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Late Glacial and Holocene vegetation history inferred from peat sequences in the Liereman depression (prov. of Antwerp, BE)

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1. Introduction

An extensive augering campaign in the area of 'Landschap De Liereman' was carried out in 2012 and 2013 by Ghent Archaeological Team (GATE) to assess the presence and potential of known and unknown prehistoric sites in this coversand area in the Campine region. Several prehistoric hunter-gatherer sites have been identified in this region (Meirsman *et al.*, 2008; Vanmontfort *et al.*, 2010; Noens & Laloo, 2013), mostly on the southwest-northeast oriented coversand ridge Korhaan in the southeastern part of the study area (Fig. 1). Although archaeological research was limited, few prehistoric sites have been localized on the coversand ridges in the north and west of the study area.

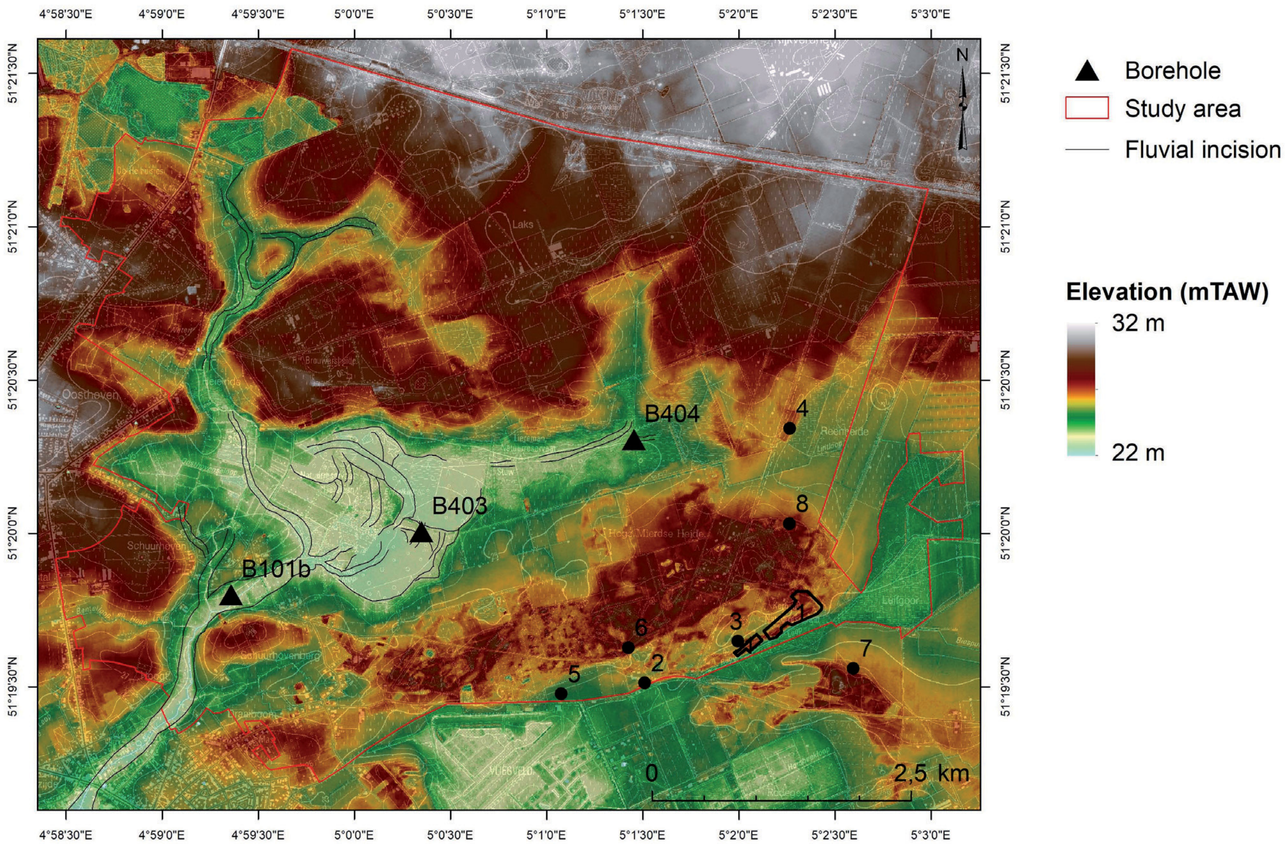


Fig. 1 – Location of cores B101b, B403 and B404 in the Liereman depression. Also indicated are the most important Final Palaeolithic and Mesolithic sites (based on Vanmontfort *et al.*, 2010): 1 Arendonk "Korhaan", 2 Oud-Turnhout "Heihuisken", 3 Arendonk "Reenheide IV", 4 Arendonk I "82 DJ", 5 Oud-Turnhout "Bergstraat", 6 Surface and auger finds, 7 Luifgoor depression, and 8 Arendonk II "Reenheide I & II".

Besides the elevated coversand ridges the research area is characterized by a large depression, the so-called Liereman depression, in the landscape. The augering survey has demonstrated the presence of peat indicating wet conditions in the Liereman depression now and in the past. However, much peat has been extracted in the past centuries (Verboven *et al.*, 2004). Besides historic sources mentioning the sale of peat from the Liereman and surroundings, the extraction of peat is visible in the present landscape. Most of the remaining peat is likely preserved in abandoned palaeochannels of the Aa river and underneath dikes that were constructed to facilitate peat transport. Peat deposits can be valuable archives of past environmental conditions, especially in coversand areas with a generally low potential for preservation of organic matter. Three peat sequences were sampled for multi-proxy palaeoecological analysis on microfossils and macrofossils with the aim of dating the period of peat formation and reconstructing the environmental conditions during this period.

Vegetation dynamics have been inferred for the entire Holocene, i. e. the past 11,500 years, based on the peat sequence in core B101b (Verbruggen *et al.*, 2019). This peat has formed in an abandoned palaeochannel in the valley of the Aa river (Fig. 1). The other two peat sequences have shown that peat formation in the Liereman, however, already started in the Late Glacial. The vegetation composition and environmental conditions in the area are reconstructed from pollen, spores, non-pollen palynomorphs and macrofossils in these two peat sequences (B403 and B404; Fig. 1).

