the SP with two opposing wedges are more apt for exploiting the blank volumes, resulting in thinner residual pieces (mostly 4 to 7 mm). The other types remain thicker and the SP with more than one axis are also wider, with an almost quadrangular shape (Fig. 7).

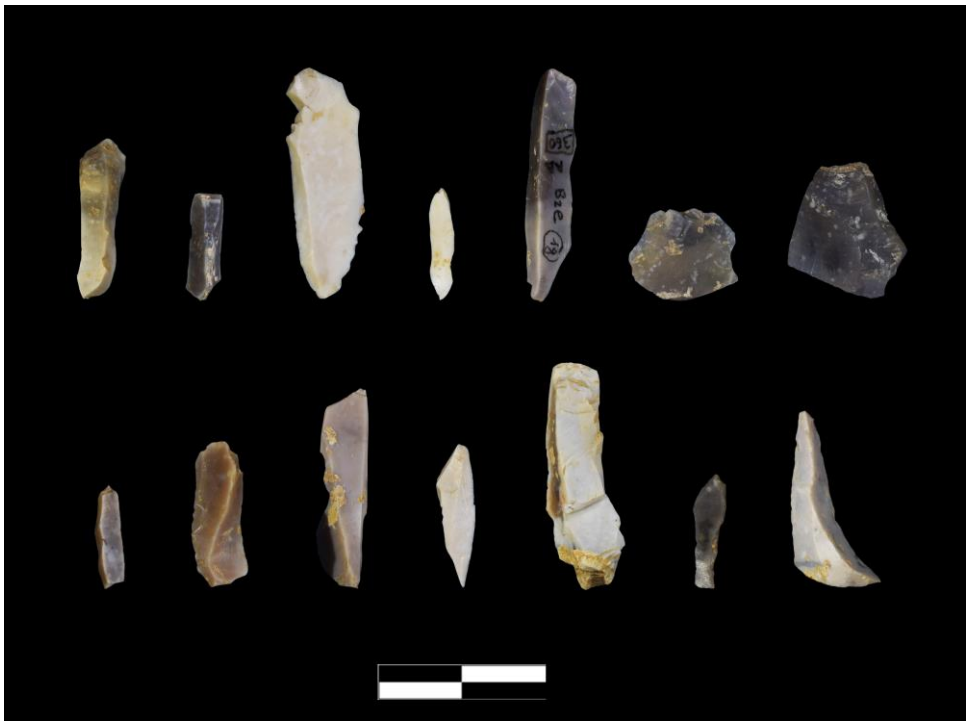

Figure 6. By-products obtained with bipolar technique. Thin, irregular and often hinged or fragmented bladelets/burin spalls and flakes (scales) can be recognized

Bipolar knapping on an anvil is a difficult technique as regards the integrity of the splintered piece: at any point in each of these stages, the blank could break; 48 SP (16.3%) were discarded due to these fractures.

Interpretation of some of these pieces has been long contested at the limit between tools or cores used for producing flakes or bladelets. Many are the burin-like SP, wherein bipolar knapping caused the detachment of burin-like spalls (bladelets) along the narrowest edges. Similarly, 160 lamellar by-products prove bipolar knapping proved to have an important role in the production of lithics at Riparo Broion at this time (Table 4). Given this preponderance, it is reasonable to think that many of the by-products obtained from the scale of SP could be the objective of the knapping activities, and the SP cores, reduced to obtain these implements. These by-products are divided on a morphometric basis, in two categories: the aforementioned bladelets/burin spalls that allude to a primitive standardization of thin blanks bearing parallel cutting edges; scales/scaled flakes (n=384) very thin, small, irregular and often fragmented or hinged. However, the low standardization of the width caliber and the high fragmentation and hinged ratio negatively affect the effective functionality of part of the bladelets.

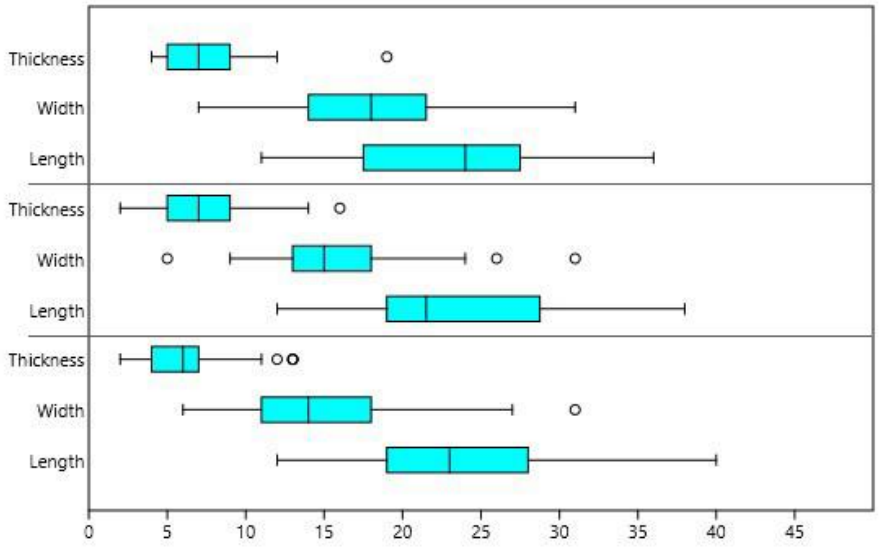

Figure 7. Distribution of thickness, width and length values for splintered pieces with two axis (top), one flat surface (middle), one axis (bottom)

4.2.4. Technologies different to the splintering technique

The rest of the assemblage points out some minor lithic productions with different technological objectives; the lamino-lamellar method has been recognized through the recurrent presence of diverse categories of products with several distinctive stages (n=67, 5.2% of the whole assemblage). The stage of production and the conceptual schemes of the reduction sequences have been only partially determined on these artifacts. In particular, the lamellar production is testified by a few dozen (n=61) bladelets, in some cases with remnants of cortical surface. The length of these products is almost always indeterminable due to the high fragmentation rate, however, width can be distributed into two ranges: 5-8 mm and 11-14 mm. Diachritic analyses attest to be unipolar, like the almost exclusive modality of production (except one single case), extended re-configuration through partial crests and lamellar-oriented production already from the early stages of decortications. There are also six core-tablets that testify the re-shaping of the usually small striking platforms. Finally, three small prismatic cores bear evidence of intense exploitation following tourning-semitourning or polihedrical progression, always volumetrically integrated even if restricted from the low management of longitudinal and transverse convexities (Fig. 8). Some flake-oriented cores and one core-on-flake were also identified, attesting an ephemeral flake assemblage represented by core-edge removal flakes, some centripetal flakes and especially many undifferentiated flakes, which were small and intensively fragmented. These general features are also expressed from the elevated incidence of undeterminable flakes and undifferentiated fragments. Some cores bear traces of multiple phases of exploitation, the first targeted to produce flakes and bladelets by direct knapping and the latter turning to bipolar knapping.

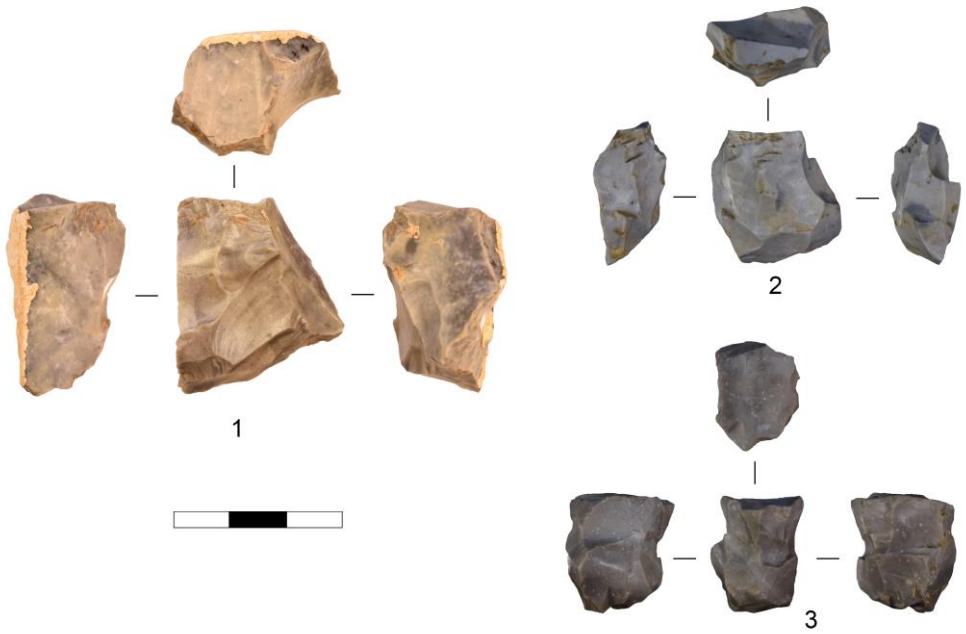

Figure 8. Small prismatic free-hand cores from layers 1f-1g. (1-2) Small bladelets and flakes have been obtained from the narrower and wider surfaces respectively in the last phases. (3) An example of tourning exploitation which developed from the flat striking platform located at the top

