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Posterholt, a Late Pleistocene – Holocene record of the vegetation history in and around the valley of the Vlootbeek, a tributary of the river Meuse (southeastern Netherlands)

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Abstract

The infill of an abandoned branch of the small river Vlootbeek, a tributary of the Meuse, revealed a record of the vegetation history from the Allerød to the Middle Ages, albeit with at least two hiatuses in its upper reach. Striking observations are the continuous presence of *Pinus* in a period long after this tree was absent elsewhere in the Dutch landscape, and the high percentages of *Tilia* pollen in the mid-Holocene. The former is explained by the sandy–gravelly subsoil in the valley of the Vlootbeek. The latter is ascribed to the short distance between the coring location and the plateau on which *Tilia* must have been the dominant tree. Anthropogenic influence is apparent from the Early Neolithic Linearbandkeramik farmers onwards.

Keywords: Anthropogenic influence, Late Pleistocene – Holocene, *Pinus*, pollen diagram, *Tilia*

Introduction

The Vlootbeek is a small tributary of the river Meuse that begins in Germany, enters the Netherlands just south of the village of Posterholt and flows past Montfort to join the Meuse near Linne. The small river has no true source but is actually a branch of the larger river Roer, splitting off before it reaches the border. It makes use of old channels in a fossilised, 2 km wide valley left by the late Glacial Roer. At the end of the Pleistocene the lower end of this wide valley became partly blocked by the formation of crescentic dunes. This, together with a tectonic tilt of the valley, forced the main stream to the north. The Vlootbeek is the remnant of the former river (H. Van der Beek, unpublished report, 1998).

In its lower course the Vlootbeek is much affected by canalisation, but near Posterholt the valley reveals traces of the past. A mosaic of former (Roer) channels and low elevations consisting of sandy and gravelly deposits is still visible in, for instance, the locality of Voorsterveld. The former channels are filled with clay and more organic material. One of the channels was sampled for pollen analysis (Fig. 1). Originally this analysis was intended to provide a landscape reconstruction connected with a series of Mesolithic campsites. These sites were the subject of excavations conducted by M. Wansleeben (Faculty of Archaeology, Leiden University) and L. Verhart (Museum of Antiquities, Leiden) in the 1990s, but the final synthesis of this research was never written and the diagram never published.

Material and methods

The core was taken by the excavators with the use of a side-filling auger and brought in 1994 to the archaeobotanical laboratory of the Faculty of Archaeology, Leiden University. The RD coordinates of the coring location are X 34651, Y 20046. The lithology is presented in Table 1.

Subsamples of 1 cm^3 (1 cm thick) were cut from the core and treated with KOH, HCl, bromoform/ethanol s.g. 2.0 and acetolysis. Before treatment, a tablet with a known quantity of *Lycopodium* spores was added following the method of Stockmarr (1971). Pollen was identified and counted by the students Per Larsen and Marjolein Alkemade, and myself. The