2. Site and core description

The Liereman depression is located east of the municipality of Oud-Turnhout in the Campine region (N Belgium; 51° 20' N, 5° 1' E). The depression in the landscape, which is likely formed as a result of wind activity, is surrounded by coversand ridges on various sides. The Aa river, an affluent of the Kleine Nete river, runs from north to south through the western part of the Liereman depression. During the Weichselian, this river migrated. During the Late Glacial, as climate became warmer the Aa moved spatially through the depression by forming meanders, which are observed using LIDAR technology. After abandonment peat accumulated in the residual channels and in other parts of the Liereman depression.

The peat sequences were cored at three locations (Fig. 1) using a 3 cm auger. The sediments were extracted in 1 m segments.

Core B101b was taken in a western palaeochannel of the Aa. The results of the palaeoecological analyses were previously discussed in Verbruggen *et al.* (2019) and will not be repeated here unless for reasons of comparison.

Core B403 was drilled through the filling of an eastern palaeochannel of the Aa. This palaeochannel is 15 m wide and is spatially traceable in the surface for at least 100 m. At this location peat is present in the interval from 345 cm below the surface upward. The peat is sandy at the base and the transition between (humic) sand and (sandy) peat is gradual. No structures were recognized in the peat below 315 cm below the surface. Peat formation is interrupted by the deposition of sand between 300 and 297 cm below the surface. Also at a depth of 250 cm the peat was considered more sandy.

Core B404 was found under a dike in the easternmost part of the Liereman depression. This dike was probably constructed during the period of peat extraction for transportation purposes. It is, therefore, likely that peat had formed in the wider area surrounding this location. This peat was later extracted for fuel, except for the peat underneath the dike.

The peat underneath the dike is formed on top of sandy deposits. It is present between 112 and 71 cm below the surface. There is a transition of more humic peat to less humic peat around 102 cm. Again, at a depth of 78 cm the peat becomes more humic. The base of the peat is sandy, whereas the top contains wood fragments. Loamy sands characterized by sandy laminations are found superimposed on the peat. This sand is likely the dike structure.

3. *Methodology*

3.1. Sampling

The peat interval of core B403 between 341 and 176 cm below the surface was divided into 1 and 4 cm segments for microfossil and macrofossil analyses, respectively. This interval was of particular interest as preliminary results suggested a Late Glacial age. Samples were stored in plastic zip bags. In total 11 intervals (mean depth: 178, 183, 243, 248, 253, 258, 263, 309, 314, 329.5 and 339 cm below the surface) were analyzed for macroremains. Four adjacent intervals were analyzed for palynological remains (mean depth: 180.5, 250.5, 311.5 and 329 cm below the surface). One additional palynological sample was scanned at a depth of 108.5 cm below the surface. This scan revealed a Holocene age, possibly Atlantic.

Similarly the peat interval of core B404 between 116 and 82 cm below the surface was sliced into 1 and 4 to 5 cm segments for microfossil and macrofossil analyses, respectively. Samples were stored in plastic zip bags. Four intervals were analyzed for macroremains (mean depth: 84, 99, 109.5 and 114 cm) and four adjacent intervals were analyzed for palynological remains (mean depth: 86.5, 96.5, 101.5 and 106.5 cm).

3.2. Palynological analysis

Palynological samples were processed according to Faegri and Iversen (1989) applying a heavy liquid separation instead of hydrofluoric acid. Samples (except for the sample at 329 cm in B403) were spiked with a known amount of Lycopodium spores to calculate pollen concentrations. The palynological material was mounted onto microscope slides using glycerine jelly. Microremains were analyzed using a compound microscope (Olympus BX41, with a maximum magnification of 1000× and with the possibility to apply phase contrast). Pollen and spores were identified using Moore *et al.* (1991), Beug (2004), the North European Pollen Flora (Punt *et al.*, 1976-2009) as well as the reference collection at BIAX *Consult*. Non-pollen palynomorphs (NPPs) were identified using various publi-cations by van Geel and colleagues (an overview is given by Miola, 2012). Ecological preferences were assessed using Weeda *et al.* (1985, 1987, 1988, 1991, 1994), Tamis *et al.* (2004), van der Meijden (2005) and Van Landuyt *et al.* (2006). Between 630 and 1260 pollen and spores were counted. The pollen sum consisted of pollen and spores from plants of regional origin including trees and shrubs of relatively dry soils, woodland and upland herbs, heather and grassland plants (Ericaceae and Poaceae, respectively), as well as crops and arable weeds. Pollen derived from local vegetation consisting of bog, marsh, riparian and aquatic plants (as confirmed by the macrobotanical analyses) were excluded from the pollen sum. Percentages of all pollen, spores and NPPs were calculated based on the upland pollen sum. Microfossil diagrams were constructed using TILIA (Grimm, 1992-2018). Curves were sorted based on their (weighted average) abundance and have been exaggerated 10× (grey envelope). For reasons of readability a selection of taxa is shown. The sequences were subjectively divided in pollen assemblage zones (PAZ). Zone boundaries were assigned between two adjacent samples.

3.3. Macrofossil analysis

Macrofossil samples were sieved using an 80 μm mesh sieve. Macroremains including pieces of charcoal were manually picked under a stereo microscope (Leica MZ 7.5 with a maximum magnification of 50×) using a fine forceps. If needed, a compound microscope (Olympus BX41, with a maximum magnification of 1000×) was used to discern cell patterns. After being dried charcoal was identified under an incident light microscope (Olympus BH, with a maximum magnification of 500×). Plant macrofossil abundances were scored in absolute quantities, whereas most animal macrofossils were assigned abundance classes (+/++/+++). Botanical macroremains were identified using Körber-Grohne (1964, 1991), Berggren (1969, 1981), Anderberg (1994) and Cappers *et al.* (2006), as well as the reference collection at BIAX *Consult*. Charcoal was identified using Schweingruber (1990). Zoological macroremains were identified using Mauquoy & van Geel (2007). Macrofossil diagrams were constructed using TILIA (Grimm, 1992-2018). Curves were sorted based on their (weighted average) abundance. The zonation in these diagrams is based on the PAZs in the microfossil diagrams.

