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ARCHAEOLOGICAL RECONTEXTUALIZATION AND FIRST DIRECT ¹⁴C DATING OF A "PSEUDO-EXCISE" DECORATED ANTLER POINT FROM FRANCE (PÉGOURIÉ CAVE, LOT). IMPLICATIONS ON THE CULTURAL GEOGRAPHY OF SOUTHWESTERN EUROPE DURING THE LAST GLACIAL MAXIMUM

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Abstract

During the Last Glacial Maximum (LGM), very specific but rare osseous decorated artifacts were produced using the "pseudo-excise" technique. These artifacts present a large geographical distribution, extending at least from the Aquitaine basin to Asturias. While in France a Badegoulian age is traditionally accepted for the "pseudo-excise" technique, this is mostly based on arguable data from old excavations and/or problematic archaeostratigraphic contexts. Since it is a key-site for this matter we have focused our attention on Pégourié Cave (Lot, France) in order to establish the chronocultural attribution of pseudo-excised pieces in southwest France. The interdisciplinary reassessment of the lithic and osseous industries from Layer 8 and 9, including inter-layer refittings, has shown (1) the irrelevance of previous stratigraphic subdivisions and (2) the strong cultural heterogeneity of this assemblage, which combines Azilian, Magdalenian, Badegoulian, Solutrean and Gravettian components. At the same time, a broad ¹⁴C program based on the direct dating of specific bone and antler technical wastes and tools—including a pseudo-excised point—was implemented after 3D recording using photogrammetry. The results obtained have allowed us to establish a new, firm confirmation of the Badegoulian age of pseudo-excised decoration and, in doing so, to more precisely define the time-range of this specific feature's trans-regional dissemination. Finally, by comparing the results with recent data notably obtained at Llonín cave (Asturias, Spain), new light has been shed on the cultural geography of southwestern Europe during the LGM, allowing us to discuss and fuel the still-controversial "Iberian Badegoulian" hypothesis.

Keywords

Badegoulian; osseous industry; lithic industry; inter-layer refitting; radiocarbon dating; photogrammetry

1. Introduction

At the start of the last Glacial Maximum (LGM; 23-19 cal ka BP: MARGO Project members, 2009; Mix et al., 2001), the Upper Palaeolithic of southwestern Europe experienced several changes whose breadth and chronology highly depends on geography and/or researchers' interpretations. The Solutrean-to-Magdalenian transition (*circa* 24-19 cal ka BP; see Table 1 for a synthetic chronocultural framework) is indeed part of a lively current debate where the

issue of the existence and geographical extent of Badegoulian technical traditions is a central focus. In short, two contradictory models have been proposed by researchers to interpret the evolving cultural trajectories of hunter-gatherer groups in this area and time-span. From a “regionalized” Solutrean substratum primarily expressed through a coherent geographical distribution of different types of lithic points (e.g., Rasilla and Santamaría Álvarez, 2005; Straus, 1977), the first model defends the idea of a general, abrupt and more or less contemporaneous change throughout this geographical area, corresponding to the development of the quite different Badegoulian technical traditions around 23 cal ka BP. This scenario, which has been broadly documented and long accepted in France, where Badegoulian industries were first defined (e. g. Allain, 1968; Allain and Fritsch, 1967; Cheynier, 1939; Vignard, 1965), was first supported in the Iberian Peninsula in the 1950s with Cheynier’s identification of specific Badegoulian tools—such as the so-called “*raclettes*”—at Parpalló Cave (Gandía, Valencia) (e.g., Aura, 2007, 1995; Breuil, 1954; Cheynier, 1951). This then extended to northwest Spain following the work of Utrilla (1989, 1981) and later, the critical reassessment by Bosselin and Djindjian of published data (Bosselin, 2000; Bosselin and Djindjian, 1999). This scenario is currently supported by research conducted between Asturias and Levantine Spain notably as part of the SOBAMA project (J.-E. Aura dir.; Aura et al., 2012; Rasilla et al., 2014). In contrast, other researchers argue that the data available in the Iberian Peninsula does not indicate abrupt changes but a process of progressive replacement of Solutrean hunting technology through the so-called “desolutreanization” process (Rasilla, 1989; Straus, 2000), directly leading to the Magdalenian technical traditions observed from around 20,5 cal ka BP (Corchón Rodríguez et al., 2015; Rios Garaizar et al., 2013; Straus et al., 2014). This second model, which excludes the Badegoulian “stage” in Spain, considers that the technical similarities are non-significant typo-technological convergences also taking place within different kinds of environments, and assumes that, between 23 and 20.5 cal ka BP, southwestern Europe was marked by a clear cultural geography (i.e., Badegoulian in present-day France *versus* Upper/Final Solutrean in the Iberian Peninsula; Banks et al., 2011, 2009). Crystallized in the early 2000s (Bosselin and Djindjian, 2000; Straus and Clark, 2000) and much more complex than a simple *logomachie* issue (Sauvet et al., 2008), the opposition between these two models still generates a lively debate (Álvarez Alonso and Arrizabalaga, 2012).

In any case, aside from the discussions regarding the comparability of the lithic subsystems on either side of the Pyrenees, it is admitted that some elements clearly demonstrate links between these two areas during the development of the Badegoulian lithic traditions in southwest France (23.5–20.5 cal ka BP: Ducasse et al., 2017, 2014). Particularly noteworthy is the large geographical distribution of specific, although rare, antler pieces using the “pseudo-excise” technique to carve specific curvilinear decoration (Fig. 1a). Usually attributed in France to the raclette-yielding Badegoulian, these decorated osseous elements are currently documented from Charente to Asturias and are claimed by proponents of the first model as strong evidence for an Iberian Badegoulian (Aura et al., 2012). On the other hand, if we accept the cultural geography implied by the second model and consider the strong specificity and scarcity of this group of pieces as an indicator of synchronous manufacturing, pseudo-excised decoration can be considered evidence for the dissemination of a specific technique and graphic theme that crossed “cultural” boundaries.

But while it currently remains difficult to draw any conclusions on the matter, it appears above all that the reliability of the baseline data is far from certain: we must indeed point out that the cultural attribution of the French specimens is essentially based on arguable data from old excavations and/or problematic archaeostratigraphic contexts that often also yield Upper Solutrean and Magdalenian industries (Ducasse, 2010). So, as part of the *SaM* project (Ducasse

and Renard dir.) we have started a reassessment of the baseline data. Focusing on the case of Pégourié Cave (Lot, France) which is a key-site for this issue, as it has been considered to clearly demonstrate the Badegoulian age of the pseudo-excise technique (Utrilla, 1986: 205), this paper presents the results of an interdisciplinary approach, combining classical taphonomic lithic studies based on inter-layer refittings (Bordes, 2000; Klaric, 2003) and the direct dating of specific bone and antler elements—including a pseudo-excised point—in order to (1) test the reliability of the archaeostratigraphical framework of the Badegoulian sequence at Pégourié and, in doing so, (2) clarify the chronocultural attribution of these unique artifacts.

2. The “Pseudo-excise” technique: background, definition and corpus

Prior to Utrilla’s seminal paper (1986) and several years after the isolated descriptions of Breuil and Saint-Périer (1927), Peyrony (1938) and Cheynier (1949) in southwest France, it is to I. Barandiarán that we owe the term “pseudo-excise” to define the carving technique used to produce specific decorations on antler artifacts from the Vasco-Cantabrian region (notably from the Upper Solutrean of Aitzbitarte IV: Barandiarán, 1973). Referring to the excise decoration technique applied to Bronze and Iron Age ceramics, this term is here used to describe a specific way of carving lines and outlines, not through a continuous line but through a juxtaposition and/or superimposition of short oblique strokes sometimes carving deep into the antler (clearly visible in [Figs. 1b #5 and 6](#)). It was not until the work of P. Utrilla, published at the end of the 1980s (Utrilla, 1986), that the link between the Spanish and French pieces was clearly made, fueling the Badegoulian hypothesis for the Vasco-Cantabrian assemblages. Indeed, while in the very early 1980s M.-R. Séronie-Vivien (Séronie-Vivien et al., 1981) and M.-F. Hemingway (Hemingway, 1980: 205-206) described the “pseudo-excise” technique at Pégourié ([Fig. 1b #2](#)) and made clear comparisons with other French pieces ([Fig. 1b #1](#)) and with the Upper Solutrean of Aitzbitarte IV ([Fig. 1b #6](#)), they refused to relate these distant geographical areas and these distinct chronocultural contexts, arguing that “one can suppose that this technique (...) is just an early stage in the production of a continuous and deeply carved line” (Séronie-Vivien et al., 1981). It was not until the publication of the Pégourié monograph (Séronie-Vivien, 1995) that Séronie-Vivien finally made this connection, probably influenced by several papers by Utrilla (Utrilla, 1990, 1986). Utrilla’s line of argument for proposing a Badegoulian age for all pseudo-excised pieces rested on (1) the specific nature of the technique used, regardless of the iconographic motif; (2) the “well-stratified” cases of Pégourié Layer 8 and Laugerie-Haute Layer 12 and (3) her reassessment of the Aitzbitarte IV layer III industries, which she considered an archaeological mix between Upper Solutrean and Badegoulian components (Utrilla, 1989: 405).

However, among the several pieces published as “pseudo-excised” (Utrilla, 1986; Séronie-Vivien, 2005), which have not always been directly reexamined, one can distinguish two groups according to the iconographic motif and/or degree of certainty regarding the technique used. The first and “initial” group corresponds to antler splinters or points with curvilinear decoration, generally consisting of three parallel, longitudinal lines ([Fig. 1b](#)). The second group includes related pieces sharing (1) the same technique but associated with more complex and diverse decoration or (2) the same motif (i.e., parallel, longitudinal lines) but for which the use of the “pseudo-excise” technique is uncertain. As one of us has already pointed out (Ducasse, 2010: 360) and without repeating here what has been fully addressed in a recent publication (Duarte et al., 2014), the definition, corpus and age of “pseudo-excised” pieces currently suffer from several imprecisions. Firstly, among the seven sites counted in France by Séronie-Vivien (2005), excluding Pégourié Cave, three were excavated between the end of the 19th and the very beginning of the 20th centuries (i.e., Laugerie-Basse, Le Placard and Le Chaffaud caves), while

the four others were excavated between the 1930s and the 1950s (i.e. Isturitz Cave and Jolivet and Badegoule rockshelters). In Spain, apart from Llonin Cave, which we will come back to later, the situation is similar, since none of the sites yielding “pseudo-excised” pieces were excavated after the 1970s (Duarte et al., 2014). Thus, a significant number of these antler objects were found during old excavations and their relation to specific technocomplexes is often difficult to determine retrospectively. Secondly, the latter group of pieces described above was essentially established on the basis of bibliographic research and old and unclear drawings and/or descriptions that are clearly not sufficient to establish a firm technical diagnosis. Thus, considering these uncertainties, and following the work of Duarte and colleagues (2014) for the Spanish data, we present in Table 2 a revised corpus of “pseudo-excised” pieces. Regarding the French corpus, we chose to focus only on pieces meeting the initial criteria (i.e., the first group, see above and Fig. 1b), waiting for a direct analysis of the questionable (Laugerie-Basse) or deviant (Chaffaud) specimens. We consequently considered only four sites located between the Charente and Quercy regions. While estimating the number of “pseudo-excised” pieces at Le Placard (de Maret excavations) or Badegoule (Cheynier excavations) is impossible without an entire reassessment of the bone and antler collections, they are only represented by one or two specimens at Laugerie-Haute and Pégourié as well as in the Basque Country, Cantabria and Asturias.

On the basis of this revised corpus, the available radiometric data indicate a large chronological range, between 23 and 19.5 cal ka BP (18260 ± 360 BP; 23–21 cal ka BP at Laugerie-Haute; 16433 ± 131 BP; 20–19.5 cal ka BP at Rascaño), covering the entire LGM time span (MARGO Projet members, 2009; Mix et al., 2001) (Table 2). While this ^{14}C data seems to contradict the hypothesis of a sub-synchronicity, it must be noted that these measurements (1) are essentially from the beta-counting method applied to bulk samples of bones and obtained during the 1970s (note the very high standard deviations); (2) do not systematically concern the layers containing “pseudo-excised” pieces but sometimes underlying and/or overlying layers and (3) are often from non taphonomically-controlled archaeological contexts. Thus, it appears that the link between the radiometric data and the “pseudo-excised” pieces is generally highly questionable and needs to be clarified.

3. Material and methods

3.1. Pégourié Cave: archaeological context

Located in southwestern France (Fig. 2a), more precisely in the Quercy region, Pégourié Cave (Caniac-du-Causse, Lot) was discovered in 1963 by the Société Spéléologique et Préhistorique de Bordeaux. The 75-meters-long cave has been dug into the Jurassic limestone of an asymmetric sinkhole on the Causse de Gramat plateau. It takes the form of two successive elongated halls separated by a narrow passage, extending into two low, narrow galleries (Fig. 2b). The 21-year excavation was conducted in the first hall by M.-R. Séronie-Vivien from 1967 to 1988, revealing a stratigraphy of almost two meters, yielding several archaeological layers covering the time range between the Gravettian (Layer 10) and the Bronze and Iron Ages (Layers 2 and 3; Fig. 2c). According to the excavators, the Palaeolithic and Epipalaeolithic sequence is made up of three archaeological units, some of which are subdivided into several distinct layers: Unit 6 attributed to the Middle Gravettian; Unit 5 attributed to the Badegoulian (Layers 9 to 8); and Unit 4 attributed to the Azilian (Layers 7 to 4) (Fig. 2d). Each layer composing the Badegoulian unit has been divided into sublayers according to the sedimentary variations observed during the fieldwork and has been the subject of a separate analysis of the archaeological components. Thus, typological comparisons and radiometric data from Layer 9b

to 8a1 led M.-F. Hemingway (1980), Bosselin and Djindjian (1988) and M.-R. Séronie-Vivien (2005, 1995) to define distinct but closely comparable archeostratigraphic frameworks for the Badegoulian occupations of Pégourié (Table 3). In the most recent publication (Séronie-Vivien, 2005), trends in the proportions of lithic tools such as *raclettes*, transverse burins (currently considered as cores: Bodu and Chehmana, 2008; Ducasse, 2012) and backed bladelets allowed the author to define a Lower (*inférieur*; Layer 9b), Middle (*moyen*; Layers 9a to 8b) and Upper Badegoulian phase (*supérieur*; Layer 8a). Thus, the Badegoulian sequence of Pégourié Cave is considered to show a specific typo-technological evolution from its earlier stages to its later stages, characterized by a sort of “Magdalenization” process—i.e., a gradual emergence of characteristic typo-technological Magdalenian features, notably an increase in bladelet production and backed bladelet manufacturing (Bosselin, 2000).

