The Uluzzian technology of Grotta di Fumane and its implication for reconstructing cultural dynamics in the Middle – Upper Palaeolithic transition of Western Eurasia.

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Abstract. From the intricate ensemble of evidence related to the Middle–Upper Palaeolithic transition and the presumed first spread of anatomically modern humans in Europe, the Uluzzian has attracted major attention in the past few years. Although the Uluzzian has been supposedly viewed as a product of modern humans settling in Mediterranean Europe, the techno-cultural complex has been the subject of few investigations aiming to clarify its chronology, bone industry, and settlement dynamics. Further, little is known of its technological structure. This article presents the results of an extensive study of the lithic and bone technologies from assemblages recovered at Fumane Cave in the north of Italy. Results confirm that the Uluzzian is a flake-dominated industry that brings together a set of technological innovations. The Levallois is the most used method in the initial phase, which is replaced by more varied flaking procedures and an increase in bladelets and flake-blades. Sidescrapers and points also represent a Mousterian feature in the initial phase, while splintered pieces, backed knives and other Upper Palaeolithic tools increase in the later phase. Our results suggest that the Uluzzian is rooted in the Mousterian lithic technological context and cannot be viewed as a proxy for anatomically modern humans, the carriers of the abrupt cultural changes related with the Aurignacian.

Key-words: ~~Middle-Upper~~ Palaeolithic~~ transition~~, Uluzzian, Stone knapping, ~~Lithic and~~ bone tool~~osseous technology~~, ~~innovation~~Innovation, Italy.

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Introduction

The reconstruction of the biological and cultural changes occurring at the time of the spread of anatomically modern humans (AMH) in Western Eurasia is one of the most challenging research topics in prehistory and palaeonthropology, feeding continuous debates in how to disentangle the complex body of evidence related to the replacement of Neanderthals, between 50 and 40ky cal BP (d'Errico et al., 1998; d'Errico, 2003; Trinkaus et al., 2003, Hublin, 2014; Villa and Roebroecks, 2014; Fu et al., 2015). This phase in human evolution is highly significant, as some scholars claim the earliest successful dispersal of our species from Africa into Europe occurred approximately 50ky cal BP (Mellars, 2006), during the favorable environmental conditions of the late GIS 14/13 interval (Muller et al., 2011), and promoted, as assumed on the basis of genetic evidence, by Neanderthal demographic contraction (Castellano et al., 2014), possibly provoked by the resurgence of Heinrich ~~S~~Event 5 conditions, a climatic low at ~ 48ky that just precedes GI (Greenland Interstadial) 12. These claims are based on the assumption that in the eastern Mediterranean the Initial Upper Palaeolithic (IUP), which is represented by industries combining elements of the Levallois method with features more typical of Upper Palaeolithic volumetric blade technologies, were manufactured by AMH (Marks, 1983; Bar-Yosef, 2002; Kuhn et al., 2009; Douka et al., 2013), and that comparable industries, known as Bohunician, were present in central-eastern Europe (Richter et al., 2008; Hublin, 2014), marking a significant change from the previous Mousterian

(Marks and Ferring, 1988; Kuhn et al., 1999) and Keilmesser (Hopkinson, 2004; Richter, 1997) complexes. This scenario is based on the recovery of a maxilla in level XXIV or XXV of Ksar Akil (Douka et al., 2013), along with isolated teeth from Üçagızli cave in southern Turkey, which show a predominance of AMH traits, along with one specimen that also possesses Neanderthal features (Kuhn et al., 2009). Fluvial deposits at Ust-Ischim in Central Asia produced an AMH femur, genetically typed and radiometrically placed at around 45ky cal BP, a period in which IUP industries appear (Fu et al., 2014; Zwyns, 2012). Although isolated from the MP and IUP cultural contexts, the anatomically modern calvaria from Manot Cave, Israel, adds further evidence to the Near East anthropological mosaic of no later than 47.3 ky Cal BP (Hershkovitz et al., 2014).

Questions remain regarding humans, their behavior, subsistence, and, above all, how cultural innovations can highlight substantial cognitive differences, which are represented across the archaeological record by the appearance of the well-known techno-complexes, the Châtelperronian, Neronian, Lincombian-Ranisian-Jerzmanovician (LRJ), Széletian, Bohunician, Uluzzian, and others (Otte, 2014; Slimak, 2008b). Whether the relation between these differences and their makers ~~this scenario~~ is consistent is a matter of debate, however, given the noted weak evidence, other than the correlation between Neanderthal remains and the Castelperronian (Hublin et al., 1996) and the leaf pointed tools in the Lincombian-Ranisian-Jerzmanovician (Flas, 2011, 2014), of direct association between human remains, especially AMH, and cultural remains.

One of the most intriguing techno-complexes is the Uluzzian, found in the Italian peninsula and in the extreme south of the Balkans (Moroni et al., 2013; Peresani, 2014), two regions of potential interest to the study of human dynamics in the Middle-Upper Palaeolithic Transition (MUPT) and with implications for populations in a geographically-limited space with high ecological diversity, that extended from the shallow marine reach of MIS3 and onward in the Adriatic zone (Shackleton et al. 1984; van Andel et al. 2003). The Uluzzian represents a distinct industry, identified on the basis of small, crescent-shaped microliths, a combination of Middle and Upper Palaeolithic stone tool types, and variable incidence of splintered pieces associated with bone industries, perforated marine shells and mineral pigments (Palma di Cesnola, 1993). At Italian and Greek sites, the Uluzzian is best known from the cave sedimentary sequences of the Uluzzo Bay (Grotta del Cavallo, Grotta Bernardini, Grotta di Uluzzo C) in south Apulia, in Campania (Grotta La Cala, Grotta di Castelcivita), in Tuscany (Grotta La Fabbrica) (Figure 1), and in the Peloponnese (Klissoura I, layer V [Koumouzelis et al., 2001], and Kephalari [Felsch, 1973]), where it systematically overlies the Mousterian and is separated by discontinuities or a sterile level that indicates an absence of stratigraphic alternation with the final Mousterian or the Aurignacian (Giaccio et al., 2008).

At present, the Uluzzian is the only known transitional techno-complex related exclusively to AMH in Europe (Benazzi et al., 2011). However, there is doubt over whether AMH, represented by dental remains, actually manufactured the Uluzzian (Zilhao et al., 2015). This has created intense debate, requiring more taphonomic data from the transitional sequence in question, in order to solve the uncertainties caused by possible sediment disturbance and mixing of assemblages. Broglio (in Bartolomei et al., 1992), first reported the discovery of the backed “Uluzzian type” piece in layer A4I at Grotta di Fumane and hence the presence of this techno-complex in northern Italy. However, he considered the record of this level to be contaminated by the Proto-Aurignacian levels above it. This stimulated a diversity of views on the reliability of the Uluzzian in the region, with some supporting its existence (d'Errico et al., 1998; Zilhão and d'Errico, 1999) and others rejecting the evidence based on weak techno-typological similarities with other material from southern Italy (i.e. the absence of typical crescents) (Riel-Salvatore and Negrino, 2009). The lack of information on knapping technology led some (Kuhn and Bietti, 2000; Bietti and Negrino, 2007) to cast doubt on the existence of the Uluzzian in central Italy as well, citing a set of techno-typological dissimilarities between the industry of Grotta La Fabbrica, layer 2 and those of the Uluzzo Bay in southern Italy. In the Tuscan site, dissimilarities are ascribable to the scarcity of backed knives, the exploitation of rough pseudo-prismatic cores and centripetal Levallois cores, with the splintered pieces interpreted as bipolar cores rather than tools. However, the data presented by Bietti and

Negrino (2007) are not sufficient to establish that this assemblage should be considered a representative of the late Mousterian in central Italy rather than a true Uluzzian assemblage, especially given the presence of a bone awl. Presumed dissimilarities with the Uluzzian of the core Apulian area were additionally strengthened by the absence of diagnostic levels at coastal sites in Lazio, including Grotta Breuil (Rossetti and Zanzi, 1990-91), Grotta Barbara (Mussi and Zampetti, 1990-91), and Grotta del Fossellone (Blanc and Segre, 1953). It should be emphasized that some of these deposits were investigated over 50 years ago, failing to meet modern standards of excavation, or, as in the case of Grotta Breuil, comprising limited, residual deposits. The fact that lack of evidence does not prove absence in a given region has been confirmed recently by the discovery of the open-air Uluzzian site, Colle Rotondo, near the Lazio coast, that is characterized by a single level with a lithic industry containing splintered pieces, a few short end-scrapers with inverse thinning, and three backed knives (Pennacchioni, personal communication). Colle Rotondo may support the existence of open-air Uluzzian sites in Tuscany and Campania (see Palma di Cesnola, 1993 for a review), which have been known for some time, but which lacked a precise chronological, taphonomic, and functional framework. This situation had led some authors to refute their existence, citing post-depositional disturbances to explain the coexistence of artifacts belonging to different techno-complexes (Gioia, 1990; Mussi, 1990).