4. Radiocarbon dates

Macroremains and charcoal of terrestrial plants were selected for AMS radiocarbon dating (Tab. 1) on three and four levels in B403 and B404, respectively. The seven radiocarbon dates were obtained by the Royal Institute for Cultural Heritage in Brussels. Uncalibrated

Core	*Depth (cm)*	*Labcode*	*Material dated*	*^{14}C age (^{14}C yr BP)*	*Calibrated age (cal BC/AD, 2 σ)*
B403	181-185	RICH-21658	*Betula* sp. catkin scale (2), *Carex* sp. (2), *Menyanthes trifoliata* (1), *Schoenoplectus lacustris* (1), herbaceous stem (2), indet. charcoal (1)	10465 ± 45	10610-10180 BC
B403	307-316	RICH-21000	*Betula* sp. fruit (7), deciduous leaf fragment (1), *Carex riparia* (1), *Schoenoplectus lacustris* (1)	10950 ± 53	11020-10760 BC
B403	327-331	RICH-21656	*Betula* sp. fruit (1), *Betula nana* fruit (1), indet charcoal (3), indet wood (1), *Carex* sp. (1), *Menyanthes trifoliata* (1), *Cyperaceae* (1)	11759 ± 53	11780-11510 BC
B404	82-86	RICH-21001	*Sphagnum* twig incl. leafs (4), *Carex rostrata* (10, incl. 3 utricles), *Menyanthes trifoliata* (2), *Rhynchospora alba* (7)	133 ± 30	1670-1950 AD
B404	97-101	RICH-21655	*Betula* sp. fruit (3), *Carex caryophyllea* (1), *Carex rostrata* (3, incl. utricle), *Carex* sp. (6 + 3 fragments, incl. 1 utricle), *Juncus articulatus/acutiflorus* (4), *Menyanthes trifoliata* (3), *Rhynchospora alba* (2), *Schoenoplectus* sp. (1), *Sparganium emersum* endosperm (1)	8427 ± 41	7580-7370 BC
B404	107-112	RICH-21002	*Betula* sp. fruit (1), deciduous leaf fragment (1), *Carex aquatilis*-type (9), *Carex flava*-type (1), *Carex riparia* (1), *Carex rostrata* (1), *Carex* sp. (6), *Eleocharis palustris/uniglumis* (1), *Schoenoplectus* sp. (1), *Sparganium emersum/natans* (1)	11281 ± 55	11320-11100 BC
B404	112-116	RICH-21659	*Betula* sp. catkin scale (1), *Carex elata* (2), *Carex* sp. (2), *Sparganium emersum* endosperm (1), indet. charcoal (1)	11945 ± 113	12150-11590 BC

Tab. 1 – Radiocarbon dated samples of core B403 and B404 taken in the Liereman depression.
Ages have been calibrated (IntCal13; 95.4 % probability) using OxCal 4.3.2.

radiocarbon dates (expressed in ^{14}C years before present or BP) were converted to calendar years BC/AD using Oxcal 4.3.2 (Bronk Ramsey, 2016) applying the IntCal13 calibration curve (Reimer *et al.*, 2013).

5. Results and interpretation

5.1. B403 – PAZ B403-1 – Allerød?

Peat formation in the eastern palaeochannel of the Aa river in the central part of the depression started during the early Allerød (11780-11510 cal BC; 327-331 cm) (GI-1c; *sensu* Björck *et al.*, 1998 or zone 2a *sensu* Hoek, 1997) and continued throughout the Allerød. The middle AMS date dates the 307-316 cm interval at the Allerød/Younger Dryas boundary (11020-10760 cal BC). The macrobotanical remains in the top of the analysed interval date to the middle of the Younger Dryas (10610-10180 cal BC). Yet, the pollen spectra of all three levels show remarkably little variation (Fig. 2) and also the macroremains do not show clear vegetation shifts suggesting the entire peat sequence was formed under relatively stable environmental conditions. The Allerød and Younger Dryas, however, are climatically very different and are generally characterized by different pollen spectra. The vegetation in Belgium and The Netherlands in the Younger Dryas is often dominated by pollen from open vegetation consisting of grasses, sedges and heliophilous herbs (see Janssen, 1974; van Geel *et al.*, 1981; Hoek, 1997; Verbruggen *et al.*, 1996). Close to the Liereman, high percentages of grass pollen (90 %) have been observed in sediments of Younger Dryas age near Zammel in the valley of the Grote Nete (Verbruggen, 2016). This implies that one or two AMS dates have to be rejected. The peat in B403 is characterized by high percentages of *Betula* (birch, ~60 %), followed by *Pinus* (pine, ~13 %) and Poaceae

