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A palynological study of a Holocene deposit from Grand-Bongard (Hautes-Fagnes, Belgium)

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Abstract

A peat deposit from a valley in the Hautes-Fagnes was studied palynologically. The radiocarbon-dated pollen profile spans most of the Holocene and constitutes one of the most detailed records of post-glacial vegetational changes in E. Belgium. The peat formation started near a *Betula-Pinus* forest and five regional pollen zones could be distinguished. The first zone is dominated by *Pinus* and *Betula* (Preboreal), the second by *Corylus* (Boreal) and the third by *Alnus* (Atlantic). The elm decline and the first signs of human influence characterize the fourth zone (Subboreal). The fifth zone (Subatlanticum) shows maxima of Fagus and *Carpinus* and an obvious increase of human influence (e.g., Cerealia).

The peat succession in situ took place under mesotrophic conditions as a consequence of the geographical situation of the site near the rivulet Helle. Although there has been some variation in the moisture conditions at the site, the drainage in the valley was so constant that extreme fluctuations did not occur.

Introduction

The valley of Grand-Bongard (50° 32′ N, 6° 8′ E) is situated along the rivulet Helle, in the N.E. part of the Hautes-Fagnes plateau (Fig. 1). The valley profile (altitude of sampling site 530 m) is asymmetrical, the left side has a long weak slant (c. 4.5% over 3.25 km), the right slope is steep and shorter (c. 13% over 2.25 km). The water of the rivulet is acid (pH 4.4–5).

The samples for the present study were taken from a peat deposit along the right bank of the rivulet. The thickness of the deposit was 175 cm. The same site had been sampled and studied before by Gavray (1982), but only the analysis of a selection of pollen types was carried out and no detailed macrofossil analysis was available. The present sample series was taken upon the suggestion of Prof. R. Schumacker (Station Scientifique des Hautes-Fagnes, Mont Rigi, Robertville).

The plateau of the Hautes-Fagnes, which originated during the rise of the Hercynic Massif, mainly consists of quartzites and phyllites. A strong decay of the phyllites, under tropical conditions during the Tertiary (Wunstorf 1937, 1943) resulted in kaolinitic clays, which formed an impermeable loam layer (Mückenhausen 1958) on top of the rocky subsoil. During periglacial periods loess layers were deposited which are still present on the relatively higher parts of the plateau; in the valleys the loess deposits have been eroded. Where loess is absent, the impermeable loamy subsoil caused stagnation of precipitation water on the plateau and, in combination with the local climatic conditions, raised bogs developed during the Holocene.

The Hautes-Fagnes form the first important bar-

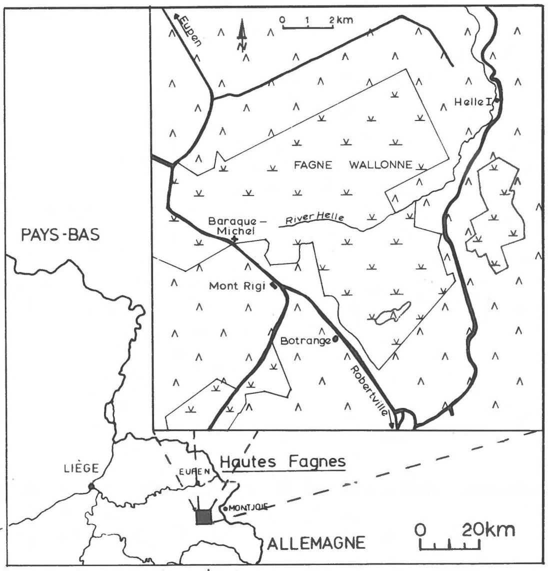


Fig. 1. Location map.

rier to the predominantly western winds. The forced rise of the oceanic air masses results in condensation and an abundant precipitation.

According to the 'Service de Climatologie de l'Institut Royal Météorologique de Belgique' (Sneyers et al., 1981) the main climatic characteristics of the Hautes-Fagnes are:
maximum average temperature: January 0.9° C – July 18.2° C;
minimum average temperature: January – 4.2° C – July 9.7° C;
maximum precipitation: 140 mm (July);
minimum precipitation: 94 mm (April);
total average annual precipitation 1450 mm;
average number of rain days: 195 days;
average number of fog days: 110 days;
average number of snow days: 43 days.

Four principal vegetation types can be distinguished in the area:

- On relatively dry, silty soils: forest dominated by *Fagus sylvatica,* with *Luzula* and *Vaccinium myrtillus.*
- On poor and humid, silty soils: forest of *Quercus robur, Betula pubescens* and *B. pendula* with *Molinia caerulea.*
- In valley bottoms, on soils rich in minerals and organic matter: *Alnus glutinosa* carr.
- On loamy soils in the more elevated area: peat-forming *Sphagnum* species.

In many places these natural climax vegetation types have been disturbed and changed by human interaction. This process started at the beginning of the Neolithic period. On the basis of palynological data, Froment (1975) concluded that a notable increase in human impact took place in the 13th Century AD. Deforestation, burning and reclamation for opening up new fields and grasslands and also for coal mining strongly reduced the forested area and also caused the extension of heath fields. The natural vegetation of bogs was damaged by mowing, peat-digging (for fuel and stable litter), and burning, and finally was destroyed by draining of the peat deposits, which started already in the 16th Century. In the 19th Century planting of *Picea* was stimulated in order to make the heath lands economically more valuable (Froment 1972). Nowadays a considerable part of the Hautes-Fagnes plateau is forested with *Picea abies* and *P. sitchensis* but some remnants of the *Fagus-* and *Quercus/ Betula*-forests are still present.

On gentle slopes and on depressions in the plateau raised bogs are present (e.g., Fagne Wallone, Fagne de Clefay, Königlisches Torfmoor). In many places the actual vegetation is dominated by *Molinia* as a consequence of human impact on the original raised-bog vegetation which was dominated by *Sphagna, Eriophorum* and several ericaceous taxa (Damblon 1976; 1980). The stand of vegetation of the valley fen at the sampling site Grand-Bongard is dominated by *Betula, Molinia, Juncus* and *Sphagna.* Near the site a coniferous forest with some *Fagus* is located.