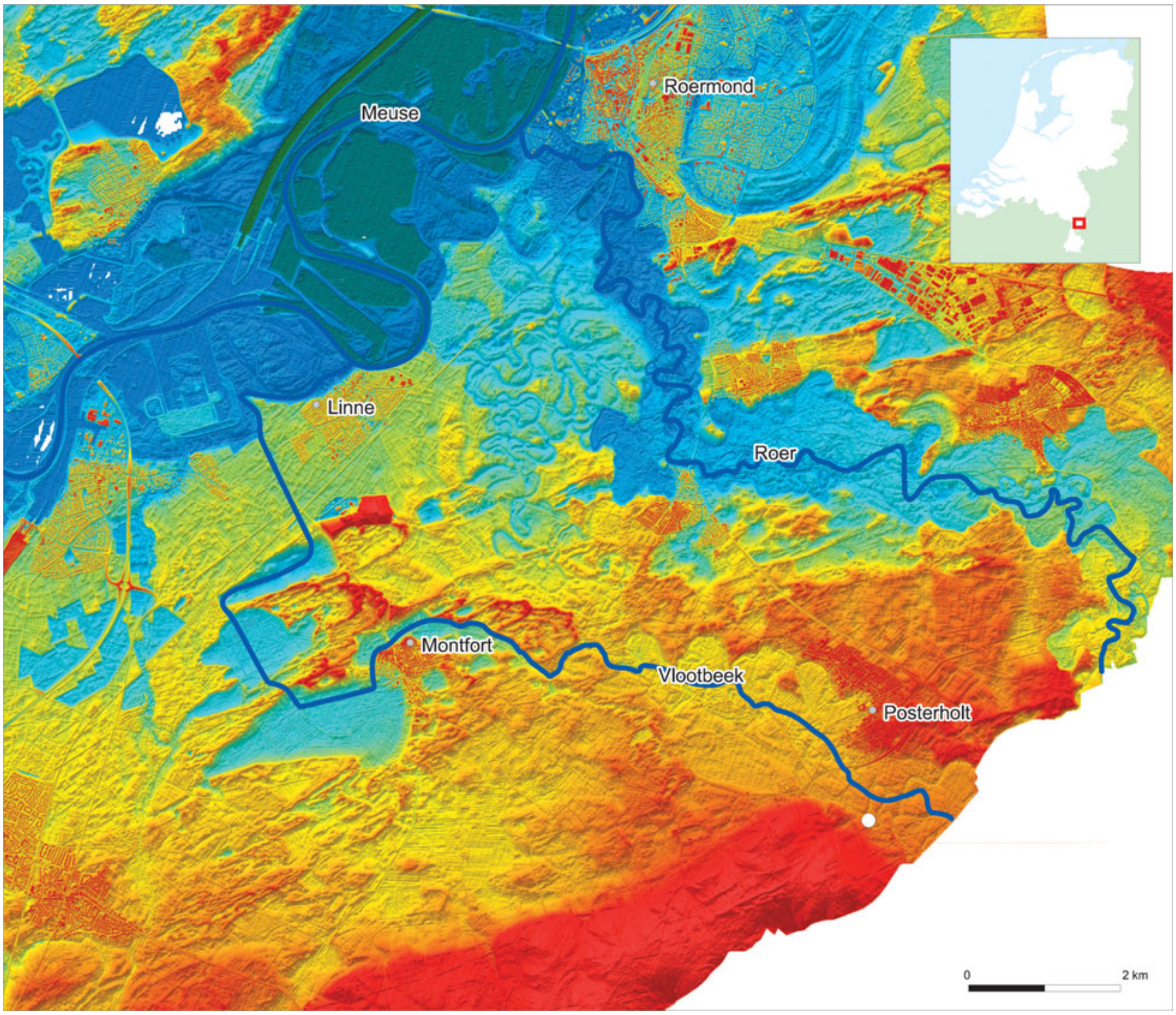

Fig. 1. AHN map of the Vlootbeek and Roer valleys. The location of the core is indicated by a white dot. Highest areas are red, lowest dark blue.

Table 1. Description of the core.

Depth below surface (cm)	
0–3	Peaty clay
3–18	Peat
18–21	Peaty clay
21–35	Peat
35–37	Peaty clay
37–78	clay
78–86	Peaty clay
86–94	Clay
94–103	Peaty clay
103–118	Clay
118–119	Gravel
119–121	Clay
121–123	Peaty clay
123–125	Clay
End coring	Gravel

identification key used was that of Faegri et al. (1989). Some non-pollen palynomorphs were counted with the aid of Pals et al. (1980) and Van Geel et al. (1981, 1989). Diagrams were drawn with the aid of TILIA and TILIAview (Grimm, 2011).

The sediments offered not much material suitable for dating, but five samples were sent to Groningen (the Netherlands) for ^{14}C-dating (Table 2).

Results

The pollen diagram is presented as a percentage diagram in Figure 2. The pollen sum chosen is an upland (dryland) sum excluding all taxa that could have contributed to organic matter in the former channel. These taxa include *Alnus*, but also *Salix*, Poaceae and Cyperaceae. In view of the age of the lower part of the sequence this choice may be questionable. This is a well-known dilemma when Late Pleistocene and Holocene records have to appear in a single diagram (see e.g. Janssen &

Table 2. Posterholt ^{14}C dates; calibration Oxcal 4.2, 95.4% probability.

