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# TWENTY YEARS ON, A NEW DATE WITH LASCAUX

## REASSESSING THE CHRONOLOGY OF THE CAVE'S PALEOLITHIC OCCUPATIONS THROUGH NEW <sup>14</sup>C AMS DATING

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Aside from the stylistic debates and quarrels fueled by the studies of its painted and engraved walls, the Lascaux Cave stands out by its very weak and contradictory radiometric framework (Delluc and Delluc 2012). In addition to this, no comprehensive, interdisciplinary study of the rich archaeological assemblages has been conducted for almost forty years (Leroi-Gourhan and Allain 1979). The LASCO project (Langlais and Ducasse coord.) aims to fill this gap by proposing a global reassessment of the osseous and lithic artifacts, ornaments, ochres and lamps. As part of this work, a new effort has been made to clarify the Paleolithic chronology of the human activities documented by this stratified evidence. Five reindeer remains taken from the cave's main areas (Axial Gallery, Passageway, Nave, Shaft), some showing clear evidence of anthropic exploitation, were therefore selected to be dated in order to test (1) the chronological homogeneity of the occupations, as already suggested by a high typo-technological coherence and, if this was confirmed, (2) the hypothesis of an attribution to the Badegoulian-to-Magdalenian transition phase, as indicated by prior inter-site comparisons (Langlais 2010 ; Ducasse *et al.* 2011; DEX\_TER project: Ducasse and Langlais coord.). All the selected samples were sent to the Oxford Radiocarbon Accelerator Unit (ORAU) and run on a Mini Carbon DAting System (MICADAS) after an ultrafiltration pretreatment. While the sample from the Passageway area failed due to low collagen yield, the other four produced reliable and highly comparable measurements centered on a <sup>14</sup>C age of 17,600 uncal. BP (21.5-21 cal ka BP). These results confirm the two basic assumptions described above and contradict the diachronic framework defined by the 1948-2002 radiometric data, while restoring a certain degree of chronological consistency which fits well with the main typo-technological features of the lithic and osseous equipment (Allain 1979, Leroy-Prost 2008 and ongoing analysis). After a brief outline of the existing radiometric data and a detailed description of the sampling and dating strategy, the reliability of the results and their impact on our understanding of the cave's phase(s) of occupation(s) are discussed in depth. While the issue of the precise "cultural" attribution of the dated assemblages and the links between the latter and the parietal art are beyond the scope of this paper, these new data represent a first but significant step towards a global renewal of the highly controversial chronological framework of the Lascaux Cave.

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« Speed dating » à Lascaux. De nouveaux repères  $^{14}\text{C}$  pour les occupations paléolithiques de la grotte.

Au-delà des débats et querelles stylistiques nourris par l'étude de ses parois peintes et gravées, la grotte de Lascaux dispose aujourd'hui d'un cadre radiométrique lacunaire et, qui plus est, contradictoire (Delluc et Delluc 2012). En dehors des résultats obtenus à partir de charbons non directement associés au matériel ainsi que des nombreuses mesures  $^{14}\text{C}$  et U-Th visant à discuter de la chronologie de formation des gours du Passage (Genty *et al.* 2011), le niveau paléolithique n'a bénéficié jusqu'ici que de cinq datations, dont seulement deux ont été réalisées depuis l'étude monographique publiée en 1979 (Leroi-Gourhan et Evin 1979 ; Aujoulat *et al.* 1998). Le projet LAsCO (Langlais et Ducasse coord.) vise à combler cette lacune conjointement à une réévaluation globale des vestiges lithiques et osseux, des colorants, des parures et des lampes. Dans ce cadre, un nouveau programme de datation a été engagé afin de clarifier la chronologie des occupations humaines paléolithiques, occupations dont témoignent les nombreux vestiges découverts en stratigraphie. Ainsi, cinq restes de renne issus des principaux secteurs de la grotte (Diverticule axial, Passage, Nef, Puits) et montrant pour certains des indices évidents d'exploitation par l'Homme, ont été sélectionnés pour datation dans le but de tester (1) l'homogénéité chronologique des occupations, déjà suggérée par une forte cohérence typo-technologique, et, le cas échéant (2) l'hypothèse d'une attribution de ces assemblages à un intervalle temporel compatible avec la transition badegoulo-magdalénienne comme le laissent supposer certaines comparaisons inter-sites (Langlais 2010 ; Ducasse *et al.* 2011; DEX\_TER project: Ducasse and Langlais coord.). L'ensemble des échantillons a été confié au Radiocarbon Accelerator Unit d'Oxford (ORAU) qui, après un prétraitement par ultrafiltration, a réalisé les mesures via un Mlni Carbon Dating System (MICADAS). Si l'échantillon issu du Passage n'a malheureusement donné aucun résultat en raison d'un faible taux de collagène conservé, les quatre autres ossements ont permis l'obtention de mesures fiables et remarquablement comparables, globalement centrées autour de 17,600 BP non calibré (soit 21,5-21 cal ka BP). Tout en confirmant les hypothèses de départ, ces premiers résultats contredisent l'effet de diachronie engendré par les résultats obtenus entre 1948 et 2002 et rétablissent par là même un certain degré de cohérence qui semble s'accorder avec les principales caractéristiques typo-technologiques des industries lithiques et osseuses (Allain 1979 ; Leroy-Prost 2008 et analyses en cours). Après un bilan synthétique des données existantes et une description détaillée de la stratégie d'échantillonnage mise en œuvre, la présente contribution s'attache à discuter le plus objectivement possible la fiabilité de ces résultats et, ce faisant, de leur impact sur notre compréhension et caractérisation de la (ou des) phase(s) d'occupation de la grotte. Si la question de l'attribution « culturelle » des assemblages datés, mais aussi celle de leurs liens avec les dispositifs pariétaux dépassent le cadre de cet article, ces nouvelles données représentent une étape importante vers un renouvellement global du cadre chronologique, si controversé, de la grotte de Lascaux.

**MOTS-CLÉS** Grotte de Lascaux, datation  $^{14}\text{C}$ , renne, Badegoulien, Magdalénien.

## 1 | THE LASCAUX PARADOX: THE SHOEMAKER'S CHILDREN ALWAYS GO BAREFOOT

The story of the age and cultural attribution of the parietal art of Lascaux is a long-running one: the most famous Paleolithic painted cave is also one of the least understood in terms of chronology. This question is far from trivial, however, as locating Lascaux through time means placing it within a techno-socio-economic environment, as part of a wider dynamic anthropological system. From the very first Gravettian hypothesis proposed by H. Breuil or D. Peyrony (Breuil 1950 - p. 361 and raised again in Jaubert 2008 - p. 462-463) to the Solutrean attribution defended notably by N. Aujoulat (Aujoulat 2004) and the more "traditional" Magdalenian theory (Glory 1964 ; Allain 1979 ; Delluc and Delluc 2012), no consensus would appear to be emerging after nearly 80 years of scientific debate. The relevance of this simple question is open to debate, since the idealized homogeneous Lascaux could theoretically house *several* Lascaux as prehistorians have often noted (e.g. Leroi-Gourhan 1971 - p. 258 ; Aujoulat 2004 - p. 56-61). The elements used to argue in favor of these chronocultural assumptions are uneven and based mostly on (1) stylistic comparisons (sometimes compared with sites that are also poorly dated, leading to circular reasoning) and/or (2) archaeological remains discovered during the early surveys (i.e. the Ravidat and Laval collections), the construction of the ventilation system (1957-1958) and the Breuil, Blanc, Bourgon (1948-1949) and Glory (1960-1961) excavations in the Shaft.

Beside the main typo-technological features of the lithic and osseous industries variously considered as chronoculturally diagnostic (Allain 1979) or, on the contrary, ubiquitous (Aujoulat 2004 - p. 59), the archaeological record has frequently been used as datable material (i.e. charcoal : see below), since the black paintings of Lascaux remain undatable because of the use of manganese dioxide. Less well known is the fact that Lascaux went down in the history of radiometric dating by being one of the first Paleolithic sites to be dated by the inventor of the radiocarbon method himself (Arnold and Libby 1951). Thus, forty years before the Chauvet case (Chauvet *et al.* 1995 - p. 110-114), the very first charcoal  $^{14}\text{C}$  ages from Lascaux already upset the stylistic chronology, contradicting the "Pope of Paleolithic Prehistory" who did not accept the results (Breuil 1954) and ushering in the still-debated issue of the contemporaneity between the paintings and the archaeological assemblages (e.g. Nougier 1963 - p. 29). Despite this controversy, one could argue that conservation issues have dominated scientific research (e.g. Lacanette *et al.* 2007 ; Martin-Sanchez *et al.* 2014 ; Lacanette and Malaurent 2015 ; Xu *et al.* 2015), and in turn the so-called "Sistine Chapel of Prehistory" has been "sanctuarized" by prehistorians, not only physically but also scientifically. Aside from the important work conducted on the parietal art (e.g. Aujoulat 2004, 2002 ; Chalmin *et al.* 2004) and one-off research led in the framework of the recent publication of Glory's unfinished monograph (e.g. Leroy-Prost 2008 ; Vannoorenberghe 2008 ; see below), no comprehensive, interdisciplinary study of the rich archaeological assemblages has been done for years now. As the 2020s approach, new attribution arguments are therefore rare and only five discordant

radiocarbon dates are available to discuss the chronological issue of the Upper Paleolithic occupations of the cave. Only two of them have been obtained since the 1979 monograph (see below).

After being at the forefront of the emerging radiometric dating method, the Lascaux archaeological context has been under-explored for several years despite the thorny questions raised about its homogeneity, age and chronocultural attribution. The LASCO project<sup>1</sup> aims to fill this gap by proposing a global reassessment of the archaeological remains. As part of this, a new effort has been made to clarify the chronology of the Paleolithic human activities documented by this stratified evidence. Before the detailed presentation of the typo-technological and functional analyses of the lithic and osseous equipment, and setting aside the issue of their links with the parietal assemblages (beyond the scope of this paper), we present here the results of a new dating program, reopening the debate twenty years on, in the light of new dating practices and quite new comparison data.

## 2 | REVIEW OF THE EXISTING DATA: A SIXTY-YEAR STORY

Proposing a solid review of the available radiometric data from the Lascaux Cave (**tabl. 1** and **fig. 1**) amounts to an exegesis of different sources whose degree of precision is highly variable. As is often the case with radiometric data, it is crucial to return to the original sources, as several contradictions can appear from one paper to another. In this specific case, and besides the re-transcription errors, some of these contradictions can be explained by constant improvements to the dating method with “real-time” effect, as illustrated by the Groningen ages corrected by the laboratory in light of the “Suess-effect” (Suess 1955) (**table 1**: GrO lab code became GrN after correction). A. Glory’s papers and archives, the latter luckily published by G. and B. Delluc (Glory 2008), remain indispensable since the prehistorian conscientiously reported a lot of information regarding the nature, size (sometimes very precisely) and location of the dated samples. He also summed up the discussion with the laboratories when needed, allowing us to follow his global strategy step by step and discuss the results critically. On the contrary, apart from the recent dating effort focused on the calcite flowstone (see below and Genty *et al.* 2011), we will see that the publication of the direct AMS ages on osseous equipment (Aujoulat *et al.* 1998 *versus* Delluc and Delluc 2012 *versus* Valladas *et al.* 2013) suffers from imprecisions and contradictions that unfortunately limit our interpretations.

