The medieval house site Poppendam in the former raised bog area of Waterland

Around 950 AD the great *hausse* of bog reclamations in Holland began. Causes for broad-scale reclamation activities must be sought in a number of factors: a population density increase, a higher level of social organisation, loss of arable land elsewhere due to the formation of Younger Dunes (in coastal area of Holland) and climate change. Medieval settlements in pleistocene sandy areas ended as a consequence of the extension of drift sand areas.

One of the excavated medieval house sites in Waterland is near Poppendam, between the villages Zunderdorp and Ransdorp (Willemsen *et al.*, 1996). It was situated along one of the main drainage rivulets of the raised bog complex. Today the site is part of a moist pasture area used for dairy farming. Pottery and ^{14}C-dating indicate that Poppendam is one of the earliest house sites in Waterland. There were five occupation layers on top of the bog surface, separated from each other by layers of sods of peaty material. Apparently the accumulation layers were gradually sinking down in the bog deposit, and therefore new accumulation material was deposited several times. The site had been in use for about two centuries before it was abandoned (Bos, 1988).

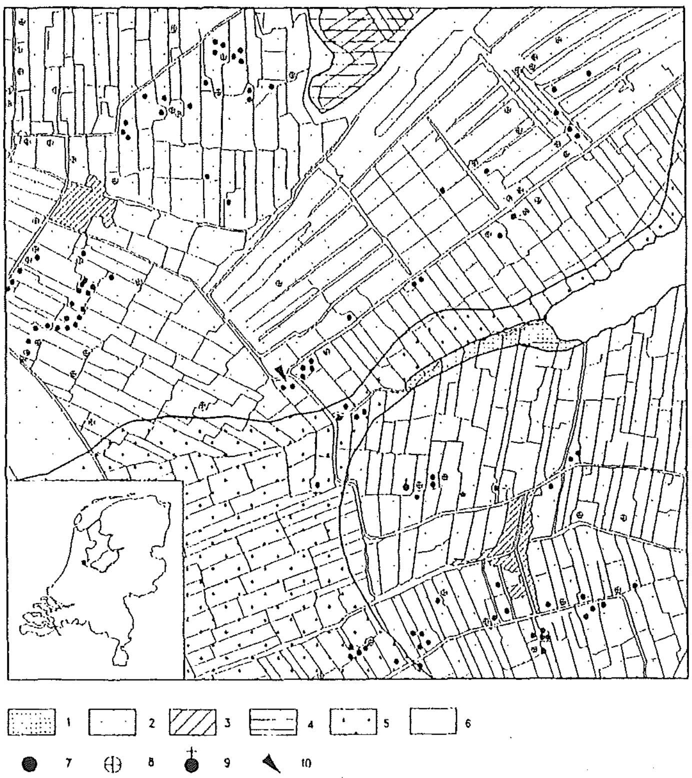
Plant remains from successive accumulation layers and from the peat just under these layers indicate the changing environmental conditions during the earliest settlement phase. The ditches must have caused drying out and oxidation of the bog surface. Oxidation will have resulted in the release of nutrients, so that plants of mesotrophic conditions (like *Gentiana pneumonanthe* and*Molinia caerulea*) got a chance. Other species which were found just under and in the cultural layers also indicate that, as a consequence of the reclamation, the original bog vegetation became disturbed. Various fungal spores indicate the presence of dung (see diagram showing selection of taxa), and thus eutrophication. Evidence for grazing is based on the presence of taxa of the Lolio-Potentillion anserinae.

Dehydration, oxidation and enhanced biological break down of the surface peat made the former raised bog areas vulnerable for storm surges. Early indications for the influence of the sea (temporary inundations) are present: the paleo-record (halophytic plants!) indicates temporary inundations with brackish water. This also explains the need to build houses on artificial mounts.

The study of Poppendam also showed that at this site eutrophication preceded the arrival of the pioneers: ^{14}C-AMS dates of selected seeds of plants of eutrophic conditions were older than the archaeological dates and ^{14}C dates of the pioneer phase (see below).

Radiocarbon dates of seeds of Bidens tripartita, Eleocharis palustris, Polygonum lapathifolium and Polygonum spec. The seeds were selected from the transition between raised bog deposit and earliest accumulation layer of the house site at Poppendam. Dates show that eutrophication took place before reclamation of the area by medieval pioneers in the 10th century AD.