Prior to our study, four ^{14}C dates had been published for Layers 8 and 9, obtained via the beta counting method at the laboratory of Lyon-CDRC (Table 4). The dated samples involved bulk bone samples of a 400 to 800 g mass harvested from a circa 1m² surface and from the complete thickness of Layers 8a2 to 9a. Despite the chronocultural evolution defined by Séronie-Vivien, these four measurements are not statistically different and, given the high standard deviations, once calibrated they cover almost the same chronological range of between 22 and 19.5 cal ka BP. Whereas Layer 9b (Lower Badegoulian according to Séronie-Vivien) has not been officially dated, it is important to note that the bulk sample dated to 24200 ± 1100 BP (Ly-1835; 30.9–26.5 cal ka BP) and attributed to Gravettian Layer 10 was actually collected from Layer 9b. The apparent inconsistency of the results led the excavator to reassign this dating to the Gravettian layer: “Given the typological data, it is unlikely that Layer 9b could be so old. It is more likely that the bulk bone sample comes from the upper part of Layer 10” (Séronie-Vivien et al., 1981). As they cast doubt on the clear distinction between the Gravettian and the earliest Badegoulian industries, the radiometric data also illustrate a rather complex distinction between the later Badegoulian industries and the Azilian component since some reindeer bones from Layer 7 have been directly dated to 16090 ± 320 BP (Ly-5258; 20.2–18.7 cal ka BP; Table 4).

Aside from these chronological considerations, the lithic and osseous industries from the Badegoulian of Pégourié yield uncommon elements that equally call into question their chronocultural homogeneity. Indeed, besides highly varied and sometimes unusual osseous implements (Séronie-Vivien, 2005, 1995 and see below) including, among others, bone single-beveled points (Final Gravettian? e.g., Saint-Périer, 1920; Leroy-Prost, 1979; Ducasse et al., 2017), an antler double-beveled point and groove-and-splinter waste products (Middle and/or Upper Magdalenian? e.g., Pétilion and Ducasse, 2012; Langley et al., 2016), several lithic tools and weapon implements depart from the classic Badegoulian tool kits. Such is the case of some shouldered points, including typical Solutrean ones found in the uppermost layers (8a and 8b). In the absence of a Solutrean level, Séronie-Vivien excluded the hypothesis of Solutrean occupations at Pégourié and thus interpreted these elements as “maintaining the Solutrean retouching technique [in the Badegoulian] in order to produce projectile points” (Séronie-Vivien, 2003: 70). Finally, a previous exploratory study carried out in 2004–2005 as part of a doctoral thesis (Ducasse, 2010: 355–367) and, notably, inter-layer refittings found between several lithic elements from Layers 9a–8c–8b (i.e. bladelet debitage in Pyrenean flint; Ducasse and Langlais, 2007), highlighted the need to completely reassess Pégourié’s archaeostratigraphic framework before any attempt at interpreting the “special” features of the Badegoulian assemblages. Although the two “pseudo-excised” antler artifacts were found in Layers 9a and 8c, both attributed to Séronie-Vivien’s “Middle” phase, corresponding to *raclette*-yielding industries (Fig. 2d), it is clear that, given the existing doubts about the possible chronocultural mixing that seem to affect the Badegoulian layers, the age of French “pseudo-

excised” pieces cannot be easily inferred from such a complex and contradictory framework. In order to discuss the archaeological reality of Séronie-Vivien’s archaeostratigraphic framework and the homogeneity of the Badegoulian assemblages, a dual approach was carried out, combining lithic inter-layer refittings and direct ^{14}C dating of characteristic bone and antler artifacts.

3.2. Inter-layer refittings

This process was carried out according to the well-known, classical approach of lithic “taphonomy” (Villa, 1982; Bordes, 2000; Klaric, 2003; Bertran et al., 2017: 22-24). In the specific case of Pégourié, despite the equally important and informative role of faunal remains (e.g., Mallye, 2011) and osseous industries (e.g., Pétilion, 2006) in such work, we chose to limit this approach to the lithic industry. Indeed, no such refittings were found among the osseous industry and, although Pégourié’s faunal assemblage is extremely rich and diverse, the majority of it is currently in a state that prevents its detailed analysis (i.e., remains still impregnated with sediment, without individual labels, and not stored in appropriate containers), and solving this obstacle was beyond the scope of this work. Similarly, for reasons of time and feasibility, the non-flint component of the lithic industry from the Badegoulian layers (quartz and quartzites, basalt, etc.) was not included in the study and the lithic industry of the Gravettian and Azilian layers was also left aside (although a certain amount of admixture with the Badegoulian layers can be suspected, see above). Furthermore, the inter-layer refittings carried out in 2004–2005 with the Pyrenean flint mentioned above were not included in the present study because this material was no longer available for reanalysis. Therefore, we have focused our analyses on specific flint raw material from the Badegoulian unit that meet several requirements, namely: (1) easy identification at a macroscopic scale; (2) a stratigraphic distribution covering the entire Badegoulian sequence and/or a small assemblage size and (3) an *in situ* exploitation. Taking advantage of the important archaeopetrographic work carried out by Séronie-Vivien (Séronie-Vivien, 1995: 55-65), we selected 13 flint types from the 44 defined through the analyses of the Badegoulian industries. The inter-layer refittings tests were carried out on:

- flint-type 37 corresponding to Gavaudun-type flint (Morala, 1983, 1984, 2017); this lower Coniacian flint is considered a lithologic marker since its geographical distribution is strictly limited to the Lède Valley area (Lot-et-Garonne), about 60 km to the west of Pégourié Cave (as the crow flies);
- flint-types 13 and 29 corresponding to Fumélois-type flint from the Turonian sequence of Lot-et-Garonne, near the Gavaudun outcrops (Morala, 1983, 1984; Turq and Morala, 2013; Morala, 2017). Given its quantitative importance within the Badegoulian assemblages, an original dinoflagellate component, and the possible existence of residual Turonian outcrops near Pégourié cave, Séronie-Vivien has argued for a possible local origin (Séronie-Vivien, 1995: 60-61); since no decisive evidence has confirmed this hypothesis, we have considered Fumélois-type flint as allochthonous raw material;
- flint-type 44 has been cautiously attributed to the Senonian or Coniacian sequence (Séronie-Vivien, 1995: 56) and the procurement area is thought to be localized about 15 to 20 km to the west (Gourdonnais area); nevertheless, this very specific raw material shares certain features with the Fumélois-type flint (i.e., very fine-grained flint, oily-looking, and a very thin cortex showing a clear-cut delineation with the siliceous matrix) which raises questions about its real geological attribution and thus its geographical origin (i.e., Fumélois area?);
- flint-type 15a, 33, 38, 39, 45, 46 and 52; according to Séronie-Vivien, these flint types correspond to certain or possible Tertiary continental flint (Ludian); refittings between

types corresponding to certain and possible specimens have allowed several attributions to be established; a local origin is proposed (2 to 12 km from the cave: pebbles from the Lot alluvium and plaque-form flints available near the cave).

This selective approach was compensated by the quantitative importance of types 13 and 44 within each layer, which respectively represent 13 to 34 per cent and 6 to 17 per cent of the total (Séronie-Vivien, 1995: 64–65). Parallel to these systematic, targeted refitting tests, isolated tests were carried out on other flint types during the study (e.g., types 24 and 54 attributed to Bergeracois-type flint). Only the stratigraphic attribution of the lithic artifacts was considered in this study and no 3D scatterplots were produced, as for a large part of the assemblage, the stratigraphic attribution is the only information available: many artifacts have no 3D coordinates, or only approximate ones (i.e., they are attributed to altitudinal “spits”). Furthermore, Séronie-Vivien’s original, hand-written field notes are currently missing and the only version available to us (a partially digital version) poses several problems (e.g., quite frequently, a single entry number corresponds to several artifacts) requiring a detailed examination beyond the scope of this study.

3.3. Direct ¹⁴C dating of characteristic bone and antler artifacts

To complete this “taphonomic” approach, while revising the chronological framework of Pégourié’s occupations, a ¹⁴C dating program was implemented focusing on characteristic bone and antler artifacts. This program, which was based on a micro-sampling strategy (see below), was designed following previous work carried out as part of several projects in southwest France, such as the Magdatis (J.-M. Pétilion and V. Laroulandie dir.), Madapca (P. Paillet dir.) and SaM projects (S. Ducasse and C. Renard dir.) (e.g., Barshay-Szmidt et al., 2016; Bourdier et al., 2014; Ducasse et al., 2017, 2014; Pétilion and Ducasse, 2012). Given the suspicion of chronological heterogeneity in the flint industry (see above) and the unusual diversity of the Badegoulian osseous industry from Pégourié, we selected artifacts with specific typological and technological characteristics, found in the main excavation area, and, whenever possible, for which 3D coordinates were available. Out of the 153 osseous artifacts in layers 8–9, the 14 objects selected for radiocarbon dating were (Fig. 3–5):

- two antler flakes evidencing the use of the knapping technique to work reindeer antler (1.8b and 1.8c; Fig. 3 #3 and 6). Recent research has confirmed that, in accordance with early statements by Allain et al. (1974), this type of flake is frequent in Badegoulian assemblages and is typical of the antler-working techniques of that period (e.g., Pétilion and Averbough, 2012; Pétilion and Ducasse, 2012). A systematic search among Pégourié’s faunal assemblage yielded 62 flakes of this type.
- three artifacts evidencing the use of the groove-and-splinter technique (GST): an antler waste product (1.8; Fig. 3 #5), an antler splinter (1.8b; Fig. 3 #1) and a bone splinter (1.8a; Fig. 3 #2), all showing the edges of longitudinal grooves on both sides. Although the GST is documented in the Gravettian (e.g., Goutas, 2009) and is very widespread in the Magdalenian, there is currently no convincing evidence for its use on either bone or antler during the Badegoulian (Pétilion and Ducasse, 2012). A Gravettian or Magdalenian origin was thus suspected for these elements. In the osseous assemblage from Pégourié, only six artifacts (including the three selected for dating) bear traces of the GST.
- two fragments of slender bone points with a single-beveled base from Layers 8b and 9 (Fig. 4 #1 and 6), the only osseous artifacts from Pégourié suggestive of a Late

Gravettian age, according to previous studies of similar implements (Leroy-Prost, 1979; Baumann, 2014; Ducasse et al., 2017).

- two fragments of antler projectile heads, both from Layer 8a, and for which an attribution to the Early Middle Magdalenian (EMM) was suspected: a single-beveled point of the Lussac-Angles type (Fig. 4 #3), and a fragment of half-round rod (Fig. 4 #5; see arguments for an EMM age in Pétillon, 2016; Chauvière et al., 2017; Langlais et al., 2017). A third projectile point fragment, not selected for direct dating, was also suggestive of an EMM chronology (a proximal fragment of a wide, double-beveled point: Séronie-Vivien, 1995: 243, figure 8.35 #5).
- two fragments of antler projectile points for which a Badegoulian age was suspected: one of three self-barbed points (1.8a; Fig. 4 #2) similar to the specimens from the Badegoulian layers of Cuzoul de Vers (Le Guillou, 2012:321; Pétillon and Ducasse, 2012, fig. 14); and a fragment of single-beveled point from Layer 8a recycled as a blunt tool (Fig. 4 #7; pressure flaker? Pétillon and Chauvière, 2017). The bevel on this point has oblique striations and its general characteristics (dimensions and shape) are reminiscent of the single-beveled points of the “Placard” type (Breuil, 1937; Borao, 2011), considered specific to the Badegoulian, and also present in the Pégourié assemblage, notably linked to “pseudo-excised” artifacts (see below and Séronie-Vivien, 1995: 267, figure 8.56 #2).
- one decorated fragment of antler point, interpreted as the proximal part of a point with massive base (1.8a; Fig. 4 #4): the series of alternate short, curved lines is evocative of similar decoration on some implements from Placard and Lascaux (Breuil, 1937; Leroi-Gourhan and Allain, 1979).
- one scapula with a possible figurative engraving (Séronie-Vivien, 1995:252, fig. 8.44 #7): given the scarcity of evidence for portable art in Badegoulian contexts, it was considered necessary to confirm the Badegoulian age of this engraving.
- one proximal-mesial fragment of a striated single-beveled antler point with pseudo-excised decoration from Layer 8c (Fig. 5a). This decoration is partly obliterated by a longitudinal break probably related to the use of the object as a projectile point (“splitting” fracture due to a misplaced shot: Pétillon et al., 2016: 51). The remaining part, however, presents all the criteria of the classic pseudo-excision motif and technique (Utrilla, 1986; Duarte *et al.*, 2013 ; see above: section 2): the three parallel, undulating lines are clearly reminiscent of those on the pieces from Laugerie-Haute Est and Aitzbitarte IV (Fig. 1b); as can be seen from the detailed views (Fig. 5b), each of these lines is composed of a juxtaposition of short, oblique, deeply carved strokes and ends with a twisted, continuous slender striation that accentuates the wave-like pattern of the motif.

