



Twenty years on, a new date with Lascaux. Reassessing the chronology of the cave's Paleolithic occupations through new 14C AMS dating

Sylvain Ducasse, Mathieu Langlais

► To cite this version:

Sylvain Ducasse, Mathieu Langlais. Twenty years on, a new date with Lascaux. Reassessing the chronology of the cave's Paleolithic occupations through new 14C AMS dating. PALEO: Revue d'Archéologie Préhistorique, 2019, 30 (1), pp.130-147. 10.4000/paleo.4558 . hal-02885865

HAL Id: hal-02885865

<https://hal.science/hal-02885865>

Submitted on 9 Jul 2020

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution - NonCommercial - NoDerivatives 4.0 International License

TWENTY YEARS ON, A NEW DATE WITH LASCAUX

REASSESSING THE CHRONOLOGY OF THE CAVE'S PALEOLITHIC OCCUPATIONS THROUGH NEW ^{14}C AMS DATING

Sylvain Ducasse^a,
Mathieu Langlais^{a,b}

a. CNRS, UMR 5199 « PACEA », Université de Bordeaux, Bâtiment B2, Allée Geoffroy Saint-Hilaire, CS 50023, FR-33615 Pessac Cedex - sylvain.ducasse@u-bordeaux.fr; mathieu.langlais@u-bordeaux.fr

b. SERP, Universitat de Barcelona, Gran Via de Les Corts Catalanes, 585, E-08007 Barcelona

ABSTRACT

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 ^{14}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.

PALEO 30 | t. 1
DÉCEMBRE 2019
PAGES 130 À 147

KEY-WORDS Lascaux Cave, radiocarbon dating,
Reindeer, Badegoulian, Magdalenian.

« Speed dating » à Lascaux. De nouveaux repères ^{14}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}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 Mini 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}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}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-Sánchez *et al.* 2014 ; Lacanette and Malauré 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 ; Vannoorenbergh 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 project¹ 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 typological 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 ^{14}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.

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

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 ^{14}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 $15,566 \pm 900$ BP was published in 1951 (lab code C 406: Arnold and Libby 1951 ; Glory 1964 ; indicated as $15,516 \pm 900$ 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 ^{14}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: $8,510 \pm 100$ BP or GrO 1182: $8,270 \pm 100$ BP for the layer 16 sample; GrN 1514: 8100 ± 75 BP or GrO 1514: $8,060 \pm 75$ BP for the Passage one). This evidence was confirmed a few years later (1962) with the age of $9,070 \pm 90$ 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 $17,190 \pm 135$ BP (GrN 1632 or GrO 1632: $16,950 \pm 135$ BP; indicated as $17,190 \pm 140$ 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 $16,100 \pm 500$ BP (Sa 102; indicated as $16,000 \pm 500$ BP in Leroi-Gourhan and Evin 1979).

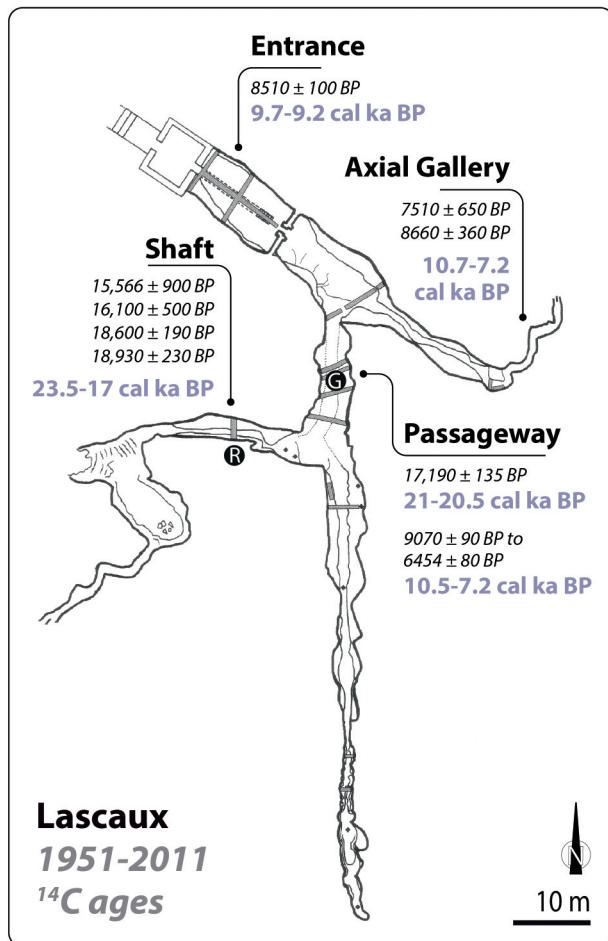
2.2 | Additional data as part of the monograph study (1975)

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

Area	Location	Excavators/Sampler	Date of sampling	Nature	Sample references	Lab	Method	Lab Code	Uncalibrated age (BP)	Calibrated age (BP, $\pm 2\sigma$)	Comments	References
Shaft	H. Breuil, S. Blanc, M. Bourgon	1948	Charcoal	Chicago	C-406	15.566 \pm 900	21,431-16,827	15,516 \pm 900 in Leroi-Gourhan and Evin, 1979	Leroi-Gourhan and Evin, 1979 ; Glory, 1964, 2008			
Entrance (screen cone)	Layer 16	A. Glory	1957	Charcoal (150 g.)	Groningen	8,50 ± 100	9,736-9,271	Formerly GRO 1182; 8,270 \pm 100 (SUESS correction, 1962)	Glory, 1964, 2008			
Passageway	G Section, undetermined Gour;	A. Glory	1957	Charcoal (50 g.)	Groningen	GrN-1514	8,100 \pm 75	9,380-8,728	Formerly GRO 1514; 8,060 \pm 75 (SUESS correction, 1962)	Glory, 1964, 2008		
Passageway	"on the surface of the calcite"; Layer 1	A. Glory	1962	Charcoal	Groningen	GrN-3184	9,070 \pm 90	10,497-9,920	Formerly GRO 1632; 16,950 \pm 135 (SUESS correction, 1962); 17,190 \pm 135	Glory, 1964, 2008		
Passageway	Layer 3; "from the bottom of the archaeological layer"	A. Glory	1958	Charcoal	Groningen	GrN-1632	17,190 \pm 135	21,136-20,378 \pm 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	Sa-102	16,100 \pm 500	20,725-18,389	16,000 \pm 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	7,550 \pm 650	10,193-7,244	Submitted to dating in 1975 by Art. Leroi-Gourhan	1979	
Axial Gallery	Terminal Passage; "right above the Magdalenian layer"	Art. Leroi-Gourhan	1975	Charcoal	Lyon	Beta counting	Ly-1197	8,650 \pm 360	10,689-8,772	GfA-96682 in Glory et al., 2011;	Leroi-Gourhan and Evin, 1979	
Shaft	H. Breuil, S. Blanc, M. Bourgon	1948-1949	Antler Splitter produce with the GST	LSX 17*	Gif-sur-Yvette	AMS	GfA-95582	18,600 \pm 190	22,926-21,995	Described as a "fragment of antler splitter" in Aujoüat et al., 1998	Aujoüat et al., 1998	
Shaft	H. Breuil, S. Blanc, M. Bourgon	1948-1949	Antler Point	LSX 15* or LSX 20*	Gif-sur-Yvette	AMS	GfA-101110	18,930 \pm 230	23,421-22,385	Described as a point with longitudinal groove in Aujoüat et al., 1998; "Asagai bone" in Valadas et al., 2013	Valadas et al., 2013	
Passageway	Gour C	D. Genty et al.	2011	Charcoal	Gif-sur-Yvette	AMS	GfA-09457	6,454 \pm 80	7,558-7,181	"spear bone" in Valadas et al., 2013	Genty et al., 2011	
Passageway	Gour C	D. Genty et al.	2011	Charcoal	Gif-sur-Yvette	AMS	GfA-09458	6,464 \pm 35	7,439-7,308	9,2 cm above the Gour C	Genty et al., 2011	
Passageway	Gour C	D. Genty et al.	2011	Charcoal	Gif-sur-Yvette	AMS	GfA-09455	6,098 \pm 35	7,985-7,735	3,7 cm above the Gour C	Genty et al., 2011	
Passageway	Gour C	D. Genty et al.	2011	Organic matter	Saclay	AMS	GfA-09456	6,639 \pm 50	7,985-7,436	19 cm above the Gour C	Genty et al., 2011	
Passageway	Gour C	D. Genty et al.	2011	Organic matter	Saclay	AMS	SaCA-16006	7,063 \pm 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	7,970 \pm 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 \pm 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 \pm 35	7,922-7,695	19 cm above the Gour C	Genty et al., 2011	

— TABLEAU 1 —

Récapitulatif de l'ensemble des mesures ^{14}C obtenues à Lascaux entre 1951 et 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).

