Contribution of archaeobotany to understand taphonomic phenomena. The case of a Preboreal palaeochannel of Autrecourt-et-Pourron (Ardennes, France)

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Abstract – Palaeoecology, through the analysis of the interactions between environmental factors and ecosystems, refines the knowledge of the structuring process of plant communities and helps to understand the complexity of past environments. However, it is necessary to analyse the taphonomic phenomena (deposition, conservation, degradation) affecting plant macrofossil assemblages in order to perform relevant palaeoecological analyses. Indeed, plant macrofossils may be under or over-represented in carpological assemblages, depending on the resistance of their cell membranes and the sedimentary condition deposits. For this reason, it is necessary to estimate the representative quality of the conserved part as a source of information. Like all archaeological documents, the plant archives are distorted by the processes of formation of the sedimentary levels and, ignore the diagenetic history of the sedimentary layers could lead to wrong palaeoecological interpretations. To this aim, we analysed plant macrofossils contained in the wet sediments of a Meuse palaeochannel (Autrecourt-et-Pourron, Ardennes, France). This archaeobotanical study of an oxbow lake dated to the Preboreal (11.7–10.7 ka cal. BP), provides a reference of a taphonomic referential according to a hierarchy of organic remain preservations. This framework successfully helped the palaeoecological interpretations of the Autrecourt-et-Pourron off-site, and it has brought robustness to environmental history reconstruction of the early Holocene in the Ardennes Meuse.

Keywords: Taphonomy / Conservation / ecofacts / oxbow lake / waterlogged sediment / archaeobotany / plant macrofossils

Résumé – Contribution de l’archéobotanique à la compréhension des phénomènes taphonomiques. Le cas d’un paléochenal Préboréal d’Autrecourt-et-Pourron (Ardennes, France). La paléoécologie, par l’analyse des interactions entre facteurs environnementaux et écosystèmes, affine la connaissance des mécanismes de structuration des communautés végétales et, aide à comprendre la complexité des environnements passés. Cependant afin d’entreprendre des analyses paléoécologiques pertinentes, il est nécessaire d’analyser en amont les phénomènes taphonomiques (dépôt, conservation, dégradation) affectant les assemblages macrofossiles de plantes. En effet, les macro-restes végétaux, en fonction de la résistance de leurs membranes cellulaires et des conditions sédimentaires de dépôts, peuvent se trouver sous- ou surreprésentés dans les ensembles carpologiques. C’est pourquoi, l’évaluation de la représentativité des restes permet d’estimer la qualité représentative de la part conservée en tant que source d’information. Comme tous documents archéologiques, les archives végétales nous arrivent déformées par les processus de formation des niveaux sédimentaires et ne pas prendre en considération l’histoire diagénétique des couches sédimentaires pourrait conduire à des interprétations paléoécologiques erronées. Pour entreprendre ce travail, nous nous sommes attachés à l’étude des macrofossiles végétaux contenus dans les sédiments humides d’un paléochenal de la Meuse (Autrecourt-et-Pourron, Ardennes, France). Cette étude archéobotanique d’un bras-mort de rivière daté de la période Prèboréal (11,7–10,7 ka cal. BP), pose les

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1 Introduction

Wetlands and lakeshores sites, is known to provide outstanding conservation. Organic archaeological material such as architectural wood elements, perishable artefacts and plant remains allow to reconstruct societal and environmental history (Pétrequin and Pétrequin, 1984; Bourquin-Mignot et al., 1999; Lebreton et al., 2011). These preservation conditions allowed developing scientific research programs based on materials and topics that cannot easily be addressed while studying sites on dry soils where organic remains have almost systematically disappeared (Schaal and Pétrequin, 2016). In wetland and anaerobic conditions, plant remains preservation is due to a process that stops or strongly slows down the activity of microorganisms and physico-chemical reactions, and is called “waterlogging” (Retallack, 1981; Bleicher and Schubert, 2015; Lebreton et al., 2017; Bleicher et al., 2018). Archaeobotanists consider waterlogged preservation to be exceptional, but they also point that robust interpretation of plant assemblages depends on the ability to reconstruct the history of their deposit (Lundström-Baudais et al., 1983; Dietsch, 1997; Schaal, 2000). They are questioning the formation of sedimentary layer that can influence the taphonomic history (Marinval-Vigne et al., 1989; Behre and Jacomet, 1991; Gee and Sander, 1997; Berger et al., 2008; Birks, 2014; Bleicher and Schubert, 2015; Antolin et al., 2017a; Steiner et al., 2018). The characterisation of fossilisation indicators is complex, as they cover both sediment deposition circumstances or “biostratigraphic” processes, and post-deposition circumstances or “diagenetic” processes (Holyoak, 1984; Martin-Closas and Gomez, 2004; Antolin et al., 2017b). The preservation state of plant remains can be classified into two main indicators: (i) chemical indicator, when anaerobic and humid condition changes towards drying and oxidation, macrofossils are damaged or destructed due to resumption of chemical actions and/or micro-organisms that decompose organic matter; (ii) physical indicator, weathering and physical process generated by natural action of water and sediment transport and/or by human action which mainly causes fragmentation of remains, surfaces degradation and re-deposition of rests. It is therefore important to determine which factors or combination of factors are affecting the deposition of plant macrofossils and if some taxa are under- or over-represented in archaeological assemblages (Ferguson, 1995, 1996).