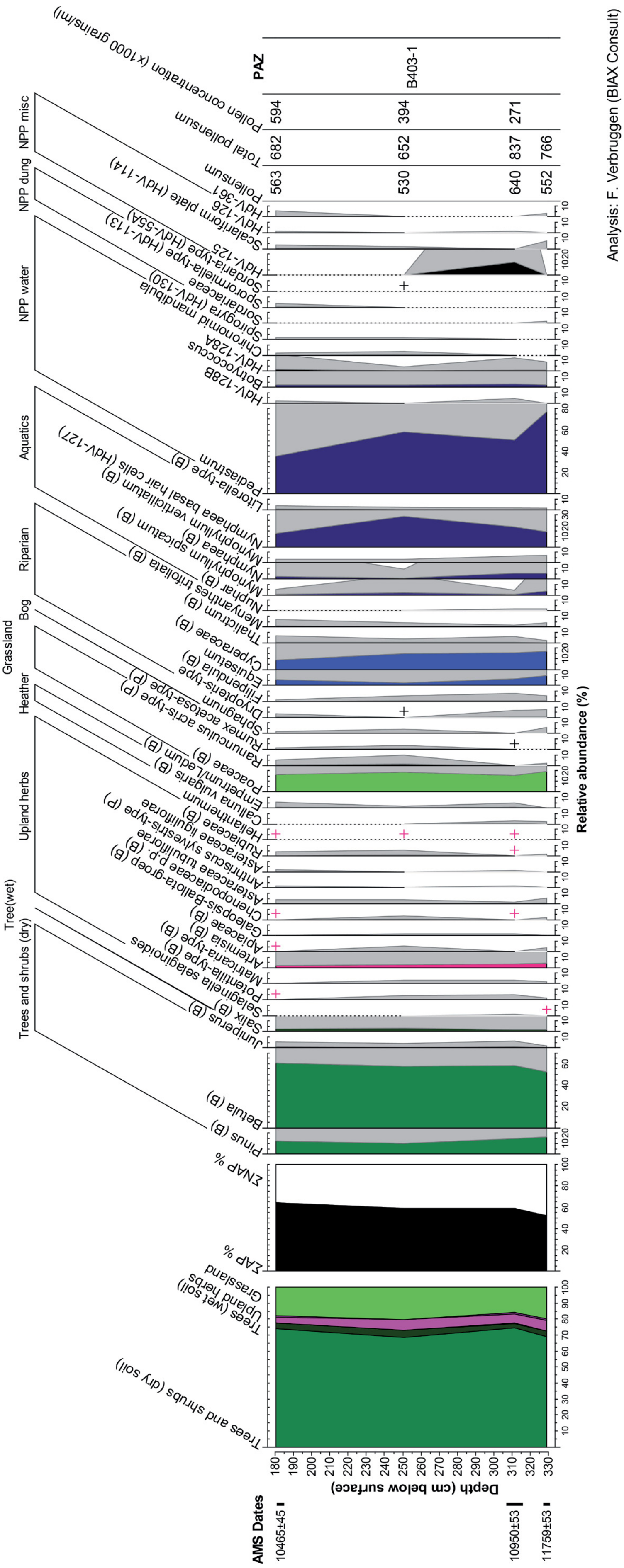


Fig. 2 – Microfossil diagram of the Liereman, core B403, showing selected taxa.

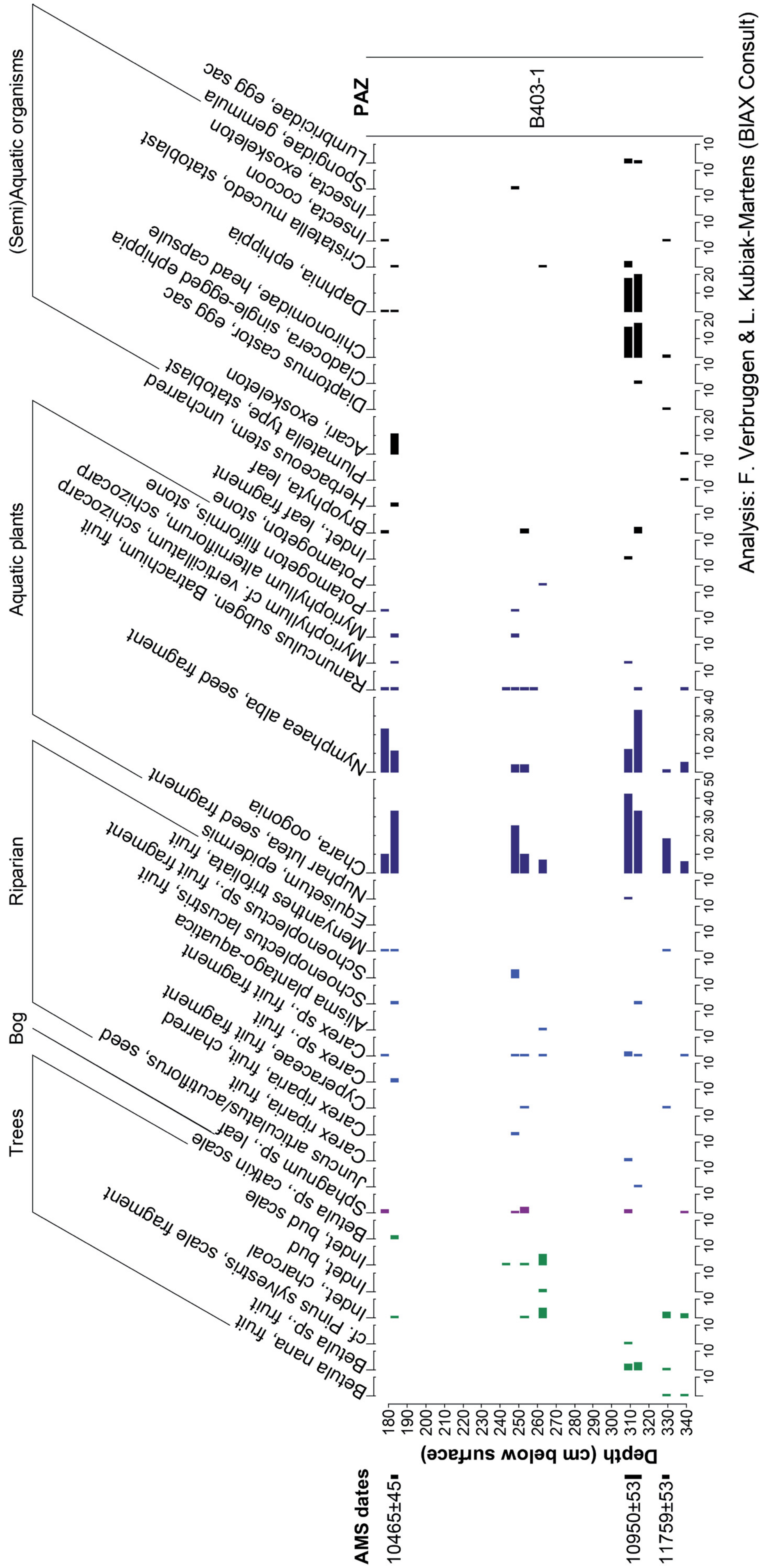


Fig. 3 – Macrofossil diagram of the Liereman, core B403, showing all taxa.

(grasses, ~18 %). Such a spectrum is to be expected during a warmer phase in the Late Glacial (or earliest Holocene). Considering the dynamic nature of Late Glacial vegetation on the one hand and the relatively stable pollen spectra with high arboreal pollen percentages throughout the peat of B403 it is more likely that the upper two AMS dates should be rejected. Retrieval using an auger may have resulted in the intrusion of younger material. These younger remains are not visually detectable in the macrofossil record, but can be discerned in the microfossil record as pollen of several thermophilous trees such as *Corylus* (hazel), *Quercus* (oak), *Alnus* (alder), *Ulmus* (elm) and *Tilia* (lime) occurs sporadically throughout the peat sequence of B403. Additionally one pollen grain of Cerealia-type was found at a depth of 250.5 cm indicating contamination. The more sandy deposits that were observed at this depth may, therefore, have been the result of contamination caused by the coring through younger layers on top of the peat.