**FIGURE 1**

A sixty-year story: summary of the 1951-2011 ^{14}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}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).

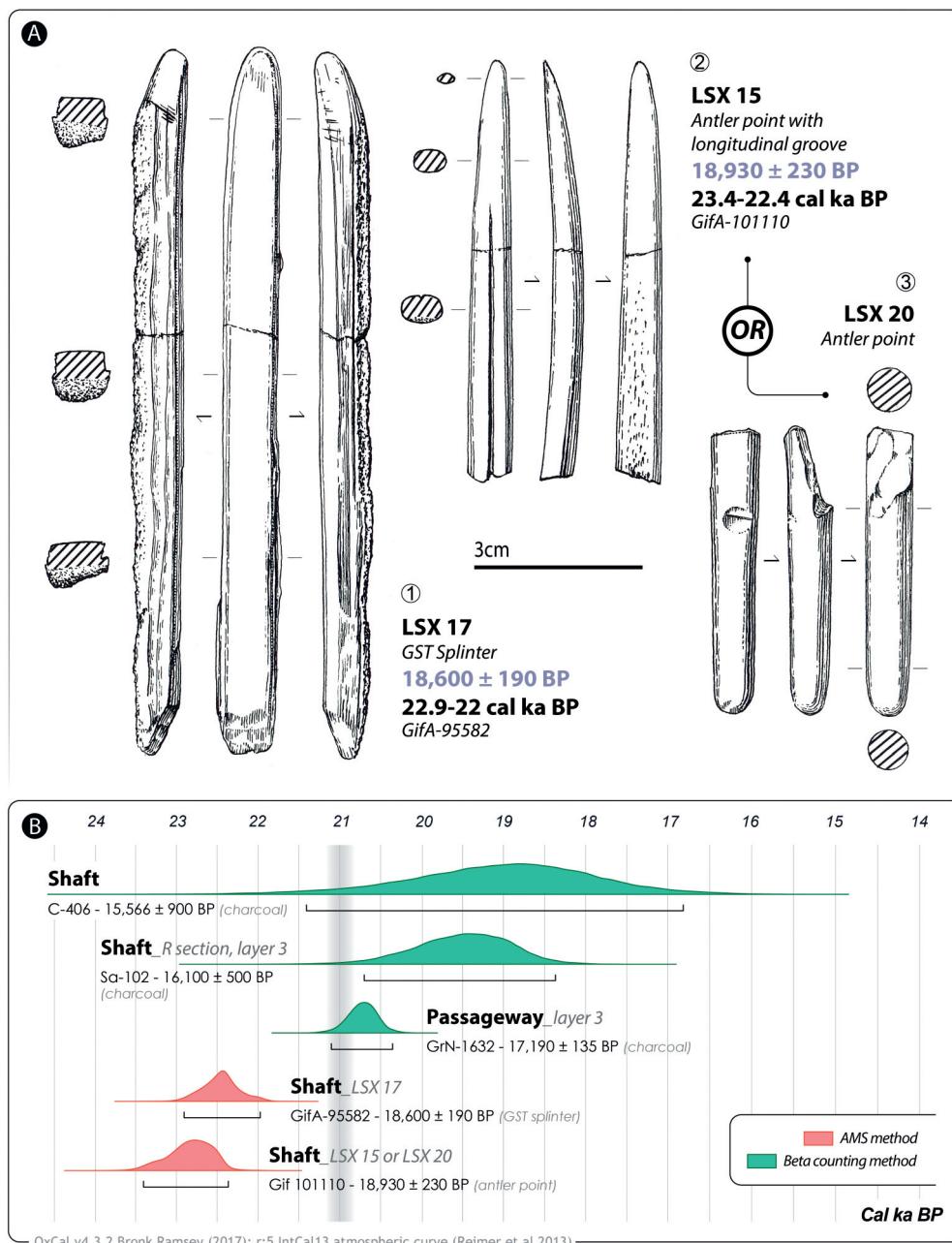
Gallery area (**fig. 1**), “right above the Magdalenian layer” (Leroi-Gourhan 1979 - p. 71), were sent to J. Evin to be dated at the CDRC Laboratory in Lyon. These samples gave two Mesolithic-like ages (Ly 1196: $7,510 \pm 650$ BP for the “Upside-down Horse”; Ly 1197: $8,660 \pm 360$ BP for the Terminal Passage) that were similar to previous ages obtained from different parts of the cave entrance (see above). Non-anthropic 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 ; Pétillon 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)², 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: $18,600 \pm 190 \text{ BP}$ and GifA 101110³: $18,930 \pm 230 \text{ BP}$; 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 is 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 ($18,600 \pm 190 \text{ BP}$ 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 ^{14}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 ^{14}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 nonexistent 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 $18,640 \pm 71$ BP or $22.7-22.3$ cal ka BP and $18,730 \pm 110$ 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 ^{14}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 project⁴). 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 Plénioglaïa ? 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; Vannoorenbergh 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) (Vannoorenbergh 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 -C²"; 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 recording⁵, 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 MIInI CArbon DAting System (MICADAS: e.g. Fewlass *et al.* 2018; E. Henderson, personal communication).