Depth (cm)	AMS date	Sample	^{14}C date	Vegetation
12–14	3580 ± 80 BP	GrN-27623	2191–1696 cal BC	bulk peat
27	5490 ± 60 BP	GrA-63462	4460–4233 cal BC	hazelnut shell
33	6310 ± 40 BP	GrA-65938	5367–5215 cal BC	thin charred twigs
32.5–35	6980 ± 100 BP	GrN-27624	6028–5674 cal BC	bulk peat
91	10,260 ± 80 BP	GrA-23000	10 443–9766 cal BC	*Salix* twig and leaf

IJzermans-Lutgerhorst, 1973). Local pollen zones were drawn visually, based on changes in upland taxa percentages.

Zone 1 is characterised by the dominance of *Betula*. Among the upland herbs *Helianthemum* may be noted. A substantial part of the Poaceae and Cyperaceae may also have belonged to the upland vegetation. The landscape presents a combination of birch forest and steppe. *Nuphar* reveals the presence of a lake at the coring location.

In *zone 2 Betula* is partly replaced by *Pinus*, *Juniperus* and *Populus*. In the upland vegetation *Artemisia* stands out, together with other steppe elements like *Astragalus* and again *Helianthemum*. The strictly local vegetation, represented by, for instance, *Myriophyllum verticillatum*, *M. spicatum* and *Nuphar*, shows that lake-like conditions still prevail.

Zone 3 sees the return of *Betula*, but the other trees do not disappear entirely. In addition, *Salix* is seen to have been important, presumably also in the upland. Herbs like *Artemisia*, *Armeria* and *Plantago maritima* indicate that the herb vegetation is still steppe-like. Aquatic taxa are still present but tend to disappear. Zones 1, 2 and 3 must be placed in the Late Pleistocene.

The next zone, *zone 4*, is characterised by a strong decline in *Betula* pollen percentages after an initial rise. *Juniperus* and *Populus* are absent from this zone onwards. *Pinus* dominates the record, but the first deciduous taxa, *Corylus* and *Quercus*, make their appearance. The border between zones 3 and 4 is sharp and a hiatus in deposition might be expected, but the curves of local taxa, like *Myriophyllum verticillatum* and *Filipendula*, do not show anything of the kind. Also, the lithology provides no indication of a hiatus. The lower part of the zone is provided with an accelerator mass spectrometry (AMS) ^{14}C date of 10,260 ± 80 BP obtained from a *Salix* twig and complete leaf. This date may be thought too old, but comparable dates also turn up elsewhere and there is no reason to reject it (Bos et al., 2007).

Zone 5 is a zone of *Corylus* dominance, but *Pinus* remains important as well. The percentages of *Quercus* pollen rise; *Ulmus*, *Hedera* and *Myrica* appear. Traces of herb vegetation are hardly visible. At the start of the zone the sediment is a peaty clay, but during its remainder true clay deposition took place, obviously smothering the former lake.

Zone 6 starts with the appearance of *Tilia*. Furthermore the highest values of *Ulmus* are seen in this zone. *Pinus* pollen percentages decline. Herb vegetation is sparsely represented.

Zone 7 is characterised by the dominance of *Tilia*. *Corylus* and *Pinus* pollen percentages decline strongly, but *Quercus* percentages show a rise. Surprisingly for a zone dominated by *Tilia*, the herb pollen percentages, expressed in the NAP component of the AP–NAP (arboreal pollen–non-arboreal pollen) diagram, rise as well. This is mainly due to a rise in Ericales and *Polypodium*, but other herbs also appear. Locally *Alnus* appears, together with marsh ferns (Monoletae psilatae), indicating the presence of carr and marsh conditions in low-lying areas. At the beginning of this zone the lithology shows a return to stagnant wetland conditions allowing peat formation. A ^{14}C date, obtained from bulk material at the base of the peat, places this change at 6980 ± 100 BP. The strong changes observed hint at a hiatus in the sequence between zones 6 and 7. AMS ^{14}C dates obtained for horizons above the bulk material sample give 6310 ± 40 BP and 5490 ± 60 BP.