UtC-1223	1250 ± 70 BP	700-750, 760-828 and 832-874 cal AD
UtC-1224	1240 ± 50 BP	718-740 and 768-876 cal AD



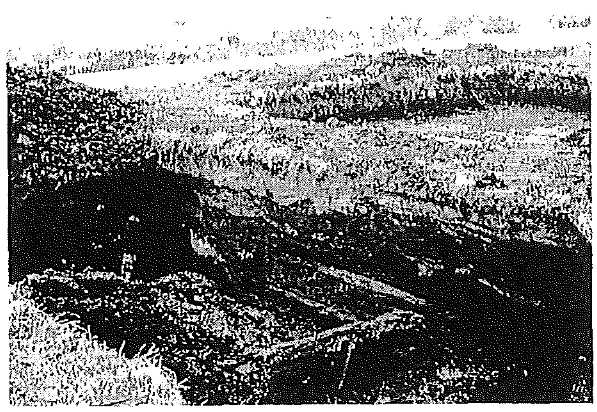
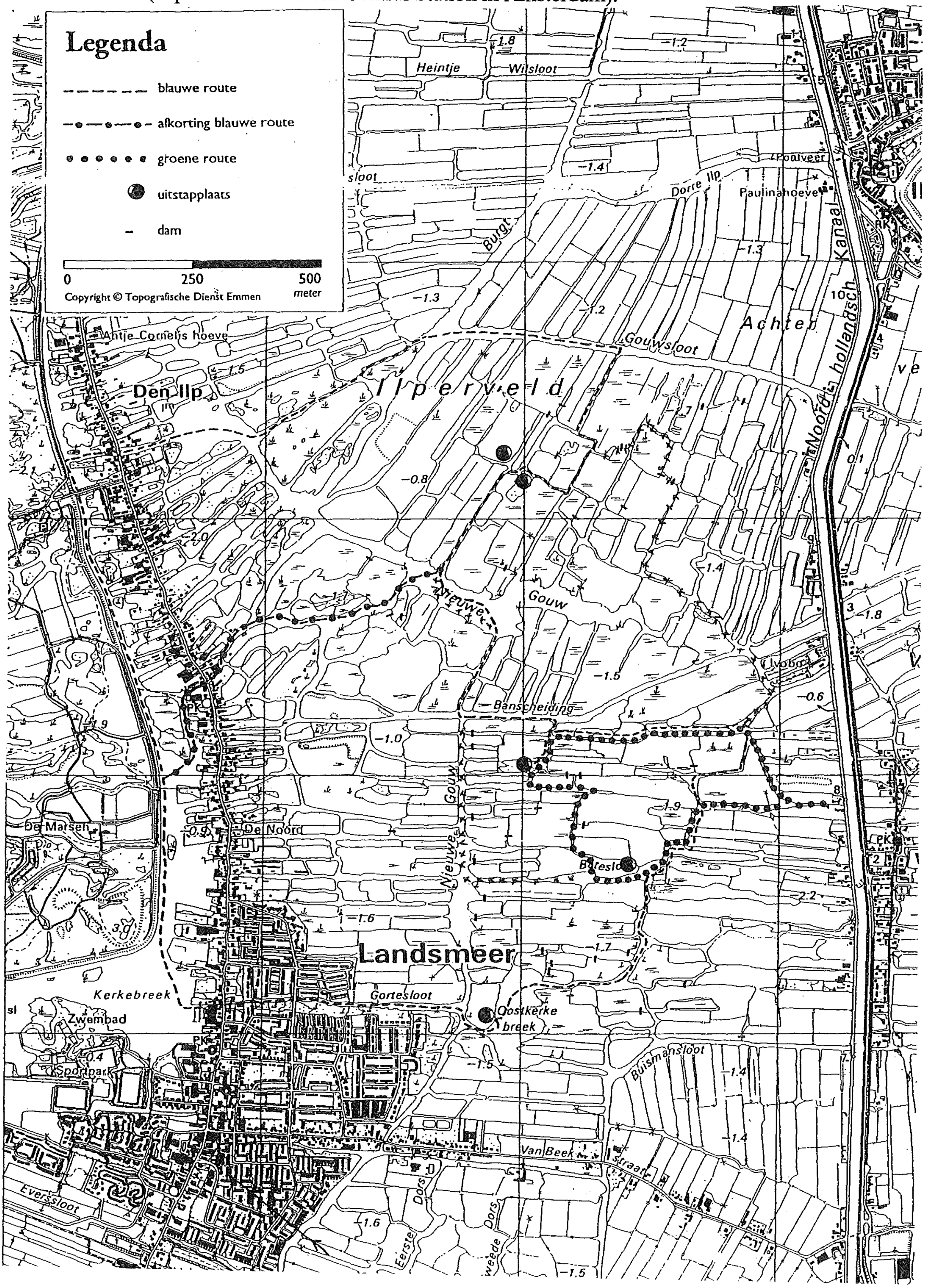