Whereas all the <sup>14</sup>C ages on charcoal, organic matter and antler artifacts are reported in table 1 with details of the major inconsistencies, the following sub-section proposes a comprehensive review of the four main dating programs carried-out since 1951.

### 2.1 | The initial dating effort by Glory: first tests on charcoal (1951-1962)

The very first Lascaux samples that were selected for dating by the <sup>14</sup>C method correspond to charcoals discovered during the 1948-1949 excavation of the Shaft by H. Breuil, S. Blanc and M. Bourgon. These charcoals were collected between several blocks that were interpreted as stone lamps by the excavators and were sent to W.F. Libby and J.R. Arnold from the Chicago laboratory. The result of 15,566 ± 900 BP was published in 1951 (lab code C 406: Arnold and Libby 1951 ; Glory 1964 ; indicated as 15,516 ± 900 BP in Leroi-Gourhan, Evin 1979) and gave a preliminary sense of the chronological framework of the cave’s Paleolithic occupations, contradicting the previous Gravettian hypothesis proposed by Breuil and Peyrony (Breuil 1950, 1952).

In 1957, A. Glory tasked the Groningen laboratory with dating three large batches of charcoal from the Passageway (two batches from G section: see **fig. 1**) and from the entrance scree cone (one batch collected in B section, layer 16). Since <sup>14</sup>C ages could not be obtained from any of these samples, Glory decided to submit two further samples of carbonaceous material from what he calls “the first [of three] carbonaceous layer” sealed by a calcite layer (the second one being situated, according to him, within the Paleolithic layer: Glory 1964). While the first sample (150 g) was taken between layers 16 and 17 of the entrance scree cone (**fig. 1**), the second one (50 g) was taken from the bottom of a gour in the Passageway area (G section) and more precisely “on the surface of the calcite” (Leroi-Gourhan and Evin 1979 – p. 83). The results provided evidence of a Mesolithic age component on top of the archaeological deposit, but without any associated industries (GrN 1182: 8,510 ± 100 BP or GrO 1182: 8,270 ± 100 BP for the layer 16 sample; GrN 1514: 8100 ± 75 BP or GrO 1514: 8,060 ± 75 BP for the Passage one). This evidence was confirmed a few years later (1962) with the age of 9,070 ± 90 BP (GrN 3184) obtained from a sample collected within layer 1 of the Passageway, corresponding to layer 17 of the entrance (Glory 1964).

The sampling of a few “big fragments [of charcoal], removed from the bottom of the archaeological layer” (i.e. layer 3; Glory 2008 - p. 91) enabled the Groningen laboratory to obtain a far more accurate measurement than the first one from the Shaft, in 1958. The age of 17,190 ± 135 BP (GrN 1632 or GrO 1632: 16,950 ± 135 BP; indicated as 17,190 ± 140 BP in Leroi-Gourhan and Evin 1979 - p. 83) thus confirmed the Magdalenian chronology of the cave’s Paleolithic occupations. Finally, in 1961, a charcoal sample collected by A. Glory during his excavation of the Shaft (R section, layer 3) was dated by the Saclay laboratory, giving an age of 16,100 ± 500 BP (Sa 102; indicated as 16,000 ± 500 BP in Leroi-Gourhan and Evin 1979).

### 2.2 | Additional data as part of the monograph study (1975)

Almost fifteen years after the A. Glory’s seminal effort, two further charcoal samples were submitted to radiometric measurement for the publication of the monograph. Thus, in 1975, charcoals collected by Glory at the foot of the “Upside-down Horse” and a sample taken by Arl. Leroi-Gourhan in the Terminal Passage, both located in the Axial

[1] Lascaux sols Contextualisation. Lascaux reconnu ? Contextualisation des sols paléolithiques de la cavité (Langlais and Ducasse coord.)

Area	Location	Excavators/Sampler	Date of sampling	Nature	Sample references	Lab	Method	Lab Code	Uncalibrated age (BP)	Calibrated age (BP, 2σ)	Comments	References
Shaft		H. Breuil, S. Blanc, M. Bourgon	1948	Charcoal		Chicago	Beta counting	C-406	15,566 ± 900	21,431-16,827	15,516 ± 900 in Leroi-Gourhan and Evin, 1979	Leroi-Gourhan and Evin, 1979; Glory, 1964, 2008
Entrance (screes cone)	Layer 16	A. Glory	1957	Charcoal (150 g.)		Groningen	Beta counting	GRN-1182	8,510 ± 100	9,736-9,271	Formerly GRN-1182: 8270 ± 100 (SUESS correction, 1962)	Glory, 1964, 2008
Passageway	G Section, undetermined Gour; "on the surface of the calcite"	A. Glory	1957	Charcoal (50 g.)		Groningen	Beta counting	GRN-1514	8,100 ± 75	9,380-8,728	Formerly GRN-1514: 8060 ± 75 (SUESS correction, 1962)	Glory, 1964, 2008
Passageway	Layer 1	A. Glory	1962	Charcoal		Groningen	Beta counting	GRN-3184	9,070 ± 90	10,497-9,920		Glory, 1964, 2008
Passageway	Layer 3; "from the bottom of the archaeological layer"	A. Glory	1958	Charcoal		Groningen	Beta counting	GRN-1632	17,190 ± 135	21,136-20,378	Formerly GRN-1632: 16,950 ± 135 (SUESS correction, 1962); 17,190 ± 140 in Leroi-Gourhan and Evin, 1979	Leroi-Gourhan and Evin, 1979; Glory, 1964, 2008
Shaft	R Section, Layer 3	A. Glory	1959	Charcoal		Saclay	Beta counting	Sa-102	16,100 ± 500	20,725-18,389	16,000 ± 500 in Leroi-Gourhan and Evin, 1979	Leroi-Gourhan and Evin, 1979; Glory, 1964, 2008
Axial Gallery	At the foot of the Upside-down Horse; "right above the Magdalenian layer"	A. Glory	1957-1959	Charcoal		Lyon	Beta counting	Ly-1196	7,510 ± 650	10,193-7,244	Submitted to dating in 1975 by Arl. Leroi-Gourhan	Leroi-Gourhan and Evin, 1979
Axial Gallery	Terminal Passage; "right above the Magdalenian layer"	Arl. Leroi-Gourhan	1975	Charcoal		Lyon	Beta counting	Ly-1197	8,660 ± 360	10,689-8,772		Leroi-Gourhan and Evin, 1979
Shaft		H. Breuil, S. Blanc, M. Bourgon	1948-1949	Antler	LSX 17*	Gif-sur-Yvette	AMS	GIFA-95582	18,600 ± 190	22,926-21,995	GIFA-96682 in Genty et al., 2011; Described as a "fragment of antler splinter" in Aujoulat et al., 1998 and "reindeer antler (H148)" in Valladas et al., 2013	Aujoulat et al., 1998
Shaft		H. Breuil, S. Blanc, M. Bourgon	1948-1949	Splinter, produce with the GST	LSX 15* or LSX 20*	Gif-sur-Yvette	AMS	GIFA-101110	18,930 ± 230	23,421-22,385	Described as a "fragment of longitudinal groove in Aujoulat et al., 1998, "Asagai bone" in Genty et al., 2011, "Fragments from a spear" or "spear bone" in Valladas et al., 2013	Genty et al., 2011; Delluc and Delluc, 2012; Valladas et al., 2013
Passageway	Gour C	D. Genty et al.	2011	Charcoal		Gif-sur-Yvette	AMS	GIFA-09457	6,454 ± 80	7,558-7,181	3,7 cm above the Gour C	Genty et al., 2011
Passageway	Gour C	D. Genty et al.	2011	Charcoal		Gif-sur-Yvette	AMS	GIFA-09458	6,464 ± 35	7,436-7,308	9,2 cm above the Gour C	Genty et al., 2011
Passageway	Gour C	D. Genty et al.	2011	Charcoal		Gif-sur-Yvette	AMS	GIFA-09455	6,508 ± 35	7,485-7,325	16.3 cm above the Gour C	Genty et al., 2011
Passageway	Gour C	D. Genty et al.	2011	Charcoal		Gif-sur-Yvette	AMS	GIFA-09456	6,639 ± 50	7,585-7,436	19 cm above the Gour C	Genty et al., 2011
Passageway	Gour C	D. Genty et al.	2011	Organic matter		Saclay	AMS	Saca-16006	7,003 ± 40	7,936-7,738	2,65 cm above the Gour C	Genty et al., 2011
Passageway	Gour C	D. Genty et al.	2011	Organic matter		Saclay	AMS	Saca-16007	7,670 ± 40	8,544-8,398	9,5 cm above the Gour C	Genty et al., 2011
Passageway	Gour C	D. Genty et al.	2011	Organic matter		Saclay	AMS	Saca-16008	7,005 ± 40	7,937-7,740	13,15 cm above the Gour C	Genty et al., 2011
Passageway	Gour C	D. Genty et al.	2011	Organic matter		Saclay	AMS	Saca-16009	6,963 ± 35	7,922-7,695	19 cm above the Gour C	Genty et al., 2011

— TABLEAU 1 —

Summary of <sup>14</sup>C ages obtained at Lascaux Cave from 1951 to 2011. \*: refers to the codification system used by C. Leroy-Prost (Leroy-Prost 2008). Calibration was carried out with the OxCal program (v4.3.2: Bronk Ramsey 2017) using the IntCal13 calibration curve (Reimer et al. 2013).

Récapitulatif de l'ensemble des mesures <sup>14</sup>C obtenues à Lascaux entre 1951 et 2011. \*: codification utilisée par C. Leroy-Prost (Leroy-Prost 2008).