With this context in mind, the aim of this work is twofold, (1) to propose an adapted taphonomic approach for off-site sediment deposits based on grain-size, organic carbon content and degree of degradation of the macrofossils, and (2) to cross-check this information with past environmental settings in order to reconstruct the environmental history of Autrecourt-et-Pourron. To study the taphonomy of plant macro-remains, we selected the archaeological site of Autrecourt-et-Pourron, “Le Pré du Roi” (Ardennes, France). It intersects some palaeochannels of the Meuse River, most of them dating back to the early Holocene (11.7–10.7 ka cal. BP). Based on questioning and assessing quality of conservation of plant macrofossils in a fluvial and marshy context, we present a statistical reference system for the conservation of waterlogged plant remains preserved in oxbow lake sediments.

2 Material and methods

2.1 Study area

The fluvio-palustrine sequence of Autrecourt-et-Pourron “le Pré du Roi” (49°36'57", 391°N/5°2'53", 781°E/altitude ca. 155 m a.s.l.) is located in the Meuse Valley (Fig. 1). The Meuse River flows in a northwesly direction through Jurassic (Late-Lias) marly bedrock, following the Jurassic cuesta scarp of the Eastern Parisian Basin. Airborne imagery and LIDAR-DEM resources (Institut Géographique National, IGN) provide a comprehensive overview of the present-day alluvial landscape, which includes a low sinuosity channel (Canal de l’Est), partly-located on the northwestern border of the valley floor and a 2 km-wide floodplain. This floodplain was shaped by both recent meandering planforms and older irregular palaeochannels with narrowing expansion. Such palaeochannels of the PalaeoMeuse river system were incised by a 4 m-thick layer composed of fluvial gravels corresponding to the Pleniglacial valley infilling of Weichselian age (Lefèvre et al., 1993). The study carried out here was undertaken at the same time archaeological excavations of 2008 and 2012 (O. Brun, unpublished). Both field surveys highlighted several palaeochannels of the PalaeoMeuse River, including a well-preserved palaeochannel sequence (Fig. 2). Several stratigraphical units (SU) were defined according to a continuous vertical succession (Section 3–6) exposed from the bottom of Trench N°6 which was also continuously sampled for the palaeoecological reconstruction (Tab. 1).

2.2 Radiocarbon dating

Samples were directly collected from a 160 cm thick section including a fluvio-palustrine deposit with organic horizons. Based on the different lithostratigraphic units and organic material availability, 10 samples of wood and terestrial plants were dated by the AMS radiocarbon method (14C) in the Beta-Analytic (US) and Poznan-Radiocarbon (Poland) laboratories (Tab. 2). Oxcal 4.3 (Ramsey, 2017) was used to calibrate the AMS 14C ages based on the Northern Hemisphere terrestrial IntCal13 calibration curve (Reimer et al., 2013). Calibrated radiocarbon ages are expressed as ka cal yr BP, while the absolute chronology based on an age-depth model was constructed with a 2σ confidence envelope using

Mots clés : Taphonomie / Conservation / écofacts / paléochenal / sédiment humide / archéobotanique / macrorestes végétaux
R-studio and CLAM package (Blaauw, 2010) and linear interpolation between the dated intervals was applied (Fig. 3).