FIGURE 1 ABOUT HERE

Although understanding of Uluzzian chronology (Douka et al., 2013), subsistence (Boscato and Grezzini, 2011; Tagliacozzo et al., 2013), and bone technology (d'Errico et al., 2012) has advanced in recent years, further research is needed on lithic technology and other remains, such as perforated marine shells of various species of Gasteropoda and Glycimeris, interpreted as personal ornaments at Cavallo and La Cala, and red and yellow dying materials (Ronchitelli et al., 2009). Lithic technology is especially important with regard to the cultural implications of the innovations generated around the Uluzzian techno-complex from 43ky cal BP (Douka et al., 2014). These innovations mark a departure from the preceding Neanderthal-created Mousterian techno-complexes (Mussi, 2001), which are characterized in various caves of the Italian peninsula by the application of the Levallois method for the production of blades, convergent blades, and points. The only one to include the Uluzzian levels is Castelcivita, while other records like Riparo Oscurusciuto levels 4 and 1 (Boscato et al., 2011), Grotta del Capriolo, Buca della Iena, Buca del Tasso, Grotta all'Onda (Dini and Koehler, 2009), and Grotta Reali levels 2abc and 2β/2γ (Peretto, 2012) are limited to the Middle Palaeolithic. Laminar Levallois production requires constrained parameters, a well-structured operative sequence, quality raw materials of adequate dimensions, and hence, a greater investment in their procurement. Blade-making begins with the exploitation of lateral convexities, shaped stepwise either by Levallois core-edge removal or ordinary flakes, and then proceeds until the discarding of the core, although with a number of variants. Core reduction may involve the opening of new platforms that are opposite or lateral to the unipolar platform (Boscato et al., 2011; Peresani, 2012; Peresani et al., 2013). The centripetal modality has a clearly subordinate role to the unipolar, in that it acts at the end of the main reduction sequence.

While the techno-functional objectives of these products still remains unknown, they appear to have been used both as rough or retouched tools, such as sidescrapers instead of bilateral and convergent scrapers. Other contexts, especially in Liguria, share the presence of laminar Levallois technology with the sites mentioned above. However, within sequences where the final Mousterian technological expressions are represented, these expressions are by the exclusive presence of the Discoid method, such as in Arma delle Manie level II (Leger, 2011-12), or the association of this method with that of Levallois, like Mochi Shelter and Bombrini Shelter (Negrino and Tozzi, 2008). Thus, contrary to the traditional view of some authors that cultural modifications in the Middle Palaeolithic are absent or at a very slow rhythm (Mellars, 2006), the continuities or abrupt replacements of technologies that are common within the late Mousterian of MIS3 (Delagnes and Meignen, 2007) also occurred along the Italian Peninsula.

From the earliest descriptions, Uluzzian lithic technology has been recognized as a system primarily oriented towards flake production. Although no quantitative data have so far been produced, Palma di Cesnola (1989, 1993) describes non-typified flaking characteristics where the cores, generally of an irregular shape, show a primarily unidirectional pattern, although bidirectional detachments are frequent. Bidirectional, orthogonal, and polydirectional cores are also present, usually of a polyhedral form, but commonly Discoid. Cores-on-flakes and centripetal cores are also present. The flakes present a polygonal contour, or a cortical or flat back opposed to the cutting edge, and they are often partly cortical with the occasional faceted butt. A further method of flake-making was based on anvil percussion, which produced irregular flakes and the frequent splintered-type pieces (Gambassini, 1997; De Stefani et al., 2012; Dini and Tozzi, 2012; Kaczanowska et al., 2010). These characteristics were later confirmed by other authors at Grotta La Fabbrica (Dini and Conforti, 2011; Dini and Tozzi, 2012), Castelcivita, Cavallo, Klissoura I (Kaczanowska et al., 2010) and have been preliminarily compared across Italian assemblages. Nevertheless, these are limited to short descriptions of only some aspects of flake production (De Stefani et al., 2012) that do not account for other modes of manufacture, such as the blade-bladelet system and splintered pieces, or very limited re-examinations that seek to assess human mobility (Gambassini, 1997; Riel-Salvatore, 2009; Riel-Salvatore and Barton, 2004; Ronchitelli et al., 2009; Moroni et al., 2013).

The present paper will assess the Uluzzian technology in relation to the techno-complex that immediately precedes it by evaluating the results of a complete study of the lithic and bone tool assemblages at the key site of Grotta di Fumane in northern Italy. The discovery of this cultural record, sandwiched between the final Levallois Mousterian and the Proto-Aurignacian, has been briefly described in previous preliminary notes based on the field archaeological record and the main diagnostic features of the lithic assemblages (Peresani, 2008, 2012). Nevertheless, no data were provided on the variability in flaking methods, the appearance of new procedures and specific retouched tools, the disappearance of the most common methods used in the Mousterian, such as the Levallois, or the use of bone as a raw material for shaping formal tools. All of this information has been examined in the present work, with the aims of assessing if the Uluzzian technology shares elements of continuity or discontinuity with the preceding Mousterian complexes and the successive Proto-Aurignacian and how these elements contribute to understanding the cultural impact of the Uluzzian. The confirmation of the existence of new behavioral traits in the MUPT, and hence a bio-cultural shift in this zone of Mediterranean Europe, will be also discussed in the context of the behavioral variability of the populations present at the time, including exploring whether the technological traits are a proxy for population replacement.

Grotta di Fumane, the Middle Palaeolithic – Upper Palaeolithic Transition and the Uluzzian

Grotta di Fumane lies at the foot of the Monti Lessini Plateau (Veneto Pre-Alps) and has been excavated since the 1990s. Details about its morphology, Late Pleistocene stratigraphic sequence, and its cultural content are available from numerous publications (Martini et al., 2001; Broglio and Dalmeri, 2005; Broglio et al., 2006; Peresani et al., 2008, 2011a). At the base of a rock cliff, a main cavity (B) and two associated tunnels (A and C) preserve a finely layered sedimentary succession spanning the late Middle Palaeolithic and the Early Upper Palaeolithic, with structures and dense scatters of remains in units A11, A10, A9 and A6-A5 (Mousterian), A4 and A3 (Uluzzian), A2 and A1 (Proto-Aurignacian), and D3 (Aurignacian) (Figure 2). Currently, layers A9 to A2-A1 have been extensively excavated at the entrance to the cave and partly excavated in the cave mouth.

FIGURE 2 ABOUT HERE

In layer A5, the latest Mousterian occupation takes place prior to 43.6 – 43.0 cal BP (Higham et al., 2009). Recent extensive excavations of the A6-A5 complex revealed combustion structures and the related waste of burnt materials connected to a large area with flake and bone scatters (Peresani et al., 2011a). The lithic evidence shows close similarities with layers A11, A10V, and A10 due to the extensive use of the blade-focused unipolar Levallois technology (Peresani, 2012) that is based on a main operational sequence that shifts to a centripetal pattern at the end of the reduction sequence. Levallois blades, blade-flakes and other by-products were shaped into simple or convergent scrapers and points. There is also sporadic production of bladelets and discoidal flakes (Peresani et al., 2013). The bone industry is represented by 131 flakes used like retouchers (Jéquier et al., 2012) and one side scraper (Romandini et al., 2014). Hunting focused on red deer, ibex, roe deer, chamois, giant deer and bovid, most often between the end of spring and the beginning of autumn and only occasionally during winter (Romandini et al., 2014). Birds were also hunted (Peresani et al., 2011b), and some bear bones show traces of human modification.

The Uluzzian layers A3 and A4 were excavated at different times from 1989, at variable extensions from the cave entrance and in the cave mouth. More extensive explorations were carried out in 2005 – 2006 in a 20m^2 area at the left side of the cave-entrance (Figure 2), with the aim of clarifying the cultural contents and taphonomic conditions (Peresani, 2008). While post-depositional contamination is reported in the eastern sector of the cave from the dispersion of Aurignacian artifacts in the Uluzzian units (Peresani, in progress), unperturbated sedimentary conditions were observed in the west-central area beneath the current vault and at the confluence of the A and B tunnels (Fig. 2). Here the stratigraphic sequence of the complexes A2 – A9 is also finely layered and its reliability is supported by the chronology between A5+A6 and A2 (Higham et al., 2009; Douka et al., 2014). The Uluzzian levels furthermore contain hearths and other dwelling structures that enhance stratigraphic consistency (Peresani, 2008 contra Longo et al., 2012). Once the contaminating elements are discounted, the cultural contents of the entire Uluzzian stratigraphic complex offer a starting point for discussions of its techno-typological profile, and demonstrates elements of continuity and discontinuity with the final Mousterian and the Proto-Aurignacian, respectively.