Besides this latter object, a second artifact was considered by Séronie-Vivien as pertaining to the “pseudo-excision” group: a complete, single-beveled antler point from Layer 9 with an oval cross-section and several lines carved on the upper side (Fig. 5c). However, a careful examination shows that these lines are made of continuous, longitudinal strokes and that the “barbed” aspect of some of these lines (with a series of small, systematically right-hand “spurs”) might be due to the repeated, uncontrolled slipping of the flint tool out of the main carving track. Given the uncertain attribution of this decoration to the “pseudo-excision” group in the strict sense of the term, this artifact was excluded from the dating program.

Finally, the 15th implement selected for radiocarbon dating, which was the only unworked piece, was a red deer (*C. elaphus*) molar tooth from Layer 8c. This species represents 5.5% of the fauna from Layer 8 and is the dominant ungulate species in the overlying Layer 7 (80.5%; Séronie-Vivien, 1995: 74). It was selected because of its uncommon occurrence in LGM faunal

assemblages (including Badegoulian ones), which raised the suspicion that it could actually be of a younger, Late Glacial age (admixture with the Azilian?). This broad selection, made up of fifteen samples from Layer 8a to Layer 9, has allowed us to (1) clarify the issue of the cultural homogeneity of the Pégourié assemblages, (2) define a robust radiometric framework for the Badegoulian component through the direct dating of the knapping technique and, on this basis, (3) discuss the Badegoulian attribution of some original typological elements and more especially of the “pseudo-excised” pieces.

3.4. Sampling methods details

Compared to faunal or charcoal samples, the direct ^{14}C dating of bone and antler artifacts raises significant problems due to their relative scarcity, their typological and/or technological importance and, on a broader level, their heritage status. These problems must be assessed on a case-by-case basis depending on the technical and morphometric features, conservation status and mass of each selected specimen. In order to save maximum information prior to any destructive operation, we designed a specific sampling strategy reducing, if not suppressing the impact of direct dating on these archaeological artifacts. After recording the morphometric and technological data and taking photos of all the dated pieces, each finished object (i.e., tool or hunting implement) was subject to a 3D photogrammetric recording (see details in the following section). Once these requisite steps had been taken, and apart from the half-round rod from l.8a and the fragmented single-beveled bone point from Layer 8b which were simply cut at one end (cutting a post-depositional fracture), the same series of operations was carried out: (1) selecting the best-preserved zone (i.e., good thickness of compact tissue, non-fissured zone in order to avoid the fragmentation of the object, absence of visible technical marks); (2) cleaning of the selected zone by abrasion of the outer layer of the object, which was potentially contaminated (tool used: wood drill with a 3 mm bit mounted on a mini drill); (3) removal of the material to date by successive micro-drilling in order to obtain several solid samples with a total mass varying between 350 and 590 mg depending on the pieces (tool used: micro-coring device made up of a 7 mm diameter hollow bit with a jagged end, mounted on a rotary tool with a flexible shaft). The drill and drill bits were cleaned by ultrasound immersion between each series of samples in order to avoid any possible inter-sample pollution. The samples obtained in this way were stored in sterile Eppendorf tubes. Finally, all the samples (i.e., sawed or micro-drilled ones from finished objects or faunal remains) were submitted to the Lyon/Saclay (ARTEMIS program: Billard, 2008) and Oxford laboratories; ultrafiltration was applied in each case.

3.5. 3D photogrammetric recording of dated pieces: technical details

Several techniques are available for 3D digitizing small objects. The team at the Royal Belgian Institute of Natural Sciences have carried out experiments on these methods, in order to assess their qualitative and quantitative advantages and drawbacks (Mathys et al., 2014, 2013). Hence, among the diverse options (i.e., lasergrammetry, structured light scanning and CT scanning), photogrammetry was chosen. In this case, it provides the best ratio between quality (shape and texture), portability and price. However, as the only significant drawback, this method does not provide any recording of the internal shape as could be obtained with a CT scan. The system that was used was composed of two synchronised cameras (Nikon D5 and D810) mounted on a rigid arm, jointly linked to an automated turntable (development: Get in Situ Sàrl and C2L-APAR). It notably enabled a quick, automated and standardized acquisition and allowed the scale determination of each 3D virtual object to be accurately controlled. For the whole collection, the resolution of the raw picture was better than 0.3 mm on the object. The accuracy and resolution obtained for each 3D model was in the same order of magnitude. A specific

acquisition with a bellows was made for Peg 341 (Fig. 5b). The aim was to enhance the resolution of the 3D model in order to obtain more details about the shaping of the “pseudo-excise” pattern designed on its upper part. The magnification of the picture reaches 2X and the 3D results are twice as detailed. A curvature computation was calculated according to the algebraic point set surfaces (APSS) by Guennebaud and Gross (2007) and presented jointly with the hillshaded output. Light versions of each 3D models can be found on the *Sketchfab* website at the following address: <https://sketchfab.com/getinsitu/collections/pegourie>

4. Results

4.1. Deconstructing the Badegoulian cultural framework of Pégourié cave

Thirty-nine refitting units and six pairing units (linked to seven distinct refitting units) were established, including 128 artifacts in total (Table 5; N=107 if only the refitting units are considered). The refitting units comprise between two and seven artifacts per unit. Among them, 16 involve intra-layer refittings (including units linking one or more objects from the same subdivision—i.e., 1.8a, b, c, 1.9a, b—to another from the same layer but without a subdivision indication—1.8 or 1.9 undifferentiated), while the remaining 23 involve inter-layer and inter-subdivision connections (Fig. 7 and 8 #1-3). Six of the latter present variations between the artifact labeling and the database information (i.e., the same artifact number referring to different layers), introducing some doubts which are difficult, if not impossible, to address without the original field notes. However, we must highlight the fact that most of these contradictions concern layers in direct contact with each other (1.7/1.8a; 1.8c/1.9a; 1.9b/1.10) and may correspond to layer reattributions made by M.-R. Séronie-Vivien after the fieldwork. Excluding LR23, for which one of the three artifacts corresponds to “undifferentiated” Layer 8 (Table 5), 11 of the 17 certain inter-layer refittings link two distinct layers/subdivisions whereas the remaining five link three distinct layers/subdivisions (Fig. 6b). Most of the refitting units, whatever the number of artifacts concerned, link pieces from theoretically non-successive subdivisions, and the connected subdivisions are sometimes located at both extremities of the Badegoulian sequence. Indeed, several breakage refittings or debitage refittings link artifacts from Layers 9b and 8a, respectively attributed to the Lower and Upper Badegoulian according to Séronie-Vivien (i.e., LR15; LR39 or LR40; Fig. 8 #1-3). Several others show links between the Lower and Middle Badegoulian (i.e., LR9; LR10; LR12; etc.; Fig. 7b) or between the Middle and Upper Badegoulian (i.e., LR1; LR3; LR4 or LR8; Fig. 7a). Most of the inter-layer refittings connect two adjacent squares (N=15 of 26; 12 of these link only two different squares; note that these squares are 2 x 2 m large) or artifacts from the same square (N=8). But the fact remains that according to the database some of the inter-layer refittings show quite a large planimetric extension. This is the case of LR15, which includes artifacts from three distinct layers (1.8a; 1.8c and 1.9b) and five distinct squares (Fig. 8 #2). However, although it is difficult to interpret the exact meaning of inter-layer refitting without a 3D scatterplot analysis—since they could indicate (1) localized taphonomic issues and/or (2) inadequate definition of the archaeological units during the fieldwork—these initial results confirm the high permeability of each layer/subdivision. Thus, they show at the very least that the assemblages from Pégourié Cave can no longer be considered and used as an example of the diachronic evolution of Badegoulian traditions.

4.2. Highlighting the chronological and cultural heterogeneity of the “Badegoulian” unit

Once the three-stage cultural framework of the Pégourié’s Badegoulian unit had been seriously questioned through the identification of several wide-scale inter-layer refittings, the basic issue

was the question of its chronological and cultural heterogeneity. Given the apparent contradiction between (1) the very homogeneous previous radiometric data (see above and Table 4) and (2) the extensive evidence for possible chronocultural mixing within lithic and osseous industries so far interpreted as cultural originalities (see above: e.g., Solutrean-type shouldered points; Lussac-Angles antler point; etc.) (Séronie-Vivien, 2003, 2005), the results of the direct ^{14}C dating program were eagerly awaited.

Ten of the fifteen samples delivered an age, the five others failed due to a very low collagen yield (Table 6). Unfortunately, the two single-beveled bone points samples from Layer 9 and 8b (hypothetical Gravettian age; see above and Ducasse et al., 2017), the self-barbed antler point and decorated antler bipoint samples from Layer 8a (hypothetic Badegoulian age; e.g., Averbouh and Pétilion, 2011) and the GST waste from Layer 8a2 could not be dated. Despite these failures, the results obtained for the four waste products, the four finished objects, the engraved bone and the red deer tooth are indisputable, widely extending the previous chronological range of the Layer 8 and 9 occupations from 22.5 to 14 cal ka BP, far beyond the chronological limits of the Badegoulian. Indeed, while the dated antler flakes delivered Badegoulian ages as expected—defining at least two phases of occupation since the 2 measurements do not overlap with each other (Fig. 9)—, four age measurements clearly involve a Middle Magdalenian time range, and the last two fit within an Upper Magdalenian and/or an Early Azilian attribution. Therefore, in line with previous work (e.g., Pétilion and Ducasse, 2012), the groove-and-splinter technique waste from Layer 8 and 8b do not reflect a “Magdalenization” process during the Badegoulian since direct radiometric dating has demonstrated once again that they are evidence of mixing with a Magdalenian component. Together with the Lussac-Angles antler point from Layer 8a (Table 6: 15130 ± 70 BP; 18.6–18.1 cal ka BP), they can be clearly attributed to the early stages of the Middle Magdalenian (15600 ± 120 BP and 15780 ± 120 BP; 19.1–18.6 and 19.4–18.8 cal ka BP) as defined by Barshay-Szmidt et al. (2016). With a Magdalenian age of 14705 ± 75 BP (18.1–17.6 cal ka BP) the half-round rod from Layer 8a fits well with the transition phase between Early and Late Middle Magdalenian (Barshay-Szmidt et al., 2016: 86). The engraved bone from Layer 8b and the red deer tooth from Layer 8c have given similar ages of 12420 ± 50 BP and 12380 ± 60 BP (14.8–14.1 cal ka BP; Table 6) which remain difficult to interpret in that, according to Barshay-Szmidt et al. (2016), they can refer to both the Late Upper Magdalenian and Early Azilian occupations. Note that Séronie-Vivien mentioned the existence of mixing between the uppermost Badegoulian layer and the lowermost Azilian layer, notably demonstrated via the direct dating of a reindeer remain from Layer 7 (see above and Séronie-Vivien, 1995: 46). Some lithic elements from Layer 8a, such as possible Azilian point fragments, could also indicate mixing between these two units (Ducasse, 2010: 356; Séronie-Vivien et al., 1981: 256).

In summary, the new radiometric data strongly contradict the idea of a “relatively short occupancy period” (Séronie-Vivien, 1995: 46) supported by the previous ^{14}C dating and demonstrate the cultural heterogeneity of the so-called “Badegoulian” assemblages of Pégourié Cave. These results clearly show three quite distinct chronocultural phases (Fig. 9):

- the first one, consistent with a Badegoulian chronology (e.g., Ducasse et al., 2014), ranges from 22.5 to 21 cal ka BP;
- the second one, consistent with a Middle Magdalenian chronology (e.g., Barshay-Szmidt et al., 2016), ranges from 19.5 to 17.5 cal ka BP;
- the final one, consistent with an Upper Magdalenian (engraved bone?) and/or Early Azilian chronology, dates to around 14.5 cal ka BP.

In detail, the stratigraphic distribution of the dated pieces within each phase shows just how unreliable the classic archaeostratigraphic framework of Pégourié was (Fig. 9), thus confirming

the preliminary data obtained from the inter-layer refitting tests (see above): while Layer 8b includes artifacts attributable to each of the three chronological phases (in red), Layer 8c shows evidence of, at a minimum, not only a Badegoulian but also an Upper Magdalenian/Azilian chronology (in green). Finally, according to the typological and chronological data, Layer 8a seems to combine Badegoulian and Middle Magdalenian components (in purple). Moreover, significant chronological gaps are documented between each phase, theoretically corresponding to the Lower Magdalenian (21–19.5 cal ka BP) and the Late Middle Magdalenian/Early Upper Magdalenian (17.5–15 cal ka BP). It is also interesting to note that no ages older than the Badegoulian have been documented. It goes without saying, however, that we must be prudent in interpreting these gaps since (1) most of the samples were selected based on specific and suspected chronocultural features; (2) a broad ^{14}C dating program of specific faunal remains could complete the picture and, as we partly already know, (3) several specific typo-technological features unfortunately suggest broader mixing within the “Badegoulian” unit. Thus, apart from the Magdalenian (e.g., Fig. 8 #1?) and Solutrean lithic evidence (Fig. 8 #5-6), the ongoing comprehensive study has shown the existence of a possible Gravettian component, notably within the non-dated Layer 9a (Fig. 8 #7-8), in association with Badegoulian elements (Fig. 8 #4). This Gravettian evidence echoes the issue of the chronocultural attribution of the slender, single-beveled bone points from Layer 8b and 9-undifferentiated (for which a Late Gravettian age could be proposed: Baumann, 2014; Ducasse et al., 2017; Leroy-Prost, 1979) and reminds us that the age of 24200 ± 1100 BP (31–26.5 cal ka BP; Table 4) for the Middle Gravettian Layer 10 was actually obtained from a bulk bone sample from Layer 9b (see above).