A study of the development of the valley of Grand-Bongard by Gavray (1982) showed that during the Late-Glacial period no peat deposits were formed as a result of the local topography, the frequently shifting river bed, and the strong erosive force of the Helle rivulet. At the start of the Holocene the course of the Helle rivulet followed the left-hand side of the valley and peat deposits were formed on the right-hand side. During the Holocene the Helle gradually moved to the right-hand side again and as a consequence a considerable part

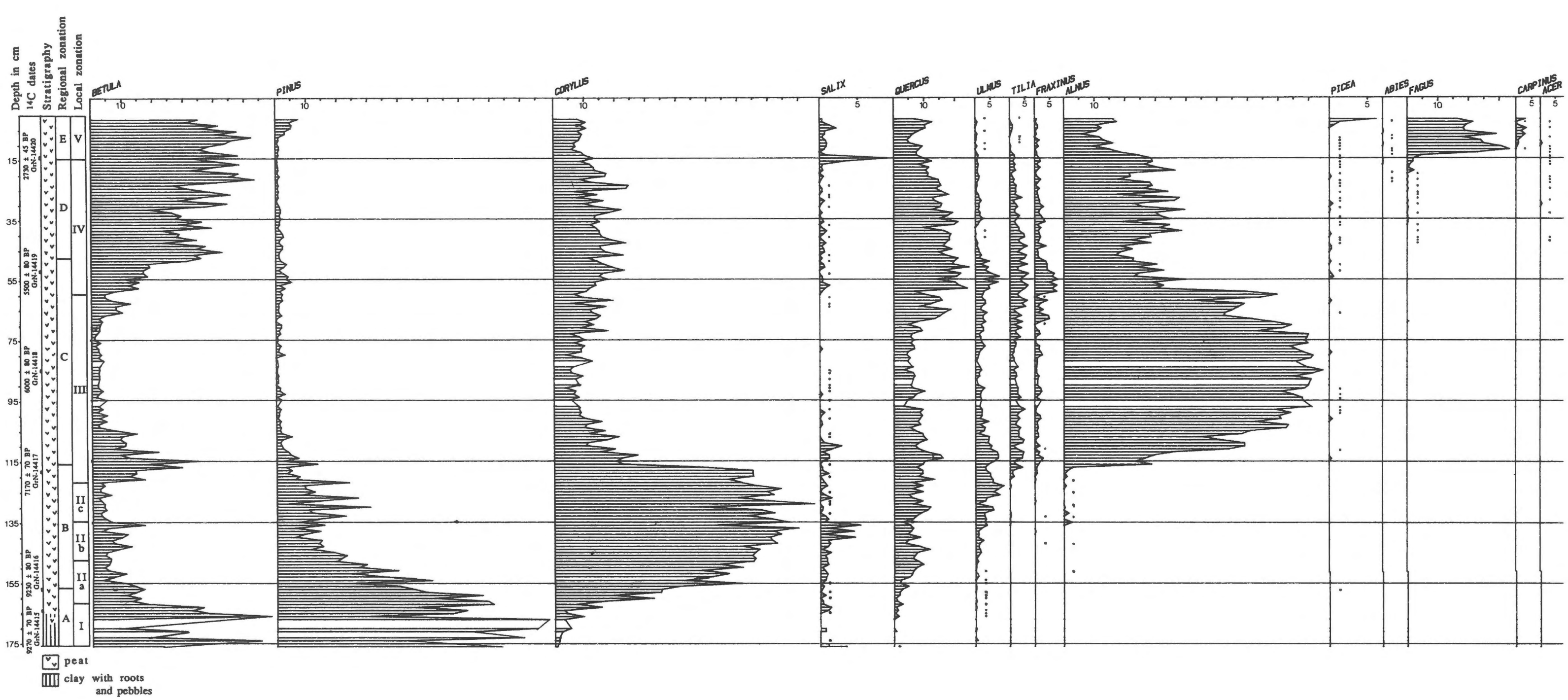
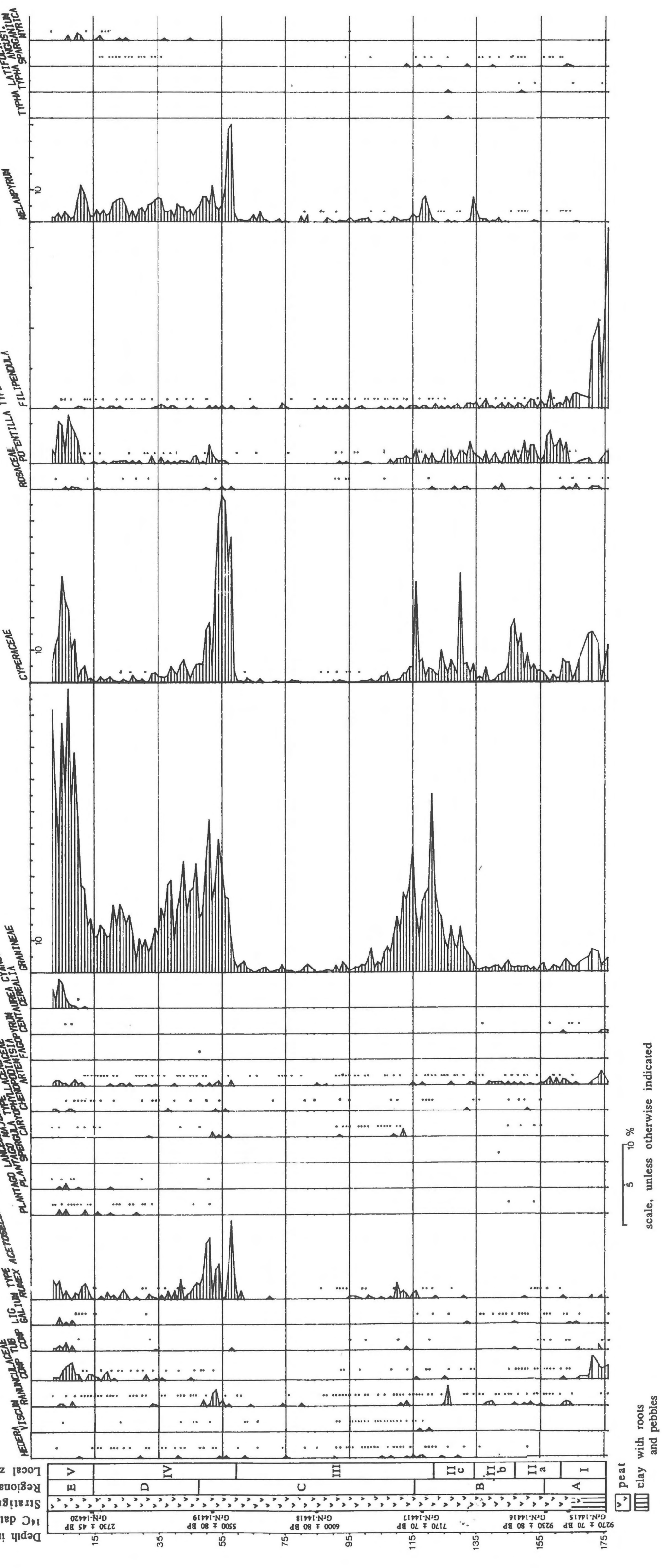


Fig. 2. Grand-Bongard, tree pollen diagram.