4.2.5. Retouched tools

Tools are 95 in total, almost exclusively in a fragmentary condition due to recycling in the SP (34 cases) (Table 4). The majority of the tools are prepared backed implements, among which, there are 16 knives with curved backs and 41 fragments with abrupt retouch (Figs. 9, 10 and 11). In almost all cases the abrupt or semi-abrupt retouch is manufactured starting from the lower surface in a unipolar sense. The back is moderately invasive and demolishes the original blank, variably producing large flakes to small bladelets at half or full thickness; retouched edges have slightly convex to a very curved profile. Only two cases bear bipolar retouched backs. In these two pieces, the bipolarity is not a consequence of the knockback on a platform as a result of the direct retouch: the blanks are retouched in the first phase on a surface, and then on the other after the piece was rotated (Fig. 9, no. 3). The fragments with undifferentiated abrupt retouch are characterized, on the contrary, by marginal and straight retouch. Despite their partial or fragmentary state mostly due to splintering, at least four backed knives are classifiable like the typical Uluzzian “lunate” variety of tools (Figs. 9, no. 2a and 10, nos. 1, 2).

Further typical Upper Paleolithic tools are sporadic, and include six end-scrapers, two retouched blade and bladelet (Fig. 9, nos. 8,9). The retouched blade is manufactured on a regular blank (80x24x11 mm) having long and parallel edges that converge at the distal end; both edges have simple and direct retouch (Fig. 9, no. 7) and scaled and stepped retouch on the right side. Retouch intensity progressively decreases towards the point where the edges converge. The end-scrapers are of the frontal and shouldered types, manufactured on wide and thin flakes. Very few side-scrapers are denticulate, and simple retouched flakes are also part of the retouched tools. Lastly, a group of 9 flakes issued from resharpening of backed pieces from the ventral face or occasionally from the back itself by means of a blow perpendicular to the tool axis. No clear impact fracures have been observed on this material.

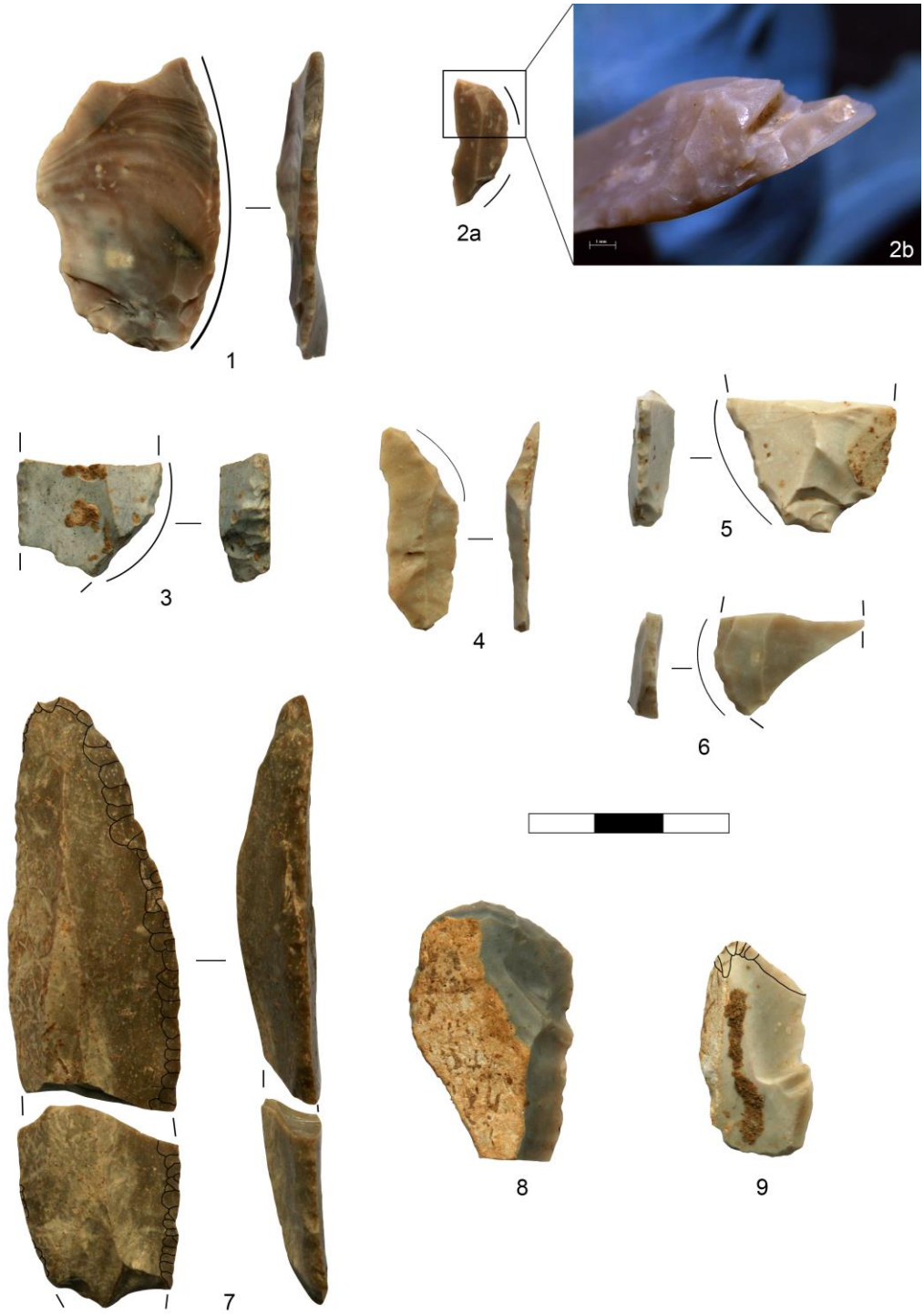

Figure 9. Retouched tools from layers 1f-1g. (1) Curved backed knife on thin flake. (2a) Small lunate backed piece with proximal and distal retouches that partially renew a distal fracture (2b). (3) Fragment of a curved backed piece made on a thick flake by bipolar abrupt retouch. (4) Curved backed knife shaped by partial and direct abrupt retouch. (5-6) Fragments of curved backed knives made by direct abrupt retouch. (7) Refitting of a retouched blade characterized by direct, scaled retouch on the right edge, and marginal retouch on the left edge, converging on a frontal end-scraper. (8-9) Frontal end-scrapers on flake

4.3. Bone tools

Bone tools from 1g are represented by three semi-complete artifacts (Fig. 12, 1-3) and a distal fragment of awl. Two (Fig. 12, 1 and 3) were likely obtained from anatomical elements naturally shaped for the purpose (ulna or telemetacarpals) and later refined with a lithic tool. The first bone tool is a pointed artifact, possibly an awl, modified

mainly through longitudinal scraping (Fig. 12 (A-C)), which measures 6.5cm in length, 0.8cm in width and 0.5cm in thickness. Clear and uniform polishing is evident in many areas not covered by concretions and not affected by fractures or roots. The second tool is a broken end of a probable needle with traces of scraping (Fig. 12, 2 (D)) that contributed to creating a polygonal-shaped section to the tip, measuring 2cm in length and 0.2cm in diameter. The pointed extremity is broken with wear traces that are not detectable due to an iron-manganese coating. The third worked bone object is the tip of, what appears to be, an awl, which has been reshaped through deep longitudinal scraping (Fig. 12, 3 (E-F)). The artifact measures 3.7cm in length, 0.5cm in width and 0.4cm in thickness. The fourth tool is a pointed artifact, likely an awl, made from a bone fragment. The pointed tip has an old fracture which probably developed through usage. Traces of longitudinal scraping (Fig. 12, 4 (G-H)) produced during the tool shaping process are distinct, in addition to use traces represented by cut-marks. Clear and uniform polishing is evident in many areas. The artifact measures 1.8 cm in length, 0.7 cm in width and 0.2 cm in thickness.

