doi 10.4436/jass.98021

JASs Reports
Journal of Anthropological Sciences
Vol. 98 (2020), pp. 99-140

Breaking through the Aquitaine frame: A re-evaluation on the significance of regional variants during the Aurignacian as seen from a key record in southern Europe

Armando Falcucci[1], Nicholas J. Conard[1, 2] & Marco Peresani[3, 4]

1) *Department of Early Prehistory and Quaternary Ecology, University of Tübingen, Schloss Hohentübingen, D-72070 Tübingen, Germany*
e-mail: armando.falcucci@ifu.uni-tuebingen.de

2) *Tübingen-Senckenberg Center for Human Evolution and Paleoecology, Schloss Hohentübingen, D-72070, Tübingen, Germany*

3) *Università di Ferrara, Dipartimento di Studi Umanistici, Sezione di Scienze Preistoriche e Antropologiche, Corso Ercole I d'Este, 32, I-44100 Ferrara, Italy*
e-mail: psm@unife.it

4) *Consiglio Nazionale delle Ricerche, Istituto di Geologia Ambientale e Geoingegneria, Gruppo di Ricerche Stratigrafiche Vegetazione, Clima, Uomo. Laboratorio di Palinologia e Paleoecologia, Piazza della Scienza 1, I-20126 Milano, Italy*

Summary - *The cultural dynamics that led to the appearance of the Aurignacian have intrigued archaeologists since the start of Paleolithic research. However, cultural reconstructions have often focused on a restricted region of Europe, namely the northern Aquitaine Basin. The Mediterranean Basin, though, is also a region worthy of consideration when testing if the Protoaurignacian was followed by the Early Aurignacian adaptive system. Fumane Cave is a pivotal site for tackling this issue because it contains evidence of repeated human occupations during the time span of the European Aurignacian. Here we investigate the diachronic variability of the lithic assemblages from five cultural units at Fumane Cave using a combination of reduction sequence and attribute analyses. This paper also reassesses the presence and stratigraphic reliability of the organic artifacts recovered at Fumane Cave. Our results show that the features of the Protoaurignacian techno-typology are present throughout the stratigraphic sequence, and by extension, to the onset of Heinrich Event 4. Additionally, the appearance of split-based points in the youngest phase is evidence of extensive networks that allowed this technological innovation to spread across different Aurignacian regions.*

Keywords - *Aurignacian, Early Upper Paleolithic, Paleolithic Archaeology, Lithic Technology, Human Evolution, Anatomically Modern Humans.*

Introduction

Background and aim of research

Given its chronological position and geographic spread, the Aurignacian is perhaps the most studied techno-complex of the Upper Paleolithic (e.g. Bon, 2006; Breuil, 1912; de Sonneville-Bordes, 1960; Delporte, 1968; Djindjian, 1993; Garrod, 1938; Laplace, 1966; Peyrony, 1933). The cultural and economic changes that occur in this period mark a turning point in human evolution that is perceived as evidence for the definitive expansion of modern humans into Europe (Conard, 2002; Davies, 2007; Hublin, 2015; Mellars, 2006a). Human remains, found in a few stratified sites, strongly support this scenario (Bailey *et al.*, 2009; Benazzi *et al.*, 2015). The appearance of the Aurignacian is dated to approximately 43–42 ky cal BP and the earliest Aurignacian cultural remains are mainly found along the Mediterranean belt and the Danube, both considered to be natural paths to the European subcontinent (Barshay-Szmidt *et al.*, 2018; Barshay-Szmidt *et al.*, 2020; Davies & Hedges, 2008; Davies *et al.*, 2015; Douka *et al.*, 2012; Higham *et al.*, 2012; Hopkins *et al.*, 2016; Nigst *et al.*, 2014; Szmidt *et al.*, 2010; Wood *et al.*, 2014).

In the last decades, a constantly growing database has permitted researchers to define the main features of the Aurignacian phenomenon and various attempts have been made to disentangle its complex synchronic and diachronic variability (Bar-Yosef & Zilhão, 2006; Bon, 2002; Bon *et al.*, 2006; Hahn, 1977; Laplace, 1966; Le Brun-Ricalens, 2005b). However, most previous research has been conducted in the northern Aquitaine Basin, a region that had a prominent role in the construction of Paleolithic research itself (Groenen, 1994). Thus, being constrained to a limited region of its important geographic spread, a slightly biased narrative of the Aurignacian cultural phenomenon has been constructed (Anderson *et al.*, 2018).

The Aurignacian was first divided into four successive stages based on the typological variability of lithic and organic tools (Bordes, 2006; de Sonneville-Bordes, 1960; Delporte, 1964, 1968; Demars, 1992; Demars & Laurent, 1992; Peyrony, 1933, 1935). These definitions were then complemented by technological studies conducted over the last decades (Bon, 2002; Bon & Bodu, 2002; Bon *et al.*, 2010; Bordes, 2002; Chiotti, 2005; Le Brun-Ricalens, 1993; Le Brun-Ricalens, 2005b). Outside of southwestern France, several Aurignacian assemblages have been discovered in cave and open-air sites. Rather than focusing on defining regional signatures, the main concern of archaeologists has often been to extend the "Aquitaine Model" (see Bordes, 2006) to the rest of the Europe (e.g. Broglio, 2000; Cortés-Sánchez *et al.*, 2019; Demidenko *et al.*, 2012; Dinnis *et al.*, 2019a,b, 2020; Hahn, 1977; Kozlowski & Otte, 2000; Laplace, 1966; Otte & Derevianko, 2001; Zilhão & d'Errico, 1999). Recently, researchers, ourselves included, have raised doubts about the application of this model on a supra-regional scale (Bataille, 2013; Bataille & Conard, 2018; Bataille *et al.*, 2018, 2020; Conard & Bolus, 2006, 2015; Falcucci *et al.*, 2017; Hauck *et al.*, 2018; Sitlivy *et al.*, 2012; Tafelmaier, 2017). We have argued, in fact, that the variability and definition of the oldest stages, known as Protoaurignacian (PA) and Early Aurignacian (EA), have been over-simplified to better construct scenarios of modern humans' arrival into Europe. According to some, these variants represent two distinct routes of dispersal along natural paths such as the Mediterranean boundaries and the Danube Basin (Conard & Bolus, 2003; Hublin, 2015; Mellars, 2004, 2006b; but see: Chu, 2018). To others, they are instead successive stages reflecting different settlement dynamics (Anderson *et al.*, 2015; Bon, 2005).

In this regard, a recent study has concluded that the shift from the PA to the EA adaptive system was triggered by the deterioration of the environment at the onset of the Heinrich Event 4 (HE4) (Banks *et al.*, 2013a, b; contra: Higham *et al.*, 2013; Ronchitelli *et al.*, 2014); a drastic cooling episode in the North Atlantic (Bond & Lotti, 1995; Hemming, 2004) that propagated both into the eastern and western Mediterranean through atmospheric and ocean circulation (e.g. Badino *et al.*, 2020; Fedele *et al.*, 2004; Panagiotopoulos *et al.*, 2014; Sanchez Goñi & Harrison, 2010; Sánchez Goñi *et al.*, 2020). This model is based on the subdivision of the Aurignacian in the Aquitaine Basin, although it clearly aims to be applied over the whole extension of Europe.

But does the archaeological evidence from the southern Alpine range and the Italian Peninsula support this scenario? Careful investigations and reassessments of pivotal sites are the best way to respond to this question and further understand the complex population dynamics that characterized the Early Upper Paleolithic.

The Italian Aurignacian

The Italian Aurignacian is represented by several stratified sites and surface collections that are distributed in different environmental settings, close to the modern coastlines and up to Alpine and Apennine regions (Mussi, 2002; Palma di Cesnola, 2001). The Italian research tradition was strongly influenced by work conducted by G. Laplace in the late sixties and seventies (Laplace, 1966, 1977; Plutniak & Tarantini, 2016) and technological assessments have been conducted in only a few cases (e.g. Bertola *et al.*, 2013; D'Angelo & Mussi, 2005; Dini *et al.*, 2010, 2012). Among those, Fumane Cave is the site that has received the attention, although research has mostly focused on the earliest manifestations of the Aurignacian (Bertola *et al.*, 2013; Broglio *et al.*, 2005; De Stefani *et al.*, 2012; Falcucci *et al.*, 2017; Falcucci & Peresani, 2018). The presence of several cultural units that both pre- and postdate the occurrence of HE4, allow us to carefully address the internal variability of the Aurignacian in the Venetian region. Here, besides Fumane Cave, evidence of Aurignacian sites is poor and difficult to evaluate. At Tagliente Rockshelter, located in the Monti Lessini, an Aurignacian assemblage was found within a stratigraphic unit that was partially mixed with Mousterian and Epigravettian implements (Bartolomei *et al.*, 1982). At Paina, in the Colli Berici, few Aurignacian lithic implements were found together with a fragmented organic point (Bartolomei *et al.*, 1988). Few open-air sites distributed in the pre-Alpine range and in the sub-Alpine belt complement the Aurignacian in this area (Broglio *et al.*, 2003).

Some authors have suggested that PA technical traditions persisted longer in Italy than in other regions (Anderson *et al.*, 2015; Bon *et al.*, 2010; Mussi, 2002; Palma di Cesnola, 2001). For this reason, Palma di Cesnola (2001) and Mussi (2002) proposed that the prefix Proto- be abolished because it gives the impression that assemblages included in this group have an absolute chrono-stratigraphic significance with respect to others, as for instance, is the case with the corresponding "Aurignacian 0" in western Europe (Bon *et al.*, 2010; Bordes, 2006). Fewer "typical" Aurignacian assemblages exist and have been sorted mainly by the presence of split-based points (SBPs) and other organic artifacts (Blanc & Segre, 1953; Degano *et al.*, 2019; Laplace, 1977; Mussi *et al.*, 2006; Palma di Cesnola, 2001; Tejero & Grimaldi, 2015), although some authors have suggested that the two variants be lumped together, given the high resemblance of their main typological features (Gheser *et al.*, 1986). Careful reassessments are needed to address these issues in a more parsimonious way, emphasizing technological signatures and diachronic variability of stratified sites. In this framework, new data have been recently produced at Bombrini, in northwestern Italy, by Riel-Salvatore & Negrino (2018a,b). Their results suggest that the PA was a technological system that survived well beyond the HE4 and the roughly contemporaneous Campanian Ignimbrite volcanic eruption (see references in: Giaccio *et al.*, 2017). Similar conclusions, even if at a preliminary level, were reached by Broglio and the research team of Ferrara University at Fumane Cave (Broglio, 1997; Higham *et al.*, 2009).

With the aim of shedding new light on the cultural dynamics that characterized the Aurignacian in northeastern Italy, we present a detailed comparison of five cultural units (A2, A1, D3base, D3b*alpha*, and D3ab) from Fumane Cave. We investigate assemblage variability and re-evaluate the organic artifacts to detect evidence of cultural modifications and/or stability throughout the stratigraphic sequence. We thus test whether the earliest PA cultural units A2–A1 (Falcucci *et al.*, 2017) are followed by assemblages that can be attributed to the EA (as defined by: Arrizabalaga *et al.*, 2009; Bon *et al.*, 2010; Bordes, 2006; Teyssandier, 2007; Teyssandier *et al.*, 2010). We discuss the values and drawbacks of the use of cultural taxonomy and examine the evidence for circulation of technological innovations across different regions during the Aurignacian. Finally, we present future research directions that will lead to a better understanding of the initial stages of the Upper Paleolithic south of the Alps.

Fumane Cave and the Aurignacian stratigraphic sequence

Fumane Cave, excavated since 1988, lies at the foot of the Monti Lessini Plateau (Venetian Pre-Alps). Details about the cave's structure, Late Pleistocene stratigraphic sequence, and paleoclimatic significance, as well as its paleontological and cultural content, are available in numerous publications (Bartolomei *et al.*, 1992a; Benazzi *et al.*, 2015; Broglio *et al.*, 2003; Broglio & Dalmeri, 2005; Broglio *et al.*, 2005; Cassoli & Tagliacozzo, 1994; Falcucci *et al.*, 2017; Higham *et al.*, 2009; López-García *et al.*, 2015; Peresani, 2012; Peresani *et al.*, 2016a). A main cave and two associated tunnels preserve a finely-layered sedimentary succession (Supplementary Material Fig. 1a,b) spanning the late Middle Paleolithic and the Early Upper Paleolithic, with features and dense scatters of remains in units A11, A10, A9, and A6–A5 (Mousterian: Peresani, 2012; Peresani *et al.*, 2013), A4 and A3 (Uluzzian: Douka *et al.*, 2014; Peresani *et al.*, 2016a), A2–A1 (Protoaurignacian: Bertola *et al.*, 2013; Broglio *et al.*, 2005; Cavallo *et al.*, 2017; Falcucci *et al.*, 2017; Falcucci & Peresani, 2018; Falcucci *et al.*, 2018), D6, D3, and D1c (Aurignacian lato sensu: Broglio & Dalmeri, 2005), and D1d (early Gravettian: Falcucci & Peresani, 2019).

The earliest Aurignacian unit A2 was dated to 41.2–40.4 ky cal BP (Higham *et al.*, 2009; Higham, 2011). A dispersion of ocher over a large extent of the area and a considerable change in the content of anthropogenic material (Broglio *et al.*, 2009) marked a clear boundary with unit A3 (Cavallo *et al.*, 2017, 2018). The overlying unit A1, a thin anthropogenic level with horizontal bedding, was only found at the cave entrance and was described as virtually indistinguishable from A2 in the cave mouth. Frost activity affected layers A3 and A2 in the easternmost part of the cave entrance. As a result, materials from A2 likely infiltrated into A3 (Benazzi *et al.*, 2014; Peresani *et al.*, 2016a). In the inner eastern side of the cave mouth, layer A2 was tilted and compressed towards the cave wall, forming a pronounced stratigraphic deformation. Despite that, unit A2 was described as a well-defined sedimentary body that spanned from a few to ten centimeters in thickness. Unit A2 differed markedly from both underlying and overlying units due to its dark-brownish color, its texture and its high charcoal, bone and lithic density, as well as the clear presence of features (i.e. combustion features, post-holes, and toss-zones) located at the cave entrance (Broglio *et al.*, 2006a,b; Peretto *et al.*, 2004). A few combustion features were discovered within shallow basins excavated at the edges of the Uluzzian (Peresani *et al.*, 2016b) and late Mousterian units. A few lithic implements from these units might have thus ended up in the Protoaurignacian assemblages.

The youngest Aurignacian phase is represented by several layers mainly embedded in the stratigraphic complex D3 (Supplementary Material Fig. 2), which is located in the front part of the cave. The macro-unit D differs from the macro-unit A in that it is formed of very coarse materials, such as boulders and stones. These materials collapsed from the cave walls and sealed the cave entrance. The progressive disruption of the cave walls is correlated to a protracted period of climatic deterioration (Broglio *et al.*, 2003; López-García *et al.*, 2015). Not surprisingly, human foragers frequented the cave less often during this time than during the formation of units A2–A1. Despite that, archaeological findings were recovered in several layers embedded in macro-unit D.

For the sake of completeness, it is worth noting that the stratigraphy of the upper deposit excavated in the cave mouth is different than that of the cave entrance. Differing sediment composition and excavation history played a similar role. At the cave entrance, D3 was divided into several units. The lowermost unit was named D3base and was described as a thin layer in direct contact with and transitioning from unit A1. Above D3base, excavators described two layers, named D3d (Supplementary Material Fig. 2b) and D3b*alpha* (Supplementary Material Fig. 2c) and later interpreted these as part of a single, rather short, accumulation event during which human activity is the most evident. We will group the lithic assemblages recovered in these units and refer to the unit as D3b*alpha.* D3d stands for the French word *Dallage* (pavement in English) and refers to an anthropogenic feature made up of angular, small sized blocks (ca. ten centimeters in size). They were arranged to form a sub-horizontal pavement bounded by boulders with a diameter of ca. 1.2 meters. In close proximity to this pavement, an accumulation of several lithic artifacts and a SBP were found around a combustion feature (Broglio *et al.*, 2006b). This human accumulation event took place after the HE4, at about 38.9–37.7 ky cal BP (95.4% of reliability), as suggested by a radiocarbon date obtained from a charcoal sampled within the combustion feature (Higham *et al.*, 2009). The uppermost part of D3 was divided into two arbitrary spits: D3a and D3b (Supplementary Material Fig. 2a). Despite being the most extended deposits, archaeological materials are scanty if compared to the preceding units. D3a was considered an almost sterile unit and sediments were quickly removed and only partially sieved. Thus, the frequency of the small lithic fraction (i.e. bladelets and chips), may be slightly underestimated. We consider D3a and D3b as a single unit, which we refer to as D3ab.

At Fumane Cave, there are clear boundaries between stratigraphic layers surrounding the Aurignacian and there is a lack of significant deformations in most of the front part of the cave, suggesting that the integrity of the Aurignacian assemblages remained intact. Furthermore, there is no supporting evidence of percolation of stone implements from and to the D3 complex. A similar statement cannot be made for the upper Aurignacian units described in the cave mouth, where perturbations between occupations have likely taken place. This issue, coupled with the fact that correlation to the previously described units is problematic, has prompted us to exclude all materials recovered in this area and conduct a careful examination of the post-depositional processes that affected these units. Here, the eastern portion of the upper sequence is different than that of the western part. In the eastern side, two units were identified on top of unit A2. Unit D6 was a loose stony layer, followed by a very thick layer named D3+D6. In the western side, unit D6 was, instead, covered by a thin anthropogenic level named D3a+b and by several units grouped in the stratigraphic complex D1. Among them, D1c was attributed to the Aurignacian and D1d to the Gravettian (Bartolomei *et al.*, 1992b; Broglio, 1997). Recent investigations have confirmed the attribution of unit D1d (Falcucci & Peresani, 2019).

The Early Upper Paleolithic ecological context at Fumane Cave has been reconstructed from the study of macro- and micro-faunal remains. Results show the presence of both forest and cold and open habitat fauna, typical of the alpine grassland steppe above the tree line (Broglio *et al.*, 2003; Cassoli & Tagliacozzo, 1994). Compared to the late Mousterian context, this data reflects a decrease in woodland formations and climatic cooling. López-García *et al.* (2015) have described two main phases taking place during the formation of the Aurignacian deposit. The first was recorded in units A2 and A1 and relates to a cold and dry phase, probably related to the HE4 event. The second phase (D3 complex) was instead relatively cold and humid. A warm period characterized the formation of D1d, while Heinrich Event 3 was identified in D1e.