The archaeological material was either directly excavated using a 33x33cm grid or recovered from wet sieving. The layers are mostly constituted of frost-shattered slabs with variable amounts of sand and aeolian dust, the latter becoming prevalent from the entrance to the exterior zone. A4 is flat and horizontal with stones of variable size, gradually dipping into the main tunnel B. Sand content increases to dominate the sedimentary composition towards tunnel A. Due to this sedimentary variability, different facies and sub-layers have been defined (A4I - A4VI, A4IIsand). The boundary with the underling unit A3 is clear. A3 is largely composed of thermoclastic stones of variable size, horizontally embedded, and sand varies from rare loose lenses to thin layers in the stony area in the western zone below tunnel A. Sedimentary variability has thus produced different facies and sub-layers (A3I, A3II, A3IIsand). The upper limit with the Aurignacian level A2 is marked by a level of ocher over a large part of the area and by a considerable change in the anthropic content. This limit, however, appears disturbed in the easternmost zone of the cave entrance, caused by post-depositional deformations due to frost, which produced a re-arrangement of stones. Portions of A2 are infiltrat~~lat~~ed into A3, producing an intense dispersion of the Aurignacian stone implements in the layer below. This zone yielded a mesio-lingual portion of a lower molar with a short segment of root preserved (Fumane 6, Benazzi et al., 2014). Its attribution to the Uluzzian or the Proto-Aurignacian remains uncertain due to the post-depositional disturbance mentioned above. Conversely, in the central and western zone, where stratification is regular and unaffected by post-depositional perturbation, layer thickness increases, limits are horizontal, and dwelling structures have been brought to light, more in A3 than in A4 (Figure 2), which give this context reliability. Specifically, structure A3SI is a large fire-place with few flakes and bone shafts scattered around, structures A3SII and A4SI are small fire-places, structure A3SIV is a concentration of over 200 discarded flakes and bladelets, cores, one backed knife, bones and charcoals.

The Uluzzian ecological context is indicated by the association of forest fauna together with “cold” and open habitat species that were present above the tree line. Red deer are better represented than roe deer and bison, although, compared to A4, a decrease of red deer in favor of ibex and chamois and the appearance of bison and woolly rhinoceros, wolverine, lynx, and ermine can be noted in A3 (Tagliacozzo et al., 2013). This context reflects climatic cooling from A5 –A6 to A3 that could fall into the cold stadial between GIS12 and GIS11 (Douka et al., 2013), as also indicated by the micromammal associations (Lopez-Garcia et al., 2015). Hunting focused on red deer and ibex, but giant deer, roe deer, bison and chamois were also pursued, and selected parts were processed in the cave. Bear, wolf and fox were exploited, as well, for their fur and possibly meat. Birds like golden eagle, Alpine chough, and black grouse were also disarticulated and stripped of flesh (Tagliacozzo et al., 2013).

In layer A2, dwelling structures, lithic assemblages, bone and antler tools, painted stones, and ornamental objects (Broglio et al., 2006; Bertola et al., 2009) mark the arrival of the first Aurignacians after 41.2 – 40.4 cal BP (Higham et al., 2009). In A2, the oldest Aurignacian layer, structures are mostly located in the southern zone at the entrance to and outside the cave, and include post-holes, hearths, and accumulations of burnt remains, bones, and lithics. The lithic implements are regular blades, and straight and twisted bladelets and microbladelets produced by direct organic percussion from carenoid-type, pyramidal, and prismatic unipolar cores. These items were shaped into points and Dufour bladelets using marginal abrupt retouch, and show use-wear traces that suggest their use as weapon points or for insertion in cutting and scraping composite tools (Broglio et al., 2005). Personal ornaments consist of a few grooved red deer incisors and more than 800 perforated shell beads belonging to 60 different taxa (Gurioli et al., 2005). A few rock fragments were painted with red ocher, a material also widely dispersed on the soil, showing an anthropomorphic figure with the head surmounted by two horns, an animal, and other motifs (Broglio et al., 2009).

Materials and methods

The conceptual and analytical approach to technological analysis of knapped stones follows Inizan et al. (1995), Lenoir and Turq (1995), Delagnes (1990), Boëda (1994) and Guette (2002) for the Levallois. To reconstruct reduction sequences, morpho-technical, diacritic, and morphometric analyses were conducted on the cores, complete blanks, and by-products deemed to have had a significant role in production, as well as some refitted pieces. 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. Morphometric data (length, breadth and thickness) were taken following the morphological axis of the flake, with attention to the cortical products, the end-products and the core. Morpho-technical and morphometric data help to identify the aims of the flaking procedures and, when combined with the diacritic analysis, enable reconstruction of the knapping procedure. The analysis was limited to artifacts of modules (length + width) greater than 4cm. 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.

Initially, this study considered 3481 lithic artifacts in total. From this assemblage, 312 artifacts, undeterminable due to intense fragmentation and physical and chromatic alteration caused by thermal stress, were excluded, along with less than 1000 artifacts securely identifiable as Aurignacian on technological and typological grounds (complete and fragmentary Dufour bladelets, unretouched bladelets of comparable size and shape, carinated bladelet cores and end-scrapers, rejuvenation flakes of blade and bladelet-cores and other by-products). These Aurignacian artifacts were recovered in the eastern zone of the cave entrance, more frequently in A3 (866) than in A4 (48). In contrast, the central and western zones, which contain the dwelling structures A3SI, A3SII, A3SIV and A4SI, are devoid of Aurignacian artifacts and altered pieces, and the Uluzzian material has been found in an excellent state of preservation. Therefore in total, the Uluzzian lithic industry analysed comprised 2255 items, including flakes, cores, and retouched tools. The differences in frequencies of the main artifact classes of end-products and tools between the two Uluzzian assemblages were subjected to testing of independence by chi-square and Fisher exact tests using Stata 11.0.

Except for the few bone retouchers that were the subject of a previous study (Jéquier et al., 2012), the bone industry is composed of one awl and two fragments of worked rib that were analysed directly, avoiding the use of resin replicas. For each artifact, anatomical provenance and animal species have been recorded. Measurements of the specimens included length, width and thickness. For the identification and differentiation of technological and functional traces from animal modifications (e.g., pits, punctures, scores), trampling abrasion, and modern mechanical alterations produced during the excavation we referred to the available scientific literature (Haynes, 1983; Shipman and Rose, 1988; Olsen, 1989; Blumenshine 1995; Fisher, 1995; Villa and d'Errico, 2001; Blasco et al., 2008).

The analysis of technological and functional traces was based on criteria defined in the scientific literature (Maigrot, 1997; Christidou, 1999; Legrand, 2007). In particular, location, appearance, development, extension, and distribution of manufacturing and use-wear traces have been recorded. Additionally, observations on archaeological artifacts have been verified through experimental comparison. The latter involved a collection of artifacts documenting various prehistoric manufacturing techniques (e.g., grooving, percussion, cutting, scraping, abrasion) as well as a reference collection of use-wear traces produced after using bone artifacts in various activities (such as hide treatment, wood processing, hafting). Taphonomic, technological and functional traces were analysed using a Leica S6D Greenough stereoscope (magnification up to 220X), a stereoscope Nikon-SMZ-10 (magnification 0.75-70X) and a metallographic microscope Nikon Eclipse ME 600 (magnification 10-200X).

Results and preliminary discussion

Variability within the two lithic assemblages, originating from the production of flakes, rather than blades and bladelets, is evident (Figures 3, 4, 6 – 8). Such variability marks an important break in technological behaviors with respect to the preceding Levallois blade Mousterian of the A5-A6 complex. Across the Uluzzian sequence, further changes are also recorded: the most notable are represented by the use of Levallois technology, which prevails in A4 and disappears in A3, and by the appearance of new flaking methods and the increase of the blade/bladelet component from A4 to A3 (Table 1). The difference between the two assemblages at the level of the main classes of artifacts has also been successfully tested (Pearson's chi-squared test = 77.0882 [df = 8], p=0.000). Analogously, the technological profile of A3 is totally distinctive from the overlying Proto-Aurignacian (Broglio et al., 2005).

