



HAL
open science

Late MIS 3 interstadial vegetation in coversands at Saint-Vincent-de-Paul, Southwest France

David Aoustin, Pascal Bertran, Chantal Leroyer

► **To cite this version:**

David Aoustin, Pascal Bertran, Chantal Leroyer. Late MIS 3 interstadial vegetation in coversands at Saint-Vincent-de-Paul, Southwest France. *Quaternaire*, 2022, vol. 33/3, pp.193-206. 10.4000/quaternaire.17053 . hal-03950388

HAL Id: hal-03950388

<https://hal.science/hal-03950388>

Submitted on 21 Jan 2023

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.

1 **Late MIS 3 interstadial vegetation in coversands at Saint-Vincent-de-Paul, southwest France.**

2 David Aoustin¹, Pascal BERTRAN^{2,3*} & Chantal LEROYER⁴

3

4 ¹ CNRS /UMR 6566 CReAAH, Laboratoire Archéosciences, Campus de Beaulieu, bât. 24-25, 35042
5 RENNES Cedex [david.aoustin@univ-rennes1.fr]

6 ² Inrap, 140 avenue du Maréchal Leclerc, 33130 Bègles, France (pascal.bertran@inrap.fr)

7 ³ PACEA, UMR 5199 CNRS, Université de Bordeaux, allée Geoffroy-Saint-Hilaire, 33605 Pessac, France

8 ⁴Ministère de la Culture / UMR 6566 CReAAH, Laboratoire Archéosciences, Campus de Beaulieu, bât.
9 24-25, 35042 RENNES Cedex [chantal.leroy@univ-rennes1.fr]

10 * corresponding author

11

12 **ABSTRACT**

13 An archaeological survey carried out at Saint-Vincent-de-Paul, about 11 km northeast of Dax (Landes,
14 southwest France) made it possible to investigate a new sequence of aeolian sands overlying a Middle
15 Pleistocene alluvial terrace of the Adour River. A peat level with wood fragments was found between
16 2.2 and 2.4 m depth at the bottom of a gully incised in, and then filled with aeolian sands. The peat,
17 ¹⁴C dated on wood fragments to 26,731 ± 101 BP (31,136-30,844 cal BP) and 28,066 ± 106 BP (32,821-
18 31,655 cal BP), can be correlated with the interstadial GI-5.1 (or possibly GI-5.2) of the Greenland Ice
19 Core Chronology, i.e., in the latter part of Marine Isotope Stage (MIS) 3. The scarcity of Pleistocene
20 peats in the region makes this discovery highly valuable for documenting the palaeoenvironments
21 contemporary with the Middle Gravettian. The peat was cross-studied for pollen, non-pollen
22 palynomorphs (NPPs), charred particles and woody macroremains. At the beginning of peat formation,
23 a reed bed associated with willows developed locally in a treeless landscape. The surrounding area was
24 covered by steppe vegetation, dominated by sagebrush. Later, the gully was colonized by birch trees,
25 accompanied by *Salix*, *Myrica*, *Calluna* and *Erica cf. tetralix*. Finally, a sphagnum bog colonized by
26 *Myrica*, *Calluna* and *Erica cf. tetralix* developed. The phase of woodland growth was synchronous with
27 an increase in charred particles. This study together with the previous analyses made on regional MIS
28 3 peats strongly suggests that patches of boreal forest repeatedly developed in favorable locations in
29 the Landes region during the interstadials of the Last Glacial and lends support to the assumption of
30 discontinuous aeolian activity in the coversand area.

31 **Keywords:** Late MIS 3 peat, Landes, southwest France, pollen, xylology

32 **RESUME**

33 VEGETATION INTERSTADIAIRE DE LA FIN DU SIM 3 DANS LES SABLES EOLIENS LANDAIS A SAINT-
34 VINCENT-DE-PAUL, SUD-OUEST DE LA FRANCE.

35 Des sondages archéologiques réalisés à Saint-Vincent-de-Paul, à environ 11 km au nord-est de Dax
36 (Landes, sud-ouest de la France) ont permis d'étudier une nouvelle séquence de sables éoliens
37 recouvrant une terrasse alluviale de l'Adour attribuée au Pléistocène moyen. Un niveau de tourbe
38 avec des fragments de bois a été trouvé entre 2,2 et 2,4 m de profondeur au fond d'une ravine

39 incisée dans les sables éoliens, puis remplie par de nouveaux apports sableux. La tourbe, datée au ^{14}C
 40 sur des fragments de bois de $26\,731 \pm 101$ BP ($31\,136\text{-}30\,844$ cal. BP), et $28\,066 \pm 106$ BP ($32\,821\text{-}31$
 41 655 cal. BP) peut être corrélée avec l'interstadaire GI-5.1 (ou peut-être GI-5.2) de la chronologie
 42 glaciaire du Groenland, c'est-à-dire dans la dernière partie du stade isotopique marin (SIM) 3. La
 43 rareté des tourbes pléistocènes dans la région rend cette découverte d'un grand intérêt pour
 44 documenter les paléoenvironnements contemporains du Gravettien moyen. La tourbe a fait l'objet
 45 d'études croisées pour le pollen, les microfossiles non polliniques (NPPs), les particules végétales
 46 carbonisées et les macrorestes ligneux. Au début de la formation de la tourbe, une roselière associée
 47 à des saules s'est développée localement dans un paysage dépourvu d'arbres. La zone environnante
 48 était couverte d'une végétation steppique, guidée par l'armoise. Plus tard, le ravin a été colonisé par
 49 des bouleaux, accompagnés de *Salix*, *Myrica*, *Calluna* et *Erica cf. tetralix*. Enfin, une tourbière à
 50 sphaignes peuplée de *Myrica*, *Calluna* et *Erica cf. tetralix* s'est développée. La densification des
 51 boisements locaux et l'accroissement consécutif de la biomasse se sont accompagnés de
 52 l'augmentation des particules carbonisées. Cette étude, ainsi que les analyses précédentes
 53 effectuées sur des tourbes régionales du SIM 3, suggèrent fortement que des parcelles de forêt
 54 boréale se sont développées de manière répétée dans les endroits favorables des Landes pendant les
 55 interstades du Dernier Glaciaire et soutient l'hypothèse d'une activité éolienne discontinue dans la
 56 zone des sables de couverture.

57 **Mots-clés** : Tourbe de la fin du SIM 3, Landes, sud-ouest de la France, pollen, xylogologie.

58

59 1. Introduction

60 While pollen sequences documenting the Last Glacial (e.g., Woillard, 1978; De Beaulieu and Reille,
 61 1984, 1992a, 1992b; Guiter *et al.*, 2003; Fletcher *et al.*, 2010; Sirocko *et al.*, 2016; Duprat-Oualid *et*
 62 *al.*, 2017 ; Kern *et al.*, 2022) remain scarce in western Europe, they are especially rare and
 63 discontinuous in Aquitaine, southwest France (Paquereau and Schoeller, 1959; Paquereau, 1961;
 64 Diot, 1999). As a result, vegetation contemporary with the Last Glacial remains very poorly
 65 documented there. The closest available data are mainly from the Massif Central (Reille and De
 66 Beaulieu, 1988, 1990; De Beaulieu and Reille, 1992b), the Pyrenees (Olfield, 1968; Andrieu-Ponel *et*
 67 *al.*, 1988; Jalut *et al.*, 1992; Jalut *et al.*, 1998; González-Sampériz *et al.*, 2006) and the Loire and
 68 Garonne basins recorded in the marine sediments of Bay of Biscay (Sanchez-Goñi *et al.*, 2008,
 69 Fletcher *et al.*, 2010). These records provide only an imperfect picture of lowland vegetation in
 70 Aquitaine, either because of the altitude (Massif Central and Pyrenees) or because the pollen inputs
 71 come from a wide geographical area (Bay of Biscay).

72 The Pleistocene peat levels discovered during preventive archaeological work offer the opportunity
 73 to document in detail, albeit during small time windows, the glacial palaeoenvironments of the
 74 region. Although discontinuous, these records provide information on the vegetation mosaic
 75 characterizing a region and may allow the identification of potential refuge areas for temperate
 76 trees. Due to poor drainage, the Landes plateau has yielded numerous occurrences of peat
 77 intercalated in the aeolian 'Sable des Landes' Formation. Some of these levels have been the subject
 78 of pollen analysis and numerical dating, which made it possible to relate them to interstadials of the
 79 first half of Marine Isotopic Stage (MIS) 3 (i.e., 55-40 ka; Cestas-Les Pins de Jarry, Bertran *et al.*, 2009,
 80 2020; Barp-Pot aux Pins, Sitzia *et al.*, 2015) (Fig. 1) or to the Middle Pleistocene (Hourtin, Sitzia *et al.*,

81 2015, north of the coversands not shown in Fig. 1). The discovery of a peat level about 15 cm thick at
82 Saint-Vincent-de-Paul in the southern margin of the 'Sable des Landes' provides an opportunity to
83 document another late MIS 3 interstadial and is the focus of this paper. The presence of wood
84 fragments gives this peat an exceptional character.

85 **2. Geomorphological setting**

86 The study site is located in the Adour valley on the right bank, approximately 11 km northeast of Dax
87 (southwest France) (Fig. 1). The 1:250,000 digital geologic map of Aquitaine (Bourbon, 2019)
88 indicates that the bedrock is a high alluvial terrace of the Adour River (Fv, Lower to Middle
89 Pleistocene). Aeolian sands several meters thick, which are an integral part of the 'Sable des Landes'
90 Formation (Sitzia *et al.*, 2017), overlie the alluvial deposits. The geotechnical drillings carried out as
91 part of the development of the site did not reach the alluvium at a depth of 3 m. According to
92 borehole BSS002EAWU located approximately 3.3 km to the southwest and stored in the Banque du
93 Sous-Sol of the Bureau des Recherches Géologiques et Minières (<http://infoterre.brgm.fr/>), the sands
94 would reach 5.5 m in thickness in the area. The aeolian cover has yielded two ages by Optically
95 Stimulated Luminescence (OSL), one related to the Middle Pleistocene (~160 ka), the other to the
96 Upper Pleistocene (~26 ka) in the Pontonx quarry 3 km to the southeast (Bertran *et al.*, 2020).

97 The topography visible from the 5 m DEM of the Institut Géographique National (RGEALTI® 5 m)
98 shows that the area is covered by ridges 1 to 2 m high and oriented WNW-ESE, which correspond to
99 the arms of elongated parabolic dunes (Fig. 2A). These degraded dunes have been dated to the
100 Younger Dryas (~12 ka) at various points in the Landes, notably at Castets and Saint-Geours-de-
101 Maremne (Bertran *et al.*, 2020), and mark the ultimate evolution of Pleistocene coversands. The
102 relief was then dissected by a network of gullies connected to tributaries of the Adour River.