2.3 Geochemical analyses

For each sediment sample, the grain-size range was assessed with a laser granularity analyser (Coulter LS 230). Samples were prepared by decarbonation (10% H₂O₂) and dissolution of the organic matter (HCl). They were sieved using a 2-mm mesh and then deflocculated with a few millilitres of sodium hexametaphosphate (Na₆O₁₈P₆). After homogenisation, the samples were introduced gradually using an eyedropper, and the concentration values were checked. The different granulometric fractions of the sample were measured by laser sensor. The analyser measured the relative proportions of clay (0.04–2 μm), silt (2–50 μm) and sand (50–2000 μm) with an accuracy of < 1%.

Dry sediment samples (ca. 100 mg) were analysed for Total Organic Carbon (TOC) with a CNS analyser. The TOC content was measured by thermocatalytic oxidation (Elementar, Vario TOC cube analyser).

2.4 Analysis of plant macrofossils

The 29 carpological samples with a thickness of 5 centimetres and a volume of 10 to 20 litres were extracted...
continuously on a stratigraphic column 85-cm wide. After sampling, sediments were water-sieved with several meshes (2, 1, 0.5, and 0.25 mm). Sieved macrofossils were fully sorted under a stereomicroscope with a magnification of 2x to 60x.

Extracted elements were seeds, bryophytes, buds, vegetative parts (internodes, leaf abscission scars), twigs larger than 2 mm in diameter, whole leaves, needles, and charcoal over 1 mm in diameter. Plant macrofossils were identified using standard specialised literature (Berggren, 1969; Beijerinck, 1976; Tomlinson, 1985; Cappers et al., 2006) and the reference collections from the Chrono-environnement Laboratory and GéoArchÉon company. The count is based on the fact that each whole macrofossil consists of one specimen. The fragments were also counted and then converted into an estimated integer (minimum number of individuals) using the “méthode au jugé” (Pradat, 2015). All data were recorded in the AGAM database (Schaal, 2019a). To measure functional diversity, the ecological requirements (Ellenberg, 1992; Julve, 1998) of species were averaged and weighted by the abundance of fossil remains.

2.5 Taphonomic criteria

We considered five descriptors, defined according to qualitative and quantitative parameters. The letters in parentheses correspond to abbreviations of the different conservation status.

- Sclerification rate of cell walls of plant macrofossil: sclerified (S), not sclerified (N), mixed-intermediate sclerification, (M).
- Fragmentation rate: whole (W) or fragmented (F).
- Degradation rate of external tissues: intact (I) or degraded (D).

We tested the influence of these descriptors on macrofossils’ potential preservation using a Principal Component Analysis (PCA) based on plant macrofossil concentrations, except for “algae oogons” and “charred remains” as they result from different taphonomic processes. PCA was done with R and the vegan package (Oksanen et al., 2019). Thus, samples
Table 1. AMS radiocarbon dates, depth and dated material of Autrecourt-et-Pourron section 3–6 as indicated in Figure 2. The shaded line was not considered in in the age model.

<table>
<thead>
<tr>
<th>Autrecourt sample</th>
<th>Depth cm</th>
<th>Laboratory N°</th>
<th>Dated material</th>
<th>$\delta^{13}C$ (%)</th>
<th>Age $^{14}C$ yr B.P. without d13C correction</th>
<th>Conventional Age $^{14}C$ yr B.P. with d13C correction</th>
<th>Calibrated age (cal yr B.P. 2s) INTCAL13 (95.4%)</th>
<th>Calibrated age (cal yr B.P. 2s) INTCAL13 (68.2%)</th>
<th>Calibrated age (cal yr B.C. 2s) INTCAL 13 (95.4%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017-PR354-US326</td>
<td>355</td>
<td>Beta-469433</td>
<td>Waterlogged <em>Linum alpinum</em> seeds (3)</td>
<td>$-26.0$</td>
<td>9810 ± 50</td>
<td>9790 ± 50</td>
<td>9338–9177</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2012-PR406-US326a</td>
<td>360</td>
<td>Beta-460229</td>
<td>Waterlogged wooden twigs</td>
<td>$-27.6$</td>
<td>10 140 ± 30</td>
<td>11 998–11 626</td>
<td>10 049–9 977</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2012-PR353-US303</td>
<td>400</td>
<td>Beta-460231</td>
<td>Waterlogged wooden twigs</td>
<td>$-27.9$</td>
<td>10 310 ± 30</td>
<td>12 377–11 962</td>
<td>10 428–10 013</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
of Autrecourt-et-Pourron were classified qualitatively, and a reference system was created for the site.