High *Betula* pollen percentages of ~60 % characterize the peat sequence, suggesting the local presence of birches. This is further demonstrated by the presence of birch fruits and catkin scales in B403 (Fig. 3). Some of the fruits were not produced by tree birches, but by *Betula nana* (dwarf birch), which was locally present. Furthermore, *Pinus* was present. Relatively low pollen percentages suggest that pine occurred (extra)regionally. One find of a scale fragment most likely formed by pine, however, shows that some trees were probably present in the direct vicinity. The Liereman depression was dominated by a vegetation that is characteristic of wet environments. Macroremains of aquatic plants such as *Nyphaea alba* (white water-lily) and *Chara* (stonewort) as well as microremains of the green alga *Pediastrum* are very abundant in this PAZ. Both *Nymphaea alba* and *Chara* prefer calm, clear stagnant water (Weeda *et al.*, 1985; Smith, 1955). Characeae in particular are considered indicators of clear, carbonate-rich water with a low trophic state (e. g. Simons & Nat, 1996). They are typical pioneers that rapidly colonize newly formed waters (Beltman & Allegrini, 1997) by producing oospores that are able to germinate rapidly in the following vegetation season (Krause, 1997). Also *Nuphar lutea* (yellow water-lily), *Myriophyllum verticillatum* (whorled water-milfoil) and *Ranunculus* subgenus *Batrachium* (water-crowfoot) were present in these pristine waters in the Liereman depression. Around the water a riparian or marsh vegetation was found, mainly consisting of Poaceae, Cyperaceae (sedges, amongst which *Carex riparia*; greater pond-sedge and *Schoenoplectus lacustris*; common club-rush) and *Equisetum* (horsetail).

All in all, this diverse wetland environment (Fig. 4) with open water was likely an attractive site for game and hunter-gatherers. The presence of herbivores can be confirmed by the find of ascospores of coprophilous fungi (*Sordaria*-type, HdV-55A; van Geel, 1978, *Sporormiella*-type, HdV-113; van Geel *et al.*, 2003 and a member of the Sordariaceae family) in the peat of B403.

5.2. B404

5.2.1. PAZ B404-1: 116-106 cm – Allerød

In the easternmost part of the Liereman depression peat formation started at the onset of the Allerød (12150-11590 cal BC) and continued throughout the first half of this period (11320-11100 cal BC) (zone 2a *sensu* Hoek, 1997). *Betula* is the most abundant arboreal pollen type, followed by *Salix* (willow) and *Pinus* (Fig. 5). The local presence of *Betula* is demonstrated by the find of a birch fruit and catkin scale in the lower part of the peat (Fig. 6). It remains unclear which birch species produced these macroremains.

During this period the sampling location was submerged. The aquatic plant M. *verticillatum* dominates the microfossil and macrofossil spectrum (pollen percentage 450 %).

Whorled water-milfoil is an aquatic plant that generally inhabits clear or at most slightly turbid, stagnant or slowly-flowing calcareous fresh water. Similar to the peat in B403 the Allerød interval in B404 shows the presence of Characeae and water-crowfoot indicating a clear, carbonate-rich water column in the eastern part of the Liereman depression. Additionally *Potamogeton natans* (broad-leaved pondweed), *Hippuris vulgaris* (common mare's tail), *Myriophyllum spicatum* (spiked water-milfoil) as well as freshwater algae such as *Botryococcus* were present. A riparian vegetation consisting of Cyperaceae, *Eleocharis palustris/uniglumis* (common/slender spike-rush), horsetail, *Sparganium emersum/natans* (unbranched/least bur-reed) and *Schoenoplectus* surrounded the submerged areas. A pollen percentage of 37 % indicates that grassland played an important role in the Late Glacial landscape. Grasses (partly possibly reed) likely grew in the fringes of the depression and in the open forests. In open parts of the landscape the heliophilous plant *Artemisia* (mugwort) was clearly present.

5.2.2. PAZ B404-2: 102-96 cm – Late Boreal

This interval differs from the base of the peat both in age and in botanical content. The AMS date indicates that this PAZ dates to the Late Boreal (7580-7370 cal BC) suggesting a hiatus between PAZ B404-1 and -2. Pollen of *Alnus*, *Pinus* and *Betula* is quite abundant at 101.5 cm which is in agreement with the Late Boreal (Fig. 5). Fruits of *Betula* show that birch was locally present (Fig. 6). This section may correspond to the top of pollen assemblage zone Lie-2 of peat core B101b (Verbruggen *et al.*, 2019). In the western part of the depression pollen of *Pinus* is much more frequent than in the eastern part during this period. This may be attributed to the presence of pine stands which were likely present on the coversand ridges close to the coring location of B101b. Since *Pinus* pollen is known to float well in water, the proximity of the Aa river may also have played a role in the more abundant deposition of pine pollen in the western part of the Liereman depression. Furthermore, spores of *Dryopteris*-type are common in this interval indicating the presence of