The following zone, *zone 8*, starts with a sharp decline in *Tilia* pollen percentages, a rise in *Quercus* and the start of the continuous curve of *Fagus* pollen. *Carpinus* appears, which is rather soon after the appearance of *Fagus*. A long-lasting hiatus between zones 7 and 8 would explain this. The lithology shows an intercalation of (peaty) clay at this point. It is quite possible that something happened to disturb the smooth continuity of the sequence. A conventional ^{14}C date based on bulk material provides a date of 3580 ± 80 BP for the centre of the zone and is discussed below.

The last zone, *zone 9*, shows an important share of upland herb pollen, including Cerealia (mostly *Secale*), *Fagopyrum*, *Centaurea cyanus* and Ericales. Tree pollen comprises *Juglans*. Locally the *Alnus* carr with its undergrowth of marsh fern (Monoletae psilatae) appears to decline whilst *Typha latifolia* pollen percentages rise strongly. During this zone both the upland and the wetland environment were deforested to an important degree.

Discussion

The Posterholt diagram represents the Late Pleistocene and large parts of the Holocene. Such long records are rare in this part of

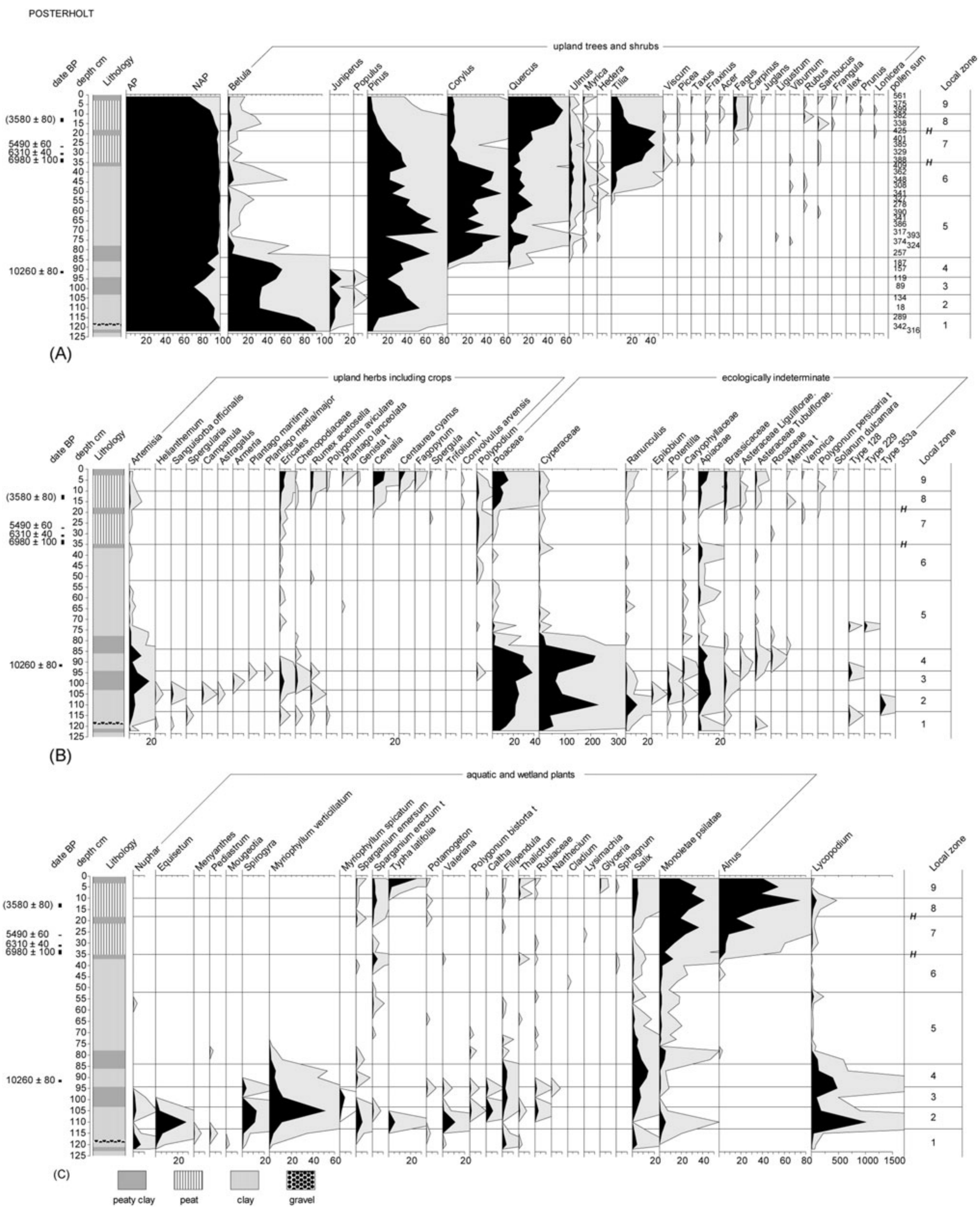

Fig. 2. *The Posterholt pollen diagram: (A) upland trees and shrubs; (B) upland herbs including crops, and ecologically indeterminate taxa; (C) aquatic and wetland plants. Depth below surface, exaggeration of curves 10× in grey. One* ^{14}C *date (in parentheses) is questionable. Hiatuses are indicated by H in the local zone column.*

the Netherlands (Bos & Zuidhoff, 2015, p. 8). It has two hiatuses in its upper reach.

Zones 1 and 2 are attributed to the Allerød. The sequence *Betula* forest, followed by *Pinus–Betula* forest together with *Juniperus*, belongs to this period. The forest was rather open as is indicated by the presence of steppe herbs, first and foremost *Artemisia*, but also other taxa like *Helianthemum* and *Astragalus*, which might not have been detected if the forest had been dense. The pollen reflects an upland covered with a light forest with much undergrowth, or with a mosaic of stands of trees and open patches. The former channel had developed into a (small) lake.