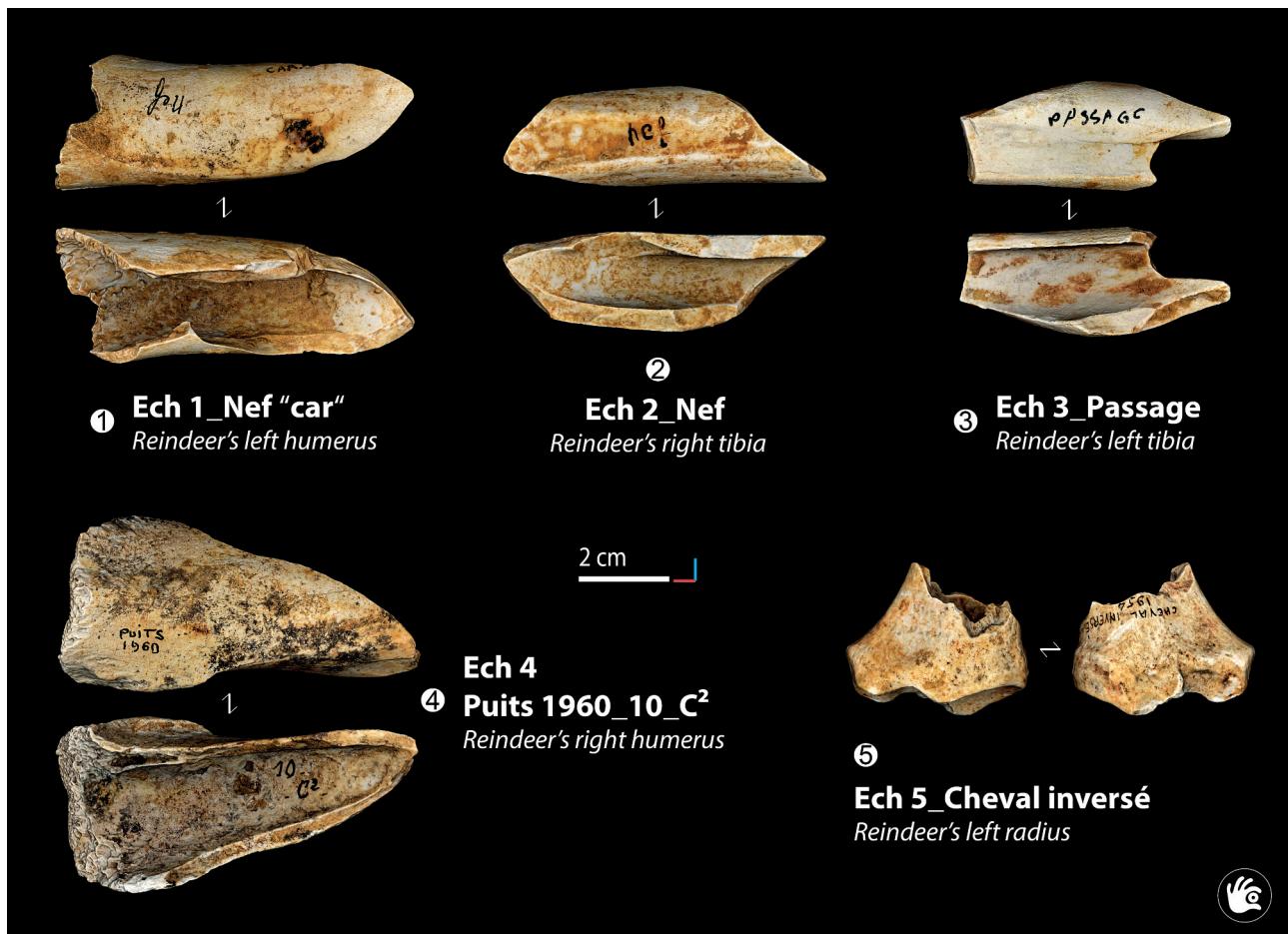
4 | RESULTS AND DISCUSSION

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 inverse") 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). 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 $17,600 \pm 90$ uncal. BP). These results provide striking confirmation of the consistency of the two tested hypotheses are reminiscent of the initial ^{14}C framework available notably for the Passageway-layer 3 ($17,190 \pm 135$ 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 ^{14}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 ^{14}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; infography 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)⁶. 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 hypothetic 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 ¹⁴C 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.

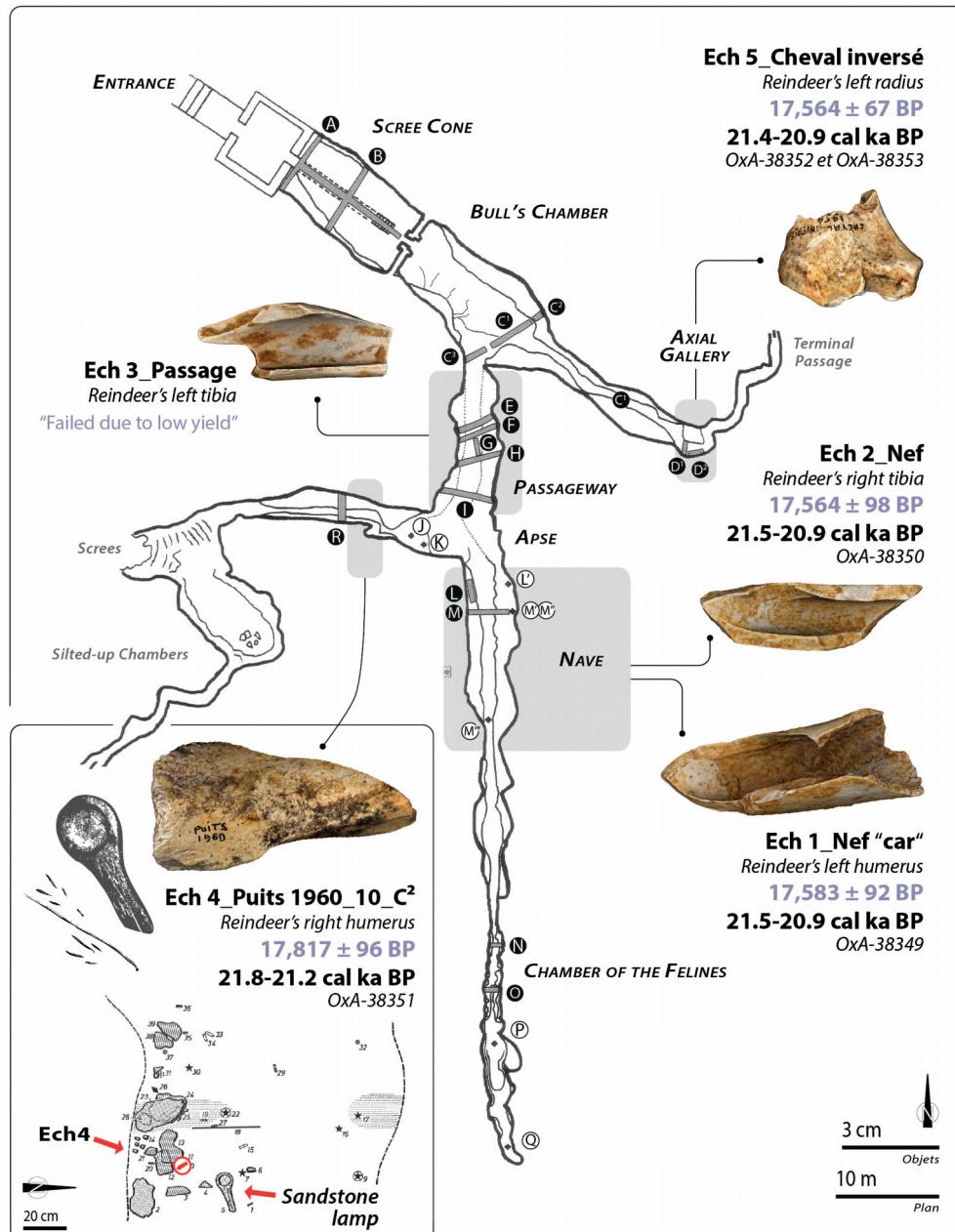


FIGURE 4

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 ² -	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>							<i>17,564 ± 67</i>	<i>21,486-20,966</i>

— 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).

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**)⁷. As Lassac, Aude (Sacchi 1986 ; Ducasse 2010 ; Pétillon and Ducasse 2012), La Contrée-Viallet, Allier (Lafarge 2014) or Casserole, Dordogne (Ducasse *et al.* submitted)⁸ show, the very end of the *raclette*-yielding Badegoulian can currently be set around $17,500 \pm 100$ 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 $17,100 \pm 100$ 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

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).

obtained for the Lascaux assemblages (**fig. 6**; Pétillon 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; Pétillon *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 ($17,817 \pm 96$ uncal. BP : 21.8-21.2 cal ka BP; **fig. 4**)⁹.

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 typotechnological 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 typotechnological 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 ¹⁴C essays, this new dating program provides a series of highly coherent ages that could

[7] The selection of AMS ¹⁴C 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.