3 Environmental history of Autrecourt-et-Pourron

3.1 cold steppic environment

Sandy and clayey silts (SU326, SU327 and SU328) deposited in low sedimentation dynamics, while herbaceous plants and taxa from basophilic grassland vegetation such as Linum alpinum, Scabiosa columbaria and Knautia arvensis are dominants (Fig. 4). The record of Linum alpinum in SU326 is meaningful in terms of paleoclimate, as this species only grows today in subalpine areas, above 1500 m a.s.l. (Julve, 1998). Salix is the dominant tree, as it grew directly near palaeochannel. In addition, plants typical of eroded sandy and stony soils, such as Arenaria serpyllifolia and Linaria supina, together with the recorded fungal species Cenococcum geophilum, indicative of short environmental stress (Kroll, 1988; van Geel et al., 1989; Walker et al., 2003; Eide et al., 2006), suggest most certainly an erosion of soil and organic matter in the floodplain. Sporadic fluvial inputs observed as overflow facies in SU327 and SU328 are in agreement with such biological features. The notable abundances of Urtica dioica, Chenopodium rubrum, Ranunculus repens and Prunella vulgaris might suggest the presence of large herbivores (Bos et al., 2006) since coprophilous fungi (Sordariaceae and Sporormiella), which could be indicators of grazing pressure (van Geel and Aptroot, 2006; Gauthier et al., 2010), have been observed in the pollen samples (E. Gauthier, personal communication, Apr. 2020).

3.2 Channel infilling

During SU329 phase, a decline of Betula sp. was observed, suggesting a greater distance from wooded areas in the valley (Fig. 4). A decrease in Salix sp. was also detected in the floodplain, while Poaceae steppe, Thalictrum and Filipendula wet meadows were significantly well-represented. Plant macrofossils assemblages were strongly dominated by Chara oogonia and Carex rostrata, indicative of aquatic environments. This sudden change in the vegetation composition together with the development of organic mud in SU329 suggest that channel abandonment occurred away from the active river system. Furthermore, the presence of aquatic and helophytic plants, such as Myriophyllum spicatum and Carex rostrata, indicate slightly colder average temperatures than before.

3.3 Development of riparian environment

In the silts, the moisture content was rather stable and provided a suitable environment for the preservation of organic material, the plant macrofossils in the peat layers (SU330 to SU332) were more deteriorated. This taphonomic bias, even if low, should be carefully considered in palaeoecological interpretations. In the diagram (Fig. 4), aquatic plants virtually disappeared and were replaced by marsh plants, especially Carex elata, Filipendula ulmaria and Thalictrum flavum.
In addition, the biodiversity of terrestrial grasses sharply decreased. Then in SU331 (dark peat), the specific composition of marshland plants changed: *C. elata* and *T. flavum* were replaced by *Sparganium erectum* and *Filipendula ulmaria* as the principal species. Large helophytic plants with rhizomes, such as *Typha* and *Sparganium*, developed in connection with the nutrient-rich peat. Based on their ecological requirements, appearances of the tree species *Prunus spinosa* and *Rhamnus cathartica*, and the herbaceous forest plants *Stachys sylvatica* and *Luzula sp.* were favoured by the soil texture and its organic-rich content (Ellenberg, 1992; Julve, 1998). The abandoned channel was colonised by trees and grasses that composed the riparian vegetation.

3.4 An abandoned channel

In SU332, *Betula* sp. was noticeable, while a high density of *Salix* sp. macro-remains was observed together with the first occurrence of *Populus* (Fig. 4). The results reveal that an alluvial forest developed in the floodplain. Changes in the composition of the aquatic community (*Ranunculus aquatilis* and *Hippuris vulgaris* as the main species) provide evidence of hydrodynamic fluctuations. These wetter and more anoxic conditions favoured the conservation of the organic remains. The alluvial sedimentation also changed with massive clay deposition as observed previously in SU333. These facies settled out from suspension in a backwater area of the floodplain, thus in the distal part of the fluvial distributary system. This upper layer of grey clay was strongly subjected to erosional factors, resulting in the carpological material being most likely moved and reworked, causing fragmentation and even destruction. Given the absence of fossil remains of aquatic plants, it can be assumed that the channel was definitely abandoned.