The Uluzzian industries have been made on flint of different carbonatic formations, which, in the western Monti Lessini, range from the Upper Jurassic to Middle Eocene and are easily collected within 5 – 10 km from the site. The most widespread types distinguished on the base of macroscopic features are from the Maiolica and the Scaglia Rossa formations, as well as the Tertiary calcarenites and Scaglia Variegata. Flint also abounds in loose coarse stream or fluvial gravels, slope-waste deposits, and soils in the immediate surroundings of the cave. Given the extensive use of fine-grained flints largely available in the cave surroundings as recorded in the Uluzzian and in the all lithic assemblages of the Mousterian sequence, the Fumane evidence does not enable assessment at the economic level of whether the Uluzzian raw material procurement patterns indicate increasing dependence on fine-grained, non-local rocks, in contrast to the final Mousterian. This is, however, the case at Cavallo and Castelcivita caves (Riel-Salvatore and Negrino, 2009) and at La Fabbrica, where jasper is the most utilized raw material in layer 2 (Dini and Tozzi, 2012). Again at Fumane, the use of very few older patinated artifacts, collected in contexts outside the cave and exploited as cores in A3, has also been noted as a practice that was also observed in other Mousterian units of Fumane, such as unit A9 and the Quina complex in BR1 - BR3 (Peresani et al., 2014).

Flake making and tool design in A4

The lithic production in A4 is characterized by the predominant role of the strong Levallois component in the technical system, which is distinguished from that of the preceding Mousterian by the disappearance of the unipolar modality in favor of the centripetal (Table 1). Also present are artifacts ascribable to the application of centripetal, laminar-lamellar, discoidal, and Kombewa-type methods, but these remain subordinate to Levallois production in the assemblage (Table 1). Together, these forms of exploitation are aimed at producing flakes to be transformed into ordinary scrapers and especially into backed pieces that, along with splintered pieces, make their emergence in this layer, as both of these latter two types of artifacts are absent in layers A5–A6.

TABLE 1 ABOUT HERE

Levallois flaking

Nearly each step of the Levallois reduction sequence is represented by flakes and cores, which reflect the technical aims that began in the initial reduction and were pursued throughout the whole process of exploitation up to core discard (Table 1). Moreover, these flakes provide good evidence (through the presence of predetermined flakes, core-edge removal flakes, trimming of striking platform, re-preparation of flaking surface) for the recognition of options and ways of predetermining shape and size by the manufacturers. Percussion was direct, with a hard hammer.

The number of large semi-cortical and Levallois flakes with multidirectional patterns on the dorsal face and faceted butts suggests that the centripetal recurrent method was used from the onset of reduction sequences (Figure 3). Centripetal flakes display a polygonal or fan-like outline when the core-edge was partially removed. This combination of core-edge removals with centripetal flakes determined, as a whole, the shaping of the core face with limited maintenance of the peripheral core convexities. This process was seemingly uninterrupted and led to a high number of blanks per core, but featured a low degree of metric and morpho-technical standardization for possible functional edges, as seen in other industries across Italy (Kuhn, 1995). No evidence of a preferential method has been revealed compared to other Levallois assemblages along the sequence. Platforms were accurately trimmed, even from the onset of the sequence. Levallois flakes range between 19 and 66mm in length, with multi-modal distribution at 34 and 42mm in length and mean at 37mm. Breadth ranges from 15 to 45mm with an mean of 27mm.

FIGURE 3 ABOUT HERE

Levallois cores

Levallois cores are few (Figure 3) and show careful platform preparation that extended around almost the whole perimeter. Sizes vary between 40 and 67mm, and core exploitation stopped as a result of the volume reduction as much as the usual flaking accident such as hinging. None of the cores were discarded due to incipient fractures, voids, or other elements reflecting poorly selected raw material.

Flakes from ordinary centripetal cores

Evidence of flake production based on centripetal modality with a degree of predetermination lower than Levallois is supported by several artifacts. Few flakes show that core exploitation may also involve orthogonal patterns (Figure 3[10 – 11]). This procedure is recurrent, the level of predetermination is low, and platforms are weakly trimmed. Flakes are generally thin and show polygonal outlines. The percussion is direct with a hard lithic percussor.

Discoid flaking

Over 20 artifacts have been ascribed to the Discoid technology, including pseudo-Levallois points, core-edge removal backed flakes, and a few polygonal flakes. They do not show patination that is different from the assemblage, or double patination, contrary to what is viewed in the Discoid technology featured in unit A9, where 0.7% of the total flakes were recycled using older artifacts (Peresani et al., 2014). Discoid production in A4 can be considered a real, even if ephemeral, occurrence.

Flake-blades and bladelets

The appearance of blades and bladelets is recorded as still incipient in A4 (Table 1). The blade cores are structured with two opposing striking platforms, which are flat and inclined from 70° on a single surface through exploitation by a bipolar modality (Figure 4). The blades extracted are scarce in number, rather thick and sometimes cortical. The back of the core is not prepared; control parameters of predetermination are ensured by lateral blades, which remove part of the side of the core in order to delineate the lateral convexities, while the distal convexity is delineated by marginal detachments from the opposing platform. Blades and bladelets have flat and large butts, prominent bulbs, and punctiform percussion points suggesting that percussion was direct, with a hard lithic hammer. The scarcity of artifacts does not allow recognition and definition of the size range, but it is possible to determine that the length of the abandoned cores does not exceed 52mm among the blades, and 29 – 34mm among the bladelets, which oscillate between, on average, 12 to 18mm in width.

FIGURE 4 ABOUT HERE

Flakes from cores-on-flakes

The exploitation of the lower face of some flakes as cores is also recorded. The procedure involves the faceting of a striking platform followed by reduction of the proximal zone of the flake-core aimed at producing a few ordinary centripetal flakes and centripetal Levallois flakes. The predetermined items are very few, with sizes ranges between 20 and 40mm in length.

Splintered pieces

The use of the bipolar technique is common, as suggested by 22 splintered pieces and 26 fragments recognized as products of this bipolar exploitation. The splintered pieces are primarily derived from the bipolar flaking of a variety of flakes. Amongst these flakes there are ordinary pieces, cortical flakes, and some cores that are no longer recognizable. There is also no shortage of evidence for the exploitation of some Levallois products. In terms of dimensions, the splintered pieces are not small, and their means are 36.6, 28.3, and 8.6mm respectively for length, width, and thickness, with maximums of 60, 41, and 14mm. The splintering is not intense, appearing rather marginally on both poles, associated sometimes with abraded edges. The detachments are generally irregular, even if a few bladelets are recognized, as is seen through the refitting of a splintered piece demonstrating that bladelets could be produced sporadically from these artifacts (Figure 5[6]). The flakes have irregular forms, sometimes retaining portions of the ventral face of the splintered piece. Size is slightly smaller for splintered flakes, with averages of 32.5, 25.4 and 6.3mm respectively for length, width and thickness, reaching maximum values of 45, 54 and 14mm.

FIGURE 5 ABOUT HERE

Retouched tools

Scrapers are the prevailing tool type in this assemblage (Table 2). Other implements include very few denticulates and a couple of marginally retouched points made on elongated Levallois flakes. New implements include backed knives and the above-described splintered pieces. Simple scrapers largely prevail over double, transverse and convergent types. These have generally been shaped on flakes derived from the initial decortication, on Levallois recurrent flakes, more unidirectional than centripetal, and a small number on Kombewa-type flakes, Discoid core-edge removal flakes, flake-blades and core repairing flakes. The retouch is simple and moderately invasive, with less marginal or strongly invasive reduction of the original blank. There was also the practice of thinning the lower face, as opposed to the retouched edge. Among the typological groups of major relevance, it can be noted that the simple and double scrapers have comparable size ranges, with general averages at 45.4, 30.1, and 8.4mm respectively for length, breadth, and thickness, whereas double and convergent tools are a bit longer than simple scrapers. Unlike scrapers, the rare notches and denticulates were less made on predetermined flakes than cortical, laminar flakes, and centripetal flakes, which in many cases bear a thick side opposed to the retouched one.

The backed knives (Figure 5[1–5]) are made on thin (4 – 7mm) flakes, produced from the decortication phase and the main phases of core exploitation. Other supports selected for these kinds of tools are Kombewa-type flakes, centripetal flakes, and typical Levallois flakes, averaging 25.6mm in width. The abruptly retouched back is either straight or convex, entirely or partially covering the length of the edge. On the opposed side, a thin edge is left unretouched.