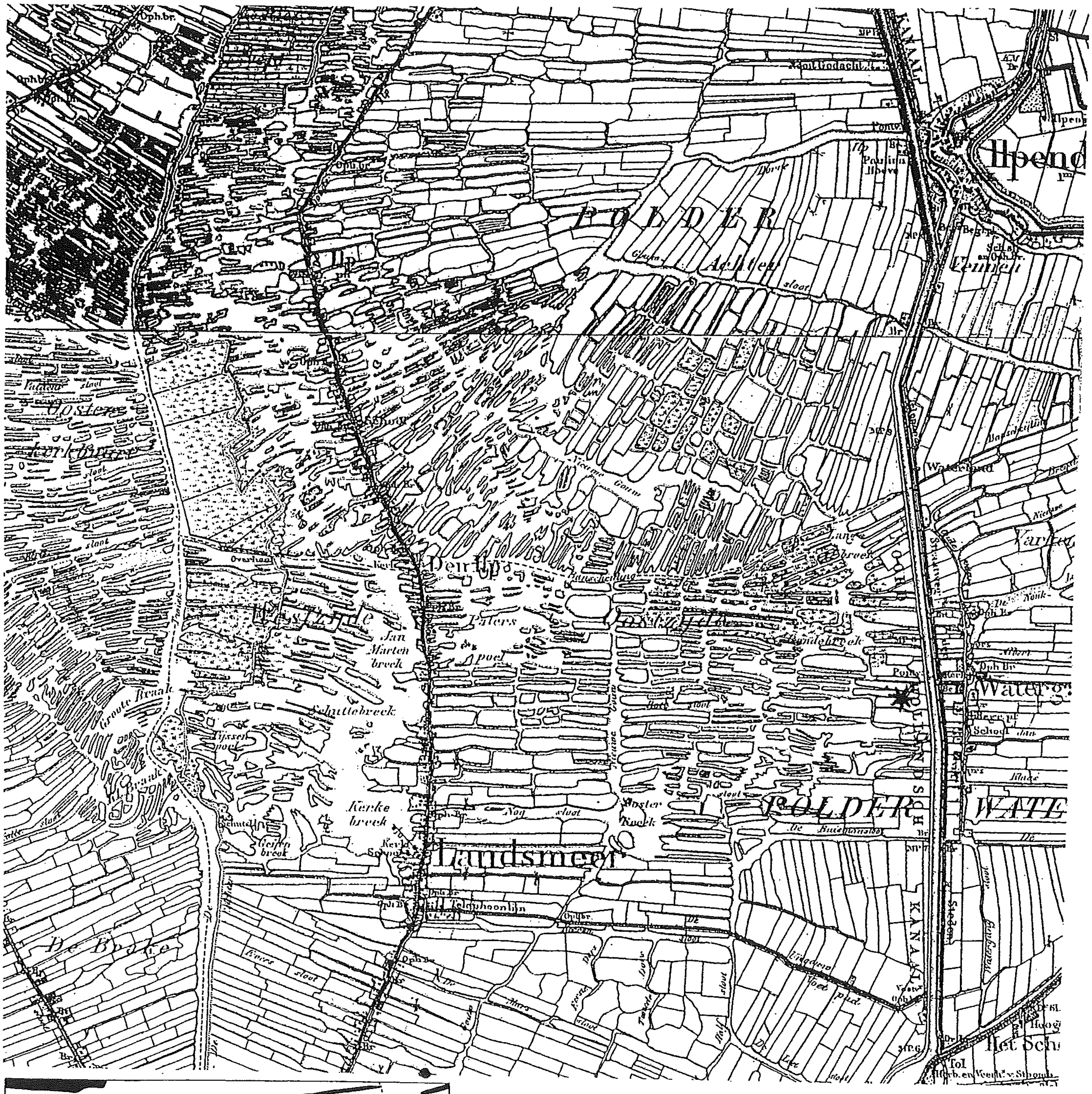
Fig. 2. Poppendam, multiphased house site. The five occupation layers are shown as light bands within the peat. Between these layers anthropogenic accumulation material is deposited shown in black. Each layer probably partly had sunken in the raised-bog deposit before a new layer was added (with kind permission of Dr J.M. Bos).