103 **3. Methods**

104 A peat block was collected in trench CM1-T10 (Fig. 3) for a multidisciplinary study including pollen
105 and spores, non-pollen palynomorphs (NPPs), charred particles and woody macroremains. For the
106 palynological study (pollen and NPPs), all samples were processed following the standard method
107 developed by Faegri and Iversen (1975), which consists of chemical treatments with 10% NaOH, 37%
108 HCl and 48% HF. Then a separation with a heavy liquid ($ZnCl_2$, density=2) has been carried out. No
109 acetolysis was made in order to recognize any contamination by exogenous pollen stocks. Finally, the
110 rest of the sediment was sieved using 10 μm and 200 μm mesh sieves.

111 The preparation involved a volume of 4 cm³ of sediment. To estimate the richness in palynomorphs,
112 the absolute pollen concentrations (number of pollen grains and spores per cm³ of sediment) were
113 calculated according to the method of Stockmarr (1971). Palynomorphs were mounted in a mobile
114 medium (glycerine) and identified at 500 \times and 1000 \times magnification. Identification of spores and
115 pollen material was made using determination keys (Faegri and Iversen, 1975; Moore *et al.*, 1991;
116 Beug, 2004), photographic atlases (Reille, 1992, 1995, 1998) and the CReAAH pollen reference
117 collection. The names of taxa followed by "type" refer to nomenclature of "The Northwest European
118 pollen flora" for Asteraceae, Gentianaceae, Polygonaceae, Sparganiaceae families, and to
119 nomenclature of Moore, Webb and Collinson for Plumbaginaceae family (Punt, 1975; Punt and
120 Nienhuis, 1976; van Leeuwen *et al.*, 1988; Moore *et al.*, 1991; Punt and Hoen, 2009). Determination
121 of non-pollen microfossils was carried out with the atlas published in 1998 based on the work of van
122 Geel (van Hove and Hendrikse, 1998), supplemented by the synthesis of Miola (2012) and the

123 theses of Jouffroy-Bapicot (2010) and Cugny (2011). The diagram was built on a basic sum from
124 which sedges (Cyperaceae), spores and indeterminate grains were excluded. NPPs are expressed as a
125 percentage of the pollen sum. Microscopic charred particles (10-200 μm) observed in pollen sample
126 residues were also counted on five lines at 500 \times magnification on each pollen slides. The
127 concentration of charred particles in the sediment was obtained using an adaptation of the
128 volumetric method (Cour, 1974). This method was chosen because the morphological features of
129 charred particles differ from *Lycopodium* spores, which are spherical. The concentration of charred
130 particles is expressed as the number of charred particles per cm^3 of fresh sediment.

131 For the xylological study, macroremains recovery involved water sieving of the sediment on a column
132 of 250 μm , 500 μm and 2 mm sieves. The volume of sieved sediment ranged from 100 to 400 cm^3 ,
133 depending on the available sampling volume (Table 1). Wood analysis was performed on the remains
134 larger than 2 mm. A number of 40 to 50 individuals were analyzed in the majority of samples. The
135 minimum number of fragments to be analyzed per sample was determined from the cumulative
136 frequencies of taxa as a function of the number of individuals, the optimal number being reached
137 when the frequencies of taxa are stabilized. Prior to taxonomic identification, macroscopic analysis of
138 the wood fragments was carried out under a binocular microscope, i.e. length, width, thickness,
139 presence of bark, pith, and stem starts associated or not with leaf scars, degree of ring curvature
140 according to three classes (strong, intermediate and weak). The taxonomic identification was carried
141 out with a transmitted light microscope, (x200 and x500) using xylological atlases (Schweingruber,
142 1978, 1990). For the genus *Erica*, the arrangement of leaf scars and their number, observed under
143 binocular microscope, was a criterion for the specific determination, using the flora of Rameau *et al.*
144 (1989). The taxonomic identification of the root wood could not be realized as root wood does not
145 have a uniform anatomical structure and cannot be identified except for rare cases (Schweingruber,
146 1978).

147 **4. Results**

148 **4.1. Stratigraphy**

149 The trenches carried out during the archaeological survey allowed us to observe the sedimentary
150 formations over a thickness of 3 m. The stratigraphy is relatively homogeneous on the land parcel. It
151 is schematically composed of the following units, from the top to the bottom (Fig. 3):

152 (1) A Holocene podzol, about 1 m thick. The upper horizons have been mixed by agricultural work
153 (black Ap horizon, 0.4 to 0.5 m thick). The underlying horizons (Bh, Bs) are poorly cemented by Fe
154 oxides.

155 (2) Light brown sands becoming light grey at the base, with dominant subhorizontal bedding. Levels
156 with deformed or slightly oblique bedding are present. This unit corresponds to aeolian sandsheet
157 deposits (coversands).

158 Two trenches (CM1-T10 and CM2-T9) revealed a peaty level beneath the sandy cover between 2.2
159 and 2.4 m deep (Fig. 2B). This level was described in detail and sampled in trench CM1-T10 (Fig. 3). It
160 shows at the base (Fig. 4) alternating peaty and sandy beds (2 cm thick); then brown peat with
161 abundant plant debris (4 cm) (Fig. 5), humified black peat with plant debris (3 cm), and finally, at the
162 top, alternating sand and black peaty beds (5 cm). The base of the sequence consists of coarse
163 subhorizontally bedded brown sands of alluvial origin.

164 The limited spatial extent of the peat suggests that it formed in a gully incised in aeolian deposits.
 165 Examination of the 5 m DEM (Fig. 2) indicates that the area is intersected by several small tributaries
 166 of the Adour River, notably the Pont-de-Paul creek that flows 400 m west of the parcel. These
 167 shallowly incised tributaries (2 to 3 m) form a roughly dendritic network, converging on a single,
 168 deeper talweg at the edge of the present Adour plain. The hypothesis of an ancient gully incised into
 169 the sands during an interstadial period, then largely filled by aeolian deposits during the Last Glacial
 170 Maximum can therefore be proposed to account for the localized presence of peat accumulation. In
 171 trench CM1-T10, two generations of aeolian sandy fill separated by a small incipient podzol can be
 172 distinguished. The more recent generation of sand is likely related to the emplacement of the
 173 Younger Dryas dunes.

174 **4.2. Chronology**

175 Two samples were dated by AMS-¹⁴C at the CIRAM laboratory (Martillac). A first large wood fragment
 176 (4 cm long, 1 cm wide) was taken from the median brown peat level. The age obtained (CIRAM-AV85)
 177 is 26,731 ± 101 BP, i.e. 31,136 to 30,844 cal BP (2, Intcal20). Another smaller willow fragment from
 178 the basal sand and peat beds was also dated. The age (CIRAM-4395) is 28,066 ± 106 BP, i.e. 32,821 to
 179 31,655 cal BP. The peat can therefore be correlated with one of the GI-5.1 or GI-5.2 interstadials of
 180 the Greenland ice core record (Rasmussen *et al.*, 2014), i.e., in the latter part of MIS 3. Insofar as the
 181 study of pollen assemblages (see *infra*) shows that the peat recorded only one phase of climate
 182 amelioration and no discontinuity in sedimentation is identifiable within the level, a correlation with
 183 GI-5.1 is favored here. According to this hypothesis, the small willow fragment taken from the base
 184 of the peat could correspond to slightly older material reworked at the bottom of the gully.

185 **4.3. Palynology**

186 4.3.1. Pollen and NPP

187 Pollen sedimentation conditions appear favorable, ensuring reliable and significant data from a
 188 palaeoecological point of view (Reille, 1990; Leroyer, 1997), as shown by high counts and absolute
 189 concentrations, good preservation of pollen stocks, and satisfactory taxonomic diversity (Table 2, fig.
 190 6). This has made it possible to draw up a floristic list of 44 taxa, to which can be added 26 NPPs (fig.
 191 6). The pollen assemblages (Table 3, fig. 6) allows us to identify three local pollen zones (LPZ), with
 192 the first two composed of only one sample each.

193 Characterized by the scarcity of tree pollen, the first local pollen zone (LPZ 1, sample at 15 cm from
 194 the top of the peat) covers the base of the organic level (peaty sand). The environment appears very
 195 open with the local presence of a reed bed-megaphorbia or a sedge meadow (Poaceae, Cyperaceae,
 196 Rosaceae, Ranunculaceae, *Thalictrum*), formations that thrives on waterlogged soils with little
 197 oxygen (Fare *et al.*, 2001). The absence of aquatics indicates that there was no perennial water body
 198 (Dutartre and Rebillard, 2015). In addition to pollen assemblages, the presence of this vegetation is
 199 corroborated by the predominance of *Clasterosporium caricinum* (HdV-126) and *Byssothecium*
 200 *circinans* (HdV-16), microfossils that are respectively associated with *Carex* (Cyperaceae) and
 201 Poaceae but are absent from very wet areas (van Geel, 1976; van Geel and Middeldorp, 1988; van
 202 Geel and Aptroot, 2006; Yeloff *et al.*, 2007). A few rare trees were present, mainly willows (*Salix*)
 203 whose occurrence *in situ* is confirmed by woody debris (Fig. 7) but also some rare hygrophilous
 204 shrubs (*Myrica*, Ericaceae, *Calluna*). In the surroundings, the drier areas hosted a low steppe
 205 vegetation, dominated by sagebrush (*Artemisia*) accompanied by other heliophilous herbaceous

206 species requiring well-drained soils. In light of the low pollen count (12%), the local presence of pine
 207 appears unlikely (Huntley and Birks, 1983). Its record is more likely to be the result of distant
 208 contributions in an open environment because of high pollen production and its capacity for long-
 209 distance dispersal (Heim, 1970). Similarly, the sporadic nature and low occurrence (< 0.5 %) of
 210 temperate hardwoods (*Fagus*, *Carpinus*, *Corylus*) also argue for distant contributions even though the
 211 maintenance of beech in southwestern France during the Late Pleistocene is plausible based on
 212 palaeogenetic data (de Lafontaine *et al.*, 2014). Although current pollen studies show that
 213 percentages of *Fagus* below 2% may indicate the local presence of isolated trees (Huntley and Birks
 214 1983), the persistence of beech during MIS 3 near St. Vincent de Paul cannot be assumed from our
 215 data, since it is only recorded in the basal peat sample, which also provides the greatest amount of
 216 pine pollen from distant sources.