Materials and methods

Given that the aim of this paper is a diachronic comparison between the different Aurignacian assemblages, we have restricted our sample to all materials recovered in the front part of the cave (Supplementary Material Fig. 3), where the stratigraphy is fine grained, and the youngest phase is divided into several units. Also, A2 and A1 are easily distinguishable in this area. We have thus decided to consider them as two different analytical units, contrary to our previous study (Falcucci *et al.*, 2017). By doing so, we will be able to give a more accurate narrative of the Aurignacian at Fumane Cave. In this study, we analyze five cultural units: A2, A1, D3base, D3b*alpha*, and D3ab. The oldest units A2 and A1 contain more lithic artifacts compared to the youngest phases. Human occupation of the cave was likely more intense during the formation of A2–A1. On the other hand, the upper cultural deposit formed during a faster time span as result of climatic deterioration and the progressive disruption of the cave walls. This issue, however, does not inhibit us from conducting an accurate technological comparison. Cores, blanks, tools, and by-products are present in all assemblages.

The Aurignacian deposits in the external part of the cave have been excavated since the beginning of the fieldwork at the site. Most of the studied materials were recovered from 1988 to 2006 under the supervision of A. Broglio and one of us (MP). Before systematic excavations, the D3 complex was partially damaged by clandestine excavations in the eastern part of the cave. For this reason, most of the artifacts from the youngest units come from the central-western side of the present-day cave. The archaeological material was either directly excavated using a 33×33 cm grid or recovered from wet sieving. All artifacts are available for detailed investigations, except for a small set of cores (n=5) and tools (n=17) from A2–A1 that are on display in permanent exhibitions at the Museo Paleontologico e Preistorico di Sant'Anna d'Alfaedo (Veneto, Italy). In order to conduct an extensive technological analysis of the Aurignacian lithics, all artifacts bigger than 1.5 cm in maximal dimension were counted and organized according to the identified technological classes and the sub-square of provenience. Detailed attributes were further recorded according to two sampling strategies. For A2 and A1, the sampling procedure is based on our previous work (Falcucci *et al.*, 2017), but all artifacts belonging to the back of the cave were excluded. Several square meters were selected, most of them located near the combustion features identified during the excavations. In these square meters, all blades and bladelets bigger than 1.5 cm in maximal dimension, regardless of the degree of fragmentation and all flakes with preserved butts greater than 2.0 cm in maximal dimension were subjected to attribute analysis. Furthermore, attribute analysis focused on all cores, tools and tool fragments, all complete and almost complete blades and bladelets found in the rest of the square meters located in the external part of the cave. Given the smaller sample sizes available for the uppermost layers (D3base, D3b*alpha*, and D3ab), the whole extension of the cave entrance was sampled and all recovered artifacts greater than 1.5 cm in maximal dimension were fully analyzed.

The lithic analysis approach combines two complementary methods: reduction sequence analysis (Boëda *et al.*, 1990; Conard & Adler, 1997; Inizan *et al.*, 1995; Soressi & Geneste, 2011) and attribute analysis (Andrefsky, 1998; Odell, 2004; Tostevin, 2013). The first identifies the methods of core reduction and the stages of knapping, use, and discard of stone artifacts. The second is particularly valuable because it provides quantitative data on the numerous discrete and metric features that can be recorded on individual artifacts. The attributes recorded in the database are based on recent studies and have been shown to be valuable for understanding laminar technologies at the onset of the Upper Paleolithic (e.g. Nigst, 2012; Zwyns, 2012). Additionally, diacritic analyses (Dauvois, 1976; Pastoors *et al.*, 2015; Roussel, 2011) were performed to reconstruct the chronology, the direction of removals, the stages of production on exhausted and initial cores, and short sequences of removals on blanks. By doing this, the detailed core reduction processes can be identified (Falcucci & Peresani, 2018).

We use the unified taxonomy by Conard *et al.* (2004) in order to give a general overview of core categories, while the sub-classification of platform reduction strategies are based on our previous works (Falcucci *et al.*, 2017; Falcucci & Peresani, 2018). Carinated cores have been sorted, after a techno-typological analysis, in three sub-categories: core-like, end-scrapers, and burin forms. The latter two have also been included in the tool list. In our previous analysis of units A2–A1, we did not include carinated burins in the core list. Here, after a re-evaluation of the tool assemblage, we have decided to include them as one of the possible reduction strategies used for bladelet production. Core-like forms are sometimes typed as *Rabot* in the French literature (de Sonneville-Bordes, 1960; Demars & Laurent, 1992). Here, we will not list them as tools. In order to more objectively define carinated pieces, only endscrapers and burins that display regular lamellar negatives longer than 15.0 mm have been typed so. Concerning the typological list, we present a revised and simplified version of the most used Upper Paleolithic typologies (de Sonneville-Bordes, 1960; Demars & Laurent, 1992).

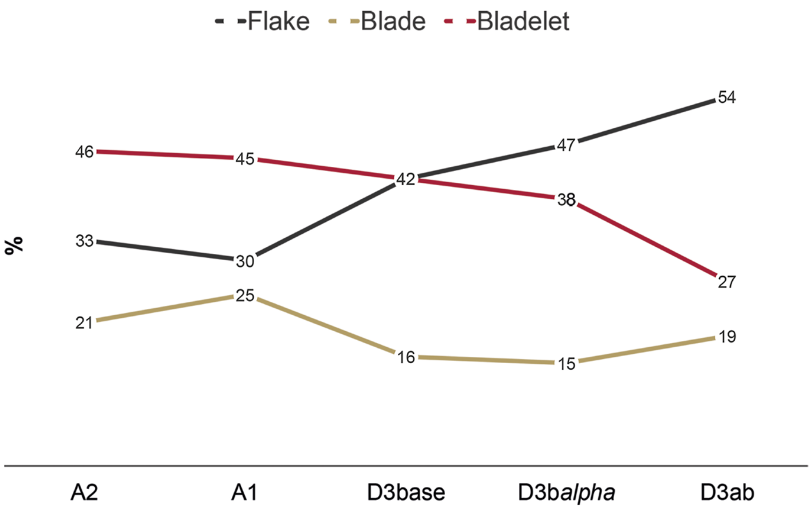

Fig. 1 - Frequencies of the main blank types (flakes, blades, and bladelets) produced throughout A2–D3ab. A2 is the oldest unit, while D3ab is the youngest. The colour version of this figure is available at the JASs website.

In order to assess the curvature of blanks, dorsal scars, and shape, we took only complete and almost complete specimens into account. This helps avoiding biases due to the high frequency of broken lithic implements. We quantified profile curvature using the categories defined by Bon (2002). We excluded retouched tools from the analysis of morphology and distal ends due to the modification of the shape via retouching. The metric boundary between blades and bladelets was placed at 12.0 mm (Tixier, 1963), in agreement with most of the studies conducted on Aurignacian assemblages and according to our case study. Overall, our technological comparison between units is made in both a qualitative and a quantitative way. Differences were statistically tested by using both discreet and metrical variables in IBM SPSS Statistics 24. Pearson's chi–squared tests were used for discreet variables while metric differences were assessed by using non-parametric tests (Mann–Whitney and Kruskall–Wallis), given that our samples are not normally distributed according to Shapiro–Wilk and Kolmogorov–Smirnov tests. Finally, we used the Holm–Bonferroni sequential correction test to reduce the probability of performing a type 1 error (Holm, 1979).

Results

Raw material procurement

The knappers selected flints from different carbonatic formations, which, in the western Monti Lessini, range from the Upper Jurassic to Middle Eocene. They were easily collected within 5–15 km from the site. The most widespread types, distinguishable based on macroscopic features (Bertola, 2001), are from the Maiolica, the Scaglia Rossa, the Scaglia Variegata, and the Ooliti di San Virgilio formations. Excellent, knappable raw material nodules also abound in loose coarse stream or fluvial gravels, slope-waste deposits, and soils in the immediate surroundings of the cave. Jurassic and Tertiary coarse flint originating from carbonatic sandstones, frequently found in large-sized and homogeneous nodules, were almost exclusively used to produce blades (Falcucci *et al.*, 2017). In units A2–A1, a small sample of blanks (n=70) and retouched bladelets (n=9) have been made on the extra-local red Radiolarite of the Lombard Pre-Alps, found today all along the Lombardy Basin, ca. 50 km from the site (Bertola *et al.*, 2013). Besides Radiolarite, knappers principally used the same range of flints throughout the sequence.

Tab. 1 - Quantitative analysis of the knapped assemblages (> 1.5 cm). Note that artifacts that were described both as tools and cores have been included in the tool category. Percentages are given in brackets. Table adapted from Falcucci (2018).

	BLANK	TOOL	CORE	ANGULAR DEBRIS	TESTED NODULE	TOTAL
D3ab	382 (73.0%)	70 (13.4%)	17 (3.3%)	54 (10.3%)	-	523
D3b*alpha*	561 (78.2%)	106 (14.8%)	12 (1.7%)	38 (5.3%)	-	717
D3base	830 (79.5%)	144 (13.8%)	5 (0.5%)	65 (6.2%)	-	1044
A1	3235 (78.2%)	648 (15.7%)	34 (0.8%)	219 (5.3%)	1 (-)	4137
A2	8055 (77.2%)	1458 (14.0%)	34 (0.3%)	883 (8.5%)	4 (-)	10434
Total	**13063**	**2426**	**102**	**1259**	**5**	**16855**

Quantitative analysis of the knapped assemblage

The quantitative analysis of assemblages A2–D3ab shows little diachronic changes (Tab. 1). Blanks dominate all assemblages, followed by tools, angular debris, and cores. There is no difference between the frequency of blanks compared to tools (Chi²=49.922, p=0.3), with tool frequency remaining stable throughout the sequence. Core assemblages are dominated by bladelet and blade cores and remain at low values, with a slight increase in layers D3b*alpha*–D3ab. Overall, the paucity of cores (n=102, 0.6%) suggests that knappers reduced raw material nodules intensely on-site and often exported non-exhausted cores.

Table 2 summarizes the frequency of the main blank types across the assemblages and gives a technological overview for each class. Laminar products (blades and bladelets together) dominate A2–A1, while they progressively decrease towards the top of the sequence (Fig. 1). Specifically, while the frequency of blades is rather stable, the frequency of bladelets is low in layer D3ab. Instead, flakes start to increase from D3base–D3b*alpha*. All steps of the reduction sequence are represented, from the decortication to the discard of exhausted cores. Raw material decortication resulted mostly in the production of blades and flakes of variable sizes and with unidirectional removal scars. For this reason, and as already noted in A2–A1 (Falcucci *et al.*, 2017), bladelets with cortical remains are rare (about 5-8%).

Blank production

A discussion about flake production in a laminar-dominated assemblage is always complicated by the fact that many of the flakes recovered are the outcomes of the various operations carried out to shape and maintain blade and bladelet cores. Furthermore, the flake class is generally very broad because it includes all those products that fall outside of the common definition of laminar blank. Cores are therefore the most useful artifacts to evaluate the presence of independent flake reduction strategies. Flake cores are present in all the studied assemblages, with percentages that increase from the 9% in A2 to the 21% in D3ab. The higher share of flake cores in D3b*alpha*–D3ab is in agreement with the general increase of flakes. There are some differences in the identified core reduction methods (Tab. 3).

Parallel cores are only found in the oldest units. These cores follow a centripetal system of reduction and are similar to the centripetal cores recovered in the Uluzzian units (Peresani *et al.*, 2016a). We suggested that the presence of these objects may represent the outcomes of minor post-depositional processes that affected A2–A1 (Falcucci *et al.*, 2017). Multidirectional cores are present in all assemblages. This group includes cores that have removals from two or more faces and multiple striking platforms. They have polyhedral morphologies and frequently display hinged negatives of removals. Finally, in

Tab. 2 - Distribution of blank types across the studied assemblages. Blank types are further divided according to four technological classes, referring to different stages of the reduction sequence. The categories full production and semi-cortical contain all blanks likely obtained during the optimal reduction phases. The category initialization contains all blanks deemed to have had a role in the core's shaping-out (e.g. fully cortical and crested blanks), while the category maintenance lumps all blanks related to the re-organization of the core convexities and maintenance of optimal flaking angles (e.g. lateral blades, neo-crested blanks, and core tablets). The count includes blank types of tools. Rounded percentages are given in brackets.

	A2	A1	D3BASE	D3B*ALPHA*	D3AB
Flake	**3172 (33%)**	**1164 (30%)**	**407 (42%)**	**311 (47%)**	**242 (54%)**
Full production	2391	865	294	220	163
Semi-cortical	434	162	77	56	40
Initialization	215	69	20	20	11
Maintenance	132	68	16	15	28
Blade	**1973 (21%)**	**982 (25%)**	**156 (16%)**	**97 (15%)**	**84 (19%)**
Full production	1501	760	107	64	55
Semi-cortical	299	143	29	18	12
Initialization	53	18	3	3	3
Maintenance	120	61	17	12	14
Bladelet	**4361 (46%)**	**1735 (45%)**	**411 (42%)**	**259 (39%)**	**123 (27%)**
Full production	4061	1603	367	233	106
Semi-cortical	208	88	27	16	9
Initialization	23	11	7	1	1
Maintenance	69	33	10	9	7
Undetermined	**6 (-)**	**2 (-)**	**0 (-)**	**0 (-)**	**3 (1%)**
Total	**9512**	**3883**	**974**	**667**	**452**

D3b*alpha*–D3ab flakes were mostly obtained from unidirectional cores (Supplementary Material Fig. 4a,b). These cores are made from nodules and thick cortical flakes and show flat striking platforms and straight flaked surfaces. The flaking direction is unidirectional and the reduction pattern sub-parallel. Last negatives are frequently hinged. Flakes with unidirectional hinged scars and plain butts are common among blanks and are likely to be the result of this reduction strategy (Supplementary Material Figs. 4d-g). The diacritic analyses suggest that the multidirectional cores recovered in D3b*alpha*–D3ab were reduced by following a series of independent and rather organized reduction phases based on consecutive unidirectional reduction phases (Supplementary Material Fig. 4c,h). The knapping progression usually started with a set

Tab. 3 - Distribution of the reduction strategies identified on flake cores across the studied assemblages.

	A2	A1	D3BASE	D3B*ALPHA*	D3AB
Parallel	2	1	-	-	-
Unidirectional	-	-	-	1	2
Multidirectional, unorganized	2	3	1	1	-
Multidirectional, organized	-	-	-	1	2
Total	**4**	**4**	**1**	**3**	**4**

of flakes detached from a flat striking platform. Once the flaking surface had lost its convexities, the core was rotated to begin a new, unidirectional reduction phase from an opposite or perpendicular removal surface. This pattern has not been found in A2–D3base, where flakes were removed from different faces without any specific organization. To summarize, flake production is more important in the youngest cultural units of Fumane Cave, where flake cores show, in some cases, a degree of predetermination that was not found in the oldest assemblages. Nevertheless, flakes never represent the main goal of the knapping.

We have divided laminar cores into different reduction strategies according to the objectives of production (Tab. 4). All the reduction strategies identified in A2–A1 (Falcucci *et al.*, 2017) were also found in the youngest cultural units. Core reduction procedures in these layers do not differ from what we have already described in Falcucci & Peresani (2018). The listed core types do not represent strict categories. They share several technological features such as the preparation of flat striking platforms and a unidirectional approach to knapping. Cores were made from nodules, thick flakes, and by-products of lithic production. The selected blanks were roughly prepared and flaking surface decortication was partial or even absent. In the case of nodules, the most common operation consisted of the removal of a thick cortical flake to open a steep striking platform. A laminar blank was then detached along the longitudinal axis of the core, usually on a narrow face, to make blank production easier to start. Non-invasive crests were applied only when the morphology of the core blank did not permit laminar products to be directly extracted. In some cases, cores were oriented according to the transversal axis to exploit their thickness in the framework of carinated reduction strategies. In most cases, the goal of blank production was bladelets. Blade cores are less common than bladelet cores, while blade-bladelet cores were found in A2, A1, and D3ab. Most of these cores attest to a simultaneous production of blanks of varied sizes.

Independent and systematic blade productions were carried out on semi-circumferential and wide-faced flat cores. Only in D3b*alpha* was blade production performed on the narrow side of a thick semi-cortical flake (Supplementary Material Fig. 5). This core has a few blade negatives, up to 93.2 mm in length. These are followed by a reorganization of the core's structure to perform an independent bladelet production. Blade cores are always characterized by a unidirectional sub-parallel reduction pattern. Blanks were produced in a linear and consecutive knapping progression along the perimeter of the flaking surface (Supplementary Material Fig. 6). Lateral convexities were usually maintained through the use of naturally backed and neo-crested blades. Flat striking platforms were, in most cases, prepared and reshaped using core tablets. In A1 and D3ab (Supplementary Material Fig. 6b), two blade cores display faceted striking platforms. Blades with faceted platforms do never represent more than the 2% of the blank assemblages. The knapping technique used to produce blades shows little variability (Tab. 5).

The external platform angle is usually under 75 degrees (≥ 96%) and blades frequently display ventral lipping, dorsal thinning, and narrow platforms that, together, are evidence for the use of a direct marginal percussion. There are some differences in the presence of bulbs and intensity of lipping, but it is not clear what the meaning of such variability expresses. The assessment conducted on the macro-tool category suggests that soft stone hammers were used during the maintenance and optimal production phases of platform cores (Caricola *et al.*, 2018). From a morphometrical standpoint, blades usually have sub-parallel edges and dorsal scar patterns, which agrees with the observations made on blade cores. Blades are similarly sized across the assemblages (Tab. 6). There are no differences in thickness or robustness of blanks, while there are some differences in the distribution of the width values. Descriptive statistics show that blades from D3ab are broader, while blades from D3base are slightly narrower. Concerning the length, complete blades from D3base–D3ab are too few to draw conclusions. If complete blades from these units are grouped (overall median: 46.3 mm) and compared to A2 (median: 47.4 mm), differences are not significant (Mann–Whitney, U=1870; p=0.5).

Blade cores show an intense degree of exploitation, although they were usually discarded when blade production could not be pursued In other words, blade cores were not systematically reduced into bladelet cores (for a detailed explanation see: Falcucci *et al.*, 2017). Blade and bladelet productions were, however, not strictly separated. Exhausted blade cores could be selected and reorganized to carry out independent bladelet productions. This is the case for two cores from A1 and D3b*alpha*. Blades were also detached during the elaborate maintenance operations carried out on semi-circumferential and narrow-sided bladelet cores (see below) and during simultaneous reduction strategies. Because of these operations, blades displaying from one to multiple bladelet negatives on the dorsal side were produced. The frequency of these blanks does not differ across the studied assemblages (Chi^2=6.8492; p=0.1), suggesting consistency in the overall technological organization.

Cores with bladelet scars are the most common type of core in the assemblages, with frequencies that vary from 86% in A2 to 70% in D3ab (Tab. 4). Bladelet production was based on several and, in most cases, independent reduction strategies, whose presence and frequency show few diachronic changes and demonstrate the

Tab. 4 - Distribution of platform cores according to the identified reduction strategies and the objectives of production. Core fragments are excluded from the list. *one core in A1 and one in D3ab show a carinated reduction strategy carried out prior to or after the re-orientation of the core.