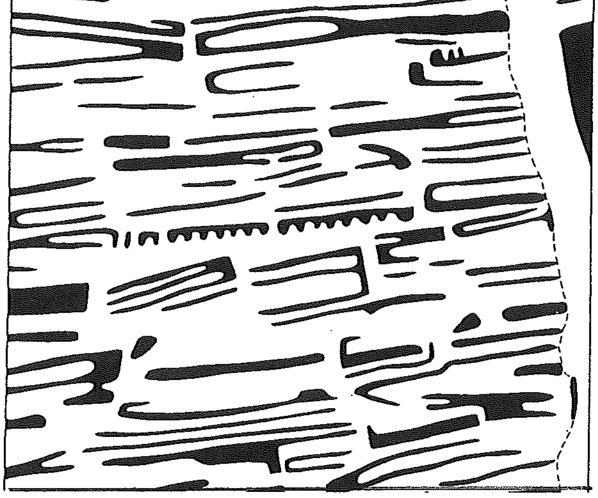
Geomorphological map of the Poppendam area, Waterland. Topographical map 1:25.000, sheet 25E. Coordinates 127.5.08/490.13. Inset map: Location of the Poppendam site, The Netherlands. Legend: 1 = *Carex* peat; 2 = *Sphagnum* peat; 3 = village 4 = reworked subsoil; 5 = *Phragmites* peat; 6 = water; 7 = medieval occupation site; 8 = presumed medieval occupation site; 9 = former church; 10 = Poppendam, house site.

Wednesday 8 September:
We leave the hotel in Spanbroek and we will visit the nature reserve Ilperveld (not far from Amsterdam) by boat. In this area Dirk van Smeerdijk studied the peat deposits which were formed between 4600 and 800 BP, and we will see how fresh oligotrophic peat is still formed, especially after 'Verlandung' in the pits that were made by peat diggers.
We will leave the Ilperveld in the early afternoon. Shopping (food for in the train?) is possible in Landsmeer. We will be in time in Amsterdam for those of you who will take the train to Switzerland (departure 20.05 from Central Station in Amsterdam).