217 The base of the brown peat (LPZ 2, sample at 10 cm) shows a profound local environmental change.
 218 The wetland was colonized by birch trees (*Betula*), accompanied by willows and rarer Ericaceae and
 219 marsh heather (*Calluna*). The development of trees created a filter to distant inputs of pine pollen,
 220 which supports the idea that pine was not established in the immediate vicinity. Similarly, the
 221 perception of steppe vegetation (*Artemisia*, Asteraceae, Chenopodiaceae) decreased, but it is not
 222 possible to assess whether it really declined. Although more constrained, a reed bed remained in the
 223 site. It evolved somewhat with the appearance of meadowsweet (*Filipendula*) and bur-reed
 224 (*Sparganium emersum* type) at the side of Cyperaceae and Poaceae. Bur-reed indicates, in the
 225 absence of true aquatic plants, soils that are often wet but without perennial water (Aniotsbehere,
 226 1999). This interpretation is corroborated by the microfossils HdV-128 and HdV-187d, the latter
 227 infatuated with *Phragmites* and *Carex*, both of which indicate shallow, eutrophic water (Pals *et al.*,
 228 1980; van Geel *et al.*, 1983). However, the appearance of copepod spermatophores could suggest the
 229 at least temporary occurrence of open water (van Geel, 1978). These small crustaceans can also be
 230 related to the establishment of sphagnum mosses (Mighall *et al.*, 2006), reported by their spores and
 231 the presence of *Tilletia sphagni* (HdV-27), which is dependent on them (van Geel, 1978).

232 The third pollen (LPZ 3, samples at 7.5, 5 and 2 cm) zone shows the development of a sphagnum bog,
 233 which is attested, in addition to the rise of *Sphagnum* spores, by *Tilletia sphagni* (HdV-27). Other
 234 microfossils typical of sphagnum bogs are present, e.g. *Assulina muscorum* (HdV-32a) and *Callidina*
 235 *angusticollis* (HdV-37). The former has broad ecological requirements, but has a high relative
 236 abundance in drier stages of bogs (Payne *et al.*, 2012). The evolution of vegetation appears to have
 237 been gradual with, initially (LPZ 3a), the retreat of birch trees to the benefit of willows, with also
 238 some Ericaceae and bog myrtle (*Myrica*). Then (LPZ 3b and c), the site was colonized by *Myrica*, a
 239 shrub specific to acidic and humid soils, especially peat bogs (Bournerias, 1979). Birch trees (LPZ 3b)
 240 and then willows (LPZ 3c) disappeared almost completely, but a few Ericaceae and *Calluna* remained.
 241 The development of a denser local vegetation led to the non-perception of pines. On the other hand,
 242 the persistence of a reed bed is testified by pollen of Poaceae and Cyperaceae but also by the
 243 presence of microfossils that are attached to them such as *Clasterosporium caricinum* (HdV-126) and
 244 sometimes *Glomus cf. fasciculatum* (HdV-207) (van Geel *et al.*, 1989, 2003).

245 4.3.2. Palynofacies and charred particles

246 The palynofacies consists mainly of fresh non-woody plant debris, i.e. rootlets of Cyperaceae, tissues
 247 of aerial parts of Monocotyledons, indeterminate herbaceous tissues, and more rarely Bryophyte and
 248 *Sphagnum* tissues. Charred particles are rarer, especially in the two lower samples (15 and 10 cm),

249 where their concentrations are less than 1500 debris/cm³. However, the charred particles increase
 250 abruptly from 7.5 cm where they reach their maximum concentration (117,365/cm³) and then
 251 decrease to around 85,000/cm³. They include remains of woody and herbaceous nature, of which
 252 some correspond to tissues of aerial parts of Monocotyledons. Their size is small, mostly less than
 253 100 µm, but some herbaceous remains can reach up to 420 µm in length and 140 µm in width. The
 254 increase in the concentration of charred particles is synchronous with the densification of local
 255 woodlands, corroborating their association with a higher biomass characteristic of wetter
 256 interstadials (Daniau *et al.*, 2009, 2010).

257 **4.4. Macroremains**

258 4.4.1. Representativeness of data

259 While a minimum of 40-50 individuals was analyzed in most samples, the optimum number was not
 260 systematically reached (i.e. for sample 0-4 cm). Wood fragment concentrations increased from the
 261 base to the top (Table 1), reaching up to 243 fragments per 100 cm³ of sediment in the top sample.
 262 Only five taxa were identified, i.e. birch (*Betula pendula/pubescens*), willow (*Salix*), marsh heather
 263 (*Erica cf. tetralix*), heather (*Erica*) and Ericaceae (Table 3). The high rate of indeterminate debris results
 264 from the abundance of root fragments, which do not allow identification except occasionally for birch
 265 (Schweingruber, 1978, 1990).

266 Preservation of woody material is variable across layers and taxa. For example, *Erica cf. tetralix* and
 267 Ericaceae fragments are generally well preserved in the four samples where they were identified (Table
 268 4). The condition of willow fragments is variable, but mostly quite poor, while birch fragments are
 269 poorly preserved in the three lower samples (7.5-10, 10-15 and 15-17 cm). The willow and birch
 270 fragments have a compressed cross section. The fragments are small with a length ranging from 0.06
 271 to 5.1 cm (mean 1.3 cm) and a width from 0.05 to 2 cm (mean 0.25 cm). In fact, the different species
 272 show slightly different sizes (Table 4). When the cross-section is complete, the diameter could be
 273 calculated. It never exceed 0.5 cm and is mostly smaller than 0.25 cm. The largest diameters
 274 correspond mainly to indeterminate remains, to which are added one fragment of birch and one of
 275 heather. The woody material is, therefore, of small size. When identifiable, the curvature of the rings
 276 is always strong, except for one individual with intermediate curvature, pointing to small branches.

277 4.4.2. Evolution of the macroremain assemblages

278 The general diagram (Fig. 8) shows the predominance of willow (*Salix*) ahead of birch (*Betula*) in the
 279 three lower samples (7.5 to 17 cm), followed by indeterminate remains (4 and 5 cm) and, finally,
 280 heather (*Erica*) at the top. *Salix* has its maximum representation at 10-15 cm then decreases somewhat
 281 (7.5-10 cm) and then disappears completely from 7.5 cm. Its evolution as woody fragments roughly
 282 follows that documented by the pollen assemblages, which shows the retreat of willow in the upper
 283 levels (Fig. 6). However, the relative abundance of *Betula* in the basal peaty sand beds raises questions,
 284 as it is not attested in pollen assemblages. Since this absence cannot be attributed to a deficit in pollen
 285 production and dispersal (Heim, 1970), it is likely that the birch fragments correspond to roots, which
 286 are identifiable for this species (Schweingruber, 1978, 1990). They would, therefore, derive from the
 287 birch stand that later established in the site.

288 *Erica* appears in the 7.5-10 cm sample. It is the only taxon recorded in the two overlying samples (0-5
 289 cm) that yielded mainly indeterminate woody debris (>90%). *Erica* becomes largely predominant at

290 the top, especially if we accept that the Ericaceae fragments refer to this genus. The woody debris thus
 291 documents an environment somewhat different from that depicted by palynology, as it includes no
 292 remains of *Myrica* but almost exclusively of *Erica cf. tetralix*. This difference is likely due to two factors,
 293 the pollination mode of Ericaceae, which are always under-represented in pollen assemblages (Heim,
 294 1970) even if in areas where *Erica sp* are locally abundant, pollen values >25% can be frequent (Huntley
 295 and Birks, 1983), and the very local information provided by the macroremains. It can be assumed that
 296 only marsh heather was growing at the sampled site, while bog myrtle was located a little further away,
 297 but probably in the immediate vicinity as *Myrica* usually has a low pollen representation, even where
 298 it is abundant and growing luxuriantly (Huntley and Birks, 1983).

299 5. Discussion

300 As mentioned above, continental records documenting the Last Glacial vegetation remain scarce in
 301 Western Europe. Vegetation is mainly documented by a few long continental sequences geographically
 302 distant from southwest France, supplemented by fragmentary records from northwest Europe coming
 303 from organic levels intercalated in glacial deposits (Fletcher *et al.*, 2010). The pollen analyses carried
 304 out on the peaty levels discovered during preventive archaeological work in the Landes region are
 305 closely related to the latter. Although discontinuous, these records have the advantage of being close
 306 to each other and of having been deposited in a similar geomorphological context, i.e. Pleistocene
 307 coversands. Also dated to MIS 3, they allow for comparison with the Saint-Vincent-de-Paul record.

308 Two sites near the town of Cestas (Fig. 1) have been analyzed and dated. In both sites, the peat levels
 309 are cryoturbated and have developed in interdune depressions in connection with the rise of the
 310 groundwater table. At Barp-Pot aux Pins, the peat was OSL-dated between 50 ± 3 ka and 55 ± 3 ka and
 311 correlated with GI-14 (Sitzia *et al.*, 2012, 2015). Pollen assemblages are dominated by *Pinus*, ahead of
 312 Ericaceae, Poaceae and *Myrica*. The internal evolution of the peat level attests to a rise in woody
 313 species (*Pinus*, *Myrica*, Ericaceae) at the expense of Poaceae. The peat sample analyzed at Cestas-Les
 314 Pins de Jarry was ^{14}C -dated on bulk sediment to $23,550 \pm 160$ BP (27,330-28,020 cal BP) and $22,390 \pm$
 315 120 BP (26,140-26,670 cal BP) (Bertran *et al.*, 2009). Nevertheless, an OSL date on aeolian sand made
 316 10 cm above the peat subsequently provided an age of 40.2 ± 2.7 ka (Bertran *et al.*, 2020), which
 317 strongly suggests that the ^{14}C ages were rejuvenated probably due to illuvial organic matter derived
 318 from the superficial podzol. Therefore, this level could correspond to a relatively old MIS 3 interstadial
 319 (GI-9 to GI-14). The single pollen assemblage obtained shows a pattern quite similar to the last phase
 320 seen at Saint-Vincent-de-Paul, and is dominated by Poaceae, *Myrica*, Ericaceae, *Pinus* and *Betula*. If
 321 the distribution of the different taxa is not completely similar (Ericaceae, *Pinus*, *Betula* and Poaceae
 322 are better perceived there than *Myrica*), it nevertheless refers to the same type of environment.

323 Overall, the MIS 3 peat levels described in the Landes show the development of localized woodlands
 324 during various interstadials, mainly composed of cold-tolerant species typical of the boreal forest
 325 (*Salix*, *Betula*) associated with hygrophilous plants such as *Myrica* and Ericaceae. *Pinus*, more or less
 326 abundantly represented in pollen assemblages, is probably present only at great distance from the
 327 sites (cf. Cheddadi *et al.*, 2006). It is only known in the region as macroremains (charcoal) during the
 328 Alleröd interstadial in palaeosols preserved beneath Younger Dryas dunes (Bertran *et al.*, 2009; Sitzia
 329 *et al.*, 2015). Better representation of *Pinus* during GI-14 than GI-5, which suggests greater regional
 330 abundance, is in line with the Bay of Biscay record (Sanchez-Goñi *et al.*, 2008; Fletcher *et al.*, 2010).
 331 The absence of thermophilous tree taxa such as *Quercus* and *Fagus* is also noteworthy. The single
 332 occurrence of a *Fagus* pollen grain in the basal peat sample cannot lend support to the debate about

333 the presence of beech stands in the Landes during MIS 3 proposed from genetic studies (de Lafontaine
334 *et al.*, 2014).