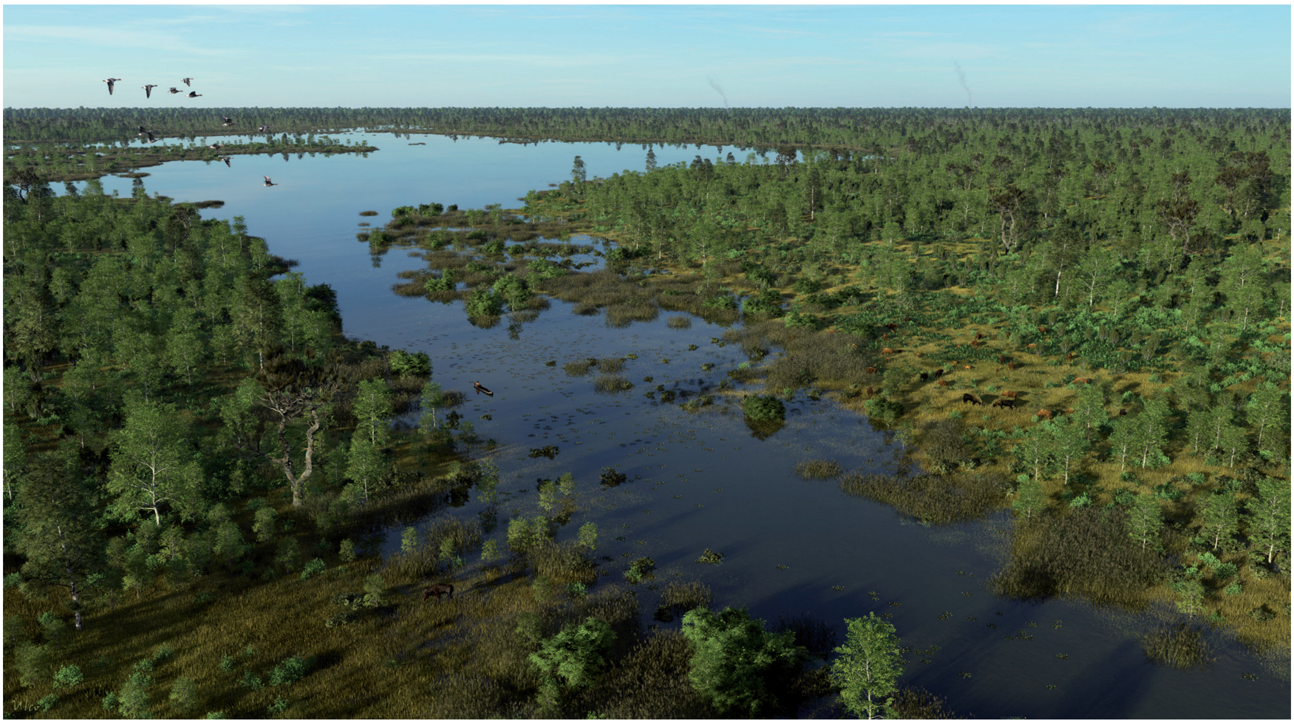


Fig. 4 – Reconstruction of the Allerød landscape in and around the Liereman depression (© Province of Antwerp, Heritage Service, and Ulco Glimmerveen).

ferns in the Liereman depression. However, ferns became less abundant in the landscape throughout this PAZ. Also, Cyperaceae pollen percentages decrease from 101.5 cm to 96.5 cm. Pollen of grasses are less abundant in this PAZ indicating a reduction of the grasslands when compared to the Late Glacial.

In this PAZ ascospores of two different dung fungi were found. Both *Sordaria*-type and *Podospora*-type (HdV-368; van Geel *et al.*, 1981) ascospores are present indicating the presence of large herbivores in the Liereman during the Late Preboreal.

Remains of aquatic plants are rare in this PAZ. This suggests that open water no longer characterized the eastern part of the depression. This may be attributed to a decrease in groundwater levels and/or the natural process of vegetation succession eventually leading to terrestrialization. This was also observed in core B101b (Verbruggen *et al.*, 2019). The lowering of the groundwater may have resulted in compaction of the peat, which most probably was further enhanced during the period of peat extraction. The schizocarps and pollen of *M. verticillatum* that were highly abundant in the previous interval are present in lower numbers in this interval. The presence of these remains may be explained if the lowermost part of this 4 cm interval would be of Late Glacial age. This implies that the hiatus is present around 102 cm below the surface, which could be confirmed by a change in peat lithology (from more humic to less humic peat) at this particular depth. What the effect of this is on the AMS-date is unknown. However, there is no evidence in the microfossil and macrofossil record that this date may not be correct.

5.2.3. PAZ B404-3: 82-87 cm – Post-Medieval Times

In the top of the studied interval of peat core B404 there are many changes in both the macrofossil (Fig. 6) and the microfossil record (Fig. 5) when compared to the previous intervals. The macrofossil record is dominated by thousands of leafs and several sporangia of *Sphagnum* (peat moss) indicating that this peat is formed in an oligotrophic raised bog. This is in agreement with fruits of *Rhynchospora alba* (white beak-sedge), a sedge species that is often associated with *Sphagnum* (Weeda *et al.*, 1994). Also bottle sedge (*Carex rostrata*) is a species that occurs mostly in oligotrophic to mesotrophic acidic waters. As the English name bog-bean suggests *Menyanthes trifoliata* also occurs