The effect of peat dredging in Twiske and Ilperveld



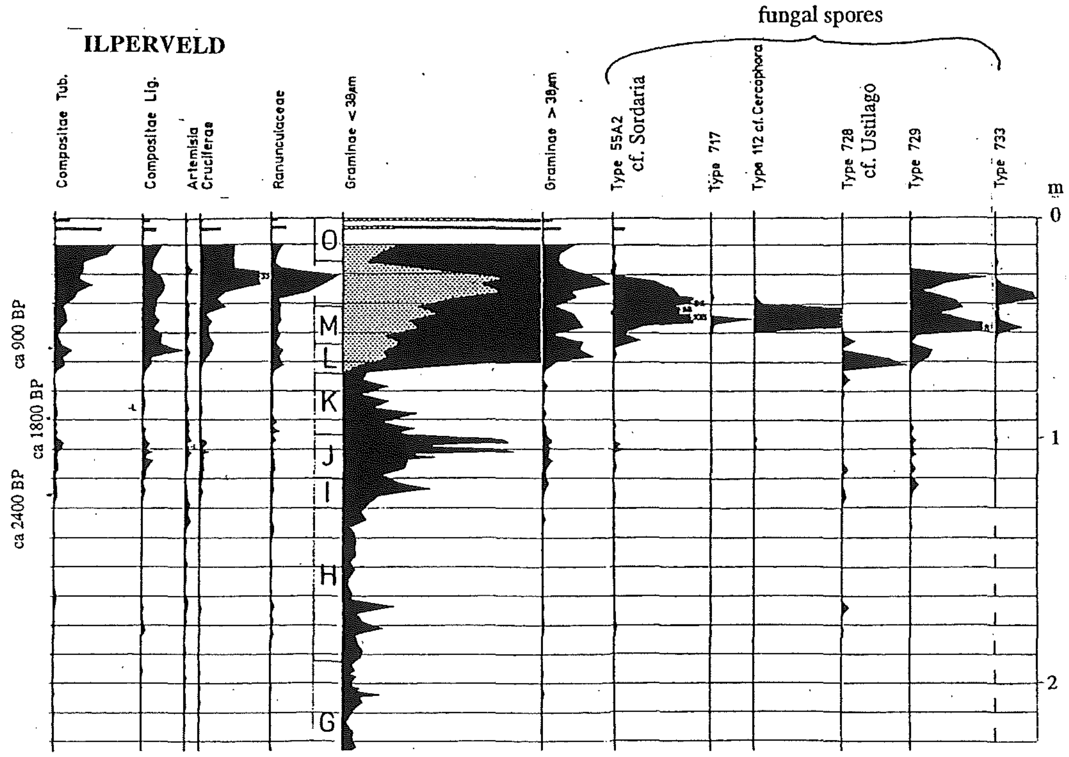


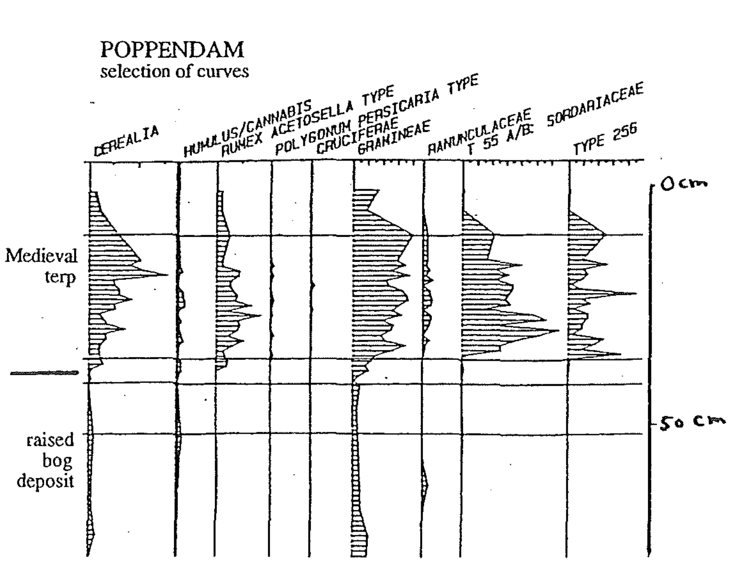
Part of a map in the Oostzaan area, dating 1818 AD, and showing the effects of peat dredging. The remaining land is shown in black. Later the open water was filled in by vegetation (Verlandung). Archaeological data were lost (Bos, 1988)

The vegetation succession in the nature reserve Ilperveld

The peat deposit in the Ilperveld nowadays is still more than 3 m thick. Bakker and van Smeerdijk (1982) published a detailed study (pollen, non-pollen palynomorphs, macrofossils), including the marine deposit under the peat. It contained, among others, seeds and pollen of *Salicornia* spec. and *Armeria maritima*. The spectrum of taxa, in combination with the sandy, clayey sediment indicates the former presence of a salt marsh before peat growth started. After withdrawal of the sea a shallow brackish ---> freshwater area was formed; a reed swamp came into existence with *Calystegia sepium* and *Althaea officinalis*. The diagram shows that after the change from brackish to fresh water conditions, there was the change from eutrophic to mesotrophic to oligotrophic (increasing influence of rainwater). The development of a Birch carr preceded raised bog vegetation with a dominance of *Sphagna*. The upper ca 50 cm of the core represents the period of reclamation, settlements, grazing, related eutrophication. The water in the area became brackish after inundations (storm surges). The study of the medieval 'terp' (artificial mount) of Poppendam showed details about the early human impact phase. The following pages show the Ilperveld pollen record. During the excursion Dirk van Smeerdijk will join us and he will show the other diagrams ('Types' and macrofossils) as well.

The diagram below shows a selection of curves (some human impact indicators) of the upper part of the Ilperveld sequence. Apart from the pollen taxa there are also some types of fungal spores strongly related with human impact: the phase of local domesticated herbivores is characterised by many spores of coprophilous fungi.





The accumulation layers of the Poppendam-'terp' (Willemsen *et al.*, 1996) also contain a mycoflora with human impact indicators (Sordariaceae).