	A2	A1	D3BASE	D3B*ALPHA*	D3AB
Initial core					
Narrow face	3	3	2	2	3
Wide face	1	-	-	2	-
Transverse	1	3	1	-	-
Semi-circumferential					
Blade	1	1	-	1	-
Bladelet	5	5	1	-	2
Blade-bladelet	1	-	-	-	1
Narrow-sided					
Blade	-	-	-	-	-
Bladelet	3	6	-	1	-
Undetermined	-	-	-	-	1
Wide-faced flat					
Blade	1	-	-	-	1
Bladelet	1	3	-	-	-
Blade-bladelet	1	-	-	-	-
Carinated					
Core-like	2	1	-	1	-
Endscraper	3	-	1	3	2
Burin	6	2	2	-	-
Multi-platform*					
Blade	-	-	-	-	-
Bladelet	4	6	-	-	3
Blade-bladelet	-	2	-	1	-
Total	**33**	**32**	**7**	**11**	**13**

Tab. 5 - List of mean values (in millimeters) ± standard deviations, width to thickness (W/T) ratios, and discrete attributes recorded on blades to diagnose the knapping technique, and the results of the Kruskall–Wallis and Pearson's chi–squared tests that we conducted. P-values in bold are significant. EPA stands for external platform angle. Rounded percentages are given in brackets.

	A2	A1	D3BASE	D3B*ALPHA*	D3AB	TEST
Platform measurements						
Thickness	1.5 ± 1.0	1.5 ± 1.1	1.5 ± 0.8	1.8 ± 1.3	1.8 ± 1.0	H=6.518; p=0.2
Width	4.2 ± 2.4	4 ± 2.5	4 ± 2.2	4.2 ± 2.4	4.4 ± 2.3	H=2.911; p=1
W/T ratio	3.4 ± 2.7	3.3 ± 2.7	3 ± 2.1	2.7 ± 1.5	2.7 ± 1.1	H=0.9003; p=0.9
Platform type						
Plain	344 (76%)	136 (69%)	65 (82%)	33 (72%)	37 (84%)	
Linear	54 (12%)	29 (15%)	9 (11%)	4 (9%)	3 (7%)	
Punctiform	6 (1%)	9 (5%)	-	2 (4%)	2 (5%)	
Cortical	9 (2%)	2 (1%)	2 (3%)	1 (2%)	1 (2%)	Chi²=34.257
Faceted	3 (1%)	3 (2%)	-	1 (2%)	1 (2%)	p=0.2
Dihedral	11 (2%)	2 (1%)	2 (3%)	-	-	
Abraded	5 (1%)	6 (3%)	-	2 (4%)	-	
Undetermined	19 (4%)	10 (5%)	1 (1%)	3 (7%)	-	
Bulb						
no	256 (57%)	101 (51%)	36 (46%)	18 (39%)	14 (32%)	Chi²=15.682
yes, moderate	183 (41%)	85 (43%)	42 (53%)	27 (59%)	28 (64%)	**p<0.05**
yes, pronounced	12 (3%)	11 (6%)	1 (1%)	1 (2%)	2 (5%)	
Lip						
no	39 (9%)	20 (10%)	9 (11%)	11 (24%)	8 (18%)	Chi²=13.126
yes, moderate	170 (38%)	88 (45%)	49 (62%)	26 (57%)	26 (59%)	**p<0.05**
yes, pronounced	242 (54%)	89 (45%)	21 (27%)	9 (20%)	10 (23%)	
Dorsal thinning, yes	398 (88%)	176 (89%)	71 (90%)	37 (80%)	37 (84%)	Chi²=3.755; p=0.4
Bulbar scars, yes	94 (21%)	42 (21%)	10 (13%)	8 (17%)	7 (16%)	Chi²=2.611; p=0.6

need to produce end-products of different sizes. Bladelet cores can be divided into two macro-classes: cores that have been oriented according to the longitudinal axis of the blank, such as semi-circumferential and narrow-sided cores, and cores oriented according to the transversal axis, classified as carinated cores. In A2–A1, bladelet production is mostly based on the longitudinal axis of the core blank (Supplementary Material Fig. 7a–d).

Tab. 6 - Metric comparison of the mean values (in millimeters) ± standard deviations, median values (in millimeters), and robustness (width to thickness ratio) of blades, and results of the Kruskall–Wallis tests that we conducted. P-values in bold are significant. Length values are not considered given the small number of complete blades recovered in the youngest assemblages. Tools are excluded from the analysis.

	A2	A1	D3BASE	D3B*ALPHA*	D3AB	KRUSKALL-WALLIS TEST
Width						
Mean ± St. dev.	16.2 ± 4.0	16.6 ± 4.1	15.8 ± 4.1	16.8 ± 4.8	17.6 ± 4.9	
Median	14.9	15.4	14.6	14.7	16.7	H=13.96; **p<0.05**
Thickness						
Mean ± St. dev.	4.2 ± 2.2	4.2 ± 2.1	4.1 ± 2.1	4.3 ± 1.9	4.5 ± 2.0	
Median	3.7	3.6	3.5	3.9	4.0	H=5.947; p=0.2
Robustness (W/T)						
Mean ± St. dev.	4.4 ± 1.6	4.6 ± 1.7	4.6 ± 1.9	4.3 ± 1.6	4.3 ± 1.4	
Median	4.2	4.4	4.4	3.9	4.1	H=2.746; p=0.6

Carinated technology is also common and results in the discard of carinated burins (Supplementary Material Fig. 8a, c), carinated cores-like (Supplementary Material Fig. 9b), and carinated endscrapers (Supplementary Material Fig. 9a). Carinated cores increase in the upper sequence. Carinated burins were only recovered in D3base (Supplementary Material Fig. 8b, d), while in D3b*alpha*–D3ab, carinated reduction strategies are only conducted on carinated cores-like (Fig. 9d) and carinated endscrapers (Supplementary Material Fig. 9e–h). Besides carinated cores, semi-circumferential cores are still very important (Supplementary Material Fig. 7e–f). Multi-platform cores were not found in D3base–D3b*alpha*, while they are present in D3ab. Here, one bladelet core displays two different reduction phases that combine carinated technology and a narrow-sided reduction strategy (Supplementary Material Fig. 9g). In D3b*alpha*, bladelet cores were likely exported. Many of the recovered cores were in fact abandoned during the initial phases of blank production because of knapping mistakes and irregularity in the selected raw materials (Supplementary Material Fig. 10).

The variability highlighted in the bladelet production falls within a rather coherent technological spectrum. The reduction procedures conducted on carinated cores are very similar across the studied units. The flaking surface is often isolated by detaching flakes at the intersection with the core flanks, transverse to the main production axis. This operation leads some cores to acquire a nosed morphology (Supplementary Material Fig. 9d, f, and h), although twisted bladelets are never the goal of this reduction strategy. Bladelet negatives are relatively short, curved, and on-axis. The alternated convergent reduction pattern and the maintenance operations carried out on carinated cores are comparable to what we observed among semi-circumferential bladelet cores (Falcucci *et al.*, 2017; Falcucci & Peresani, 2018). At this point, it must be stressed that the association between carinated pieces and bladelet production is not always straightforward. At Fumane Cave, the use-wear analysis conducted on the endscrapers has shown that some of the carinated artifacts were used to work soft materials, such as hide (Aleo *et al.*, 2017). It is interesting that tools with wear traces show, in most cases, a flaked surface shorter than

Tab. 7 - Comparison of the discret attributes recorded on bladelets, and results of the Pearson's chi–squared tests that were conducted. Note that profile curvature and dorsal scar pattern take into account only complete and almost complete specimens. Retouched tools are excluded from the analysis of the distal ends. Rounded percentages are given in brackets.

MORPHOLOGICAL ATTRIBUTES	A2	A1	D3BASE	D3B*ALPHA*	D3AB	PEARSON'S CHI-SQUARED TEST
Profile						
Straight	82 (27%)	30 (26%)	9 (23%)	12 (29%)	4 (21%)	
Slightly curved	82 (27%)	27 (23%)	6 (15%)	11 (26%)	4 (21%)	Chi²= 20.512
Curved	81 (27%)	37 (32%)	13 (33%)	6 (14%)	7 (37%)	p=0.2
Intense curvature	15 (5%)	6 (5%)	4 (10%)	8 (19%)	2 (11%)	
Twisted	44 (14%)	17 (15%)	7 (18%)	5 (12%)	2 (11%)	
Orientation						
Axial	245 (83%)	114 (90%)	75 (91%)	59 (88%)	29 (85%)	Chi²=6.166
Off-axis	49 (17%)	12 (10%)	7 (9%)	8 (12%)	5 (15%)	p=0.2
Dorsal scar pattern						
Unidirectional sub-parallel	147 (48%)	72 (62%)	23 (48%)	25 (51%)	12 (63%)	Chi²=8.2037
Unidirectional convergent	131 (43%)	34 (29%)	20 (42%)	24 (49%)	7 (37%)	p=0.08
Other	26 (9%)	11 (9%)	5 (10%)	-	-	
Distal end - dorsal view						
Pointed	157 (52%)	51 (40%)	43 (52%)	37 (55%)	17 (50%)	Test pointed/ no pointed
Convex or concave	99 (33%)	58 (46%)	30 (37%)	20 (30%)	11 (32%)	Chi²= 6.2325
Straight	34 (11%)	16 (13%)	3 (4%)	10 (15%)	3 (9%)	p=0.2
Irregular	13 (4%)	2 (2%)	6 (7%)	-	3 (9%)	

20.0 mm – a value that is under the 25th percentile of bladelet length values (see below).

Overall, the objective of lithic production was usually a bladelet with convergent edges obtained by a knapping progression that alternated removals at the center of convergent flaking surface with lateral oblique blanks that maintained its lateral convexities. When the core blank was a nodule, a narrow and convergent surface was isolated on a favorable area of the core in order to produce a set of pointed bladelets (Falcucci & Peresani, 2018). This operation was very common among semi-circumferential cores and allowed the production to be pursued over the course of several reduction phases. Common maintenance blanks were lateral comma-like and technical blanks. In some cases, these blanks were the size of small blades displaying multiple bladelet negatives on the dorsal face (Falcucci *et al.*, 2017).

The discreet attributes recorded on bladelets from A2–D3ab cultural units (Tab. 7) attest to the production of bladelets with similar properties

Tab. 8 - Metric comparison of the mean values (in millimeters) ± standard deviations, median values (in millimeters), robustness (width to thickness ratio), and elongation (length to width ratio) of bladelets, and results of the Kruskall–Wallis tests that we conducted. P-values in bold are significant. Tools are excluded from the analysis.

	A2	A1	D3BASE	D3B*ALPHA*	D3AB	KRUSKALL-WALLIS TEST
Length						
Mean ± St. dev.	27.5 ± 9.7	30.2 ± 9.6	27 ± 9.0	23.8 ± 5.7	25.5 ± 6.0	
Median	25.4	29.6	25.7	23.5	25.2	H=14.41; **p<0.05**
Width						
Mean ± St. dev.	8.6 ± 2.0	8.9 ± 1.9	8.6 ± 2.0	8.3 ± 2.1	8.9 ± 2.1	
Median	8.7	9.1	8.7	8.4	9.1	H=11.12; **p<0.05**
Thickness						
Mean ± St. dev.	2.2 ± 1.0	2.4 ± 1.1	2.1 ± 0.9	2.1 ± 0.8	2.3 ± 0.9	
Median	2.0	2.1	2.0	1.9	2.1	H=11.45; **p<0.05**
Robustness (W/T)						
Mean ± St. dev.	4.4 ± 1.7	4.3 ± 1.6	4.5 ± 1.6	4.2 ± 1.4	4.2 ± 1.5	
Median	4.3	4.1	4.3	4.1	3.8	H=5.192; p=0.3
Elongation (L/W)						
Mean ± St. dev.	3.4 ± 0.9	3.5 ± 0.9	3.2 ± 0.9	3.3 ± 1.2	3.2 ± 1.0	
Median	3.2	3.5	3.0	2.9	2.8	H=8.991; p=0.06

and support the strong technological link between the studied assemblages. Curved profiles, of different intensity grade, dominate. Twisted bladelets, that are said to be obtained from the sides of carinated cores (Le Brun-Ricalens, 2005a), are always represented in low frequencies and the twisting is slightly pronounced. Blank orientation is, in most cases, axial to the flaking direction. Unidirectional convergent dorsal scars are the most common pattern, except for A1. Differences are, however, not significant. The same can be said of pointed distal ends. The metric analysis shows some differences between the different cultural units that are statistically significant (Tab. 8), though it is not possible to detect a progressive reduction of bladelets' sizes. Based on the descriptive statistics, the groups that stand out are A1 and D3b*alpha*. In the former, longer bladelets were produced, while in the latter bladelets are smaller both in length and width values. Therefore, Kruskal–Wallis tests were repeated without A1 when comparing length values (H=3.472; p=0.3) and without D3b*alpha* when comparing width values (H=5.6; p=0.1). In both cases, the differences were not significant.

Tools

The typological composition of the studied assemblages is listed in Table 9. All assemblages are dominated by retouched bladelets: the highest

Tab. 9 - Distribution of tool types. Undet. stands for undetermined. Rounded percentages are given in brackets.

	A2	A1	D3BASE	D3B*ALPHA*	D3AB
Retouched bladelet	**1262 (87%)**	**541 (83%)**	**115 (80%)**	**67 (63%)**	**38 (54%)**
Retouched blade	**80 (5%)**	**43 (7%)**	**8 (6%)**	**8 (8%)**	**5 (7%)**
unilateral	50	20	7	5	2
bilateral	28	19	1	2	2
pointed	1	2	-	1	-
Aurignacian retouch	1	2	-	-	1
Burin	**40 (3%)**	**16 (2%)**	**6 (4%)**	**3 (3%)**	**2 (3%)**
simple	17	4	2	1	-
on prepared platform	9	4	1	2	2
on truncation	1	3	1	-	-
dihedral	7	3	-	-	-
carinated	6	2	1	-	-
busked	-	-	1	-	-
Endscraper	**25 (2%)**	**15 (2%)**	**6 (4%)**	**11 (10%)**	**13 (18%)**
on flake	7	7	5	4	5
on blade	12	6	-	3	6
flat-nosed	-	-	-	1	-
carinated, frontal	4	-	1	3	-
carinated, thick-nosed	-	-	-	-	2
double	1	-	-	-	-
circular	1	2	-	-	-
Composite	**12 (1%)**	**7 (1%)**	**4 (3%)**	**2 (2%)**	**3 (6%)**
burin + endscraper	1	1	-	-	-
burin + lateral retouch	4	4	1	1	-
endscraper + lateral retouch	7	2	3	1	3
Truncation	**10 (1%)**	**3 (-)**	**2 (1%)**	**2 (2%)**	**-**
Retouched flake	**15 (1%)**	**16 (2%)**	**1 (1%)**	**8 (8%)**	**6 (8%)**
Splintered piece	**11 (1%)**	**6 (1%)**	**2 (1%)**	**5 (5%)**	**2 (3%)**
Undet. retouched piece	**3 (-)**	**1 (-)**	**-**	**-**	**1 (1%)**
Total	**1458**	**648**	**144**	**106**	**70**

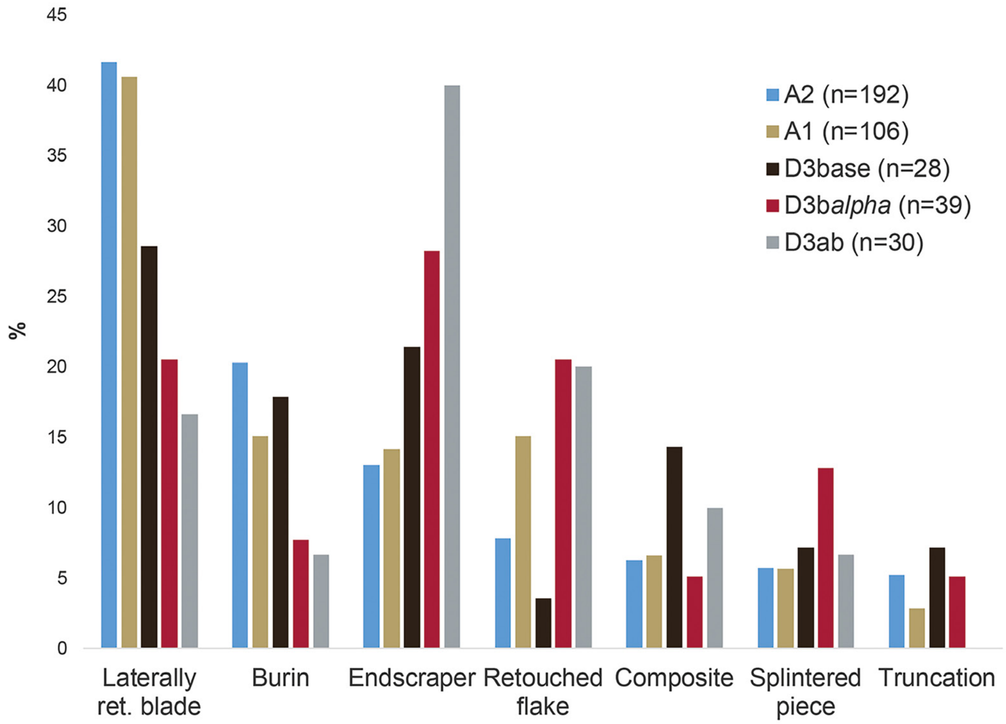

Fig. 2 - Bar-charts comparing the frequencies of common tool types identified throughout A2–D3ab. See the color legend to identify the cultural units. For each tool type, bar-charts are organized starting from unit A2 (left) up to unit D3ab (right). The colour version of this figure is available at the JASs website.

frequency is found in A2, and the lowest in D3ab. Differences in the distribution of common tool types (Fig. 2) are easier to appreciate by excluding retouched bladelets from the general count.

In A2–A1 (Fig. 3), laterally retouched blades and burins are more abundant, while in D3b*alpha*–D3ab (Fig. 4), endscrapers increase in frequency. Laterally retouched blades have evidence of unilateral and bilateral retouch, and only in a few cases are these pointed by retouch. Retouching is, in most cases, direct and usually has a scalariform or marginal shape (Fig. 3d–e and Fig. 4d). Aurignacian retouch is rare (Fig. 3f and Fig. 4h) and missing in D3base and D3b*alpha*. Most burins are simple and made mainly on blades. Only in A2–D3base were dihedral (Fig. 3b–c) and carinated burins found. In D3base, one carinated burin can be further classified as busked (Supplementary Material Fig. 8b). Most endscrapers display a thin working edge shaped by short lamellar removals. Some are made on retouched blanks (Fig. 3h, j, and k and Fig. 4j). The working edge was frequently reshaped and we identified several traces of the different activities conducted (Aleo *et al.*, 2017). Carinated endscrapers increase in frequency towards the top of the sequence, although the limited number of tools does not allow to run statistical tests to back this observation. Two thick-nosed endscrapers were recovered in D3ab, while one flat-nosed endscraper was recovered in D3b*alpha* (Fig. 4g). Finally, retouched flakes are more common in the youngest phases (Fig. 4f). Overall, common tools were made on blades and flakes and only few on bladelets (Supplementary Material Tab. 1). The number of tools on flakes increases in D3base, which agrees with the general frequency of flakes in the youngest units.