335 The interstadial vegetation dynamics recorded in southwest France do not differ significantly from
336 those seen elsewhere in lowland western Europe, with the development of a few trees (*Salix*, *Betula*,
337 *Juniperus*) in the context of an open vegetation dominated by Poaceae and Cyperaceae (Guiter *et al.*
338 2003; Fletcher *et al.*, 2010; Kern *et al.*, 2022). Comparison with the long French continental records (La
339 Grande Pile, Les Echets, Velay maars, Sost, Barbazan, Lourdes) is not always easy because of the low
340 resolution and poor chronological control that limit correlations to the various MIS 3 interstadials. The
341 Velay sequences (Lac du Bouchet, Ribains), geographically closest but located at much higher
342 elevation, reflect punctual extensions of *Pinus* and *Picea* into an open *Betula* and *Salix* boreal forest
343 during the Upper Pleniglacial, which were attributed to long-distance transport or to older pollen
344 stocks reworked by erosion (Reille and de Beaulieu 1988, 1990; de Beaulieu and Reille, 1992a). In the
345 French Pyrenees, the Barbazan, Sost and Lourdes pollen sequences (Andrieu-Ponel *et al.*, 1988; Jalut
346 *et al.*, 1992; Jalut *et al.*, 1998) attest to the occurrence of *Picea* up to ca. 26 ka cal BP together with few
347 mesothermophilous trees (mainly *Quercus* and *Corylus*). By contrast, the El Portelet sequence in the
348 drier Spanish Pyrenees only records the presence of *Pinus* and *Juniperus*, while the few pollen grains
349 from mesothermophilous trees were thought to reflect long-distance transport (Gonzalez-Sampéniz *et al.*,
350 2006). At Bergsee (southwest Germany), sharp increases in *Betula* and *Pinus* are recorded,
351 accompanied by *Juniperus* that evoke the development of open boreal forests (Duprat-Oualid *et al.*,
352 2017). Pine played a notable role there, which has already been observed at La Grande Pile during the
353 "Grand Bois Complex" correlated to the end of MIS 3 (de Beaulieu and Reille, 1992a). Recent reanalysis
354 of the Füramoos sequence (southern Germany) allows better correlation with the late MIS 3
355 interstadials, which were marked by rapid tree extensions including *Betula*, *Pinus* and sporadically
356 *Picea*. However, vegetation remained dominated by Cyperaceae and Poaceae grasslands and
357 sagebrush steppe (Kern *et al.*, 2022).

358 Finally, late MIS 3 pollen assemblages from core MD04-2845, located offshore but not far from the
359 Landes, indicate a development of deciduous oaks (*Quercus* deciduous type) together with boreal
360 forest (*Pinus*, *Abies*, *Picea*, *Betula*) during the interstadials (Sanchez-Goñi *et al.*, 2008; Fletcher *et al.*,
361 2010), in sharp contrast to the Landes records. This obviously reflects a regional signal that includes
362 refuge areas in the valleys of the Pyrenees where thermophilous trees were able to survive during the
363 Glacial, and possibly in the Massif Central (although thermophilous trees are not recorded in the
364 available pollen sequences). These also clearly demonstrate the specific character of the Landes
365 vegetation, largely related to the acidic nature of the soils developed on aeolian sand.

366 The development of peat in the Landes region, although rarely preserved presumably due to deflation,
367 strongly suggests that the aeolian dynamics was only intermittently active during the Last Glacial, or
368 at least that sand transport was spatially restricted to a few favorable areas during the interstadials.
369 Concurrently, overland flow and gully incision were active. The gullies, later plugged by new inputs of
370 aeolian sand, provide favorable contexts for the preservation of peat. The discovery of peat levels in a
371 similar context at Saint-Paul-les-Dax, dated to $28,230 \pm 140$ BP (32,480 – 31,530 cal BP), i.e. GI-5.2
372 (Béague, 2014), and at Pontonx, dated to $32,410 \pm 450$ BP (37,800 – 35,300 cal BP), i.e. GI-8 (Bertran,
373 unpublished report), allows us to anticipate the possibility that other interstadials may be documented
374 in the future thanks to preventive archaeological work in the region.

375 **7. Conclusion**

376 The peat level discovered during preventive archaeological work at Saint-Vincent-de-Paul in the Landes
 377 region (southwestern France) documents the vegetation of interstadial GI-5.1, ca. 31 ka cal BP (or
 378 possibly GI-5.2). This level was preserved at the bottom of a gully incised in aeolian sands. During the
 379 early peat formation, a reed bed associated with willows developed in an open sagebrush steppe
 380 landscape. The gully was then colonized by birch trees, accompanied by willows, *Myrica*, *Calluna* and
 381 *Erica cf. tetralix*. *Sphagnum* peat finally formed. Comparison with other analyses of MIS 3 peat in the
 382 region shows that patches of boreal forest developed locally repeatedly during the interstadials. It
 383 shows as well that aeolian activity was discontinuous and probably restricted to spatially limited
 384 favorable areas during these periods. The sporadic discovery of other peat levels in similar contexts
 385 also dated to MIS 3 suggests the possibility of documenting other interstadials in the future if careful
 386 attention is paid to these finds.

387 **Acknowledgements**

388 The person in charge of the archaeological operation, V. Duphil, and the Inrap scientific and technical
 389 director of Aquitaine, L. Detrain, are thanked for their help. The study was financed by Inrap and a
 390 project led by W. Banks (UMR PACEA, CNRS-University of Bordeaux), whom we thank. M.F. Sanchez-
 391 Goñi and an anonymous reviewer are greatly acknowledged for their detailed and constructive
 392 comments on the manuscript.

393 **References**

- 394 ANDRIEU-PONEL V., HUBSCHMAN J., JALUT G. & HERAIL G., 1988 - Chronologie de la déglaciation des
 395 Pyrénées françaises. Dynamique de sédimentation et contenu pollinique des paléolacs ; application à
 396 l'interprétation du retrait glaciaire. *Bulletin de l'Association française pour l'étude du quaternaire*, **25**
 397 (2-3), 55-67.
- 398 ANIOTSBEHERE J.-C., 1999 - Les plantes aquatiques des milieux marécageux de Gironde. *Feuillets de la*
 399 *société linnéenne de Bordeaux*, 130 p.
- 400 BEAGUE N., 2014 - Saint-Paul-lès-Dax. Les Pins de Gouillard – Plaine sportive. Rapport de Diagnostic
 401 Archéologique, Inrap NAOM, Bègles.
- 402 BERTRAN P., ALLENET G., GE T., NAUGHTON F., POIRIER P. & SANCHEZ GONI M.-F., 2009 - Coversand
 403 and Pleistocene palaeosols in the Landes region, southwestern France. *Journal of Quaternary Science*,
 404 **24** (3), 259–269.
- 405 BERTRAN P., ANDRIEU E., BATEMAN M.D., FUCHS M., KLINGE M., MAREMBERT F., 2020 - Mapping
 406 and chronology of coversands and dunes from the Aquitaine basin, southwest France. *Aeolian*
 407 *Research*, **47**, 100628.
- 408 BEUG H.J., 2004 - *Leitfaden der Pollenbestimmung für Mitteleuropa und angrenzende Gebiete*,
 409 München, Friedrich Pfeil, 542 p.
- 410 BOURBON P., 2019 - *Gestion des eaux souterraines en Région Aquitaine. Carte géologique numérique*
 411 *à 1/250 000 de la région Aquitaine*. Notice technique. Rapport final, BRGM/RP-68881-FR.
- 412 BOURNERIAS M., 1979 - *Guide des groupements végétaux de la région parisienne*. 3e éd., Sedes-
 413 Masson 1984, 483 p.

- 414 CHEDDADI R., VENDRAMIN G.G., LITT T., FRANÇOIS F., KAGEYAMA M., LORENTZ S., LAURENT J.M., DE
 415 BEAULIEU J.-L., SADORI L., JOST A. & LUNT D., 2006. Imprints of glacial refugia in the modern genetic
 416 diversity of *Pinus sylvestris*. *Global Ecology and Biogeography*, **15**, 271-282.
- 417 COUR P., 1974 - Nouvelles techniques de détection des flux et des retombées polliniques : étude de la
 418 sédimentation des pollens et des spores à la surface du sol. *Pollen et spores*, **16** (1), 103-141.
- 419 CUGNY C., 2011 - *Apports des microfossiles non-polliniques à l'histoire du pastoralisme sur le versant*
 420 *nord Pyrénéen : entre référentiels actuels et reconstitution du passé*. Thèse de l'Université Toulouse-Le
 421 Mirail, vol. 1, 280 p. (<http://tel.archives-ouvertes.fr/tel-00854984/>).
- 422 DANIAU A.-L., SANCHEZ-GONI M.F. & DUPRAT J., 2009 - Last glacial fire regime variability in western
 423 France inferred from microcharcoal preserved in core MD04-2845, Bay of Biscay. *Quaternary*
 424 *Research*, **71**, 385-396.
- 425 DANIAU A.-L., d'ERRICO F. & SANCHEZ GONI M.F., 2010 - Testing the Hypothesis of Fire Use for
 426 Ecosystem Management by Neanderthal and Upper Palaeolithic Modern Human Populations. *PLoS*
 427 *ONE* **5** (2), e9157 (doi:10.1371/journal.pone.0009157).
- 428 DE BEAULIEU J.-L. & REILLE M., 1984 - A long upper Pleistocene pollen record from Les Echets, near
 429 Lyon, France. *Boreas*, **13**, 111-132.
- 430 DE BEAULIEU J.-L. & REILLE M., 1992a - The last climatic cycle at La Grande Pile (Vosges, France). A new
 431 pollen profile. *Quaternary Science Reviews*, **11**, 431-438.
- 432 DE BEAULIEU J.-L. & REILLE M., 1992b - Long Pleistocene sequences from the Velay plateau (Massif
 433 Central, France) I. Ribains maar. *Vegetation History and Archaeobotany*, **1**, 233-242.
- 434 DE LAFONTAINE G., AMASIFUEN GUERRA C. A., DUCOUSSO A., SANCHEZ-GONI M. F. & PETIT R. J., 2014
 435 - Beyond skepticism: uncovering cryptic refugia using multiple lines of evidence. *New Phytologist*, **204**,
 436 450-454.
- 437 DIOT M.F., 1999 - Le Pléistocène de la façade atlantique du Nord-Médoc (France) : synthèse sur la
 438 palynologie des « Argiles du Gurd » s.l. et comparaison avec les données de l'Aquitaine. *Quaternaire*,
 439 **10** (2-3), 213-225.
- 440 DUPRAT-OUALID F., RIUS D., BÉGEOT C., MAGNY M., MILLET L., WULF S. & APPELT O., 2017 - Vegetation
 441 response to abrupt climate changes in Western Europe from 45 to 14.7k cal a BP: the Bergsee
 442 lacustrine record (Black Forest, Germany). *Journal of Quaternary Science*, **32**, 1008-1021.
- 443 DUTARTRE A. & REBILLARD J.P., 2015 - *Les principaux végétaux aquatiques du Sud-Ouest de la*
 444 *France*. Agence de l'eau Adour-Garonne - IRSTEA, 204 p.
- 445 FAEGRI K. & IVERSEN J., 1975 - *Textbook of pollen analysis*. Wiley & sons, Chichester, 4th ed., 328 p.
- 446 FAO, 2006 - Guidelines for soil description. Food and Agriculture Organization of the United Nations,
 447 fourth edition, Rome.
- 448 FARE A., DUTARTRE A. & REBILLARD J.-P., 2001 - *Les principaux végétaux aquatiques du Sud-Ouest de*
 449 *la France*. Agence de l'eau Adour Garonne – Cemagref, 189 p.