In zone 3 the forest reverted to a dwarf shrub vegetation with scattered *Betula* copses accompanied by *Juniperus* and presumably *Salix*, because part of the *Salix* pollen may have come from the upland. This change is attributed to the onset of a period with a colder climate, the Younger Dryas. In most parts of the wider region, i.e. the valley of the Meuse and its surroundings, forests disappeared (Hoek, 1997), but as Bos et al. (2007) remarked, in some sheltered places remnants of the original forest survived along small lakes. Posterholt may have been one of those.

After zone 3 the upland vegetation returned to forest as is apparent from the AP–NAP curves. The sequence in which the trees appear is typical for the Holocene in the Netherlands. Zone 4 represents the Preboreal, a period with a dominance of *Pinus*, but with the first records of the warmth-loving deciduous taxa *Corylus*, *Quercus* and *Ulmus*. The modest thickness of the peaty clay deposited during this period does not afford sufficient resolution to detect subzones such as the Friesland- or Rammelbeek-phases (for subzones see e.g. Bos et al., 2007). The local lake has disappeared.

A substantial part of the diagram comprises the Boreal (zones 5 and 6). The share of *Pinus* in the forests declines but during the Holocene *Pinus* never disappears. As described in the introduction, the local landscape presented, and still consists of, a mosaic of former channels and sandy–gravelly low elevations. *Pinus* may very well have survived on the latter. Another explanation for the occurrence of *Pinus* pollen might be that this pollen was not released by the Vlootbeek valley vegetation but arrived with the clay deposited during this period. Arguments against this hypothesis are that the majority of the pollen grains were undamaged and that other diagrams obtained for the region do not show such high *Pinus* percentages. The corings Bolberg and Bennebroek, for instance, also revealed clastic sediments in the Boreal, but only a modest share of *Pinus* (Janssens, 2011). Nevertheless, the pollen may have derived from locally reworked older sediments as the result of Mesolithic hunter-gatherers' activities (suggestion by A.J. Kalis, oral communication). Consultation with the archaeologists M. Wansleeben and L. Verhart revealed that, though they detected some 30 campsites in the neighbourhood, these were small and short-lived. According to them the impact of the Mesolithic population cannot have been important enough to cause redeposition of older sediments. Therefore, it is quite possible that light local *Pinus* stands existed and were the source of attraction for the hunter-gatherers (see for local stands also Bos & Van Geel, 2016).