Fig. 3 - Selection of tools from assemblages A2–A1. Burin on truncation (a), dihedral burins (b–c), laterally retouched blades (d–e), Aurignacian blade (f), endscrapers on blade (g, i, and l), endscrapers on laterally retouched blade (h and j), and endscraper on laterally retouched flake (k). Arrows indicate the direction of the blow. (Photos: A. Falcucci, drawings: G. Almerigogna). The colour version of this figure is available at the JASs website.

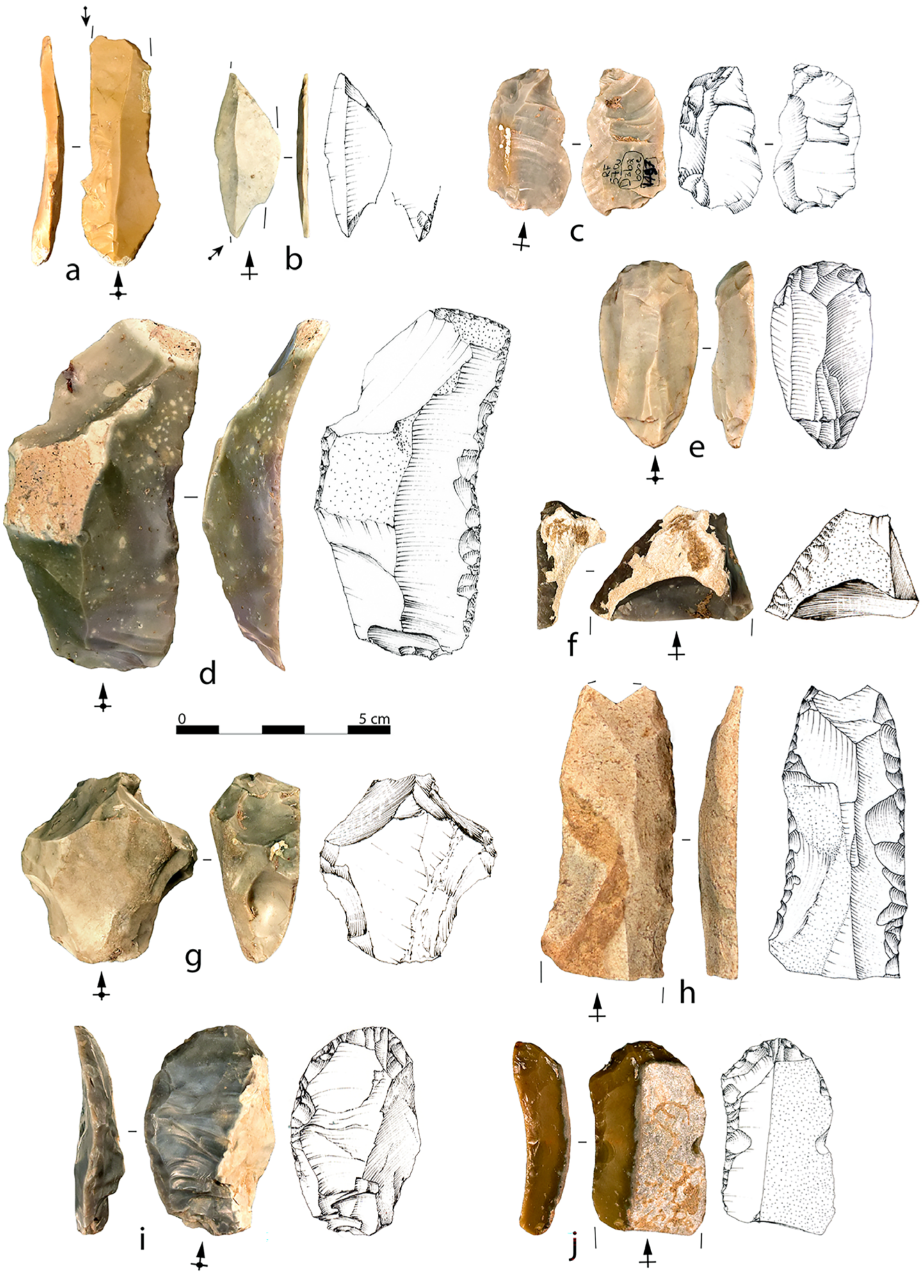

Fig. 4 - Selection of tools from assemblages D3base–D3ab. Burin on breakage (a), burin on truncation (b), splintered piece (c), laterally retouched blade (d), endscrapers on flake (e and i), laterally retouched flake (f), flat-nosed endscraper (g), Aurignacian blade (h), endscraper on blade (j). D3base = a; D3balpha = b–g; D3ab = h–j. Arrows indicate the direction of the blow. (Photos: A. Falcucci, drawings: G. Almerigogna). The colour version of this figure is available at the JASs website.

Tab. 10 - Distribution of retouched bladelets according to the degree of breakage. Almost comp. stands for almost complete. Rounded percentages are given in brackets.

	PROXIMAL	MESIAL	DISTAL	ALMOST COMP.	COMPLETE	TOTAL
D3ab	18 (47%)	15 (39%)	5 (13%)	-	-	**38**
D3b*alpha*	25 (37%)	28 (42%)	7 (10%)	1 (1%)	6 (9%)	**67**
D3base	39 (34%)	49 (43%)	18 (16%)	-	9 (8%)	**115**
A1	186 (34%)	251 (46%)	84 (16%)	2 (-)	18 (3%)	**541**
A2	371 (29%)	627 (50%)	190 (15%)	10 (1%)	64 (5%)	**1262**

The distribution of retouched bladelets, according to the preserved parts, is not significantly different across the units (Tab. 10; $Chi^2=23.011$; $p=0.1$). The degree of breakage is very high; proximal and mesial fragments are represented the most. In D3ab, no complete retouched bladelets were found. Given that the large majority of bladelets are broken, a morphological and technological comparison across assemblages is complicated. However, it can be said that retouched bladelets do not differ from unretouched ones. They usually have slightly curved and curved profiles, with little or no twisting present. Distal ends are almost never off-axis. Sub-parallel and convergent scar patterns are represented in similar percentages to those found in the blank assemblages. They have, in almost all cases, regular outline morphologies and tools with preserved cortical remains are always below the 2% of the overall samples. Retouched bladelets are made on by-products of the production in only two cases: one in A2 and one in D3b*alpha*.

Retouching is usually marginal, semi-steep, and continuous all along the edge(s) (Fig. 5). The shape is regular and generally follows the initial morphology of the blanks. On the bladelets with alternate retouch, the modification on the dorsal side is less invasive compared to the retouch on the ventral side. Sometimes it can be described as a slight abrasion that creates a thin angle. Overall, the intensity of retouch varies in relation to the morphology of the selected blank and the objective of production. In fact, bladelets with convergent retouch show a higher retouch intensity on the distal side with angles close to 90 degrees with respect to the ventral face. All studied assemblages show a strong lateralization of ventral retouch, almost always located on the right side (between 96% and 98%). This pattern is typical of the Aurignacian techno-complexes (Falcucci *et al.*, 2018; Le Brun-Ricalens, 2005b; Le Brun-Ricalens *et al.*, 2009; Tsanova *et al.*, 2012).

We have categorized bladelets with lateral retouch, convergent retouch, and retouched bladelets with truncation according to the position of retouch (Tab. 11). There is little diachronic variability in the distribution of alternate, direct, and inverse retouches. Alternate retouch decreases in frequency towards the top of the sequence, while direct and inverse retouches increase slightly. In D3b*alpha*, bladelets with direct retouch are the most represented types. Bladelets with convergent retouch are frequent at Fumane Cave. Direct retouch is most common, followed by alternate retouch. In a previous work, we showed that the frequency of these tools is underestimated due to the high degree of breakage (Falcucci *et al.*, 2018). When only specimens with a preserved distal tip (complete blanks and distal fragments) are considered, the frequency of bladelets made pointed by retouch is much higher in each of the studied assemblages. Differences in the distribution of bladelets with lateral and convergent retouch across the cultural units are thus not significant (Supplementary Material Tab. 2; $Chi^2=2.2044$; $p=0.7$).

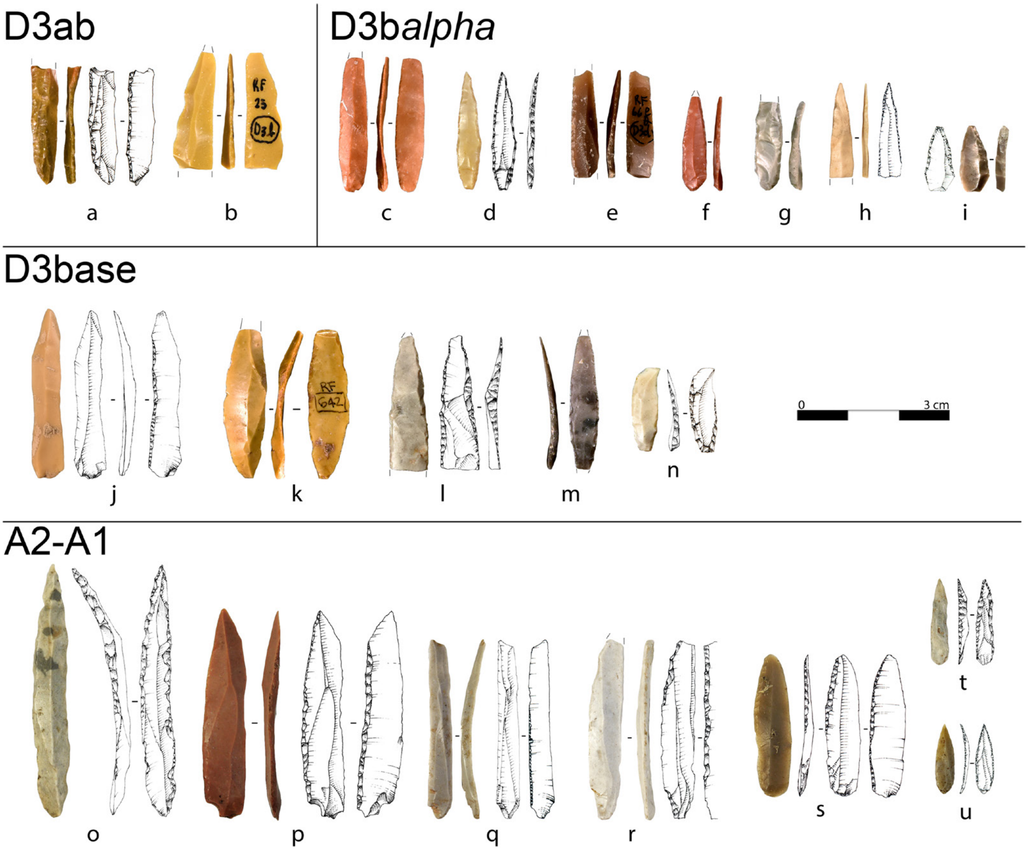

Fig. 5 - Selection of retouched bladelets sub-grouped according to the cultural units of provenience. a–c, e, g, j–l, n, and q–s are bladelets with lateral retouch. d, f, h–i, m, o–p, and t–u are bladelets with convergent retouch. Artifacts are oriented with the butt at the bottom of the figure. (Photos: A. Falcucci, drawings: G. Almerigogna). The colour version of this figure is available at the JASs website.

From a metric standpoint, retouched bladelets show differences in size that are statistically significant (Tab. 12), though no clear pattern can be identified. Compared to unretouched bladelets, they are always narrower and slender. The smaller tools are found in D3b*alpha*, which is in agreement with what we noticed among the blanks. Instead, retouched bladelets from D3ab are comparable to the artifacts recovered in the lowermost assemblages. Finally, the robustness is similar across all samples.

Beyond lithics: organic tools and ornamental objects

Before trying to summarize the outcomes of this techno-typological investigation, it is important to take into consideration the presence of other artifacts, such as ornamental objects, organic tools, and painted stones, within each of the studied units. To do so, we will consider only those artifacts that were recovered in the studied area. Extensive information on these findings can be found in numerous publications (Bartolomei *et al.*, 1992b; Bertola *et al.*, 2013; Broglio *et al.*,

Tab. 11 - List of retouched bladelets divided according to the types defined in Falcucci* et al. *(2018) and the position of retouch. The last group lumps all retouched bladelets. Rounded percentages are given in brackets.

	A2	A1	D3BASE	D3B*ALPHA*	D3AB
Bladelet with lateral retouch					
Alternate	684 (54%)	270 (50%)	59 (51%)	22 (33%)	17 (45%)
Direct	208 (16%)	101 (19%)	20 (17%)	20 (30%)	10 (26%)
Inverse	252 (20%)	120 (22%)	24 (21%)	18 (27%)	10 (26%)
Bladelet with convergent retouch					
Alternate	48 (4%)	13 (2%)	3 (3%)	1 (1%)	1 (3%)
Direct	53 (4%)	26 (5%)	9 (8%)	6 (9%)	-
Inverse	3 (-)	-	-	-	-
Bladelet with lateral retouch + truncation					
Alternate	4 (-)	7 (1%)	-	-	-
Direct	7 (1%)	2 (-)	-	-	-
Inverse	3 (0%)	2 (-)	-	-	-
Overall retouched bladelets					
Alternate	736 (58%)	290 (54%)	62 (54%)	23 (34%)	18 (47%)
Direct	268 (21%)	129 (24%)	29 (25%)	26 (39%)	10 (26%)
Inverse	258 (20%)	122 (23%)	24 (21%)	18 (27%)	10 (26%)
Total	**1262**	**541**	**115**	**67**	**38**

2003; Broglio & Dalmeri, 2005; Broglio *et al.*, 2006a, 2009; Peresani *et al.*, 2019).

Pierced marine shells are the most common ornaments at Fumane Cave and demonstrate the movements of people and/or contacts between people within a large area. It is worth mentioning that the Tyrrhenian and Adriatic coastlines were approximately 200 km and 400 km, respectively, from Fumane Cave at the time of the Aurignacian occupations (Antonioli, 2012; Benjamin *et al.*, 2017; Siddall *et al.*, 2008; Waelbroeck *et al.*, 2002). Shells are mostly concentrated in the back of the cave, while their number significantly decreases in the front part. Here, the major concentration was found in A2 (n=66), followed by the D3 complex (n=35), and A1 (n=21). The most common species of shell is *Homalopoma sanguineum*. Others species are rare, such as one *Dentalium sp.* found in A1 (Peresani *et al.*, 2019). The presence of an Atlantic species, *Littorina obtusata*, suggests that the Aurignacian foragers had contacts far beyond the Italian Peninsula (Vanhaeren & d'Errico, 2006). Besides pierced shells, one grooved deer incisor was recovered at the top of unit A1.

Tab. 12 - Metric comparison of the mean values (in millimeters) ± standard deviations, median values (in millimeters), and robustness (width to thickness ratio) of retouched bladelets, and results of the Kruskall-Wallis tests that we conducted. P-values in bold are significant. Statistic tests were not performed for length values given the small number of available complete artifacts from the D3base–D3balpha assemblages and the absence of complete tools in D3ab.

	A2		A1		D3BASE		D3B*ALPHA*		D3AB		KRUSKALL-WALLIS TEST
	MEAN	*MEDIAN*	*MEAN*	*MEDIAN*	*MEAN*	*MEDIAN*	*MEAN*	*MEDIAN*	*MEAN*	*MEDIAN*	
Length	29.0 ± 8.9	27.8	28.4 ± 6.5	30.9	26.9 ± 6.8	25.9	19.6 ± 4.4	19.2	-	-	-
Width	6.4 ± 1.7	6.2	6.7 ± 1.7	6.5	6.3 ± 1.7	6.1	5.8 ± 1.7	5.5	6.2 ± 1.6	6.2	H=23.52; **p<0.05**
Thickness	1.6 ± 0.5	1.6	1.7 ± 0.5	1.6	1.5 ± 0.4	1.6	1.5 ± 0.6	1.4	1.5 ± 0.4	1.5	H=19.94; **p<0.05**
Robustness (W/T)	4.1 ± 1.1	3.9	4.1 ± 1.1	3.9	4.2 ± 1.1	4.1	4.2 ± 1.3	4.1	4.2 ± 1.3	3.9	H=2.678; p=0.6

The bone industry is characterized by a series of common tools such as awls and perforators made from long bone diaphysis and by antler points. In a few cases, the proximal part of the point is still preserved, allowing to point to be further classified as a SBP. Two SBPs were recovered in the D3 complex, but artifacts confidently attributable to this type were not found in A2–A1, although an antler point lacking its proximal part was found at the top of layer A1. Future research will focus on the presence of by-products from the manufacture of SBPs to further assess antler exploitation throughout the stratigraphic sequence.

Three stones painted with red ocher were recovered in the front part of the cave. These stones were part of the cave walls that partly collapsed because of climatic deteriorations. Two fragments, an anthropomorphic figure and an undetermined motif, were found in the upper sequence, and one fragment with a painted animal was found at the interface between A2 and D3base. The large amount of red ocher found in A2 (Broglio *et al.*, 2009; Cavallo *et al.*, 2017, 2018) may be interpreted as evidence for cave painting during the earliest occupations. Detailed comparative analyses of these fragments are required to ascertain from what part of the collapsed wall they originate.

Discussion

Summary of the Protoaurignacian sequence of Fumane Cave

We analyzed five successive lithic assemblages (A2–D3ab) from the Early Upper Paleolithic deposit of Fumane Cave. Results show that no major diachronic changes occur throughout the stratigraphic sequence. The variable and systematic bladelet productions and the marked frequency of bladelet tools are clear evidence of cultural continuity (Falcucci, 2018). However, it is important to underline the fact that continuity should not be interpreted as a stasis in the technological behavior of foragers that visited the cave over the course of several millennia. Based on the techno-typological variations and the re-evaluation of the organic artifacts recovered therein, we observed several similarities and differences.

The main goal of Protoaurignacian knappers was to obtain lamellar blanks, using comparable reduction strategies. In the oldest cultural units (A2–A1) the use of carinated technology is less evident than in D3base–D3ab. Interestingly, among carinated core types, carinated burins are only present in A2–D3base. Nevertheless, semi-circumferential and narrow-sided cores were the favored strategy throughout the sequence, possibly because knappers frequently oriented the raw materials according to the longer axis available to obtain more elongated products. This is also clear when morphological and metric attributes of bladelets are taken into consideration, as the high frequency of pointed artifacts stands out.

As for blade production, similar reduction procedures were used to produce blades across the studied units. Blade cores were unidirectional, and blanks, frequently with sub-parallel edges, were detached from flat striking platforms during linear and consecutive knapping progressions (Falcucci & Peresani, 2018). Having said that, blades discarded at the site also come from the elaborate re-shaping phases performed on bladelet cores. Flake production is more common in the uppermost units. Flakes from D3b*alpha*–D3ab were obtained from unidirectional cores, a different strategy than the parallel and multidirectional core reduction strategies represented in the underlying units.