Depth in cm
14C dates
Stratigraphy
Regional zonation
Local zonation
15
35
55
75
95
115
135
155
175
2730 ± 45 BP GrN-14420
5500 ± 80 BP GrN-14419
6000 ± 80 BP GrN-14418
7170 ± 70 BP GrN-14417
9230 ± 80 BP GrN-14416
9270 ± 70 BP GrN-14415
E
D
C
B
A
V
IV
III
II c
II b
II a
I
HEDERA
VISCUM
RANUNCULACEAE
COMP TUB
COMP LIG
GALIUM TYPE
RUMEX ACETOSELLA type
PLANTAGO LANCEOLATA
PLANTAGO MAJOR/MEDIA
SPERGULA TYPE
CARYOPHYLLACEAE
CHENOPODIACEAE
ARTEMISIA
FAGOPYRUM
CENTAUREA CYANUS
CEREALIA
GRAMINEAE
CYPERACEAE
ROSACEAE
POTENTILLA TYPE
FILIPENDULA
MELAMPYRUM
TYPHA LATIFOLIA
TYPHA ANGUSTIFOLIA
SPARGANIUM
MYRICA
10
peat
clay with roots and pebbles
5
10 %
scale, unless otherwise indicated

a

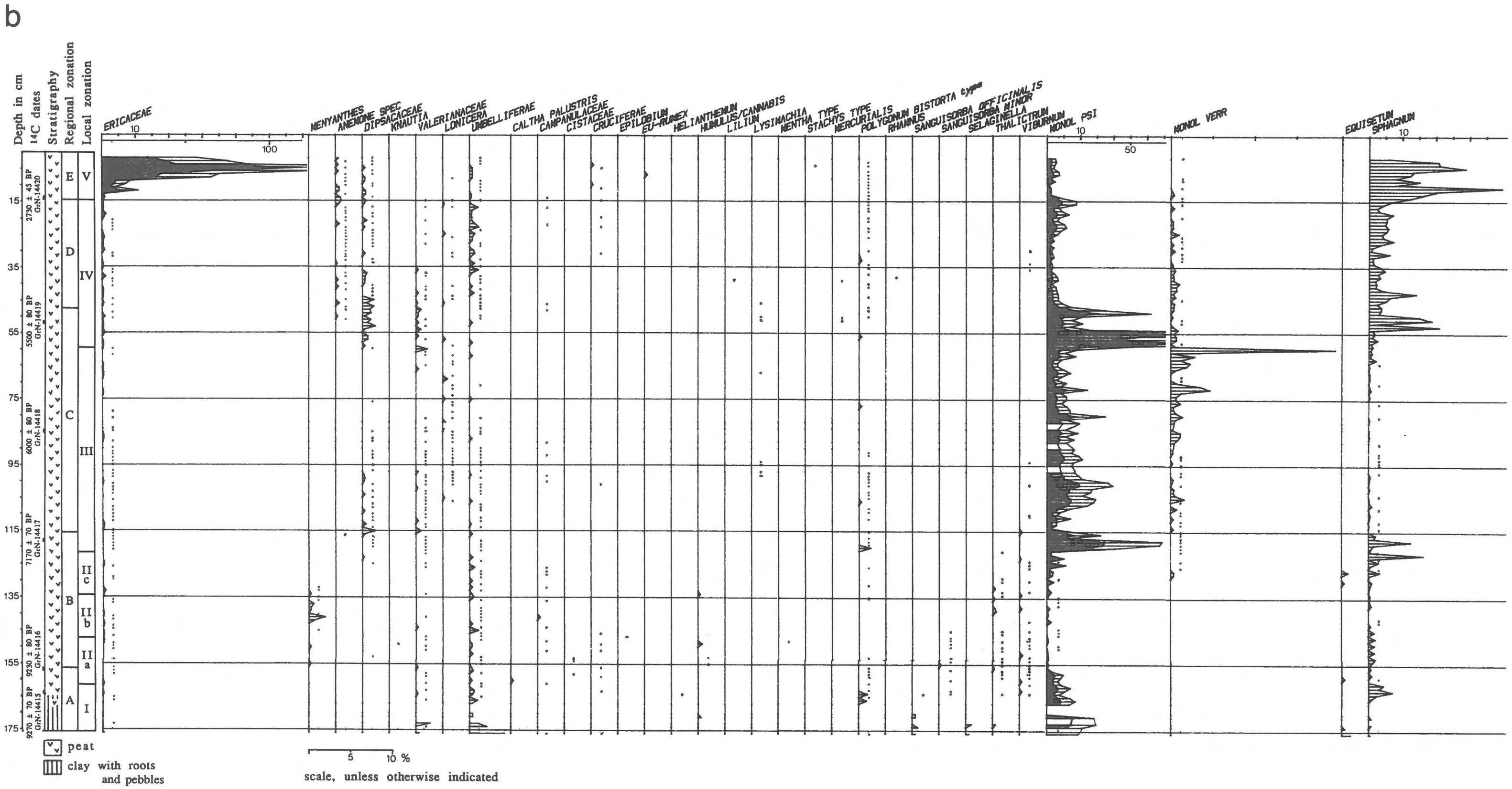


Fig. 3a, b. Grand-Bongard, herbaceous taxa.