4.3. Confirming the Badegoulian age of “pseudo-excise” technique at Pégourié

In this context of chronocultural mixing, it clearly appears that the Badegoulian age of the “pseudo-excise” technique at Pégourié was far from self-evident. While some Badegoulian-like typological features of the artifacts could be consistent with this hypothesis (i.e., single and striated beveled points), direct ^{14}C dating was the only way to conclude the debate. The age of 17960 ± 90 BP (22–21.5 cal ka BP) obtained for the specimen from Layer 8c fits in perfectly within the “local” Badegoulian framework—notably bounded by the two ages obtained from antler flakes which are highly-specific Badegoulian technical waste products (Allain et al., 1974; Pétilion and Averbouh, 2012; Rigaud, 2004)—as well as within the regional and extra-regional Badegoulian framework defined through recent AMS dating (Fig. 10). Since the chemical results given by the ORAU lab allow to consider this measurement as a highly reliable one, there are two possible interpretations: either the pseudo-excised point came from contemporaneous but different cultural groups (i.e. long-distance and “cross-cultural” exchange system), or it was plainly part of the traditional Badegoulian osseous equipment. While the first hypothesis cannot be demonstrated, we argue that in this context the most parsimonious assumption is to consider the result obtained at Pégourié as the first tangible argument confirming the Badegoulian age of the “pseudo-excise” technique used to carve the classic curvilinear decoration made of the three parallel, longitudinal lines. More precisely, as we can see from Figure 10, the pseudo-excise technique appeared during the latter part of the Late Badegoulian (i.e., *raclette*-yielding industries).

5. Discussion

The impact of the results presented in this paper can be measured and discussed at different thematic and geographical scales. Observation at the level of the site itself has led to: (1) a complete reconsideration of the so-called typo-technological originalities of the Badegoulian assemblages from Pégourié, some of which in fact involve chronocultural admixtures and (2) a

definitive rejection of the previous radiometric framework which was composed of irrelevant “averaged” ages. This result puts an end to the debate on the chronocultural attribution of the French “pseudo-excised” antler artifacts and, in doing so, confirms the existence of a specific Badegoulian graphic expression (indeed, although decorated osseous artifacts were already documented in the French Badegoulian, they corresponded to ubiquitous Upper Palaeolithic features; e.g., Le Guillou, 2012). But it also causes a domino effect which clearly reopens the debate on an LGM cultural geography in southwestern Europe.

5.1. What is left of the diachronic evolution and the original typo-technological features of the Badegoulian at Pégourié?

As already suggested (Ducasse, 2012, 2010; Pétilion and Ducasse, 2012), this study confirms the strong heterogeneity of these industries, which contain Magdalenian, Badegoulian, Solutrean, Gravettian and probably Azilian components irrespective of the stratigraphical order. Beside simple typo-technological observations, the prevalent inter-layer refittings and the results of the direct dating of specific osseous artifacts show that Pégourié can no longer be considered a reliable stratigraphy for the Badegoulian. In such circumstances, the diachronic evolution trend proposed by Séronie-Vivien, starting with an alleged “Lower” stage similar to Le Cuzoul de Vers (Layers 27 to 22: Clottes and Giraud, 1989; Ducasse, 2010) or Casserole rockshelters (NA6: Morala, 1993) and ending with an Upper Badegoulian announcing the advent of the Magdalenian traditions, must be rejected. Despite a long-term Badegoulian occupation between 22.5–21 cal ka BP, it remains impossible to distinguish several Badegoulian components corresponding to distinct stages. While bladelet production and backed (micro-)bladelets are now widely recognized in the Badegoulian (e.g., Bodu and Chehmana, 2008; Ducasse, 2012, 2010; Langlais et al., 2016; Sacchi, 2003), the definition of the “Upper” stage of Pégourié, marked by an increase in bladelet implements, must now be considered in the light of its mixture with Magdalenian components. Similarly, the presence of waste produced by groove-and-splinter technique can no longer be considered an evidence for an advanced Badegoulian stage showing a technical and cultural proximity with the Magdalenian traditions, since direct dating once again confirmed that this presence is the result of taphonomical issues (i.e., chronocultural admixtures: Pétilion and Ducasse, 2012). It is becoming equally difficult to argue for the Badegoulian production of Solutrean-type shouldered points as proposed by Séronie-Vivien (2003) and the hypothesis of unrecognized, discrete Solutrean occupations cannot be excluded (i.e., short-term hunting camps). In this context, no clear data allows the Badegoulian component to be linked to these objects, which we thus consider to be intrusive. Note that recently, Banks and colleagues interpreted this feature, together with the existence of “pseudo-excised” artifacts, as the expression of the “southern” nature of the Badegoulian of Pégourié (Banks et al., 2011; fitting well with the hypothesis of a concomitant development of the Final Solutrean in the Iberian Peninsula and Badegoulian in southwest France defended by some researchers; see above). According to Séronie-Vivien (2003), the Badegoulian unit also yielded some “Mediterranean-style” points (Demars and Laurent, 1989) which could equally fuel the question of non-Badegoulian southern influences. However, whereas this latter type of lithic implement is well documented regionally at Le Cuzoul de Vers in *raclette*-yielding industries (Clottes and Giraud, 1989b; Ducasse, 2010) raising at least the issue of the cultural relationship between the Badegoulian and Salpétrian (e.g. Bazile and Boccaccio, 2008; Bosselin and Djindjian, 1997), the Pégourié specimens are clearly misinterpreted fragments of backed bladelet or possible backed bladelet roughouts (Ducasse, ongoing). Thus, the high degree of chronocultural admixture in the Badegoulian unit together with the approximate original typo-technological reading of such artifacts lead us to reject these arguments, which are based on highly unreliable data.

5.2. Pégourié and the hidden traps of old-fashioned ^{14}C sampling strategy

These first elements show that the results of previous studies based on published data or direct observations without the required critical distance from the Séronie-Vivien chronocultural framework should be treated with caution. This is particularly striking in relation to the radiometric framework: our results show just how irrelevant the previous framework was and thus that it must be fully rejected. Indeed, it is only by coincidences that the apparently coherent time span for the Badegoulian occupations of Pégourié (see above: 22–19.5 cal ka BP) was congruent with other available Upper Badegoulian sequences dated by beta counting methods, such as Le Cuzoul de Vers (Clottes and Giraud, 1989), Laugerie-Haute Est (Delibrias and Evin, 1980) and Fritsch (Trotignon et al., 1984) rockshelters. At Pégourié, the sampling strategy, consisting in collecting bulk samples of bones from the bottom to the top of each layer, has created an illusion of chronological homogeneity by mixing artifacts potentially attributable to a large chronocultural time span (Fig. 10: ranging at least from the Badegoulian to the Upper Magdalenian/Early Azilian). The obtained average ages, even if compatible with a Badegoulian chronology, have consequently no archaeological meaning and obscure the high chronocultural admixture of the unit. This specific example raises the broader question of the use we make of radiometric data in the context of multi-stratified archaeological sites. Indeed, aside from the important issues of the method used (i.e., beta-counting *versus* AMS methods and their implications in terms of sampling strategies) and the pretreatment protocol (Higham et al., 2006), the Pégourié case is a further demonstration of how meticulously one must use published measurements: we should remove every set of radiometric data from our chronological models that comes from old and/or non-taphonomically-controlled archaeological contexts, regardless of any apparent consistency.

5.3. The domino effect: the human connections between southwest France and northwest Spain circa 22 cal ka BP

Nonetheless, the new radiometric framework for the Pégourié sequence, which is essentially based on directly-dated antler artifacts, has allowed to (1) stimulate debate on the typotechnological evolution of the Badegoulian osseous toolkit through a comparison with older industries (Pétillon and Chauvière, 2017) and (2) clearly establish, for the first time, the period during which “pseudo-excised” artifacts appeared in southwest France, corresponding, as already said, to the latter part of the Late Badegoulian (i.e., between 22 and 21.5 cal ka BP). While we shall not discuss here the former aspect, since a specific study is currently ongoing (Pétillon and Chauvière), the latter aspect must be discussed at an extra-regional scale of observation.

Considering the current debate about the end of the Solutrean traditions in the Iberian Peninsula (see above) and postulating the synchronous manufacturing for these artifacts (Fig. 1a), there are two possible conclusions to this latter result: either the distribution of the “pseudo-excised” decorations around 22 cal ka BP reflects symbolic links between the last Solutrean groups from the Vasco-Cantabrian area and the Late Badegoulian groups from the Aquitaine; or, as proposed by Utrilla (1986), Séronie-Vivien (2005), Sauvet et al. (2008) or Aura et al. (2012), it reflects the synchronous development of *raclette*-yielding Badegoulian traditions from Aquitaine to Asturias. According to recent AMS measurements (note that we consider only calibrated AMS measurements in this discussion), the first hypothesis could be supported by work carried out in the caves of Arlanpe (Basque Country; Rios-Garaizar et al., 2013) or Las Caldas (Asturias; Corchón Rodríguez et al., 2015; Corchón Rodríguez dir., 2017) where industries yielding Solutrean concave base points are documented until about 20.5 cal ka BP. However the time-range between 21.5 and 20 cal ka BP corresponds at other sites, such as Mirón Cave (Cantabria),

to Initial Magdalenian occupations (contemporary with, and possibly comparable to the French Lower Magdalenian: e.g., Langlais et al., 2015) while, in this specific site, the underlying industries with concave base points are not younger than 21.5 cal ka BP (Straus et al., 2011, 2013, 2014; Straus and González Morales, 2018). Thus, while we cannot exclude this hypothesis, it nevertheless remains very difficult to support since (1) the cultural attribution of the presumed contemporary sites on the north-west coast of Spain remains controversial: as it is, a single chronological range refers to two different cultural traditions inhabiting and exploiting the same territories (i.e., Final Solutrean and Initial Magdalenian), (2) several key sites show poorly explained contradictions between the ^{14}C measurements and the stratigraphic order, and (3) the hypothesis of chronocultural mixing is rarely tested as a possible explanatory factor of this synchronic variability and uncommon, original typo-technological combinations (Fontes, 2016). As is shown in this paper, such a critical approach (i.e., inter-layer refittings, direct ^{14}C dating of typo-technologically specific osseous artifacts and, if possible, 3D scatterplots of characteristic objects and dated samples) may lead to important changes in the baseline data, particularly but not exclusively in the case of old excavations.

Hence, given this latter issue and by contrasting the results presented here with several recent studies carried out in the French Pyrenees and Asturias, we believe that the second hypothesis (i.e., existence of Badegoulian-like traditions in Spain) should be seriously considered. Our proposition comes in four points:

1) *The geographical distribution of the classic curvilinear pseudo-excise decoration includes the area with industries yielding Upper Solutrean concave base points*

According to the geographical distribution of artifacts showing the classic curvilinear decoration consisting of three parallel, longitudinal lines (Fig. 1b), links between the Charente (Le Placard Cave, subject to direct observation to confirm the technique used), the Dordogne (Lauerie-Haute and Badegoule rockshelters), the Lot (Pégourié Cave) and the southern Basque Country (Aitzbitarte IV) can be proposed. As indicated above, the “pseudo-excise”-yielding industries at Aitzbitarte IV (Layer IV) were originally attributed to the Upper Solutrean (Barandiarán, 1963) with concave base points (Schmidt, 2015, p. 70). The great technical and morphological similarities between the “pseudo-excised” decoration from Aitzbitarte (Fig. 1b #6) and the specimens from the French Badegoulian (especially from Lauerie-Haute and Pégourié: Fig. 1b #1 and 2) together with the suggested presence of *raclettes* within the assemblages (Utrilla, 1989) could be considered as strong evidence of a Badegoulian-like component mixed with the Upper Solutrean one.

2) *(True) raclettes have a specific chronocultural significance*

Keeping in mind that the French Badegoulian cannot be captured in a single lithic tool, *raclettes* must at any rate be considered as a specific Late Badegoulian feature, not only from a typological but also from a technological perspective (Cretin, 2000; Ducasse, 2012, 2010; Fourloubey, 1996; Morala, 1993): *raclette* blanks are produced from a specific *schéma opératoire* and are transformed by a very characteristic abrupt retouch that gives them highly variable shapes. Cases of combinations of *raclettes* and other Solutrean or Magdalenian specific features derive from chronocultural admixtures (e.g., Le Piage Layer CE: Champagne and Espitalié, 1981, Bordes et al., 2006; Lauerie-Haute-Est: Bordes, 1958) or typo-technological misinterpretations (*raclettes* sometimes seem to be confused with simple retouched flakes or technical waste, giving a misleading impression of ubiquity). Recent work carried out at Les Harpons Layer D (Haute-Garonne), excavated by R. de Saint-Périer between 1912 and 1930 has shown, for instance, that the presence of several “typical *raclettes*” (Foucher, 2004: 91) within

an industry which has also yielded Upper Solutrean concave base points was only the tip of the iceberg: a comprehensive and interdisciplinary reassessment confirmed the existence of a clear lithic and osseous Badegoulian component at Les Harpons (and, by extension, in the French Pyrenees) typo-technologically comparable with the well-known and well-dated assemblages from the northern Aquitaine (Ducasse et al., 2017).

3) *The French Pyrenean industries yielding Solutrean concave base points are not younger than 23–22.5 cal ka BP*

Direct dating of Badegoulian-specific antler technical waste at Les Harpons D has allowed us to (1) reject the previous measurements obtained from a non-diagnostic faunal remain that was then supposed to be linked to the Upper Solutrean component (17670 ± 80 BP; Lyon 1187–GrA 15933; Foucher and San Juan, 2001) and (2) propose a *terminus ante quem* for the Pyrenean Upper Solutrean industries yielding concave base points (Table 8 and Fig. 11b; Ducasse et al., 2017). Indeed, the result obtained (18960 ± 110 BP; OxA-26878) is congruent with older Badegoulian measurements available from the Quercy (Le Cuzoul de Vers: Ducasse et al., 2014), the Lot-et-Garonne (Cassegros Cave; ongoing program: Ducasse and Le Tensorer coord.) and the Dordogne (Casserole Rockshelter; ongoing program: Lenoble and Detrain coord.), placing the end of the Upper Solutrean between 23.1 and 22.5 cal ka BP.