Tool composition shows variability across the studied sequence. It is important to keep in mind that differences in the frequency of tools may be the outcome of factors such as uneven sample sizes, stochastic variation, and differences in site-use through time. Retouched bladelets are the most frequent tool type across the whole studied sequence. Their frequency is although higher in the oldest cultural units A2–A1. Endscrapers gradually increase in frequency from D3base and represent the main type of common tool in D3b*alpha*–D3ab, whereas laterally retouched blades and different burin types are more common in A2–A1. Finally, in A2–A1 common tools are made on blades, while in D3base–D3ab tools on flakes are more frequent.

Aside the lithic assemblages, marine shells were commonly used as ornamental objects at Fumane Cave and organic tools were made from bone and antler. No organic points were recovered in A2, while a mesio-distal antler point was found at the top of unit A1. SBPs made from antler were only recovered in D3b*alpha*–D3ab.

Overall, this detailed assessment supports our previous attribution of units A2–A1 to the PA (as defined in: Falcucci *et al.*, 2017) and confirms that no differences can be identified, on a techno-typological basis, between the two assemblages. The rest of the studied assemblages present few differing features and can be grouped into two phases: D3base and D3b*alpha*–D3ab. D3base presents only a few variations of the general composition of the lithic assemblage, while they are more distinct in D3b*alpha*–D3ab. From now on, we will refer to the youngest phase as the *late* PA in order to underline the continuity that characterizes the cultural sequence at Fumane Cave.

Testing the adaptive shift to the Early Aurignacian

According to Banks *et al.* (2013a), the adaptive shift that marked the beginning of the EA and the disappearance of the PA over the extension of the European sub-continent was triggered by the deterioration of the environment at the onset of HE4. Several researchers have criticized the validity of this scenario because of both its discard of inconvenient data when running Bayesian modeling and for the strict cultural separation between the two Aurignacian variants (Bataille *et al.*, 2018; Falcucci *et al.*, 2017; Higham *et al.*, 2013; Ronchitelli *et al.*, 2014). A growing chronological database attests to the beginning of the EA well before the cut-off of ca. 39.9–39.2 ky cal BP. This is, for instance, the case at Isturitz (Barshay-Szmidt *et al.*, 2018), Pataud (Higham *et al.*, 2011), Geißenklösterle

(Higham *et al.*, 2012), Willendorf II (Nigst *et al.*, 2014; contra: Teyssandier & Zilhão, 2018), and possibly at Lapa do Picareiro (Haws *et al.*, 2020). Although criticisms have been raised over the dates obtained in Central Europe (Banks *et al.*, 2013b; Teyssandier & Zilhão, 2018; Zilhão & d'Errico, 2003), this database suggests a statistical overlap between assemblages that show either PA and EA affinities (Wood *et al.*, 2014). In this framework, our assessment of the Aurignacian sequence of Fumane Cave, which contains evidence of human occupations that both pre- and postdate the occurrence of HE4, provides us with the rare opportunity to address this issue and the archaeological validity of a model that relies on the assumption that the chrono-cultural sequence established in the Aquitaine Basin is applicable to all of Europe.

The *late* PA at Fumane Cave has a lithic signature that does not fit into the classic Aquitaine sequence, where it appears that consensus about the techno-typological features of the EA has been reached (Bon, 2002; Bon *et al.*, 2010; Bordes, 2006; Chiotti, 2005; de Sonneville-Bordes, 1960; Teyssandier *et al.*, 2010). Several major divergences can be underlined. At Fumane Cave, blades from the youngest assemblages are not more robust and platforms are almost never faceted. Laterally retouched blades only rarely display the so-called Aurignacian retouch (de Sonneville-Bordes, 1960). This type of modification, which is said to be virtually absent in the PA and common in the EA (Bordes, 2006), is represented in unit A2 and never increases in frequency in the upper sequence. The independence of bladelet production is not a viable characteristic with which to define the EA, given that this feature characterizes the PA also (Bataille, 2017; Bataille *et al.*, 2018; Falcucci *et al.*, 2017; Falcucci & Peresani, 2018; Normand *et al.*, 2007; Ortega Cobos *et al.*, 2005; Porraz *et al.*, 2010; Riel-Salvatore & Negrino, 2018b; Slimak *et al.*, 2006b; Tafelmaier, 2017). The EA is said to be characterized by a bladelet production that is almost exclusively conducted on carinated cores. At Fumane Cave, carinated technology is never the sole reduction strategy responsible for the production of bladelets, though carinated pieces gradually increase in frequency throughout the sequence. Bladelets in EA assemblages are seldom retouched. Contrary to this, retouched bladelets are always the most common tool type within the sequence of Fumane Cave. Finally, the simultaneous production of blades and bladelets has only rarely been described in the EA (Chiotti, 2005; Tafelmaier, 2017; Teyssandier, 2007), whereas at Fumane Cave it is a common feature.

Our case study represents an example of how challenging it is to use diachronic local signatures to construct straightforward supra-regional models. We cannot subdivide the Aurignacian into four development phases extrapolated from a restricted region, namely southwestern France, as several authors have already argued (e.g. Bataille & Conard, 2018; Clark & Riel-Salvatore, 2005; Conard & Bolus, 2006, 2015; Davies, 2001; Hauck *et al.*, 2018; Moreau *et al.*, 2015; Sitlivy *et al.*, 2014). Accepting that regional variation exists, one major implication is that the PA does not necessarily refer to a pioneering phase of human dispersal, as suggested by Anderson *et al.* (2015). Instead, we consider the PA to be an adaptive system (see Tafelmaier, 2017) that is a rather effective set of behavioral features that allowed foragers to cope with shifting climatic conditions in the course of few thousand years.

Fumane Cave is not unique in the archaeological record of northern Italy. At Bombrini Rockshelter (Liguria, northwestern Italy), for instance, the formation of the two PA cultural units (A2 and A1) spanned from ca. 40,710 to ca. 35,640 ky cal BP (Benazzi *et al.*, 2015). Recent studies confirm that neither the HE4 nor the Campanian Ignimbrite volcanic eruption altered the defining features of the assemblages (Riel-Salvatore & Negrino, 2018a). At Mochi Rockshelter (Liguria, northwestern Italy), the recent identification of two PA occupations (Grimaldi *et al.*, 2014) that precede the well-known PA assemblage from unit G (Bietti & Negrino, 2008; Kuhn & Stiner, 1998; Laplace, 1977) and the long chronological span that characterizes the latter (Douka *et al.*, 2012) are in agreement with the evidence from Bombrini.

According to Tejero & Grimaldi (2015), the assemblage from unit F can be assigned to the EA as defined in southwestern France, although the radiocarbon dates obtained (ca. 36 ky cal BP: Douka *et al.*, 2012) are significantly younger than the ones available for that region.

Data from southern Italy is still incomplete, sometimes deriving from old excavations or surface collections. For instance, additional research is needed to test the hypothesis of an abrupt end of the PA due to the Campanian Ignimbrite volcanic eruption in southern Tyrrhenian Italy (but see: d'Errico & Banks, 2015; Lowe *et al.*, 2012), whose ashes have been found on top of PA layers at Castelcivita Cave and the open-air site of Serino (Accorsi *et al.*, 1979; Gambassini, 1997; Wood *et al.*, 2012), and of the possible cultural interactions that occurred between the makers of Uluzzian and Aurignacian techno-complexes (Benazzi *et al.*, 2011; De Stefani *et al.*, 2012; Giaccio *et al.*, 2017; Marciani *et al.*, 2019; Moroni *et al.*, 2013, 2018; Mussi, 2002; Mussi *et al.*, 2006; Palma di Cesnola, 2001, 2004, 2006; Riel-Salvatore, 2007; Ronchitelli *et al.*, 2014; Villa *et al.*, 2018). Differences between northern and southern Italy seem to be marked. For instance, the frequency of retouched bladelets in southern assemblages is lower when compared to the northern sites (Riel-Salvatore, 2010). The further development of specific retouched bladelet types in the cultural units successive to the earliest PA at Castelcivita Cave (Campania, southwestern Italy: Gambassini, 1997) and Paglicci Cave (Apulia, southeastern Italy: Palma di Cesnola, 2004, 2006) is evidence of specific regional adaptation mechanisms that need to be examined more closely. Valuable information might come, for example, from a reassessment of Serino (Campania, southwestern Italy), a single-layered open-air site that was discovered beneath nearly 3 m of tephra and whose two-phase structure is diagnostic of the CI (Accorsi *et al.*, 1979; Giaccio *et al.*, 2008). Researchers have usually interpreted the site as a short-term occupation of PA foragers, with a dense scatter of remains mostly located near a combustion feature. Interestingly, only four retouched bladelets were recovered from the site. Among those, two artifacts are similar to the so-called micro-points of Castelcivita. In the southeast, the site of Paglicci Cave contains three PA cultural units (Unit 24 a0-a1, a2-a4, bI-bII) dated by radiocarbon to ca. 34–29 ky uncal BP (Palma di Cesnola, 2004). The PA sequence is sealed by the Codola tephra, which is dated to ca. 33 ky BP and gives a more reliable age determination (Giaccio *et al.*, 2008). Although new technological assessments are needed, the presence of this tephra unit might help researchers to understand the long temporal span of the PA south of the Alps and the continuous presence of foragers in regions adjacent to the origin of the CI volcanic eruption. Further, the typological (Palma di Cesnola, 2004) and technological (Wierer, 2013) analyses of the PA assemblages show that retouched bladelets are more numerous in the youngest cultural unit and that they have been modified by direct retouch to obtain a peculiar outline morphology (one convex edge opposed to a straight/concave edge) not seen elsewhere in Italy. Furthermore, carinated cores are still present, but are always in very low frequency (Palma di Cesnola, 2006; Wierer, 2013).

The persistence of the PA in Italy, and thus the contemporaneity with the EA on a supra-regional scale, is considered possible by Bon (2002, 2006) and Anderson *et al.* (2015). Our data point toward the same direction, although it is now clear that technological continuity does not imply cultural isolation. This study has permitted to identify an internal variability within the PA sequence of Fumane Cave. The gradual changes that occur attest to common chrono-cultural trends that link Fumane Cave to some western European regions, where a clear cultural break between PA and EA is difficult to detect. Differences with the classic definition of EA, as well as resilience of PA traits, are frequently emphasized.

In the Pyrenean region, the recently excavated site of Isturitz contains several layers that have been attributed to PA and EA occupations (Normand & Turq, 2005). The EA from units C 4b1 and C 4b2 is characterized by the presence of SBPs (Normand *et al.*, 2007), bovine teeth, and basket-shaped beads used as personal ornaments (White & Normand, 2015). In terms of the lithic assemblages, the increase in the number of end-scrapers and carinated cores and the presence of Aurignacian blades are considered supporting evidence for a shift to an EA phase. The researchers also emphasize that there are several differences compared to the classic definition, such as the high proportion of retouched bladelets (ca. 23% in C 4b1) and the interdependence of blade and bladelet reduction systems (Barshay-Szmidt *et al.*, 2018; Normand, 2006; Normand *et al.*, 2007). The cultural unit C 4c4 is described as a transitional phase, suggesting a regional development of the EA (Normand, 2006; Szmidt *et al.*, 2010). In Cantabria, the PA unit VII and EA units VI–V of Labeko Koba (Arrizabalaga & Altuna, 2000) were recently re-analyzed by Tafelmaier (2017). Tafelmaier shows the strong technological affinities that exist between PA and EA technological systems in the realm of bladelet production. As in the previous case, carinated reduction strategies increase in the EA, while from a typological standpoint retouched bladelets are less common (from ca. 50% to ca. 10%) and endscrapers are more common. It is also interesting to note that flakes are numerous in the EA units, similar to the youngest cultural phases of Fumane Cave. Similar data come from the site of La Viña (Fortea Pérez, 1995; Santamaría, 2012), although taphonomic processes may have resulted in the mixing of supposedly EA and late Aurignacian assemblages (Santamaría, 2012; Wood *et al.*, 2014). In west-central France, the site of Les Cottés contains PA (US 04inf.) and EA (US 04sup.) units that are chronologically indistinguishable (Talamo *et al.*, 2012). The EA unit consists of techno-typological traits that are also well represented in the underlying PA (Roussel & Soressi, 2013). Research conducted some decades ago in south-eastern France shows that sites such as Pêcheurs (Lhomme, 1976), Esquicho Grapaou units B.R. 1 and C.C. 1 (Bazile, 1974), Rainaude (Onoratini, 1986), and Observatoire unit E (Onoratini *et al.*, 1999), assigned to the EA based on the presence of SBPs and carinated cores, present several features that diverge from the classic definition. For this reason, Slimak *et al.* (2006a) have observed that the use of two strict groups such as PA and EA does not allow us to well appreciate the development of the Aurignacian in the Rhône Basin. The authors conclude that a Mediterranean variant of the EA with several PA features is very likely. The duality that seems to exist between the Atlantic and Mediterranean Aurignacian has also been emphasized by other authors, who suggest that new regional assessments be conducted to identify better the defining features of the latter variant (Anderson *et al.*, 2018; Le Brun-Ricalens & Bordes, 2007).

Data from Central Europe is worthy of consideration as well. In the Swabian Jura, for instance, the Aurignacian begins with assemblages that differ greatly from the PA identified in south and western Europe and that are rich in carinated cores and almost completely devoid of retouched bladelets (Conard & Bolus, 2006; Hahn, 1977; Teyssandier, 2007). The lithic industries at Geißenklösterle have been described by Teyssandier (2007) as being close to the EA of the Aquitaine Basin, although Conard & Bolus (2006) have stressed that the Aurignacian of the Swabian Jura has a strong regional signal. Distinct chrono-cultural phases have not yet been identified, but Teyssandier (2008) has suggested a possible change in the organization of the lithic assemblages within the sequence of Geißenklösterle that may not be solely related to the functional variability of the site. Furthermore, new data from the ongoing excavations at Hohle Fels suggest that the technological features of the Aurignacian of the Swabian Jura are more diverse than previously thought (Bataille & Conard, 2018; contra: Dinnis *et al.*, 2019b). The ongoing analyses of the lowermost horizons will better define these components and the diachronic development of the Aurignacian in the region.

In the light of the data we have presented above and case studies we have taken into consideration, we strongly encourage researchers to focus their attention on critical reassessments of regional signatures in order to construct high-resolution chrono-cultural narratives. Only by doing so, will it be possible to better understand the formation of the

Upper Paleolithic and model scenarios of humans' dispersal across Europe and mechanisms of cultural adaptation. One major issue that researchers need to tackle is the loose adoption of cultural taxonomic terms, which, together with the sometimes-uncritical use of radiocarbon dates, are the sole parameters used to schematize the highly variable archaeological record of Europe. This can hinder our ability to understand cultural processes. Taxonomic terms should be better framed if they are to be used to understand human behavior and cultural evolution (Reynolds & Riede, 2019). We notice that cultural taxonomy tends to almost exclusively rely on diachronic change, ignoring spatial variability. Little attention is given to the spatial distribution of cultural variants and to the differences that might be related to specific human adaptations to different environments. In the particular case of Fumane Cave, we do not use new taxonomies to define the *late* PA cultural units (e.g. Fumanian: Conard & Bolus, 2006) in order to avoid unnecessary confusion and an over-fragmentation of the archaeological record, which may prevent, in the long run, cross-regional comparisons (Sauer & Riede, 2019). Nevertheless, we want to stress the significant differences between the archaeological record south of the Alps and the record of Central Europe and southwestern France. Italy may not be the sole exception to a rather monolithic cultural framework, given that researchers tend to classify assemblages that show a high degree of internal variability into strict cultural phases, such as PA for assemblages dated prior to HE4 and EA for assemblages that postdate this climatic event. Overall, we consider cultural taxonomy a precious tool to enable profitable communication between scientists across different research traditions. However, different levels of taxonomies (Brew, 1946) may be needed to describe and interpret the archaeological record with regard to external and internal factors, such as environmental and climatic constraints or specific site-use strategies.

Split-based points and cultural interactions between foragers

The youngest cultural units at Fumane Cave cannot be grouped into the EA. This assessment has demonstrated that the PA was an efficient adaptive system that responded well to the needs of foragers gravitating to the Venetian Pre-Alps. Its techno-typological features clearly persist throughout the stratigraphic sequence with some temporal variations that are less distinct when compared to other regions. The use of similar reduction strategies to produce blades, and especially bladelets, can be seen as evidence for the presence of a stable population in northeastern Italy with strong knapping traditions. However, the isolation of general trends in the realm of lithic technology that link Fumane Cave to other southern and western European regions demonstrate the possibility of cultural interactions between foragers. Supporting evidence for this hypothesis is the appearance of SBPs at several sites across Europe (Doyon, 2017; Liolios, 2006).

The SBP has historically been considered a true expression of the EA (de Sonneville-Bordes, 1960; Peyrony, 1933, 1935), replaced by types of organic points in successive stages of the Aurignacian (but see: Moreau *et al.*, 2015). This type of organic artifact remains important to the definition of the EA today (Banks *et al.*, 2013b, a; Teyssandier, 2007; Teyssandier & Zilhão, 2018). Only a small percentage of sites contains SBPs and more generally organic points. Outside of the Aquitaine and the Swabian Jura, finds are scattered (Tafelmaier, 2017). Nevertheless, it is not rare that archaeologists ascribe a cultural unit to the EA based solely on the presence of a SBP (Banks *et al.*, 2013a; de Sonneville-Bordes, 1960; Hahn, 1977; Tejero & Grimaldi, 2015). An example is Fumane Cave. Some authors have argued that units A1 (but see above) and D3 correspond to EA phases (Banks *et al.*, 2013a,b; Teyssandier & Zilhão, 2018). This interpretation is debatable because, as we have shown here, no clear cultural shift to the EA is visible in the lithic technology.

The manufacture of a SBP requires a highly standardized procedure (Tartar & White, 2013) that seems unlikely to have been reinvented in multiple regions without any technological transfer. Its presence in the *late* PA of Fumane Cave thus suggests the existence of inter-regional contacts between foragers that allowed technological innovations to spread over large areas. This is not unrealistic if one considers the extensive exchange networks required for the circulation of marine shells of both Mediterranean and Atlantic origins across hundreds of kilometers (Taborin, 1993; Vanhaeren & d'Errico, 2006). As for the timing of its appearance, the debate is still open. It is often said that when SBPs are found within a clear stratigraphic framework, they are never associated to the lowermost cultural unit (Doyon, 2017; Hahn, 1977). Also, a chronological comparison of directly or indirectly dated SBPs across Europe suggests that this artifact type does not date to the earliest manifestations of the Aurignacian (Tafelmaier, 2017). The ongoing excavations at Hohle Fels attest instead to the presence of SBPs in the lowermost Aurignacian horizons (Conard & Malina, 2008). More data is thus needed to test whether SBPs were only manufactured starting from a second stage of the Aurignacian.