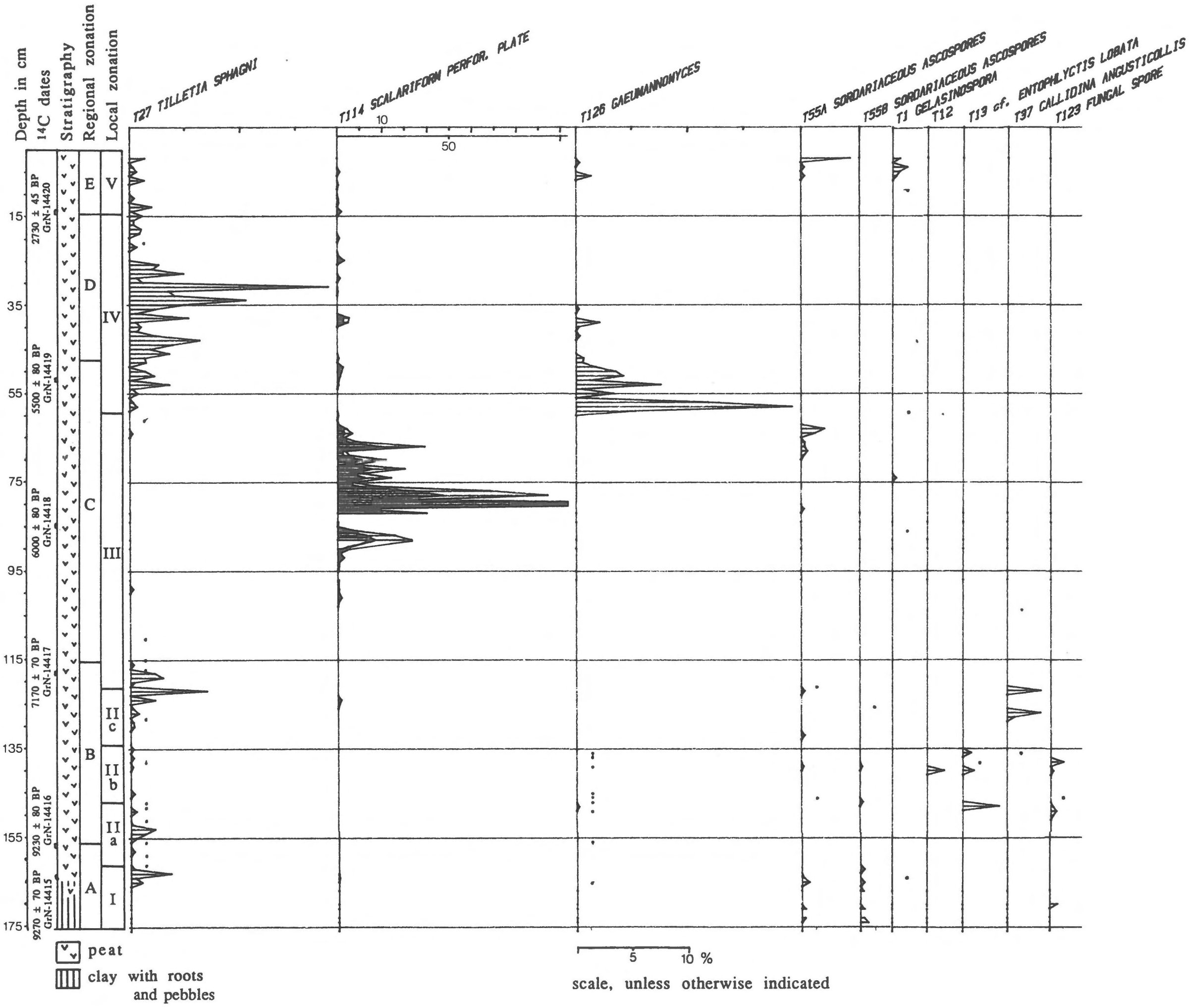


Fig. 4. Grand-Bongard, spore types.

of the peat deposits was eroded completely and the deposit became exposed along the rivulet.

In 1985 a vertical peat face was made and the deposit was sampled in metal boxes. A continuous series of subsamples of 1 cm thickness was studied for pollen, spores, fungal remains, algae, macrofossils, etc.. These subsamples were treated with KOH and subsequently acetolysed. Clay particles were removed by means of a bromoform-alcohol-mixture treatment (Faegri & Iversen 1975). For each microfossil sample a total of 275 to 500 tree pollen grains was recorded. The frequencies of all other microfossils were calculated as a percentage of this tree pollen total ($\sum$-pollen). The volumes of the subsamples for the microfossil analysis (c. 0.4 cc) were measured in order to calculate pollen concentrations. Subsamples for the study of macrofossils were boiled in a 5% KOH solution for 5 minutes and subsequently strained through a sieve with $130 \times 130\,\mu m$ meshes. Fruits and seeds were identified with the help of the atlasses of Berggren (1969, 1981) and Beijerinck (1976) and with the help of Dr J.P. Pals, Amsterdam.

The results of the microfossil analysis are shown in the diagram Figs. 2, 3a, 3b, 4 and 5. The records of the macrofossil analysis are shown in Fig. 6.