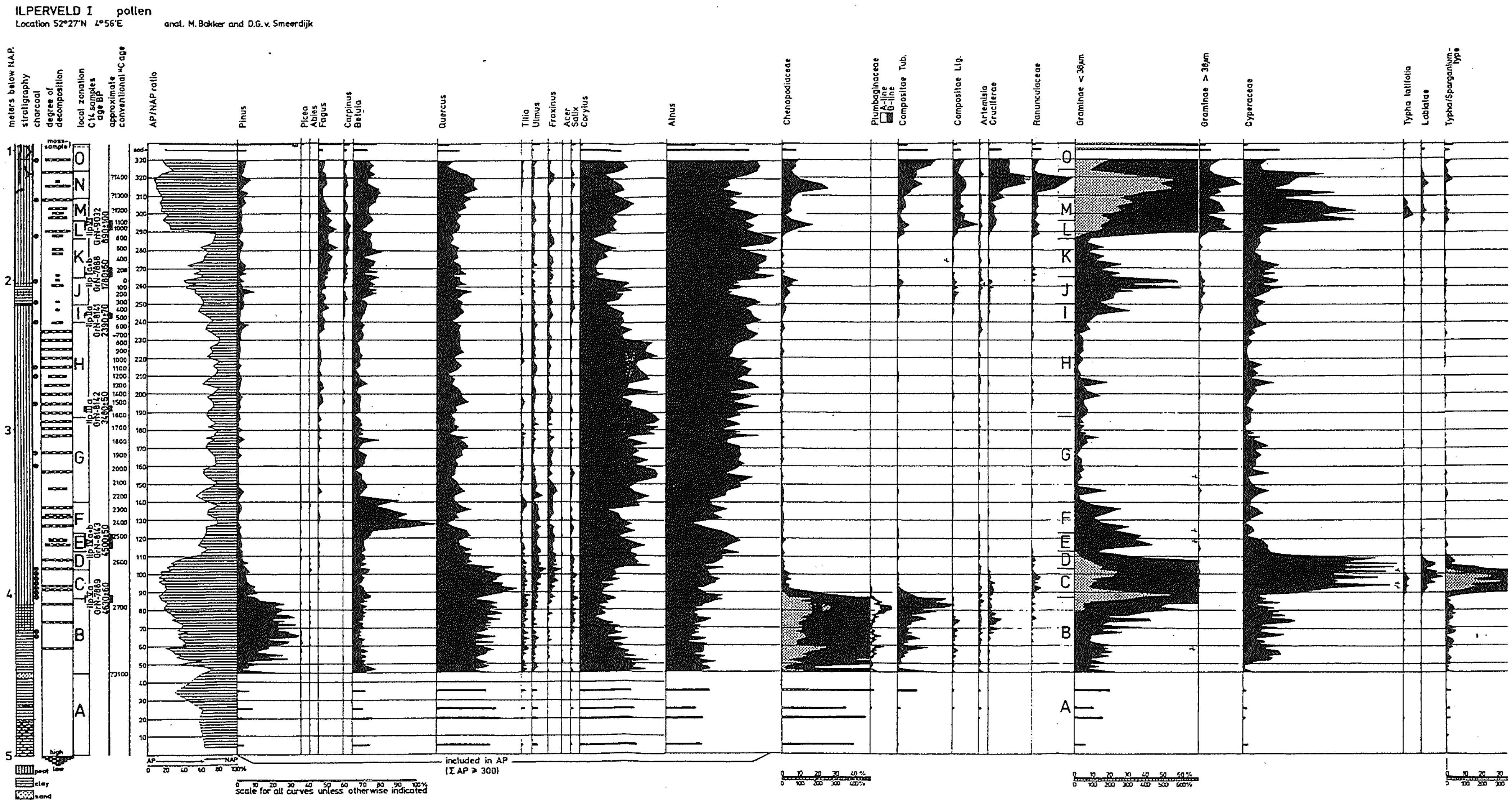