In a recent summary of the work conducted at Fumane Cave, one of us (Falcucci, 2018) has proposed a tentative interpretation to address this issue that we will address and expand on this paper. During the time span from 42 to 35 ky cal BP, the regions south of the Alps were not isolated from the rest of Europe. Two important bridges favored the movement of people both towards the east and the west. In the northeast, due to sea levels being about 70 m below the present-day coastline (Benjamin *et al.*, 2017), a huge plain, covered today by the Adriatic Sea, connected Italy to the Balkans. In the northwest, the coastal Ligurian corridor allowed movements to and from Mediterranean France. Direct and/or indirect long-distance contacts between groups of foragers were thus possible. In the specific case of Italy, the circulation of marine shells and siliceous raw materials across hundreds of kilometers (Bertola *et al.*, 2013) are important evidence supporting the marked dynamic human behavior during the Early Upper Paleolithic. Also, particularly interesting is the discovery of a sidescraper made from northeastern pre-Alpine chert at Bombrini Rockshelter, proving that connections existed between the two extremes of northern Italy (Negrino & Riel-Salvatore, 2018).

These conditions are important prerequisites that allow us to formulate a scenario based on existing ethnographic literature. Several scholars have addressed topics related to the diffusion of ideas, and many have focused their attention on the invention and subsequent circulation of cutting-edge tools (Kelly, 2013; Kroeber, 1940; Mulvaney, 1976; Murdock, 1960; Tostevin, 2013; Wiessner, 1983, 1984). An exceptional example comes from the ethnographic record of Australia, where Mulvaney (1976) has shown that groups of sub-contemporary foragers are affected by cultural innovations from as far away as 1,200 km. This information is extremely valuable for addressing the presence of objects such as SBPs in Italian *late* PA contexts. We consider that Aurignacian groups across the different regions of Europe had a high degree of social intimacy (sensu Tostevin, 2007), as demonstrated by the fact that they shared a common technological background visible in the manufacture of stone tools (Bataille *et al.*, 2018; Tafelmaier, 2017). Human groups that share a similar material culture are more likely to exchange cultural information (Eerkens & Lipo, 2007). In this framework, the SBP might have represented an innovative tool type that allowed people to manufacture highly effective composite hunting weapons and that, as a result, traveled quickly across the Aurignacian world. Future research might focus on the operational procedures involved in the production of SBPs to detect variations in the manufactural processes across Europe. In the case of Fumane Cave, this question might not be easy to answer given that SBPs were likely introduced as finished tools, as evidenced by the likely absence of debitage waste (Broglio & Dalmeri, 2005). Having said that, we stress that SBPs should not be used as a unique piece of evidence to attribute a stratigraphic unit to the EA variant, but a thorough analysis of all features characterizing the archaeological assemblage is required

Conclusions and future research

This paper presented a technological analysis of the lithic assemblages and a re-evaluation of the organic artifacts from five cultural units at Fumane

Cave in northeastern Italy. Our goals were to define a chrono-cultural narrative of the Aurignacian at Fumane Cave and identify a possible cultural break in the stratigraphic sequence that might be related to a shift from the PA to an EA adaptive system. Our results show that the PA techno-typological features (Falcucci *et al.*, 2017) clearly persist throughout the stratigraphic sequence with some gradual variations that are less distinct when compared to other regions. PA features are not related to a certain time span and the occurrence of HE4 does not coincide with a shift to the EA, as suggested by Teyssandier *et al.* (2010). This study thus challenges the generalization of applying the Aquitaine reference sequence (Bon *et al.*, 2010; Bordes, 2006) and the model proposed by Banks *et al.* (2013a) to all of Europe. In other words, all models have their own regional limits.

The PA south of the Alps was a resilient adaptive system that helped foragers to survive and thrive under changing climatic conditions (Riel-Salvatore & Negrino, 2018a). It cannot, thus, be considered a less effective set of behavioral features prior to the affirmation of the EA. In our view, the Aurignacian represents a broad cultural taxonomic group with a polythetic nature of different techno-typological features (sensu Clarke, 1978). It can be seen as a landscape of spatial and temporal variability with multiple poles and end points (Falcucci, 2018). In this framework, the Aquitaine sequence represents only a regional pole of such variability.

Our results provide further evidence that cultural attributions should not be drawn from single tool types. For instance, SBPs cannot be used to identify an EA cultural unit if other features of the assemblage are considered as well. On the contrary, the discovery of SBPs across different European regions is evidence of the existence of information exchange and inter-regional networks between groups of foragers that were open to technological innovations and had similar needs (see also: Bataille, 2013; Bataille *et al.*, 2018; Tafelmaier, 2017). In this regard, new findings from some eastern European regions seem promising (Hopkins *et al.*, 2016; Hopkins *et al.*, 2018), although they still need to be accurately described. The internal variability that characterizes the PA at Fumane Cave and the appearance of SBPs in the youngest cultural units demonstrate that foragers at the south of the Alps were not culturally isolated. They, however, maintained strong local traditions over the course of several millennia. Reassessments of pivotal sites will be beneficial in emphasizing the complexity of the Aurignacian and better defining regional trajectories. They have been overlooked to model the expansion of modern humans into Europe, considered as a monolithic climatic and environmental landscape.

Overall, the biocultural processes that favored the expansion of the Aurignacian across a range of environments, the cultural trajectories that may have occurred during this expansion, and the relationships between the Aurignacian and other technocomplexes are yet to be fully understood. Our reevaluation of the cultural sequence at Fumane Cave represents, thus, only the beginning of a large-scale study that will take into account several sites south of the Alps. In the debate over the formation of the Upper Paleolithic, Italy provides an ideal test case due to its geographic position and ecological variability at the intersection between eastern and western Mediterranean Europe, its important archaeological sites dating to this period, and the discovery of modern human remains associated with its Early Upper Paleolithic assemblages. However, only a few assemblages have been recently investigated from a technological perspective. We will bring together new data from both southern and northern Italy to conduct inter-site comparisons and construct more dynamic models of cultural change during the Early Upper Paleolithic.

Data Sharing

All relevant data underlying the findings described in this paper are within the paper and its supporting material. The Protoaurignacian lithic assemblages from Fumane Cave are permanently stored at the University of Ferrara, Dipartimento di Studi Umanistici, Sezione di Scienze Preistoriche e Antropologiche, Corso Ercole I d'Este, 32, I-44100 Ferrara, Italy.

Acknowledgments

Research and fieldwork at Fumane Cave is coordinated by the University of Ferrara (M. Peresani) in the framework of a project supported by the Ministry of Culture – SAPAB Archaeological Superintendence, public institutions (Lessinia Mountain Community - Regional Natural Park, B.I.M. Adige, Fumane Municipality), private associations and companies, and in collaboration with Italian and European research centers. Research reported in this publication was supported by the Deutsche Forschungsgemeinschaft (DFG) under grant agreement no. 431809858 – FA 1707/1-1 (project title: Investigating Early Upper Paleolithic Technological Variability and Cultural Dynamics South of the Alps; recipient: A. Falcucci). Part of the data was collected thanks to a doctoral scholarship (2015–2018) granted to A. Falcucci and funded by the state of Baden-Württemberg and the University of Tübingen (Evolution of Cultural Modernity research project). The authors are grateful to R. Duches and a team of students for organizing the lithic collections in 2015. The authors thank the Editor-in-Chief and three anonymous reviewers whose comments helped improve this paper.

Author contributions

AF, MP, and NJC: designed the research
AF and MP: collected the data
AF: performed statistical analysis and wrote the first draft of the manuscript
All authors read, provided feedback, and contributed to the final manuscript.

References

Accorsi C.A., Aiello E., Bartolini C. *et al.* 1979. Il giacimento paleolitico di Serino, Avellino: stratigrafia e paletnologia. *Atti Soc. Toscana Sci. Nat.*, 86: 435-487.

Aleo A., Duches R., Rots V. *et al.* 2017. A technological and functional examination of the Aurignacian end-scrapers from Grotta di Fumane. *PESHE*, 6: 8.

Anderson L., Bon F., Bordes J.-G. *et al.* 2015. Relier des espaces, construire de nouveaux réseaux : aux origines du Protoaurignacien et des débuts du Paléolithique supérieur en Europe occidentale. In N. Naudinot, L. Meignen, G. Binder *et al.* (eds): *Les systèmes de mobilité de la Préhistoire au Moyen Âge XXXVe rencontres internationales d'archéologie et d'histoire d'Antibes*, pp. 57-73. Éditions APDCA, Antibes.

Anderson L., Lejay M., Brugal J.-P. *et al.* 2018. Insights into Aurignacian daily life and camp organization: The open-air site of Régismont-le-Haut. *Quat. Int.*, 498: 69-98.

Andrefsky W. 1998. *Lithics: Macroscopic approaches to analysis*. Cambridge University, Cambridge.

Antonioli F. 2012. Sea level change in western-central mediterranean since 300 kyr: comparing global sea level curves with observed data. *Alpine and Mediterranean Quaternary*, 25: 15-23.

Arrizabalaga A. & Altuna J. 2000. Labeko Koba (País Vasco). Hienas y humanos en los albores del Paleolítico superior. *Munibe*, 52.

Arrizabalaga A., de Quiros F.B., Bon F. *et al.* 2009. Early evidence of the Aurignacian in Cantabrian Iberia and the North Pyrenees. In M. Camps & C. Szmidt (eds): *The Mediterranean from 50,000 to 25,000 BP: Turning Points and New Directions*, pp. 255-292. Oxbow Books, Oxford.

Badino F., Pini R., Ravazzi C. *et al.* 2020. An overview of Alpine and Mediterranean palaeogeography, terrestrial ecosystems and climate history during MIS 3 with focus on the Middle to Upper Palaeolithic transition. *Quat. Int.*, 551: 7-28.

Bailey S.E., Weaver T.D. & Hublin J.J. 2009. Who made the Aurignacian and other early Upper Paleolithic industries? *J. Hum. Evol.*, 57: 11-26.

Banks W.E., d'Errico F. & Zilhão J. 2013a. Human-climate interaction during the Early Upper Palaeolithic: Testing the hypothesis of an adaptive shift between the Proto-Aurignacian and the Early Aurignacian. *J. Hum. Evol.*, 64: 232-232.

Banks W.E., d'Errico F. & Zilhão J. 2013b. Revisiting the chronology of the Proto-Aurignacian and the

Early Aurignacian in Europe: A reply to Higham *et al.*'s comments on Banks *et al.* (2013). *J. Hum. Evol.*, 65: 810-817.

Bar-Yosef O. & Zilhão J. 2006. *Towards a Definition of the Aurignacian*. Instituto Português de Arqueologia, Lisbon.

Barshay-Szmidt C., Normand C., Flas D. *et al.* 2018. Radiocarbon dating the Aurignacian sequence at Isturitz (France): Implications for the timing and development of the Protoaurignacian and Early Aurignacian in western Europe. *J. Archaeol. Sci. Rep.*, 17: 809-838.

Barshay-Szmidt C., Bazile F. & Brugal J.-P. 2020. First AMS 14C dates on the Protoaurignacian in Mediterranean France: The site of Esquicho-Grapaou (Russan-Ste-Anastasie, Gard). *J. Archaeol. Sci. Rep.*, 33: 102474.

Bartolomei G., Broglio A., Corai P. *et al.* 1982. Dépot wurmien à industrie protoaurignacienne à lamelles Dufour dans l'abri Tagliente (Mons Lessini, Verona, Italie). *Eraul*, 13: 45-63.

Bartolomei G., Broglio A., Cattani L. *et al.* 1988. Nuove ricerche nel deposito pleistocenico della grotta di Paina sui colli Berici (Vicenza). *Atti dell'Istituto Veneto di Scienze, Lettere e Arti*, 146: 111-160.

Bartolomei G., Broglio A., Cassoli P. *et al.* 1992a. La Grotte de Fumane. Un site aurignacien au pied des Alpes. *Preistoria Alpina*, 28: 131-179.

Bartolomei G., Broglio A., Cassoli P. *et al.* 1992b. Risultati preliminari delle nuove ricerche al Riparo di Fumane. *Annuario storico della Valpolicella*: 9-64.

Bataille G. 2013. *Der Übergang vom Mittel- zum Jungpaläolithikum auf der Halbinsel Krim und in der Kostenki-Borshchevo-Region am Mittel-Don. Adaptionsstrategien spät-mittelpaläolithischer und frühjungpaläolithischer Gruppen*. Ph.D. Dissertation, University of Cologne.

Bataille G. 2017. Extracting the "Proto" from the Aurignacian. Distinct Production Sequences of Blades and Bladelets in the Lower Aurignacian Phase of Siuren I, Units H and G (Crimea). *Mitteilungen der Gesellschaft für Urgeschichte*, 25: 49-85.

Bataille G. & Conard N.J. 2018. Blade and bladelet production at Hohle Fels Cave, AH IV in the Swabian Jura and its importance for characterizing the technological variability of the Aurignacian in Central Europe. *PLoS One*, 13: e0194097.

Bataille G., Tafelmaier Y. & Weniger G.-C. 2018. Living on the edge – A comparative approach for studying the beginning of the Aurignacian. *Quat. Int.*, 474: 3-29.

Bataille G., Falcucci A., Tafelmaier Y. *et al.* 2020. Technological differences between Kostenki 17/II (Spitsynskaya industry, Central Russia) and the Protoaurignacian: Reply to Dinnis et al. (2019). *J. Hum. Evol.*, 146: 102685.

Bazile F. 1974. Nouvelles données sur le Paléolithique supérieur ancien en Languedoc oriental. *XX° Congrès Préhistorique de France*: 24-28.

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

Benazzi S., Peresani M., Talamo S. *et al.* 2014. A reassessment of the presumed Neandertal remains from San Bernardino Cave, Italy. *J. Hum. Evol.*, 66: 89-94.

Benazzi S., Slon V., Talamo S. *et al.* 2015. The makers of the Protoaurignacian and implications for Neandertal extinction. *Science*, 348: 793-796.

Benjamin J., Rovere A., Fontana A. *et al.* 2017. Late Quaternary sea-level changes and early human societies in the central and eastern Mediterranean Basin: An interdisciplinary review. *Quat. Int.*, 449: 29-57.

Bertola S. 2001. *Contributo allo studio del comportamento dei primi gruppi di Homo sapiens sapiens diffusi in Europa. Sfruttamento della selce, produzione dei supporti lamellari, confezione delle armature litiche nel sito aurignaziano della Grotta di Fumane nei Monti Lessini (Verona).* Ph.D. Dissertation, University of Bologna.

Bertola S., Broglio A., Cristiani E. *et al.* 2013. La diffusione del primo Aurignaziano a sud dell'arco alpino. *Preistoria Alpina*, 47: 17-30.

Bietti A. & Negrino F. 2008. L'Aurignacien et le Gravettien du Riparo Mochi, l'Aurignacien du Riparo Bombrini: comparaisons et nouvelles perspectives. *Arch. Inst. Paléontologie Humaine*, 39: 133-140.

Blanc A.C. & Segre A.G. 1953. Excursion au Mont Circé. *INQUA, IV° International congress. Roma-Pisa*.

Boëda E., Geneste J.-M. & Meignen L. 1990. Identification de chaînes opératoires lithiques du Paléolithique ancien et moyen. *Paléo*, 2: 43-80.

Bon F. & Bodu P. 2002. Analyse technologique du débitage aurignacien. In B. Schmider (ed): *L'Aurignacien de la grotte du Renne. Les fouilles d'André Leroi-Gourhan à Arcy-sur-Cure (Yonne)*, pp. 115-133. CNRS, Paris.

Bon F. 2002. *L'Aurignacien entre mer et océan: réflexion sur l'unité des phases anciennes de l'Aurignacien dans le Sud de la France*. Société préhistorique française, Paris.

Bon F. 2005. Little big tool. Enquete autour du succés de la lamelle. In F. Le Brun-Ricalens (ed): *Productions lamellaires attribuées à l'Aurignacien*, pp. 479-484. MNHA, Luxembourg.

Bon F., Maíllo Fernández J.M. & Ortega Cobos D. 2006. *Autour des concepts de Protoaurignacien, d'Aurignacien archaïque, initial et ancien. Unité et variabilité des comportements techniques des premiers groupes d'hommes modernes dans le sud de la France et le nord de l'Espagne*. UNED, Madrid.

Bon F. 2006. Les termes de l'Aurignacien. In F. Bon, J.M. Maillo Fernandez & D. Ortega-Cobos (eds): *Autour des concepts de Protoaurignacien, d'Aurignacien archaïque, initial et ancien. Unité et variabilité des comportements techniques des premiers groupes d'hommes modernes dans le sud de la France et le nord de l'Espagne*, pp. 39-65. UNED, Madrid.

Bon F., Teyssandier N. & Bordes J.-G. 2010. La signification culturelle des équipements lithiques. In M. Otte (ed): *Les Aurignaciens*, pp. 46-65. Errance, Paris.

Bond G.C. & Lotti R. 1995. Iceberg Discharges into the North Atlantic on Millennial Time Scales During the Last Glaciation. *Science*, 267: 1005-1010.

Bordes J.-G. 2002. *Les interstratifications Châtelperronien/Aurignacien du Roc-de-Combe et du Piage (Lot, France): analyse taphonomique des industries lithiques, implications archéologiques.* Ph.D. Dissertation, University of Bordeaux I.

Bordes J.-G. 2006. News from the West: a revaluation of the classical Aurignacian sequence of the Périgord. In O. Bar-Yosef & J. Zilhão (eds): *Towards a Definition of the Aurignacian*, vol. 45, pp. 147-171. IPA, Lisbon.

Breuil H. 1912. Les subdivisions du Paléolithique Supérieur et leur signification. *Congrès International d'Anthropologie et d'Archéologie Préhistorique (XIVe session)*.

Brew J.O. 1946. The use and abuse of taxonomy, in: The archaeology of Alkali Ridge Utah. *Papers of the Peabody Museum of Archaeology and Ethnology*, 21: 44-66.

Broglio A. 1997. L'estinzione dell'uomo di Neandertal e la comparsa dell'uomo moderno in Europa. Le evidenze della Grotta di Fumane nei Monti Lessini. *Atti Ist. Veneto SS. LL. AA.*, 105: 1-55.

Broglio A. 2000. Considerations on the Aurignacian industries from Krems-Hundssteig in the middle Danube basin and Fumane in the Adige basin. In Z. Mester & A. Ringer (eds): *A la recherche de l'homme préhistorique*, vol. 95, pp. 311-320. Etudes et Recherches Archéologiques de l'Université de Liège, Liège.

Broglio A., Cremaschi M., Peresani M. *et al.* 2003. L'Aurignacien dans le territoire préalpin: la Grotte de Fumane. In S.A. Vasilev, O. Soffer & J.K. Kozlowski (eds): *Perceived landscapes and built environments. The cultural geography of Late Palaeolithic Eurasia*, vol. 1122, pp. 93-104. British Archaeological Reports, International Series.