5. Personal ornaments and the engraved cortical flake

Initial reporting (Romandini et al. 2012) describes three marine shells, attributed to *Dentalium inaequicostatum* (now *Antalis inaequicostata*) discovered in 1f and 1g. However, given the outlined bending and smoothed surface of these tiny pieces, it is probable that the specimens taxonomically belong to *Antalis vulgaris* (Fig. 13, nos. 1-3). After revising the collection, two additional fragments have been recovered: one attributed to *Antalis vulgaris* (Fig. 13, no. 5), and one classified as *Antalis dentalis* or *inaequicostata*, deduced by the presence of ribs on the dorsal side in a longitudinal disposition in relation to the main axis (Fig. 13, no. 4). The external surface of one of the three dentalia has been scraped along the main axis of the shell (Fig. 13, no. 1 (A)). It also bears short-medium and transverse striations isolated in close proximity to the lower margin which has been smoothed on the internal and the external surfaces, and obstacles the identification of any trace of the manufacturing process. Shell segments are characterized by their small size, transverse and flute beak fractures (Fig. 13, nos. 1-2, 4-5) and external polishing (Fig. 13 (B, E, F)); these features do not allow the identification of their position in respect to the apical end and/or the anterior larger aperture. It is assumed that the shell was first scraped in order to obtain a flat surface, and later properly segmented through transversal sawing (Taborin, 1993) and/or fractures caused by flexion-torsion. Microwear analysis is currently in progress as traces of red ocher have become evident in two dentalia (Fig. 13 (B and D)). All five dentalia clearly originate from at least three distinct specimens (see sections in Fig. 13, nos. 1-5) that could have been collected from the Adriatic coast (positioned, at the time, 190km from the site; Fig. 1). A fourth shell is the freshwater *Theodoxus danubialis*, found in 1f. The shell wall near the stoma was intentionally perforated (Fig. 13, no. 6) and then suspended, as suggested by the smoothness of the lower edge (Fig. 13 (G)). Near the stoma, there are also particles of red ocher (Fig. 13 (H)). Unlike the *Antalis*, the origin of *Theodoxus danubialis*, can be traced locally.

FIGURE 13 ABOUT HERE

A splintered flake with cortical back opposed to a thin edge with microscarrings (Fig. 14 (3)) was engraved on the back. A pattern is visible, composed of two long grooves which follow the longitudinal axis of the flake, with additional grooves related to the previous form, highly variable in orientation (Fig. 14 (2)). Surface alteration within the deep grooves limit the possibility of reconstructing the manufacture technique of the engravings. Black and red stains dispersed across the cortex should be ascribed to the weathering of the original cobble.

FIGURE 14 ABOUT HERE

6. Discussion

The cultural evidence produced by layers 1f-1g of Riparo Broion is ascribable with certitude to the Uluzzian technocomplex on the base of a suite of criteria initially designed by A. Palma di Cesnola (1989) and grounding the tecno-typological features of the lithic assemblage. However, not only lithics are an exclusive component for identifing the presence of this transitional complex, in that bone awls, bone tools and ornamental shells make their sistematic appearance in cave contexts where these materials have more chances to preserve (D'Errico et al. 2012; Moroni et al. 2013; Peresani et al. 2016). The lithic industry in 1f-1g is far from being ascribed to the Middle Palaeolithic, given the lack of any diagnostic Mousterian component like Levallois or Discoid technology, and the ordinary variety of Mousterian scrapers, points and denticulates which are a typical component of the late Middle Palaeolithic assemblages in the north-east of Italy (Peresani 2011; Peresani et al. 2013). The Uluzzian taxonomy for Riparo Broion mostly grounds on specific features espressed from the lithics: the splintering technique and the backed pieces, being other aspects minoritary at this specific context.

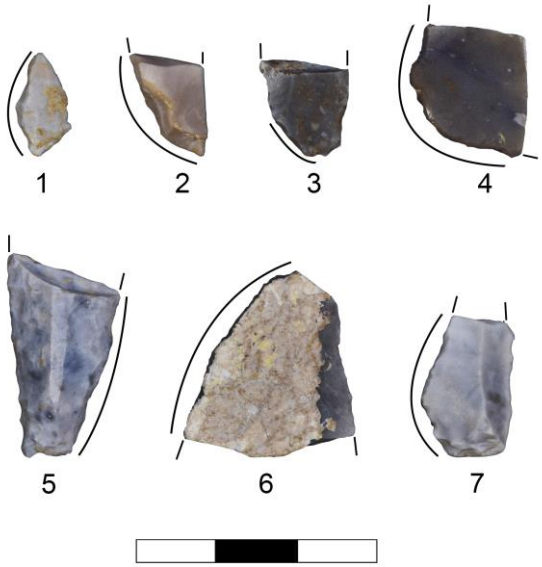

Figure 10. Fragmented retouched tools with abrupt retouch. (1-2) Possible lunate fragments. (3) Fragmentary bladelet with marginal retouch. (4) Fragment with markedly curved abrupt retouch. (5) Double-retouched bladelet with straight direct abrupt retouch. (6-7) Fragments of backed knives

6.1. Splintering technique.

Splintered pieces (SP) are a basic component of the Uluzzian that makes it distinct from other transitional technocomplexes in Europe and from the final Mousterian and the Protoaurignacian in Italy. This remains the case, despite these having low frequencies in the latest Mousterian layers at Grotta Fossellone, Grotta Cavallo, Grotta Castelcivita and Grotta La fabbrica (Gambassini 1997; Sarti et al. 2017; Villa et al. 2018) and in the Aurignacian at Grotta Barbara (D'Angelo and Mussi 2005) and at Grotta Fumane (Bartolomei et al. 1992). Since the original description published by A. Palma di Cesnola (1989), all the products created from bipolar knapping on mineral anvils were considered to be the diagnostic signature of this technocomplex. However, the incidence with which SP are recorded across reference collections ranges from 34.9% (layer PIE) to 54.8% (layer RPI) at Castelcivita; from 35.1% (layer EIII) up to 69% (layer EII-I) at Cavallo, from 23% to 61% at Mario Bernardini Cave and Uluzzo Cave according

to the last count carried out (Riel Salvatore 2009), 37.9% at Colle Rotondo and 44.2% at La Fabbrica (Villa et al. 2018). Assemblages that have highly varied frequencies of SP should be re-analysed based on bipolar technique, as demonstrated by the doubled values of products and by-products (67.0%) from layer EIII, published after a recent re-counting of the material excavated in the 1963-1964 at Cavallo (Moroni et al. 2018). Currently, there have been a number of marked similitudes noted between assemblages at Riparo Broion and layer EIII at Cavallo, and possibly layer EII-I, unless reanalysis does not change the role this technique played across the Uluzzian. To reinforce comparability between artifacts at a morphological scale, it deserves to be noted that SP from layer EIII have also been recognized as cores, and quadrilateral pieces, chisel-like in profile, which have recurring traits should be ascribed to a common technological pattern (Moroni et al. 2018). In addition, pebbles were rarely used in EIII of Cavallo and not used at Broion, due to their scarcity in the surrounding landscape where soils, slope deposits and primary outcrops of carbonatic rocks supplied nodules, blocks and plaquettes. Before being intensively reduced via bipolar flaking for achieving products of variable size from small to hyper-micro-lithic, all this material was exploited by a primary, direct percussion technique. Although refitting studies and above all functional data are still in an embrionic state, we are prone to interpret the largest fraction of this bipolar industry as a result of a full reduction process aimed to produce a variety of flakes and bladelets. Additional similitudes or differences with Cavallo EIII can be envisaged in the original cores destined to be exploited by bipolar percussion. However, differences lay in the use of "lastrine" at Cavallo, the reduction of which drives the morphological evolution of the cobble into a narrow and sticky core yielding small blades, bladelets and microbladelets (Moroni et al. 2018). This is similar to the roughly square-shaped blanks used to produce variably sized chunks from the two core flat faces. Another minor part of the cores comes from the exploitation of quadrangular or triangular "lastrine" to achieve elongated blanks which, again, is not the case here at Broion. However, the design of bipolar exploitation at Broion reveals how elongated products can be produced by "predetermined" modification of the original blank profile and the general lay-out of the future core. In this way, steep edges were created intentionally through abrupt retouch to guide the blows and control the production of micro-bladelets. In EIII this requirement is overcome by the occurrence on the core of lateral steep edges on the natural cobbles or the flakes.