The lower ground around the sandy hillocks may have been covered by *Myrica* brushwood. This shrub grows on moist soils, poor in nutrients and with a low pH. It requires an Atlantic climate; at present the region around Posterholt lies at the southern limit of its distribution in the Netherlands (Weeda et al., 1985). Stands of *Myrica* are poor in other species, which may explain the near absence of herb pollen in the diagram. Although the lake in the channel that provided the pollen diagram no longer existed at that time, other lakes may still have been present in the maze of former channels. In its entirety the landscape around Posterholt may have presented a desirable environment for hunter-gatherers.

On the better soils, the nearest being the land close to the left bank of the Vlootbeek, south of the place of coring, *Corylus* gained dominance. *Quercus* was present in the landscape, but another well-known tree from the mid-Holocene, *Ulmus*, appears not to have got much chance to establish stands.

A hiatus follows zone 7 that is attributed to the Atlantic, an attribution confirmed by three ^{14}C dates. The nature of the deposit has changed, as has the composition of the vegetation. *Myrica* loses importance and *Alnus* carr with an undergrowth of marsh ferns (Monoletae psilatae) appears instead. A new water regime must lie behind this.

The most conspicuous change is the strong presence of *Tilia* pollen percentages at the expense of *Corylus* mentioned above. Apparently *Tilia* becomes the dominant tree; this fact is commented on in a separate section below. According to Berendsen and Zagwijn (1984), the few grains of *Taxus* suggest a date in the Subboreal. But *Taxus* berries are well known at Erkelenz–Kückhoven from the Early Neolithic (Linearbandkeramik) with dendro-dates of 5090 and 5057 ± 5 BC (Knörzer, 1989; Schmidt et al., 1998), a locality not far from Posterholt. The *Taxus*–Subboreal connection may not be applicable to this part of the Netherlands. A presence in the second half of the Atlantic is therefore plausible (see also Woldring et al., 2010).

Another remarkable aspect is that despite the dominance of *Tilia*, which provides much shade, the curves of *Quercus* and NAP rise. This implies the presence of lighter forest and open space in the landscape. As *Tilia* forest is supposed to have covered pre-eminently the plateau outside the valley (see below), this more open landscape where *Quercus* could thrive and herbs could attribute pollen to the pollen rain was to be found in the valley. The local sandy–gravelly soils may not have been suited to *Tilia*, but this may not be the only explanation. It is tempting to attribute at least part of the openness to farming activities. The area is known to have been exploited from the Early Neolithic Linearbandkeramik culture onwards (Brounen, 1985; Wansleeben, 1987). In particular, the browsing and grazing of livestock may have affected the original vegetation. The

AMS date of 6310 ± 40 BP (5367–5215 cal BC) for the start of the rise in NAP is in accordance with this attribution. The first occupation of the southeastern Netherlands and adjacent Germany occurred between 5300 and 5200 cal BC (Van de Velde, 2007). People settled on loess, but Bakels (1982) suggested that the areas on the fringes of the loess-covered plateaus were needed by Linearbandkeramik farmers as pasture land, as the dense forest on the plateaus may not have offered enough feed. The valley of the Vlootbeek may have been one of these areas.

The values of *Tilia* fall suddenly at the boundary between zones 7 and 8, and, as argued earlier, this must be due to a hiatus in the record. To a very moderate degree the place of *Tilia* may have been taken over by *Fagus*. However, it is *Quercus* that became the most important tree. The rise in its pollen curve is accompanied by a rise in upland pollen percentages. *Quercus* does well in open stands and sheds more pollen there, and the general picture is one of a landscape undergoing deforestation. *Quercus* trees may have been spared. The occurrence of a continuous Cerealia curve shows that part of the landscape was converted into arable fields. The strong rise in Poaceae pollen percentages most probably represents meadows and pastures. The rise in the Ericales curve may be explained as the appearance of pasture land as well, in this case on the poorer soils. A ^{14}C date based on bulk peat suggests a serious impact on the environment in a period at least around 3580 ± 80 BP (2191–1696 cal BC), that is in the Bronze Age. To a certain degree this date is plausible. The continuous *Fagus* curve in the Well–Aijen diagram is also placed in the Bronze Age part of the Subboreal (Bos & Zuidhoff, 2015). However, some pollen grains of *Carpinus* are also present, which means a Subatlantic date. It is therefore also plausible to attribute the deforestation to farmers of the Iron Age, sometime after 800 cal BC. In that case the ^{14}C date has to be rejected, although there is no obvious reason for its being wrong.

