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## **Continuities and Discontinuities in the Human Settlement of the Aquitaine Basin between 19.5 cal. ka BP and 13.5 cal. ka BP: The Radiocarbon Evidence**

### ***Continuités et discontinuités dans le peuplement humain du Bassin aquitain entre 19,5 cal. ka BP et 13,5 cal. ka BP : les données radiocarbone***

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**Abstract:** Previous studies of Magdalenian <sup>14</sup>C dates (ca. 19.5-13.5 cal. ka BP) in the western Aquitaine basin have found a disparity in continuity of occupation between the northern part of this western basin (Gironde) and the southern part (western Pyrenees), with a lack of occupation in the northern part ca. 17.5-15.5 cal. ka BP (corresponding to the Late Middle Magdalenian), interpreted as a local depopulation episode triggered by environmental factors. Here we expand on that research to see whether this pattern holds on a wider geographic scale. We compiled a corpus of 373 <sup>14</sup>C AMS dates from the five sub-regions of the Aquitaine basin. Results confirm that other northern regions (Vienne and Charente) are also virtually devoid of occupation between 17.5 cal. ka BP and 15.5 cal. ka BP, and that the northeast of the basin (Dordogne and Lot) also shows a decline in the number of occupations at that same period, although we do evoke the possibility that this pattern might be due partly to sampling biases. Our results show that the western Pyrenees pattern of continuous occupation holds true also for the southeastern part of the basin (central Pyrenees). Other areas (Centre east) are more difficult to interpret, largely because of the lack of <sup>14</sup>C data. These findings lead us to reconsider some previously held tenets about the demography of the Aquitaine basin after the LGM: for instance, the role of the basin as a base for post-LGM population movements towards more northern regions of Europe; and the interpretation of some Pyrenean sites as “aggregation sites”. We end by proposing some avenues for further testing of these various scenarios.

**Keywords:** Aquitaine, Late Pleniglacial, Late Upper Paleolithic, Magdalenian, radiocarbon, settlement, southwestern France.

**Résumé :** Le Bassin aquitain a fréquemment été caractérisé comme une des régions d'Europe de l'Ouest présentant le peuplement le plus dense et le plus continu pendant et après le Dernier Maximum glaciaire. À l'échelle locale, des contrastes apparaissent cependant. Un projet portant sur le Magdalénien de l'ouest aquitain (projet Magdatis) a ainsi montré l'existence d'un peuplement magdalénien continu dans le piémont des Pyrénées occidentales, tandis que, de l'autre côté du Sable des Landes, les plaines de Gironde montraient

un hiatus documentaire entre 17,5 cal. ka BP et 15,5 cal. ka BP (Magdalénien moyen récent). Ce hiatus avait été interprété comme un épisode local de dépeuplement lié aux conditions environnementales rigoureuses du HS1a-b. L'objectif de cette étude est de prolonger ce travail en recherchant si un événement similaire peut être observé ailleurs dans le Bassin aquitain, en nous appuyant sur les données radiocarbone. Le Bassin aquitain a été divisé pour cela en cinq sous-régions (nord-ouest : nord de la Gironde, Charente et Vienne ; nord-est : Dordogne et Lot ; centre-est : Tarn, Tarn-et-Garonne, Lot-et-Garonne ; sud-est : Ariège, Haute-Garonne et Hautes-Pyrénées ; sud-ouest : Pyrénées-Atlantiques et sud des Landes). Les limites chronologiques de l'étude ont été fixées à 19,5 cal. ka BP et 13,5 cal. ka BP, soit la période s'étendant entre la transition du Magdalénien inférieur au Magdalénien moyen et le début de l'Azilien. Au total, 373 dates  $^{14}\text{C}$  ont été compilées de plusieurs sources (publications, base Banadora, littérature grise avec autorisation des auteurs), en excluant les dates provenant de contextes naturels et les dates non AMS. Des graphiques de dates calibrées ont été réalisés pour chaque sous-région, et des cartes de chaleur des sites magdaléniens dans le Bassin aquitain ont été dressées pour trois intervalles de deux mille ans : 19,5-17,5 cal. ka BP, 17,5-15,5 cal. ka BP et 15,5-13,5 cal. ka BP. Ce travail confirme l'extrême rareté des indices de présence humaine dans l'ensemble de la sous-région nord-ouest durant l'intervalle 17,5-15,5 cal. ka BP (trois dates sur trois sites, toutes discutables). Dans la sous-région nord-est, le nombre de sites (et de dates) est nettement réduit pendant ce même intervalle par rapport aux phases précédente et suivante : seulement quatre ensembles archéologiques et une sépulture. Les données de la sous-région centre-est sont difficiles à interpréter par manque de dates  $^{14}\text{C}$  en nombre suffisant. Enfin, le corpus de dates des sous-régions sud-est et sud-ouest confirme la continuité du peuplement magdalénien dans les Pyrénées centrales et occidentales, avec même une surreprésentation de l'intervalle 17,5-15,5 cal. ka BP, qui correspond à la phase d'occupation la plus intensive de plusieurs sites majeurs. Cette image contrastée est peut-être en partie due à des biais de conservation des sites et de fermeture des cavités, ou à un manque de datations pour certaines séquences importantes, en particulier dans le nord-est. Quoiqu'il en soit, ces résultats invitent à nuancer le rôle démographique du Bassin aquitain au Magdalénien : il est devenu possible d'envisager que, pendant une partie de cette période, ce bassin ait pu n'être qu'une marge de peuplement du monde magdalénien. La rareté relative des indices de peuplement humain dans le nord du bassin pendant l'intervalle 17,5-15,5 cal. ka BP pourrait également changer notre interprétation de certains caractères du Magdalénien des Pyrénées à cette période : la fréquence de certains objets spécifiques rares ailleurs dans le bassin, et l'intensité de fréquentation de certains gisements classiquement vus comme des sites d'agrégation pourraient ainsi être vues sous un nouvel éclairage. L'approfondissement de cette enquête nécessitera : l'enrichissement du corpus de dates  $^{14}\text{C}$  par AMS pour les régions nord-est et centre-est ; l'extension de la zone d'étude vers l'est (contreforts du Massif central) ; la comparaison avec les réseaux de circulation de matières premières, lithiques en particulier ; la comparaison avec les dates provenant de séquences naturelles dans la même région ; et une mise en parallèle plus fine des fluctuations de peuplement avec les changements environnementaux.

**Mots-clés :** Aquitaine, Magdalénien, Paléolithique supérieur récent, peuplement, Pléniglaciaire récent, radiocarbone, sud-ouest de la France.

Stretching over ca. 80,000 km<sup>2</sup> between the Armorican massif, the Massif central, the Pyrenees and the Atlantic, the Aquitaine basin is one of the two major sedimentary basins in France. Various referred to as “southwestern France”, “Aquitaine”, or “the French part of the Franco-Cantabrian region”, it was repeatedly characterized as one of the most densely and continuously populated areas in Western Europe during and after the Last Glacial Maximum (LGM; e.g. Bocquet-Appel *et al.*, 2005; French and Collins, 2015). This is due to its large number of Magdalenian sites, which yield a rich and seemingly continuous record of radiocarbon dates between ca. 21 and 14 cal. ka BP. In this perspective, after acting as a population refugium during the LGM, the Aquitaine basin would have played an important role in the subsequent resettlement of more northerly parts of Europe (e.g. Kretschmer, 2015; Maier, 2017).

However, a closer look at a more local scale reveals a more contrasted picture, suggesting that the intensity and continuity of human occupation during the Magdalenian was heterogeneous across the region. A large part of the central Aquitaine basin, corresponding to the Landes sands and extending eastwards into the Garonne valley, appears to have been unattractive to hunter-gatherers during most of the Upper Paleolithic, including the Magdalenian, because of its repulsive environmental con-

ditions (Bruxelles and Jarry, 2011; Bertran *et al.*, 2013 and 2020; Sitzia, 2014; Sitzia *et al.*, 2015). Significant human resettlement in this area occurred only at the end of the Upper Magdalenian and thereafter, during the Late Paleolithic and Mesolithic (Belbéoc'h and Lenoir, 2011; Gourc *et al.*, 2016; Merlet and Vignaud, this volume).