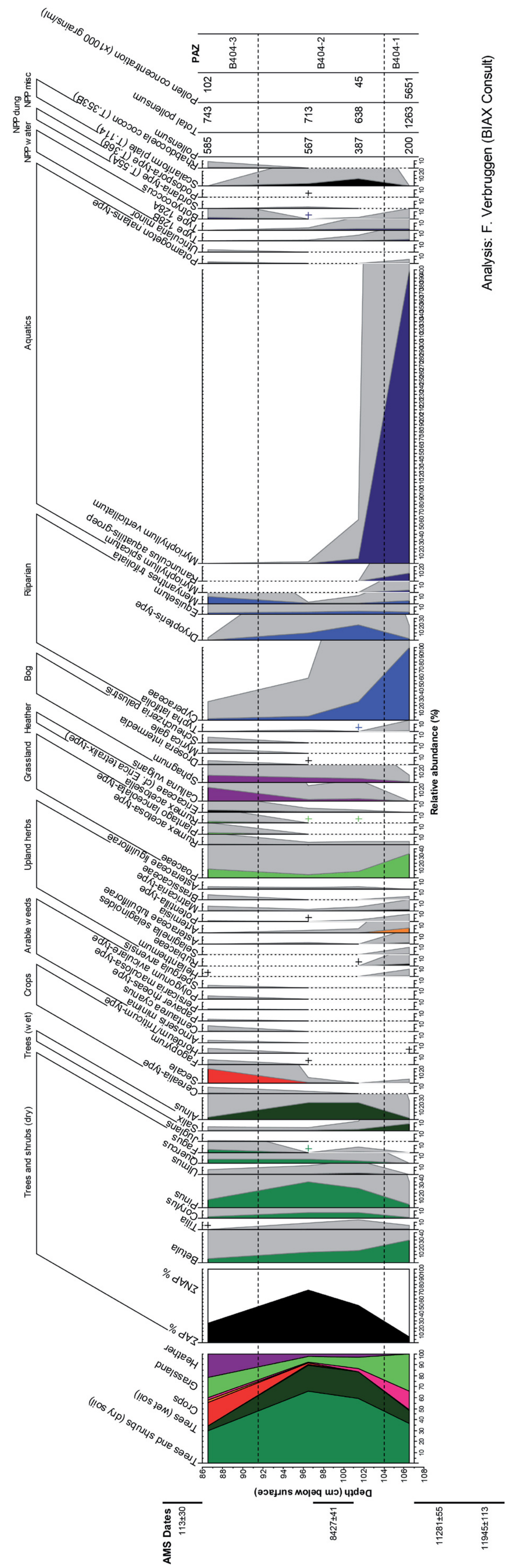
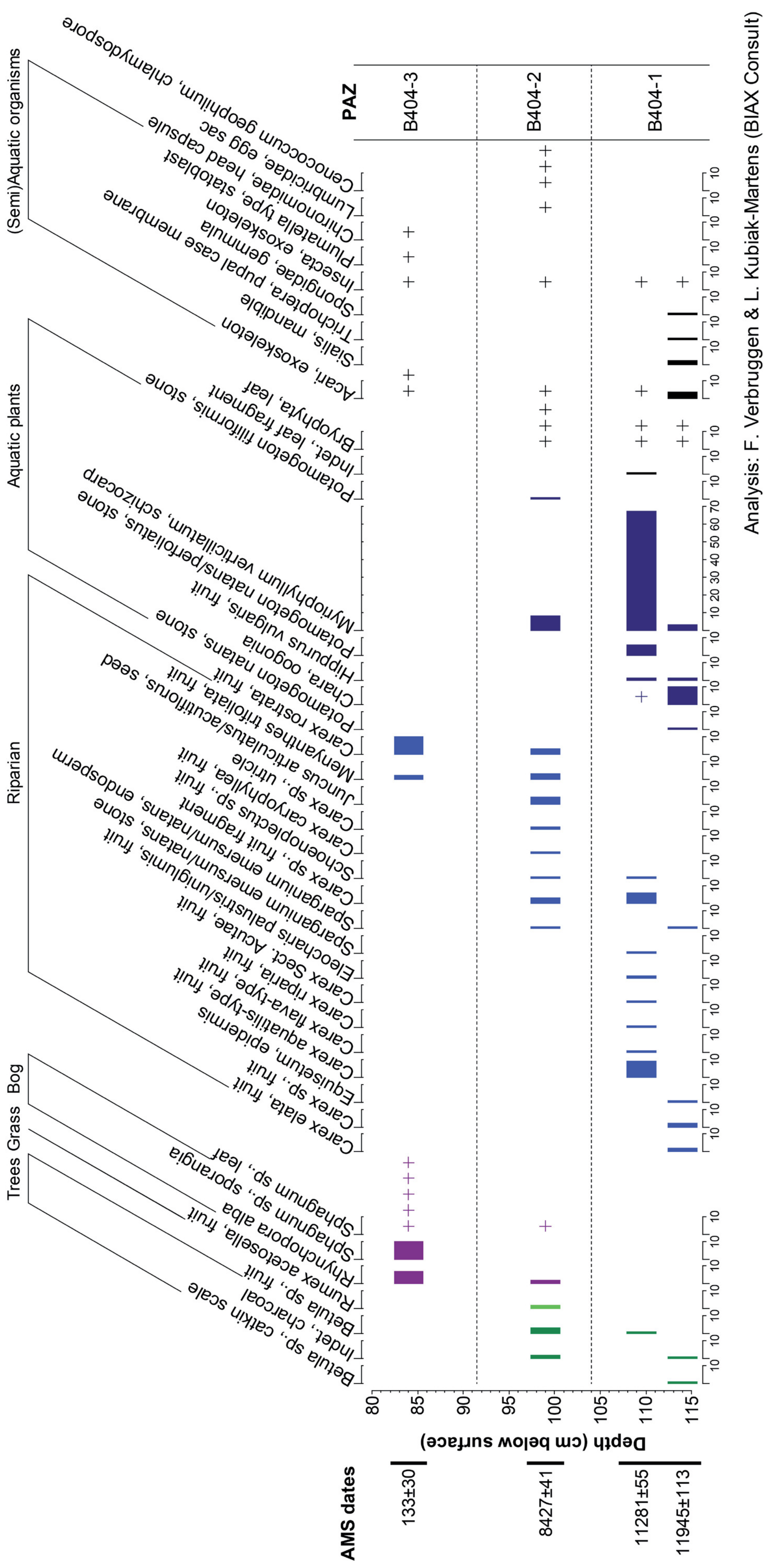


Fig. 5 – Microfossil diagram of the Liereman, core B404, showing selected taxa.



Analysis: F. Verbruggen & L. Kubiak-Martens (BIAX Consult)

Fig. 6 – Macrofossil diagram of the Liereman, core B404, showing all taxa.

in bogs, especially along the edges and in bog pools that are fed by groundwater. It is also known to occur in pools in degrading bog/*Sphagnum* peat (Weeda *et al.*, 1988). Similarly *Utricularia minor* (lesser bladderwort) is a plant of nutrient-poor, acidic shallow water in bog pools and abandoned peat cuttings (Weeda *et al.*, 1988). *Sphagnum* peat (Dutch: hoogveen) is known for its quality as a fuel. *Sphagnum* peat contains very little clastic material and consists largely of organic matter. For this reason *Sphagnum* peat was extracted in large quantities over the past centuries (e. g. Leenders, 1989). The peat in this interval was probably the type of peat the extractors in this area preferred.

The macroremains clearly indicate the presence of *Sphagnum* peat in this interval. This interpretation is supported by the palynological remains. As expected *Sphagnum* spores (11 %) and pollen of *Menyanthes* (10 %) and Cyperaceae (3 %) are present, as well as pollen of *Drosera intermedia* (oblong-leaved sundew) and *Scheuchzeria palustris* (Rannoch-rush). Also *Calluna* (heather; 20 %) played an important role in this bog ecosystem. Trees such as *Pinus* (11 %), *Quercus* (6 %), *Betula* (6 %), *Fagus* (beech; 4 %), *Alnus* (4 %) and *Corylus* (3 %) were present in the landscape, most likely on the coversand ridges. Pine, birch and oak, the three most abundant tree taxa in this interval, also occur in bog environments. The relatively low arboreal pollen percentages indicate a rather open landscape.

The question arises how old this *Sphagnum* peat was. The bog-specific macroremains that were selected for an AMS-date (Tab. 1) show that the *Sphagnum* peat is at most a few centuries old (1650-1950 AD). This implies that the *Sphagnum* peat that was extracted from the Liereman depression was actually living (and likely growing) *Sphagnum* peat.