Stone tool design and use in A3

The lithic production in A3 is aimed almost exclusively at producing flakes. This system is based on a variety of methods, united by a low level of technical elaboration. The most widely used is the recurrent centripetal, which is supported by other operations oriented towards the production of large individual fragments, elongated flakes with a backed edge, and Kombewa-type flakes. Alongside this production there is a laminar-lamellar production observed in a simple operational chain. The presence of splintered pieces is pronounced. Backed pieces, various scrapers, some denticulates, and an end-scraper represent the lithic tools, marking differences with layer A4 as checked via Fisher's exact test (p=0.001).

<u>Centripetal flaking</u>

Similarly to layer A4 but with major incidence, a centripetal flaking procedure has been used with low degree of predetermination (Figure 6[1–3]). It is recurrent, with the striking platforms weakly trimmed and the core face roughly prepared and scarcely maintained. The flaking angle is around 70° – 80°, and the percussion technique involved the use of a hard hammer. Another case is a pyramidal core with few converging flake detachments (with one refit), struck from a peripheral flaking platform of a roughly-prepared block that was affected by a large void at the base. At the general level, flakes are thin (<4.5mm) and have a squared or polygonal outline.

Single large flaking

There is ephemeral evidence of the production of single and wide flakes from large cores made on naturally shattered slabs. The core shows rhombohedral longitudinal profiles outlined by an inclined striking platform, roughly prepared by the upper flaking face, the lower left natural face, and by a roughly prepared distal convexity. The sides were previously backed by the upper face. This volume was exhausted after a large and thin predetermined flake was removed using direct percussion (Figure 6[4]). Refitting shows that this scheme was preceded by thin unipolar rectangular flake removals from both sides that created shallow lateral convexities.

FIGURE 6 ABOUT HERE

Flakes from cores-on-flake

There are also procedures involving the exploitation of cores-on-flakes (Figure 6[5]). Generally, the exploitation starts from the proximal zone of the core after rough preparation of the striking platform on the dorsal face, and preparation of the flaking face is also embedded in the reduction sequence. The aim was to produce from one to three Kombewa-type ordinary flakes using the centripetal pattern, followed by the discard of the core. The predetermined items are very few, with sizes ranges from 20 to 40mm in length and breadth.

Unipolar flaking

Flakes longer (mean 40.8mm) than they were wide (mean 28.8mm) with a cortical back opposite a rough cutting edge were extracted from naturally shattered plates. Prior to exploitation, these plates were prepared by roughly shaping an inclined striking platform on one of the short sides of the core, while the other side was modified into an inclined surface to be used like a distal convexity. The same holds for one of the longest sides, shaped into an inclined surface to be used as a transverse core convexity. The opposed back is left thick and rough and does not show any trace of modification (Figure 7 [1]). Flakes of about 7mm thick were extracted as a single strike or from a few more on the upper core face. Cores were generally discarded after a few reduction cycles. The lower face was left unmodified. Percussion was direct with a hard percussor.

Alternate flaking This method produced the following flake types: Fl1 – flakes usually longer (around 5 – 7cm) than they were wide, with thick edges (~ 70°); Fl2 – thin flakes of comparable length and width and centripetal pattern; Fl3 – chunky and sturdy flakes with thick, straight profiles, sometimes longer than large, and with thick edges (~ 70°). Butts are flat to convex; many show laterally-oriented scars. The core has two hierarchical faces forming a rhomboidal structure (in section), with two main, parallel faces (A1 and A2) reduced from the detachment of Fl1 and Fl2, sometimes overpassed, and faces (B) not over 4 – 5cm long used for detaching Fl3. These faces are also striking platforms for A1 and A2 (Figure 7 [2 – 6]). The core convexities are configured as such: Fl1 are limited in the distal zone by the inclined scars of face B; pronounced lateral convexities of Fl3 are shaped by adjacent Fl3 scars or by a cortical back. The thickness of Fl3 relies on the position of the percussion point, cutting faces A1 or A2. Percussion was direct with a hard percussor. Reduction preceded alternation between one of the A1 or A2 faces followed by reduction in core length after one to three Fl3 were removed.

FIGURE 7 ABOUT HERE

Blade/bladelet making

Although the frequency of blades decreased from A4 to A3, the incidence of bladelets markedly increased in this layer (Table 1). The blades are rather short and wide, with a rectilinear profile, trapezoidal section, and unipolar pattern on the dorsal face. Hard hammer was used for percussion. The bladelets were extracted from small pebbles collected downstream, modified by creating a flat striking platform on the largest or narrowest face and then exploited on the wider or longer side. Core exploitation started from a natural edge or the convex natural surface of the pebble, with detachments of small cortical and semi-cortical flake-bladelets and the first bladelets (Figure 8). These end-products have large flat, dihedral, and faceted butts and triangular sections. Prominent bulbs and punctiform percussion points are ascribable to the use of small hard lithic hammers. The longitudinal profile is straight to curved. Transverse convexities were maintained by unipolar flake-bladelets with natural sides, and longitudinal convexities were broadly shaped from plunged blows. Refittings show that series of unipolar bladelets were also detached from pseudo-pyramidal cores with up to three short striking platforms. On some cores, refittings also demonstrate that rejuvenation of the striking platform may have occurred (Figure 8 [1]).

FIGURE 8 ABOUT HERE

Levallois

Levallois flakes were largely produced by the centripetal recurrent modality, as shown by the number of semi-cortical and Levallois flakes with multidirectional patterns and faceted butts. Flakes have a polygonal or fan-like outline, and the core volumes and peripheral core convexities were poorly maintained.

Splintered pieces

The frequency of splintered pieces in A3 is higher than in A4. The splintered pieces primarily come from bipolar flaking of a moderate variety of flakes, amongst which are mostly ordinary cortical flakes and those cores that are no longer recognizable (Figure 9 [7 – 10]). The splintered pieces do not exceed 50mm in length, with thicknesses up to 18mm, recorded from a refit of three fragments. On the smaller pieces, the two opposing ridges show microscarring produced by repetitive blows, responsible for invasive to marginal splintering on both poles, sometimes elongated, and generally well visible on one of the faces. The flakes generally have an irregular form, thicknesses between 7 and 3mm, and sometimes retain portions of the ventral face of the splintered piece. The dimensions are slightly smaller than the splintered pieces. Only one artifact has a slight marginal back.

Tools

In addition to the splintered pieces described above, retouched tools include sidescrapers, points, backed knives, end-scrapers and other types. Scrapers are subordinate to splintered pieces. Simple and transverse scrapers are the best represented types, with only one convergent type. Two cases of thinning of one or both of the faces, as opposed to the retouched edge, are observed. These tools have generally been shaped on flakes derived from the initial decortication, two on Levallois unipolar flakes, but many from predetermined unipolar flake-blades and centripetal flakes. There is also evidence for the recycling of a Discoid flake. The retouch is simple and moderately invasive, with limited reduction of the original blank. Sizes are comparable among the typological groups, with averages at 40.7, 33.2, and 9.3mm respectively for length, breadth, and thickness. There are also a few points on Levallois unipolar flakes and different types of end-products, shaped by marginal retouch, denticulate retouch, or thinning on the lower face and smaller than the scrapers. The backed knives are made on thin (3 – 9mm) flakes, produced from the main phase of core exploitation (Figure 9 [1 – 5]). Supports selected for these tools are centripetal flakes, and only in one case was a unipolar flake-blade observed. Mean sizes are 39.1 (length), 22.1mm (breadth), and 6.9mm (thickness). Most of these were recycled from fragmented items. The abruptly retouched back is either straight or convex, entire or partial on the edge opposed to the thin and unretouched edge. The only end-scraper recovered in A3 is on a cortical flake, marginally retouched on the front opposite to a trimmed edge, and thinned widely on its lower face (Figure 9).