Similarly, the Magdatis research project, focused on the Magdalenian settlement of the western part of the basin (Pétillon *et al.*, 2016; Laroulandie *et al.*, 2017), showed a contrast between the Gironde plains, to the northwest, and the foothills of the western Pyrenees to the southwest. While the western Pyrenees do yield a continuous record of human occupation during the Middle and Upper Magdalenian, in the Gironde, no sites are documented between ca. 17.5 cal. ka BP and 15.5 cal. ka BP, archeologically corresponding to the Late Middle Magdalenian (Barshay-Szmidt *et al.*, 2016). This absence can hardly be interpreted as the consequence of a sampling bias, since material and assemblages from this period were specifically and unsuccessfully sought in the dating program. Furthermore, the beginning of this hiatus corresponds to the onset of the extremely cold phase of HS1a, and its end coincides with the beginning of the warmer HS1c (after Naughton *et al.*, 2016); at that period, in the north of the basin, periglacial features (cryoturbations, polygons) also indicate cooling (Lenoble *et al.*, 2012),

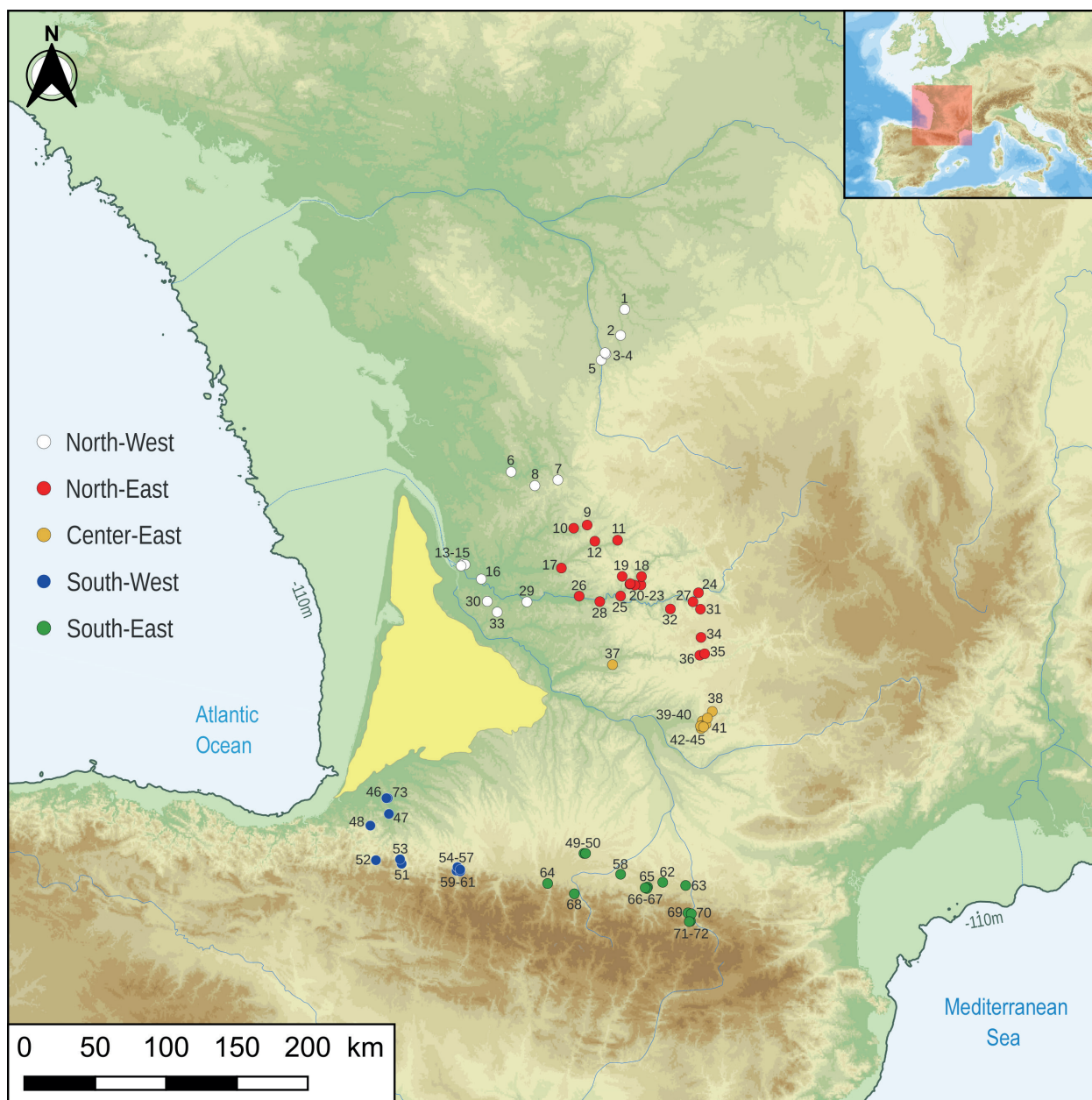
even if they do not mark the formation of a true permafrost (Andrieux et al., 2016). The Gironde hiatus was thus interpreted as a local depopulation episode triggered by environmental factors: at that period, this territory, which was then mostly a cold steppe environment exposed to intense North Atlantic westerlies, would have been too inhospitable to host human occupations or at least human occupations significant enough to be archeologically identified.

The aim of the present study is to bring this research one step further by investigating if a similar depopulation episode can be evidenced in others parts of the Aquitaine basin during the Middle and Upper Magdalenian, based on radiocarbon data. Assessing if the pattern observed in

the Gironde was a very local phenomenon, or affected a larger part of the basin, is indeed necessary for a finer understanding of the role of this region as a population base after the LGM.

## 1. MATERIAL

Our study area encompasses the whole geographic region of the Aquitaine basin, but it was necessary to split it into sub-regions for a more precise geographic approach. Five divisions were distinguished inside the basin (table 1, fig. 1):



**Fig. 1** – Sites included in the study, with color code for the five sub-regions distinguished inside the Aquitaine basin (Map A. Sécher). The Landes sands appear in yellow. Site numbers as in table 1.

**Fig. 1** – Sites inclus dans l'étude, avec code couleurs pour les cinq sous-régions distinguées à l'intérieur du Bassin aquitain (carte A. Sécher). La zone du sable des Landes est figurée en jaune. Voir le tableau 1 pour les numéros des sites.

- northwest: the northern part of the Gironde and the *départements* of Charente and Vienne;
- northeast: *départements* of Dordogne and Lot;
- centre east: *départements* of Tarn, Tarn-et-Garonne and Lot-et-Garonne;
- southeast: *départements* of Ariège, Haute-Garonne and Hautes-Pyrénées;

| Nbr | site                            | commune                  | dept |
|-----|---------------------------------|--------------------------|------|
| 1   | Roc-aux-Sorciers                | Angles-sur-l' Anglin     | 86   |
| 2   | Taillis des Coteaux             | Antigny                  | 86   |
| 3   | Marche                          | Lussac-les-Châteaux      | 86   |
| 4   | Réseau Guy-Martin               | Lussac-les-Châteaux      | 86   |
| 5   | Bois Ragot                      | Gouex                    | 86   |
| 6   | Rente d'Ortre et Bois du Breuil | Graves-Saint-Amant       | 16   |
| 7   | Le Roc de Sers                  | Sers                     | 16   |
| 8   | La Chaire-à-Calvin              | Mouthiers-sur-Boème      | 16   |
| 9   | Pont d'Ambon                    | Bourdeilles              | 24   |
| 10  | Rochereil                       | Grand-Brassac            | 24   |
| 11  | Combe-Saunière I                | Sarliac-sur-l'Isle       | 24   |
| 12  | Raymonden                       | Chancelade               | 24   |
| 13  | Fées                            | Prignac-et-Marcamps      | 33   |
| 14  | Roc-de-Marcamps                 | Prignac-et-Marcamps      | 33   |
| 15  | Roc-de-Marcamps 2               | Prignac-et-Marcamps      | 33   |
| 16  | Saint-Germain-la-Rivière        | Saint-Germain-la-Rivière | 33   |
| 17  | Gabillou                        | Sourzac                  | 24   |
| 18  | Labattut                        | Sergeac                  | 24   |
| 19  | Faurélie 2                      | Mauzens-et-Miremont      | 24   |
| 20  | Laugerie-Haute                  | Les Eyzies               | 24   |
| 21  | Laugerie-Basse                  | Les Eyzies               | 24   |
| 22  | Cap-Blanc                       | Marquay                  | 24   |
| 23  | Combarelles 1                   | Les Eyzies               | 24   |
| 24  | Peyrazet                        | Creysse                  | 46   |
| 25  | Moulin du Roc                   | Saint-Chamassy           | 24   |
| 26  | Vilazette                       | Creysse                  | 24   |
| 27  | Combe-Cullier                   | Lacave                   | 46   |
| 28  | Gare de Couze                   | Lalinde                  | 24   |
| 29  | Morin                           | Pessac-sur-Dordogne      | 33   |
| 30  | Moulin-Neuf                     | Saint-Quentin-de-Baron   | 33   |
| 31  | Murat                           | Rocamadour               | 46   |
| 32  | Piage                           | Fajoles                  | 46   |
| 33  | Faustin                         | Cessac                   | 33   |
| 34  | Pégourié                        | Caniac-du-Causse         | 46   |
| 35  | Peyrugues                       | Orniac                   | 46   |
| 36  | Petit Cloup Barrat              | Cabrerets                | 46   |

- southwest: *département* of Pyrénées-Atlantiques and southern part of the Landes.