- 450 FLETCHER W. J., SANCHEZ GONI M. F., ALLEN J. R. M., CHEDDADI R., COMBOURIEU-NEBOUT N.,
 451 HUNTLEY B., LAWSON I., LONDEIX L., MAGRI D., MARGARI V., MÜLLER U. C., NAUGHTON F., NOVENKO
 452 E., ROUCOUX K. & TZEDAKIS P.C., 2010 - Millennial-scale variability during the last glacial in vegetation
 453 records from Europe. *Quaternary Science Reviews*, **29**, 2839–2864.
- 454 GONZALEZ-SAMPERIZ P., VALERO-GARCES B.L., MORENO A., JALUT G., GARCIA-RUIZ J.M., MARTI-
 455 BONO C., DELGADO-HUERTAS A., NAVAS A., OTTO T. & DEDOUBAT J.J., 2006 - Climate variability in
 456 the Spanish Pyrenees during the last 30,000 yr revealed by the El Portalet sequence. *Quaternary*
 457 *Research*, **66** (1), 38-52.
- 458 GUITER F., ANDRIEU-PONEL V., DE BEAULIEU L.J., CHEDDADI R., CALVEZ M., PONEL PH., REILLE M.,
 459 KELLER TH. & GOEURY C., 2003. The last climatic cycles in Western Europe: a comparison between long
 460 continuous lacustrine sequences from France and other terrestrial records. *Quaternary International*,
 461 **111**, 59–74.
- 462 HEIM J., 1970 - *Les relations entre les spectres polliniques récents et la végétation actuelle en Europe*
 463 *occidentale*. Thèse, Université Louvain, Laboratoire de Palynologie et Phytosociologie, 181 p.
- 464 HUNTLEY B. & BIRKS H.J.B., 1983 - *An atlas of past and present pollen maps for Europe: 0-13,000 BP*
 465 *years ago*. Cambridge University Press, Cambridge, 668 p.
- 466 JALUT G., GALOP D., BELET J.M., AUBERT S, ESTEBAN AMAT A., BOUCHETTE A., DEDOUBAT J.J. &
 467 FONTUGNE M., 1998 - Histoire des forêts du versant nord des Pyrénées au cours des 30000 dernières
 468 années. *Journal de Botanique*, **5**, 73-84.
- 469 JALUT G., MONTSERRAT J., FONTUGNE M., DELIBRIAS G., VILAPLANA J. & JULIA R., 1992 - Glacial to
 470 Interglacial vegetation changes in the northern and southern Pyrenees: deglaciation, vegetation cover
 471 and chronology. *Quaternary Science Reviews*, **11**, 449–480.
- 472 JOUFFROY-BAPICOT I., 2010 - *Évolution de la végétation du massif du Morvan (Bourgogne-France)*
 473 *depuis la dernière glaciation à partir de l'analyse pollinique. Variations climatiques et impact des*
 474 *activités anthropiques*. Thèse de doctorat, université de Franche-Comté, Besançon, 373 p.
- 475 KERN O.A., KOUTSODENDRIS A., ALLSTÄDT F.J., MÄCHTLE B., PETEET D.M., KALAITZIDIS S.,
 476 CHRISTIANIS K. & PROOS J., 2022 - Near-continuous record of climate and ecosystem variability in
 477 Central Europe during the past 130 kyrs (Marine Isotope Stages 5-1) from Füramoos, southern
 478 Germany. *Quaternary Science Reviews*, **284**, 107505.
- 479 LEROYER C., 1997 - *Homme, Climat, Végétation au Tardi-et-Postglaciaire dans le Bassin parisien :*
 480 *apports de l'étude palynologique des fonds de vallée*. PHD thesis, University Paris I, 786 p.
- 481 MIGHALL T. M., MARTÍNEZ CORTIZAS A, BIESTER H. & TURNER S. E., 2006 - Proxy climate and
 482 vegetation changes during the last five millennia in NW Iberia: Pollen and non-pollen palynomorph
 483 data from two ombrotrophic peat bogs in the North Western Iberian Peninsula. *Review of*
 484 *Palaeobotany and Palynology*, **141** (1-2), 203-223.
- 485 MIOLA A., 2012 - Tools for Non-Pollen Palynomorphs (NPPs) analysis: A list of Quaternary NPP types
 486 and reference literature in English language (1972–2011). *Review of Palaeobotany and Palynology*,
 487 **186**, 142–161.

- 488 MOORE P.D., WEBB J.A. & COLLINSON M.E., 1991 - *Pollen analysis*. Oxford-London-Edinburgh-Boston-
489 Melbourne-Paris-Berlin-Vienna, Blackwell Scientific publications, 2nd revised edition, 216 p.
- 490 OLDFIELD F., 1968 - The Quaternary vegetational history of the French Pays Basque. I - Stratigraphy
491 and pollen analysis. *New Phytologist*, **67**, 677-731.
- 492 PALS J. P., van GEEL B. & DELFOS A., 1980 - Paleoecological studies in Klokkeweel bog near Hoogkarspel
493 (Noord Holland). *Review of Palaeobotany and Palynology*, **30**, 371-418.
- 494 PAQUEREAU M.M. & SCHOELLER M., 1959 – Quaternaire et Pliocène du Gurd (Gironde). *Bulletin*
495 *Société Géologique Française*, 7^e série, **1**, 79-83.
- 496 PAQUEREAU M.M., 1961 - Documents palynologiques sur le littoral du Gurd à Dépet (Gironde).
497 *Compte-rendu des séances de la Société Géologique de France*, **4**, 102.
- 498 PAYNE R. J., LAMENTOWICZ M., van der KNAAP W. O., van LEEUWEN J. F., MITCHELL E. A. & MAZEI Y.,
499 2012 - Testate amoebae in pollen slides. *Review of Palaeobotany and Palynology*, **173**, 68-79.
- 500 PUNT W., 1975 - The Northwest European Pollen Flora, 5: Sparganiaceae and Typhaceae. *Review of*
501 *Palaeobotany and Palynology*, **19**(2), 75-88.
- 502 PUNT W. & HOEN P. P., 2009 - The Northwest European Pollen Flora, 70: Asteraceae—Asteroideae.
503 *Review of Palaeobotany and Palynology*, **157**(1-2), 22-183.
- 504 PUNT W. & NIENHUIS W., 1976 - The Northwest European Pollen Flora, 6: Gentianaceae. *Review of*
505 *Palaeobotany and Palynology*, **21**(2), 89-123.
- 506 RAMEAU J.-C., MANSION D. & DUME G., 1989 - *Flore forestière française : guide écologique illustré. T.*
507 *1 : Plaines et collines*. Institut pour le Développement Forestier, Paris, 1785 p.
- 508 RASMUSSEN S.O., BIGLER M., BLOCKLEY S.P., BLUNIER T., BUCHARDT S.L., CLAUSEN H.B., CVIJANOVIC
509 I., DAHL-JENSEN D., JOHNSON S.J., FISCHER H., GKINIS V., GUILLEVIC M., HOEK W.Z., LOWE J.J., PEDRO
510 J.B., POPP T., SEIERSTAD I.K., STEFFENSEN J.P., SVENSSON A.M., VALLELONGA P., VINTHER B.M.,
511 WALKER M.J.C., WHEATLEY J.J. & WINSTRUP M., 2014 - A stratigraphic framework for abrupt climatic
512 changes during the Last Glacial period based on three synchronized Greenland ice-core records:
513 refining and extending the INTIMATE event stratigraphy. *Quaternary Science Reviews*, **106**, 14–28.
- 514 REILLE M., 1990 - *Leçons de Palynologie et d'analyse pollinique*. CNRS, Paris, 206 p.
- 515 REILLE M., 1992 - *Pollens et spores d'Europe et d'Afrique du Nord*. Louis-Jean, Gap, 520 p.
- 516 REILLE M., 1995 - *Pollen et spores d'Europe et d'Afrique du Nord*. Supplément 1. Laboratoire de
517 botanique historique et palynologie, Marseille, 327 p.
- 518 REILLE M., 1998 - *Pollen et spores d'Europe et d'Afrique du Nord*. Supplément 2. Laboratoire de
519 botanique historique et palynologie, Marseille, 523 p.
- 520 REILLE M. & DE BEAULIEU J.L., 1988 - History of the Würm and Holocene vegetation in the Western
521 Velay (Massif Central, France): a comparison of pollen analysis from three corings at Lac du Bouchet.
522 *Review of Palaeobotany and Palynology*, **54**, 233–248.