4 Adapted taphonomic approach

4.1 General description of the PCA results

In total, 18,065 plant macro-remains from 88 taxa were isolated and PCA results highlight a clear structuring of...
Fig. 4. Combined analysis diagram. From left to right: the age chronology calibrated before the present, lithostratigraphy, the sediment accumulation rate (year/cm), the organic carbon content (%), coals larger than 1 mm, carbonized seeds, microfauna remains, ichthyofauna and malacofauna, aquatic and terrestrial, sclerotia of *Cenoccocum*, remains of algae oogons, seeds of wetland plants, macro-remains of trees and forest plants, grasslands and wastelands, herbaceous plants not associated with a group. At the end of the diagram, the palynological data are summarized by the percentage of trees and herbaceous plants.
variables (Fig. 5). Axis 1 retains 52.7% of inertia. Axis 2 also retains 21.6% of inertia. We see clear trends in the distribution of groups according to their conservation. The samples found on the negative side of axis 1 come from the deepest SUs characterised by whole and intact non-classified macro-remains (NWI) and whole but degraded non-classified remains (NWD) associated with fungi *sclerotia*. The intermediate depth samples are located on the positive side of axis 1, associated with intact whole sclerified remains (SWI) and whole but degraded sclerified remains (SWD). Axis 2 is strongly influenced by the mixed nature of sclerification; the intact whole mixed whole plant macro-remains (IPM) are mostly distributed on the negative side of the axis. Archaeobotanical variables of the PCA are distributed according to conservation status of plants, ranging from “good” in negative part of axis to “bad” in the positive part. On one hand, this distribution correlates with grain-size and organic chemistry, pointing out that samples with the best-preserved remains have a high sand content and C/N ratio. On the other hand, the least well-preserved remains belong to samples with low sand content and C/N ratio. Intermediate samples show a wide range of variations in particle size and chemical factors in increasing or decreasing order.

4.2 Good conservation in lower units of sequence

Silt-sand, silt-clay or silt-muddy contexts (SU 326 to 329), located more than 280 cm below current ground unit and constantly bathed in the water table, are favourable for conservation of plant remains (Fig. 6). The unsclerified remains, with fragile cellular tissues, are mainly present as whole elements that do not present any morphological degradation. Bryophyte stems, Cyperaceae achenes still enclosed in their utricles, *Linaria supina*, *Rorippa palustris*, or *Linum alpinum* seeds are typical examples of these fragile macrofossils (Fig. 7A). Thus, the remains embedded in lower stratigraphic units are only slightly eroded or corroded. The confidence in fossil assemblages is robust and assemblages could be considered as representative of the ecosystems existing at the time of the unit formation.

4.3 Differential conservation in peat units

4.3.1 Light peat unit

The light brown peaty marshlands contexts, SU 330 and SU 332, located between 275–255 cm and 245–225 cm deep and still below the maximum unit of current groundwater
were positive to preservation of organic plant material (Fig. 6). However, these peat units constitute a context of poorer conservation. The carbon to nitrogen ratio, value below 20, indicates a progressive resumption of macro-remains deterioration. The fragile plant macrofossils (bryophyte leaves, Cyperaceae utricles) are absent or degraded. The proportion of remains with more resistant walls (called mixed or intermediate between unsclerified and sclerified) increases proportionally, such as fruits of Carex sp, Filipendula ulmaria, Ramunculus aquatilis or Myriophyllum spicatum (Fig. 7B). These peat units are characterised by a slowdown in water circulation, notable by an increase in proportion of silt, accompanied by a development of swampy vegetation on the edges. The most fragile remains, which do not settle quickly in the water, are degraded in an aerobic environment. A swamp zone is developing, limiting runoff inputs. Nevertheless, soil and atmosphere remain sufficiently moist, slowing down the significant degradation of organic matter. Robustness of fossil assemblages is reduced but still reliable. Taphonomic bias, although low but noticeable, should be carefully considered in palaeoecological interpretations.