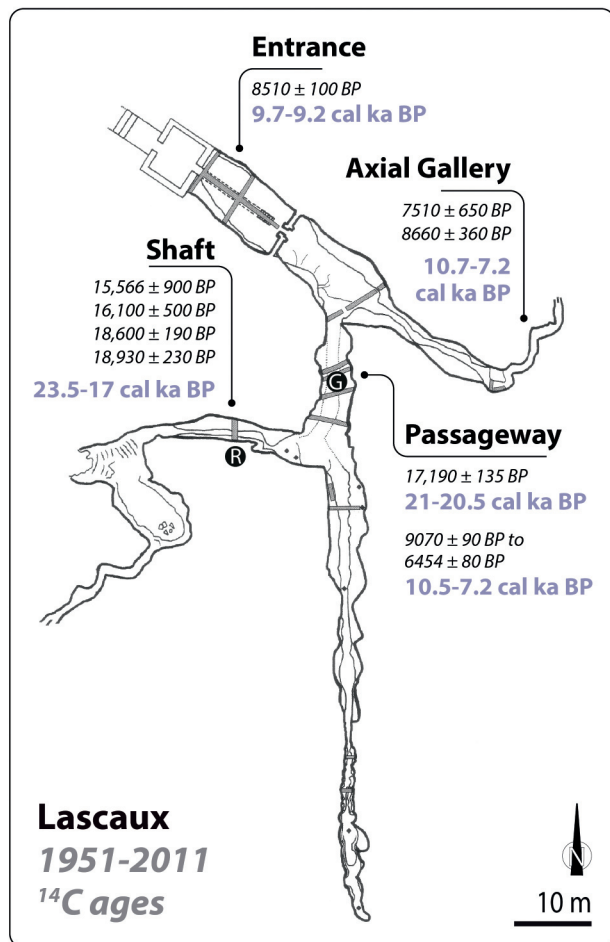


FIGURE 1

A sixty-year story: summary of the 1951-2011  $^{14}\text{C}$  ages from Lascaux (beta counting and AMS methods) and currently accepted calibrated chronological intervals for the main areas of the cave (see table 1; cave plan from Leroi-Gourhan and Allain 1979, figure 22, modified).

Soixante ans d'histoire : bilan des datations  $^{14}\text{C}$  obtenues à Lascaux entre 1951 et 2011 (comptage Beta et SMA) et intervalles chronologiques calibrés pour chacun des principaux secteurs de la grotte (cf. tableau 1 ; plan de la grotte d'après Leroi-Gourhan et Allain 1979, figure 22, modifié).

Gallery area (fig. 1), “right above the Magdalenian layer” (Leroi-Gourhan 1979 - p. 71), were sent to J. Evin to be dated at the CDRC Laboratory in Lyon. These samples gave two Mesolithic-like ages (Ly 1196:  $7,510 \pm 650$  BP for the “Upside-down Horse”; Ly 1197:  $8,660 \pm 360$  BP for the Terminal Passage) that were similar to previous ages obtained from different parts of the cave entrance (see above). Non-anthropogenic and/or unintentional transport of recent charcoals, from the entrance to several deeper areas of the cave (through flows and/or floods and/or carried under some visitors’ feet?) was thus confirmed. As suggested by Arl. Leroi-Gourhan: “water flows were undoubtedly strong in the Boreal times, during the formation of the calcite floor located at the cave entrance and in the Bull’s Chamber. This water carried charcoals into the Passageway and also probably to the Terminal Passage, within the clay layer located at the top of the Paleolithic layer » (*ibid.*).

### 2.3 | Twenty years later: changing method, changing samples (1998-2002)

By the end of the nineties, after a second gap of more than twenty years and despite over nearly 50 years of method developments and improvements (e.g. Evin and Oberlin 2000), the chronological framework of the most famous European cave still remained very sparse. At that time, only three ages could be related to the Paleolithic occupations and they had been obtained between 1951 and 1961. Alongside a comprehensive reassessment of the parietal

art (Aujoulat 2002, 2004), N. Aujoulat and colleagues therefore decided to perform new radiometric analyses (Aujoulat *et al.* 1998). Thanks to recent methodological improvements allowing dating of significantly smaller and better purified samples (e.g. Valladas *et al.* 2000 ; Tisnérat-Laborde *et al.* 2003), they chose two antler artifacts from the Breuil, Blanc and Bourgon excavation at the foot of the Shaft Scene (1948-1949) for direct dating. The first one (fig. 2A, no1) was described as “a fragment of antler splinter” (Aujoulat *et al.* 1998 - p. 320) and may correspond to LSX 17 in the Leroy-Prost inventory (Leroy-Prost 2008 - p. 128), showing edges of grooves on both sides that suggest the use of the groove and splinter technique (Allain 1979 - p. 108 ; Pétilion and Ducasse 2012 - p. 457). The second one, whose dating was announced in 1998 (Aujoulat *et al.* 1998 - p. 321), carried out in 2002 but not published until 2011 (Genty *et al.* 2011)<sup>2</sup>, was from the Blanc collection and corresponded in principle to the fragment of an antler point with a longitudinal groove pictured in the 1998 paper (fig. 2A, no2; Allain 1979, figure 92, no 1; LSX 15 in Leroy-Prost 2008). Note that in 2012, G. and B. Delluc described this second antler artifact as LSX 20 (fig. 2A, no3, Allain 1979, figure 92, no 3 ; Delluc and Delluc 2012 - p. 395), introducing a clear ambiguity since this artifact, along with LSX 15 and 17 that were destroyed entirely for dating purposes, no

[2] While this age is mentioned online as of 2009 on the Lascaux website mastered by the French Ministry of Culture and the Musée d’Archéologie Nationale (<http://archeologie.culture.fr/lascaux/fr/datation-figures-lascaux>), standard deviation and lab code are lacking.

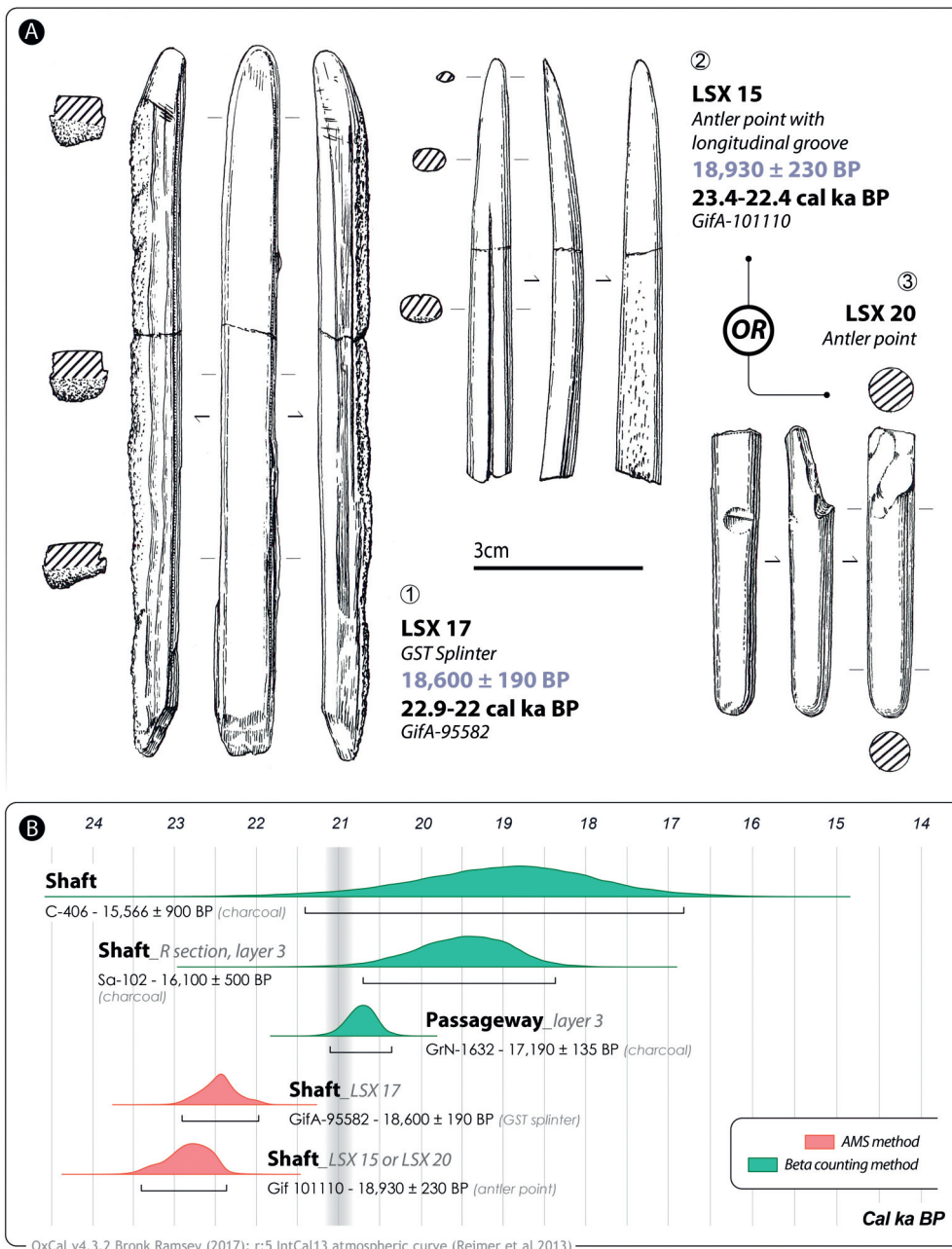


FIGURE 2

The 1998-2002 AMS dating program. A - no1-2: dated antler artifacts from the Shaft; note that there is an ambiguity as to the "identity" of the GifA-101110 sample (LSX 15; no2), sometimes deemed to correspond to LSX 20 (no3; Delluc and Delluc 2012); B - 1998-2002 results compared to the Magdalenian-like ages previously available: a diachrony? The vertical grey line centered on 21 cal ka BP corresponds to the Badegoulian-to-Magdalenian transition boundary according to Barshay-Szmidt et al. 2016 and Banks et al. 2019. Calibration was carried out with the OxCal program (v4.3.2: Bronk Ramsey 2017) using the IntCal13 calibration curve (Reimer et al. 2013).

Le programme de datation AMS 1998-2002. A - no1-2: objets en bois de renne datés issus du Puits; notez qu'une ambiguïté existe sur « l'identité » de l'échantillon GifA-101110 (LSX 15; no2), parfois relié à LSX 20 (no3; Delluc et Delluc 2012); B - Comparaison entre les résultats 1998-2002 et les âges magdaléniens obtenus précédemment: les indices d'une diachronie? La ligne verticale grise centrée autour de 21 cal ka BP correspond à la transition entre Badegoulien et Magdalénien d'après Barshay-Szmidt et al. 2016 et Banks et al. 2019.

longer exists in the collections stored at the Musée National de Préhistoire in Les-Eyzies-de-Tayac (Leroy-Prost 2008 - p. 142). In any event, the two samples were submitted to the LSCE laboratory in Gif-sur-Yvette and dated by the AMS method.

The results gave significantly older ages than the previous ones (GifA 95582: 18,600 ± 190 BP and GifA 101110<sup>3</sup>: 18,930 ± 230 BP; see above and **table 1**; Aujoulat et al. 1998; Genty et al. 2011; Valladas et al. 2013), fueling a new chronocultural attribution hypothesis that, according to the authors, was more in keeping with the stylistic features of the parietal art, stated as being situated at the "transition between the Upper Solutrean and the Badegoulian" (Aujoulat 2004 - p. 59).