- 523 REILLE M. & DE BEAULIEU J.L., 1990 - Pollen analysis of a long upper Pleistocene continental sequence
524 in a Velay maar (Massif Central, France). *Palaeogeography, Palaeoclimatology Palaeoecology*, **80**, 35-
525 48.
- 526 SANCHEZ GONI M.F., LANDAIS A., FLETCHER W.J., NAUGHTON F., DESPRAT S. & DUPRAT J., 2008 -
527 Contrasting impacts of Dansgaard–Oeschger events over a western European latitudinal transect
528 modulated by orbital parameters. *Quaternary Science Reviews*, **27** (11–12), 1136–1151.
- 529 SCHWEINGRUBER F. H., 1978 - *Mikroskopische holzanatomie*. Zürcher AG, Zurich, 226 p.
- 530 SCHWEINGRUBER F. H., 1990 - *Anatomy of European woods*. Eidgenössische Forschungsanstalt für
531 Wald, Schnee und Landschaft, Birmensdorf (Hrsg.), Haupt, Bern and Stuttgart, 800 p.
- 532 SIROCKO F., KNAPPA H., DREHER F., FÖRSTER M.W., ALBERT J., BRUNCK H., VERES D., DIETRICH S.,
533 ZEHC M., HAMBACH U., RÖHNER M., RUDERT S., SCHWIBUS K., ADAMS C. & SIGL P., 2016 - The
534 ELSA-Vegetation-Stack: Reconstruction of Landscape Evolution Zones (LEZ) from laminated Eifel maar
535 sediments of the last 60,000 years. *Global and Planetary Change*, **142**, 108-135.
- 536 SITZIA L., BERTRAN P. & LEROYER C., 2012 - Faciès et chronologie du Sable des Landes : la coupe de
537 Cestas-Pot-aux-Pins. Quaternaire Continental d'Aquitaine : un point sur les travaux récents. *Livret-
538 guide de l'excursion AFEQ - ASF 2012*, Université de Bordeaux, 122-135.
- 539 SITZIA L., BERTRAN P., BAHAIN J.-J., BATEMAN M.D., HERNANDEZ M., GARON H., LAFONTAINE G. de,
540 MERCIER N., LEROYER Ch., QUEFFELEC A. & VOINCHET P., 2015 - The Quaternary coversands of
541 southwest France. *Quaternary Science Reviews*, **124**, 84-105.
- 542
- 543 SITZIA L., BERTRAN P., SIMA A., CHERRY P., QUEFFELEC A. & ROUSSEAU D.D., 2017 - Dynamics and
544 sources of last glacial aeolian deposition in southwest France derived from dune patterns, grain-size
545 gradients and geochemistry, and reconstruction of efficient wind directions. *Quaternary Science
546 Reviews*, **170**, 250-268.
- 547 STOCKMARR J., 1971 - Tablets with spores used in absolute pollen analysis. *Pollen and Spores*, **XIII** (4),
548 615-621.
- 549 VAN GEEL B., 1976 - A paleoecological study of Holocene peat bog sections, based on the analysis of
550 pollen, spores and macro- and microscopic remains of fungi, algae, cormophytes and animals. PhD
551 thesis, University of Amsterdam.
- 552 VAN GEEL B., 1978 - A palaeoecological study of holocene peat bog sections in Germany and the
553 Netherlands, based on the analysis of pollen, spores and macro- and microscopic remains of fungi,
554 algae, cormophytes and animals. *Review of Palaeobotany and Palynology*, **25** (1), 1-120.
- 555 VAN GEEL B. & APTROOT A., 2006 - Fossil ascomycetes in Quaternary deposits. *Nova Hedwigia*, **82** (3-
556 4), 313-329.
- 557 VAN GEEL B. & MIDDELDORP A.A., 1988 - Vegetational history of Carbury Bog (Co. Kildare, Ireland)
558 during the last 850 years and a test of the temperature indicator value of 2H/1H measurements of peat
559 samples in relation to historical sources and meteorological data. *New Phytologist*, **109**, 377-392.

- 560 VAN GEEL B., van HALLEVAS D. P. & PALS J. P., 1983 - A Late Holocene deposit under the Westfrieze
 561 Zeedijk near Enkhuizen (Prov. of N-Holland, Netherlands): palaeoecological and archaeological aspects.
 562 *Review of Palaeobotany and Palynology*, **38**, 269-335.
- 563 VAN GEEL B., COOPE G.R. & van der HAMMEN T., 1989 - Palaeoecology and stratigraphy of the
 564 Lateglacial type section at Usselo (the Netherlands). *Review of Palaeobotany and Palynology*, **60**, 25-
 565 129.
- 566 VAN GEEL B., BUURMAN J., BRINKKEMPER O., SCHELVIS J., APTROOT A., van REENEN G. & HAKBIJL T.,
 567 2003 - Environmental reconstruction of a Roman Period settlement site in Uitgeest (The Netherlands),
 568 with special reference to coprophilous fungi. *Journal of Archaeological Science*, **30** (7), 873-883.
- 569 VAN HOEVE M. & HENDRIKSE M. (dir.), 1998 - A study of non-pollen objects in pollen slides. The Types
 570 as described by Dr. Bas van Geel and colleagues, S.n., Utrecht, s.n., 391 p.
- 571 VAN LEEUWEN P., PUNT W. & NIENHUIS W., 1988 - The Northwest European Pollen Flora, 43:
 572 Polygonaceae. *Review of Palaeobotany and Palynology*, **57**, 81-151.
- 573 WOILLARD G.M., 1978 - Grande Pile Peat Bog: a continuous pollen record for the last 140,000 years.
 574 *Quaternary Research*, **9**, 1-21.

- 575 YELOFF D., BROEKENS P., INNES J. B. & van GEEL B., 2007 - Late Holocene vegetation and land-use
 576 history in Denmark: A multi-decadally resolved record from Lille Vildmose, northeast Jutland. *Review*
 577 *of Palaeobotany and Palynology*, **146** (1-4), 182-192.

578

579 **Figure captions**

- 580 Figure 1: Map of aeolian deposits in southwest France, from Bertran et al. (2020) and location of the
 581 sites described in the text.

582 *Figure 1: Carte des dépôts éoliens du sud-ouest de la France, d'après Bertran et al. (2020) et localisation*
 583 *des sites décrits dans le texte.*

- 584 Figure2: Topographic maps of the study area. Relief is from RGEALTI® 5 m (Institut Géographique
 585 National). A – General map; B – Location of trenches. The black dots correspond to the trenches that
 586 have yielded the studied peat level.

587 *Figure 2 : Cartes topographiques du secteur étudié. Le relief est tiré du RGEALTI® 5 m de l'IGN. A – Carte*
 588 *générale ; B – Localisation des tranchées. Les points noirs correspondent aux tranchées qui ont livré le*
 589 *niveau tourbeux analysé.*

- 590 Figure 3: Schematic stratigraphy. The horizon labels in CM1-T10 trench are from *Food and Agriculture*
 591 *Organization (FAO, 2006).*

592 *Figure 3 : Stratigraphie schématique. La nomenclature des horizons pour la tranchée CM1-T10 est celle*
 593 *de la Food and Agriculture Organization (FAO, 2006).*

- 594 Figure 4: View of the studied peat sample.

595 *Figure 4 : Photographie du bloc de tourbe analysé.*

596 Figure 5: Close up view of the plant debris.

597 *Figure 5 : Macrophotographies des débris végétaux.*

598 Figure 6: Pollen diagram (Cyperaceae, spores and indeterminates are excluded from the sum). A -
599 Pollen and spores; B - Major pollen types, non-pollen palynomorphs and charred particle
600 concentrations.

601 *Figure 6 : Diagramme pollinique (Cyperaceae, spores et indéterminés sont exclus de la somme). A -*
602 *pollen et spores ; B - principaux types polliniques, microfossiles non polliniques et concentrations en*
603 *particules carbonisées.*

604 Figure 7: Woody fragments. A – *Salix* (5-7.5 cm); B – *Erica cf. tetralix* (0-4 cm).

605 *Figure 7 : Fragments ligneux. A – Salix (5-7,5 cm) ; B – Erica cf. tetralix (0-4 cm).*

606 Figure 8: Xylological diagram.

607 *Figure 8 : Diagramme xylologique.*

608

609 **Table captions**

610 Table 1: Concentration in woody fragments and number of fragments analyzed.

611 *Tableau 1 : Concentrations en macrorestes ligneux et nombre de fragments analysés.*

612 Table 2: Sporo-pollen concentrations, number of morphotypes and preservation of pollen and spores.

613 *Tableau 2 : Concentrations sporo-polliniques, nombre de morphotypes et préservation du pollen et des*
614 *spores.*

615 Table 3: Description of pollen, spore and non-pollen palynomorph assemblages, charred particles
616 concentration and woody remains.

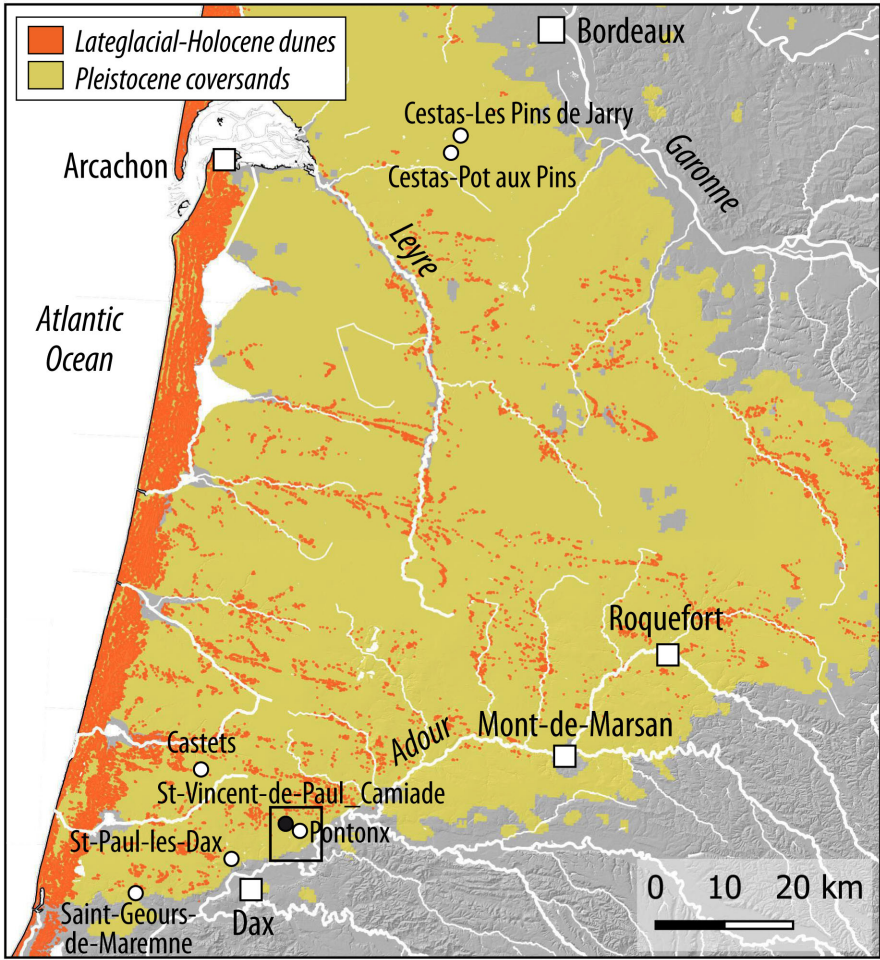
617 *Tableau 3 : Description des assemblages de pollen et spores, microfossiles non-polliniques,*
618 *concentration en particules carbonisées et macrorestes ligneux.*