Discussion over the techno-functional significance of the splintered pieces has taken into consideration their possible use as wedges to groove or splinter hard tissue (e.g., bone, antler, wood) or like an expedient reduction method to maximize the utility of raw material packages (Hayden 1980; Shott 1999; Le Brun-Ricalens 2006; Mourre and Jarry 2009-2010). At Riparo Broion, the lack on bone surface traces ascribed to splitting shafts with wedges does not support such a type of function. Again, we exclude the role of bipolar reduction in cobble-splitting before starting the reduction sequence or limited to the last exploitation of the core when too reduced to be free-hand knapped. Furthermore, an indiscrimination toward specific raw materials has been noticed for both the bipolar and ordinary exploitations of the different chert cobbles, comparable to the Uluzzian of South of Italy (Riel-Salvatore 2009; Moroni et al. 2018). Detailed functional studies on material from Italy remain in a so embrional state, that previous hypothesis based on very preliminary experimental tests on the use of SP from Castelcivita and Cavallo like wedge edges for splitting hard materials (De Stefani et al. 2012) should not be considered before studies are completed. Further to this, it was also suggested that lateral edges were used for processing soft and semi-hard materials with transversal and longitudinal motions (De Stefani et al. 2012).

Bipolar reduction could have been used in the Uluzzian to produce a maximum number of blanks without curating them carefully (Riel-Salvatore 2009). Although potentially more productive than the ordinary direct knapping, this technology marks an intrinsic characteristic when related to the primary availability of knappable stones in the region, in that at Broion, its use was not driven by particular constraints in lithic availability. There is no marked differentiation

between those that affected the Mousterian and the later technocomplexes in the Berici area. Indeed, the appearance of SP in layer A4 at Fumane assumes an innovative character, given their absence in the entire Mousterian sequence which is an industry based on a large availability of chert in the local area. At a broader scale of comparison, it is worth pointing out that along the Italian peninsula, anvil percussion was already in use in specific situations during the Middle Palaeolithic, where the low quality and the scarce availability of knappable rocks could have influenced the economic systems. This is exemplified in the Pontinian industry on the Latium coast, which demonstrates the application of this technique, purportedly to open small cobbles of flint at the onset of the reduction sequence (Bietti et al. 2009-2010). For the sake of comparison, it cannot be neglected that in the same region at Grotta Barbara (D'Angelo and Mussi 2005) and Grotta del Fossellone (Mussi et al. 2006), the bipolar technique was still in use during the Aurignacian, however like an independent reduction sequence, splintered pieces were abundant and played the role of cores aimed to obtain elongated products.

In any case, the significance of low technical investment encompasses a wide range of hypotheses. Moroni et al. (2018) have recently reviewed these by taking into account the advantage this technique had to manage costs and benefits under particular circumstances for subsistence, or the fact that bipolar knapping was only undertaken by a skilled minority. However, the adoption of such a method foreshadows reasons which encompass the simple material costs or time/environmental constraints. In their last analysis, Moroni et al. (2018), favour interplay between different active factors, such as sources and knapping properties of raw materials, land-use, socio-economic requirements and the cultural tradition to account for the abrupt appearance of the Uluzzian technological behaviour at Grotta del Cavallo. This is also supported from changes in the exploitation of the same type of fauna from the Mousterian to the Uluzzian at Cavallo and Castelcivita caves (Boscato and Crezzini 2012). As expressed by the introduction of low-cost technological systems, a change in territoriality resulting in reduced mobility has been hypothesised as an adaptive response to an ensemble of factors like climatic change, population increase and competition between groups for resources (Hiscock et al. 2011). This hypothesis has been associated with the Uluzzian in southern Italy also based on the high concentration of sites in Uluzzo Bay and its surroundings.

6.2. Backed knives

The intentionally retouched backed pieces from Riparo Broion stimulate a specific discussion on this type of artefact. Flakes shaped by abrupt retouch are ephemerally attested in Middle Palaeolithic contexts in Europe, where these implements associate to different techno-cultural traditions like the Mousterian of Acheulean Tradition type B (Bordes 1984; Soressi 2002) and the assemblages based on discoid technology (Locht and Swinnen 1994; Lemorini et al. 2003; Slimak 2008). Moreover, assemblages in the late Mousterian sequences in south-western France have been recently described to contain flakes and Levallois flakes modified using partial or total abrupt retouch for shaping a backed edge (Gravina 2016). Sometimes, this retouch was refined on a mineral anvil which eliminates the butt and part of the proximal zone of the source flake. The same author also notes variability in backing technique. Direct retouch or bipolar retouch methods respectively have been discovered in layers H and K at Le Moustier, where tools from these layers assume the lunate form. The regular contour of the backed side may suggest a possible role in the hafting process for this structure and hence requires use-wear analyses. Incipient cones, edge crushing on the dorsal surface resulting from a counterblow or a combination of both, have also been observed on the few backed pieces recovered in layers A4 and A3 at Grotta Fumane (Peresani et al. 2016). In layer A4 on this site, these flake tools were created by the decortication phase and the main phases of centripetal core exploitation, whereas others were shaped using typical Levallois flakes. The retouched back is either straight or convex, completely or partially extended along the overall edge, while the thin

unretouched edge is maintained on the opposing side. This style is comparable to pieces found in layer A3, that are mostly made on thin centripetal flakes. In comparison to their counterparts in the Uluzzian core area, the Salento coast, Moroni et al. (2018) remark after their recent re-assessment of the Cavallo layer EIII industry the atypical characteristics of the backed pieces from Fumane, represented by their size, profile, delineation of the back and manufacturing technique. We suggested that the scarcity and variability of backed tools at Fumane might be an expression of the antiquity of the Uluzzian, or may indicate a specific use of the cave in the frame of the settlement dynamics, albeit still to be reconstructed (Peresani et al. 2016). However, the low number of backed implements is not an uncommon occurrence in the Uluzzian. At Grotta La Fabbrica, crescents are scarce in comparison to denticulates and scrapers (Dini and Tozzi 2012; Villa et al. 2018). The same occurs at Castelcivita, where backed tools are less frequent than denticulates and scrapers (Gambassini 1997). At Cavallo, in addition to splintered pieces and scrapers, backed pieces and crescents occur with variable frequency, while at Klissoura Cave 1 all types of backed tools amount for 29.8% of those found in layer V (Kaczanowska et al. 2010). Noteworthy, straight and convex backed pieces have also been reported from few undated Mousterian surface sites in Tuscany, traditionally viewed by Arturo Palma di Cesnola (1989) as evidence that supports possible rooting in the Middle Palaeolithic of the Uluzzian in central Italy. Backed pieces at Cavallo appear abruptly in layer EIII (Palma di Cesnola 1989; Sarti et al. 2017) and increase as part of the well-developed Uluzzian in layer EII-I.