[3] Note that the lab code associated with this sample in Genty et al. (2011) and Delluc and Delluc (2012) lacks the "A" (Gif-101110). This normally indicates that the result was obtained by the beta-counting method (i.e. "Gif" versus "GifA"), but this not true in this case. The true lab code (GifA-101110) was published in Valladas et al. (2013).

While we are acutely aware that the spread of the AMS method and improvements to purification pretreatments generated a kind of "ageing" phenomena that was quite systematic for the Western European LGM time span (e.g. Bryant et al. 2001; d'Errico et al. 2005 - p. 274; Geneste 2002 - p. 31), and even if it remains difficult to discuss the chemical reliability of these two measurements, the first one (18,600 ± 190 BP or 22.9-22 cal ka BP) deserves comment. Firstly, contrary to what may sometimes have been claimed (e.g. Geneste 2010 - p. 201; Petrognani and Sauvet 2012), it is clearly not compatible with a Solutrean attribution, since the most recent work has shown that the 23-21 cal ka BP interval corresponds to the development of the Badegoulian technical traditions in present-day France (Ducasse et al. 2014; Banks et al. 2019; Ducasse et al. in press). Then, apart from the Gravettian issue, the oldest dated and undisputed evidence of the use of groove and splinter technique (GST) in the Upper Paleolithic in Western Europe is known around 21-20.5 cal

ka BP and corresponds to an exclusively Magdalenian phenomenon (Pétillon and Ducasse 2012 - p. 457). Use of the GST at the Lascaux Cave would therefore be at least a thousand years earlier than any other directly-dated GST evidence from southwest France (ibid., see also Ducasse et al. 2019) and would thus be the first and sole confirmed case of the use of this method during the Badegoulian (see below).

## 2.4 | Confirming the age and determining the time span activity of the calcite gours (2011)

As part of a program aiming to achieve a better understanding of the past hydrologic activity in the cave in order to discuss the links between preservation of the paintings and water flows, an extensive dating program combining U-Th and <sup>14</sup>C methods was carried-out (Genty et al. 2011). Following the first evidence from the studies by Glory and Arl. Leroi-Gourhan (see above), Genty and colleagues obtained no less than 32 <sup>14</sup>C ages from the calcite of the gours and from charcoals trapped in it or organic matter extracted from it (table 1; note that only the dated charcoals and organic matters are reported here). The results enabled them to estimate the maximum time range for the gour formation and activity between 9.5 and 5.5 cal ka BP (compared with 10.5-7.2 cal ka BP for previous data: table 1) and, in so doing, to consider the role of these hydrological phenomena on the conservation of parietal art as almost inexistent since “the calcite gour had been inactive for several thousand years” (Genty et al. 2011 - p. 498) when the “inventors” of the cave entered into it.

## 2.5 | A contrasting picture revealing a complex diachronic story and/or biased data?

Taken as a whole and considering their standard deviations once calibrated, Paleolithic-like ages from Lascaux document the 23.5-17 cal ka BP interval (fig. 2B), that is to say a wide time range encompassing the very end of the Upper Solutrean (and/or the very beginnings of the Badegoulian), the Late Badegoulian and the Lower and Middle Magdalenian. This could be considered a demonstration that the cave was occupied over a long period of time. But if we now exclude those ages with standard deviations of more than 200 years (that blur the chronological picture considerably), the documented time range would be concentrated between the Badegoulian (23-21 cal ka BP; see above) and the first part of the Lower Magdalenian (21-19.5 cal ka BP: Langlais et al. 2015), or might simply match the Badegoulian timespan. This would be notably the case if we only chose to focus our attention on the AMS dates that correspond theoretically to the most reliable data in terms of sampling conditions and method accuracy, and would be systematically preferred to beta counting ages because of the well-known comparability issues (see above). Although these two dates could refer to the chronology of the “classic” *raclette*-yielding Badegoulian industries as documented for example at Le Cuzoul de Vers, layers 1 to 21 (Ducasse 2010 ; Clottes et al. 2012; layer 6 dated to 18,640 ± 71 BP or 22.7-22.3 cal ka BP and 18,730 ± 110 or 22.9-22.4 cal ka BP: Ducasse et al. 2014), the nature of the first dated artifact (GST) and the main characteristics of the industries which

are lacking in classic Badegoulian typo-technological features, as already stated by Allain (Allain 1979), challenge either our ability to recognize certain technocomplexes in specific “symbolic” contexts or –and this will be the standing hypothesis of the present paper– the reliability of the measurements themselves.

In short, and without venturing too far into the debate around the “cultural” attribution of the lithic and osseous industries (that will be the subject of a future publication), it appears that following the first three main dating programs, the chronology of the Paleolithic occupations of the Lascaux Cave, although not aberrant, remains extremely imprecise and raises several methodological issues. We should bear in mind that it is the result of almost fifty years of intermittent and generally limited work (four dates in more than thirty-five years between 1962 and 1998, in the framework of 2 distinct programs), over a period that demonstrated the shortcomings of the <sup>14</sup>C method and brought significant improvements, leading notably to very different sampling strategies (i.e. from bulk charcoal samples to single manufactured artifacts). The diversity of (1) the laboratories involved from 1951 to 2002, (2) the methods used, (3) the type of material dated and (4) the sampling strategies therefore limits the comparability of the results, not only among themselves, but also with the radiometric framework now accepted for the most part of the Upper Paleolithic in present-day France (e.g. Barshay-Szmidt et al. 2016 ; Banks et al. 2019). It is on account of this situation that we decided to design a new dating program able to overcome these issues and to clarify the picture, parallel to the comprehensive analysis of the archaeological record led in the LASCO project.

## 3 | A NEW DATING PROGRAM:

### MAINS GOALS AND SAMPLING STRATEGY

Conceived as the first phase of a wider dating program at Lascaux, the work presented here was carried out to test (1) the chronological homogeneity of the occupations, as already suggested by a high typo-technological coherence (Allain 1979 and ongoing work) but challenged by the state of the art recalled above and, if that was confirmed, (2) the hypothesis of an attribution to the “Badegoulian-to-Magdalenian transition” phase, fueled by several prior inter-site comparisons (Langlais 2010 ; Ducasse et al. 2011; DEX\_TER project<sup>4</sup>). While benefiting from the most recent improvements in radiocarbon dating, we therefore set up, to the extent possible, a reproducible, transparent, and simple but robust sampling strategy that allows results to be compared, reviewed, and discussed in the framework of future research endeavors.

### 3.1 | What about dating bones?

While new direct AMS dating on osseous artifacts should theoretically be the most cost-effective alternative since it would allow an absolute chronology of specific and representative typological and technical facts, we chose – mainly for conservation reasons– to begin by focusing our attention on a forgotten part of the archaeological record

[4] Lascaux au cœur d'un réseau culturel inédit à la fin du Pléistocène ? Les industries à lamelles à dos DEXtre marginal dans leur TERritoire (Ducasse et Langlais coord.).



available for dating, namely the faunal remains. If this choice may seem surprising, it should be recalled that the published faunal spectra show a fairly homogeneous assemblage dominated by reindeer remains (Rangifer tarandus; NR=217 out of a total of 248: Vannoorenberghé 2008 - p. 170, table XXI), several anatomical portions of which show evidence of carcass processing (*op. cit.*). In addition, these reindeer remains are represented in the main areas of the cave (*op. cit.* - p. 179, table XXII) and as far as we know, they have surprisingly never been submitted to radiometric dating, not even with negative results. The first phase of this dating program therefore aimed to select reindeer samples from the main areas in order to test the contemporaneity of the butchery activities across the cave and, in doing so, refine the time-span of the Paleolithic occupations and activities. Some of the very rare secondary species (e.g. deer, boar and hare), which raise the question of their association with the Paleolithic component, may be the subject of a second dating program (see below).

Since the faunal assemblages studied and published by Bouchud (1979) have not been located for now, the available corpus from which we made the selection corresponds to the Glory “treasure” found in the late nineties in his house at Le Bugue, Dordogne (Delluc and Delluc 2008). This assemblage of 115 pieces yielded close to 100 items of reindeer remains from the Entrance (N=8), the Axial Gallery (N=5), the Passageway (N=15), the Shaft (N=8), the Nave (N=7) and the Chamber of the Felines (N=55) (Vannoorenberghé 2008). It has been examined at the Musée National de Préhistoire in Les-Eyzies-de-Tayac (MNP) with the collaboration of S. Madelaine. Based on relevant criteria such as clear labelling (allowing an unambiguous spatial location), evidence of anthropic modification (i.e. cut-marks, etc.) and/or a sufficient available mass and/or a good state of conservation, we selected the following five pieces discovered in the Nave, Passageway, Shaft and Axial Gallery areas (**fig. 3, 4** and **tabl. 2**):

- ECH1: diaphyseal fragment of left humerus from the Nave, labelled “Nef-car”;
- ECH2: diaphyseal fragment of right tibia from the Nave, labelled “Nef” and showing a percussion notch;
- ECH3: diaphyseal fragment of left tibia from the Passageway, labelled “Passage” and showing cutmarks;
- ECH4: diaphyseal fragment of right humerus from the Shaft, labelled “Puits 1960 10 -C<sup>2</sup>-; this bone was discovered during the 1960-1962 Glory excavation and is reported on the plan published in 1979, situated right by the famous sandstone lamp (**fig. 4**; Leroi-Gourhan 1979 - p. 69);
- ECH5: Left radius from the Axial Gallery, labelled “Cheval inversé”, that is to say that it was collected at the foot of this specific painted panel.

### 3.2 | Sampling and dating methods

After a 3D photogrammetric recording<sup>5</sup>, each selected bone was subject to a sampling phase prior to submission to the Oxford Radiocarbon Accelerator Unit (ORAU). This sampling phase was performed at the MNP and consisted

of a simple sawing with a Dremel circular saw (*Black&Decker* RT 650) equipped with fiberglass wheels (cut-off wheel no409). A new wheel was used for each bone in order to avoid any inter-sample pollution. As far as possible, we sampled areas without any labelling information and in an apparent good state of preservation. As reported in **table 2**, the obtained sample masses varied from 1.4 to 2.3 g in weight and the masses lost during sampling did not exceed 0.3 g in weight.

According to the laboratory information, the pretreatment phase followed the usual standard, including systematic ultrafiltration (Brock *et al.* 2010). However, instead of using the regular accelerator mass spectrometer, ORAU included the Lascaux samples in the schedule of the acceptance-testing phase for their new MIni CARbon DAting System (MICADAS: e.g. Fewlass *et al.* 2018; E. Henderson, personal communication).