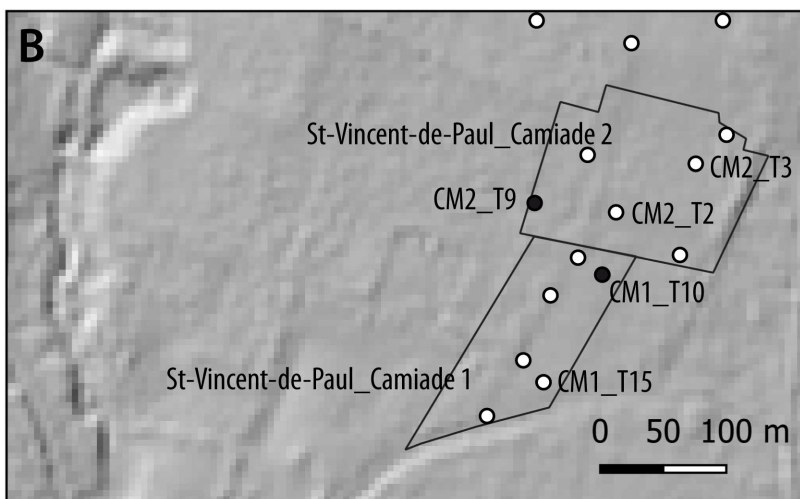
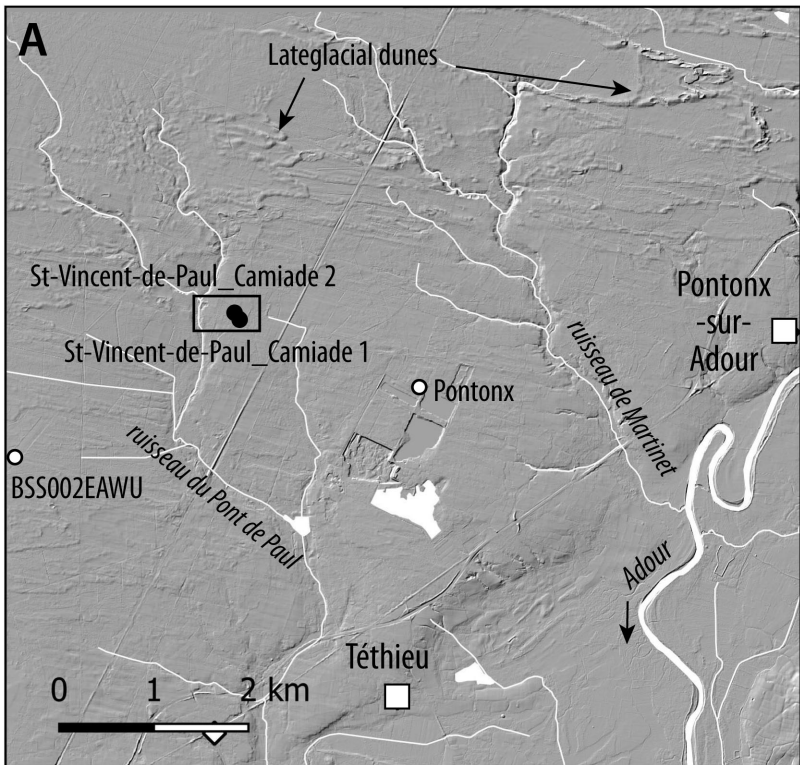
619 Table 4: Preservation, size and curvature of woody remains.