However, the most abundant, and perhaps also the most remarkable pollen type in this peat is that of the cereal *Secale* (rye; 20 %). *Secale* is one of the most extensively cultivated cereals on the (cover)sand areas from the Late Middle Ages onward. In contrast to *Triticum* (wheat) *Secale* can be successfully grown on relatively nutrient-depleted sandy soils and is, therefore, considered less demanding than most other cereals. The coversand ridges were likely exploited for *Secale* cultivation. Other cultivated crops include *Fagopyrum esculentum* (buckwheat) on the one hand and *Hordeum* (barley) and/or *Triticum* on the other hand. Pollen of arable weeds such as *Centaurea cyanus* (cornflower), *Arnoseris minima* (lamb succory), *Rumex acetosella* (sheep's sorrel) and *Spergula arvensis* (corn spurrey) is also clearly present in this interval. These plants are often found in plant communities of the Sclerantho annui-Arnoseridetum association which occurs in areas with continuous cultivation of winter cereals on relatively nutrient-depleted, acidic soils (Haveman *et al.*, 1998). This suggests continuous rye cultivation in this region. Other anthropogenic indicators such as *Plantago lanceolata* (ribwort plantain), *Persicaria maculosa*-type (redshank-type) and *Polygonum aviculare*-type (knotgrass-type) occurred on more nutrient-rich soils.

6. Conclusions

Palaeoecological analyses on the peat in both core B403 and B404 has shown that water levels were relatively high in the Liereman depression during the Allerød. The deeper parts on the eastern side of the depression were submerged. *Chara* and *Nymphaea alba* were the first pioneer species that thrived in this newly formed water, which was clear, carbonate-rich and oligotrophic. Plants of the Cyperaceae family were a major constituent of the riparian flora surrounding the open water. *Betula* dominated the regional landscape. Dwarf birches were present and likely also tree birches. Some pines grew between the birches on the drier soils, while willow was present on the wetter soils. The presence of *Artemisia* suggests that the landscape was open. The environment of the

Liereman was in many ways an attractive site for Final Palaeolithic hunters-gatherers, possibly explaining the dense concentration of *Federmesser* Culture sites to the south of the depression. The elevated coversand ridges provided a dry habitat for camps and shelters, whereas the depression yielded fresh water. In the depression edible plants could have been collected. Also game frequented this water-rich landscape and was likely hunted as a stable source of protein and fat.

Forests expanded during the Late Boreal, as observed by an increase in arboreal pollen in B404. *Pinus* was present on the dry sandy soils, whereas *Alnus* was likely more prominent in the wetter depression. Groundwater levels had decreased since the Allerød and/or a natural vegetation succession eventually led to terrestrialization. The eastern part of the Liereman depression was likely a marsh wetland with little open water. Game frequented this area.

The top part of the studied peat interval of B404 shows that during Modern Times *Sphagnum* peat developed in the oligotrophic raised bog ecosystem that characterized at least the eastern side of the depression. This newly formed mainly rainwater-fed *Sphagnum* peat, along with the underlying groundwater-fed peat was extracted during the past centuries for fuel purposes. During this period crop cultivation played a large role in (the vicinity of) the Liereman depression as mainly *Secale* was cultivated, likely on the nutrient-depleted coversand ridges. Anthropogenic influence can clearly be discerned in the palynological record.

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Abstract

An augering campaign in search of prehistoric sites in the area of "Landschap De Liereman" (Province of Antwerp) has shown the presence of peat in the subsurface of the Liereman depression. Microfossils (pollen, spores and non-pollen palynomorphs) and macrofossils (such as seeds) in two peat sequences were analyzed. The aim of this palaeoecological investigation was to determine the age of the peat and to reconstruct the landscape in which it was formed. This study has demonstrated that peat formation in the eastern and central part of the Liereman depression started in the early phase of the Allerød (11780-11510 cal BC). During this warm phase of the Late Glacial the depression became an ecologically diverse wetland ecosystem with open water. This attracted game and, therefore, hunter-gatherers. Peat also accumulated during the Late Boreal (7580-7370 cal BC) in the eastern part of the depression, where alder occurred. Pine and birch woodlands were present on the bordering coversand ridges. Peat formation in the eastern part of the depression continued until a few centuries ago. *Sphagnum* peat formed in a raised bog ecosystem. This (living) organic-rich peat was preferably extracted for fuel purposes. During the period of peat extraction the landscape was strongly influenced by man. Rye cultivation played a significant role on the nutrient-depleted coversand ridges.

Keywords: The Liereman, Province of Antwerp (BE), peat, palaeoecology, Allerød, Late Boreal, peat extraction.

Samenvatting

Tijdens een verkennend booronderzoek met als doel om prehistorische sites te duiden in het gebied van "Landschap De Liereman" (Provincie Antwerpen) is de aanwezigheid van veen in de ondergrond van de Lieremandepressie aangetoond. Twee veensequenties zijn onderzocht op microfossielen (pollen, sporen en niet-pollen palynomorfen) en macrofossielen (waaronder zaden). Dit palaeoecologisch onderzoek had tot doel om de ouderdom van het aanwezige veen te bepalen en om het landschap te reconstrueren waarin dit veen zich heeft ontwikkeld. Deze studie heeft laten zien dat veenvorming in het oostelijke en centrale deel van de depressie reeds in het Vroeg Allerød (11780-11510 cal v. Chr.) aanving. Gedurende deze warme periode tijdens het Laat Glaciaal ontwikkelde de depressie zich tot een ecologisch divers wetland ecosysteem met zoetwaterbronnen. Dit trok wild aan en daarmee ook jagers-verzamelaars. Ook gedurende het Laat Boreaal (7580-7370 cal v. Chr.) accumuleerde veen in het oostelijke deel van de depressie alwaar els voorkwam. Berken-dennenbossen bevonden zich op de aangrenzende dekzandruggen. Veenvorming in het oostelijke deel van de depressie vond plaats tot enkele eeuwen geleden. Veenmosveen vormde zich aldaar in een hoogveengebied. Dit levende, zeer organische veen werd als turf gestoken om brandstof te verkrijgen. In de periode van veenontginningen werd het landschap sterk door de mens beïnvloed. Zo speelde de verbouw van rogge een belangrijke rol op de schrale dekzandruggen.

Trefwoorden: De Liereman, provincie Antwerpen (BE), veen, palaeoecologie, Allerød, Laat Boreaal, turfwinning.

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