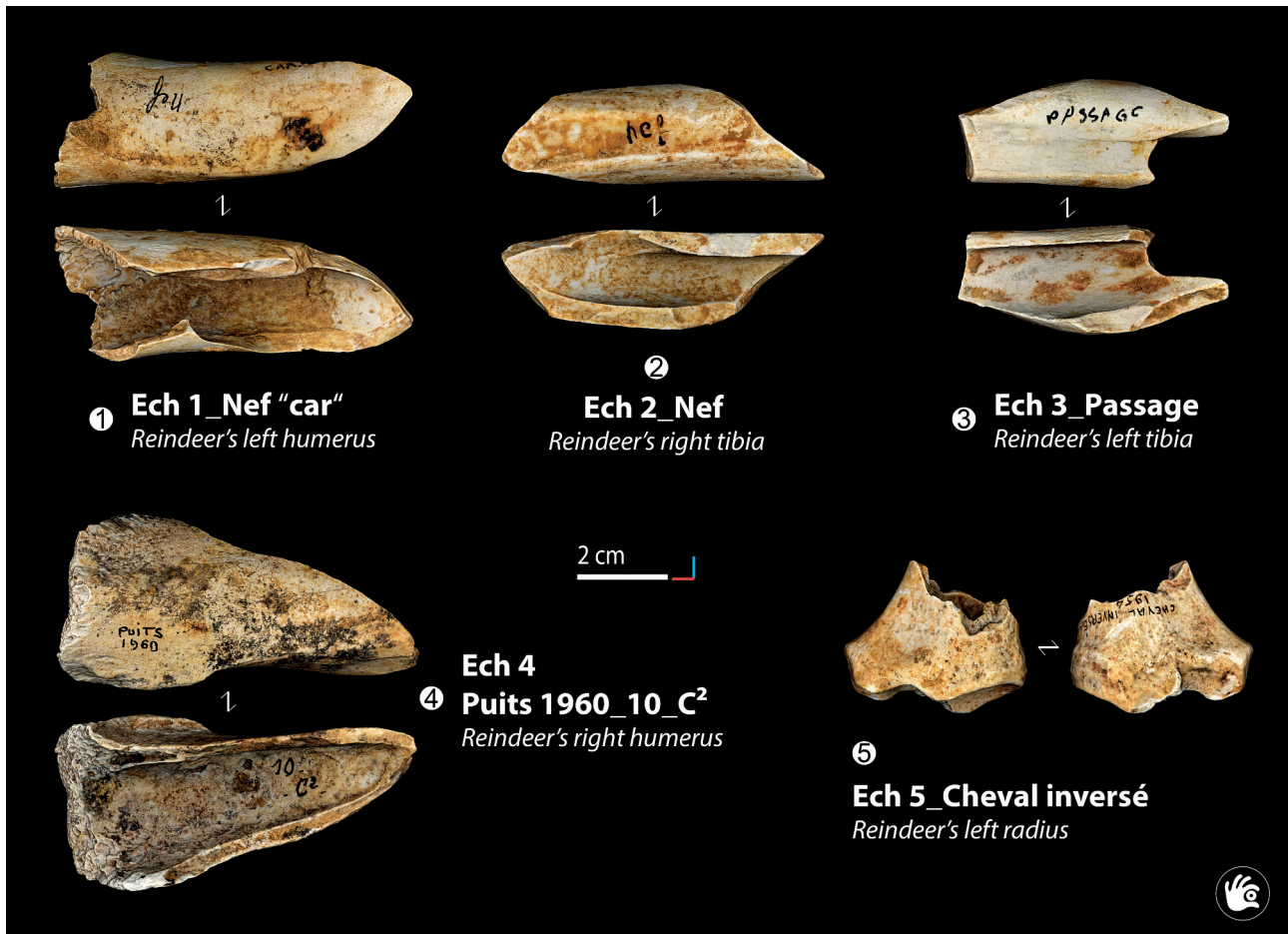
## 4 | RESULTS AND DISCUSSION

Apart from the ECH3 sample from the Passageway that failed due to low collagen yield and deprived us of a time stream for this specific area, all the other samples delivered an age considered as chemically reliable by the laboratory (**tabl. 2** and **tabl. 3**). It is interesting to note that this intra-laboratory reliability was tested by a double check of the ECH5 sample (Axial Gallery, “Cheval inversé”) that was dated twice, delivering two strictly similar ages. As recommended by Bronk Ramsey (2009 - p. 341) and indicated in the final row of **table 2**, these two measurements were combined before calibration using the “R\_Combine” tool in OxCal v.4.3.2 (Bronk Ramsey 2017; see also [https://c14.arch.ox.ac.uk/oxcalhelp/hlp\\_analysis\\_eg.html](https://c14.arch.ox.ac.uk/oxcalhelp/hlp_analysis_eg.html)). The four highly consistent and quite accurate ages obtained by the ORAU lab allow us to restrict the reindeer carcass processing—and by extension the associated industries—to a very short period of time between 21.8 and 21 cal ka BP (**table 2** and **fig. 4**) with a certain focus around 21.5-21 cal ka BP (i.e. about 17,600 ± 90 uncal. BP). These results provide striking confirmation of the consistency of the two tested hypotheses are reminiscent of the initial <sup>14</sup>C framework available notably for the Passageway-layer 3 (17,190 ± 135 uncal. BP : 21-20.5 cal ka BP; beta counting method; **fig. 2**). They open up a whole area of debate requiring detailed discussion and probably further analysis to interpret their great discrepancy with the Shaft AMS data from antler artifacts.

### 4.1 | Challenging the diachronic hypothesis: is Lascaux a “one-shot” occupation?

Based on the remarkable synthesis of Allain (1979) and the recent work of Leroy-Prost (2008), as well as on our own observations (Langlais 2010 - p. 275-277 and SD unpublished pers. obs. 2013/2014), all of which emphasize the strong typo-technologic coherence of the lithic and osseous industries, the first underlying question of this dating program was to discuss the archaeological value of the diachrony inherited from the 1948-2002 <sup>14</sup>C essays (**fig. 2**; probably due to various methodological causes: see above). Once calibrated, the results presented here restore a certain degree of chronological consistency, showing strict <sup>14</sup>C contemporaneity between the Nave and the Axial Gallery, and high compatibility with the lightly older age

[5] The LAsCO project includes a comprehensive 3D photogrammetric recording of the lithic and osseous industries (ongoing work X. Muth; Get in Situ) in order to create a virtual archaeological collection called “LAsCOTek”.



— FIGURE 3 —

The 2019 AMS dating program: dated samples (reindeer) from the Nave (no1-2), Passageway (no3), Shaft (no 4) and Axial Gallery (no5); all the pictures are derived from the 3D photogrammetric models (X. Muth, ©Get In Situ; infographie S. Ducasse).

Le programme de datation AMS 2019 : échantillons datés (renne) issus de la Nef (no1-2), du Passage (no3), du Puits (no4) et du Diverticule axial (no5) ; montage des différentes vues réalisé d'après les modèles photogrammétriques (X. Muth, ©Get In Situ; infographie S. Ducasse).

obtained for the Shaft (fig. 4). Leaving aside the C-406 and Sa-102 measurements that show very high standard deviation and are thus useless (table 1), we can see that these new AMS ages on reindeer bones differ significantly from the Gif-sur-Yvette data on antler artifacts, as the latter are about 1,000 years older without any chronological overlap with the former (fig. 5). There are therefore two possible conclusions to explain this difference: either the bones (and subsequently the butchery activities) and antler worked artifacts (and subsequently the manufacture and/or deposit of these pieces) actually correspond to distinct chronological events inside the Shaft, or the chemical reliability of the ages produced in the late nineties and the early 2000s must be called into question.

Although the first hypothesis must wait for further investigations, it could echo with the descriptions of Glory that highlight the existence of a discrete “paleosol” underlying the archaeological layer in the Shaft (Glory

2008 - p. 74-78 ; Leroi-Gourhan 1979 - p. 66)<sup>6</sup>. Furthermore, since the anatomical structure of the corpus of dated reindeer bones could theoretically correspond to a single individual (intentionally?) dispersed throughout the main sectors (see above), the possibility that the obtained ages could document a very specific event within a hypothetical long-term occupation of the cave (i.e. between 23.5-21 cal ka BP) cannot be totally dismissed. However, pending further evidence supporting this first hypothesis, we consider that the current archaeological evidence matches the second hypothesis best. Beside the already mentioned high coherence of the lithic and osseous industries that lack Solutrean and Badegoulian specific artifacts but which is consistent with the 2019 ages (see below), inter-site comparisons lead to consider the two Gif ages as outliers. First, as already stated, the technological features of GifA 95582 (GST) appear to clearly contradict its Badegoulian-like <sup>14</sup>C age. As illustrated in figure 6, direct

[6] It is nevertheless important to note that according to Glory this “paleosol” (layer E from R section: Glory 2008 - p. 74) yielded very few charcoals and that the Paleolithic industries were not included in. It is therefore unlikely that the dated antler artifacts, which were discovered by Breuil, Blanc and Bourgon in the forties, were from an older, undefined archaeological layer.