The last spectra give evidence that the uppermost part of the sequence was deposited in the Middle Ages. Although *Juglans*, a tree introduced by the Romans, may be placed earlier, the presence of *Fagopyrum* and *Centaurea cyanus* indicates a medieval age (Bakels, 2012; Bakels et al., 2015).

The importance of lime (*Tilia*) in the mid-Holocene forest

An outstanding feature of the Posterholt diagram is the high value reached by *Tilia* pollen percentages in local zone 7 (Fig. 2). The taxon *Tilia* represents two species, *Tilia cordata* Mill. and *T. platyphyllos* Scop., the only indigenous lime species in the Netherlands. At present, natural lime forests are absent in the country, though a few trees can still be found (Maes & Van Vuure, 1989). The pollen of the two species display differences (Christensen & Blackmore, 1988), but there is a non-negligible overlap between the pollen types (see also Beug, 2004, p. 323). At the time of counting, the taxon was not split into a *T. cordata* type and a *T. platyphyllos* type. Macroremains were not found, but in contemporaneous deposits in the valley of the Elsbach in nearby Germany *Tilia* fruits were preserved and identified as *T. cordata* (Becker, 2000). Surprisingly, the *Tilia* fruits described for contemporaneous deposits in the Netherlands, for instance in the Alblasserwaard and the surroundings of Zwolle, were all described as *T. platyphyllos* (relational archaeobotanical database for advanced research (RADAR) version 2010, maintained by O. Brinkkemper, RCE Amersfoort, Netherlands).

The striking dominance of *Tilia* is not restricted to Posterholt. K.K. Koelbloed (unpublished report, 1976) found the same at Melick, a locality 6 km to the northwest of Posterholt, a record repeated by new research at the same locality by M. Van Dinter (unpublished report, 1994). Janssen (1960) and Kalis & Meurers-Balke (2003) detected high percentages of *Tilia* pollen in some peats of South-Limburg, a region just to the south, and Otten (2013) in abandoned branches of the river Meuse just west of the Vlootbeek area. Munaut (1967) published high percentages in the uplands of Belgian Limburg and Brabant.

Greig (1982) provided an overview of past lime forests in northern and central Europe. He wondered why some pollen diagrams show low percentages of lime whilst others display high percentages. He concludes: 'This study has shown evidence that lime forest, rather than as traditionally supposed mixed oak forest, was the dominant vegetation of areas of northern Europe in the Atlantic period … No clear explanation can yet be advanced to account for its irregular distribution.'

Janssen (1960) sought the explanation in the size of the peat deposit in combination with the bad dispersal of *Tilia* pollen grains. *Tilia* is entomophylous. He writes on p. 68: 'high percentages are reached only in case the distance between the site where *Tilia* trees are growing and the site where the pollen was collected is but small.' Therefore he placed the lime forest in the valleys as part of an Alno-Ulmion (now Alno-Padion). In 1978 I questioned this reconstruction (Bakels, 1978, pp. 34–35) and opted for lime forests on the higher plateaus outside the valleys, inspired by the work of Munaut.

Since then I have been looking into this matter and have twice had the opportunity to compare pollen percentages obtained from a peat in a valley of a larger river with those obtained from the narrower valley of a tributary and to establish the relative contribution of the taxa *Tilia*, *Quercus*, *Ulmus* and *Fraxinus*, the 'classic' components of the upland forests in the mid-Holocene, formerly taken together as Quercetum mixtum, a now obsolete term (Bakels, 2009). The conclusion was that *Tilia* percentages are much higher in smaller valleys, which may be explained by the smaller distance from the coring location to the plateau. As a matter of fact the first supposition of Janssen was right, but his conclusion was not.