These sub-regions correspond to administrative territorial divisions and, broadly, to comparably-sized concentrations of sites, as well as to “fieldwork areas” of specific researchers and teams. Even though they could of course have been framed slightly differently, these five

| Nbr | site                 | commune                 | dept |
|-----|----------------------|-------------------------|------|
| 37  | Cassegros            | Trentels                | 47   |
| 38  | Fontalès             | Saint-Antonin-Noble-Val | 82   |
| 39  | Pénovaire            | Penne                   | 82   |
| 40  | Courbet              | Penne                   | 81   |
| 41  | Magdeleine-la-Plaine | Penne                   | 81   |
| 42  | Montastruc           | Bruniquel               | 82   |
| 43  | Gandil               | Bruniquel               | 82   |
| 44  | Lafaye               | Bruniquel               | 82   |
| 45  | Plantade             | Bruniquel               | 82   |
| 46  | Dufaure              | Sorde-l' Abbaye         | 40   |
| 47  | Bourrouilla          | Arancou                 | 64   |
| 48  | Isturitz             | Saint-Martin-d'Arberoue | 64   |
| 49  | Harpons              | Lespugue                | 31   |
| 50  | Rideaux              | Lespugue                | 31   |
| 51  | Harregi              | Aussurucq               | 64   |
| 52  | Orkatzeko            | Lecumberry              | 64   |
| 53  | Etxeberri            | Camou-Cihigue           | 64   |
| 54  | Laa 2                | Arudy                   | 64   |
| 55  | Bignalats            | Arudy                   | 64   |
| 56  | Poeymaü              | Arudy                   | 64   |
| 57  | Malarode             | Arudy                   | 64   |
| 58  | Marsoulas            | Marsoulas               | 31   |
| 59  | Tastet               | Sainte-Colome           | 64   |
| 60  | Espalungue           | Arudy                   | 64   |
| 61  | Saint-Michel         | Arudy                   | 64   |
| 62  | Mas d'Azil           | Mas d'Azil              | 9    |
| 63  | Portel               | Loubens                 | 9    |
| 64  | Labastide            | Labastide               | 65   |
| 65  | Enlène               | Montesquieu-Avantès     | 9    |
| 66  | Tuc d'Audoubert      | Montesquieu-Avantès     | 9    |
| 67  | Trois-Frères         | Montesquieu-Avantès     | 9    |
| 68  | Troubat              | Troubat                 | 65   |
| 69  | Bédeilhac            | Bédeilhac-et-Aynat      | 9    |
| 70  | Rhodes 2             | Arignac                 | 9    |
| 71  | Niaux                | Niaux                   | 9    |
| 72  | Vache                | Alliat                  | 9    |
| 73  | Duruthy              | Sorde-l' Abbaye         | 40   |

**Table 1** – List of sites as on fig. 1, fig. 2, fig. 3 and fig. 4.

**Tabl. 1** – Liste des sites sur les fig. 1, fig. 2, fig. 3 et fig. 4.

divisions provide an efficient framework for the presentation and discussion of the results, as a complement to the vision given by the chronological heat maps (see below).

The geographic distribution of the sites (fig. 1) highlights the wide empty space represented by the Landes sands (yellow area on figure 1) and the Garonne valley to the east of the Landes. This gap is accentuated by the fact that our map is restricted to those sites that were  $^{14}\text{C}$ -dated by AMS (see below). But it nonetheless corresponds to a true scarcity of Upper Paleolithic sites in that area, despite the important activity of preventive archeology in recent years, and despite the existence of sedimentary deposits that could have yielded assemblages from this period. As was briefly mentioned above, in the Landes sands, this situation is most likely due to the presence of a cold sandy desert that had a repulsive effect on human settlement during most of the Upper Paleolithic (Bertran et al., 2013 and 2020; Sitzia, 2014; Sitzia et al., 2015). The situation is similar along the alluvial corridor of the Garonne valley, where powerful west-east winds probably created inhospitable conditions for both large fauna and human groups (Bruxelles and Jarry, 2011).

The chronological scope of the study was set to cover the period from the end of the LGM (as per Clark et al., 2009; MARGO project members, 2009) to the end of the GIS-1c; that is, between 19.5 cal. ka BP and 13.5 cal. ka BP. In terms of archeological cultures, this time frame includes the transition between the Lower and Middle Magdalenian, the Middle Magdalenian (19.5 cal. ka BP-16 cal. ka BP), the Upper Magdalenian (16.5 cal. ka BP-14 cal. ka BP) and the beginning of the Azilian (14.5 cal. ka BP-13.5 cal. ka BP; for chronological boundaries see Langlais et al., 2016; Sécher et al., 2018; Fat Cheung and Langlais, 2020; Langlais, 2020).

Radiocarbon dates were used as a proxy for human occupation, relying on the fact that this region was the subject of numerous dating programs in the last decades. Published dates were collected from the literature. Unpublished dates were collected from one public database (Banadora: <https://www.arar.mom.fr/banadora/>) and from grey literature (unpublished PhDs, research reports and excavation reports). In the latter case, either they were from our own research, or they were cited only with explicit permission from the authors of the work (see acknowledgements).

In this study, radiocarbon dates obtained from archaeological contexts are assumed in a first approach to be indicators of human presence at a given site, at a given time period in calendar years. They are not used as evidence for the presence of a particular culture, or Magdalenian phase, etc. without prior examination of their archeological context. In other words, we do not infer the presence of Middle Magdalenian at a site only from the fact that this site yielded  $^{14}\text{C}$  dates contemporary with the Middle Magdalenian.

Samples from non anthropic contexts (natural traps, etc.) were excluded. Dates done with the classic method (beta counting) were excluded as well: only the AMS dates were taken into account. Arguments for this latter choice

have been given elsewhere (Ducasse et al., 2014, 2019 and 2020; Ducasse and Langlais, 2019): in short, while both methods are equally reliable *per se*, beta-counting dates were often done on bulk bone samples, increasing the probability of stratigraphic mixing; and many of these classic dates were done at a time when pretreatment methods were less efficient at removing contaminants, thus carrying a higher risk of age rejuvenation. Furthermore, omitting these classic dates does not remove a lot of chronological information: the standard deviation (SD) of these dates is generally higher than that of AMS dates, resulting in less precise temporal resolution, so consequently less suitable to the detection of chronological hiatuses; and the number of classic dates is today largely exceeded by the number of AMS measurements available (for example, in the Pyrenean part of our study area: southeast and southwest sub-regions, 164 AMS dates with a mean SD of  $\pm 78$  were included in our study; while only 64 classic dates with a mean SD of  $\pm 218$  were found in the literature).

A total of 373 AMS radiocarbon dates were included in the study (Supplementary Information 1 and 2). Since precise information on the pretreatment method is rarely provided, we assumed all these AMS dates to be methodologically comparable, except specific cases (see below). Of these 373 dates, 96% ( $n = 357$ ) were made on bone, tooth or antler; 4% ( $n = 15$ ) on charcoal; and one date is mentioned as made on humus (table 2). Eleven dating laboratories are involved, the three major players being Oxford ( $n = 128$ , or 34%), the group composed of the Lyon, Saclay and Gif-sur-Yvette facilities (together  $n = 123$ , or 33%) and Poznan ( $n = 56$ , or 15%). A quarter

|            | Osseous | Charcoal | Humus | Total |
|------------|---------|----------|-------|-------|
| GifA       | 39      | 6        | 1     | 46    |
| SacA       | 1       | 0        | 0     | 1     |
| Lyon       | 9       | 0        | 0     | 9     |
| Lyon(SacA) | 63      | 0        | 0     | 63    |
| GifA(SacA) | 3       | 1        | 0     | 4     |
| OxA        | 112     | 0        | 0     | 112   |
| Lyon(OxA)  | 12      | 4        | 0     | 16    |
| Poz        | 55      | 0        | 0     | 55    |
| Lyon(Poz)  | 1       | 0        | 0     | 1     |
| Beta       | 32      | 3        | 0     | 35    |
| GrA        | 13      | 0        | 0     | 13    |
| Wk         | 12      | 0        | 0     | 12    |
| Col & Kn   | 3       | 0        | 0     | 3     |
| Erl        | 2       | 0        | 0     | 2     |
| AA         | 0       | 1        | 0     | 1     |
| Total      | 357     | 15       | 1     | 373   |

**Table 2** – Radiocarbon dates included in the study: laboratory codes and nature of samples.

**Tabl. 2** – Dates radiocarbones incluses dans cette étude : codes laboratoire et nature des échantillons.

| Sub-region  | Départements                           | Sites dated | Dates previously published | Dates from grey literature | Total number of dates |
|-------------|--|-------------|----------------------------|----------------------------|-----------------------|
| Northwest   | Gironde (north), Charente, Vienne      | 15          | 68                         | 21                         | 89                    |
| Northeast   | Dordogne, Lot                          | 21          | 78                         | 17                         | 95                    |
| Centre east | Tarn, Tarn-et-Garonne, Lot-et-Garonne  | 9           | 12                         | 13                         | 25                    |
| Southeast   | Ariège, Haute-Garonne, Hautes-Pyrénées | 14          | 63                         | 15                         | 78                    |
| Southwest   | Pyrénées-Atlantiques, Landes (south)   | 14          | 60                         | 26                         | 86                    |
| Total       |  | 73          | 281                        | 92                         | 373                   |

**Table 3** – Radiocarbon dates included in the study: distribution according to sub-region and bibliographic status.

**Tabl. 3** – *Dates radiocarbone incluses dans cette étude : distribution selon leur sous-région et leur statut bibliographique.*

of these dates (24.7%) were previously available only on Banadora or in grey literature (table 3). In each of the five sub-regions, the number of dated sites is between 9 and 21, and the number of dates is between 78 and 95, with the exception of the central-eastern area, which is less well documented (see discussion below).