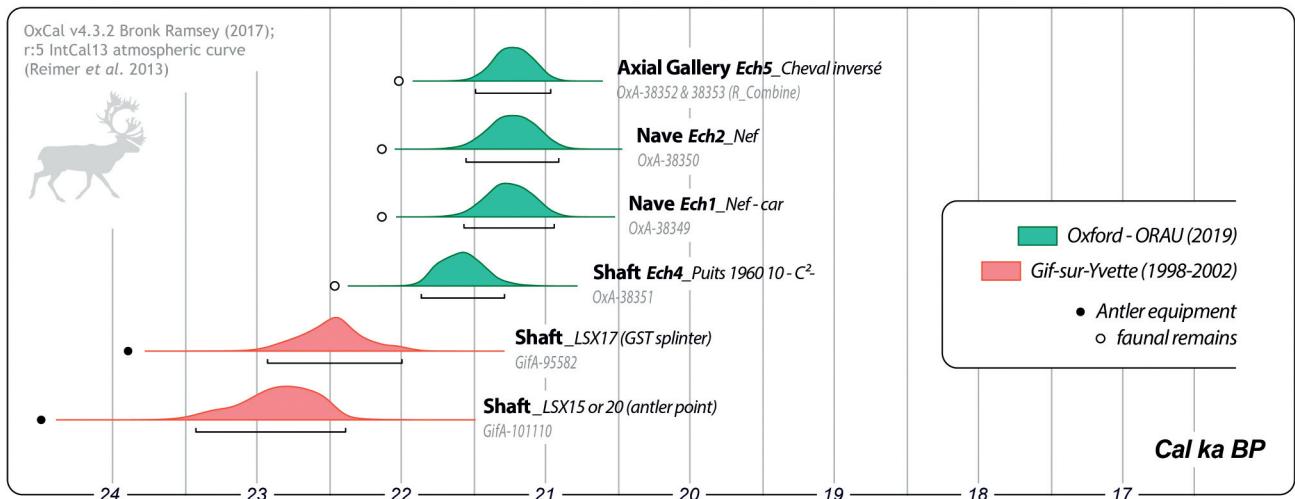
[9] Note that layer 3A from Solvieux is also known for his famous engraved stone slab showing incomplete figurative elements (horse and cervid; Gaussen and Sackett 1984), whose style is often compared to the norms described at Lascaux or Gabillou, notably in the way the hoofs are represented (e.g. Clottes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

Sample code	Lab code	Used (mg)	Yield (mg)	%Yield	Excess (mg)	%C	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	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 ^{14}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	$17,480 \pm 180$	$21,644-20,635$	Ly-2484 (Poz)	$16,538 \pm 144$	$20,328-19,579$
Gandil	25	Lower Magdalenian	bone	GifA-97307	$17,290 \pm 180$	$21,409-20,418$	Ly-2485 (Poz)	$16,507 \pm 144$	$20,287-19,553$

— 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,

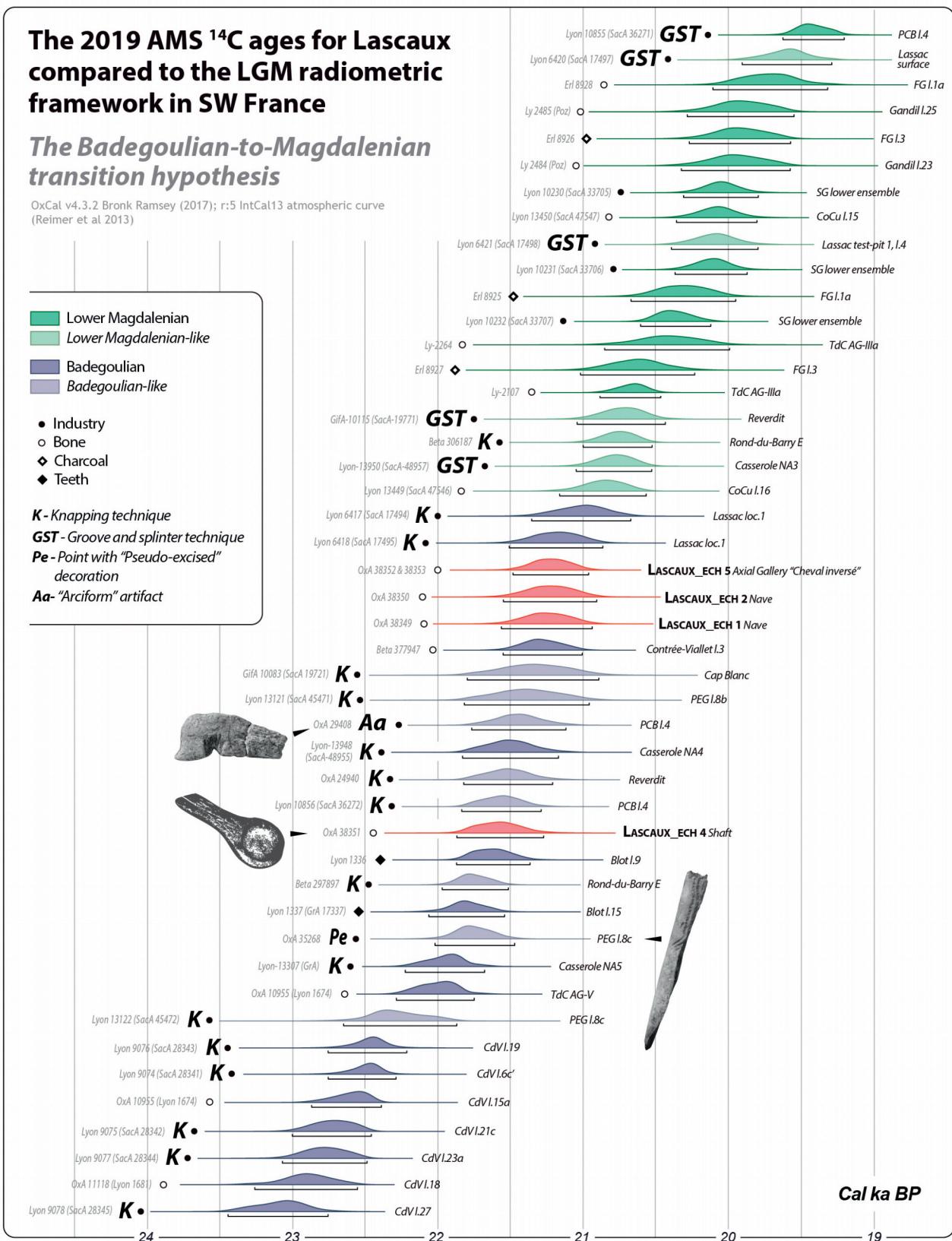
J. Jacquier and M. Langlais), two more dating programs are already planned. The next one can be performed in the short-term and will concern, as far as possible, other faunal remains corresponding to (1) secondary Paleolithic-like species (horse, red deer) and (2) postglacial-like species (deer, boar 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	Calibrated age (BP) [BP, 2 _o]	Uncalibrated age (BP)	References
Biot	15	Late Badegoulian	J8 15-41	Teeth	-	Gra-17337 (Lyon-1337)	18,000 ± 80	22,095-22,543	BANADORA; Banks et al. 2019
Biot	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	GifA-10083 (Saa-4921)	17,640 ± 160	20,908-20,895	Bourdié et al. 2011	
Casseneole	NA3	Late Magdalenian-like	L15 41- effet de paroi	Antler	Lyon-1-3950 (Saa-48957)	17,230 ± 90	21,050-20,331	Ducasse et al. submitted	
Casserolle	NA4	Late Badegoulian	O14b #1	Antler	Lyon-1-3948 (Saa-48955)	17,760 ± 100	21,830-21,170	Ducasse et al. submitted	
Casserolle	NA5	Late Badegoulian	I25 n°34	Antler	22,124 ± 678	Ducasse et al. submitted			
Combe Culier	15	Lower Magdalenian/LDDM industry	I25 n°475	Bone	Lyon-1-3450 (Saa-47547)	16,640 ± 90	20,361-19,808	Langlais et al. 2018	
Combe Culier	16	Lower Magdalenian/LDDM industry	I25 n°9	Bone	Lyon-1-3449 (Saa-47546)	17,290 ± 100	21,165-20,570	Langlais et al. 2018	
Contrié-Vaillat	3	Late Badegoulian	-	Bone	Beta-377947	17,610 ± 70	21,554-21,009	Lafarge 2014	
Cuzoul de Vers	6c'	Late Badegoulian	C724 KA n°289	Antler	Lyon-9074 (Saa-28341)	18,620 ± 100	22,757-22,290	Ducasse et al. 2014	
Cuzoul de Vers	15a	Late Badegoulian	C725 DS n°230	Bone	Oka-10974 (Lyon-1676)	18,730 ± 100	22,871-22,391	Ducasse et al. 2014	
Cuzoul de Vers	18	Carré E5	-	Bone	Oka-11118 (Lyon-1681)	19,020 ± 110	22,262-22,355	Oberlin and Valladas 2012	
Cuzoul de Vers	19	Late Badegoulian	C723 D4 n°1772	Antler	Lyon-9075 (Saa-28343)	18,590 ± 110	22,572-22,216	Ducasse et al. 2014	
Cuzoul de Vers	21c	Late Badegoulian	C725 J4 n°1555	Antler	Lyon-9076 (Saa-28342)	18,860 ± 110	23,003-24,460	Ducasse et al. 2014	
Cuzoul de Vers	23a	Lower Badegoulian	C726 IS n°636	Antler	Lyon-9077 (Saa-28344)	18,920 ± 110	23,072-22,489	Ducasse et al. 2014	
Cuzoul de Vers	27	Lower Badegoulian	C726 DS n°1192	Antler	Lyon-9078 (Saa-28345)	19,150 ± 110	23,446-22,757	Ducasse et al. 2014	
Fongrasse	-	Lower Badegoulian	-	Charcoal	Er-8925	16,838 ± 143	20,674-19,955	Bazile 2006	
Fongrasse	1a	Lower Badegoulian	-	Burnt bone	Er-8928	16,338 ± 153	20,111-19,322	Bazile 2006	
Fongrasse	1a	Lower Badegoulian	-	Charcoal	Er-8926	16,518 ± 133	20,274-19,577	Bazile 2006	
Fongrasse	3	Lower Badegoulian	-	Charcoal	Er-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	20,357-19,553	Jaubert 2013	
Lassac	Iocus 1	M6 CK rel 6	Antler	Antler	Lyon-6417 (Saa-17494)	17,400 ± 110	21,357-20,676	Pétillon and Ducasse 2012	
Lassac	Iocus 1	W section	Antler	Antler	Lyon-6418 (Saa-17495)	17,530 ± 100	21,512-20,868	Pétillon and Ducasse 2012	
Lassac	Test pit 1, layer 4	Surface survey collections	Antler	Antler	Lyon-6420 (Saa-17497)	16,230 ± 100	19,910-19,293	Pétillon and Ducasse 2012	
Pégourie	8b	Lower Magdalenian-like	Peg 257 c8b K5 3764	Antler	Lyon-6421 (Saa-17498)	16,650 ± 100	20,396-19,900	Pétillon and Ducasse 2012	
Pégourie	8c	Late Badegoulian-like	Peg 283 c8c K6 3475	Antler	Lyon-13121 (Saa-45471)	17,680 ± 150	21,821-20,961	Ducasse et al. 2019	
Pégourie	8c	Late Badegoulian-like	Peg 341 K6 4312	Antler	Lyon-13122 (Saa-45472)	18,440 ± 170	22,651-22,872	Ducasse et al. 2019	
Petit Clou Barrat	4	PCB06 Q716 d1 n°278	Antler	Decorated single beveled point using the "pseudo-excise" technique	Oxa-35268	17,950 ± 90	22,019-21,469	Ducasse et al. 2019	
Petit Clou Barrat	4	PCB08 R70D 83 n°91	Antler	GST splinter	Lyon-10855 (Saa-36271)	16,100 ± 70	19,629-19,208	Chauvière et al. 2017	
Petit Clou Barrat	4	PCB08 P72A d20 n°680	Antler	Antler	Lyon-10856 (Saa-36272)	17,800 ± 80	21,838-21,292	Chauvière et al. 2017	
Reverdit	-	Lower Magdalenian-like	Peg 283 c8c K6 3475	Antler	Oxa-35268	17,950 ± 90	21,770-21,122	Bourdier et al. 2017	
Rond-du-Barry	E	Late Badegoulian-like	J13-1	Antler	GifA-10115 (Saa-19771)	17,180 ± 110	21,043-20,437	Bourdier et al. 2011	
Rond-du-Barry	E	Lower Magdalenian-like	G13-42	Antler	Oxa-24940	17,770 ± 90	21,875-21,213	Remy 2013; Raynal et al. 2014	
Saint-Germain-la-Rivière	-	Lower ensemble	-	Antler	Beta-3073-2517	17,960 ± 70	21,973-21,517	Remy 2013; Raynal et al. 2014	
Saint-Germain-la-Rivière	-	Lower ensemble	-	Antler	Beta-306-187	17,210 ± 80	21,003-20,529	Barshay-Smidt et al. 2016	
Le Taillis-des-Coteaux	-	Lower Magdalenian	-	Osseous industry	Lyon-10230 (Saa-33705)	16,620 ± 80	20,313-19,799	Barshay-Smidt et al. 2016	
Le Taillis-des-Coteaux	-	Lower Magdalenian	-	Osseous industry	Lyon-10231 (Saa-33706)	16,670 ± 80	20,371-19,875	Barshay-Smidt et al. 2016	
Le Taillis-des-Coteaux	-	Lower Magdalenian	-	Osseous industry	Lyon-10232 (Saa-33707)	16,900 ± 80	20,608-20,125	Primault et al. 2007; Primault 2010	
Le Taillis-des-Coteaux	-	Lower Magdalenian	-	Osseous industry	Lyon-12180 (Lyon-2107)	16,920 ± 170	20,853-19,992	Primault et al. 2007; Primault 2010	
Le Taillis-des-Coteaux	-	Lower Magdalenian	-	Osseous industry	Oka-12180 (Lyon-2107)	17,130 ± 65	20,885-20,466	Primault et al. 2007; Primault 2010	
Le Taillis-des-Coteaux	-	Lower Magdalenian	-	Osseous industry	Lyon-2639	18,140 ± 85	22,285-21,750	Primault et al. 2007; Primault 2010	