Considering the on-going debate on the origin of the Uluzzian (Bietti and Negrino 2007; Riel-Salvatore 2009; Moroni et al. 2013; 2018; Zilhão et al. 2015; Peresani et al. 2016) and of the Châtelperronian (Bordes 1968; Pelegrin and Soressi 2007; Bar-yosef and Bordes 2010; Bordes and Teyssandier 2011; Ruebens et al. 2015; Roussel et al. 2016; Gravina et al. 2018), backed pieces should assume a wider significance, in that they encompass late Mousterian variability and thus are not limited exclusively to association with the MTA-B assemblages. It is worth noting that at the end of the regional Mousterian sequences in south and south-western France, the above-mentioned appearance of discoid and Levallois technologies (Jaubert et al. 2011) includes backed pieces selected from the Levallois flakes that differ significantly morphometrically from their Châtelperronian counterparts, not only this, but also in terms of backing technique and the imposed form of lunate. The practice of abruptly backing one of the edges of a laminar blank, a flake characterized by a regular transverse profile or a previously created asymmetrical profile, appears a phenomenon encompassing the late Middle Palaeolithic and some of the earlieast Upper Palaeolithic cultures. Detailed comparisons and in-depth morphometric and functional analyses are necessary for shedding light on the possible significance of these implements (Moroni et al. 2013).

6.4. Other aspects of minor relevance

6.4.1. End-scrapers and retouched blades

There are too few end-scrapers in layers 1g and 1f to be compared with the EIII Cavallo cave assemblage, where these tools mark a specific component, prevail in great numbers over the other tool classes, and are generally shaped with semi-circular fronts on thin plates (42.7%; Moroni et al. 2018). In the Uluzzian at La Fabbrica cave OSL dated to 40±1.6 ka (Villa et al. 2018), retouched artifacts include denticulates and scrapers, whereas end-scrapers and truncations are scarce. Comparably, this specific type of tool remains extremely sporadic if unknown in the industries preceding the Uluzzian in Tuscany, Campania and Apulia (Palma di Cesnola 1989; Riel-Salvatore 2009). Furthermore, although it is represented by only one specimen, the appearance of end-scrapers in the Uluzzian layer A3 at Fumane is a phenomenon that has no comparison with the late Middle Palaeolithic industries in the same region, which are dominated by scrapers of different types and sizes (Peresani 2012; Peresani et al. 2013a). In contrast, end-scrapers spread in the successive

Protoaurignacian across Italy (Palma di Cesnola 1989), notably at Fumane (Bertola et al. 2013). Here, these tools are generally manufactured from blades and other flaked products, but also shorter, intensively sharpened flakes with slightly convex longitudinal profiles or worked axial and distal parts. Long frontal end-scrapers are the most numerous, however carinated and nose forms are underrepresented (Aleo et al. 2017).

Figure 11. Retouched tools exploited and reduced by splintering bipolar technique mainly on a single axis. (1-4) Backed knives and fragments. (5-6) End-scrapers

Too few retouched blades have been identified to be considered for comparison. However, one blade markedly differs from the rest of the assemblage, being much larger, composed of SVA chert – there being no other examples of which on the site, and bearing Aurignacian typological features on the retouched edge. This blade was separated into two fragments, which were found in two different locations on the site. One was found in the spoil of the unauthorized excavation, and the other in 1f in close proximity to the north cliff of the shelter.

6.4.2. Direct stone knapping for flakes and bladelets

The evidence of recurrent centripetal exploitation of flake cores is too ephemeral to be investigated in detail at Riparo Broion. However, this method of flake making is known in the Uluzzian assemblages (De Stefani et al. 2012), likewise at Fumane, where, in layer A3, flakes and cores have weakly trimmed striking platforms.

In layer A3, there is also a marked increase in the number of bladelets recorded. Their production was based on unipolar knapping on a flat striking platform, and starting from a natural edge. Bladelets have large flat butts, triangular sections, prominent bulbs, and straight to curved longitudinal profiles. Transverse and longitudinal convexities were maintained, the striking platform rejuvenated, and also pseudo-pyramidal cores with more than one striking platform were used. No traces of extended re-configuration from partial crests have been observed like at Riparo Broion. In this Uluzzian site, blades and bladelets have no comparable morphometric and dimensional features with its Protoaurignacian counterparts. This has been frequently recorded at Fumane where bladelets are the primary focus of stone knapping. Bladelets originate from a broad range of independent strategies, represented by three core reduction methods, platform, multidirectional, and parallel (Falcucci et al. 2017; Falcucci and Peresani 2018), while blade production is embedded in the core reduction. Curved profiles of different intensity grades dominate the population, with straight profiles being more common among bladelets. Although dorsal scar patterns are largely unidirectional rather than bidirectional, the major difference between these two categories is the clear relevance of the unidirectional convergent scar pattern among bladelets. This is also related to the high number of pointed bladelets with convergent retouch. This feature is significant in the toolkit of the Protoaurignacian groups in sites across southern Europe (Falcucci et al. 2018).

6.4.3. Bone technology

Because of their fragmentary nature, it is tricky to compare the bone tools from Riparo Broion with the Uluzzian bone industry from Grotta del Cavallo, Castelcivita and La Fabbrica as much of the Aurignacian bone industry from Grotta di Fumane. In fact, with the exception of the tip of a probable needle that could be compared with the Aurignacian bone needles from Fumane (Bertola et al. 2013), the other two tools could represent the mesial-distal portions of awls or other pointed tools. Nevertheless, some observations can be summarized as follows. First, it should be specified that the different environmental contexts characterizing the Uluzzian sites from southern Italy in respect to Riparo Broion and Grotta di Fumane, are reflected in the different types of blanks turned into tools. In the southern sites, there is a selection of red deer metapodials and horse fibulae and metapodials; the greater availability of horse skeletal parts is displayed also in tools thicknesses and dimensional ratios (width-thickness) (D'Errico et al. 2012), which are greater compared to Riparo Broion and Fumane. On the contrary, there are affinities between Uluzzian sites and Riparo Broion regarding the morphology of the distal part of the awls characterized by a round section, and the proximal part, which is more oval. Other similarities have been observed through the examination of the working techniques (scraping and abrasion) and the distribution of use-wear traces close to the tool's distal vertex. Moreover, these features are also shared with the Aurignacian bone industry from Fumane (Broglio et al. 2006). At Fumane, the handful of bone tools (one awl and two fragments of worked rib) found in layer A3 (Peresani et al. 2016), provide less substantial evidence of the Uluzzian worked-bone industry than is known at Grotta del Cavallo, Castelcivita, La Fabbrica and Riparo Broion. This is with the exception of the only bone scraper (Romandini et al. 2014) and bone retouchers (Jéquier et al. 2012) found at the site, which are artifacts commonly found in the MP-UP transitional technocomplexes.

Figure 12. Bone industry from layer 1g. (1) Broken tip of an awl reassembled from three fragments caused from bone dehydration and micrographs showing deep oblique scrapes to the major axis (A), longitudinal scraping and polishing (B), longitudinal scraping and abrasion (C). (2) Broken tip of a needle and micrograph of longitudinal scraping and fine polishing (D). (3) Broken tip of an awl or point (E) and micrograph of fine longitudinal scrapings (F). (4) Pointed artifact, likely an awl; stereomicroscope detail old fracture (G) and the longitudinal scraping and the use traces represented by cut-marks and uniform polishing (H); White arrows show the direction of these traces

6.4.4. Ornamental objects

In the extensive debate surrounding the modifications in human societies that occurred in concomitance with the spread of Anatomically Modern Humans in Europe, a key role is played by the shell assemblages largely used as ornamental and symbolic objects (Vanhaeren and d'Errico 2006). Although Neanderthals were not unaware of their use (Peresani et al. 2013; Hoffmann et al. 2018), the occurrence of marine and freshwater shells rises considerably across Early Upper

Palaeolithic sites and in areas located great distances inland (Taborin 2003; White 2004), where the lack of sea shells was compensated by freshwater taxa. As an example, the open site of Kostenki 14 revealed tens of specimens of *Theodoxus fluviatilis* (Sinitsyn 2003).