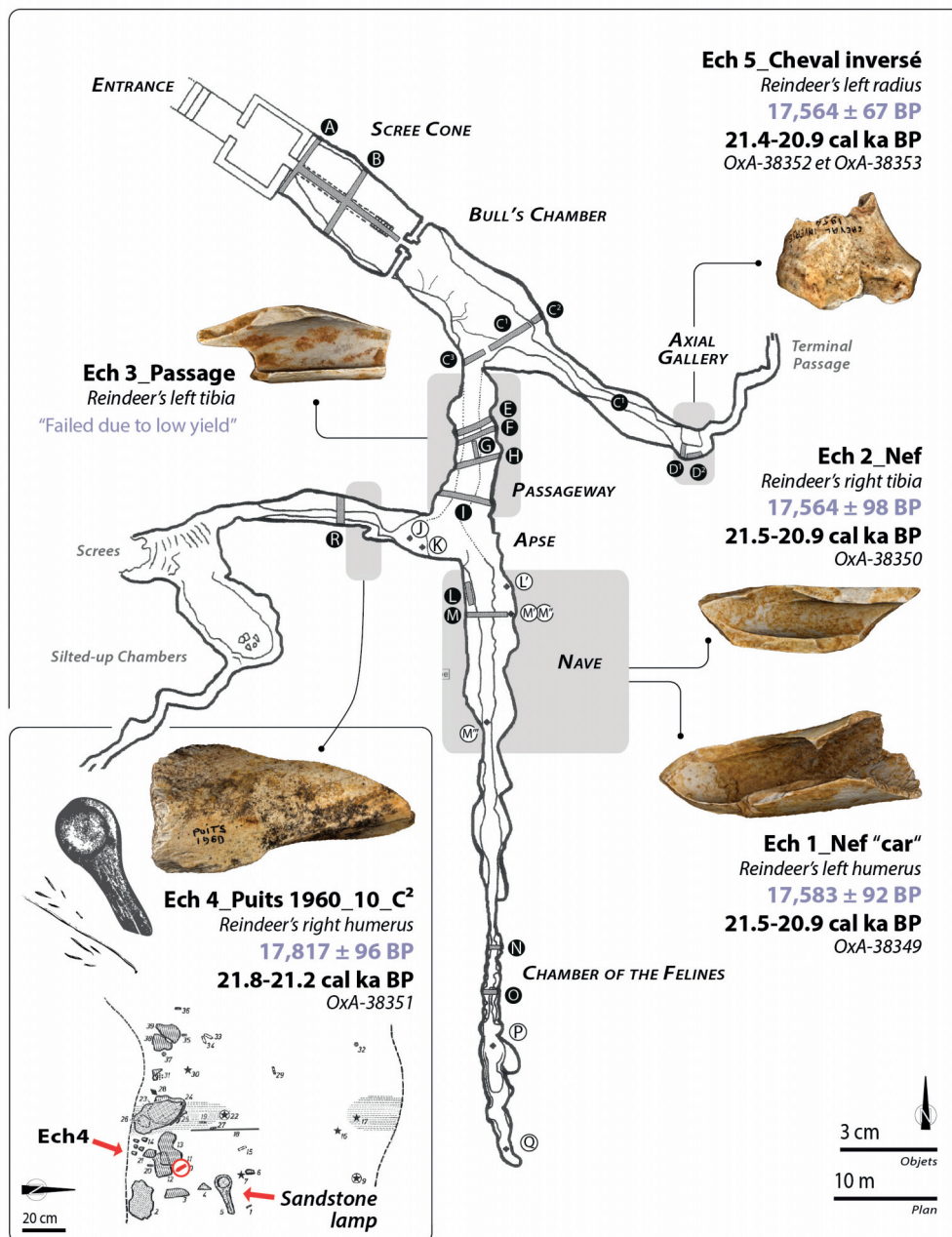


FIGURE 4

Location of the dated samples and new AMS ages within the main cave areas; the white letters on black correspond to the stratigraphic sections described by Glory (cave plan from Leroi-Gourhan and Allain 1979, figure 22, modified).

Localisation des échantillons datés et des mesures obtenues au sein des principaux secteurs de la grotte ; les lettres blanches sur fond noir correspondent aux coupes stratigraphiques relevées par Glory (plan de la grotte d'après Leroi-Gourhan et Allain 1979, figure 22, modifié).

dating of numerous antler manufacturing waste from French Badegoulian and Magdalenian contexts document the chronological succession of the knapping technique older than 20.5 cal ka BP – and the GST – younger than 21 cal ka BP. Second, if we consider the other directly dated artifact to be LSX 15 (fig. 2A #2), it would be the first confirmed case of a Badegoulian antler point with longitudinal groove since it has been previously demonstrated that this kind of typological association results from chronocultural admixtures with Magdalenian artifacts (e.g. Pégourié Cave, Lot : Ducasse *et al.* 2019). Lastly, even if this argument is not decisive as such and cannot be generalized, we must recall that examples of discrepancies between laboratories have sometimes been documented, and may not be due exclusively to archaeological issues. In that respect, the specific case of Gandil rockshelter (Tarn-et-Garonne) appears to be relevant since it also involves the Gif-sur-Yvette laboratory. The Lower Magdalenian layers 23 and 25, shown to be a unique

archaeological assemblage (Langlais *et al.* 2007), delivered two self-consistent but very different series of AMS ages (table 4): 1,000 years separate the Gif and Lyon ages, with the former giving the older and least consistent results with respect to the typo-technological features (Langlais 2010 - p. 129 ; Jaubert 2013 ; Valladas *et al.* 2014). In any event, archaeological evidence and inter-site comparisons lead us to opt for considering the 1998-2002 results as highly questionable, pending new contradictory data.

#### 4.2 | A winning bet: the Badegoulian-to-Magdalenian transition hypothesis confirmed

The second question was highly dependent on the answer to the first one. If we now consider, in the light of the results presented in table 2, that the most part of the archaeological remains discovered in the main areas of the cave correspond to a chronologically coherent assem-



Sample code	Area	Labelling	Specie	Anatomical part	Lateralization	Lab code	Uncalibrated Age (BP)	Calibrated age (BP, 2σ)
ECH1	Nave	Nef - car	Reindeer	Humerus (diaphysis)	Left	OxA-38349	17,583 ± 92	21,566-20,941
ECH2	Nave	Nef	Reindeer	Tibia (diaphysis)	Right	OxA-38350	17,564 ± 98	21,552-20,910
ECH3	Passageway	Passage	Reindeer	Tibia (diaphysis)	Left	<i>failed due to low yield</i>		
ECH4	Shaft	Puits 1960 10 -C <sup>2</sup> -	Reindeer	Humérus (diaphyse)	Right	OxA-38351	17,817 ± 96	21,872-21,275
ECH5	Axial Gallery	Cheval inversé	Reindeer	Radius	Left	OxA-38352	17,549 ± 97	21,529-20,894
ECH5	Axial Gallery	Cheval inversé	Reindeer	Radius	Left	OxA-38353	17,578 ± 92	21,558-20,936
						<i>R_Combine OxA-38352 and 38353</i>	17,564 ± 67	21,486-20,966

— TABLEAU 2 —

New AMS ages (MICADAS) on reindeer remains collected in the main areas of the cave (Glory collection stored at Museum of Prehistory in Les-Eyzies). Note that since the ECH5 sample has been dated twice, the two measurements were “R\_Combine” using OxCal program (see the last row). Calibration was carried out with the OxCal program (v4.3.2: Bronk Ramsey 2017) using the IntCal13 calibration curve (Reimer *et al.* 2013).

*Nouvelles datations SMA sur vestiges attribués au renne et issus des principaux secteurs de la grotte (collection Glory conservées au MNP). Dans la mesure où l'échantillon ECH5 a fait l'objet de deux mesures, celles-ci ont été combinées via le logiciel OxCal (fonction « R\_Combine » ; voir la dernière ligne du tableau).*

blage dated between 21.5 and 21 cal ka BP, we are consequently able to globally confirm our starting hypothesis (Langlais 2010 ; Ducasse *et al.* 2011): while a radiometric measurement is —of course— not equal to a cultural attribution, we can still clearly affirm that the industries of Lascaux are linked with the increasingly complex Badegoulian-to-Magdalenian transition phase, as several items of evidence already suggested through inter-site comparisons (Ducasse *et al.* 2011, figure 31 and 36 ; Delluc and Delluc 2012).

On a purely chronological level and by comparing with the regional and extra-regional chronological frameworks defined through recent AMS dating (Langlais *et al.* 2015 ; Barshay-Szmidt *et al.* 2016 ; Banks *et al.* 2019 ; Ducasse *et al.* 2019, in press), the results obtained here fall within the last third of the Late Badegoulian time-span (fig. 6 and table 5)<sup>7</sup>. As Lassac, Aude (Sacchi 1986 ; Ducasse 2010 ; Pétilion and Ducasse 2012), La Contrée-Viallet, Allier (Lafarge 2014) or Casserole, Dordogne (Ducasse *et al.* submitted)<sup>8</sup> show, the very end of the *raquette*-yielding Badegoulian can currently be set around 17,500 ± 100 uncal. BP, i.e. between 21.5-21 cal ka BP. To date, and beside the Gif-sur-Yvette AMS ages for Gandil layer 23-25 (see the review above and table 4), no “classic” French Lower Magdalenian industry yielding backed microbladelets and GST (*sensu* Saint-Germain-la-Rivière lower ensemble, Gironde: Langlais *et al.* 2015; or Le Taillis des Coteaux AG-IIIa: Primault *et al.* 2007 ; Primault 2010) has been dated to before 17,100 ± 100 uncal. BP, i.e. between 21-20.5 cal ka BP. Furthermore, while this chronological milestone is also valid for directly dated GST manufacturing wastes as stated above, it is quite interesting to note that numerous directly-dated antler flakes from the Badegoulian and/or undertermined or unclear chronocultural contexts appear to be strictly contemporaneous with the new AMS ages

obtained for the Lascaux assemblages (fig. 6; Pétilion and Ducasse 2012 ; Bourdier *et al.* 2014 ; Chauvière *et al.* 2017 ; Ducasse *et al.* 2019). Among them, several taphonomically-questionable and/or anciently excavated sites yield very specific *lamelles à dos dextre marginal* (LDDM) that we propose to link with a significant part of the lithic hunting equipment from Lascaux (Ducasse *et al.*, 2011 and ongoing study). The same specific type of retouched bladelets have notably been documented at Bouyssonie Cave (Corrèze; Langlais *et al.* in press), at Les Scilles, layer B attributed to the Lower Magdalenian (Haute-Garonne; Pétilion *et al.* 2008 ; Langlais *et al.* 2010) and Solvieux, layer 3A attributed to the Late Badegoulian (Dordogne; Sackett 1999, plate 15 ; Ducasse *et al.*, 2011 and pers. obs.), in association with shaped sandstone lamps strongly recalling the famous Lascaux *brûloir* (Glory 1961 ; Beaune *et al.* 1986 ; Beaune 1987) which has been indirectly dated through the result delivered by the ECH4 bone sample (17,817 ± 96 uncal. BP : 21.8-21.2 cal ka BP; fig. 4)<sup>9</sup>.

Thus, we would not say here that the industries of Lascaux are Badegoulian, no more than we would argue for a Lower Magdalenian attribution since the classic typo-technological criteria defining these two technocomplexes are lacking. Given the current increasing complexity of the panorama for the 21.5-20.5 period, we will limit ourselves to underlining the now clearer links existing between Lascaux and the LDDM-yielding industries known across this chronologic interval, that are currently being defined (e.g. Langlais *et al.* 2018, in press ; Primault *et al.* in press). Far beyond the chronological issue, any answer to this question should await a comprehensive typo-technological reassessment of these specific assemblages and such work is currently being conducted within the framework of the DEX\_TER project.

## 5 | CONCLUSION

The results presented in this paper are a first but significant step towards a global renewal of the highly controversial chronological framework of the Lascaux Cave. Twenty years after the last <sup>14</sup>C essays, this new dating program provides a series of highly coherent ages that could

[7]: The selection of AMS <sup>14</sup>C ages presented in Figure 6 and Table 5 has been built in order to locate the new Lascaux AMS ages chronologically within the currently accepted chronological framework for the Badegoulian and the Lower Magdalenian. Since a complete comparison dataset is not possible in the scope of the present paper, we focused this selection on data from taphonomically-controlled assemblages from southwest France. These assemblages had to be representative of the oldest and youngest known ages for each techno-complex in this area. Given the issue of the technological features of some of the previously dated artifacts (GST splinter; see the discussion in the text), this corpus was supplemented by the selection of directly dated antler flakes (K) and groove and splinter technique manufacturing wastes (GST) for the 23.5-19 cal ka BP time span, whatever the degree of chronocultural homogeneity of the assemblages concerned.