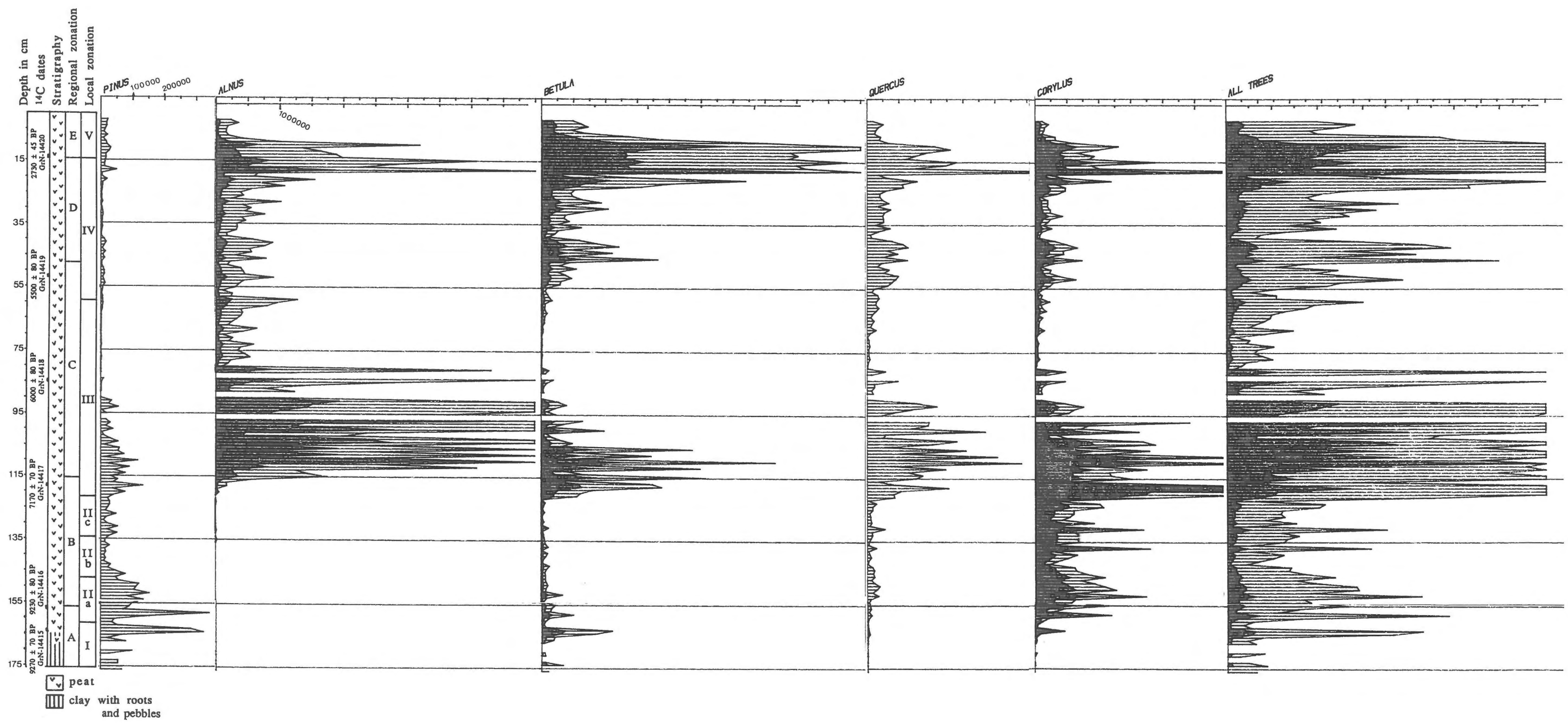
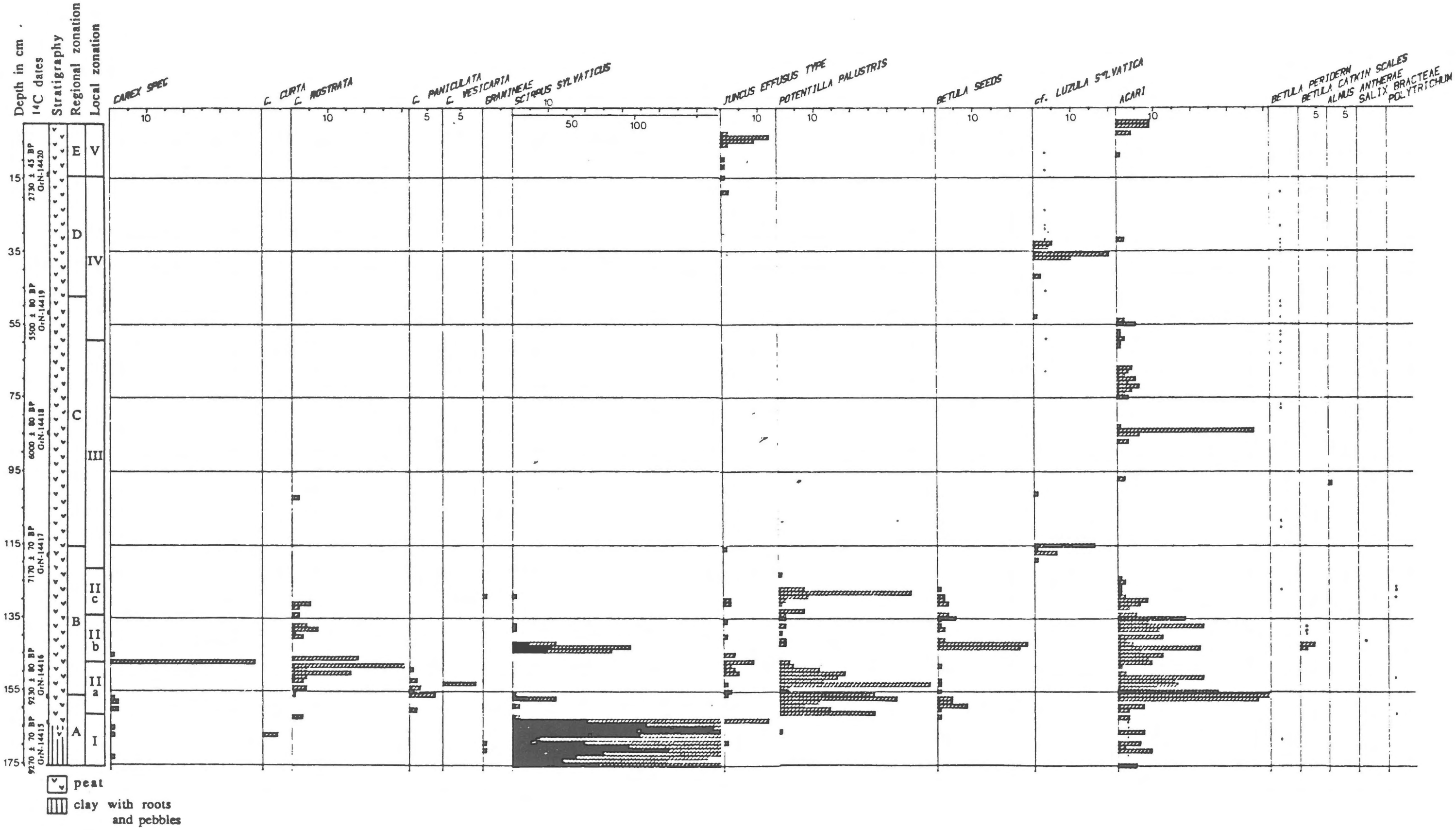


Fig. 5. Grand-Bongard, tree pollen concentration diagram.

a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5500 ± 80 BP GrN-14419
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7170 ± 70 BP GrN-14417
9230 ± 80 BP GrN-14416
9270 ± 70 BP GrN-14415
CAREX SPEC
C. CURTA
C. ROSTRATA
C. PANICULATA
C. VESICARIA
GRAMINEAE
SCIRPUS SYLVATICUS
JUNCUS EFFUSUS TYPE
POTENTILLA PALUSTRIS
BETULA SEEDS
cf. LUZULA SYLVATICA
ACARI
BETULA PERIDERM
BETULA CATKIN SCALES
ALNUS ANTHERAE
SALIX BRACTEAE
POLYTRICHUM
peat
clay with roots and pebbles