The combination of Well–Aijen (Bos & Zuidhoff, 2015) and Posterholt presents a third case. It is clear that Posterholt has

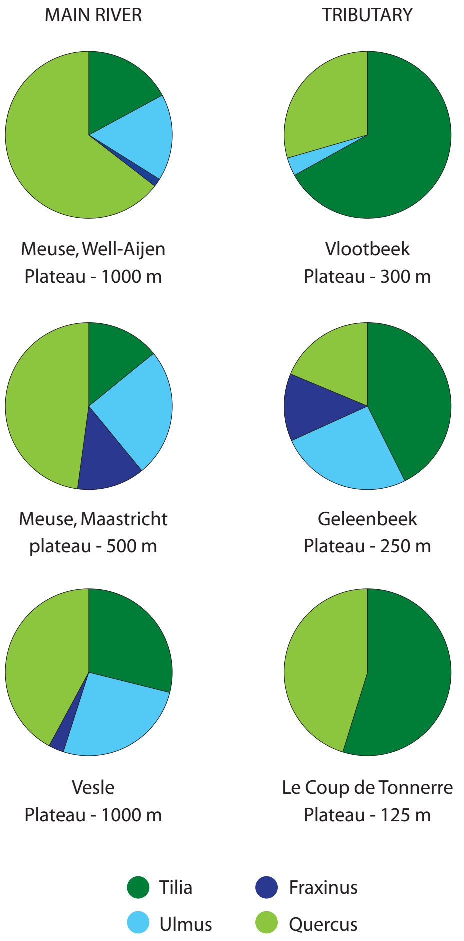

Fig. 3. The proportion of the pollen percentages of the main four deciduous trees in the mid-Holocene, average of four spectra per location. The values obtained from a location in the wide valley of a main river are compared with those from a location in the narrower valley of a tributary within the same region. The distances from the coring location to the nearest plateau are mentioned. Three sets are presented: Meuse and Vlootbeek (central Limburg), Meuse and Geleenbeek (southern Limburg), and Vesle and Le Coup de Tonnerre (Aisne, France).

the higher share of *Tilia* (Fig. 3). Although the valley of the Vlootbeek appears wide on maps, the mid-Holocene valley was not wide at all and the plateau is nearby. Therefore, the reconstruction of a lime forest expressly on the high parts of the landscape is plausible.

Everywhere lime forests disappeared after the mid-Holocene, as on the plateau bordering the Vlootbeek valley. Pollen analyses in adjacent regions of Germany showed that the decline of lime is due to anthropogenic influence (Bunnik, 1999; Knörzer et al., 1999; Becker, 2000). Though the 'sudden' *Tilia* decline in the Posterholt diagram may be due to a hiatus in the sequence, the diagram reveals the presence of anthropogenic indicators and a rise in Ericales pollen percentages just before the possible gap. It is therefore not unlikely that the lime forests in the vicinity of the Vlootbeek also disappeared as the result of human action.

Conclusion

The fill of the former channel of the Vlootbeek revealed a substantial part of the vegetation history in and around this branch of the river Roer during the late Pleistocene and the Holocene. The persistence of pine in the record is striking. This tree that commonly almost completely disappears from the Dutch landscape is seen to linger on as a rather important component of the local forest. Most probably, its stands survived on the sandy–gravelly elevations in the wide valley.

An entirely different vegetation seems to have developed on the plateaus outside the valley, the nearest situated south of the course of the Vlootbeek, where in the Atlantic the landscape appears to be covered by lime forest. The predecessor of this kind of forest was presumably tall hazel shrub.

Valley and plateau together must have presented a variegated landscape that should have been attractive to the hunter-gatherers of the first half of the Holocene. Farming societies later took root in this region and in the end the landscape underwent severe deforestation. Only oak appears to have been spared in the long run.

During the Holocene the water regime in the part of the Vlootbeek also studied underwent changes. The deposition of clay smothering the former lake is one indication of such change. The occurrence of alder carr in an area where formerly bog myrtle is supposed to have grown is another and suggests a shift from mesotrophic to eutrophic conditions. In all, the surroundings of the Vlootbeek near Posterholt presented a variegated and dynamic landscape throughout the Holocene.

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