— TABLEAU 5 —

Selection of AMS ¹⁴C dates covering the currently admitted Badegoulian and Lower Magdalenian time span, used in Fig. 6 (MSU: medium-sized ungulate; GST: groove-and-splinter technique). Calibration was carried out with the Oxcal program (V4.32; Bronk Ramsey 2017) using the IntCal13 calibration curve (Reimer et al. 2013).

Sélection de datations par SMA couvrant l'intervalle chronologique aujourd'hui admis pour le Badegoulien et le Magdalénien inférieur (cf. fig. 6 ; MSU : ongulé de taille moyenne ; GST : double rainure).



— FIGURE 6 —

The 2019 AMS ^{14}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: Pégourie; 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!

ACKNOWLEDGEMENTS

This research was carried out as part of the LAsCO and DEX_TER projects, both coordinated by the authors and funded by the Direction Régionale des Affaires Culturelles de Nouvelle Aquitaine (French Ministry for Culture) and the LabEx Cluster of Excellence "LaScArBx" (ANR-10-LABX-52). We are grateful to Jean-Jacques Cleyet-Merle, director of the MNP, for granting us access to the Lascaux collections and to Catherine Cretin for ensuring the best possible study conditions. We would like to thank Le Bugue Town Hall for delegating the responsibility for the Glory collection to the MNP, including the dated artifacts. We would also like to thank Stéphane Madelaine for his helpful advice and availability during the sample selection phase. Many thanks to Xavier Muth for the bone pictures derived from the 3D photogrammetric models and to Brigitte Delluc and Valérie Feruglio for providing us with highly valuable information about the previous ^{14}C dating programs. Our sincere thanks to Aitor Ruiz-Redondo for his last minute proofreading and to William Banks for his linguistic help. We would like to thank Emma Henderson, Thomas Higham and staff from the ORAU laboratory. Lastly, we are grateful to the four reviewers for their very useful and constructive suggestions that helped us to improve the initial manuscript.