4) *A highly comparable chronocultural framework has recently been documented in Asturias*

Lastly, considering the strong typo-technological similarities and specificities of the Pyrenean and the Vasco-Cantabrian Upper Solutrean, which notably share the same lithic hunting tool kit (i.e., concave base points and short “hooked” shouldered points) and are connected through raw material circulation (i.e. Chalosse-type flint; e.g., Las Caldas: Corchón Rodríguez et al., 2013; Tarrío et al., 2013), one could assume that they share the same chronology and duration. Despite the counterexamples presented above, the archaeosequence of Llonín Cave (Fig. 1a; Asturias) fuels this hypothesis, showing a strong congruence with data from southwest France. The excavation carried out in the Galería sector by J. Fortea and M. de la Rasilla (Fortea Pérez et al., 1995) has highlighted an archaeological succession including an industry yielding Upper Solutrean concave base points (Level IV) and an industry yielding *raclettes* and “pseudo-excised” artifacts attributed to the Badegoulian (Level III; Rasilla et al., 2014; note, however, that the motif of three parallel, longitudinal lines is missing: Duarte et al., 2014). Beyond this however, the AMS radiometric framework fully echoes the French one (Fig. 11c): while the Upper Solutrean is not younger than 23 cal ka BP (Aura et al., 2012; reflecting the results obtained at Les Harpons D: see above), several unpublished ^{14}C measurements allow the Badegoulian-like occupations to be dated to around 22–21.5 cal ka BP (Rasilla et al., 2017), that is to say, in the same range as the directly dated “pseudo-excised” antler point from Pégourié Cave presented in this paper (Fig. 11a).

6. Conclusions

The results presented in this paper have allowed us to conclusively establish the link between “pseudo-excised” artifacts and *raclette*-yielding French Badegoulian industries and, in doing so, to reconsider the cultural link between French and Spanish “pseudo-excise”-yielding industries. Within the framework of the long-lasting debate of the existence of an Iberian Badegoulian (Bosselin and Djindjian, 2000, 1999; Straus and Clark, 2000), fueled by conflicting information (see above), we propose an archaeostratigraphic and radiometric correlation favoring the hypothesis of comparable and sub-contemporaneous cultural changes

from Asturias to southwest France (Fig. 11; regardless to the geographical origin and modalities of cultural dissemination). Of course, this model is open to discussion and further studies need to be carried out to (1) confirm and complement the data obtained at Les Harpons D regarding the Pyrenean Upper Solutrean and Badegoulian chronology and characteristics and, using the example of Pégourié, (2) discuss in greater depth the coherence of the French corpus of “pseudo-excised” artifacts, mostly known and defined from a bibliographic perspective. Parallel to the reassessment of each archaeological context, typo-technological analysis and direct dating, a specific focus should be made on the technological characteristics of each presumed “pseudo-excised” decoration. This work would provide greater credibility to a very specific and original Badegoulian feature, which is currently “blurred” because of the application of too broad and imprecise attribution criteria, which have rendered it a catch-all category (Duarte et al., 2014).

In any case, beyond the hypothesis proposed in this paper, this study illustrates the urgent need to take a critical look at the baseline data we use to build models, especially—but not exclusively—when dealing with old excavations and collections. The combination of inter-layer lithic refittings and direct dating of specific bone and antler artifacts has led us to completely reshape the archaeostratigraphical framework of Pégourié Cave which is regrettably often considered a key Badegoulian site (e.g., Djindjian, 2018: 347) despite warnings issued in previous works (Ducasse, 2010; Ducasse and Langlais, 2007). While we must be as prudent as possible when considering non-taphonomically-controlled and/or formerly-defined archaeostratigraphic sequences, this example equally shows how wary we must be of current—and highly popular—chronological modelling analyses based on large databases. Beside the issue of Bayesian modelling (e.g., Bayliss, 2015), these models often include old and non-AMS data (i.e., often corresponding to bulk bone samples leading to potential “averaged” measurements) which are generally lacking the context of precise samples and information regarding the sampling strategy. How many “Pégourié” type cases are still hidden in the Western European LGM key-site database, skewing our accepted models?

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	France	Cantabrian Spain	
		Model 1	Model 2
Cultural sequences	Solutrean: 25,5-23	Solutrean: 25,5-23	Solutrean: 25,5-20
	Badegoulian: 23-21,5	Badegoulian: 23-21,5	
	Lower Magdalenian: 21,5-19,5	Initial Magdalenian: 20-19	Initial Magdalenian: 20-19
	Early Middle Magdalenian: 19,5-18	Lower Magdalenian: 19-17	Lower Magdalenian: 19-17
References	<i>e.g. Renard, 2010; Renard, 2011; Ducasse, 2012; Ducasse et al., 2014; Barshay-Szmidt et al., 2016</i>	<i>e.g. Utrilla, 1981; Aura et al., 2012; Rasilla et al., 2014</i>	<i>e.g. Straus et al., 2013; Fontes, 2016; Corchón Rodríguez dir., 2017</i>

Table 1 - Synthetic chronocultural framework of the geographical area and time-span addressed in this paper.

	Town	Site type	Excavator	Layer	Number	Cultural attribution	¹⁴ C age (BP)	Calibrated age (BP)	Lab ref.	Material	Method	References
France												
<i>Pégourié</i>	Caniac-du-Causse (Lot)	Cave	M.-R. Séronie-Vivien (1967-1988)	8c & 9	2	Badegoulian	17490 ± 520 (8b) 17420 ± 390 (9a)	22442-19964 22084-20107	Ly-1394 Ly-1836	bulk bone sample	14C	Séronie-Vivien, 2005, 1995
<i>Laugerie-Haute Est</i>	Les Eyzies-de-Tayac (Dordogne)	Shelter	F. Bordes (1957-1959)	12	1	Badegoulian	between 17040 ± 440 and 18260 ± 360	21785-19570 22945-21187	Ly-973 Ly-972	bulk bone sample	14C	Bordes, 1958; Delibrias and Evin, 1980
<i>Badegoule</i>	Lardin-Saint-Lazare (Dordogne)	Shelter	A. Cheynier (1928-1939)	II	<i>unknown</i>	Badegoulian						Cheynier, 1939; Utrilla, 1990, 1986 Breuil, 1937; Chollot-Varagnac, 1980
<i>Le Placard</i>	Vilhonneur (Charente)	Cave	A. de Maret (1876-1890)	D-E / 4-5	<i>unknown</i>	Badegoulian/Lower Magdalenian						
Southern Basque Country												
<i>Aitzbitarte IV</i>	Rentería (Guipuzcoa)	Cave	J.-M. de Barandiarán (1960-1964)	base of Layer IV	1	Upper Solutrean/Archaic Magdalenian	17950 ± 100*	22030-21435	GrN-5993	bulk bone sample	14C	Altuna, 1972; Utrilla, 1990, 1986
Cantabria												
<i>Rascaño</i>	Miera	Cave	J. González-Echegaray and I. de Barandiarán (1974)	V	1	Archaic Magdalenian	16433 ± 131	20159-19513	BM-1455	bulk bone sample	14C	González-Echegaray and Barandiarán, 1981; Utrilla, 1990, 1986
Asturias												
<i>Llonín</i>	Peñamellera alta	Cave	J. Fortea Pérez and M. de la Rasilla (1984-1998)	III (Galería)	2	Badegoulian	circa 18000 BP			bone & charcoal	AMS	De la Rasilla et al., 2014; Duarte et al., 2014; Fortea Pérez et al., 1995
<i>Cueto de la Mina</i>	Posada de Llanes	Shelter	Conde de la Vega del Sella (1914-1915)	E	1	Upper Solutrean						Duarte et al., 2014

<i>Cova Rosa</i>	Ribadesella	Cave	F. Jordá and A. Gómez Fuentes (1975-1979)	6a or backdirt of clandestine excavation	1	<i>unknown</i>						Duarte et al., 2014; Utrilla, 1990, 1986
Spanish Levant**												
<i>Parpalló</i>	Gandía (Valencia)	Cave	L. Pericot (1922-1931)	<i>unspecified</i>	<i>unspecified</i>	Badegoulian	18510 ± 100 (Talud Layer 11)	22621-22095	OxA-22629	bone	AMS	Aura et al., 2012
<i>Volcán de Faro</i>	Cullera (Valencia)	Cave	J. Aparicio Pérez (1968-1971)	<i>unspecified</i>	<i>unspecified</i>	Badegoulian						Aura et al., 2012

Table 2 - Inventory of French and Spanish sites yielding decorated antler pieces produced using the “pseudo-excise” technique: stratigraphic position, number of specimens, current cultural attribution and radiometric data (*according to Utrilla, 1986, the link between this age and Layer IV remains unclear; **sites yielding “a technique that closely resembles the pseudo-excise”: Aura et al., 2012; Ly=Lyon, GrN=Groningen, BM=British Museum, OxA=Oxford accelerator). Calibration was carried out with the OxCal program (v4.3.2: Bronk Ramsey 2017) using the IntCal13 calibration curve (Reimer et al., 2013).

	Layers				
	9b	9a	8c	8b	8a
Cultural framework					
Séronie-Vivien, 2005	Lower Badegoulian		Middle Badegoulian		Upper Badegoulian
Séronie-Vivien, 1995	Lower Badegoulian		Late Badegoulian		Terminal Badegoulian
Bosselin and Djindjian, 1988**	Early Badegoulian		Late Badegoulian		
Hemingway, 1980*			Late Initial Magdalenian		

Table 3 - Cultural framework of the Badegoulian sequence of Pégourié cave. *framework not based on the entire collection since the excavation was ongoing (from Hemingway, 1980); **based on published data.

Layer	References	Material	Nature of sample	Mass (mg)	¹⁴ C age (BP)	Calibrated age (BP)	Lab ref.
8a2	.	Reindeer bone	Bulk sample	800	16,890 ± 300	21,171-19632	Ly-5257
8b	.	Bone	Bulk sample	400	17,490 ± 520	22,442-19,964	Ly-1394
8(a or b)*	.	Reindeer bone	Bulk sample	800	17,320 ± 420	22,055-19,940	Ly-1834
9a	n°642	Bone	Bulk sample	400	17,420 ± 390	22,084-20,107	Ly-1836
7 - disturbed	.	Reindeer bone	Bulk sample	500	16,090 ± 320	20,206-18,742	Ly-5258
10**	.	Bone	Bulk sample	750	24,200 ± 1100	30,915-26,520	Ly-1835

Table 4 - Beta-counting radiocarbon dates for the Badegoulian layers of Pégourié (from Séronie-Vivien, 1995).

*a doubt arises regarding the exact origin of the dated sample, since the same lab code refers to different information depending on the source used (Séronie-Vivien, 1995; Séronie-Vivien et al., 1981); **according to Séronie-Vivien et al., 1981, the dated sample initially came from Layer 9b and was reassigned to Layer 10, given the older ¹⁴C age. Calibration was carried out with the OxCal program (v4.3.2: Bronk Ramsey, 2017) using the IntCal13 calibration curve (Reimer et al., 2013).

Layers ►	2/9a	7/8a	8	8a	8a2	8a2/8b	8b	8b/8c	8c	8c/9a	9	9a	9b	9b/10	Total
LR01							1		1						2
LR02							2								2
LR03					1	1	1		4						7
LR04							1		1						2
LR05							2		3	1					6
LR06									2						2
LR08					1				1						2
LR09									2			2	2		6
LR10												1	1		2
LR11													6		6
LR12							1						3		4
LR13									3						3
LR14					2										2
LR15					1				1				3		5
LR16				1									1		2
LR17													2		2
LR18											1			1	2
LR19							2		1			1			4
LR20									2						2
LR21									1				1		2
LR22									2						2
LR23					1		1		1						3
LR24													4		4
LR25													2		2
LR26													1	1	2
LR27					1										2
LR28					1				1						2
LR29							1						1		2
LR30					1				1						2

LR31							1	1				1		3	
LR32										1		1		2	
LR33											2			2	
LR34												2		2	
LR35												2		2	
<i>LR36</i>								<i>1</i>	<i>1</i>					2	
LR37							2							2	
<i>LR38</i>	<i>1</i>											<i>1</i>		2	
LR39						1							1	2	
LR40						1							1	2	
Subtotal	1	1	3	5	4	1	15	1	29	1	2	7	35	2	107
P1 (LR5 and 6)					1		2		2	1		1		7	
P2 (LR12)													2	2	
P3 (LR3)							3		1					4	
P4 (LR2)				1			2		2				1	6	
P5 (LR15)													1	1	
P7 (LR11)									1					1	
Total	1	1	4	5	5	1	22	1	35	2	2	8	39	2	128

Table 5 - Stratigraphic distribution of the 2015/2016 conjoining units (LR: lithic refitting; P: pairing; italicized text: inter-layer refitting showing some uncertainties due to differences in information between the field database and the artifact labeling).