[8] To which other unpublished ages from Cassegros (Lot-et-Garonne; ongoing monograph publication) could be added.

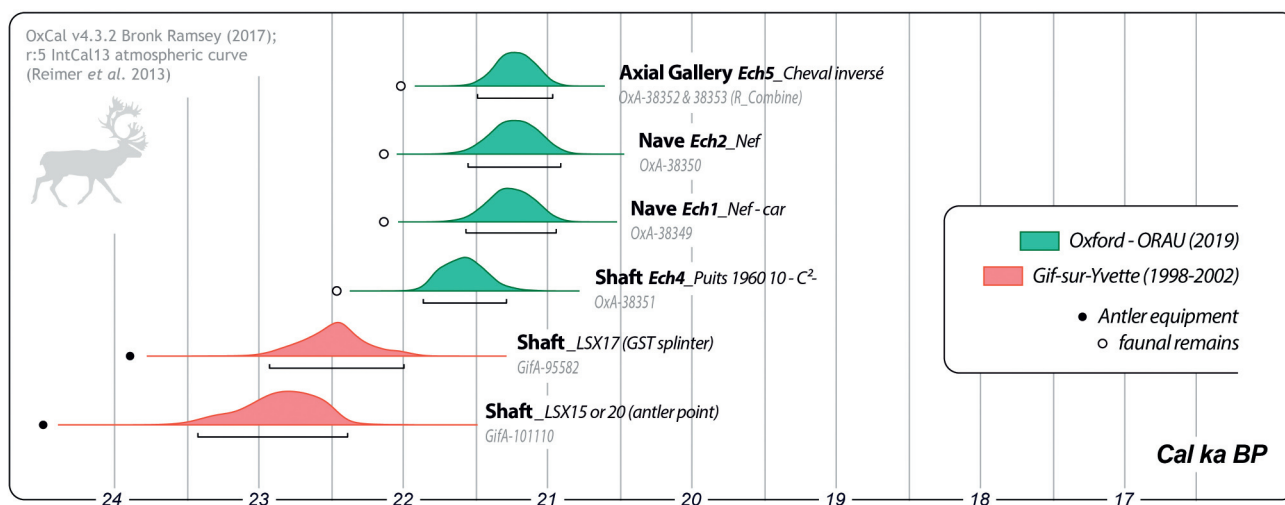
[9] Note that layer 3A from Solvieux is also known for his famous engraved stone slab showing incomplete figurative elements (horse and cervid; Gausson and Sackett 1984), whose style is often compared to the norms described at Lascaux or Gabillou, notably in the way the hoofs are represented (e.g. Clottes *et al.* 1986).

Sample code	Lab code	Used (mg)	Yield (mg)	%Yield	Excess (mg)	%C	δ <sup>13</sup> C	δ <sup>15</sup> N	CN
ECH1	OxA-38349	509	18.08	3.6	13.08	45.9	-19.5	4	3.3
ECH2	OxA-38350	598	8.08	1.4	3.19	44.1	-19	4.3	3.3
ECH4	OxA-38351	657	32.21	4.9	27.28	45.5	-19.1	3.7	3.3
ECH5	OxA-38352	528	11.27	2.1	6.32	46.6	-19.3	3.5	3.3
ECH5	OxA-38353	570	22.9	4	17.68	47	-18.9	3.7	3.3

TABLEAU 3

Detailed chemical results.

Détail des données chimiques.



— FIGURE 5 —

New AMS <sup>14</sup>C ages compared to the 1998-2002 ages from the Shaft. Calibration was carried out with the OxCal program (v4.3.2: Bronk Ramsey 2017) using the IntCal13 calibration curve (Reimer et al. 2013).

Comparaison des nouvelles dates AMS (2019) avec les mesures obtenues entre 1998 et 2002 pour le Puits.

Site	Layer	Cultural Attribution	Sample nature	Gif-sur-Yvette			Lyon		
				Lab code	Uncalibrated Age (BP)	Calibrated age (BP, 2σ)	Lab code	Uncalibrated Age (BP)	Calibrated age (BP, 2σ)
Gandil	23	Lower Magdalenian	bone	GifA-96417	17,480 ± 180	21,644-20,635	Ly-2484 (Poz)	16,538 ± 144	20,328-19,579
Gandil	25	Lower Magdalenian	bone	GifA-97307	17,290 ± 180	21,409-20,418	Ly-2485 (Poz)	16,507 ± 144	20,287-19,553

— TABLEAU 4 —

The inter-lab comparability issue: example from Gandil rockshelter (Tarn-et-Garonne). Data-lists according to Langlais et al., 2007 and Jaubert, 2013. Calibration was carried out with the OxCal program (v4.3.2: Bronk Ramsey 2017) using the IntCal13 calibration curve (Reimer et al. 2013).

La question de la comparabilité inter-laboratoire : L'exemple de l'abri Gandil (Tarn-et-Garonne).

easily be related to the very specific lithic and osseous industries discovered in the main cave's areas. By depicting strong inter-area contemporaneity and confirming a Badegoulian-to-Magdalenian chronology, the previous diachronic framework and the surprisingly old ages often used to defend a Solutrean attribution are brought into question, not only for the archaeological assemblages, but also for the cave art. While the issue of the links between the new radiometric framework presented above and the parietal art have still to be discussed in light of interdisciplinary and crossover studies, our results fly in the face of the Solutrean attribution hypothesis of the industries, in line with their main typo-technological features.

To precise this new chronology and to continue to systematically test this new coherence parallel to our petrographic, typo-technological and functional reassessment (ongoing work A. Averbouh, S. Caux, S. Ducasse,

J. Jacquier and M. Langlais), two more dating programs are already planned. The next one can be performed in the short-term and will concern, as far as possible, other faunal remains corresponding to (1) secondary Paleolithic-like species (horse, red deer) and (2) postglacial-like species (deer, boar and hare). The hypothetical third program may be possible over the medium-term for heritage status reasons and would consist in new direct dating of a typo-technological selection of bone and antler artifacts from the main areas of the Cave (i.e. points and/or tools, decorated or not), as successfully done in globally comparable chronological contexts (e.g. Pétillon and Ducasse 2012; Barshay-Szmidt et al. 2016; Chauvière et al. 2017; Ducasse et al. 2019). Favored by recent methodological advances (Cersoy et al. 2017), such an approach would directly challenge the archaeological reliability of the results obtained through the seminal work