Selecting only the AMS radiocarbon dates means that a number of Magdalenian sites are excluded from the sample, either because they were only dated with the classic method, or because they were not dated at all, for lack of dating program or for lack of datable material (i.e. most open-air sites). As a consequence, certain phenomena are not visible on our maps, such as the resettlement of one part of the Landes area in the Upper Magdalenian, only evidenced by open-air sites without <sup>14</sup>C dates (Belbéoc'h and Lenoir, 2011; Gourc et al., 2016; Merlet and Vignaud, this volume; and see above). We are aware of these biases, but this methodological choice was precisely made to avoid mixing radiometric chronology with cultural attribution made on technotypological grounds, the correlation of the two being a work in itself, beyond the scope of this article. Some of these undated sites, though, will be referred to in the discussion.

## 2. METHODS

We plotted the dates of each region (without modeling them), from youngest (at the top) to oldest (at the bottom) to see visually whether we could see any gaps in presence. Plots (see figures below) show calibrated dates, with 95.4% confidence intervals (2 *sigma*); these were calculated using OxCal 4.4.4 (Bronk-Ramsey, 2009), which is based on the IntCal20 curve (Reimer et al., 2020).

There are five plots, one for each of the five regions outlined above. In those cases where a sample was dated twice (this is usually done as part of standard laboratory

protocol), we used the R\_Combine function in OxCal to get an average date and used that in the graphs. The sample identifier on the left-hand column is the lab code. Further details about any sample can be found in the Supplementary Materials.

The three maps (see figures below) were designed using QGIS (open-source GIS software) and are based on the cartographic work of one of us (Sécher, 2017). The topographic background was made using radar data from the SRTM mission (NASA joint program; Farr et al., 2007). Paleo-coastal and paleo-river data were derived from public databases (Verheul et al., 2015; Zickel et al., 2016).

These maps aim to report the density of <sup>14</sup>C-dated Magdalenian sites for each of the three selected 2000-year phases: 19.5-17.5 (Early Middle Magdalenian, or EMM, and transition to the Late Middle Magdalenian), 17.5-15.5 (Late Middle Magdalenian, or LMM, and transition to the Upper Magdalenian) and 15.5-13.5 ky cal. BP (Early Upper Magdalenian, or EUM; Late Upper Magdalenian, or LUM; and transition to the Azilian). The heat map is an interesting visual solution that allows us to understand the spatial distribution of the <sup>14</sup>C-dated sites and their concentration (hot spots).

We created the density raster (i.e. heat map) from a vector layer of input points using core density estimation. We have taken care to consider that a site is equal to a single point, regardless of the number of known dates.

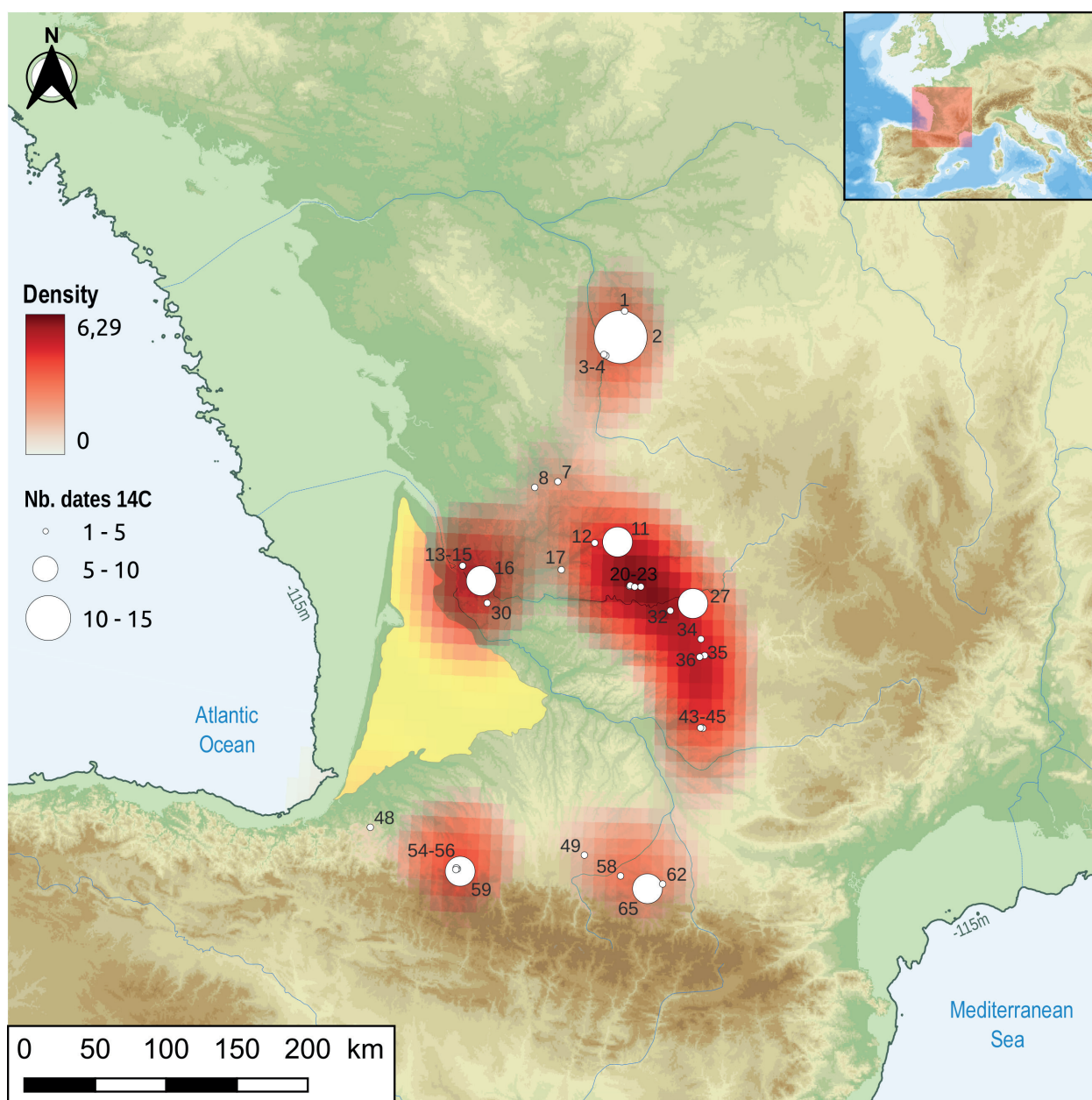
The density is therefore calculated from the number of points at a given location. A large number of points grouped together gives higher values: the hot spots. The main parameter for obtaining the heat map is the search radius, defined as the distance around a point from which the influence of a point will be zero. Larger values result in greater smoothness, but smaller values show finer details and variations in point density. A value of 0.75° of arc, in the WGS84 coordinate system (epsg:4326), is the most suitable for our study scale. The other parameters are those used by default by QGIS (v. 3.24.2).

For information purposes, we then added to the map the number of dates obtained for each site. The more dates a site has, the larger the point size will be.

### 3. RESULTS

In the northwestern part of the basin, the distribution of the radiocarbon dates confirms the extreme scarcity of anthropic evidence for the period between 17.5 cal. ka BP and 15.5 cal. ka BP (table 4; fig. 2 to fig. 5). The preceding period, between 19.5 cal. ka BP and 17.5 cal. ka BP, is documented by 51 dates from 11 sites; and the following

one, between 15.5 cal. ka BP and 13.5 cal. ka BP, yielded 35 dates from six sites. In-between, only three dates, from three different sites, are currently known; and each of them is questionable. The youngest of these three dates (from Morin BI, Gironde: OxA-19699, 13065 ± 60 BP, 15861-15421 cal. BP at 2σ) actually slightly overlaps the lower limit of the 15.5-13.5 time slice so it is not clearly in the 17.5-15.5 ka cal. BP time slice; the three other samples from the same BI layer produced slightly younger dates, thus more clearly belonging in that younger time slice (Barshay-Szmidt et al., 2016; Mallye et al., 2018). The second of these three dates (from the single layer of Réseau Guy-Martin, Vienne: Beta-359094, 13560 ± 50 BP, 16554-16199 cal. BP at 2σ) is not consis-



**Fig. 2** – Density raster (heat map) of the Aquitaine basin reporting the density of Magdalenian sites AMS-dated between 19.5 and 17.5 cal. ka BP; see explanations in text (map A. Sécher).