Layer	References	Material	Nature of sample	¹⁴ C age (BP)	Calibrated age (BP)	Mass (mg)	Yield	%Yield	Excess	%C	δ ¹³ C	δ ¹⁵ N	C:N	Lab ref.
8b	Peg 257 c8b K5 3764	Antler	Flake	17,680 ± 150	21,821-20,961	640	24,3	3,8	.	.	.	.	3,3	Lyon 13121 (SacA 45471)
8c	Peg 283 c8c K6 3475	Antler	Flake	18,440 ± 170	22,651-21,872	660	25,5	3,8	.	.	.	.	3,3	Lyon 13122 (SacA 45472)
8b	Peg 162 c8b K5 2287	Antler	Splinter with edges of grooves (GST)	15,600 ± 120	19,137-18,608	430	23,7	5,5	.	.	.	.	3,3	Lyon 13123 (SacA 45473)
8	Peg c8 (no coordinates)	Antler	GST manufacturing waste	15,780 ± 120	19,381-18,784	660	15,3	2,3	.	.	.	.	not measured due to low yield after ultrafiltration	Lyon 13124 (SacA 45474)
8a2	Peg c8 (no coordinates)	Bone	Splinter with edges of grooves (GST)	Failed due to a very low yield	.	350	.	.	.	.	.	.	.	.
8c	Peg 341 K6 4312	Antler	Decorated single beveled point using the "pseuso-excise" technique	17,960 ± 90	22,019-21,469	440*	37,57	8,5	32,47	44,1	-18,8	3,4	3,1	OxA-35268
8a	Peg 986 J5 7103	Antler	Decorated bipoint	Failed due to a high CN of 3.6	.	490	.	.	.	.	.	.	3,6	.
8a	Peg 395 K7 6070	Antler	Recycled single- beveled point	18,310 ± 90	22,404-21,911	490*	21,25	4,3	16,25	44,4	-19,5	3,8	3,2	OxA-35269
8a	Peg 1242 M6	Antler	Self-barbed point	Failed due to a high CN of 3.5	.	350	.	.	.	.	.	.	3,5	.
8a	Peg 1026 J6 6073	Antler	Half-round rod	14,705 ± 75	18,104-17,666	560*	36,47	6,5	31,53	44,7	-19,5	4	3,2	OxA-35270
8a	Peg 3496 J6 14253	Antler	Lussac-Angles point	15,130 ± 70	18,591-18,166	430*	11,99	2,8	7,05	44,6	-19,1	4,7	3,1	OxA-35271
8b	Peg 3058 M6 13491	Bone	Single-beveled point	Failed due to a very low yield	.	590	.	.	.	.	.	.	.	.

9	Peg 514 K5 4863	Bone	Single-beveled point	Failed due to a very low yield	.	490	.	.	.	.	.	.	.	.
8b	Peg 1229 L7 9915	Bone	Engraved bone (portabe art)	12,420 ± 50	14,877-14,183	1080	97,5	9	.	.	.	.	3,2	Lyon 14001 (SacA 49554)
8c	Peg 460 L5	Tooth	<i>Cervus elaphus</i>	12,380 ± 60	14,805-14,123	1230	39,1	3,2	.	.	.	.	3,2	Lyon 14002 (SacA 49555)

Table 6 - Direct AMS dating of Pégourié osseous industry, specific faunal species and mobile art from Badegoulian Levels 8a to 8c (GST: groove-and-splinter technique);
*Lab mass measurement; calibration was carried out with the OxCal program (v4.3.2: Bronk Ramsey, 2017) using the IntCal13 calibration curve (Reimer et al., 2013).

Site	Excavators	Layer	References	Material	Nature of sample	¹⁴ C age (BP)	Calibrated age (BP)	Lab code	Bibliographic references
Cuzoul de Vers (Lot)	J. Clottes/J.-P. Giraud	27	CZ 86 D5 c.27 n°1192	Antler	Flake	19150 ± 110	23446-22757	Lyon-9078 (SacA-28345)	Ducassee et al., 2014
Cuzoul de Vers (Lot)	J. Clottes/J.-P. Giraud	18	square E5	Antler	Flake	19020 ± 110	23262-22555	OxA-11118 (Lyon-1681)	Ducassee et al., 2014
Cuzoul de Vers (Lot)	J. Clottes/J.-P. Giraud	22	CZ 86 I5 c.23a n°636	Antler	Blank splinter	18920 ± 110	23072-22489	Lyon-9077 (SacA-28344)	Ducassee et al., 2014
Cuzoul de Vers (Lot)	J. Clottes/J.-P. Giraud	21c	CZ 85 J4 c.21c n°1555	Antler	Flake	18860 ± 110	23003-22460	Lyon-9075 (SacA-28342)	Ducassee et al., 2014
Cuzoul de Vers (Lot)	J. Clottes/J.-P. Giraud	6	.	Bone	MSU diaphysis	18730 ± 110	22889-22383	OxA-10955 (Lyon-1674)	Oberlin and Valladas, 2012
Cuzoul de Vers (Lot)	J. Clottes/J.-P. Giraud	15	square B2 or B3	Bone	MSU diaphysis	18730 ± 100	22871-22391	OxA-10974 (Lyon-1676)	Oberlin and Valladas, 2012
Cuzoul de Vers (Lot)	J. Clottes/J.-P. Giraud	6c'	CZ 84 K4 c.6c' n°289	Antler	Base of shed antler with knapping stigmata	18620 ± 100	22757-22290	Lyon-9074 (SacA-28341)	Ducassee et al., 2014
Petit Cloup Barrat (Lot)	J.-C. Castel/F.-X. Chauvière	8a1	PCB05 U72 dec.25 n°608	Bone	MSU diaphysis	18595 ± 150	22876-22101	Lyon-3366 (Poz)	Chauvière et al. 2008
Cuzoul de Vers (Lot)	J. Clottes/J.-P. Giraud	19	CZ 83 D4 c.19 n°1772	Antler	Flake	18590 ± 110	22757-22216	Lyon-9076 (SacA-28343)	Ducassee et al., 2014
Oisy (Nièvre)	P. Bodu/G. Debout/L. Chehmana	4	Y31 niv.4L TAM	Tooth	.	18050 ± 120	22246-21538	Lyon-6399 (SacA-17476)	Debout et al., 2012
Oisy (Nièvre)	P. Bodu/G. Debout/L. Chehmana	3	B26.3 niv.3	Tooth	.	17810 ± 110	21885-21220	Lyon-6398 (SacA-17475)	Debout et al., 2012
Lassac (Aude)	D. Sacchi	locus 1	West section	Antler	Flake	17530 ± 100	21512-20868	Lyon-6418 (SacA-17495)	Pétillon and Ducassee, 2012
Lassac (Aude)	D. Sacchi	locus 1	M6 CX rel. 6	Antler	Flake	17400 ± 110	21357-20676	Lyon-6417 (SacA-17494)	Pétillon and Ducassee, 2012

Table 7 - Selection of AMS ¹⁴C dates covering the entire time span of the French Badegoulian, used in Figure 10 (MSU: medium-sized ungulate). Calibration was carried out with the OxCal program (v4.3.2: Bronk Ramsey, 2017) using the IntCal13 calibration curve (Reimer et al., 2013).

Site	Excavators	Layer	References	Material	Nature of sample	¹⁴ C age (BP)	Calibrated age (BP)	Lab code	Bibliographic references
Les Harpons	R. de Saint-Périer	D	HARP-3	Antler	Flake	18960 ± 110	23134-22507	OxA-26878	Ducasse et al., 2017
Les Harpons	R. de Saint-Périer	D	HARP-1	Antler	Base of shed antler showing sectioning stigmata	18450 ± 100	22524-21999	OxA-26876	Ducasse et al., 2017
Llonín	J. Fortea Pérez and M. de la Rasilla	IV	.	Bone	.	19300 ± 110	23563-22935	OxA-22700	Aura et al., 2012
Llonín	J. Fortea Pérez and M. de la Rasilla	IV	.	Bone	.	19330 ± 100	23576-22975	OxA-22699	Aura et al., 2012
Llonín	J. Fortea Pérez and M. de la Rasilla	IV	.	Bone	.	19480 ± 110	23792-23089	OxA-22698	Aura et al., 2012

Table 8 - Badegoulian AMS ¹⁴C dates from Les Harpons Layer D (from Ducasse et al., 2017) and Upper Solutrean dates from Llonín Layer VI (from Aura et al., 2012) used in Figure 11. Calibration was carried out with the OxCal program (v4.3.2: Bronk Ramsey, 2017) using the IntCal13 calibration curve (Reimer et al., 2013).

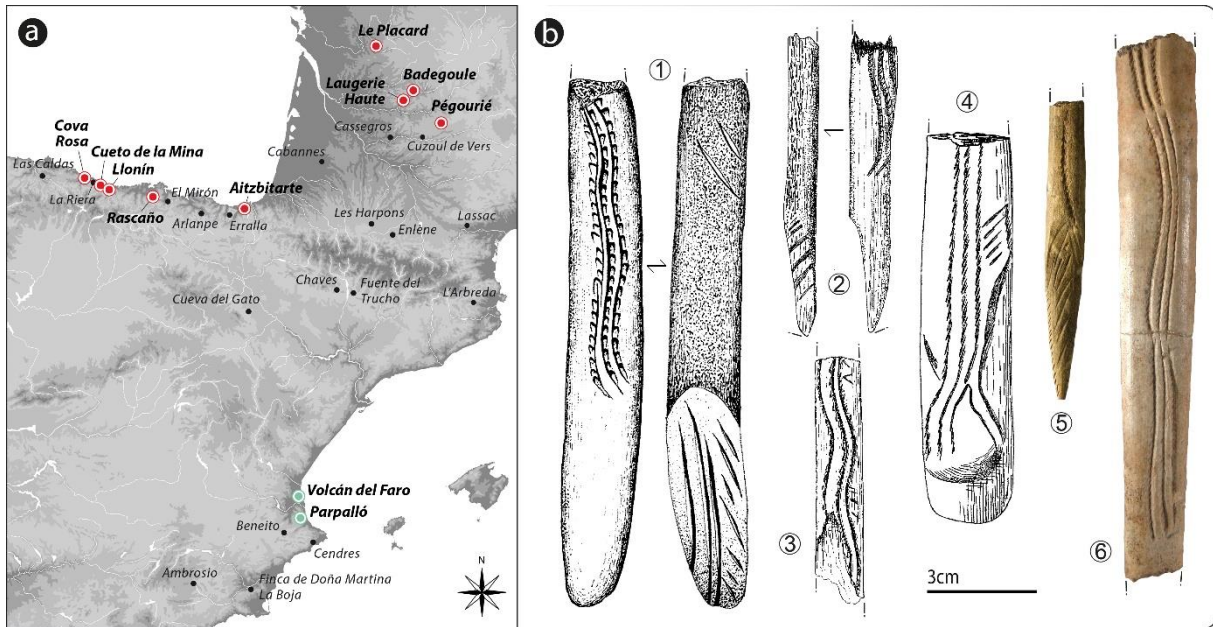


Figure 1 - A: map of the distribution of French and Spanish sites yielding decorated antler pieces using the “pseudo-excise” technique (in red: clearly attested, in green: possible) and main Upper/Final Solutrean, Badegoulian and Archaic Magdalenian sites (in black); B: examples of pieces showing the specific curvilinear design generally made of two or three parallel lines (1: Laugerie-Haute Est-Layer 12, from Utrilla, 1986; 2: Pégourié-Layer 8c, from Séronie-Vivien, 1995; 3 & 4: Le Placard-Layer D-E or 4-5, from Breuil, 1937 and Breuil and Saint-Périer, 1927; 5: Rascaño-Layer 5, from <http://www.spainisculture.com>; 6: Aitzbitarte IV, picture S. Ducasse).

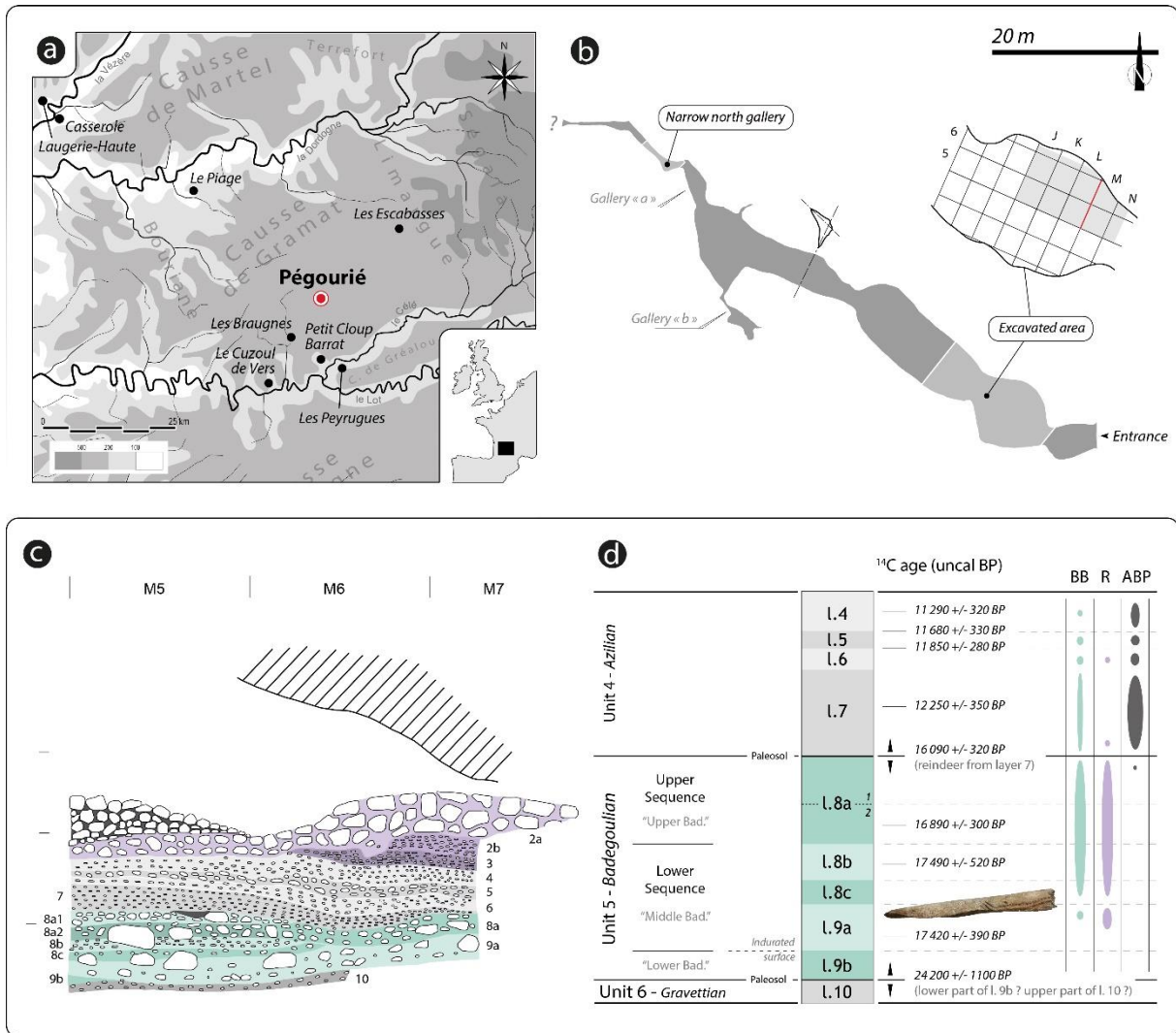


Figure 2 - A: location of Pégourié Cave and main Badegoulian sites in the Quercy region (base map © M. Jarry); B: ground plan of the cave and location of the main excavated area (from Séronie-Vivien, 1995, modified; in red: position of the stratigraphic cross-section illustrated in C); C: stratigraphic cross-section in M5–6–7 (from Séronie-Vivien 1995, modified); D: cultural framework from Séronie-Vivien, 2005; radiometric data (beta counting method) and stratigraphic distribution of backed bladelets (BB), raclettes (R) and Azilian backed points (ABP).