FIGURE 9 ABOUT HERE

Bone tool technology and use

The osseous industry comprises a few bone retouchers, one awl, and two fragments of worked rib. Retouchers typically identified by punctiform impressions, linear impressions, striae, and wells, were mostly made using cervid femoral shafts (Jéquier et al., 2012), consistent with the faunal spectra and the taphonomic analysis (Tagliacozzo et al. 2010). They share many common features with the A5 – A6 Mousterian assemblage (Jéquier et al., 2012), in that species and anatomical elements are usually the same. However, an *Ursus* femur and a probable canine in A4 are remarkable for their uniqueness, forcing comparison with the overlying Aurignacian, despite the substantial difference in number of retouchers between the Uluzzian and the Mousterian complexes (21 versus 131 respectively; Jéquier et al., 2013). The awl (Figure 10 [a]) was made on a longitudinal half of a rib of a medium-large mammal, obtained through incision and splitting (Figure 10 [a1]; Camps-Fabrer, 1990) (and later shaped by flint scraping along the lower surface and the distal end (Figure 10 [a2]). The tip of the awl is characterized by a functional hinged fracture (Figure 10 [a3]), whereas the surface shows deep and fine striations, round depressions, and flat-domed polish when observed at high magnification with a metallographic microscope (Figure 10 [a4–a5]). Similar fractures and surface modifications were obtained on a comparative series of modern bone awls experimentally used to pierce leather colored with ocher (Figure 10 [a6]). Other functional modifications such as rounding, polish, striae, and depressions on the distal part of the awl suggest that this tool was used to pierce ochered leather (Figure 10 [a1–a3]). The ocher residues trapped in the trabecular interstices of the lower surface of the rib (Figure 10 [a2]) possibly result from intense percolation from the Aurignacian A2R layer above, in the area of tunnel B (Broglio et al., 2009) and, for this reason, cannot be associated with use of the awl. Another mid-lateral posterior rib portion of a medium – large sized mammal (Figure 10 [b]) shows traces of flint scraping on its surfaces (Figure 10 [b7–b8]). By thinning both edges into an acute angle, scraping aimed to create a cutting beveled edge on one lateral side of the rib. No functional traces were identified on this artifact.

FIGURE 10 ABOUT HERE

Discussion

Variable but morphologically non-standardized flakes are a shared element in the Uluzzian industry, which at a general level correlates with Fumane, where flake making aimed to produce unipolar flake-blades with cortical or uncortical ~~débitage~~ back, centripetal flakes and large invasive flakes. Compared to the industries of central and southern Italy, layer A4 of Fumane is more focused on one of the main objectives, which are flakes made from centripetal methods. Of these, the most significant role is played by the Levallois system, therefore marking a partial shift in the application of this volumetric concept in respect to the final Mousterian of units A5 – A6 (Peresani 2012; Peresani et al., 2013). The change is also reflected in the retouched tools that are configured on a range of simple scrapers, contrary to the largest variety in the preceding Mousterian (Peresani et al., 2013). Nevertheless, the persistence of the Levallois in layer A4 indicates continuity from the Mousterian to the Uluzzian at the level of volumetric concept, without changes in the lithic supply, established at the local level at the expense of waste, primary exposures, and loose stream deposits (Di Taranto, 2010; Centi, 2012; Peresani et al., 2013). Under the Levallois system, variability is not novel among the Mousterian sequence of Fumane and at Grotta della Ghiacciaia near Fumane (Bertola et al., 1999), nor in other diverse economic and chronological contexts in this part of Italy (Peresani, 2001), and is expressed at various levels by a group of variables that can occur as the result of a gesture, single intervention, or a sequence of interventions across the entire reduction. However, the similarities observed amongst Levallois reduction sequences undertaken predominantly through a recurrent unipolar modality reveal how this procedure was rooted in the

Late Mousterian during MIS3, from the north to the south of Italy (Gambassini, 1997; Peresani, 2009, 2012; Boscato et al., 2011; Ronchitelli et al., 2011).

Given the prevalence of flakes at Fumane and in Uluzzian technical systems, the production of elongated pieces such as laminar flakes, short blades, and bladelets remain, nevertheless, not insignificant, although these are characterized by low morpho-metric standardization (Palma di Cesnola, 1993; Riel-Salvatore, 2009). At La Fabbrica, Cavallo, and Castelcivita, unipolar cores with scarcely trimmed convexities were used for extracting laminar flakes, blades and bladelets, sometimes cortical backed, avoiding any preliminary preparation of the core face (De Stefani et al., 2012; Dini and Tozzi, 2012; Riel-Salvatore, 2009). Further exploitation of the bladelet core may involve double platforms and, sporadically, postero-lateral preparation as has also been recorded at Klissoura I, level V (Kaczanowska et al., 2010). In other cases, the exploitation of the bladelet cores can require the activation of an orthogonally-disposed face (Dini and Tozzi, 2012). The reduction of splintered pieces also made an ephemeral contribution to the production of non-predetermined bladelets as shown at Fumane layer A4.

The bladelet component does not represent an innovation because it is already present with variable incidence in the final Mousterian. At Fumane in levels A5 – A6, flat or slightly convex bladelets were extracted using hard hammer direct percussion from the dorsal face of large, possibly laminar, truncated flakes, or from small volumetric unprepared cores (Peresani et al., 2013). A characteristic production was identified in level FIIIe of Cavallo (Carmignani, 2010), where the artifacts were extracted from local siliceous plates, after preparation of the plane of percussion and accurate maintenance. Although the chronological position of these artifacts remains to be determined, these are assumed to fall into MIS3. A bladelet component is also present in Oscurusciuto, layer 1, dated to 43.8 – 42.2ky cal BP (Boscato et al., 2011), in Molise at Grotta Reali layer 5, between 44.5 and 39.4ky cal BP, based on prismatic unipolar cores (Peretto ed., 2012), and in the upper layers of Grotta Breuil, based on unipolar cores made from small pebbles (Rossetti and Zanzi, 1990, 1991; Bietti and Grimaldi, 1996).

The typology of the tools at Fumane reflects what is already known for the Uluzzian sequence that started shortly before 45ky cal BP and persisted for some five to six millennia until around 39ky cal BP in Italy (Douka et al., 2014). The splintered pieces are the key element that characterizes the more pronounced shift in the transition from the final Mousterian unit A5-A6 to the Uluzzian layer A5, although these are very scarce compared to all other tool types and are associated with a toolkit still traditionally Mousterian. The Uluzzian has traditionally been defined by a prevalence of Mousterian tool types like sidescrapers, denticulates and notches, an abundance of splintered pieces, a variable amount of backed pieces and crescents, and small numbers of Upper Palaeolithic tools — mainly end-scrapers and almost no burins (Palma di Cesnola, 1993). Splintered pieces thus account for an important fraction of all assemblages, with an incidence of 23-61% in respect to the rest of the toolkit in the archaic Uluzzian, where numerous backed pieces are also observed (Riel Salvatore, 2009). Backed pieces increase as part of the evolved Uluzzian in layer EII-I of Cavallo compared with layer V of Klissoura I (Kaczanowska et al., 2010), while in Fumane the scarcity of backed tools might be an expression of the antiquity of the Uluzzian, or may indicate a specific use of the cave in response to local conditions. Such heterogeneity is not common. For example, at La Fabbrica, which is still undated, retouched artifacts include denticulates and scrapers, whereas end-scrapers, crescents, and truncations are scarce. At Castelcivita, backed tools represent one of the most identifiable items, even if they are less frequent than denticulates and scrapers. At Cavallo, besides splintered pieces and scrapers, end-scrapers mark a specific component of the oldest layer, and backed pieces and crescents occur with variable frequency. Note that end-scrapers at Cavallo are thinned on the side opposed to the functional retouched edge, in a similar fashion to the single tool found at Fumane, layer A3.

Discussion over the techno-functional significance of the splintered pieces has revolved around whether they were used as wedges to groove or splinter hard tissue (e.g., bone, antler, wood) or as an expedient reduction method to maximize the utility of raw material packages (Hayden 1980; Le Brun-Ricalens 2006; Mourre and Jarry, 2009, 2010). In the case of the Uluzzian, it has been suggested that bipolar reduction was used to produce a maximum number of blanks from nodules of fine-grained raw materials without in turn curating them very heavily; this claim is based on the use of tiny irregular chips that are comparable to some ethnographic cases (Riel-Salvatore, 2009). Detailed functional studies on material from Italy remain in a preliminary state, but some initial work on splintered pieces from Castelcivita and Grotta del Cavallo suggests that functional units have been used like wedge edges for splitting hard material; this is also suggested by breaks made from repeated percussion marks on the opposite edge, and lateral edges that were mainly used for processing soft and semi-hard material with transversal and longitudinal motions (De Stefani et al., 2012). The contribution of Fumane to detail the use of splintered pieces also remains limited, due to the preliminarity of the ongoing micro-wear analyses. Based on the first observations (made on the Uluzzian Fumane stone tools), it seems that the poles of the tool acted like wedge edges for splitting hard material, like wood or bone (S.Ziggiotti, personal communication).