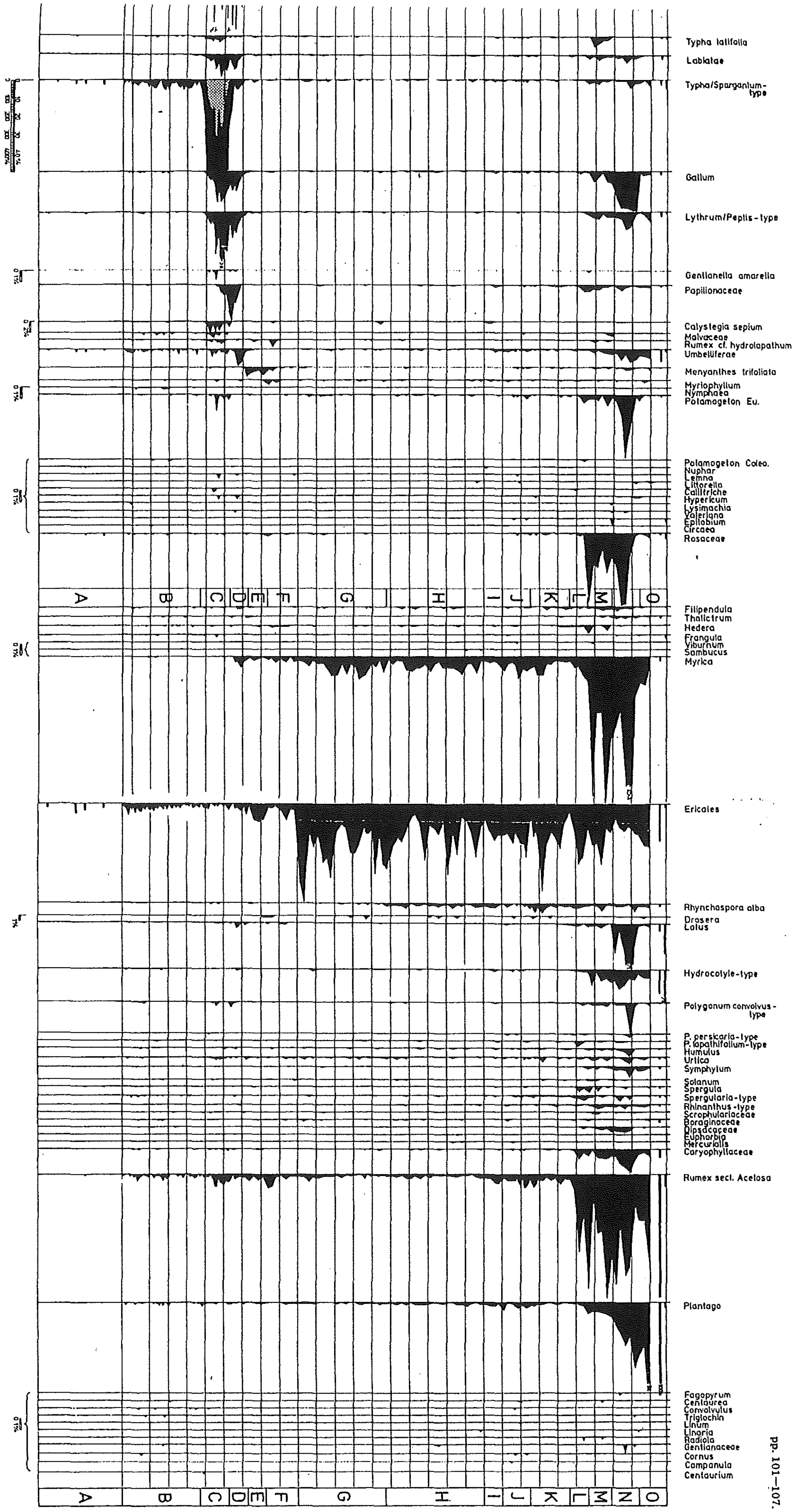