REFERENCES

- ALLAIN J. 1979 - L'industrie lithique et osseuse de Lascaux, *In* : Arl. Leroi-Gourhan, J. Allain (Eds.), *Lascaux inconnu*, XII^e supplément à *Gallia Préhistoire*. Paris : Ed. du CNRS, p. 87-120.
- ARNOLD J.R., LIBBY W.F. 1951 - Radiocarbon Dates. *Science*, 113, 2927, p. 111-120.
- AUJOULAT N. 2002 - *Lascaux, le rôle du déterminisme naturel : des modalités d'élection du site aux protocoles de construction des édifices graphiques pariétaux*, Thèse de Doctorat, Université de Bordeaux I, 594 p.
- AUJOULAT N. 2004 - *Lascaux. Le geste, l'espace et le temps*. Paris : Ed. du Seuil, collection « Arts rupestres », 274 p.
- AUJOULAT N., CLEYET-MERLE J.-J., GAUSSEN J., TISNERAT N. et VALLADAS H. 1998 - Approche chronologique de quelques sites ornés paléolithiques du Périgord par datation Carbone 14, en spectrométrie de masse par accélérateur, de leur mobilier archéologique. *Paleo*, 10, p. 319-323.
- BANKS W.E., BERTRAN P., DUCASSE S., KLARIC L., LANOS P., RENARD C., MESA M. 2019 - An application of hierarchical Bayesian modeling to better constrain the chronologies of Upper Paleolithic archaeological cultures in France between ca. 32,000–21,000 calibrated years before present. *Quaternary Science Reviews*, 220, p. 188-214.
- BARSHAY-SZMIDT C., COSTAMAGNO S., HENRY-GAMBIER D., LAROULANDIE V., PÉTILLON J.-M., BOUDADI-MALIGNE M., KUNTZ D., LANGLAIS M., MALLYE J.-B. 2016 - New extensive focused AMS ^{14}C dating of the Middle and Upper Magdalenian of the western Aquitaine/Pyrenean region of France (ca. 19–14 ka cal BP): Proposing a new model for its chronological phases and for the timing of occupation. *Quaternary International*, 414, p. 62-91.
- BAZILE F. 2006 - Datations du site de Fontgrasse (Vers-Pont-du-Gard, Gard). Implications sur la phase ancienne du Magdalénien en France méditerranéenne. *Bulletin de la Société préhistorique française*, 103, p. 597-625.
- BEAUNE S.A. (de). 1987 - *Lampes et godets au paléolithique*. XII^e supplément à *Gallia Préhistoire*, Paris : Ed. du CNRS, 278 p.
- BEAUNE S.A. (de), ROUSSOT A., SACKETT J. 1986 - Les lampes de Solvieux (Dordogne). *L'Anthropologie*, 90, 1, p. 107-119.
- BOUCHUD J. 1979 - La faune de la grotte de Lascaux, *In* : Leroi-Gourhan Arl., Allain J. (Dir.), *Lascaux inconnu*, XII^e supplément à *Gallia Préhistoire*, Paris : Ed. du CNRS, p. 147-152.
- BOURDIER C., PÉTILLON J.-M., CHEHMANA L., VALLADAS H. 2014 - Contexte archéologique des dispositifs pariétaux de Reverdit et de Cap-Blanc : nouvelles données, *In* : P. Paillet (Dir.), *Les arts de la Préhistoire : micro-analyses, mises en contexte et conservation*, Actes du colloque « Micro-analyses et datations de l'art préhistorique dans son contexte archéologique », MADAPCA, Paris (16-18 novembre 2011), p. 285-294, (Paleo, numéro spécial).
- BREUIL H. 1950 - Lascaux. *Bulletin de la Société préhistorique française*, 47, 6, p. 355-363.
- BREUIL H. 1952 - 400 siècles d'art pariétal : les cavernes ornées de l'âge du renne, Montignac : Centre d'Etudes et de Documentation Préhistoriques, 419 p.
- BREUIL H. 1954 - Les datations par C14 de Lascaux (Dordogne) et Philip Cave (S. W. Africa). *Bulletin de la Société préhistorique française*, 51, 11, p. 544-549.
- BROCK F., HIGHAM T., DITCHFIELD P., BRONK RAMSEY C. 2010 - Current pretreatment methods for AMS radiocarbon dating at the Oxford Radiocarbon Accelerator Unit (ORAU). *Radiocarbon*, 52, 1, p. 103-112.
- BRONK RAMSEY C. 2009 - Bayesian Analysis of Radiocarbon Dates. *Radiocarbon*, 51, 1, p. 337-360.
- BRONK RAMSEY C. 2017 - *OxCal 4.3 manual*, 2017 http://c14.arch.ox.ac.uk/oxcalhelp/hlp_contents.html.
- BRYANT C., CARMI I., COOK G.T., GULLIKSEN S., HARKNESS D., HEINEMEIER J., MCGEE E., NAYSMITH P., POSSNERT G., SCOTT E.M., VA J., VA M. 2001 - Is Comparability Of ^{14}C Dates An Issue? A Status Report On The Fourth International Radiocarbon Intercomparison. *Radiocarbon*, 43, p. 321-324.
- CERSOY S., ZAZZO A., ROFES J., TRESSET A., ZIRAH S., GAUTHIER C., KALTNECKER E., THIL F., TISNERAT-LABORDE N. 2017 - Radiocarbon dating minute amounts of bone (3-60 mg) with ECHoMICADAS. *Scientific Reports*, 7, 7141. <https://www.nature.com/articles/s41598-017-07645-3.pdf>