Figure 3 - Bone and antler elements selected for AMS dating; 1, 2 and 5: groove and splinter technique waste and products; 3 and 6: flakes (wastes) from the knapping technique; 4: red deer tooth; note the sampled zone on #1.



Figure 4 - Bone and antler points selected for AMS dating; 1 and 6: slender bone points with a single-beveled base; 2: antler self-barbed point; 3: single-beveled Lussac-Angles point; 4: proximal part of decorated and massive base point; 5: fragment of half-round rod; 7: recycled striated single-beveled point (pressure flaker?).

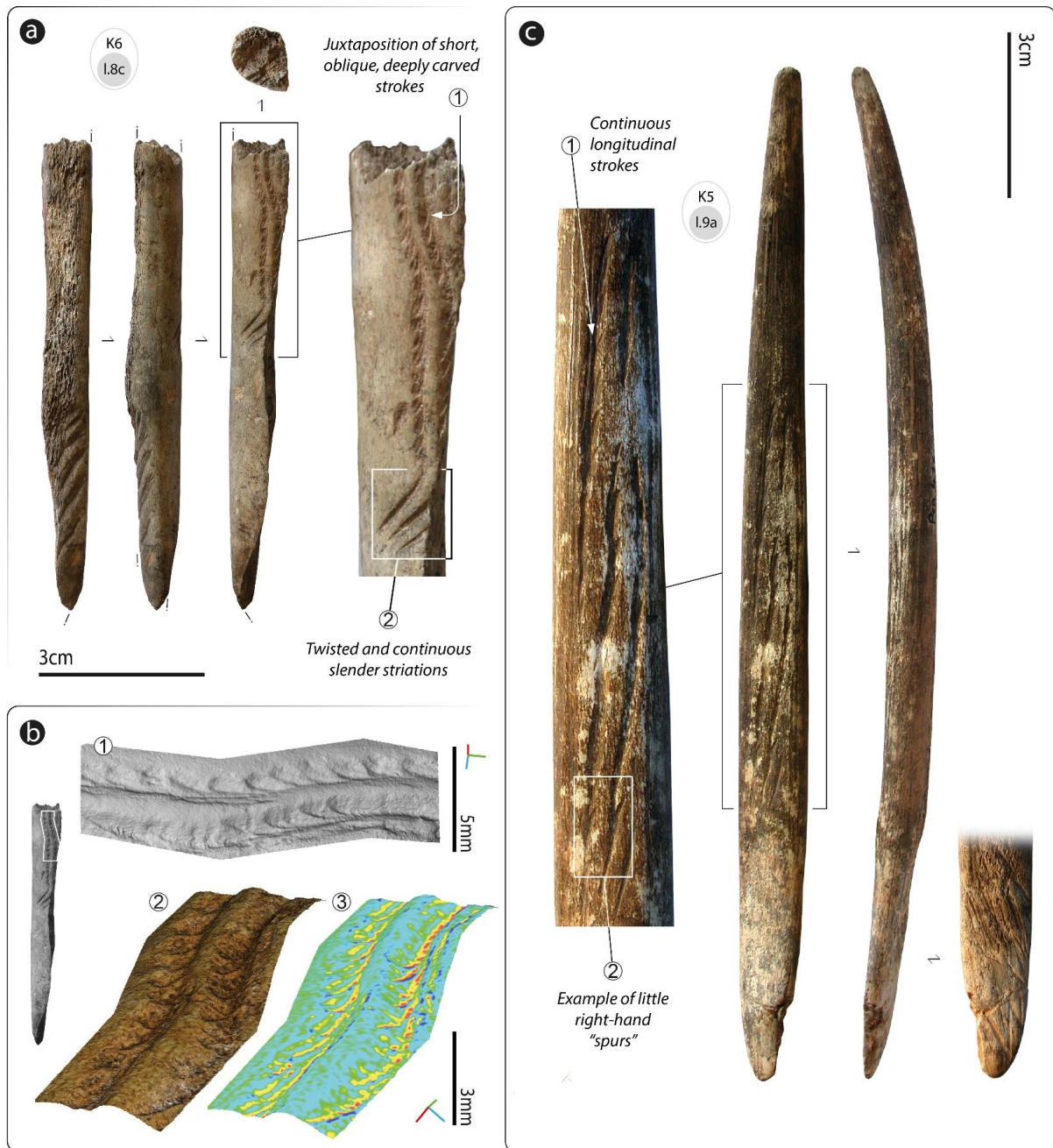


Figure 5 - A: Dated “pseudo-excised” point from Layer 8c (Peg 341); **B:** 3D zoom on the “pseudo-excision” pattern designed on Peg 341; 1: hillshaded output (clockwise); 2: textured model; 3: textured model according to the mean curvature (from blue to red : from convexity to concavity); **C:** “Pseudo-excised” point from Layer 9b, according to Séronie-Vivien, 1995, 2005; a careful examination shows the uncertain attribution of this decoration to the “pseudo-excision” group in the strict sense of the term (see comments in the text).

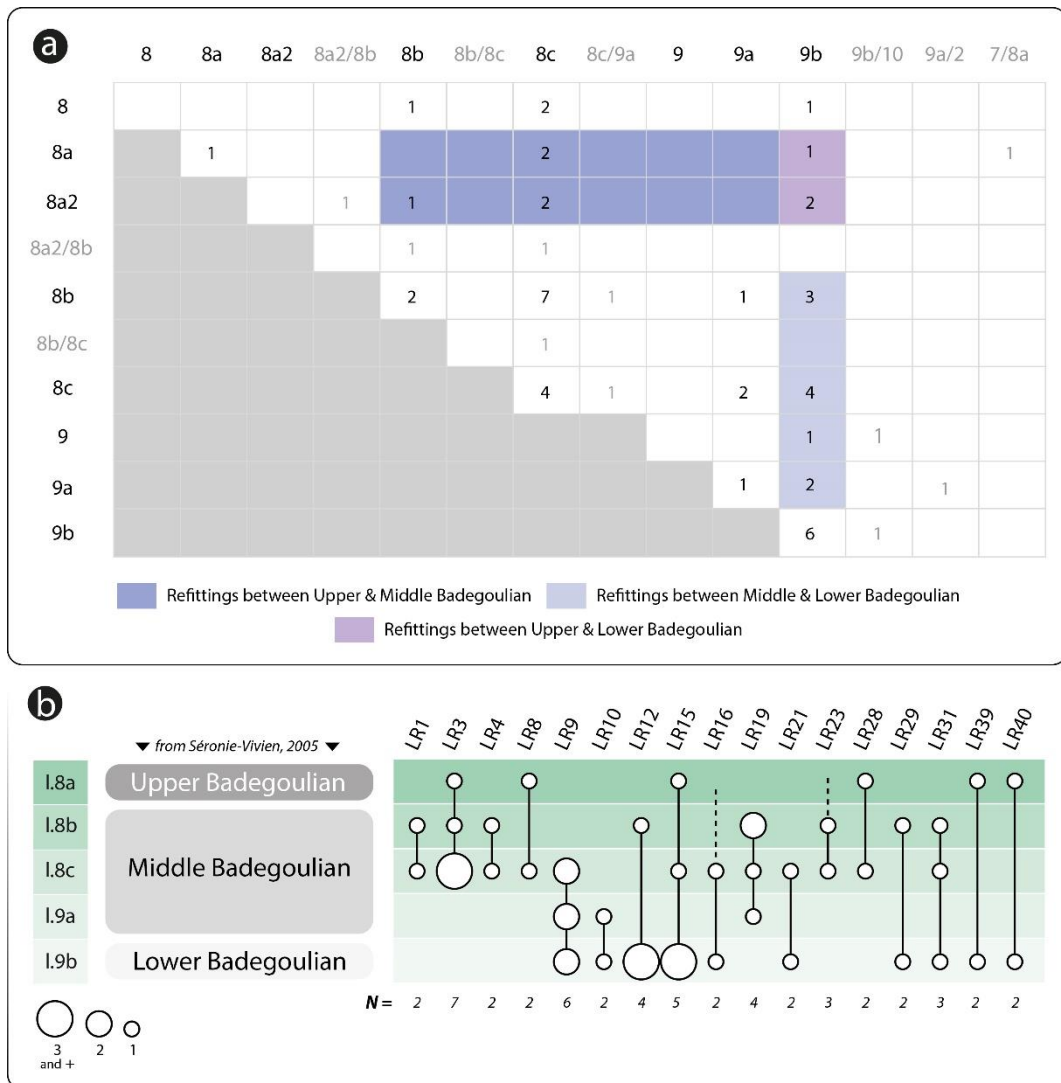


Figure 6 - A: Link counts according to the stratigraphic origin of the refitted artifacts; pairing excluded (one link = one direct or indirect connection within a refitting unit); **B:** stratigraphic distribution of the 2015/2016 inter-layer refittings, excluding uncertain ones (see the text for detailed explanations; LR: lithic refitting); cultural framework according to Séronie-Vivien, 2005.

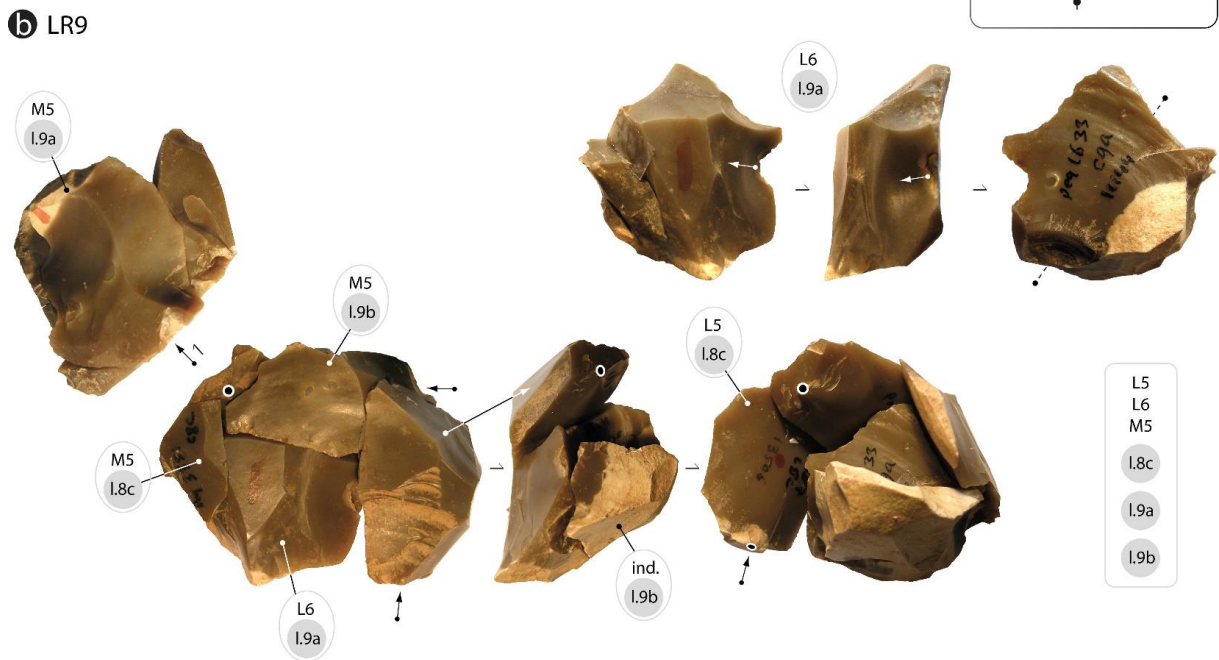
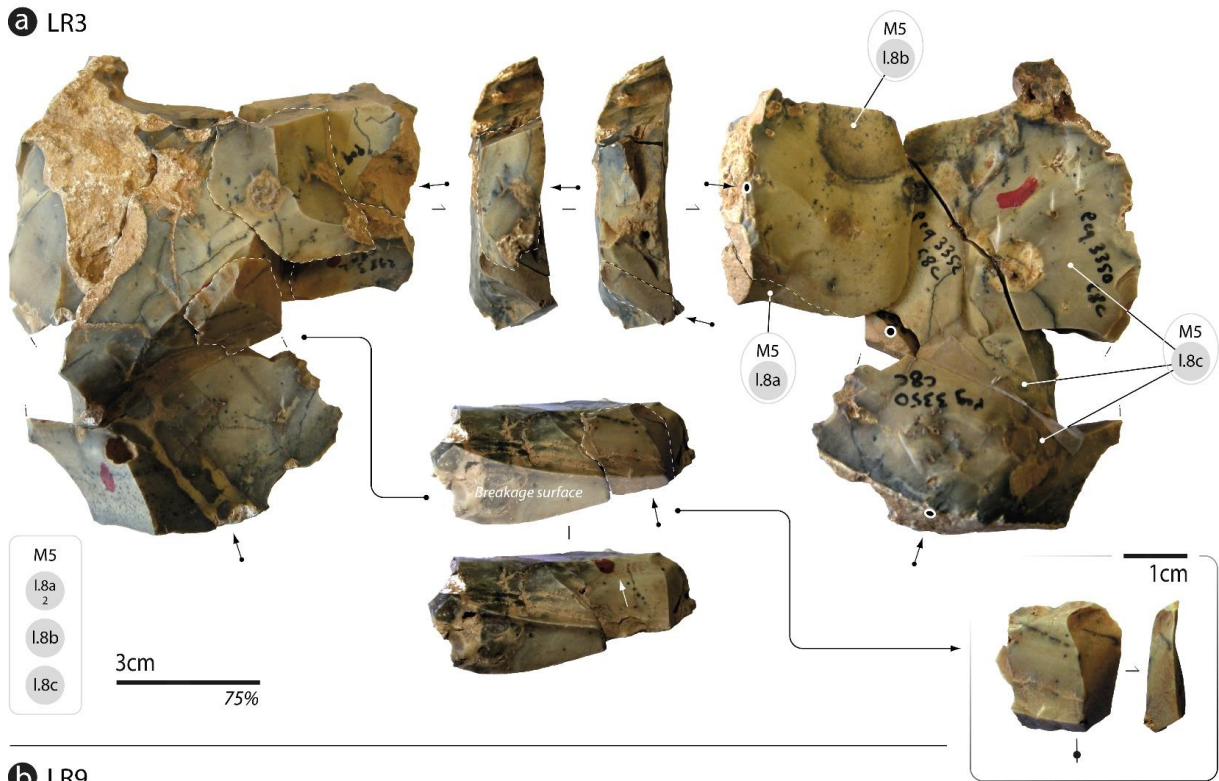