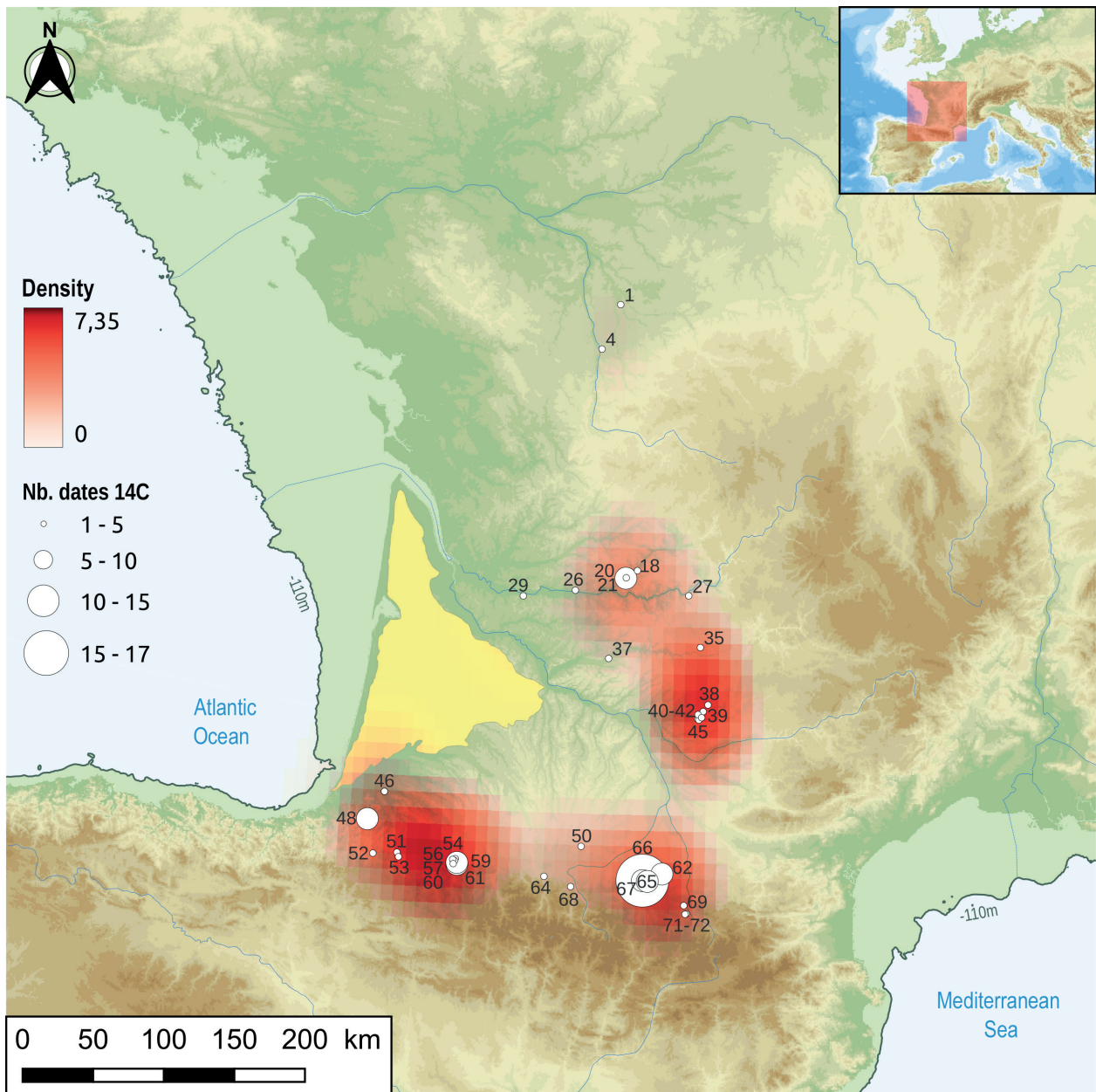
**Fig. 2** – Matrice de densité (carte de chaleur) du Bassin aquitain montrant la densité des sites magdaléniens datés par AMS entre 19,5 et 17,5 cal. ka BP ; voir explications dans le texte (carte A. Sécher).



|             | 19.5-17.5 cal ka BP |       | 17.5-15.5 cal ka BP |       | 15.5-13.5 cal ka BP |       | Total number of dates |
|-------------|---------------------|-------|---------------------|-------|---------------------|-------|-----------------------|
|             | Sites               | Dates | Sites               | Dates | Sites               | Dates |                       |
| Northwest   | 11                  | 51    | 3                   | 3     | 6                   | 35    | 89                    |
| Northeast   | 12                  | 43    | 6                   | 15    | 11                  | 37    | 95                    |
| Centre east | 3                   | 6     | 7                   | 15    | 4                   | 4     | 25                    |
| Southeast   | 4                   | 11    | 10                  | 58    | 7                   | 9     | 78                    |
| Southwest   | 5                   | 18    | 12                  | 48    | 8                   | 20    | 86                    |
| Total       | 35                  | 129   | 38                  | 139   | 36                  | 105   | 373                   |

**Table 4** – Distribution of the radiocarbon dates according to sub-region and chronological phase.

*Tabl. 4* – Distribution des dates radiocarbones selon leur sous-région et leur phase chronologique.



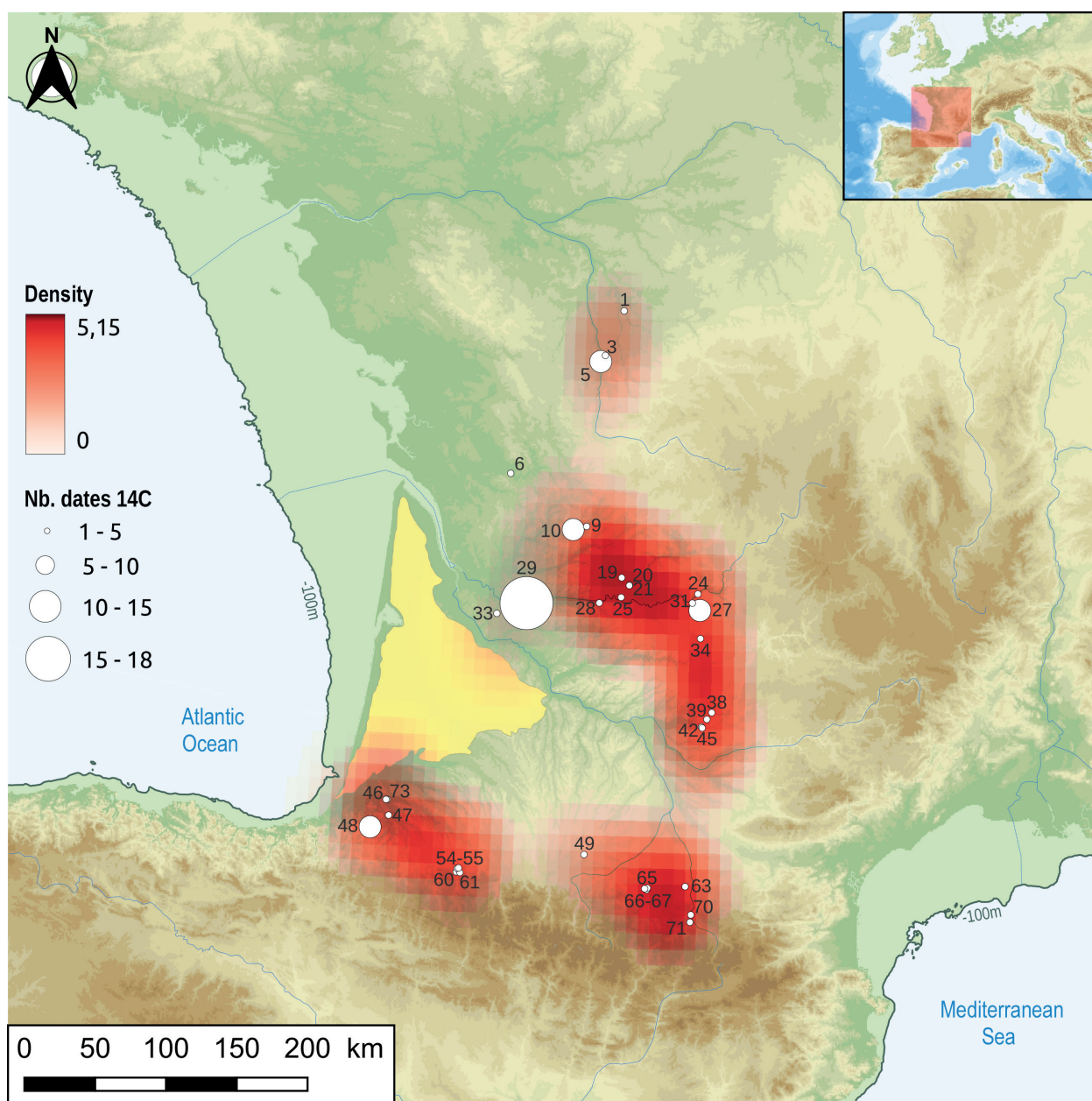
**Fig. 3** – Density raster (heat map) of the Aquitaine basin reporting the density of Magdalenian sites AMS-dated between 17.5 and 15.5 cal. ka BP; see explanations in text (map A. Sécher).