Some of the elements of continuity between the final Mousterian and the older Uluzzian at Fumane, when compared at the technological (application of the Levallois concept, ephemeral blade production) and typological (scrapers with scalar retouch) levels, are thus contrasted by a group of indicators (variability of technical aims, typological innovations) that mark, across the second level A3, the definitive separation of the Uluzzian from the Mousterian techno-complex mostly based on laminar than centripetal flake Levallois production. This separation occurs in a relatively short phase (Douka et al, 2013), in that the Uluzzian is chronologically indistinguishable from the final Mousterian (layers A5, A5-A6) at 44 – 46ky cal BP (Higham et al., 2009). This is in contrast to that recorded both in other contexts of Italy and Greece, where the time span that separates the Mousterian and Uluzzian in each known sequence is undetermined or badly dated. At La Fabbrica, there is no date for level 4, analogous to Cavallo, where the levels FIII-FI are not dated. At Castelcivita, a chronological gap of several millennia is identified, and Mousterian determinations should be considered minimum ages at best (Ronchitelli et al., 2009). At Klissoura, the gap between the lower level VII at ~47-51ky cal BP (Kuhn et al. 2010), the final Mousterian (41–40ky or

~44-45ky cal BP), and the beginning of the Uluzzian (~40-39ky cal BP) corresponds well to the stratigraphic discontinuities observed at the interface of the MP-UP layers. Although the age estimate for the start of the Uluzzian at Cavallo appears to be older (70%) than that of Fumane in northern Italy, further data are required to confirm this age range, especially from still undated sites (Douka et al., 2014). The cultural change produced by the Uluzzian is definitive, and there is no subsuming long-term persistence of Mousterian cultures after the techno-complex at any of the stratified sites and their surroundings. This is also worth considering in the western Lessini, if one accepts that the radiocarbon date produced from Riparo Mezzena, a site 10km east of Fumane, is a minimum age. At this site, explored over 50 years ago using low-standard excavation protocols with low stratigraphic resolution, Levallois Mousterian lithic industries are associated with Neanderthal remains recovered from a context reworked since the Bronze Age (layer 1b). A bovid bone from the base of the sequence, layer III, has been radiocarbon dated to 34,540 ± 655 14C BP (Longo et al. 2012), much later than the chronological position before or at the onset of the middle Würm estimated based on biostratigraphic and sedimentological data by Bartolomei and colleagues (1980). Although the position of the bone cannot be ascertained, this date has been accepted as the terminus post quem for supporting the late persistence of Neanderthals in the region (Longo et al., 2012; Condemi et al., 2013), despite the unknown age of the human remains. This implies a presumed co-existence between Neanderthals at Riparo Mezzena, Uluzzians and AMH Proto-Aurignacians (Benazzi et al., 2015) at Fumane and all along the southern Alpine slope (Broglio et al., 2006), lasting for around 5,000 years with no trace of cultural interaction. Further doubt is cast on this scenario given that Neanderthals and AMH co-existed for probably 2,600 – 5,400 years in Europe (Higham et al., 2014), during which time, it has been claimed, there was genetic exchange (Fu et al., 2015) and, assumed by several authors, bilateral transmission of cultural and symbolic behaviors via acculturation, as well as stimulus diffusion and other processes of knowledge transfers (Mellars, 1989; Tostevin, 2007; Hublin et al., 2012; but see Zilhão 2007, for a different perspective). Given the persistence of Levallois technology in the industry associated with the ~~About Mezzena~~human remains at Riparo Mezzena and the complete absence of any cultural change expressed at the level of lithic or bone tools, , it - seems more reasonable has been claimed that its chronometric requires a large n adequate dating program has to be taken fully into account (Douka et al., 2014).

Given that the Uluzzian sequence at Fumane has been adequately contextualized chronologically and palaeoenvironmentally, its relationship with the immediately preceding Mousterian can be better assessed. The Uluzzian shares some behavioral traits with the Mousterian (Levallois, bladelets), but in reality radical changes are visible in the diffusion of a series of operative sequences in flake production, which are used for the manufacture of splintered and backed pieces and the single end-scraper found. Furthermore, the Uluzzian flake industry, being characterized by such varied technology, does not compare at all with the laminarity of the recurrent Levallois seen at Fumane and other MIS3 sites in Italy and in the IUP industries of Central Europe. This quite abrupt change is also marked by the appearance of tools unknown in the Mousterian of layers from A11 to A5-A6, like the single end-scraper and the splintered and the backed pieces. Concerning the latter, it should be recognized that the retouched back is a morpho-structural element already present, albeit sporadically, in some of the industries made by means of Discoid technology, such as in unit A9 of Fumane (Lemorini et al., 2003), but also in France at Grand Champ, 50ky cal BP (Slimak, 2008a), and the well-known Mousterian of the Acheulean tradition, with marginal backed knives (Bordes, 1968). The asymmetric structure of the tools remains to be investigated in terms of the functional aims for these complexes and also the Uluzzian, whose products are nevertheless distinguished from those of previous periods by the morphological characteristics of semi-lunates, which are more frequent in the middle and late stages of the techno-complex in the south of Italy (Palma di Cesnola, 1989). The hypothesis that at least a part of these elements were for projectile points requires robust use-wear evidence (Moroni et al., 2013).

As concerns the splintered pieces, their strong appearance in layer A4 at Fumane assumes an innovative character, given their absence in the entire Mousterian sequence. 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, where the low quality and the scarce availability of the raw material could have influenced the Middle Palaeolithic economic system. This is exemplified in the Pontinian industry on the Latium coast, which demonstrates the application of this technique for the production of flakes, essentially constituting an effective means of cutting open small cobbles of flint that are characteristic of this industry and that are seen at the onset of the reduction sequence. In accordance with this, the splintered pieces are very rare or absent (Bietti et al., 2009-2010). For the sake of comparison, it cannot be neglected that in the same region, the bipolar technique played a very different role in the subsequent Aurignacian, when anvil percussion constituted an independent reduction sequence and splintered pieces were abundant, showing opposite flaking and playing the role of cores aimed at obtaining elongated products.

Further, the appearance of end-scrapers in the Uluzzian at Fumane is a phenomenon that has no comparison with the late Middle Palaeolithic industries, so dominated by scrapers of different type and size (Lemorini et al., 2003; Peresani, 2012; Peresani et al., 2013). Comparably, this specific type of tool remains unknown in the industries preceding the Uluzzian in Tuscany, Campania and Apulia (Palma di Cesnola, 1989; Riel-Salvatore, 2009). In contrast, end-scrapers spread in the successive Proto-Aurignacian, both at Fumane (layer A2, Bertola et al., 2013) and across Italy (Palma di Cesnola, 1993), in coincidence with the appearance of a strikingly different techno-typological system, which is also based on the systematic exploitation of higher quality local knappable rocks (Riel-Salvatore and Negrino, 2009) and focused on standardized blade and bladelet production that abruptly increases in number (Palma di Cesnola, 1993; Broglio et al., 2005). Unlike Fumane, in the south of Italy, evidence of continuity from the Uluzzian to the Proto-Aurignacian might be suggested by a few burins and carinated end-scrapers in the very late phase of the Uluzzian, while in the Proto-Aurignacian splintered pieces are still abundant, although regressive (Moroni et al., 2013).

Bone tools found in layer A3 at Fumane provide less substantial evidence of the Uluzzian worked bone industry than is known at Cavallo, Castelcivita, and La Fabbrica, where awls and other cylindro-conical implements were manufactured from the metapodials of red deer and the fibulae and metapodials of horse, and which exhibit a techno-typological complexity from their earliest appearance (d'Errico et al., 2012). Nevertheless, a so-claimed impact implied with the innovative use of hard animal material for producing formal tools by new techniques has been recently re-assessed by the discovery of smoothers, traditionally considered a signature of AMH, in the Mousterian of Acheulean Tradition (d'Errico et al., 2003; Soressi et al., 2013).

The appearance of formal tools in the Uluzzian at Fumane does not correlate with any changes in the exploitation of the fauna since the Final Mousterian, which does not deviate from the usual predations of ungulates and of foxes and bears (Peresani et al., 2011a), the latter also being hunted at Grotta del Rio Secco, to the east in the Carnic Pre-Alps (Romandini et al., 2013). Rather, it is well known that the animal bone flakes were used at Fumane as retouchers (Jéquier et al., 2012) and exploited for producing a scraper (Romandini et al., 2014) in the final Mousterian.

As concerns symbolism and ornamental objects in the Uluzzian, due to the short stratigraphic distance between layer A2 and the perturbation that affected the contact between A3 and the Proto-Aurignacian in the eastern zone of the Fumane cave entrance, the few pierced marine shells found in layers A3 and A4 have been considered to be material percolated from the Aurignacian assemblage (Gurioli et al., 2006) that includes Dufour bladelets and other stone and bone artifacts. These shells belong to some of the 70 taxa found in the Proto-Aurignacian units and show a comparable degree of preservation. Besides beads, coloring materials such as ocher and limonite have also not been found at Fumane, contrary to a few other sites (Cavallo, Klissoura and Cala) where perforated marine shells have been discovered since the archaic Uluzzian phase up to its final phases (Palma di Cesnola, 1989; Stiner, 2010).