- CHALMIN E., MENU M., POMIES M.-P., VIGNAUD C., AUJOULAT N., GENESTE J.-M. 2004 - Les blasons de Lascaux. *L'Anthropologie*, 108, 5, p. 571-592.
- CHAUVET J.-M., BRUNEL DESCHAMPS E., HILLAIRE C. 1995 - *La grotte Chauvet à Vallon Pont-d'Arc*. Paris : Ed. du Seuil, 118 p.
- CHAUVIÈRE F.-X., CASTEL J.-C., DUCASSE S., LANGLAIS M., RENARD C. 2017 - L'attribution chronoculturelle des « objets arciformes » du Paléolithique supérieur : apports de la datation directe de l'ébauche du Petit Clou Barrat (Cabrerets, Lot, France) et discussion autour de l'hypothèse badegoulienne. *Bulletin de la Société préhistorique française*, 114, 4, p. 619-635.
- CLOTTES J., GIRAUD J.-P., SERVELLE C. 1986 - Un galet gravé Badegoulien à Vers (Lot). *Estudios en Homenaje al Dr Antonio Beltran Martinez*, p. 61-84.
- CLOTTES J., CHALARD P., GIRAUD J.-P. 2012 - *Solutréen et Badegoulien au Cuzoul de Vers : des chasseurs de rennes en Quercy*. Liège : Etudes et recherches archéologiques de l'Université de Liège, E.R.A.U.L., 131, 488 p.
- DEBOUT G., OLIVE M., BIGNON O., BODU P., CHEHMAMA L., VALENTIN B. 2012 - The Magdalenian in the Paris Basin: New results. *Quaternary international*, 272-273, p. 176-190.
- DELLUC B., DELLUC G. 2008 - Les recherches d'André Glory à Lascaux (1952-1963), In : A. Glory (Dir.), *Les recherches à Lascaux (1952-1963). Documents recueillis et présentés par Brigitte et Gilles Delluc*, XXXIX^e supplément à *Gallia Préhistoire*, Paris : Ed. du CNRS, p. 9-21.
- DELLUC B., DELLUC G. 2012 - De quand date Lascaux ? *Bulletin de la Société historique et archéologique du Périgord*, 139, 3, p. 375-400.
- DUCASSE S. 2010 - La « parenthèse » badegoulienne : fondements et statut d'une discordance industrielle au travers de l'analyse techno-économique de plusieurs ensembles lithiques méridionaux du Dernier Maximum Glaciaire, Thèse de Doctorat, Université de Toulouse 2, 460 p.
- DUCASSE S., CASTEL J.-C., CHAUVIÈRE F.-X., LANGLAIS M., CAMUS H., MORALA A., TURQ A. 2011 - Le Quercy au cœur du dernier maximum glaciaire. *Paleo*, 22, p. 101-154.
- DUCASSE S., PÉTILLON J.-M., RENARD C. 2014 - The radiometric framework of the Solutrean and Badegoulian sequence of Le Cuzoul de Vers (Lot, France): critical view and new data. *Paleo*, 25, p. 37-58.
- DUCASSE S., PÉTILLON J.-M., CHAUVIÈRE F.-X., RENARD C., LACRAMPE-CUYAUBÈRE F., MUTH X. 2019 - Archaeological recontextualization and first direct ^{14}C 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. *Journal of Archaeological Science: Reports*, 23, p. 592-616.
- DUCASSE S., RENARD C., BAUMANN M., CASTEL J.C., CHAUVIÈRE F.-X., PESCHAUX C., PÉTILLON J.-M. (in press) - Pour une palethnologie du pauvre : apport des séquences du Sud-Ouest de la France à la définition des comportements techno- et socio-économiques lors de la transition solutréo-badegoulienne. In : C. Montoya, C. Paris, P. Bodu (Ed.), *Palethnologie du Paléolithique supérieur ancien: où en sommes-nous ? Actes du XXVIII^e congrès préhistorique de France d'Amiens, Préhistoire de l'Europe du nord-ouest : mobilité, climats et entités culturelles* (30 mai-4 juin 2016). Amiens. (Mémoire de la Société préhistorique française).
- DUCASSE S., PÉTILLON J.-M., AUBRY T., CHAUVIÈRE F.-X., CASTEL J.-C., DETRAIN L., LANGLAIS M., MORALA A., BANKS W.E., LENOBLE A. (submitted) - The Abri Casserole (Dordogne, France): Reassessing the ^{14}C Chronology of a key Upper Paleolithic Sequence in Southwestern France, *Radiocarbon*.
- D'ERRICO F., SANCHEZ-GONI M.F., VANHAEREN M. 2005 - L'impact de la variabilité climatique rapide des OIS3-2 sur le peuplement de l'Europe, In : E. Bard (Dir.), *L'Homme face au climat*, Paris : Ed. Odile Jacob, p. 265-282.
- EVIN J., OBERLIN C. 2000 - Les développements récents en datation par le radiocarbone pour l'archéologie, In : J.-N. Barrandon, P. Guibert, V. Michel (Dir.), *Datations, actes des XXI^e rencontres d'archéologie et d'histoire d'Antibes* (19-21 octobre 2000), Antibes, APDCA, p. 81-91.
- FEWLASS H., TALAMO S., TUNA T., FAGAULT Y., KROMER B., HOFFMANN H., PANGRAZZI C., HUBLIN J.-J., BARD E. 2018 - Size matters: Radiocarbon Dates of <200 µg Ancient Collagen Samples with AixMICADAS and Its Gas Ion Source. *Radiocarbon*, 60, 2, p. 425-439.
- GAUSSEN J., SACKETT J. 1984 - La pierre gravée de Solvieux. *L'Anthropologie*, 88, 4, p. 655-660.
- GENESTE J.-M. 2002 - Éléments pour une contribution intégrée des datations par le radiocarbone aux problématiques de l'archéologie paléolithique, In : *Archéologie, patrimoine culturel et datation par le carbone 14 par spectrométrie de masse par accélérateur*, Centre de Recherche et de Restauration des Musées de France, le 22 mars 2002, p. 29-34.
- GENESTE J.-M. 2010 - Le Solutréen, In : Clottes J. (Dir.), *La France préhistorique. Un essai d'Histoire*. Paris : Ed. Gallimard, NRF Essais, p. 170-201.
- GENTY D., KONIK S., VALLADAS H., BLAMART D., HELLSTROM J., TOUMA M., MOREAU C., DUMOULIN J.-P., NOUET J., DAUPHIN Y., WEIL R. 2011 - Dating the Lascaux cave gour formation. *Radiocarbon*, 53, 3, p. 479-500.
- GLORY A. 1961 - Le brûloir de Lascaux. *Gallia Préhistoire*, 4, 1, p. 174-183.
- GLORY A. 1964 - Datation des peintures de Lascaux par le Radio-Carbone. *Bulletin de la Société préhistorique française*, 61, 5, p. 114-117.
- GLORY A. 2008 - *Les recherches à Lascaux (1952-1963). Documents recueillis et présentés par Brigitte et Gilles Delluc*. XXXIX^e supplément à *Gallia Préhistoire*, Paris : Ed. du CNRS, 204 p.

JAUBERT J. 2008 - L'« art » pariétal gravettien en France : éléments pour un bilan chronologique, In : J.-P. Rigaud (Dir.), *Le Gravettien : entités régionales d'une paléoculture européenne. 3 – Pratiques funéraires et art gravettiens*. Actes de la table ronde des Eyzies (juillet 2004), p. 439-474, (*Paleo*, 20).

JAUBERT J. 2013 - Le Quercy pléistocène : région à peuplement continu depuis 0,3 Ma ? Archéo-stratigraphies et datations radiométriques. In : M. Jarry, P. Brugal, C. Ferrier (Dir.), *Modalités d'occupation et exploitation des milieux au Paléolithique dans le Sud-Ouest de la France : l'exemple du Quercy*. Actes de la session C67 du XVème Congrès de l'UISPP, Lisbonne (septembre 2006), p. 67-106, (supplément à *Paleo*, n° 4).

LACANETTE D., MALAURENT P. 2015 – Simulation of the microclimate in an archaeological cave (Lascaux, France), In : Proceedings of the CHT-15. ICHMT 6th International Symposium on Advances in Computational Heat Transfer (25-29 may 2015), Rutgers University, p. 1418-1421.

LACANETTE D., MALAURENT P., CALTAGIRONE J.-P., BRUNET J. 2007 – Étude des transferts de masse et de chaleur dans la grotte de Lascaux : le suivi climatique et le simulateur. *Karstologia*, 50, p. 19-30.

LAFARGE A. 2014 - *Entre plaine et montagne : techniques et cultures du Badegoulien du Massif central, de l'Allier au Velay*. Thèse de doctorat, Université de Montpellier, 686 p.

LANGLAIS M. 2010 - *Les sociétés magdalénienes de l'isthme pyrénéen*, Paris : Ed. du CTHS (coll. Documents préhistoriques, 26), 337 p.

LANGLAIS M., LADIER E., CHALARD P., JARRY M., LACRAMPE-CUYAUBERE F. 2007 - Aux origines du Magdalénien « classique » : les industries de la séquence inférieure de l'Abri Gandil (Bruniquel, Tarn-et-Garonne). *Paleo*, 19, p. 341-366.

LANGLAIS M., PETILLON J.-M., ARCHAMBAULT DE BEAUNE S., CATTELAIN P., CHAUVIERE F.-X., LETOURNEUX C., SZMIDT C., BELLIER C., BEUKENS R., DAVID F. 2010 - Une occupation de la fin du Dernier Maximum glaciaire dans les Pyrénées : le Magdalénien inférieur de la grotte des Scilles (Lespugue, Haute-Garonne). *Bulletin de la Société préhistorique française*, 107, 1, p. 5-51.

LANGLAIS, M., LAROULANDIE V., COSTAMAGNO S., PETILLON J.-M., MALLYE J.-B., LACRAMPE-CUYAUBERE F., BOUDADI-MALIGNE M., BARSHAY-SZMIDT C., MASSET C., PUBERT E., RENDU W., LENOIR M. 2015 - Premiers temps du Magdalénien en Gironde. Réévaluation des fouilles Trécolle à Saint-Germain-la-Rivière (France). *Bulletin de la Société préhistorique française*, 112, 1, p. 5-58.

LANGLAIS M., SECHER A., LAROULANDIE V., MALLYE J.-B., PETILLON J.-M., ROYER A. 2018 – Combe-Cullier (Lacave, Lot) : une séquence oubliée du Magdalénien. Apport des nouvelles dates ^{14}C , *Bulletin de la Société préhistorique française*, 115, 2 (Actualités scientifiques, découvertes récentes), p. 385-389.

LANGLAIS M., DELVIGNE V., JACQUIER J., LENOBLE A., BEAUVIAL C., PESCHAUX C., ORTEGA FERNANDEZ A.M., LESVIGNES E., LACRAMPE-CUYAUBERE F., BISMUTH T., PESESSA, D. (in press) - Une nouvelle archéo-séquence pour le Magdalénien en Corrèze. Focus sur le Magdalénien moyen ancien de la grotte Bouyssonie (Brive-la-Gaillarde, Corrèze). *Paleo*, 30.