*Fig. 3* – Matrice de densité (carte de chaleur) du Bassin aquitain montrant la densité des sites magdaléniens datés par AMS entre 17,5 et 15,5 cal. ka BP ; voir explications dans le texte (carte A. Sécher).

tent with the four other dates from the same layer, which are all older than ca. 18 cal. ka BP (Brou et al., 2013). The third date (from Roc-aux-Sorciers RSB4, Vienne: GifA-14192, 13720 ± 140 BP, 17035-16224 cal. BP at 2σ) is coherent with the stratigraphic order, but contradictory with the Upper Magdalenian attribution of the material found in the same RSB4 layer (Iakovleva and Pinçon, 1997).

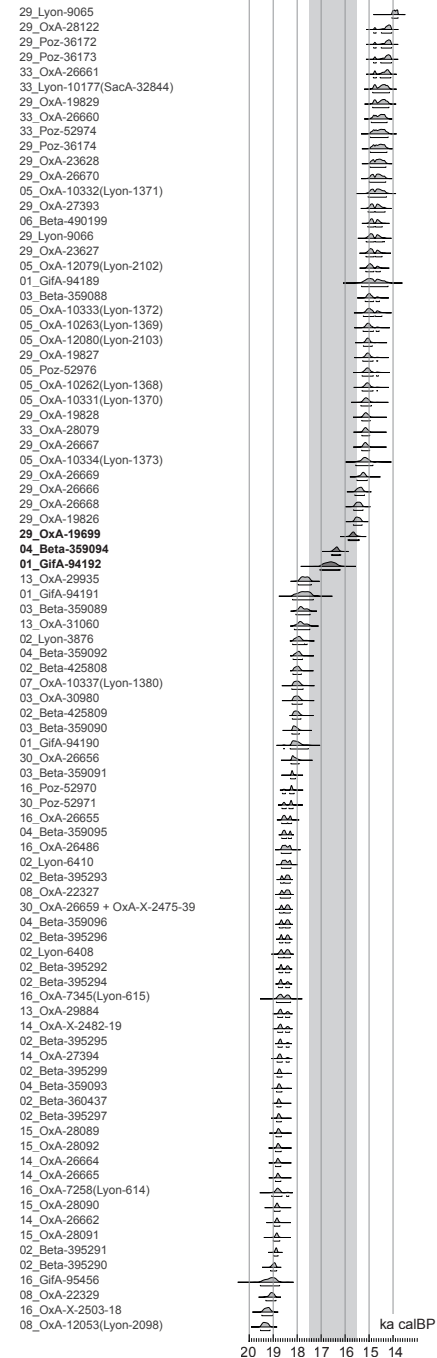
Two other sub-regions of the basin show a less clear-cut picture. In the northeastern sub-region (table 4; fig. 2 to fig. 4 and fig. 6), the numbers of dates and sites are similar in the period from 19.5 cal. ka BP to 17.5 cal. ka BP (43 dates from 12 sites) and in the period between 15.5 cal. ka BP and 13.5 cal. ka BP (37 dates from

11 sites). These figures are, however, ca. two times lower in the period from 17.5 cal. ka BP to 15.5 cal. ka BP, with only 15 dates from six sites. Among these 15 dates, the three done on reindeer bones from the Guichard excavations at Laugerie-Haute Est, Dordogne (OxA-759, 14320 ± 180 BP; OxA-761, 14320 ± 180 BP; OxA-762, 14100 ± 180 BP), cannot be accepted unquestionably and might be “too young”. They were made in the 1980s (Gowlett et al., 1986), in the “early days” of AMS dating, at a time when pretreatment methods were less efficient against contaminations. Also, they are not very consistent with their archeological context: the samples come from layers attributed by Peyrony to the “Magdalénien II” and “Magdalénien III”, which today would be considered as



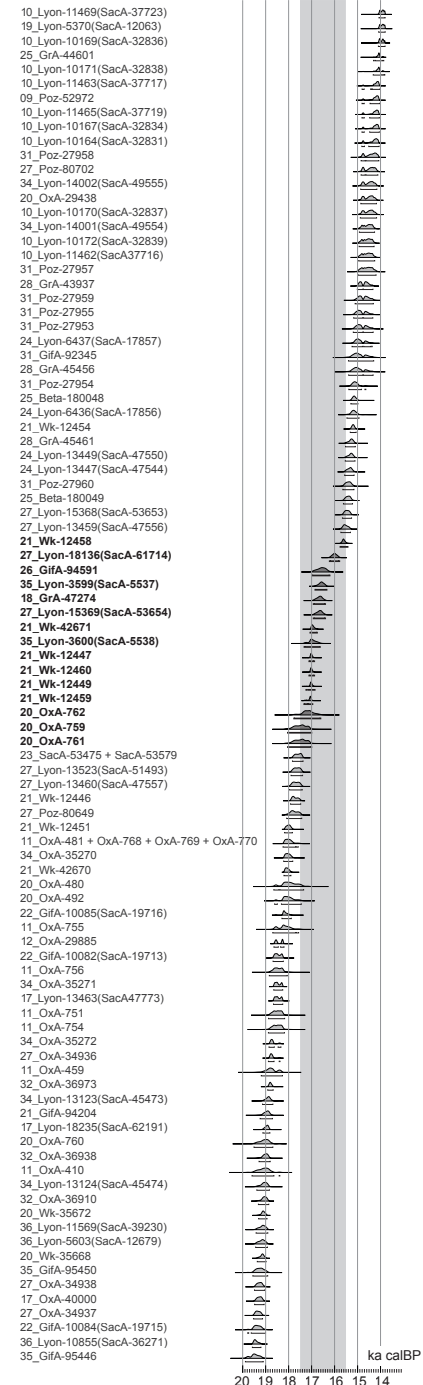
**Fig. 4** – Density raster (heat map) of the Aquitaine basin reporting the density of Magdalenian sites AMS-dated between 15.5 and 13.5 cal. ka BP; see explanations in text (map A. Sécher).

**Fig. 4** – Matrice de densité (carte de chaleur) du Bassin aquitain montrant la densité des sites magdaléniens datés par AMS entre 15,5 et 13,5 cal. ka BP ; voir explications dans le texte (carte A. Sécher).

OxCal v4.4.4 Bronk Ramsey, 2021; r:5 Atmospheric data from Reimer *et al.*, 2020

**Fig. 5** – Calibration plot of all AMS radiocarbon dates for the northwestern sub-region of the Aquitaine basin (Gironde, Charente, Vienne) for the period between 19.5 and 13.5 cal. ka BP (plot C. Barshay-Szmidt, M. Boudadi-Maligne and V. Laroulandie). The 17.5-15.5 cal. ka BP interval is highlighted in light grey and the dates falling in that interval are in bold; see discussion in text. On each line, the first two digits are the site number as in table 1.

**Fig. 5** – Graphique des dates  $^{14}\text{C}$  AMS calibrées de la sous-région nord-ouest du Bassin aquitain (Gironde, Charente et Vienne) pour la période entre 19,5 cal. ka BP et 13,5 cal ka BP (graphique : C. Barshay-Szmidt, M. Boudadi-Maligne et V. Laroulandie). L'intervalle 17,5-15,5 cal. ka BP est surligné en gris clair et les dates tombant dans cet intervalle sont en gras ; voir discussion dans le texte. Sur chaque ligne, les deux premiers chiffres correspondent au numéro de site dans le tableau 1.

OxCal v4.4.4 Bronk Ramsey, 2021; r:5 Atmospheric data from Reimer *et al.*, 2020

**Fig. 6** – Calibration plot of all AMS radiocarbon dates for the northeastern sub-region of the Aquitaine basin (Dordogne, Lot) for the period between 19.5 and 13.5 cal. ka BP (plot C. Barshay-Szmidt, M. Boudadi-Maligne and V. Laroulandie). The 17.5-15.5 cal. ka BP interval is highlighted in light grey and the dates falling in that interval are in bold; see discussion in text. On each line, the first two digits are the site number as in table 1.

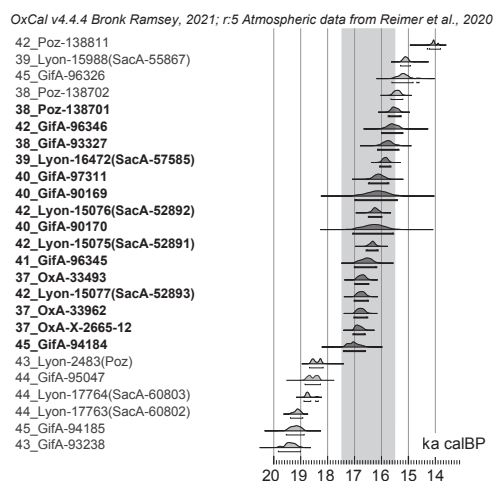
**Fig. 6** – Graphique des dates  $^{14}\text{C}$  AMS calibrées de la sous-région nord-est du Bassin aquitain (Dordogne et Lot) pour la période entre 19,5 cal. ka BP et 13,5 cal. ka BP (graphique C. Barshay-Szmidt, M. Boudadi-Maligne et V. Laroulandie). L'intervalle 17,5-15,5 cal. ka BP est surligné en gris clair et les dates tombant dans cet intervalle sont en gras ; voir discussion dans le texte. Sur chaque ligne, les deux premiers chiffres correspondent au numéro de site dans le tableau 1.