4.3.2 Dark peat unit

The SU 331 (dark brown peat horizon) is interbedded between the two units of light. It is located between 255 and 245-cm depth in the current groundwater table (Fig. 6). The concentration in remains drops from 2385 to 886 per litre of sediment. On the other hand, the average number of taxa raised from 35 to 28. A C/N ratio of 17 suggests an acceleration of decomposition of organic matter. This dark brown peat sedimentary horizon is mostly composed of intact or degraded whole sclerified plant remains, such as Sparganium erectum seeds, Salix sp. buds, Hippuris vulgaris seed; Thalictrum flavum seed; Eupatorium cannabinum fruit; Apiaceae mericarpe.

Fig. 6. Diagram with Lithostratigraphy, grain-size (%), organic carbon (%), charcoal (number/litre), carbonized seed (number/litre) and aquatic and terrestrial fauna (number/litre) data. Ecological values (moisture, reaction, nitrogen and organic matter), of the identified plant taxa at the species level, were averaged and weighted by the abundance of plant fossil remains. Depth below ground level. LPAZ: Local Pollen Assemblage Zone.

the most fragile macrofossils, such as fruit envelopes and capsules with thin and soft outer walls.

4.4 Degraded units

The upper unit of the stratigraphic section, SU333, located below the current groundwater table, consists of grey to green clay (Fig. 6). The granulometric analyses highlight strong increase in clayey deposits. The C/N ratio is the lowest found in the entire sequence/trench (14), and suggests the acceleration of organic matter alteration. The average concentration and taxonomic diversity of plant remains are at their lowest with 392 remains per litre, for 15 taxa. A majority of fragmented and/or degraded remains such as Eupatorium cannabinum and Apiaceae are characterising the macrofossil assemblages (Fig. 7D). Weathering and physical erosion are potentially the main factors responsible for high degradation, or even the total destruction of a large part of assemblage and therefore impossible to recover. Palaeoecological interpretation must be extremely careful considering this major taphonomic bias. Thus, low number of taxa, with differential conservation, could be an indicator of a water level decline.

5 Conclusion

Wetlands (lakeshores, peat bogs, rivers) are ideal contexts for archaeobotanical research, indeed, the quantity of organic material preserved is often much higher than that observed in terrestrial environments. While it is certain that absence of wet conditions leads to destruction of non-fossilised plant macrofossils, the current presence of groundwater does not presume an exceptional conservation of waterlogged subfossil material.

Up to now, for off-site, a comprehensive framework for assessing the conservation status of plant macrofossils in a wet context does not exist. Based on the various studies done in this field, we have set up a specific methodology for the analysis of the Autrecourt-et-Pourron palaeochannel. This method is based on granulometric and physico-chemical measurements of sediment to which we associate histological and morphological parameters of plant macrofossils. From the combination of these parameters, we created a taphonomic scale to assess the conservation status of archaeobotanical material. This scale makes it possible to estimate the level of confidence that we can bring to palaeobotanical assemblages.

1 Deep units of silty sediment provide an excellent preservation of plant macrofossil assemblages that will make possible to reconstruct past environments in details.
2 The unit of light peat, whose moisture content has remained sufficiently constant, is also a suitable environment for the proper conservation of organic material.
3 The unit of dark peat is strongly impacted by the degradation of plant remains and caution must be taken for the interpretation of incomplete carpological assemblages.
4 Unit of grey clay is very strongly subject to erosion factors, material is most likely moved and reworked, leading to its fragmentation and even destruction, interpretations must be consider with carefully.

Taphonomic phenomena do not affect the organic material in the same way given the histological differences of the remains. During sampling and analysis, it is therefore important to consider, independently, preservation status of each vegetation marker. The perceptible changes in taphonomy of plant macrofossils suggest that the landscape structure is changing with hydrological and climatic changes. In addition, anthropogenic causes such as the exploitation of the palaeochannel or the nearby land are possible hypothesis. However, the absence of archaeological data acquired to Autrecourt-et-Pourron for the Preboreal, do not allow for confirm or infirm a potential human impact.

In conclusion, it seems that taphonomic approach contributes significantly to the understanding and interpretations of plant macrofossil assemblages. For future palaeoecological studies, it will be important to strengthen our knowledge through multidisciplinary approaches, in order to build solid taphonomic references adapted to river and off-site sites. The framework will have to be applied to other sites of the same type to confirm the conclusions obtained at Autrecourt-et-Pourron.

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