LEROI-GOURHAN A. 1971 - *Préhistoire de l'Art occidental*. Paris : Mazenod (édition 1978), 499 p.

LEROI-GOURHAN Arl. 1979 - La stratigraphie et les fouilles de la grotte de Lascaux, In : Arl. Leroi-Gourhan, J. Allain (Eds.), *Lascaux inconnu*, XIIème supplément à *Gallia Préhistoire*. Paris : Ed. du CNRS, p. 45-74.

LEROI-GOURHAN Arl., ALLAIN J. 1979 - *Lascaux inconnu*. XII^e supplément à *Gallia Préhistoire*, Paris : Ed. du CNRS, 379 p.

LEROI-GOURHAN Arl., EVIN J. 1979 - Les datations de Lascaux, In : Arl. Leroi-Gourhan, J. Allain (Eds.), *Lascaux inconnu*, XII^e supplément à *Gallia Préhistoire*. Paris : Ed. du CNRS, p.81-84.

LEROY-PROST C. 2008 - L'industrie sur matières dures animales, In : A. Glory (Dir.), *Les recherches à Lascaux (1952-1963). Documents recueillis et présentés par Brigitte et Gilles Delluc*, XXXIX^e supplément à *Gallia Préhistoire*, Paris : Ed. du CNRS, p.119-166.

MARTIN-SANCHEZ P. M., JURADO V., PORCA E., BASTIAN F., LACANETTE D., ALABOUVETTE C., SAIZ-JIMENEZ C. 2014 – Airborne microorganisms in Lascaux Cave (France). *International Journal of Speleology*, 43, 3, p. 295-303.

NOUGIER L.-R. 1963 - *La Préhistoire*. Paris : Bloud and Gay (coll. « Religions du monde »), 144 p.

OBERLIN C., VALLADAS H. 2012 - Datations par la méthode du carbone 14 des niveaux solutréens et badegouliens de l'abri sous roche du Cuzoul, In : J. Clottes, J.-P. Giraud, P. Chalard (Eds.), *Solutréen et Badegoulien au Cuzoul de Vers. Des chasseurs de rennes en Quercy*, Liège, Etudes et recherches archéologiques de l'Université de Liège, E.R.A.U.L., 131, p.79-84.

PÉTILLON J.-M., DUCASSE S. 2012 - From flakes to grooves: A technical shift in antlerworking during the last glacial maximum in southwest France. *Journal of Human Evolution*, 62, 4, p. 435-465.

PÉTILLON J.-M., LANGLAIS M., BEAUNE S.A. DE, CHAUVIERE F.-X., LETOURNEUX C., SZMIDT C., BEUKENS R., DAVID, F. 2008 - Le Magdalénien de la grotte des Scilles (Lespugue, Haute-Garonne). Premiers résultats de l'étude pluridisciplinaire de la collection Saint-Périer. *Antiquités Nationales*, 39, p. 57-71.

PETROGNANI S., SAUVET G. 2012 - La parenté formelle des grottes de Lascaux et de Gabillou est-elle formellement établie ? *Bulletin de la Société préhistorique française*, 109, 3, p. 441-455.

- PRIMAULT J. 2010 - La grotte du Taillis-de-Coteaux à Antigny (Vienne), In : J. Buisson-Catil, J. Primault (Eds.), *Préhistoire entre Vienne et Charente. Hommes et sociétés du Paléolithique*. Chauvigny : Association des publications chauvinoises, Mém. XXXVIII. Chauvigny, APC, p. 271-293.
- PRIMAULT J., GABILLEAU J., BROU L., LANGLAIS M., GUERIN S. 2007 - Le Magdalénien inférieur à microlamelles à dos de la grotte du Taillis des Coteaux à Antigny (Vienne, France). *Bulletin de la Société préhistorique française*, 104, 1, p. 5-30.
- PRIMAULT J., BROU L., BOUCHE F., CATTEAU C., GAUSSEIN P., GIOË A., GRIGGO C., HOUARD C., LE FILLATRE V., PESCHAUX C. (in press) - L'émergence du Magdalénien : rythme des changements techniques au cours du 18^e millénaire BP au Taillis des Coteaux (Antigny, Vienne, France), In : L.G. Straus, M. Langlais (Eds.), *Magdalenian phases in Cantabria and Aquitaine: What are we talking about?* Actes du XVIII^e congrès de l'UISPP, colloque XVII-2, Paris (Séances de la Société préhistorique française).
- RAYNAL J.-P., LAFARGE A., REMY D., DELVIGNE V., GUADELLI J.-L., COSTAMAGNO S., LE GALL O., DAUJEARD C., VIVENT D., FERNANDES P., LE CORRE-LE BEUX M., VERNET G., BAZILE F., LEFEVRE D. 2014 - Datations SMA et nouveaux regards sur l'archéo-séquence du Rond-du-Barry (Polignac, Haute-Loire). *Comptes Rendus Palevol*, 13, p. 623-636
- REMY D. 2013 - *Caractérisation techno-économique d'industries en bois de cervidés du Badegoulien et du Magdalénien : le cas du Rond-du-Barry (Haute-Loire) et de Rochereil (Dordogne)*, Thèse de Doctorat, Université de Montpellier 3, p. 358 p.
- SACCHI D. 1986 - *Le Paléolithique supérieur du Languedoc occidental et du Roussillon*. XXIème supplément à *Gallia Préhistoire*, Paris : Ed. du CNRS, 276 p.
- SACKETT J. 1999 - *The archaeology of Solvieux, an Upper Paleolithic open air site in France*. Los Angeles : UCLA Institute of Archaeology, (Monumenta Archaeologica, 19), 328 p.
- SUESS H.E. 1955 - Radiocarbon Concentration in Modern Wood. *Science*, 122, 3166, p. 415-417.
- TISNÉRAT-LABORDE N., VALLADAS H., KALTNECKER E., ARNOLD M. 2003 - AMS radiocarbon dating of bones at LSCE, *Radiocarbon*, 45, 3, p. 409-419.
- VALLADAS H., TISNÉRAT-LABORDE N., OBERLIN C. 2000 - Datation carbone 14 en spectrométrie de masse par accélérateur et archéologie, In : J.-N. Barrandon, P. Guibert, V. Michel (Dir.), *Datations, actes des XXIe rencontres d'archéologie et d'histoire d'Antibes* (19-21 octobre 2000), Antibes, APDCA, p. 81-91.
- VALLADAS H., KALTNECKER E., QUILÈS A., TISNÉRAT-LABORDE N., GENTY D., ARNOLD M., DELQUÉ-KOLIĆ E., MOREAU C., BAFFIER D., CLEYET-MERLE J.-J., CLOTTES J., GIRARD M., MONNEY J., MONTES R., SAINZ C., SANCHIDRIAN J.-L., SIMONNET R. 2013 - Dating French and Spanish Prehistoric Decorated Caves in Their Archaeological Contexts. *Radiocarbon*, 55, 2-3, p. 1422-1431.
- VALLADAS H., TISNERAT-LABORDE N., KALTNECKER E., ARNOLD M. 2014 - Datation par la méthode du carbone 14 en spectrométrie de masse par accélérateur des niveaux paléolithiques de l'abri Gandil. In : E. Ladier (Dir.), *L'abri Gandil à Bruniquel (Tarn-et-Garonne) : un campement magdalénien du temps de Lascaux*, Préhistoire du Sud-Ouest (supplément, n° 13), p. 91-92.
- VANNOORENBERGHE A. 2008 - Etude complémentaire du matériel osseux de Lascaux, In : A. Glory (Dir.), *Les recherches à Lascaux (1952-1963). Documents recueillis et présentés par Brigitte et Gilles Delluc*, XXXIX^e supplément à *Gallia Préhistoire*, Paris : Ed. du CNRS, p. 167-180.
- XU S., SIRIEIX C., FERRIER C., LACANETTE-PUYO D., RISS J., MALAURENT P. 2015 – A Geophysical Tool for the Conservation of a Decorated Cave. A Case study for the Lascaux Cave. *Archaeological Prospection* (wileyonlinelibrary.com). <https://doi.org/10.1002/arp.1513>