EMM and earlier phases, with radiocarbon dates expected to be at least as old as 18 cal. ka BP according to the current consensus chronology (see references above). Apart from this dubious case, four archeological assemblages and one burial are evidence of human presence in the northeast of the Aquitaine basin between 17.5 cal. ka BP and 15.5 cal. ka BP:

- The “archeostratigraphical unit 2” (UA2) of Combe-Cullier, Lot, attributed to the LMM (Lyon-18136[SacA-61714], 13310 ± 60 BP; Lyon-15369[SacA-53654], 13740 ± 60 BP; Sécher et al., 2018; Grubert, 2021).
- Layer 3 of Les Peyrugues, Lot, attributed to the Middle Magdalenian (Lyon-3599[SacA-5537], 13700 ± 60 BP; Lyon-3600[SacA-5538], 13960 ± 100 BP; Allard, 1992; Langlais, 2010; Langlais et al., 2017; Sécher, 2017).
- One part of the stratigraphy of Abri des Marseilles at Laugerie-Basse, Dordogne (layer 12 to layer 15a after the stratigraphy by A. Roussot: Cosgrove et al., 2015), with six dates: Wk-12447, 13977 ± 32 BP; Wk-12449, 13987 ± 37 BP; Wk-12458, 13020 ± 29 BP; Wk-12459, 14031 ± 37 BP; Wk-12460, 13977 ± 32 BP; Wk-42671, 13921 ± 31 BP.
- The open-air site of Vilazette, Dordogne, level C, attributed to the Middle Magdalenian, shows the characteristics of a “blade production site” close to high-quality outcrops of Bergerac flint (GifA-94591, 13680 ± 120 BP; Boëda and Henry, 1994; Boëda et al., 1997; Henry, 1998; Langlais, 2018); it is now considered as LMM on the basis of the type of blade production (Langlais, 2020).
- The child burial of Labattut, Dordogne, directly radiocarbon-dated, appears chronologically isolated in the local archeological context of the Vallon de Castelmerle (GrA-47274, 13740 ± 60 BP; Henry-Gambier et al., 2019).

Owing to the history of research (less activity in AMS dating programs in recent years), the central-eastern zone is less documented, with only 25 dates, that is, three-four times less <sup>14</sup>C measurements than the other sub-regions (table 4; fig. 2 to fig. 4 and fig. 7). The distribution of these 25 dates across the three time slices does not show any major contrast, and suggests a relative continuity of the human settlement. But the visual examination of the plot shows another earlier gap, between ca. 18 cal. ka BP and 17 cal. ka BP (fig. 7). However, given the small number of AMS dates available for this sub-region, we cannot exclude the possibility that this distribution gap is the result of sampling choices, in other terms, a research bias.

Finally, in the southern part of the basin, the 164 dates from the southeast and southwest sub-regions confirm the continuity of the human settlement on the northern side of the Pyrenees (table 4; fig. 2 to fig. 4 and fig. 8-9). Here, the period between 17.5 cal. ka BP and 15.5 cal. ka BP is even overrepresented, with 106 dates from 22 sites (while the preceding period yielded only 29 dates from nine sites, and the following one, 29 dates from 15 sites).



**Fig. 7** – Calibration plot of all AMS radiocarbon dates for the central-eastern sub-region of the Aquitaine basin (Tarn, Tarn-et-Garonne, Lot-et-Garonne) for the period between 19.5 and 13.5 cal. ka BP (plot C. Barshay-Szmidt, M. Boudadi-Maligne and V. Laroulandie). The 17.5-15.5 cal. ka BP interval is highlighted in light grey and the dates falling in that interval are in bold; see discussion in text. On each line, the first two digits are the site number as in table 1.

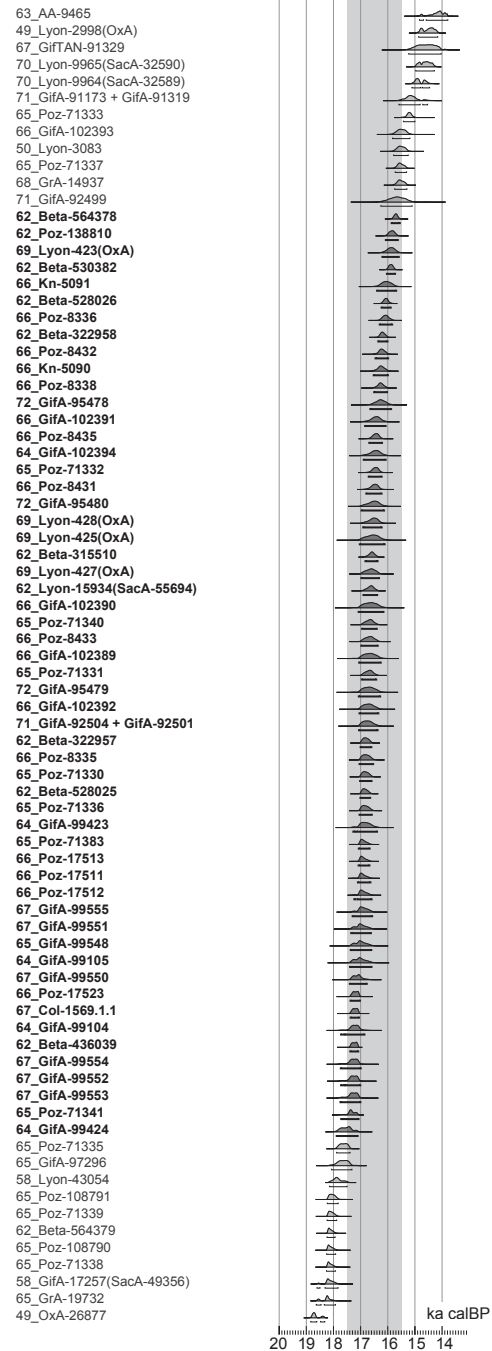
**Fig. 7** – Graphique des dates <sup>14</sup>C AMS calibrées de la sous-région centre-est du Bassin aquitain (Tarn, Tarn-et-Garonne, Lot-et-Garonne) pour la période entre 19,5 cal. ka BP et 13,5 cal. ka BP (graphique C. Barshay-Szmidt, M. Boudadi-Maligne et V. Laroulandie). L’intervalle 17,5-15,5 cal. ka BP est surligné en gris clair et les dates tombant dans cet intervalle sont en gras ; voir discussion dans le texte. Sur chaque ligne, les deux premiers chiffres correspondent au numéro de site dans le tableau 1.

It corresponds to the most intensive occupation phase of several major Magdalenian sites, or clusters of sites, in the northern Pyrenees: notably, Isturitz, Mas d’Azil (Pallier et al., this volume), the three Volp caves (Enlène, Trois-Frères and Tuc d’Audoubert) and the cluster of sites around Arudy (Espalungue, Laa 2, Malarode, Poeymaü, Saint-Michel and Tastet).

## 4. DISCUSSION

As mentioned above, in the Gironde area, the absence of anthropic assemblages between 17.5 cal. ka BP and 15.5 cal. ka BP had been interpreted as a local depopulation episode triggered by environmental factors (the onset of the HS1a cold phase: Barshay-Szmidt et al., 2016; Naughton et al., 2016; Pétillon et al., 2016; Laroulandie et al., 2017). Our results show that this scarcity of anthropic evidence extends to the rest of the northwestern Aquitaine basin, including the Charente and Vienne areas, suggesting the same environmental explanation. Furthermore, in the Charente and Vienne areas such as in Gironde, none among the undated sites yielded material that could be unequivocally attributed to the 17.5 and 15.5 cal. ka BP time period on techno-typological

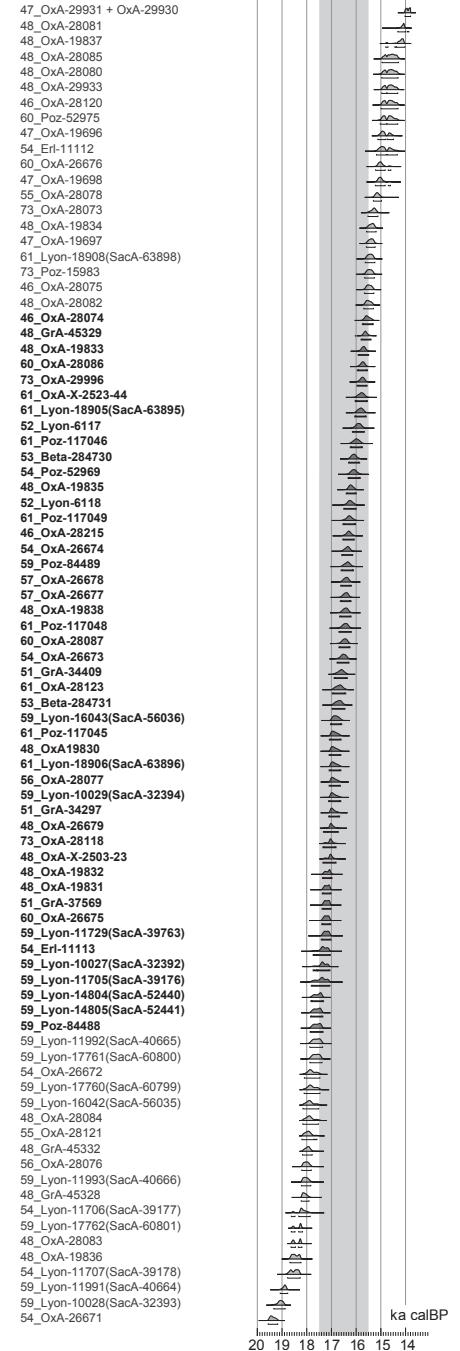
OxCal v4.4.4 Bronk Ramsey, 2021; r:5 Atmospheric data from Reimer et al., 2020



**Fig. 8** – Calibration plot of all AMS radiocarbon dates for the southeastern sub-region of the Aquitaine basin (Ariège, Haute-Garonne, Hautes-Pyrénées) for the period between 19.5 and 13.5 cal. ka BP (plot C. Barshay-Szmidt, M. Boudadi-Maligne and V. Laroulandie). The 17.5-15.5 cal. ka BP interval is highlighted in light grey and the dates falling in that interval are in bold; see discussion in text. On each line, the first two digits are the site number as in table 1.