b

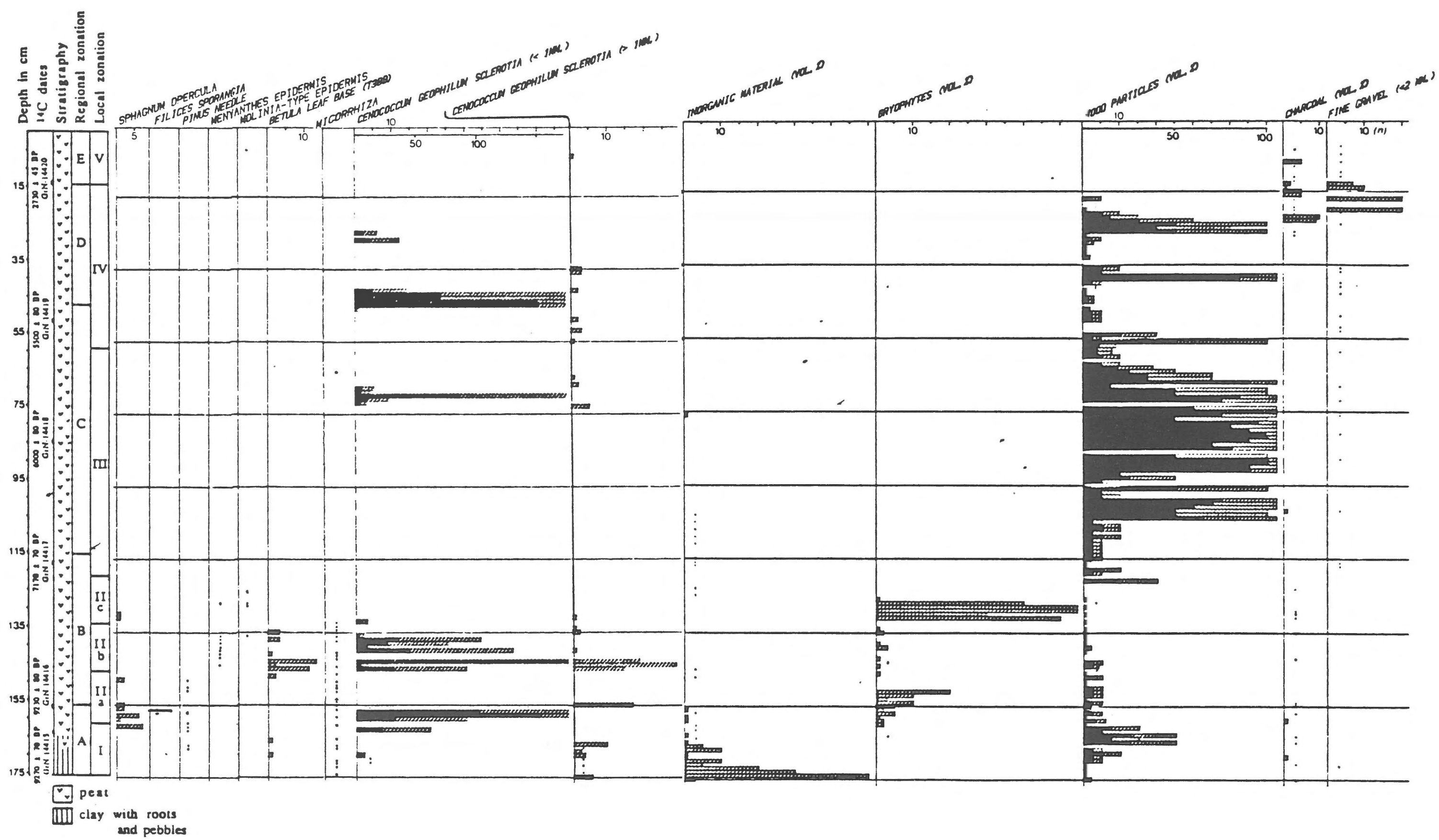

Fig. 6a, b. Grand-Bongard, fruits, seeds and other macro fossils.

Lithology

0–1 cm	recent litter layer.
1–3 cm	older litter layer with some roots of herbaceous plants.
3–10 cm	peat with many herb roots.
10–125 cm	peat; the layer of 37–39 cm is very compact and contains leaves and bark of trees; the 52–54 cm interval is a layer of bark; between 72 and 84 cm: wood (indet.).
125–150 cm	dark, compact wood peat. *Salix* wood identified at 136–138 cm. *Pinus* wood at 145–147 cm.
150–165 cm	multi-layered peat with *Corylus* nuts, *Pinus* wood and -cones.
165–176 cm	transitional layer: peat with wood of *Pinus* and *Betula*, mixed with clay and pebbles.
176 cm	clay and pebbles, not sampled.

The subsamples were numbered as follows: sample 1 was that between 0 and 1 cm depth, sample 2 that between 1 and 2 cm depth, etc.

Radio-carbon dating and the zone boundaries

Six samples were dated at the Centrum voor Isotopen Onderzoek of the Groningen State University (Table 1). In Table 2 the dates for the approximate start of the palynologically defined regional zone boundaries of the Grand-Bongard profile are given next to other dates for S.E. Belgium (Gilot et al., 1969), N.W. Germany (Overbeck 1975) and the Eastern Netherlands (Van Geel 1978, Van Geel et al., 1981).

The present fine-resolution pollen profile of Grand-Bongard and the date of sample 164 show that the sharp rise of *Corylus,* characteristic for the start of the Boreal, has about the same age as the other N.W. European dates given in Table 2.
The rise of *Alnus* (the start of the Atlantic period) was dated c. 7170 BP but this date is certainly too young as a consequence of penetration of *Alnus* roots from the levels where *Alnus* was an in-situ vegetational element (see the chapter on local vegetation, zone III).

The radio-carbon date GrN-14419 was taken at a level (sample 52) where *Ulmus* still shows relatively high percentages. The elm decline (Atlantic/Subboreal transition, sample 48) was dated at c. 5200 BP by interpolation of the uppermost two radiocarbon dates (GrN-14419 and 14420). The date of the rise of *Fagus* at the Subboreal/Subatlantic transition also agrees well with the other N.W. European dates for this phenomenon.

History of the regional forest development

Five zones, showing the main phases in the Holocene forest development, (Preboreal to Subatlantic period) could be distinguished (pollen diagrams, Figs. 2, 3a, 3b).