Figure 7 - A: Flake refitting between Layer 8a, 8b and 8c (i.e., from “Upper” to “Middle” Badegoulian); note that fragment “M5 l.8c” has been exploited as a flake core; **B1:** Refitting between Layer 8c, 9a, 9b (i.e., from “Middle” to “Lower” Badegoulian); **B2:** remaining core on fragment obtained by bipolar reduction.



Figure 8 - Examples of inter-layer refittings covering the entire Badegoulian sequence (i.e. from Layer 8a to Layer 9b; note the Magdalenian style of the burin on blade n°1) and evidence of mixing between Solutrean, Gravettian and Badegoulian components (4: example of a raclette from Layer 9a; 5-6: examples of Solutrean shouldered points from Layers 8a and 8b; 7: Noailles burin from Layer 9a; 8: rectilinear and narrow blade fitting with a Gravettian attribution from Layer 9a; note that the underlying Layer 10 yielded a Noaillian industry).

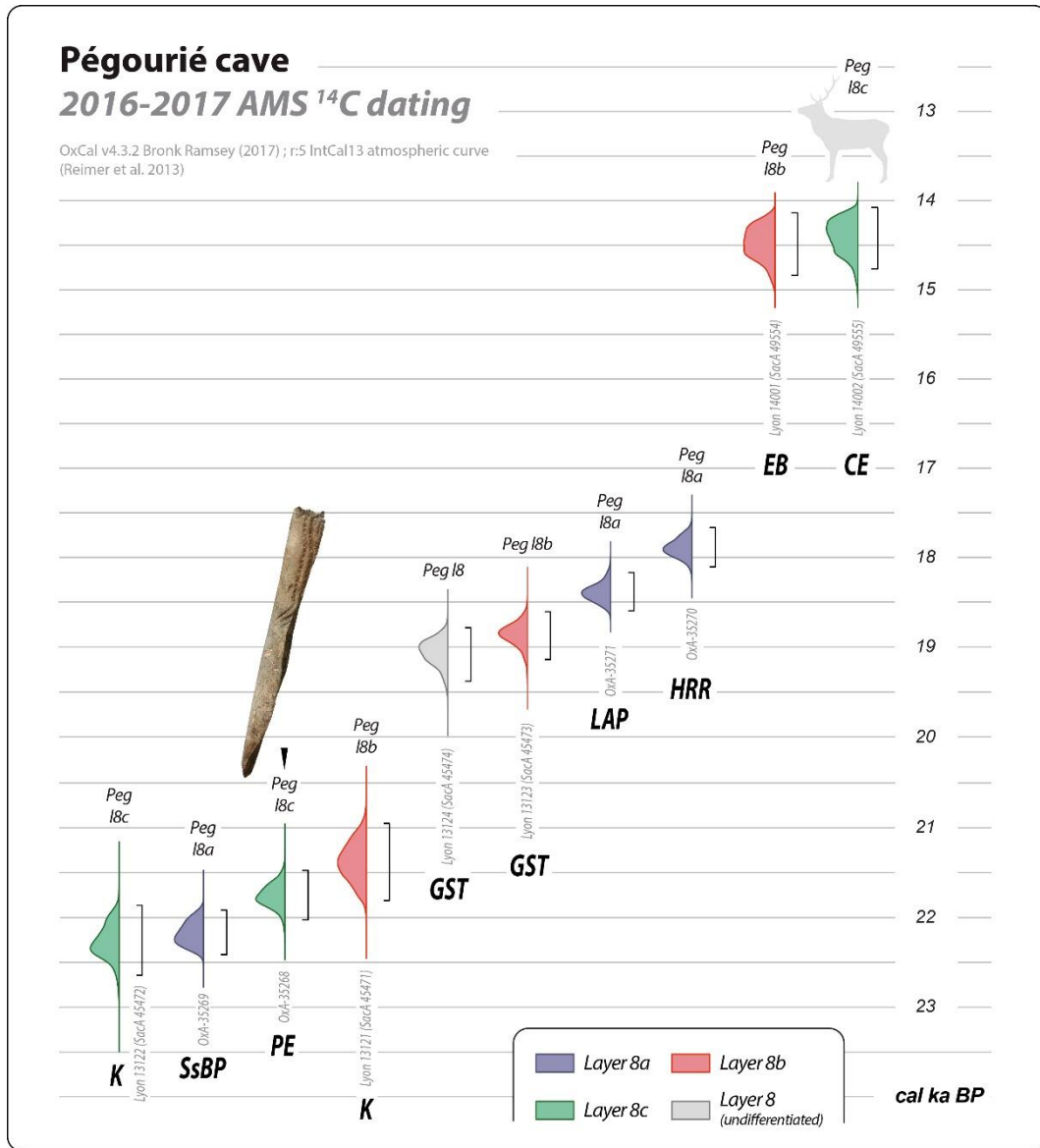


Figure 9 - Calibrated direct AMS radiocarbon dating of Pégourié osseous industry, specific faunal species and mobile art from Badegoulian Levels 8a to 8c; note the significant mismatch between the stratigraphic subdivisions and radiometric measurements (K: knapping technique; GST: groove-and-splinter technique; SsBP: single and striated beveled point; LAP: Lussac-Angles point; HRR: half-round rod; PE: pseudo-excised point; EB: engraved bone; CE: Cervus elaphus). Calibration was carried with the OxCal program (v4.3.2: Bronk Ramsey, 2017) using the IntCal13 calibration curve (Reimer et al., 2013).

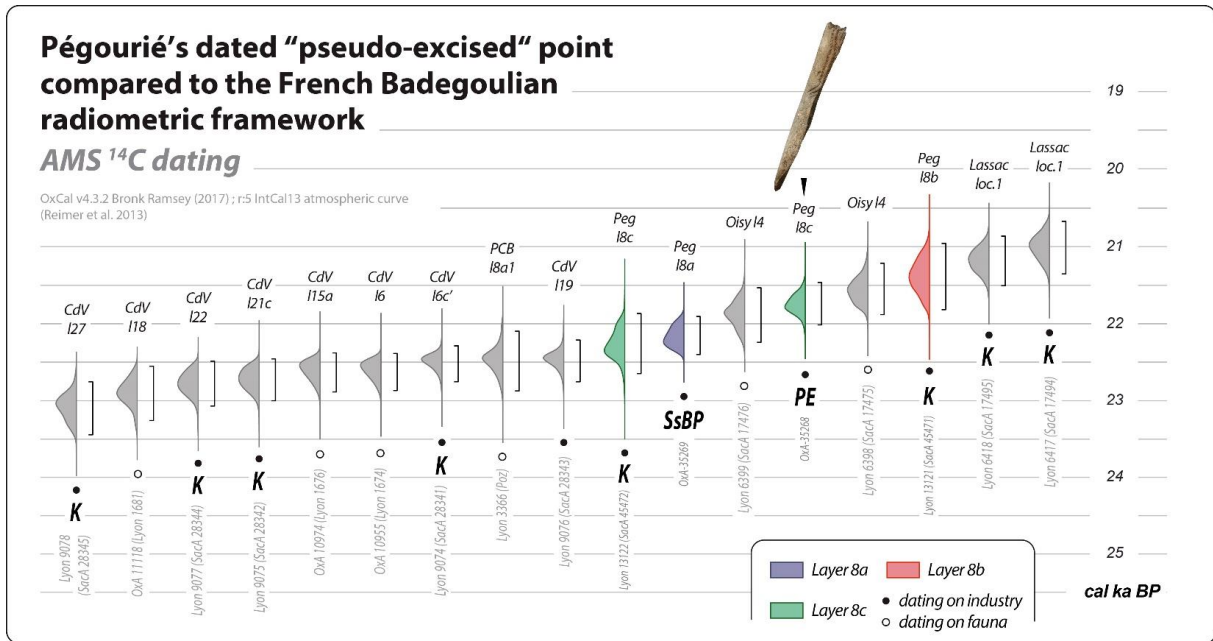


Figure 10 - Chrono-cultural position of Pégourié's dated "pseudo-excised" point. Comparison with a selection of AMS ¹⁴C dates covering the entire time span of the French Badegoulian (CdV: Cuzoul de Vers; PCB: Petit Cloup Barrat; Peg: Pégourié; K: knapping technique; SsBP: single and striated beveled point; PE: pseudo-excised point). Calibration carried out with the OxCal program (v4.3.2: Bronk Ramsey, 2017) using the IntCal13 calibration curve (Reimer et al., 2013).

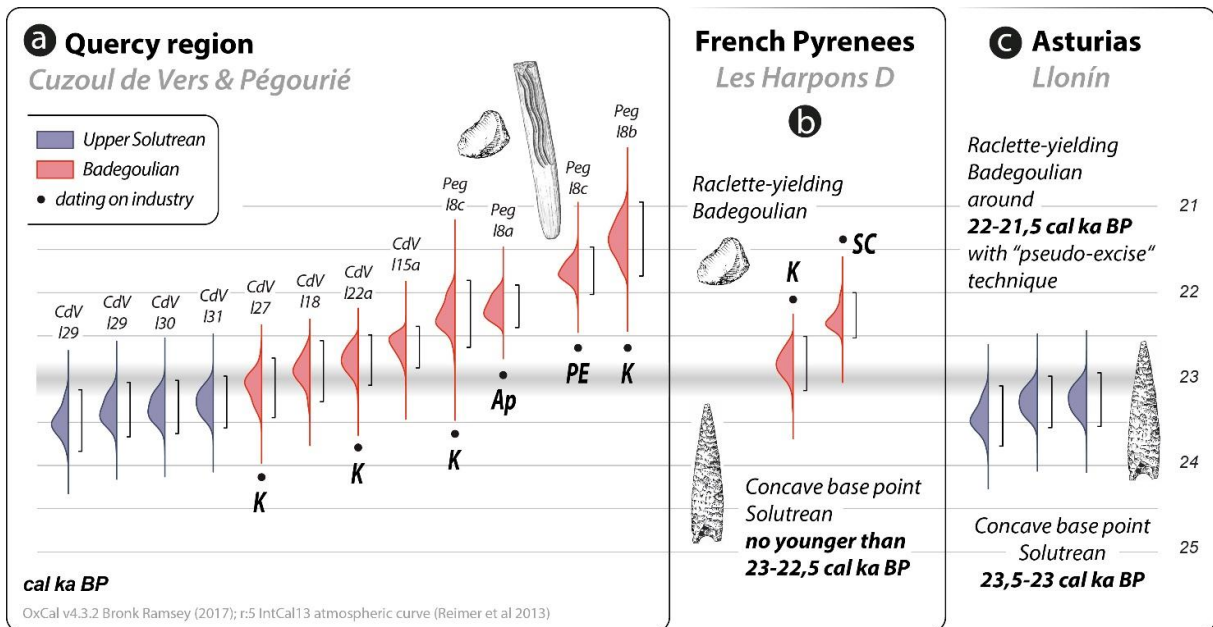


Figure 11 - Possible congruence of the archaeostratigraphic and radiometric frameworks from southwest France to Asturias between 24 and 21.5 cal ka BP (CdV: Cuzoul de Vers; Peg: Pégourié; K: knapping technique; Ap: antler point; PE: pseudo-excised point; SC: sectioning by chopping). Calibration carried out with the OxCal program (v4.3.2: Bronk Ramsey, 2017) using the IntCal13 calibration curve (Reimer et al., 2013).