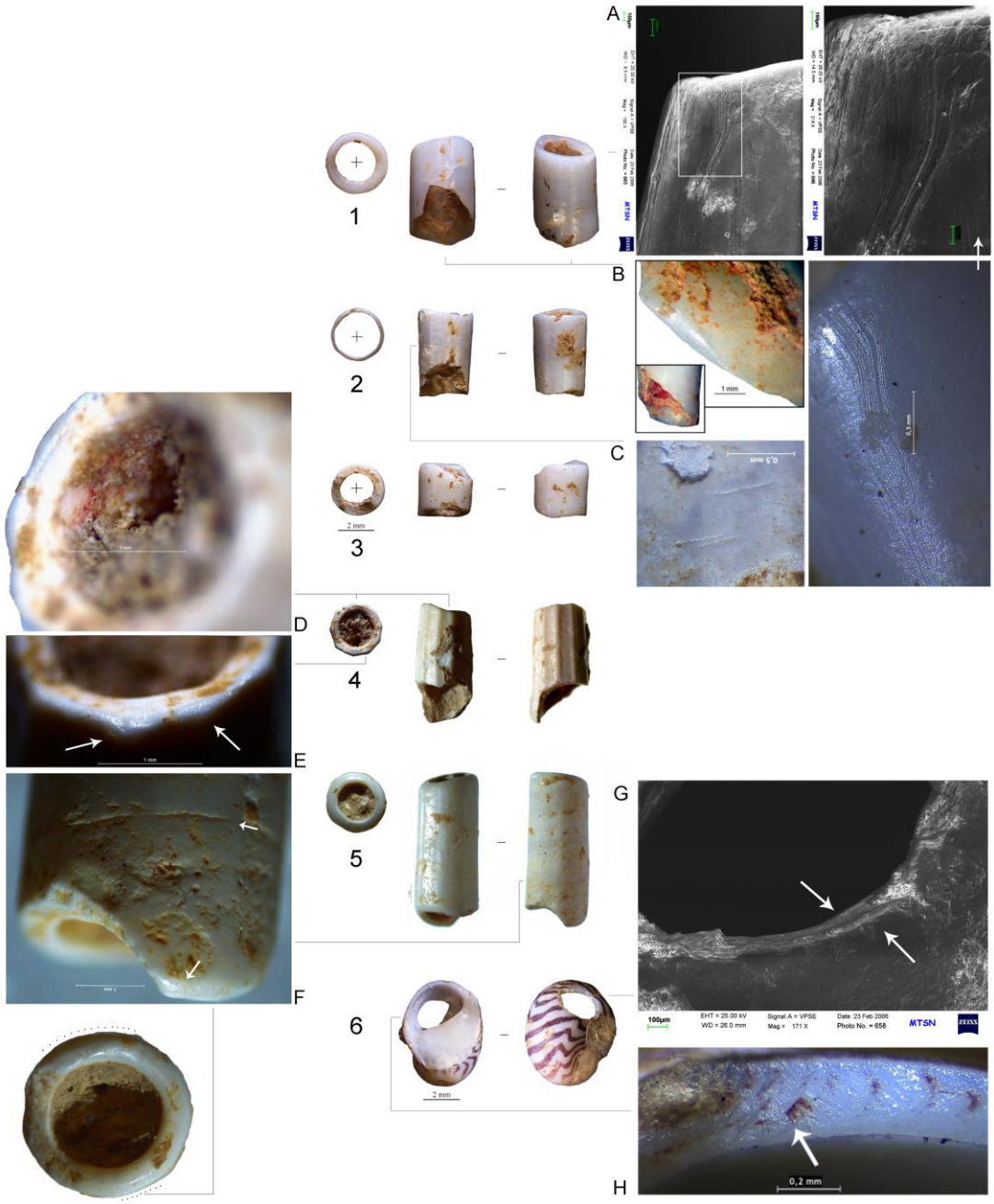

Figure 13. Ornaments from layers 1g (nos. 1 to 5) and 1f (*n*=6). Nos. 1 to 3 and 5 are fragments of *Dentalium* (*Antalis*) *vulgaris*, no. 4 of *of Dentalium (Antalis) dentalis* or *inaequicostatum*, no. 6 is a complete shell of *Theodoxus danubialis*. (A) SEM micrographs of the longitudinal scrapings oriented according to the main shell axis. (B) Stereomicroscope detail of the smoothed lower surface of the external edge; below, the detail of the interior of the scaphopoda at the time of discovery, showing a coating of red ocher. (C) Stereomicroscope detail of two short, transverse and isolated striations. (D) Stereomicroscope detail of the internal concretion sediment cover the coating of ocher. (E) Stereomicroscope detail of the smoothed lower surface of the external edge. (F) Stereomicroscope detail of a long, transverse and isolated striation with sinuous trend. (G) SEM micrograph showing the surface of the lower edge of an intentional perforation which was smoothed through use as a suspended object (shown). (H) Stereomicroscope micrograph of red ocher (indicated) in the stoma edge

Concerning the Uluzzian, the use of marine shells is not a novelty in this culture, having been reported at Grotta del Cavallo, La Cala and Castelcivita, as well as at Klissoura cave in Greece, where intentionally perforated and/or fractured shells (*Cyclope neritea*, *Columbella rustica*, *Pecten* sp., *Glycimeris*, *Antalis*) have been discovered throughout all Uluzzian phases (Palma di Cesnola 1989; Ronchitelli et al. 2009; Stiner 2010). Specifically, dentalia mark similitudes between Riparo Broion and southern Italian contexts where one fragment has also been recovered in the Aurignacian layer A1 at Grotta di Fumane (Gurioli et al. 2005; Peresani et al. in press). Unfortunately, in this latter cave the short stratigraphic distance between the oldest Aurignacian layer A2 and the Uluzzian layer A3 did not prevent the concentration of shell beads caused by a set of turbations in the eastern zone of the cave mouth that also involved Dufour bladelets and other Aurignacian stone and bone artifacts. This thus precludes every possible inference for the use of shell beads by the Uluzzian technocomplex makers. Leaving aside the grooved red deer incisors, the Aurignacian of Fumane yielded over 850 shells that belong to 73 different taxa, 62 of which are representative of the class of Gastropoda, 10 of Bivalvia and the only one mentioned Scaphopoda. Freshwater Gastropoda are represented by one perforated specimen of *Theodoxus danubialis*. Most shells are perforated and reveal a range of use-wear traces or ochre residues. Direct AMS dating of perforated *Homalopoma sanguineum*, *Nassarius circumcinctus*, and *Glycymeris insubrica* demonstrate that the shells were gathered on MIS3 beaches (Gurioli et al. 2005). Mineral pigment, such as ochre, has been detected on an abundance of shells in the lowermost layer at Fumane (Cavallo et al. 2017; 2018).