Broglio A., Bertola S., De Stefani M. *et al.* 2005. La production lamellaire et les armatures lamellaires de l'Aurignacien ancien de la grotte de Fumane (Monts Lessini, Vénétie). In F. Le Brun-Ricalens (ed): *Productions lamellaires attribuées à l'Aurignacien*, vol. 415-436. MNHA, Luxembourg.

Broglio A. & Dalmeri G. 2005. *Pitture paleolitiche nelle Prealpi Venete: Grotta di Fumane e Riparo Dalmeri*. Memorie del Museo Civico di Storia Naturale di Verona, 2a serie, Sezione Scienze dell'Uomo, 9. Verona.

Broglio A., De Stefani M., Tagliacozzo A. *et al.* 2006a. Aurignacian dwelling structures, hunting strategies and seasonality in the Fumane Cave (Lessini Mountains). In S.A. Vasilev, V.V. Popov, M.V. Anikovich *et al.* (eds): *Kostenki and the Early Upper Paleolithic of Eurasia: General Trends, Local Developments*, pp. 263-268. Nestor-Historia, Saint Petersburg.

Broglio A., Bertola S., De Stefani M. *et al.* 2006b. Le strutture d'abitato aurignaziane della Grotta di Fumane. *Dialektikê, Cahiers de Typologie analytique*: 27-43.

Broglio A., De Stefani M., Gurioli F. *et al.* 2009. The decoration of Fumane Cave in the picture of the Aurignacian art. *Anthropologie. Paris,* 113: 753-761.

Caricola I., Zupancich A., Moscone D. *et al.* 2018. An integrated method for understanding the function of macro-lithic tools. Use wear, 3D and spatial analyses of an Early Upper Palaeolithic assemblage from North Eastern Italy. *PLoS One*, 13: e0207773.

Cassoli P. & Tagliacozzo A. 1994. Considerazioni paleontologiche, paleoecologiche e archeozoologiche sui macromamiferi e gli uccelli dei livelli del Pleistocene superiore del Riparo di Fumane (Verona) (scavi 1988-1991). *Boll. Mus. Civ. St. Nat. Verona*, 18: 349-445.

Cavallo G., Fontana F., Gonzato F. *et al.* 2017. Textural, microstructural and compositional characteristics of Fe-based geomaterials and Upper Palaeolithic ocher in the Lessini Mountains, Northeast Italy: implications for provenance studies. *Geoarchaeology*, 32: 437-455.

Cavallo G., Fontana F., Gialanella S. *et al.* 2018. Heat treatment of mineral pigment during Upper Palaeolithic in North-Eastern Italy. *Archaeometry*, 60: 1045-1061.

Chiotti L. 2005. *Les industries lithiques aurignaciennes de l'abri Pataud, Dordogne,* France vol 1392. Archaeopress, BAR International Series, Oxford.

Chu W. 2018. The Danube Corridor Hypothesis and the Carpathian Basin: Geological, Environmental and Archaeological Approaches to Characterizing Aurignacian Dynamics. *J. World Prehist.*, 31: 117-178.

Clark G.A. & Riel-Salvatore J. 2005. The Compositional Integrity of the Aurignacian. *Munibe*, 57: 107-118.

Clarke D. 1978. *Analytical archaeology*. 2nd ed. Methuen, London.

Conard N.J. & Adler D.S. 1997. Lithic Reduction and Hominid Behavior in the Middle Paleolithic of the Rhineland. *J. Anthrop. Res.*, 53: 147-175.

Conard N.J. 2002. The Timing of Cultural Innovations and the Dispersal of Modern Humans in Europe. In A. Brauer, J.F.W. Negendank & M. Bohm (eds): *Proceedings of the DEUQUA-Meeting August 26-28 2002 Potsdam*, vol. 6, pp. 82-94. Terra Nova, Oxford.

Conard N.J. & Bolus M. 2003. Radiocarbon dating the appearance of modern humans and timing of cultural innovations in Europe: new results and new challenges. *J. Hum. Evol.*, 44: 331-371.

Conard N.J., Soressi M., Parkington J.E. *et al.* 2004. A unified lithic taxonomy based on patterns of core reduction. *S. Afr. Archaeol. Bull.*, 59: 12-16.

Conard N.J. & Bolus M. 2006. The Swabian Aurignacian and its place in European Prehistory. In O. Bar-Josef & J. Zilhão (eds): *Towards a Definition of the Aurignacian*, pp. 219-239. IPA, Lisbon.

Conard N.J. & Malina M. 2008. Spektakuläre Funde aus dem unteren Aurignacien vom Hohle Fels bei Schelklingen, Alb-Donau-Kreis. *Archäologische Ausgrabungen Baden-Württemberg*, 2008: 19-22.

Conard N.J. & Bolus M. 2015. Chronicling modern human's arrival in Europe. *Science*, 348: 754-756.

Cortés-Sánchez M., Jiménez-Espejo F.J., Simón-Vallejo M.D. *et al.* 2019. An early Aurignacian arrival in southwestern Europe. *Nat. Ecol. Evol.*, 3: 207–212.

D'Angelo E. & Mussi M. 2005. Galets et lamelles de l'Aurignacien du Latium (Italie Centrale): Le cas de Grotta Barbara. In F. Le Brun-Ricalens (ed): *Productions lamellaires attribuées à l'Aurignacien*, pp. 313-322. MNHA, Luxembourg.

d'Errico F. & Banks W.E. 2015. Tephra studies and the reconstruction of Middle-to-Upper

Paleolithic cultural trajectories. *Quat. Sci. Rev.*, 118: 182-193.

Dauvois M. 1976. *Précis de dessin dynamique et structural des industries lithiques préhistoriques*. Pierre Fanlac, Périgueux.

Davies W. 2001. A Very Model of a Modern Human Industry: New Perspectives on the Origins and Spread of the Aurignacian in Europe. *Proceedings of the Prehistoric Society*, 67: 195-217.

Davies W. 2007. Re-evaluating the Aurignacian as an expression of modern human mobility and dispersal. In P. Mellars, K. Boyle, O. Bar-Yosef *et al.* (eds): *Rethinking the Human Revolution: New Behavioural and Biological Perspectives on the Origin and Dispersal of Modern Humans*, pp. 263-274. McDonald Institute for Archaeological Research, University of Cambridge, Cambridge.

Davies W. & Hedges R.E. 2008. Dating a type site: Fitting Szeleta Cave into its regional chronometric context. *Praehistoria,* 9-10: 35-45.

Davies W., White D., Lewis M. *et al.* 2015. Evaluating the transitional mosaic: frameworks of change from Neanderthals to Homo sapiens in eastern Europe. *Quat. Sci. Rev.*, 118: 211-242.

de Sonneville-Bordes D. 1960. *Le Paléolithique supérieur en Périgord*. Delmas, Bordeaux.

De Stefani M., Klempererova H., Peresani M. *et al.* 2012. Continuity and replacement in flake production across the Middle-Upper Paleolithic transition: a view over the Italian Peninsula. In A. Pastoors & M. Peresani (eds): *Flakes Not Blades: The Role of Flake Production at the Onset of the Upper Paleolithic in Europe*, vol. 5, pp. 75-91. Wissenschaftliche Schriften des Neanderthal Museums, Mattmann.

Degano I., Soriano S., Villa P. *et al.* 2019. Hafting of Middle Paleolithic tools in Latium (central Italy): New data from Fossellone and Sant'Agostino caves. *PLoS One*, 14: e0213473.

Delporte H. 1964. Les niveaux aurignaciens de la Rochette. *Bull. de la Soc. d'Etudes et de Recherches Préhistoriques Les Eyzies*, 13: 52-75.

Delporte H. 1968. L'Abri du Facteur à Tursac (Dordogne) I: étude générale. *GalliaPrHist*, 11: 1-112.

Demars P.-Y. 1992. L'Aurignacien ancien en Périgord. Le problème du Protoaurignacien. *Paléo*, 4: 101-122.

Demars P.-Y. & Laurent P. 1992. *Types d'outils lithiques du Paléolithique supérieur en Europe*. Cahiers du Quaternaire, vol 14. CNRS, Paris.

Demidenko Y.E., Otte M. & Noiret P. 2012. *Siuren I Rock-Shelter. From Late Middle Paleolithic and Early Upper Paleolithic to Epi-Paleolithic in Crimea* vol. 129. The Paleolithic of Crimea IV. ERAUL, Liège.

Dini M., Baills H. & Tozzi C. 2010. Pontecosi: Aurignacian site in Tuscany (Italy). *Anthropologie. Paris*, 114: 26-47.

Dini M., Baills H., Conforti J. *et al.* 2012. Le Protoaurignacien de la Grotte La Fabbrica (Grosseto, Italie) dans le contexte de l'arc nord méditerranéen. *Anthropologie. Paris*, 116: 550-574.

Dinnis R., Bessudnov A., Reynolds N. *et al.* 2019a. New data for the Early Upper Paleolithic of Kostenki (Russia). *J. Hum. Evol.*, 127: 21-40.

Dinnis R., Bessudnov A., Chiotti L. *et al.* 2019b. Thoughts on the Structure of the European Aurignacian, with Particular Focus on Hohle Fels IV. *Proceedings of the Prehistoric Society*, 85: 29-60.

Dinnis R., Bessudnov A., Reynolds N. *et al.* 2020. Response to Bataille *et al.*'s 'Technological differences between Kostenki 17/II (Spitsynskaya industry, Central Russia) and the Protoaurignacian: Reply to Dinnis *et al.* (2019)' [J. Hum. Evol. (2019), 102685]. *J. Hum. Evol.*, 146: 102792.

Djindjian F. 1993. Les origines du Peuplement Aurignacien en Europe. In L. Bànesz & J.K. Kozlowski (eds): *Aurignacien en Europe et au Proche Orient*, pp. 136-154. Institut Archéologique de l'Academie Slovaque des Sciences, Bratislava.

Douka K., Grimaldi S., Boschian G. *et al.* 2012. A new chronostratigraphic framework for the Upper Palaeolithic of Riparo Mochi (Italy). *J. Hum. Evol.*, 62: 286-299.

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

Doyon L. 2017. *La variabilité technologique et morphométrique des pointes de projectile aurignaciennes en matière osseuse*. Ph.D. Dissertation, Université de Bordeaux and Université de Montréal.

Eerkens J.W. & Lipo C.P. 2007. Cultural Transmission Theory and the Archaeological Record: Providing Context to Understanding Variation and Temporal Changes in Material Culture. *J. Archaeol. Res.*, 15: 239-274.

Falcucci A., Conard N.J. & Peresani M. 2017. A critical assessment of the Protoaurignacian lithic technology at Fumane Cave and its implications for the definition of the earliest Aurignacian. *PLoS One*, 12: e0189241.

Falcucci A. & Peresani M. 2018. Protoaurignacian Core Reduction Procedures: Blade and Bladelet Technologies at Fumane Cave. *Lithic Technology,* 43: 125-140.

Falcucci A. 2018. Towards a renewed definition of the Protoaurignacian. *Mitteilungen der Gesellschaft für Urgeschichte*, 27: 87-130.

Falcucci A., Peresani M., Roussel M. *et al.* 2018. What's the point? Retouched bladelet variability in the Protoaurignacian. Results from Fumane, Isturitz, and Les Cottés. *Archaeol. Anthropol. Sci.*, 10: 539-554.

Falcucci A. & Peresani M. 2019. A pre-Heinrich Event 3 assemblage at Fumane Cave and its contribution for understanding the beginning of the Gravettian in Italy. *Quartär*, 66: 135-154.

Fedele F., Giaccio B., Isaia R. *et al.* 2004. The Campanian Ignimbrite Eruption, Heinrich Event 4, and Palaeolithic Change in Europe: A High-Resolution Investigation. *Volcanism and the Earth's Atmosphere*, 139: 301-325.

Fortea Pérez F.J. 1995. Abrigo de la Viña. Informe y primera valoracion de las campañas 1991-1994. *Servicio de Publicaciones de la Consejería de Educación, Cultura, Deportes y Juventud*: 19-32.

Gambassini P. 1997. *Il Paleolitico di Castelcivita: Culture e Ambiente*. Electa, Naples.

Garrod D. 1938. The Upper Palaeolithic in the light of recent discovery. *Proceedings of the Prehistoric Society*, 4: 1-26.

Gheser N., Martini F. & Morandi R. 1986. Indagine strutturale e proposta di correlazione delle industrie litiche italiane del Protoaurignaziano e dell'Aurignaziano. *Preistoria Alpina*, 22: 7-23.

Giaccio B., Isaia R., Fedele F.G. *et al.* 2008. The Campanian Ignimbrite and Codola tephra layers: Two temporal/stratigraphic markers for the Early Upper Palaeolithic in southern Italy and eastern Europe. *Journal of Volcanology and Geothermal Research*, 177: 208-226.

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

Grimaldi S., Porraz G. & Santaniello F. 2014. Raw material procurement and land use in the northern Mediterranean Arc: insight from the first Proto-Aurignacian of Riparo Mochi (Balzi Rossi, Italy). *Quartär*, 61: 113-127.

Groenen M. 1994. *Pour une histoire de la préhistoire*. Éditions Jérôme Millon, Grenoble.

Hahn J. 1977. *Aurignacien. Das ältere Jungpaläolithikum in Mittel- und Osteuropa*. Böhlau (Fundamenta, 9), Köln.

Hauck T.C., Lehmkuhl F., Zeeden C. *et al.* 2018. The Aurignacian way of life: Contextualizing early modern human adaptation in the Carpathian Basin. *Quat. Int.*, 485: 150-166.

Haws J.A., Benedetti M.M., Talamo S. *et al.* 2020. The early Aurignacian dispersal of modern humans into westernmost Eurasia. *Proc. Natl. Acad. Sci. USA, 117*: 25414-25422.

Hemming S.R. 2004. Heinrich Events: Massive late Pleistocene detritus layers of the North Atlantic and their global imprint. *Review of Geophysics*, 42: 1-43.

Higham T., Brock F., Peresani M. *et al.* 2009. Problems with radiocarbon dating the Middle to Upper Palaeolithic transition in Italy. *Quat. Sci. Rev.*, 28: 1257-1267.

Higham T. 2011. European Middle and Upper Palaeolithic radiocarbon dates are often older than they look: problems with previous dates and some remedies. *Antiquity*, 85: 235-249.

Higham T., Jacobi R., Basell L. *et al.* 2011. Precision dating of the Palaeolithic: A new radiocarbon chronology for the Abri Pataud (France), a key Aurignacian sequence. *J. Hum. Evol.*, 61: 549-563.

Higham T., Basell L., Jacobi R. *et al.* 2012. Testing models for the beginnings of the Aurignacian and the advent of figurative art and music: The radiocarbon chronology of Geissenklosterle. *J. Hum. Evol.*, 62: 664-676.

Higham T., Wood R., Moreau L. *et al.* 2013. Comments on 'Human climate interaction during the early Upper Paleolithic: Testing the hypothesis of an adaptive shift between the Proto-Aurignacian and the Early Aurignacian' by Banks *et al. J. Hum. Evol.*, 65: 806-809.

Holm S. 1979. A simple sequentially rejective multiple test procedure. *Scand. Stat. Theory Appl.*, 6: 65-70.

Hopkins R., Sirakov N., Guadelli J.L. *et al.* 2016. Did modern humans enter Europe via the Danube corridor? New results from high precision chronometric modelling. *PESHE*, 5: 126.

Hopkins R., Guadelli J.L., Guadelli A. *et al.* 2018. Testing the Danube-corridor hypothesis - New results from chronometric dating. *PESHE*, 7: 92.

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

Inizan M.L., Reduron M., Roche H. *et al.* 1995. *Technologie de la pierre taillée. Préhistoire de la pierre taillée* vol Tome 4. CREP, Meudon.

Kelly R.L. 2013. *The Lifeways of Hunter-Gatherers: The Foraging Spectrum*. 2 edition edn. Cambridge University Press, Cambridge.

Kozlowski J.K. & Otte M. 2000. The formation of the Aurignacian in Europe. *J. Anthrop. Res.*, 56: 513-534.

Kroeber A.L. 1940. Stimulus Diffusion. *Am. Anthrop.*, 42: 1-20.

Kuhn S.L. & Stiner M.C. 1998. The earliest Aurignacian of Riparo Mochi (Liguria, Italy). *Curr. Anthrop.*, 39: 175-189.

Laplace G. 1966. *Recherches Sur l'origine et l'évolution des complexes leptolithiques*. De Bocard, Paris.

Laplace G. 1977. Il Riparo Mochi ai Balzi Rossi di Grimaldi (Scavi 1939-1949). Les industries leptolithiques. *Rivista di Scienze Preistoriche,* 32: 3-131.

Le Brun-Ricalens F. 1993. Réflexions préliminaires sur le comportement litho-technologique et l'occupation du territoire du pays des Serres à l'Aurignacien. *Paléo*, 5: 127-153.

Le Brun-Ricalens F. 2005a. Chronique d'une reconnaissance attendue. Outils "carénés", outils "nucléiformes": nucléus à lamelles. Bilan après un siècle de recherches typologiques, technologiques et tracéologiques. In F. Le Brun-Ricalens (ed): *Productions lamellaires attribuées à l'Aurignacien*. MNHA, Luxembourg.

Le Brun-Ricalens F. 2005b. *Productions lamellaires attribuées à l'Aurignacien*. MNHA, Luxembourg.

Le Brun-Ricalens F. & Bordes J.-G. 2007. Les débuts de l'Aurignacien en Europe Occidentale: unité ou diversité? Du territoire de subsistance au territoire culturel. In H. Floss & N. Rouquerol (eds): *Les chemins de l'art aurignacien en Europe. Das Aurignacien und die Anfänge der Kunst in Europa*. Musée-Forum Aurignac, Aurignac.

Le Brun-Ricalens F., Bordes J.-G. & Eizenberg L. 2009. A crossed-glance between southern European and Middle-Near Eastern early Upper Palaeolithic lithic technocomplexes. Existing models, new perspectives. In M. Camps & C. Szmidt (eds): *The Mediterranean from fifty thousand to twenty-five thousand BP: Turning points and new directions*, pp. 11-33. Oxbow Books, Oxford.

Lhomme G. 1976. Un nouveau gisement paléolithique en Ardèche; l'abri des Pêcheurs à Casteijau, premiers résultats. *Etudes Préhistoriques*, 13: 1-8.

Liolios D. 2006. Reflections on the role of bone tools in the definition of the Early Aurignacian. In O. Bar-Josef & J. Zilhao (eds): *Towards a definition of the Aurignacian*, vol. 45, pp. 37-51. IPA, Lisbon.

López-García J.M., dalla Valle C., Cremaschi M. *et al.* 2015. Reconstruction of the Neanderthal and Modern Human landscape and climate from the Fumane cave sequence (Verona, Italy) using small-mammal assemblages. *Quat. Sci. Rev.*, 128: 1-13.