**Fig. 8** – Graphique des dates  $^{14}\text{C}$  AMS calibrées de la sous-région sud-est du Bassin aquitain (Ariège, Haute-Garonne et Hautes-Pyrénées) pour la période entre 19,5 cal. ka BP et 13,5 cal. ka BP (graphique C. Barshay-Szmidt, M. Boudadi-Maligne et V. Laroulandie). L'intervalle 17,5-15,5 cal. ka BP est surligné en gris clair et les dates tombant dans cet intervalle sont en gras ; voir discussion dans le texte. Sur chaque ligne, les deux premiers chiffres correspondent au numéro de site dans le tableau 1.

OxCal v4.4.4 Bronk Ramsey, 2021; r:5 Atmospheric data from Reimer et al., 2020



**Fig. 9** – Calibration plot of all AMS radiocarbon dates for the southwestern sub-region of the Aquitaine basin (Pyrénées-Atlantiques, Landes) for the period between 19.5 and 13.5 cal. ka BP (plot C. Barshay-Szmidt, M. Boudadi-Maligne and V. Laroulandie). The 17.5-15.5 cal. ka BP interval is highlighted in light grey and the dates falling in that interval are in bold; see discussion in text. On each line, the first two digits are the site number as in table 1.

**Fig. 9** – Graphique des dates  $^{14}\text{C}$  AMS calibrées de la sous-région sud-ouest du Bassin aquitain (Pyrénées-Atlantiques, Landes) pour la période entre 19,5 cal. ka BP et 13,5 cal. ka BP (graphique C. Barshay-Szmidt, M. Boudadi-Maligne et V. Laroulandie). L'intervalle 17,5-15,5 cal. ka BP est surligné en gris clair et les dates tombant dans cet intervalle sont en gras ; voir discussion dans le texte. Sur chaque ligne, les deux premiers chiffres correspondent au numéro de site dans le tableau 1.

grounds, and that could thus have contributed to “filling the gap”. However, biases affecting the archeological record must be taken into account. In the northern part of the Gironde, a large part of the archeological record is made of poorly dated open-air sites, often known only from surface finds; and the characteristics of the local Asteria limestone favored the collapse of many caves and rockshelters and the activity of quarries. These two features might result in the invisibilization of one part of the Paleolithic chronology in this area (M. Lenoir, pers. comm.; S. Ducasse, pers. obs.). In the Vienne and Charente, the end of the EMM is marked by an episode of collapse of many cave entrances (Le Fillâtre, 2013). The shelters previously occupied might thus no longer have been accessible, and the occupations immediately following the EMM in this region might have moved to other locations yet undiscovered.

The radiocarbon evidence also suggests that, between 17.5 cal. ka BP and 15.5 cal. ka BP, the northeastern part of the basin, although not deserted, was much less densely settled than in the preceding and following phases, possibly owing to the same environmental reasons. Here again, however, sampling biases must be considered: in the Dordogne and the Lot, several major stratigraphic sequences from the Magdalenian lack AMS radiocarbon dates and could therefore not be included in this study, although some of them yielded industries reminiscent of the LMM. Among others, this is the case of the lower layers from the eponymous site, La Madeleine (Capitan and Peyrony, 1928; Bouvier, 1977; collective, 2014); and the assemblage from layer IX in Le Flageolet II (Rigaud, 1970 and 1979; Cazals, 2005, p. 305; Langlais, 2010; Pétillon et al., 2020), although among the undated sites, the number of possible LMM assemblages remains small, especially compared to the large number of undated Upper Magdalenian sites in this area (e.g. for the Lot: Lorblanchet, 1972).

Strictly speaking, because of these biases, it is difficult to assert the existence of a population decrease in the whole northern half of the Aquitaine basin between 17.5 cal. ka BP and 15.5 cal. ka BP. However, and symmetrically, it is no longer possible to affirm that, during these two millennia, the northern Aquitaine basin could have acted as a base for population movements towards more northern regions: in the current state of data, only a small number of sites yield evidence of human presence in this area during this phase. This result questions our perception of the demographic role of the Aquitaine basin in the course of the Magdalenian: it is now possible to consider that, during one part of the Magdalenian, between 17.5 cal. ka BP and 15.5 cal. ka BP, corresponding to the Late Middle Magdalenian and the transition to the Upper Magdalenian, northern Aquitaine might have been only a demographic margin of the Magdalenian world. In this perspective, this result further questions the validity of the “population refugium” model applied to Aquitaine during the LGM; a model which was already needing re-evaluation given the persistence of anthropic sites in northern France during the LGM (e.g. Bodu et al.,

2014; Bignon-Lau et al., 2019; Connet et al., 2019; Montoya et al., 2019).

The relative scarcity of human evidence in the northern basin between 17.5 cal. ka BP and 15.5 cal. ka BP also changes our perception of certain features of the Magdalenian from the southern part, i.e. the Pyrenean foothills. During this phase, assemblages from the Pyrenean sub-region often include specific elements in their bone and antler industries, such as bone cutouts (*contours découpés*) or antler fork-based points, which are rarer in assemblages from northern Aquitaine. This quantitative contrast had been interpreted in terms of differences in group identity between the two areas (e.g. Pétillon, 2006; Cattelain and Bellier, 2014). However, our results suggest that this contrast might simply reflect the relative density of human settlement at that period, a density that appears higher in the Pyrenees in the current state of data.

Similarly, the intensive occupation of some Pyrenean sites at this period had been considered as the result of a specific mobility pattern: an alternation between dispersion and aggregation phases, with the “large” sites such as Gourdan, Lortet or La Vache representing the aggregation sites, while Isturitz, Le Mas d’Azil and maybe Enlène would stand out as “super-aggregation sites” (Bahn, 1984; Clottes, 1989). In light of our results, the emergence of these “super-sites” should also be considered at the scale of the whole Aquitaine basin, as one of the changes affecting the organization of the human settlement in this region after ca. 17.5 cal. ka BP. The particular intensity of occupation of some Pyrenean sites at this period might be correlated with the coeval lesser intensity in the north of the basin, and might thus reflect a reorganization of population distribution inside the basin in favor of the southern areas. Here again, no assertive conclusion can be drawn, but the findings of the present study at least reopen the question of the validity of the concept of aggregation site as applied to the Pyrenean Magdalenian.

## 5. PROSPECTS

The distribution of the 373 AMS dates from the Middle and Upper Magdalenian of the Aquitaine basin reveals a consistent geographic and chronological pattern; but its interpretation is hampered by gaps in the data. In order to test the hypotheses raised in this study, as mentioned above, it is necessary to AMS-date the putative LMM/EUM assemblages from Dordogne. The number of AMS measurements for the central-eastern part of the basin should also be at least doubled, and the number of dated sites should be increased as much as possible, in order to raise this sub-region to the same level of information as the others. A detailed comparison between our results and the data from the Massif central, east of the Aquitaine basin (e.g. Angevin and Surmely, 2013; Raynal et al., 2014; Langlais et al., 2019), would also be important to assess if a similar north-south pattern can be identified in this region as well.

Finally, while this study focused on the AMS radiocarbon dates from anthropic sites, a comparison with other human and natural proxies remains necessary. The circulation of lithic raw materials during the 17.5-15.5 cal. ka BP interval might show evidence of the human frequentation of certain areas, at least for flint provisioning, even if these areas did not yield any site dated in that interval. Correlating the chronology of anthropic sites with that of well-dated natural faunal assemblages is necessary to assess the presence and nature of animal populations at times when the evidence for human frequentation is scarce in the area (e.g. Castel *et al.*, 2008 and 2012). As well, detailed parallels between archeological and paleo-environmental data must be carried on, in order to specify which environmental constraints might have biased the archeological record or impacted human settlement.

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### **DONNÉES SUPPLÉMENTAIRES**

Jean-Marc Pétillon *et al.* (2023), Dates radiocarbone par AMS de 19.5 à 13.5 cal ka BP pour le bassin Aquitain : <https://nakala.fr/10.34847/nkl.538f2a9q>

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