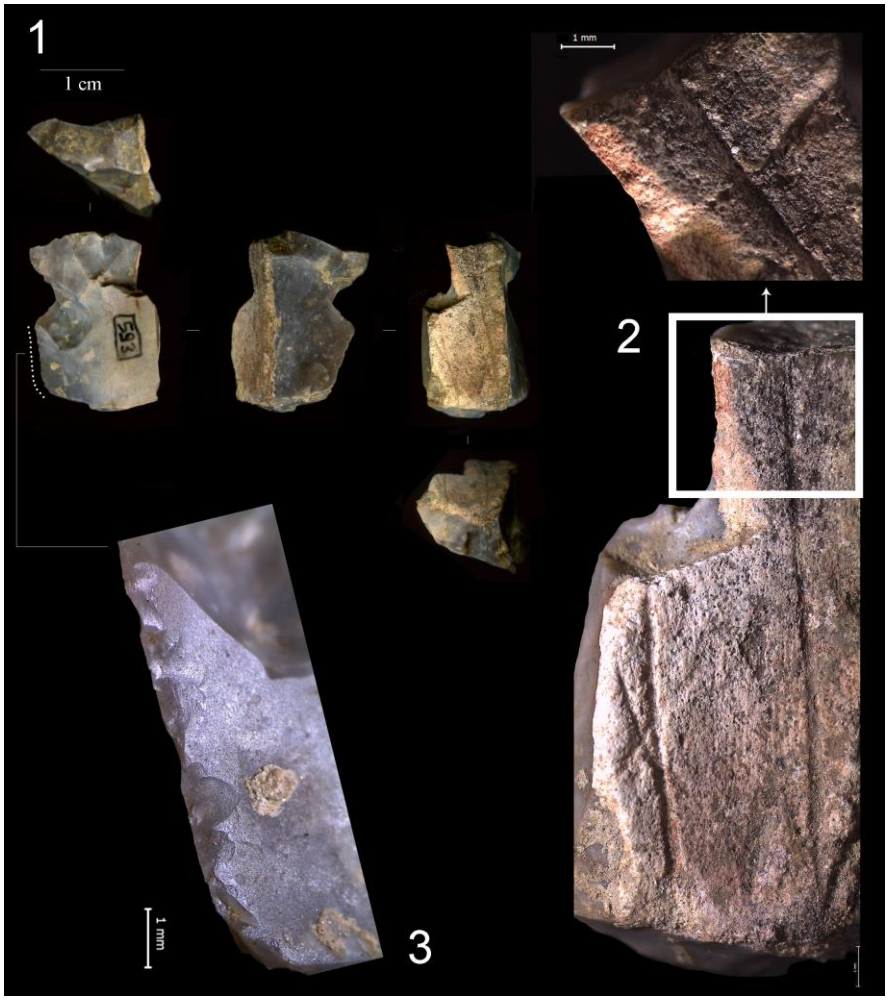

Figure 14. Splintered flake with engraved cortical back

7. Uluzzian in the north of Italy: discussing a scenario

A number of discoveries dating after the end of the Middle Palaeolithic, such as the Uluzzian phase at Fumane and, more recently, another Uluzzian horizon, bring about a new line of thinking regarding cultural change during the beginning of the Upper Palaeolithic in this part of Southern Europe. As a result, discussions revolving around the significance of the late Mousterian complexes continue, particularly regarding the impact of the Uluzzian at Riparo Broion compared to its possible counterpart, Fumane Cave.

Research so far has been unsuccessful in tracing the possible cultural relationship between the final Mousterian and the Uluzzian at Riparo Broion, largely limited by the still embryonic state of the excavation in the main sheltered zone. As discussed above, the density of Mousterian sites in north-east Italy demonstrates that this area was well-populated by Neanderthals at the end of the Middle Palaeolithic, with human presence limited to the caves and shelters in the Colli Berici (Broion, San Bernardino and possibly Col de la Stria caves) in the Lessini Mounts (Fumane, Riparo Tagliente and possibly Grotta Ghiacciaia) and the Carnic Pre-Alps to the east (Grotta Rio Secco) (Bertola et al. 1999; Peresani 2011, et al. 2014). Neanderthal population density estimates for the first half of MIS3 are not yet available, but studies on land-use patterns and mobility reveal that their settlements covered a wide biogeographic range typical of this region bounded from the north by the Alpine watershed and the South by the Adriatic Sea (Porraz and Peresani 2006; Peresani 2011; Delpiano et al. 2018). Unusually, lithic assemblages produced by humans in sheltered sites like Grotta di San Bernardino and Grotta Broion differ in their composition and density, partially due to their different position between two geological zones, the Euganean Hills and the Lessini Mountains. These have a notable availability of knapping rocks. The Berici area was occupied repeatedly on a short-term basis by Neanderthals equipped with end-products and retouched implements, but also with partially exploited cores that were introduced to the site through mobile caches (Peresani and Porraz 2004). Lithic industries record ephemeral flake-making, limited to the shaping and curation of the retouched products and the high frequency of tools made of exogenous flint. Flake-making was largely undertaken using the Levallois technique, with its characteristic unipolar and centripetal modalities.

Thus, although the resolution of the Uluzzian chronology at Riparo Broion stands at an embryonic stage, the cultural and behavioural background preceeding the appearance of this technocomplex is markedly Mousterian. Given the striking similitudes between Riparo Broion and the southern Uluzzian from Grotta del Cavallo, the following scenarios can be hypothesized for disentangling the intricate situation in the north of Italy based on the evidence of Grotta di Fumane.

7.1. Riparo Broion marks the arrival of a new population with new innovations in lithic and bone technology, including the symbolic use of objects like marine and freshwater shells.

According to the re-analysis of two human teeth found in 1964 in layer EIII at Cavallo Cave (Benazzi et al. 2011) and the above described cultural marked affinities between this site and Riparo Broion, these inhabitants were the first Anatomically Modern Humans to settle in Southern Europe and in the South of Italy. Despite the lack of any reliable evidence, the provenance of this population has been traced from the Near East, more specifically, from its coastal belt, a corridor traditionally considered to have been well-used by early *Homo sapiens* population waves since 170ky BP (Herschowicz et al. 2018). However, serious doubts have been cast on the reliability of the stratigraphic position of the teeth found at Cavallo Cave (Zilhão et al. 2015), based on the lack of data available to ascertain the consistency of the Uluzzian sequence from layers EIII to layer DI. Cavallo B and Cavallo C teeth were discovered in association with

anthropically modified faunal remains, knapped stones, bone tools and marine shells which form the foundation for this technocomplex. Due to their state of preservation, uniqueness, tiny size and lack of dentine, the teeth cannot be directly radiocarbon dated. However, Moroni and colleagues (2018), based on a recent detailed re-examination from the field notes of Arturo Palma di Cesnola, confirmed that they were recovered from undisturbed Uluzzian deposits. Furthermore, the recent analysis of two tephra layers, Y6 and Campanian Ignimbrite, sandwiching the Uluzzian at the base (layer Fa) and at the top (layer CII) respectively (Zanchetta et al. 2018), dispels doubts on the solidity of the Uluzzian at Grotta del Cavallo, and sets its duration between 45.5±1.0 ky BP and 39.85±0.14 ky BP. This date range confirms the previous chronometry based on marine shells, charcoal and a probability distribution function for layer EIII (Douka et al. 2014). Although the age estimate for the start of the Uluzzian at Cavallo appears to be older (70%) than that of Broion (Douka et al. 2014), this interval frames this site, despite the coarse resolution of the currently available data-set for this site. Current research focuses on improving this resolution to confirm the results with greater certainty.

7.2. The Uluzzian at Riparo Broion is rooted in the final Mousterian and originates from changes in Neanderthal cultural behavior.

The cultural change produced by the Uluzzian is a definitive clear-cut in the regions where this technocomplex appeared and there is no subsuming long-term persistence of Mousterian cultures thereafter (Palma di Cesnola, 1989), nor any of the stratified sites explored across north-eastern Italy. A complete evaluation of the possible relationship between the final Mousterian and the Uluzzian at Riparo Broion was not possible due to a lack of material recovered from the exposures during fieldwork. As stated above, the excavation of the top of the Mousterian sequence is one of the main goals of ongoing fieldwork which looks promising given the extension of the anthropogenic layers. The few retouched artifacts recovered from layers 7 to 9 are representative of common Mousterian lithic tool sets in the region. These include sidescrapers, transverse scrapers, a few denticulates made on cortical flakes, Levallois flakes and indeterminate blanks formed by invasive retouch. Similar typical features have been observed on late Mousterian assemblages recovered at Grotta Broion (Peresani and Porraz 2004), Grotta San Bernardino (Peresani 1995-96; Picin et al. 2010), Grotta Fumane (Peresani 2012) and others.

7.3. Uluzzian from Broion and its counterpart? Some thoughts for the reconsideration of the cultural evidence at Grotta Fumane.

Given the fact that the Uluzzian sequence at Fumane has been extensively excavated and palaeoecologically contextualized (López-García et al. 2015), its relationship with the immediately preceding Mousterian has been assessed (Peresani et al. 2016). Of the two lithic assemblages yielded from layers A4 and A3, the oldest shares marked behavioral traits with the Mousterian, and are recognizable in regard to the following: the use of Levallois technology with the application of the recurrent use of centripetal modality, whereas the unipolar modality is more frequently observed in the final Mousterian in layers A5-A6; the production of bladelets, albeit ephemeral; and the frequency of typical Mousterian retouched tools (Peresani et al. 2013). However, layer A3 records radical changes represented by the appearance of a series of operative sequences in flake production, and the dramatic decrease in the number of Levallois products. Flakes, also of Levallois origin, were used for the manufacture of splintered and backed pieces with a straight or convex back. Therefore, flakes from the industry represented in layer A3 are not comparable neither with the Levallois laminarity seen at Fumane and at MIS3 sites in Italy (Peresani 2011; Boscato et al. 2011; Marciani et al. 2016) nor with other Levallois volumetric blade based industries like the Bohunician in Central Europe (Svoboda and

Škrdla 1995; Škrdla and Rychtaříková 2012). In A3, there are flakes with weakly trimmed platforms and flaking angle around 70°–80° issued from centripetal cores; thin and wide flakes were predetermined from large shattered slabs with roughly prepared distal convexity; flakes longer than wide with a cortical back opposite a rough cutting edge were extracted from shattered plates prepared with an inclined striking platform and a distal convexity; an ensemble of flakes longer than wide with thick edges, thin flakes with centripetal pattern and chunky and straight and sturdy flakes with thick edges, flat to convex butts, was issued from bifacial cores and rhomboidal structure (Peresani et al. 2016).