Lowe J., Barton N., Blockley S. *et al.* 2012. Volcanic ash layers illuminate the resilience of Neanderthals and early modern humans to natural hazards. *Proc. Natl. Acad. Sci. USA*, 109: 13532-13537.

Marciani G., Ronchitelli A., Arrighi S. *et al.* 2019. Lithic techno-complexes in Italy from 50 to 39 thousand years BP: An overview of lithic technological changes across the Middle-Upper Palaeolithic boundary. *Quat. Int.*, 551: 123-149.

Mellars P. 2004. Neanderthals and the modern human colonization of Europe. *Nature*, 432: 461-465.

Mellars P. 2006a. Archeology and the dispersal of modern humans in Europe: Deconstructing the "Aurignacian". *Evol. Anthropol.*, 15: 167-182.

Mellars P. 2006b. A new radiocarbon revolution and the dispersal of modern humans in Eurasia. *Nature*, 439: 931-935.

Moreau L., Odar B., Higham T. *et al.* 2015. Reassessing the Aurignacian of Slovenia: Techno-economic behaviour and direct dating of osseous projectile points. *J. Hum. Evol.*, 78: 158-180.

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

Moroni A., Ronchitelli A., Arrighi S. *et al.* 2018. Grotta del Cavallo (Apulia – Southern Italy). The Uluzzian in the mirror. *J. Anthropol. Sci.*, 96: 1-36.

Mulvaney D.J. 1976. The chain of connection: the material evidence. In N. Peterson (ed): *Tribes and boundaries in Australia*, pp. 72-94. Australian Institute of Aboriginal Studies, Canberra.

Murdock J.P. 1960. How culture changes. In H.S. Shapiro (ed): *Man, culture and society*, pp. 247-260. Oxford University Press, Oxford.

Mussi M. 2002. *Earliest Italy: An Overview of the Italian Paleolithic and Mesolithic*. Springer, Boston.

Mussi M., Gioia P. & Negrino F. 2006. Ten small sites: the diversity of the Italian Aurignacian. In O. Bar-Josef & J. Zilhão (eds): *Towards a Definition of the Aurignacian*, pp. 189-209. IPA, Lisbon.

Negrino F. & Riel-Salvatore J. 2018. From Neanderthals to Anatomically Modern Humans in Liguria (Italy): the current state of knowledge. In V. Borgia & E. Cristiani (eds): *Palaeolithic Italy. Advanced studies on early human adaptations in the Apennine peninsula*, pp. 161-181. Sidestone Press, Leiden.

Nigst P.R. 2012. *The Early Upper Palaeolithic of the Middle Danube Region*. Leiden University Press, Leiden.

Nigst P.R., Haesaerts P., Damblon F. *et al.* 2014. Early modern human settlement of Europe north of the Alps occurred 43,500 years ago in a cold steppe-type environment. *Proc. Natl. Acad. Sci. USA*, 111: 14394-14399.

Normand C. & Turq A. 2005. L'Aurignacien de la grotte d'Isturitz (France): la production lamellaire dans la séquence de La Salle de Saint-Martin. In F. le Brun-Ricalens (ed): *Productions lamellaires attribuées à l'Aurignacien*, pp. 375-392. MNHA, Luxembourg.

Normand C. 2006. L'Aurignacien de la salle de Saint-Martin (Grotte d'Isturitz, commune de Saint-Martin d'Arberoue, Pyrénéesatlantiques): donnés préliminaires sur l'industrie lithique recueillie lors des campagnes 2000–2002. In F. Bon, J.M. Maíllo Fernández & D. Ortega-Cobos (eds): *Autour des concepts de Protoaurignacien, d'Aurignacien archaïque, initial et ancien. Unité et variabilité des comportements techniques des premiers groupes d'hommes modernes dans le sud de la France et le nord de l'Espagne*, pp. 145-174. UNED, Madrid.

Normand C., de Beaune S.A., Costamagno S. *et al.* 2007. Nouvelles données sur la séquence aurignacienne de la grotte d'Isturitz (communes d'Isturitz et de Saint-Martin d'Abreroue: Pyrénées-Atlantiques). In J. Evin (ed): *Congrés du centenaire de la Société préhistorique française: Un siècle de construction du discours scientifiquecen Préhistoire, 26éme Congrès préhistorique de France. Aux Conceptions d'Aujourd'hui*, vol. 3, pp. 277-293. Société Préhistorique Française, Paris.

Odell G.H. 2004. *Lithic analysis*. Springer, New York.

Onoratini G. 1986. Découverte en Provence orientale (grotte Rainaude) d'une industrie souche de l'Aurignacien. *BSPF*, 83: 240-256.

Onoratini G., Simon P. & Simone S. 1999. Mise en évidence du Protoaurignacien à la grotte de l'Observatoire (Principauté de Monaco). *Bull. Mus. Anthrop. Préhist. Monaco*, 40: 43-56.

Ortega Cobos D., Soler N. & Maroto J. 2005. La production de lamelles pendant l'Aurignacien archaïque dans la grotte de l'Arbreda: organisation de la production, variabilité des méthodes et des objectifs. In F. Le Brun-Ricalens (ed): *Productions lamellaires attribuées à l'Aurignacien*, pp. 359-373. MNHA, Luxembourg.

Otte M. & Derevianko A. 2001. The Aurignacian in Altai (Central Asia). *Antiquity*, 75: 44-49.

Palma di Cesnola A. 2001. *Le paléolithique supérieur en Italie*. Collection L'Homme des origines: Série "Préhistoire d'Europe", vol 9. Editions Jérôme Millon, Grenoble.

Palma di Cesnola A. 2004. *Paglicci: l'Aurignaziano e il Gravettiano antico*. Claudio Grenzi, Foggia.

Palma di Cesnola A. 2006. L'Aurignacien et le Gravettien ancien de la grotte Paglicci au Mont Gargano. *Anthropologie. Paris*, 110: 355-370.

Panagiotopoulos K., Böhm A., Leng M.J. *et al.* 2014. Climate variability over the last 92 ka in SW Balkans from analysis of sediments from Lake Prespa. *Clim. Past*, 10: 643-660.

Pastoors A., Tafelmaier Y. & Weniger G.C. 2015. Quantification of late Pleistocene core configurations: Application of the Working Stage Analysis as estimation method for technological behavioural efficiency. *Quartär* 62: 63-84.

Peresani M. 2012. Fifty thousand years of flint knapping and tool shaping across the Mousterian and Uluzzian sequence of Fumane cave. *Quat. Int.*, 247: 125-150.

Peresani M., Centi E. & Di Taranto L. 2013. Blades, bladelets and flakes: A case of variability in tool design at the dawn of the Middle–Upper Palaeolithic transition in Italy. *C. R. Palevol*, 12: 211-221.

Peresani M., Cristiani E. & Romandini M. 2016a. The Uluzzian technology of Grotta di Fumane and its implication for reconstructing cultural dynamics in the Middle-Upper Palaeolithic transition of Western Eurasia. *J. Hum. Evol.*, 91: 36-56.

Peresani M., Cristiani E. & Romandini M. 2016b. The Uluzzian technology of Grotta di Fumane and its implication for reconstructing cultural dynamics in the Middle–Upper Palaeolithic transition of Western Eurasia. *J. Hum. Evol.*, 91: 36-56.

Peresani M., Forte M., Quaggiotto E. *et al.* 2019. Marine and Freshwater Shell Exploitation in the Early Upper Paleolithic: Re-Examination of the Assemblages from Fumane Cave (NE Italy). *PaleoAnthropology*, 2019: 64-81.

Peretto C., Biagi P., Boschian G. *et al.* 2004. Living-Floors and Structures From the Lower Palaeolithic to the Bronze Age. *Coll. Antropol.*, 28: 63-88.

Peyrony D. 1933. Les industries 'aurignaciennes' dans le bassin de la Vézère. *BSPF*, 30: 543-559.

Peyrony D. 1935. Le gisement Castanet, Vallon de Castelmerle, commune de Sergeac (Dordogne). Aurignacicen I et II. *BSPF*, 32: 418-443.

Plutniak S. & Tarantini M. 2016. An Influential Outsider. Georges Laplace between French institutions and Italian prehistory. *History of Archaeology: International Perspectives. Archaeopress*, 11: 79-89.

Porraz G., Simon P. & Pasquini A. 2010. Identité technique et comportements économiques des groupes proto-aurignaciens à la grotte de l'Observatoire (principauté de Monaco). *Gallia Préhistoire:* 52: 33-59.

Reynolds N. & Riede F. 2019. House of cards: cultural taxonomy and the study of the European Upper Palaeolithic. *Antiquity*, 93: 1350-1358.

Riel-Salvatore J. 2007. *The Uluzzian and the middle-Upper Paleolithic transition in southern Italy*. Ph.D. Dissertation, Arizona State University.

Riel-Salvatore J. 2010. A Niche Construction Perspective on the Middle–Upper Paleolithic Transition in Italy. *J. Archaeol. Method Theory*, 17: 323-355.

Riel-Salvatore J. & Negrino F. 2018a. Human adaptations to climatic change in Liguria across the Middle–Upper Paleolithic transition. *J. Quat. Sci.*, 33: 313-322.

Riel-Salvatore J. & Negrino F. 2018b. Lithic technology, mobility and human niche construction in Early Upper Paleolithic Italy. In Lithic Technological Organization and Paleoenvironmental Change. In E. Robinson & F. Sellet (eds): *Lithic technological organization and paleoenvironmental change*, pp. 163-187. Springer, New York.

Ronchitelli A., Benazzi S., Boscato P. *et al.* 2014. Comments on "Human-climate interaction during the Early Upper Paleolithic: Testing the hypothesis of an adaptive shift between the Proto-Aurignacian and the Early Aurignacian" by William E. Banks, Francesco d'Errico, Joao Zilhao. *J. Hum. Evol.*, 73: 107-111.

Roussel M. 2011. *Normes et variations de la production lithique durant le Chatelperronien: la séquence de la Grande-Roche-de-la-Plématrie à Quinçay (Vienne).* Ph.D. Dissertation, University of Paris Ouest-Nanterre.

Roussel M. & Soressi M. 2013. Une nouvelle séquence du Paléolithique supérieur ancien aux marges sud-ouest du Bassin parisien: Les Cottés dans la Vienne. In P. Bodu, L. Chehmana K. L. *et al.* (eds): *Le Paléolithique supérieur ancien de l'Europe du Nord-Ouest*, pp. 283-297. Mémoire LVI de la Société Préhistorique Française.

Sanchez Goñi M.F. & Harrison S.P. 2010. Millennial-scale climate variability and vegetation changes during the Last Glacial: Concepts and terminology. *Quat. Sci. Rev.*, 29: 2823-2827.

Sánchez Goñi M.F., Fourcade T., Salonen S. *et al.* 2020. Muted cooling and drying of NW Mediterranean in response to the strongest last glacial North American ice surges. *GSA Bulletin*, https://doi.org/10.1130/B35736.1.

Santamaría D. 2012. *La transición del Paleolítico medio al superior en Asturias. El Abrigo de La Viña (La Manzaneda, Oviedo) y la Cueva de El Sidrón (Borines, Piloña).* Ph.D. Dissertation, Universidad de Oviedo, Spain.

Sauer F. & Riede F. 2019. A Critical Reassessment of Cultural Taxonomies in the Central European Late Palaeolithic. *J. Archaeol. Method Theory*, 26: 155-184.

Siddall M., Rohling E.J., Thompson W.G. *et al.* 2008. Marine isotope stage 3 sea level fluctuations: Data synthesis and new outlook. *Rev. Geophys.*, 46, https://doi.org/10.1029/2007RG000226.

Sitlivy V., Chabai. V., Anghelinu M. *et al.* 2012. The earliest Aurignacian in Romania: New investigations at the open air site of Româneşti-Dumbrăviţa I (Banat). *Quartär*, 59: 85-130.

Sitlivy V., Anghelinu M., Chabai V. *et al.* 2014. Placing the Aurignacian from Banat (Soutwestern Romania) into the European Early Upper Paleolithic context. In M. Otte & F. Le Brun-Ricalens (eds): *Modes de contacts et de déplacements au Paléolithique eurasiatique*, vol. 140, pp. 243-277. ERAUL, Liège.

Slimak L., Pesesse D. & Giraud Y. 2006a. La grotte Mandrin et les premières occupations du Paléolithique supérieur en Occitanie orientale. In F. Bon, J.M. Maillo Fernandez & D. Ortega Cobos (eds): *Autour des concepts de Proto-Aurignacien, d'Aurignacien initial et ancien : unité et variabilité des comportements techniques des premiers groupes d'hommes modernes dans le sud de la France et le nord de l'Espagne*, pp. 237-259. UNED, Madrid.

Slimak L., Pesesse D. & Giraud Y. 2006b. Reconnaissance d'une installation du Protoaurignacien en vallée du Rhône. Implications sur nos connaissances concernant les premiers hommes modernes en France méditerranéenne. *C. R. Palevol*, 5: 909-917.

Soressi M. & Geneste J.-M. 2011. The history and efficacy of the chaîne opératoire approach to lithic analysis: Studying techniques to reveal past societies in an evolutionary perspective. *PaleoAnthropology*: 334-350.

Szmidt C.C., Normand C., Burr G.S. *et al.* 2010. AMS C-14 dating the Protoaurignacian/Early Aurignacian of Isturitz, France. Implications for

Neanderthal-modern human interaction and the timing of technical and cultural innovations in Europe. *J. Archaeol. Sci.*, 37: 758-768.

Taborin Y. 1993. *La parure en coquillage au Paléolithique*. CNRS Editions, Paris.

Tafelmaier Y. 2017. *Technological variability at the beginning of the Aurignacian in northern Spain. Implications for the Proto- and early Aurignacian distinction*. Wissenschaftliche Schriften des Neanderthal Museums, Mettmann.

Talamo S., Soressi M., Roussel M. *et al.* 2012. A radiocarbon chronology for the complete Middle to Upper Palaeolithic transitional sequence of Les Cottés (France). *J. Archaeol. Sci.*, 39: 175-183.

Tartar E. & White R. 2013. The manufacture of Aurignacian split-based points: an experimental challenge. *J. Archaeol. Sci.*, 40: 2723-2745.

Tejero J.M. & Grimaldi S. 2015. Assessing bone and antler exploitation at Riparo Mochi (Balzi Rossi, Italy): implications for the characterization of the Aurignacian in South-western Europe. *J. Archaeol. Sci.*, 61: 59-77.

Teyssandier N. 2007. *En route vers l'Ouest. Les débuts de l'Aurignacien en Europe*. John and Erica Hedges Ltd., Oxford.

Teyssandier N. 2008. Revolution or evolution: the emergence of the Upper Paleolithic in Europe. *World Archaeol.*, 40: 493-519.

Teyssandier N., Bon F. & Bordes J.-G. 2010. WITHIN PROJECTILE RANGE Some Thoughts on the Appearance of the Aurignacian in Europe. *J. Anthrop. Res.*, 66: 209-229.

Teyssandier N. & Zilhão J. 2018. On the Entity and Antiquity of the Aurignacian at Willendorf (Austria): Implications for Modern Human Emergence in Europe. *Journal of Paleolithic Archaeology*, 1: 107-138.

Tixier J. 1963. *Typologie de l'Epipaléolithique du* Maghreb vol 2. Mémoires du Centre de Recherches anthropologiques et préhistoriques et ethnographiques, Paris.

Tostevin G. 2007. Social Intimacy, Artefact Visibility and Acculturation Models of Neanderthal-Modern Human Interaction. In P. Mellars, K. Boyle, O. Bar-Yosef *et al.* (eds): *Rethinking the Human Revolution. New Behavioral and Biological Perspectives on the Origin and Dispersal of Modern Humans*, pp. 341-357. McDonald Institute for Archaeological Research, Cambridge.

Tostevin G. 2013. *Seeing Lithics: A Middle-Range Theory for Testing for Cultural Transmission in the Pleistocene*. Oxbow Books, Oxford.

Tsanova T., Zwyns N., Eizenberg L. *et al.* 2012. Le plus petit dénominateur commun : réflexion sur la variabilité des ensembles lamellaires du Paléolithique supérieur ancien d'Eurasie. Un bilan autour des exemples de Kozarnika (Est des Balkans) et Yafteh (Zagros central). *Anthropologie. Paris*, 116: 469-509.

Vanhaeren M. & d'Errico F. 2006. Aurignacian ethno-linguistic geography of Europe revealed by personal ornaments. *J. Archaeol. Sci.*, 33: 1105-1128.

Villa P., Pollarolo L., Conforti J. *et al.* 2018. From Neandertals to modern humans: New data on the Uluzzian. *PLoS One*, 13: e0196786.

Waelbroeck C., Labeyrie L., Michel E. *et al.* 2002. Sea-level and deep water temperature change derived from benthic foraminifera isotopic records. *Quat. Sci. Rev.*, 21: 295-305.

White R. & Normand C. 2015. Les parures de l'Aurignacien ancien et archaïque de la grotte d'Isturitz: perspectives technologiques et régionales. with the collaboration of Bon. In R. White & R. Bourillon (eds): *Aurignacian Genius: Art, Technologie et Société des Premiers Hommes Modernes en Europe. Actes du symposium international, 8–10 April 2013*, vol. 7, pp. 140-166. Palethnologie New York University.

Wierer U. 2013. Variability and standardization: The early Gravettian lithic complex of Grotta Paglicci, Southern Italy. *Quat. Int.*, 288: 215-238.

Wiessner P. 1983. Style and Social Information in Kalahari San Projectile Points. *Am. Antiq.*, 48: 253-276.

Wiessner P. 1984. Reconsidering the behavioral basis for style: A case study among the Kalahari San. *J. Anthrop. Archaeol.*, 3: 190-234.

Wood R.E., Douka K., Boscato P. *et al.* 2012. Testing the ABOx-SC method: Dating known-age charcoals

associated with the Campanian Ignimbrite. *Quat. Geochronol.*, 9: 16-26.
Wood R.E., Arrizabalaga A., Camps M. *et al.* 2014. The chronology of the earliest Upper Palaeolithic in northern Iberia: New insights from L'Arbreda, Labeko Koba and La Vina. *J. Hum. Evol.*, 69: 91-109.
Zilhão J. & d'Errico F. 1999. The chronology and taphonomy of the earliest Aurignacian and its implications for the understanding of Neandertal extinction. *J. World Prehist.*, 13: 1-68.
Zilhão J. & d'Errico F. 2003. An Aurignacian «garden of Eden» in southern Germany ? An alternative interpretation of the Geissenklösterle and a critique of the Kulturpumpe model. *Paléo*, 15: 1-27.
Zwyns N. 2012. *Laminar technology and the onset of the Upper Paleolithic in the Altai, Siberia*. Leiden University Press, Leiden.

Editor, Giovanni Destro Bisol