620 *Tableau 4 : Conservation, taille et courbure des macrorestes ligneux.*

621

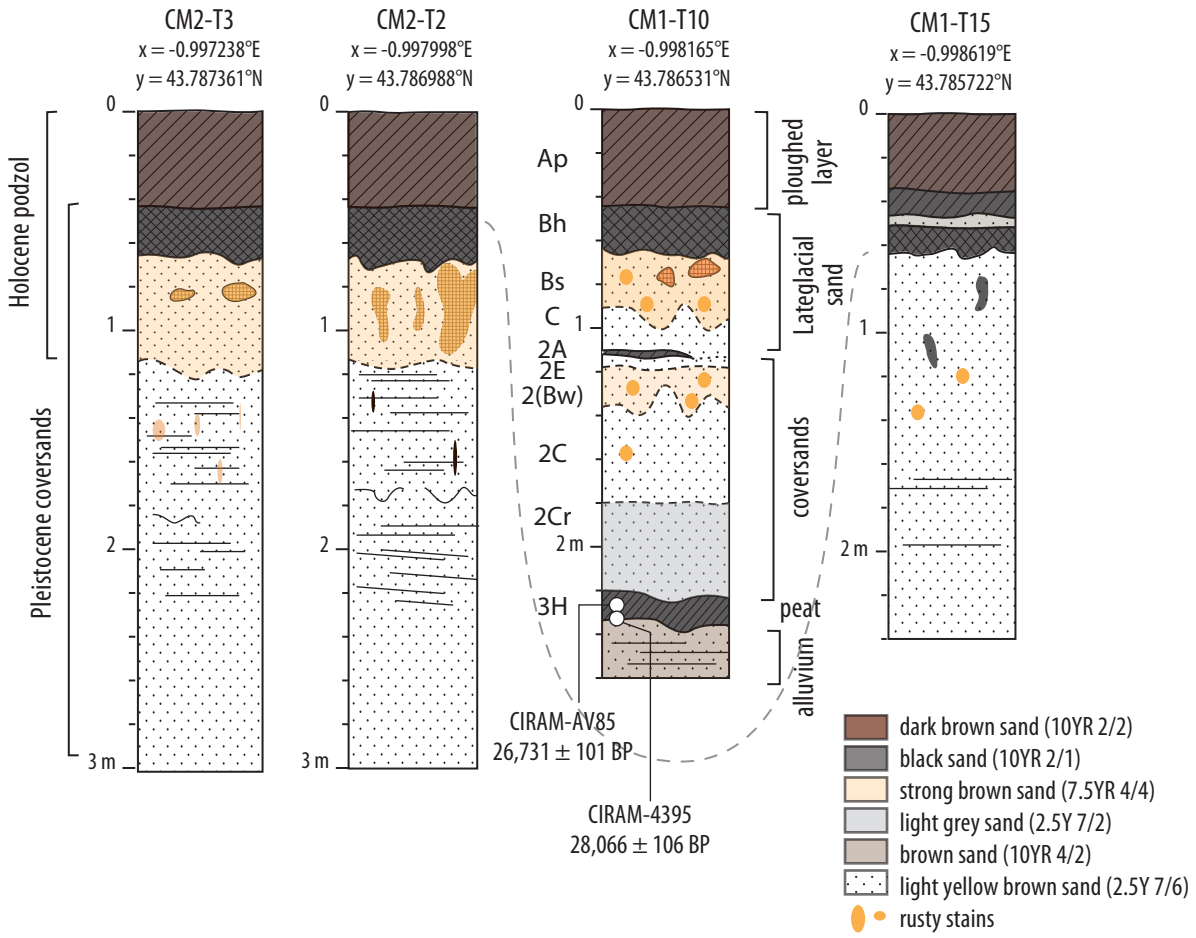
622





N

S



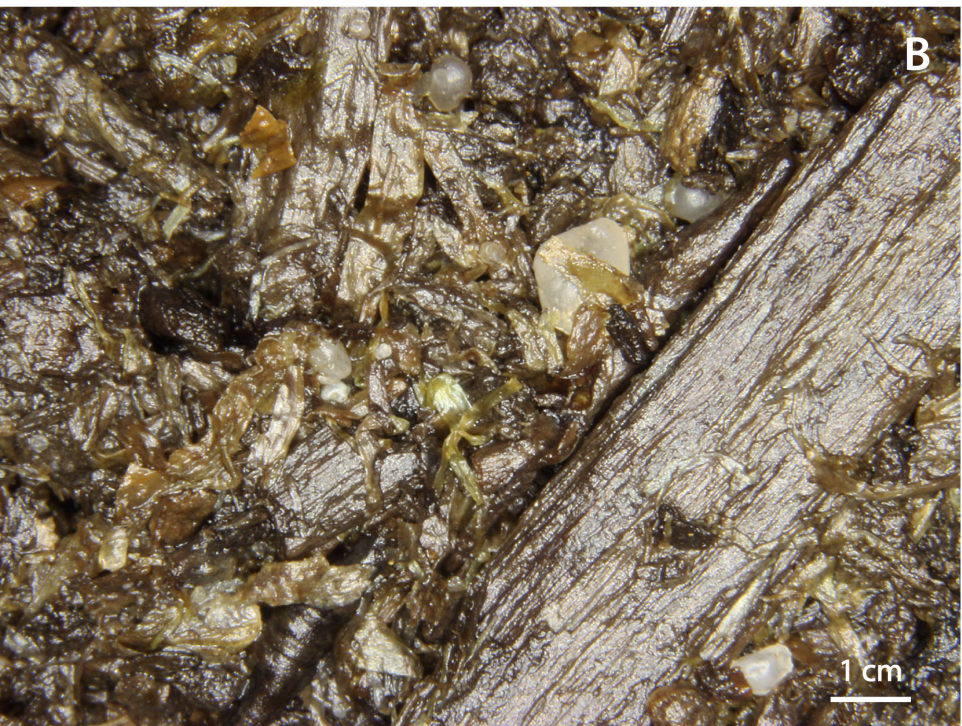


Alternating sand and
black peat beds

Black humified peat
with wood fragments

Brown peat with
wood fragments

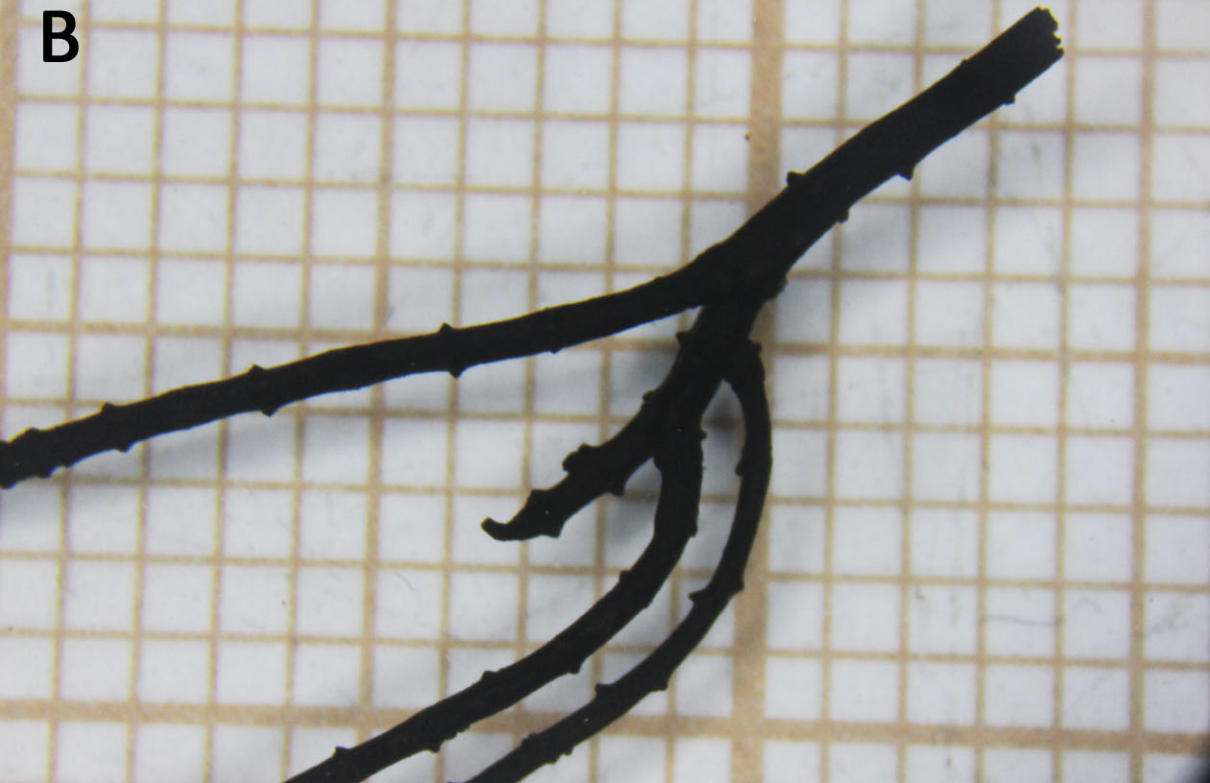
Alternating sand and
black peat beds

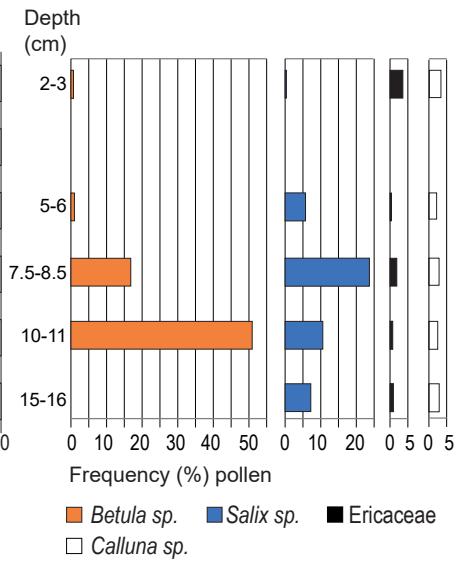
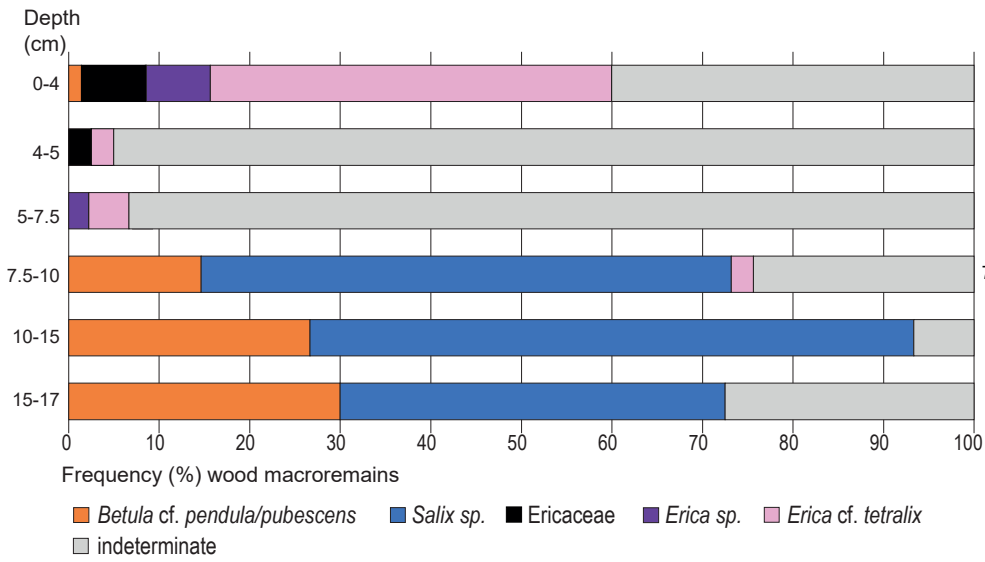


A





B





Sample number	Depth (cm)	Volume of sieved sediment (cm ³)	Total number of fragments	Concentration (fragment number/100 cm ³)	Number of fragments analysed
1	0 - 4 cm	250	607	243	70
2	4 - 5 cm	100	56	56	40
3	5 - 7.5 cm	400	130	33	45
4	7.5 - 10 cm	400	131	33	41
5	10 - 15 cm	300	82	27	45
6	15 - 17 cm	400	88	22	40

Depth (cm)	Number of pollen grains and spores counted	Number of pollen grains and spores identified	Concentration (number of pollen grains and spores/cm³ of fresh sediment)	Preservation state	Diversity (Pollen - Spores + NPPs)
2-3	931	896	238013	good, some corroded pollen grains	27 + 18
5-6	818	766	259602	good	23 + 10
7,5-8,5	636	594	97557	good, some corroded pollen grains	31 + 12
10-11	651	608	82075	good	32 + 9
15-16	2084	2059	55434	good	28 + 9

Lithology	Dep. (cm)	Pollen & spores	NPPs	Charred particles (10 µm-200 µm)	LPZ	Wood macroremains
	2-3	<i>Myrica</i> & <i>Sphagnum</i> stable // decrease of <i>Salix</i> .	Decrease of <i>Tilletia sphagni</i> (HdV-27) // rise of <i>Glomus cf. fasciculatum</i> (HdV-207) & <i>Clasterosporium caricinum</i> (HdV-126). Increase of <i>Assulina muscorum</i> (HdV-32a) & <i>Callidina angusticolis</i> (HdV-37).	Charred particles stable.	c	0-4 cm Increase of <i>Erica cf. tetralix</i> and <i>Erica</i> > und. woods > Ericaceae > <i>Betula</i>
	5-6	Extension of <i>Myrica</i> // decline of <i>Salix</i> , <i>Betula</i> , <i>Pinus</i> & Ericaceae. Decrease of Poaceae, Cyperaceae & Rubiaceae. Rise of <i>Sphagnum</i> .	Increase of <i>Tilletia sphagni</i> (HdV-27) // decrease of <i>Clasterosporium caricinum</i> (HdV-126) .	Charred particles stable.	3 b	4-5 cm Undetermined woods > <i>Erica cf. tetralix</i> & Ericaceae.
	7.5-8.5	Increase of <i>Myrica</i> & <i>Sphagnum</i> Recovery of Poaceae & Cyperaceae. Slight development of Rubiaceae and appearance of Apiaceae.	Rise of <i>Tilletia sphagni</i> (HdV-27), <i>Clasterosporium caricinum</i> (HdV-126) & <i>Glomus cf. fasciculatum</i> (HdV-207). Appearance of <i>Coniochaeta cf. ligniaria</i> (HdV-172), <i>Coniochaeta xylariispora</i> (HdV-6), <i>Neorhodochaeta</i> sp. (HdV 353b), HdV-13, HdV-179 & HdV-200.	Expansion of charred particles	a	5-7.5 cm Rise of undetermined woods > <i>Erica</i> sp. and <i>Erica cf. tetralix</i>
	10-11	Rise of <i>Betula</i> // slight decrease in <i>Pinus</i> but <i>Salix</i> and <i>Calluna</i> stable. Herbaceous decline: mainly Cyperaceae but also Asteraceae, Chenopodiaceae & <i>Thalictrum</i> . Diversification towards other herbs. Slight development of <i>Sphagnum</i> .	Disappearance of <i>Byssothecium circinans</i> (HdV-16), <i>Clasterosporium caricinum</i> (HdV-126), <i>Glomus cf. fasciculatum</i> (HdV-207) & undetermined remains. Appearance of <i>Tilletia sphagni</i> (HdV-27) & copepod spermatophores (HdV-28) and HdV-187d.	Slight increase of charred particles.	2	7.5-10 cm Decrease of <i>Betula</i> < <i>Salix</i> . Appearance of <i>Erica cf. tetralix</i>
	15-16	NAP > AP (scarce <i>Pinus</i> , <i>Salix</i> & <i>Calluna</i>) Cyperaceae > Poaceae > <i>Artemisia</i> > Asteraceae - Chenopodiaceae - <i>Thalictrum</i>	Predominance of undetermined remains (including faunal remains) <i>Clasterosporium caricinum</i> (HdV-126) > <i>Byssothecium circinans</i> (HdV-16) > <i>Glomus cf. fasciculatum</i> (HdV-207) > HdV-128 - <i>Sordaria</i> sp. (HdV-55)	Charred particles very scarce	1	10-15 cm Rise of <i>Salix</i> > <i>Betula</i> 15-17 cm <i>Salix</i> > <i>Betula</i> > undetermined woods

Depth	Taxa	Number	Percent	Preservation state			Mean length/min./max. (mm)	Mean width/min./max. (mm)	Diameter (mm)		Curvature of wood rings		
				good	medium	low			0-2.5	2.5-5.0	high	medium	ind.
0-4 cm	<i>Betula sp.</i>	1	1.4		1		11.0	2.0			1		
	<i>Erica cf. tetralix</i>	31	44.3	31			14.4/4.0/27.0	1.3/0.5/2.5	28	1	31		
	<i>Erica sp.</i>	5	7.1	4	1		14.5/0.8/26.0	0.8/0.5/3.0	4		5		
	Ericaceae	5	7.1	5			21.6/16.0/35.0	1.7/1.0/2.0	3		5		
	indetermined	28 (including 21 root fragments)	40.0	3	20	5	15.5/5.0/40.0	3.1/1.0/6.0	4	7	23		5
4-5 cm	<i>Erica cf. tetralix</i>	1	2.5	1			18.0	2.0	1		1		
	Ericaceae	1	2.5	1			6.0	1.5	1		1		
	indetermined	38 (including 28 root fragments)	95	3	28	7	10.6/5.0/24.0	2.4/1.0/5.0	10	2	28		10
5-7.5 cm	<i>Erica cf. tetralix</i>	2	4.4	2			10.5/9.0/12.0	0.7/0.5/1.0	2		2		
	<i>Erica sp.</i>	1	2.2	1			11.0	1.0	1		1		
	indetermined	42 (including 23 root fragments)	93.3	11	13	18	13.9/5.0/50.0	3.8/1.0/20.0	7	3	27		15
7.5 - 10 cm	<i>Betula cf. pendula/pubescens</i>	6	14.6		1	5	10.8/6.0/20.0	4.2/3.0/5.0		1			5
	<i>Salix sp.</i>	24	58.5	4	18	2	16.6/6.0/51.0	3.4/2.0/5.0		5	3		16
	<i>Erica cf. tetralix</i>	1	2.4	1			19.0	1.0	1				
	indetermined	10 (including 2 root fragments)	24.4	1	6	3	10.7/6.0/18.0	3.4/2.0/5.0		3			7
10-15 cm	<i>Betula cf. pendula/pubescens</i>	12	26.7		8	4	13.0/6.0/37.0	3.5/2.0/5.0	1	1	3		9
	<i>Salix sp.</i>	30	66.7		18	12	14.6/4.0/38.0	4.5/2.0/17.0			11		19
	indetermined	3	6.7				8.7/6.0/10.0	3.0/2.0/4.0			2	1	3
15-17 cm	<i>Betula cf. pendula/pubescens</i>	12	30	1	2	9	11.0/6.0/20.0	3.0/2.0/5.0	1		5		7
	<i>Salix sp.</i>	17	42.5	8	2	7	12.3/5.0/30.0	2.1/1.5/3.0			13		4
	indetermined	11	27.5	5	2	4	11.1/5.0/18.0	2.3/2.0/3.0	1		6		5