Preboreal (Zone A; sample 175-157, zone ending at c. 9250 B.P.; the Late-Glacial/Preboreal transition not recorded in the deposit)

The zone starts with maxima of the pollen curves of *Pinus* and *Betula.* A complete dominance of *Betula*

Table 1. ^{14}C-dates of Grand-Bongard

Laboratory No.	Estimated age	Corresponding sample no. (cm)	Helle no.
GrN-14420	2730 ± 45 BP	14	Helle 6
GrN-14419	5500 ± 80 BP	52	Helle 5
GrN-14418	6000 ± 80 BP	85	Helle 4
GrN-14417	7170 ± 70 BP	118	Helle 3
GrN-14416	9230 ± 80 BP	157	Helle 2
GrN-14415	9270 ± 70 BP	164	Helle 1

at the start of the Holocene is not represented in the deposit. In most diagrams showing Late-Glacial/Early Holocene records from the Hautes-Fagnes area there is no notable *Betula* maximum during the Preboreal (Woillard 1975, Geurts 1976). However, several pingo studies (Mullenders & Gullentops 1969) show a dominance of *Betula* during the Preboreal. The presence of pollen of *Sanguisorba officinalis* and *Centaurea cyanus* (cf. Iversen 1947, Schmitz 1957) and the spores of *Selaginella selaginoides* reflects the presence of these taxa as relicts from the preceding Late-Glacial period. The curves of *Artemisia* and tubuliflorous Composites contribute to the idea of a not completely closed forest vegetation. *Salix* and some thermophilous forest elements are also present in zone A: *Corylus* initially present in low frequencies, later followed by *Quercus* and *Ulmus*. Between 164 cm and 157 cm the pollen curve of *Corylus* shows a sharp rise. The pollen of *Viburnum* is of regular occurrence from sample 164 onwards. Both features reflect the transition to zone B (Boreal).

Boreal (Zone B; sample 156-116; c. 9250 B.P. – c. 7900 B.P.)

In the lower part of zone B (156 – 145 cm) *Pinus* shows a decline and *Corylus* and *Quercus* show an increase. *Ulmus* pollen is present in low percentages (2–3%). *Sanguisorba minor* pollen is present in the lower part of the Boreal period only. In the upper part of the zone (144 – 116 cm) *Corylus* shows a maximum of c. 70%. *Hedera* occurs regularly from the 136 cm level onwards. From the 120 cm level onward, *Tilia, Fraxinus* and *Alnus* pollen increase in number. The transition to the next zone (Atlantic period) is based on the sharp increase of the *Alnus* curve at 116 cm.

Atlantic (Zone C; sample 115-48; c. 7900 B.P. – c. 5000 B.P.)

The diagram shows a dominance of *Alnus* pollen and a corresponding decline of non-arboreal pollen types. *Lonicera* pollen is common from sample 107 onward. This points, in combination with abundant wood particles in the macrofossil samples and Type 114 microfossils, to an in situ *Alnus* forest. Pollen of *Hedera* and *Viscum* occur regularly, especially in the lower half of the zone. In the upper 10 cm of the zone the strictly local dominance of *Alnus* comes to an end and the percentages show more regional values from that level onward. The increase in pollen percentages of such trees as *Corylus, Quercus, Tilia* and *Fraxinus* is apparently a consequence of a lower influx of *Alnus* pollen alone.

Subboreal (Zone D; sample 47-15; c. 5000 B.P. – c. 2730 B.P.)

The *Ulmus* decline is the traditional zone-boundary for the Atlantic/Subboreal transition. Generally an acidification of the soils, in combination with human influence, during the later part of the Holocene had effects on the forest composition. *Betula* becomes an important tree: its percentages increase to values between 20 and 50. Pollen of *Fagus*

Table 2. Comparison of dates of zone boundaries (approximate start of zones in conventional radiocarbon dates BP) of Grand-Bongard with dates from other Belgian, German and Dutch sites

	Grand-Bongard	Gilot et al., 1969 S.E. Belgium	Overbeck, 1975 N.W. Germany	Van Geel, 1978, Van Geel et al., 1981 E. Netherlands
Subatlantic	c. 2730	c. 2680	c. 3050	c. 2800
Subboreal	c. 5200	c. 5000	c. 5050	c. 5000
Atlantic	(c. 7170)	c. 7630	c. 7950	c. 7900
Boreal	c. 9250	c. 9050	c. 8950	c. 9150
Preboreal			c. 10250	c. 10150

and *Acer* occur regularly. The accumulation of tree litter on relatively acid soils will have changed the herbaceous vegetation as well. The appearance of pollen of *Anemone spec.* from sample 52 onwards may reflect that *A. nemorosa* became an important element. According to Sydes & Grime (1981), *A. nemorosa* has an effective penetrative structure which is an advantage in a relatively thick litter layer. Pollen of *Plantago lanceolata* and *P. major/media* was first observed in sample 50, but becomes of regular occurrence from sample 33 upwards.

Subatlantic (Zone E; sample 14 – 1 cm; c. 2730 B.P. to the present)

Fagus shows a sharp increase at the start of the Subatlantic period and is followed by *Carpinus*. An increasing impact of man on the landscape is shown by the curves of Cruciferae, tubuliflorous and liguliflorous Compositae, Gramineae, Ranunculaceae, *Plantago lanceolata, P. major/media,* Chenopodiaceae and *Artemisia*. Most of these taxa indicate ruderal vegetation types (Behre 1981). A considerable increase of human influence is shown by the sharp rise of the ericaceous pollen curve from sample 12 onward. The increase in the values of *Carpinus* was probably at c. 2000 BP. The rise of the pollen percentages of Cerealia, in combination with liguliflorous Compositae reflects mediaeval conditions. The planting of *Picea* is reflected in the upper three samples. The low accumulation rate (relatively high pollen concentrations; see Fig. 5) of the Subatlantic deposit renders a more precise dating impossible.

Local vegetation succession

A reconstruction of the local succession of the vegetation is based on the analysis of micro- and macroscopic plant remains and pollen and spores of plants growing strictly in situ. In Table 3 the literature references for the recorded 'Types' mentioned in the present chapter are given.

Five principal zones for the in situ vegetational succession of the Grand-Bongard profile could be distinguished:

Zone I (sample 175-162)
The base of zone I is a transition layer between loamy clay with stones and peat, respectively. Both this transition layer and the peat layer on top of it (up to c. 163 cm) show many wood remains of *Betula pubescens*. Also many wood remains of *Pinus sylvestris,* cones of *Pinus* and some fragments of pine needle epidermis were recorded. Large numbers of *Scirpus sylvaticus* seeds and many sclerotia of *Cenococcum geophilum* (indicating relatively dry environments) suggest the presence of a

Table 3. Relevant selection of microfossil 'Types' recorded in the peat deposit of Grand-Bongard, with literature references

		Van Geel 1978	Van Geel et al. 1981	Van Geel et al. 1983	Bakker & Van Smeerdijk 1982	Kuhry 1985	Van der Wiel 1982	Pals et al. 1980
Type 1	*Gelasinospora* spec., ascospore	×	×			×		
Type 12	Chlamydospore, unknown fungus	×	×		×	×		
Type 13	*Entophlyctis lobata,* sporangium	×	×	×		×		
Type 27	*Tilletia sphagni,* spore	×						
Type 37	*Callidina angusticollis,* lorica	×				×		
Types 55A/B	Sordariaceous ascospores	×	×		×	×	×	
Type 114	Scalariform perforation plate occurring in vessels of *Betula Alnus, Corylus* and *Myrica*						×	×
Type 123	Fungal spore							×
Type 126	*Gaeumannomyces,* hyphopodia			×				×

rather sparse *Pinus-Betula* forest with as the first peat formers at open sites *Scirpus sylvaticus* and some *Carex* species. The occurrence of the fungal spore Type 55A/B and Type 123 is indicative of local mesotrophic conditions. The maximum of *Filipendula* and the frequently encountered pollen of Umbelliferae and Cyperaceae fit in with the ecological conditions of the site during the deposition of zone I.