The Mousterian-Uluzzian transition at Fumane is short in duration, in that the Uluzzian is chronologically indistinguishable from the final Mousterian complex at 46–44ky cal BP (Douka et al. 2014). Furthermore, and differently from what is attested in Southern Italy (Boscato and Crezzini 2012), the appearance of the Uluzzian tools at Fumane does not correlate with any detectable change in the way that fauna was exploited; Neanderthals predominantly hunted large and middle-sized ungulates like giant deer and red deer, in addition to birds and carnivores like foxes and brown bears (Peresani et al. 2011a; 2011b; Tagliacozzo et al. 2013; Romandini et al. 2018).

Again, as the investigations on the final Mousterian are still developing at Riparo Broion, any possibility to compare economic behaviours between the Uluzzian people of Broion and Fumane has been inhibited. The spatial patterning and the density of remains in layers 1f and 1g should lead to the conclusion that there was a short-term human presence here that targeted faunal resources like elk, for exploitation - the limbs of which were processed in close proximity to hearth S3. However, the poor preservation of the bones reduces visibility of human activities, and the fact that the skinning activity of prayed on ungulates is not represented in this assemblage does not mean that it did not occur elsewhere or just outside of the sheltered area. Furthermore, additional faunal material still requires detailed analyses, so we cannot exclude the current evidence regarding occupation dynamics at Riparo Broion when completing our assessment.

Thus, the close similarity between the Broion Uluzzian lithic and bone industry and that of Grotta del Cavallo, stimulates hypotheses on the scenario in north-east Italy. In their recent paper, Moroni et al. (2018), suggest that there are incongruences in the Uluzzian taxonomy at Fumane when compared to the “Classic” Uluzzian evidence from Grotta del Cavallo, which is confirmed, after their revision of material from layer EIII to the eponymous site. Although the use of local lithic raw material like “lastrine” remains peculiar for the Uluzzo Bay area by respect to the rest of Italy, Fumane exhibits a very different pattern, as also noted in another recent discussion (Villa et al. 2018). These are expressed by the marked Mousterian influence in layer A4, although less so in layer A3; the marginal role of bipolar reduction and of laminar volumetric exploitation; the atypical characteristics of the backed pieces observed in their size; the back delineation; and technology of manufacture relative to their Uluzzian counterparts at Cavallo Cave. However, it is undeniable that at Fumane, innovations in the variability of technical aims and in the typology, especially in A3, mark a cultural change by respect to the Mousterian tradition. Other behavioral differences between these Uluzzian people and the former users of the cave are provided not only by the appearance of a bone industry, but also from the features expressed from the deliberate spatial patterning of material, such as in the structure A3_SIV. This structure consists of a concentration of over 200 discarded flakes and bladelets, cores, backed knives, bones and charcoal distributed around a toss-zone. In addition to this, hearth A3_SI, a large fire-place associated with few flakes and bone shafts patterned around, and the small possible fire-place A3_SII suggest reduced intensity in human presence before the arrival of the Protoaurignacians (Peresani et al. 2016).

Given the current state of research on the Uluzzian land-use and organization of activities in sheltered sites, we cannot exclude that the divergences claimed between Fumane A3, the southern Italian sites, and now Riparo Broion are ascribable to the diverse use of caves and shelters, which may have determined the incidence of different technological procedures and typological composition of their tool-sets. A consequence of this is the deviation from the “classic”

profile and the need to enlargen the spectrum of diagnostic traits for distinguishing the Uluzzian lithic form. One further possibility to explain these divergences is grounded in chronology, thus considering that the "deviated" character of the Fumane Uluzzian in A3 derives from "archaicity" with respect to Broion. However, given the strict cultural correlation of the latter to the Cavallo EIII assemblage and the chronological time frame recently secured at 45.5±1.0ka cal BP from the tephra Y-6 in layer Fa (Zanchetta et al. 2018), this diversity in the north of Italy should be attributed to a culture. Given the coarse resolution of the currently available dataset at Riparo Broion, a new chronometric programme is on-going to ascertain whether layers A3 and 1f-1g are contemporaneous at Fumane and Broion respectively. Should this be the case, at the radiocarbon chronometric resolution between the two sites, one further interpretation explains a number of similarities and differences expressed between assemblages A3 at Fumane, and 1f-1g at Riparo Broion, claiming for cultural stimulus diffusion, a phenomenon already believed to explain the convergence observed in retouched bladelets across the Chatelperronian sequence of Quincay (Roussel et al. 2016). Comparably, the replacement of the Mousterian by the Uluzzian in the north of Italy does not preclude the diffusion of ideas between groups bearing the two technocomplexes, which overlap temporally. This leaves open the possibility of technological equifinality in the frame of biological and cultural exchanges.

Definitely, the assemblage from layer A4 at Fumane requires further re-assessment. It has been mentioned above that the Levallois was the most used method in this phase and that sidescrapers and points design were a marked Mousterian feature, while the "Uluzzian" component (splintered pieces, backed knives and bone tools) only increase later on in layer A3. This drives attribution of A4 assemblage to the Final Mousterian and its effective rooting in the region. Furthermore, as discussed above, the incidence of bipolar knapping in layer A4 is akin to the variability reported for some Late Mousterian contexts in Southern Italy, albeit this does not occur in other Late Mousterian contexts in the north-east of Italy, lacking Uluzzian levels at the top of their cultural sequences. Thus, Grotta Fumane and Riparo Broion are successions indicative of the local replacement of the "Uluzzian" over the Mousterian through time, however requiring further investigations at different analytical levels to shed light on the dynamics of this bio-cultural transition.

8. Conclusions and perspectives

We have two main reasons to believe that Riparo Broion offers unique opportunities for investigating bio-cultural dynamics at the onset of the Upper Palaeolithic in a bio-geographically key area.

The first reason is that the northern cultural frontier of the Uluzzian is an archaeological reality, which dispels doubts of its existence outside the "core" area in the southern peninsula, previously based on techno-typological dissimilarities or the lack of evidence in the central regions of Italy (Kuhn and Bietti 2000; Bietti and Negrino 2007), now nullified by the discovery of Colle Rotondo (Villa et al. 2018). In the original paper, we announced the discovery of this technocomplex at Fumane (Peresani 2008), stressing the importance of the northern Adriatic area as a corridor for attracting the movements of faunal and human groups of supposed provenience from the east during the MIS3 fall in sea-level. This increased connectivity with the Western Balkans region calls for greater effort to survey and excavate archaeological sites in this area, with cave deposits in close proximity to the present-day coastline being of key importance.

The second reason concerns cultural dynamics. Given that Neanderthals and AMH co-existed for around 2,600–5,400 years in Europe (Benazzi 2012; Higham et al. 2014; Benazzi et al. 2015; Zilhão et al. 2017), during which time, it has been claimed there was genetic exchange (Fu et al. 2015), still little is known about the possible transmission of cultural and symbolic behaviors between these distinctively acculturated people, this being the case, even despite the on-going

heated debate revolving around these arguments (Mellars 1989; Tostevin 2007; Zilhão 2007; Hublin 2015; Roussel et al. 2016). The Neanderthal population still remained active during the onset of the Uluzzian, not only in western Europe with the Châtelperronian (Ruebens et al. 2015), or in some Eurasia confined areas like Murcia in southern Spain (Hoffman et al. 2018), but also in corridors like the Ligurian Arch up to 40.5ky BP (Higham et al. 2014). Crucially, this is an area where the Uluzzian has still yet to be recorded. In this sense, the Uluzzian, viewed as a behavioral system developed in southern Europe, displaces an intriguing potential for investigating stimulus diffusion and other processes of knowledge transfer in this scenario of coexistence with different humans. This ignites the need to move away from the traditional dichotomy, commonly used to explain the significant cultural phenomena of this phase exclusively as products of one hominin taxon or another.

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