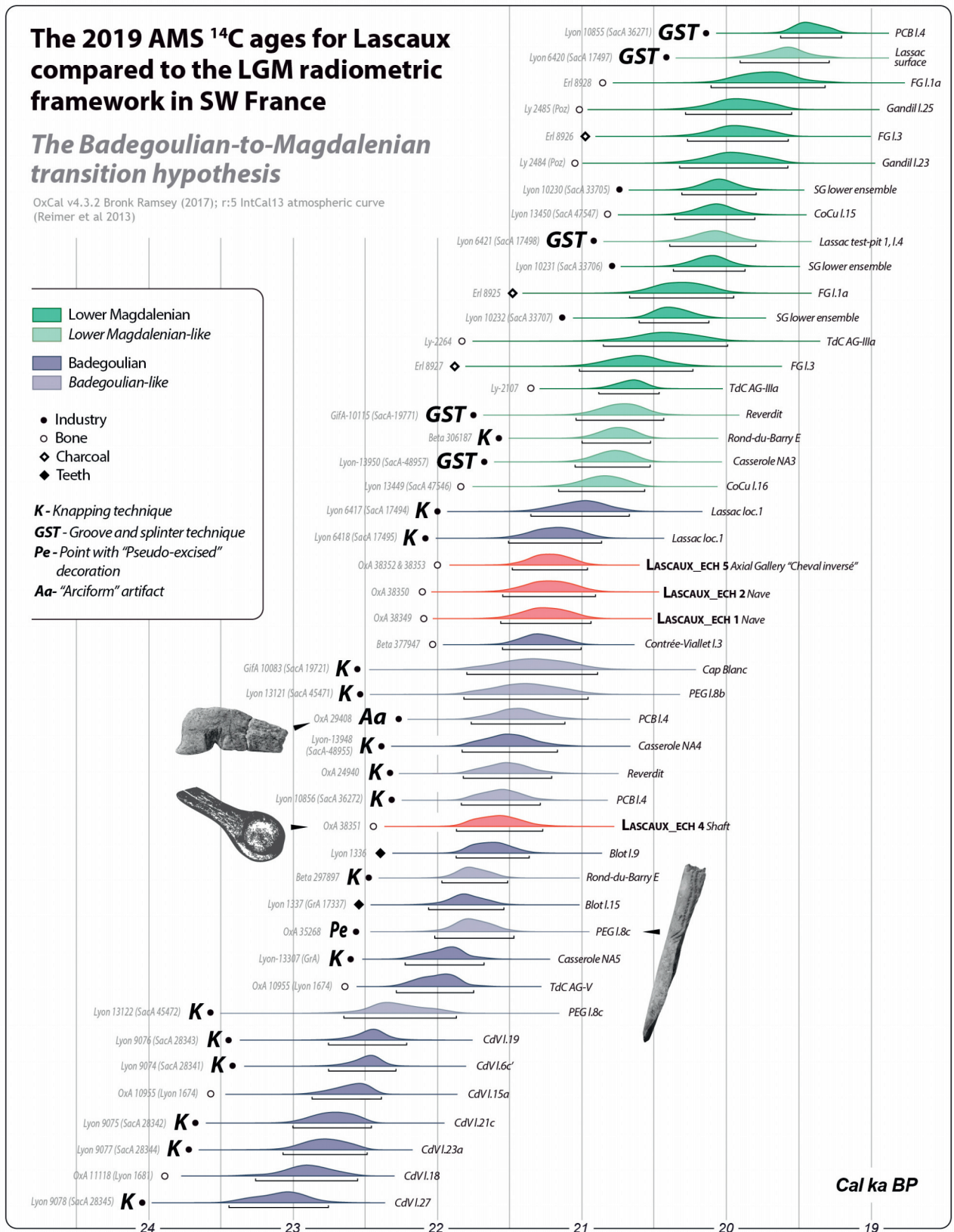


Site	Layer	Cultural Attribution	Sample references	Nature	Nature	Lab Code	Uncalibrated ages (BP)	Calibrated age (BP, 2σ)	References
Blot	15	Late Badegoulian	J8 15-41	Teeth	.	GRA-17337 (Lyon-1337)	18,000 ± 80	22,065-21,543	BANADORA; Banks et al. 2019
Blot	9	Late Badegoulian	K4 9-11	Teeth	.	GRA-17339 (Lyon-1336)	17,850 ± 80	21,874-21,368	BANADORA; Banks et al. 2019
Cap Blanc	.	Late Badegoulian-like	61.3	Antler	Antler flake	Gifa-10083 (SacA-19721)	17,640 ± 160	21,800-20,895	Bourdier et al. 2011
Casserole	NA3	Lower Magdalenian-like	L15 #1 - effe de paroi	Antler	GST splinter	Lyon-13950 (SacA-48957)	17,230 ± 90	21,050-20,531	Ducasse et al. submitted
Casserole	NA4	Late Badegoulian	O14b #1	Antler	Antler flake	Lyon-13948 (SacA-48955)	17,760 ± 100	21,830-21,170	Ducasse et al. submitted
Casserole	NA5	Late Badegoulian	N15d #34	Antler	Antler flake	Lyon-13307 (Gra)	18,100 ± 80	22,224-21,678	Ducasse et al. submitted
Combe Cuiller	15	Lower Magdalenian/LDDM industry	J25 n°475	Bone	Reindeer (metacarpal)	Lyon-13450 (SacA-47547)	16,640 ± 90	20,361-19,808	Langlais et al. 2018
Combe Cuiller	16	Lower Magdalenian/LDDM industry	I25 n°9	Bone	Bos/Bison (cervical vertebra)	Lyon-13449 (SacA-47546)	17,290 ± 100	21,165-20,570	Langlais et al. 2018
Contra-Vallat	3	Late Badegoulian	.	Bone	Horse	Beta-377947	17,610 ± 70	21,554-21,009	Lafarge 2014
Cuzou de Vers	6c'	Late Badegoulian	CZ84 K4 n°289	Antler	Flaked antler	Lyon-9074 (SacA-28341)	18,620 ± 100	22,757-22,290	Ducasse et al. 2014
Cuzou de Vers	15a	Late Badegoulian	CZ85 D5 n°230	Bone	MSU	OxA-10974 (Lyon-1676)	18,730 ± 100	22,871-22,391	Ducasse et al. 2014
Cuzou de Vers	18	Late Badegoulian	carré E5	Bone	MSU	OxA-11118 (Lyon-1681)	19,020 ± 110	22,262-22,555	Oberlin and Valladas 2012
Cuzou de Vers	19	Late Badegoulian	CZ83 D4 n°1772	Antler	Antler flake	Lyon-9076 (SacA-28343)	18,590 ± 110	22,757-22,216	Ducasse et al. 2014
Cuzou de Vers	21c	Late Badegoulian	CZ85 J4 n°1555	Antler	Antler flake	Lyon-9075 (SacA-28342)	18,860 ± 110	23,003-22,460	Ducasse et al. 2014
Cuzou de Vers	23a	Lower Badegoulian	CZ86 I5 n°636	Antler	Knapped splinter	Lyon-9077 (SacA-28344)	18,920 ± 110	23,072-22,489	Ducasse et al. 2014
Cuzou de Vers	27	Lower Badegoulian	CZ86 D5 n°1192	Antler	Antler flake	Lyon-9078 (SacA-28345)	19,150 ± 110	23,446-22,757	Ducasse et al. 2014
Fontgrasse	1a	Lower Badegoulian	.	Charcoal	Pinus	EH-8925	16,838 ± 143	20,674-19,955	Bazile 2006
Fontgrasse	1a	Lower Badegoulian	.	Burnt bone	Pinus	EH-8928	16,338 ± 153	20,111-19,322	Bazile 2006
Fontgrasse	3	Lower Badegoulian	.	Charcoal	Pinus	EH-8926	16,518 ± 133	20,274-19,577	Bazile 2006
Fontgrasse	3	Lower Badegoulian	.	Charcoal	Juniperus	EH-8927	17,100 ± 144	21,022-20,236	Bazile 2006
Gandil	23	Lower Magdalenian	.	Bone	.	Lyon-2484 (Poz)	16,538 ± 144	20,328-19,579	Jaubert 2013
Gandil	25	Lower Magdalenian	.	Bone	.	Lyon-2485 (Poz)	16,507 ± 144	20,287-19,553	Jaubert 2013
Lassac	locus 1	Late Badegoulian	M6 CX rel.6	Antler	Antler flake	Lyon-6417 (SacA-17494)	17,400 ± 110	21,357-20,676	Pétillon and Ducasse 2012
Lassac	locus 1	Late Badegoulian	W section	Antler	Antler flake	Lyon-6418 (SacA-17495)	17,530 ± 100	21,512-20,868	Pétillon and Ducasse 2012
Lassac	locus 1	Late Badegoulian	.	Antler	GST manufacturing waste	Lyon-6420 (SacA-17497)	16,230 ± 100	19,910-19,293	Pétillon and Ducasse 2012
Lassac	locus 1	Lower Magdalenian-like	.	Antler	GST manufacturing waste	Lyon-13121 (SacA-45471)	17,680 ± 150	21,821-20,961	Pétillon and Ducasse 2012
Lassac	locus 1	Lower Magdalenian-like	.	Antler	GST manufacturing waste	Lyon-13122 (SacA-45472)	18,440 ± 170	22,651-21,872	Ducasse et al. 2019
Lassac	locus 1	Lower Magdalenian-like	.	Antler	Antler flake	OxA-35268	17,960 ± 90	22,019-21,469	Ducasse et al. 2019
Lassac	locus 1	Lower Magdalenian-like	.	Antler	Decorated single beveled point using the "pseudo-excise" technique	Lyon-10855 (SacA-36271)	16,100 ± 70	19,629-19,208	Chauvière et al. 2017
Lassac	locus 1	Lower Magdalenian-like	.	Antler	GST splinter	Lyon-10856 (SacA-36272)	17,800 ± 80	21,838-21,292	Chauvière et al. 2017
Lassac	locus 1	Lower Magdalenian-like	.	Antler	"Arciform artifact" preform	OxA-29408	17,720 ± 90	21,770-21,122	Chauvière et al. 2017
Lassac	locus 1	Lower Magdalenian-like	.	Antler	GST manufacturing waste	Gifa-10115 (SacA-19771)	17,180 ± 110	21,043-20,437	Bourdier et al. 2011
Lassac	locus 1	Lower Magdalenian-like	.	Antler	Antler flake	OxA-24940	17,770 ± 90	21,825-21,213	Bourdier et al. 2011
Petit Cloup Barrat	4	Lower Magdalenian	PCB06 Q71B rd. n° 278	Antler	Antler flake	Beta-297897	17,960 ± 70	21,973-21,517	Remy 2013, Raynal et al. 2014
Petit Cloup Barrat	4	Lower Magdalenian	PCB08 R70D d5 n°91	Antler	Antler flake	Beta-306187	17,210 ± 80	21,003-20,529	Remy 2013, Raynal et al. 2014
Petit Cloup Barrat	4	Lower Magdalenian	PCB08 P72A 420 n°680	Antler	Antler flake	Lyon-10230 (SacA-33705)	16,620 ± 80	20,313-19,799	Barshay-Smidt et al. 2016
Reverdit	1a	Lower Magdalenian-like	.	Antler	Osseous industry	Lyon-10231 (SacA-33706)	16,670 ± 80	20,371-19,875	Barshay-Smidt et al. 2016
Reverdit	1a	Lower Magdalenian-like	.	Antler	Osseous industry	Lyon-10232 (SacA-33707)	16,900 ± 80	20,608-20,125	Barshay-Smidt et al. 2016
Rond-du-Barry	E	Late Badegoulian-like	J13-1	Antler	Osseous industry	Lyon-2264 (Poz)	16,920 ± 170	20,853-19,992	Primaut et al. 2007, Primaut 2010
Rond-du-Barry	E	Lower Magdalenian-like	G13-42	Antler	Osseous industry	OxA-12180 (Lyon-2107)	17,130 ± 65	20,885-20,466	Primaut et al. 2007, Primaut 2010
Saint-Germain-la-Rivière	Lower ensemble	Lower Magdalenian	.	Antler	.	Lyon-2639	18,140 ± 85	22,285-21,750	Primaut et al. 2007, Primaut 2010
Saint-Germain-la-Rivière	Lower ensemble	Lower Magdalenian	.	Antler	.	.	.	.	.
Saint-Germain-la-Rivière	Lower ensemble	Lower Magdalenian	.	Antler	.	.	.	.	.
Le Taillis-des-Coteaux	AG-IIa	Lower Magdalenian	.	Bone	.	.	.	.	.
Le Taillis-des-Coteaux	AG-IIa	Lower Magdalenian	.	Bone	.	.	.	.	.
Le Taillis-des-Coteaux	AG-Vd	Late Badegoulian	.	Bone	.	.	.	.	.

— TABLEAU 5 —

Selection of AMS <sup>14</sup>C dates covering the currently admitted Badegoulian and Lower Magdalenian time span, used in Fig. 6. Selection of datations par SMA couvrant l'intervalle chronologique aujourd'hui admis pour le Badegoulien et le Magdalénien (MSU: medium-sized ungulate; GST: groove-and-splinter technique). Calibration was carried out with the OxCal program inférieure (cf. fig. 6, MSU: ongulé de taille moyenne; GST: double rainurage).

(v4.32: Bronk Ramsey 2017) using the IntCal13 calibration curve (Reimer et al. 2013).



— FIGURE 6 —

The 2019 AMS <sup>14</sup>C ages for Lascaux compared to the LGM chronocultural framework in Southwest France: the Badegoulian-to-Magdalenian transition hypothesis. The "Badegoulian-like" and "Lower-Magdalenian-like" dating refer to compatible ages made on supposedly Badegoulian-specific (K) and Magdalenian-specific (GST) antler manufacturing wastes from mixed assemblages and/or old excavations (CdV: Cuzoul de Vers; CoCu: Combe-Cullier; FG: Fontgrasse; PCB: Petit Cloup Barrat; PEG: Pégourié; SG: Saint-Germain-la-Rivière; TdC: Taillis-des-Coteaux; see table 5). Calibration was carried out with the OxCal program (v4.3.2: Bronk Ramsey 2017) using the IntCal13 calibration curve (Reimer et al. 2013).

Comparaison des nouvelles dates AMS de Lascaux (2019) avec le cadre chronoculturel du DMG dans le sud-ouest de la France : l'hypothèse de la transition badegoulo-magdalénienne. Les datations distinguées sous les appellations « Badegoulian-like » et « Magdalenian-like » correspondent à des mesures d'âge compatibles obtenues à partir de déchets techniques en bois de cervidé considérés comme caractéristiques sur le plan « culturel », mais issus d'industries mélangées et/ou de fouilles anciennes.

of the Gif-sur-Yvette laboratory (Aujoulat *et al.* 1998 ; Valladas *et al.* 2013).

In any event, this new date *with* Lascaux kept its promises by paving the way for exciting and challenging new questions. One certainty remains: we will be seeing each other again!

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