Conclusion

Genetic evidence for interbreeding between Neanderthals and the ancestors of AMH (Green et al., 2010; Reich et al., 2010; Sankararaman et al., 2012; Fu et al., 2014; 2015) supports the hypothesis that ~~this~~ the MUPT cultural mosaic could have been produced by more than one hominin taxon. The Neanderthal population, although decreased, still remained active in some western Eurasian zones, giving rise to geographically confined techno-complexes that coincided with regional or supra-regional extensions of preceding Mousterian complexes. In southern Spain, the presence of Mousterian industries persists in association with evidence of artistic-symbolic behavior (Zilhão et al., 2010), while in western Europe the Châtelperronian originates with the production of remarkable laminar industries (Ruebens et al., 2015). On a technological level, the difference between the latter and the Uluzzian is marked, although a strong Mousterian component persists in the toolkits of layer EjopINF at La Roche-à-Pierrot à Saint Césaire, demonstrated by a taphonomic and techno-typological distinction (Soressi, 2011).

Given the evidence that the Uluzzian assumes its own technological character over time, as well as the innovations in terms of the variability in flaking methods in respect to the preceding Mousterian, there is the need to further investigate the origin, routes of diffusion, and disappearance of the Uluzzian in central Mediterranean Europe. Claims for Uluzzian roots outside Europe, based on the similitude of backed pieces from complexes like Howiesons Poort or others in eastern Africa (Moroni et al., 2013), are not supported by the temporal discontinuity of over 20,000 years as well as the large geographical gap produced from the lack of evidence of industries using backed implements in the Near East and the African complexes.

Descriptive typological approaches have led many researchers to claim that this techno-complex was the result of acculturation by Mousterian Neanderthals to AMH technology or of an abrupt behavioral change correlated to AMH in this part of Europe. These claims are far from being confirmed, as the results of our research demonstrate that innovations fall into a still frankly Mousterian cultural context and that these changes are not comparable with those expressed from the Châtelperronian, at least at the level of lithic technology, and from the other coeval techno-complexes in Eurasia. The more or less presumed association between cultural items and human remains, the Uluzzian cannot be considered a cultural proxy for the first incomers/immigrant populations, or, at least at the level of the successive Aurignacian complexes. These are characterised by the systematic adoption of the blade-bladelet production, although few deviations represented by flake-based industries were present in the Early Upper Palaeolithic in various European regions, as in, for example, Cantabria, where the persistence of Discoidal technology has been recorded (Maillo-Fernández, 2012; Baena et al., 2012). Rather, the Uluzzian was a behavioral system that was developed by hominins in southern Europe, in a large-scale context where the coexistence of human forms at least before 41.4ky cal BP (Fu et al., 2015), invokes to move forward ~~beyond~~ the traditional ~~the~~ dichotomy commonly implied to explain the cultural phenomena significant of this phase as an exclusive product of one or another human species.

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Figure captions

Figure 1. Sketch map showing the position of the Uluzzian sites in the Italian Peninsula selected for this project (1 – Grotta di Fumane, 2 – Grotta La Fabbrica, 3 – Colle Rotondo; 4 – Grotta di Castelcivita, 5 – Grotta La Cala, 6 – Grotta del Cavallo, Grotta Bernardini, Grotta di Uluzzo C).

Figure 2. Location of Grotta di Fumane (A); sketch of stratigraphy at the entrance of tunnel A with evidence of late Mousterian (A6-A5), Uluzzian (A4-A3) and Aurignacian layers (A2-D3): 1 - loess and sandy loess; 2 – loess; 3 – sand; 4 – archaeological layer with dense concentration of organic matter and charcoal; 5 – archaeological layer with organic matter and charcoal (after Peresani et al., 2011a) (B); plan of the zone (C, D) with concentration of discarded material A3SIV (E), hearths A3SII (F) and A3SI (G).

Figure 3. Uluzzian from layer A4. Levallois recurrent centripetal flakes (1, 2, 4) and flake refitted to the core (3), Levallois blade (5), sidescrapers (6-8), convergent scraper made on hinged Levallois flake refitted to the core (9), flakes with recurrent orthogonal pattern (10, 11). Arrows indicate: the direction of the blow (full ⊕ a.); the direction of the blow of refitted flakes (dashed a.); the direction of previous blows (full ○ a.). Raw materials: Maiolica (1-3, 5, 6, 9, 11), Scaglia Rossa (10), Scaglia Variegata (7, 8), Tertiary calcarenites (4) flints (scale=2cm; photo M.Obradović).

Figure 4. Uluzzian from layer A4. Blade cores (1, 2), bipolar exhausted bladelet cores (3, ~~4~~5), unipolar bladelet~~, long (5) and short (6) cores~~core (5). Raw materials: Maiolica (1~~-2~~,~~6~~4), Scaglia Variegata (2,3~~-~~,5) flint (scale=2cm; photo M.Obradović).

Figure 5. Uluzzian from layer A4. Backed knives (1-5), splintered piece with refitted bladelet (6), splintered piece (7). Raw materials: Maiolica (2), Scaglia Rossa (1,3,5), Scaglia Variegata (4,7),

Tertiary calcarenites (6) flint (scale=2cm; detailed drawings of the backed pieces are presented in Supplementary Online Material Figure S1; photo M.Obradović).

Figure 6. Uluzzian from layer A3. Centripetal flake core (1), refitted centripetal flakes (2), flake refitted to centripetal conic core (3), large single flake core reconstructed from three fragments with refitting of unipolar flake and maintenance flake (4), core-on-flake and refitted Kombewa-type flake (5). Arrows indicate the direction of the blow (full ⊕ a.); the direction of the blow of refitted flakes (dashed a.). Raw materials: Maiolica (4-5), Scaglia Rossa (1-3) flint (scale=2cm; photo M.Obradović).

Figure 7. Uluzzian from layer A3. Unipolar core (with refitted maintenance flakes) exploited for producing squared flakes with natural back opposed to cutting edge (1), cores and products issued from the alternate flaking method: Fl2-type flake detached from the main core face (A1 or A2) (3), Fl3-type flakes detached from the thickness of the core tablet (faces B) (4-6), refitting of core with Fl3-type flake (2). Arrows indicate: the direction of the blow (full ⊕ a.); the direction of previous blows (full ○ a.); the maintenance of convexities on the core-face (thin arrows on n.1). Dashed lines outline the shape of the core. Raw materials: Maiolica (5), Scaglia Rossa (1-2), Tertiary calcarenites (3,4,6) flint (scale=2cm; photo M.Obradović).

Figure 8. Uluzzian from layer A3. Unipolar short bladelet cores (1, 2) with refitted bladelets and refitting of platform preparation flakes (2), refitted bladelets (3), unipolar bladelet core (4). Arrows indicate: the direction of the blow (full ⊕ a.). Raw materials: Maiolica (1,2,4), Scaglia Rossa (3) flint (scale=2cm; photo M.Obradović).

Figure 9. Uluzzian from layer A3. Backed knives with partial (1) or complete (2-5) back, end-scraper on cortical flake with thinning on the lower face (6), refitted splintered piece (7), splintered flake (8) and pieces (9, 10). Arrows indicate the direction of the blow (full ⊕ a.). Raw materials: Maiolica (1,4,5,9,10), Scaglia Rossa (2,3,6,7), Scaglia Variegata (8) flint (scale=2cm; detailed drawings of the backed pieces are in Figure S1; photo M.Obradović).

Figure 10. Uluzzian bone tools from layer A3. Figure 10(a), top, awl (R1243) made from a rib of a medium – large mammal. Close-ups: technological modifications such as rounding, polish, longitudinal and transversal striae, depressions on the distal part of the awl (1,3,5); technological modifications produced while creating the awl blank through splitting (1); striations produced for regularizing the lower surface and the distal end of the awl by flint scraping (2,3); functional modifications (rounding, polish, striae and depressions) on the distal part of the awl (4,5) and use-wear traces experimentally produced after piercing ochered leather (6). Figure 10(b), bottom, mid-lateral posterior rib portion of a medium—large size mammal (R272b) with beveled surface produced after scraping with flint edge (close-ups 7 and 8) (photos E. Cristiani and M. Romandini) (scale=2cm).