Zone II (sample 161-122)

The start of zone II represents the phase of accelerated peat growth at the sample site. Many wood remains were recorded in the peat. Seeds of *Potentilla palustris* indicate the presence of the species. Remains of invertebrates are abundant in zone II. The zone can be divided into three subzones:

Zone IIa (sample 161-148). The abundance of seeds of *Potentilla palustris, Carex rostrata,* the *C. paniculata-* type and *Juncus* in combination with the continuous occurrence of moss remains suggest a relatively wet environment. The recorded hazel nuts and *Pinus* remains (wood and needles) indicate nearby stands of *Pinus sylvestris* and *Corylus avellana.* Sphagnum remains (leaves and opercula) are frequently encountered together with *Tilletia sphagni* (Type 27, a parasitic fungus living in spore capsules of *Sphagnum*). *Calliergon stramineum, Polytrichum commune, Carex species* and *Potentilla palustris* also indicate mesotrophic conditions. Most of the apparently locally deposited pollen types are produced by plants characteristic of vegetation types from transitions between wet and drier habitats and from relatively wet grasslands: *Filipendula, Thalictrum, Valeriana, Polygonum bistorta* and *Sparganium.*

Zone IIb (sample 147-135). The macrofossil diagram shows a steep fall of the seed frequencies of *Carex rostrata,* the *C. paniculata*-type, the *Juncus effusus*-type and *Potentilla palustris*. There are only few records of mosses. Remains of *Betula* are common (leaf abcissions) and also epidermis fragments and pollen of *Menyanthes,* remains of *Salix* (wood in samples 138-136) and there is a maximum of sclerotia of the fungus *Cenococcum.*

The changes in the in situ vegetation are interpreted as indications of drier local conditions than prevailed during zone IIa. A *Betula-Salix* brook forest existed with both drier stands (with *Galium*, Campanulaceae, *Cenococcum*) and relatively wet ones (with *Menyanthes*). The fungal remains (Type 55A/B, Type 123 and Type 12) suggest mesotrophic conditions (Van Geel 1978, Pals et al. 1980). Type 12 is also an indicator of relatively dry local conditions and the combination with *Entophlyctis lobata* (Type 13, indicating relatively wet conditions) parallels the above-mentioned, alternatively wet and dry combination of higher plants.

Zone IIc (sample 134-122). A shift to a vegetation type of relatively wet locations is shown in the diagrams. *Betula* macrofossils and *Cenococcum* show a decline and bryophytes and *Potentilla palustris* become abundant again. The fungal spore types in combination with loricae of the Rotatorian *Callidina angusticollis* (Type 37) indicate mesotrophic and wet conditions.

Zone III (sample 121-60)

Apart from highly decomposed wood there are hardly any macrofossils present. Monolete psilate and verrucate fern spores are of regular occurrence, probably indicating the local presence of *Thelypteris* and Polypodiaceae. Pollen of local herbaceous taxa show relatively low percentages, especially from sample 110 upwards.

In view of the very high pollen frequencies of *Alnus,* in combination with the presence of *Lonicera* pollen, wood particles and Type 114 microfossils, alder was a strictly in situ element at the sample site from c. sample 107 to sample 60. A stand of Alnetum at the sample site points to eutrophic conditions. The local stands of *Alnus* (and the calculations of pollen percentages with *Alnus* as an element in the pollen total) results in an underrepresentation of other local and regional taxa. The concentrations of tree pollen are high in the lower 40 cm of zone III (see Fig. 5), which is a characteristic of highly decomposed peat originally formed under relatively dry, eutrophic conditions (low accumulation rate).

Zone IV (sample 59-15)
In most samples of zone IV only few macrofossils were recorded and as a consequence the zonation is mainly based on local pollen and spore types. An increase of various herbaceous pollen types from the start of zone IV onward, is related with the decline of *Alnus* as an in situ element of the stand of vegetation. A maximum of Cyperaceae pollen and the combination with hyphopodia of *Gaeumannomyces* (Type 126) indicates the in situ occurrence of *Carex* species in the lower c. 10 cm of zone IV (cf. Van Geel et al. 1983). Also monolete psilate fern spores show maxima, which indicate a strictly local occurrence. The relatively high values of Dipsacaceae, Caryophyllaceae, *Rumex acetosella,* Gramineae, *Melampyrum* and *Artemisia* (Behre 1981) could be related to human influence in the nearby forest. The maxima of Gramineae, Cyperaceae, *Polygonum bistorta, Valeriana* and Umbelliferae point to an in situ wet grassland. The high *Sphagnum* maxima may be related to transport by water drained from the raised bogs at the Hautes-Fagnes plateau, but, as in the present day situation, *Sphagna* possibly also occurred in the understory of the forest on the slope of the valley.

Zone V (sample 14-1)
The microfossils in the upper 14 cm of the deposit reflect a relatively strong human interaction with the regional vegetation cover, but the in situ stand was left almost undisturbed. Coprophilous fungi (Type 55, Sordariaceae) may indicate that the site was accessible to large herbivores. Due to a better drainage by the approaching rivulet Helle, the conditions of the site were relatively dry. The records of ascospores of the fungus *Gelasinospora* (Type 1) are indicative of relatively dry conditions, and *Juncus effusus* indicates mesotrophic conditions and disturbance. The high *Sphagnum* percentages (up to c. 30%) may indicate run-off from the more elevated forested areas and raised bogs.

Conclusions

The pollen diagram of Grand-Bongard constitutes one of the most detailed records of post-glacial vegetational change in E. Belgium. It shows a complete and almost ideal, classical picture of the N.W. European forest succession, and some details concerning a regional human impact on the vegetation cover during the late Holocene. During most of that period the local vegetation succession of the site was under mesotrophic conditions, but a phase of an Alnetum growing in situ represents eutrophic conditions. There were several changes in the local moisture conditions that could be recorded, but the sample site in the valley of the rivulet Helle was relatively well drained throughout that time-span and extreme changes did not occur.

Acknowledgements

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