Fig.2. Pollen diagram Ilperveld I.



IJperveld

pp. 101–107.

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relational database, using the European Pollen Database structure (Hoek, 1997b). In Fig. 1, the locations of the pollen diagrams that have been used and are stored in the database are presented in black, while the other locations are presented as open symbols. With this dense pattern of palynological investigated locations a fairly adequate reconstruction of the vegetation patterns in different time windows during the Weichselian Lateglacial and Early Holocene could be made (Hoek 1997b).

For the construction of pollen diagrams a uniform pollen sum was used to calculate percentages, thus providing diagrams that allow for comparison on a similar calculation base. In this pollen sum only Lateglacial tree taxa, shrubs and dry herbs are included, i.e. the group of regional terrestrial taxa according to Janssen (1973). The local pollen taxa, aquatics and riparian herbs including Cyperaceae, as well as spores and thermophilous tree pollen, were excluded from the pollen sum. The countings were saved as TILIA percentage-files, and subsequently uniform pollen diagrams were drawn, using TILIAGRAPH 1.20 (Grimm, 1992).

Chronology

Major shifts in the main pollen taxa, dated by means of radiocarbon in several pollen diagrams distributed over The Netherlands, northern Belgium and western Germany, were used to construct a regional zonation (Table 1). With the help of 239 radiocarbon dates derived from 102 pollen diagrams from The Netherlands, Northern Belgium and Western Germany the regional vegetation development has been attached to the uncalibrated radiocarbon time-scale (Hoek, 1997c). Although uncertainties with the calibration of radiocarbon dates from the Lateglacial period occur, the radiocarbon ages of the zone boundaries have been calibrated to calendar years (cal. years BP) according to Stuiver and Reimer (1993) and Stuiver *et al.* (1998).

LATEGLACIAL VEGETATION DEVELOPMENT

For the comparison of pollen diagrams, biostratigraphy has been the most frequently used method since the introduction of palynology as a tool for vegetation and climate reconstruction. The palynological sub-division of the Weichselian and especially the Weichselian Lateglacial established by Jessen (1935) and Iversen (1942), was introduced for The Netherlands by van der Hammen (1949). In a pollen diagram obtained from a Pleniglacial pingo remnant named Hijkermeer, van der Hammen recognized the interstadial Bølling and Allerød oscillations, separated by Dryas stadials. The interstadial deposits were characterized by a higher content of organics in relation to the stadial deposits. In his dissertation, van der Hammen (1951) was able to prove a similar vegetation development at different locations in The Netherlands based on this sub-division of the Lateglacial. Since then, hundreds of pollen diagrams from Lateglacial and Early Holocene deposits were constructed and sub-divided following this work (see also van Geel *et al.*, 1989; Bohncke, 1993; Hoek 1997c).

With the introduction of the radiocarbon dating method, biostratigraphic correlation became less important and pollen diagrams were considered more frequently in a chronological context. Pollen diagrams without radiocarbon time-control, however, can only be compared to other pollen diagrams on the basis of regional biostratigraphy. A dense pattern of Lateglacial locations investigated by means of palynology has been used to reconstruct vegetation patterns for different time-windows during the Lateglacial (Hoek, 1997b). For the time-correlation of this large number of pollen diagrams used in the palaeogeographical vegetation reconstruction, biostratigraphy has been used. Besides, a regional chronological framework has been constructed with the help of radiocarbon dated pollen diagrams from The Netherlands and surroundings (Hoek, 1997c). According to this chronological study, the regional vegetation development can be considered in a time stratigraphical context and thus correlated with other proxy-records that are dated by means of radiocarbon. Using the INTCAL98 calibration dataset (Stuiver *et al.*, 1998) the radiocarbon dated zone boundaries have been calibrated to cal. years BP. In Fig. 2 a compilation of the pollen diagrams of De Borchert (van Geel *et al.*, 1981) and Usselo (van Geel *et al.*, 1989) is presented against a calibrated time-scale.

For the construction of a regional biostratigraphy, uncertainties in different factors influencing vegetation development should be as small as possible. This means that spatial variations in climate, which are important in vegetation development, but are difficult to measure must be minimized. This can be achieved if a relatively small area with a large density of observations is considered. Within The Netherlands and adjacent areas the climate conditions were quite similar during the Lateglacial.

As sealevel was between 90 and 65 meters below the present date level (Jelgersma, 1979), the coastline was more than 200 kilometers away and any climate gradient induced by the sea is negligible for The Netherlands during the time under investigation. Therefore, it might be expected that in The Netherlands there should be only minor spatial differences in climate during the Weichselian Lateglacial due to the small area and relatively large distance to the former coastline. It is assumed that, regional vegetation development in The Netherlands, as far as it was climatically induced, can be expected to be approximately synchronous, as the maximum distance between data points in the north and south is only 250 kilometers.

It is obvious that single pollen diagrams will represent certain local influences beside the regional climatic signal. Also more local variations in lithology, geomorphology and geo-hydrological conditions have influenced the vegetation development and patterns. In The Netherlands these abiotic environmental conditions have been investigated in various studies and the abiotic landscape that existed during the Lateglacial is therefore well-known (Hoek, 1997b).

Regional biostratigraphical zonation

The lower and upper boundary of the Lateglacial can be defined on palynological grounds. The lower boundary is according to van der Hammen (1951) characterized by the rise in the *Artemisia* curve, being the first clear sign of a climatic amelioration. *Artemisia* was already present during the cold Pleniglacial and the increase in percentage was not a result of immigration of this taxon. On approximately the same grounds, *Betula*, which was present since the early part of the Lateglacial in The Netherlands, was responding to the climatic amelioration at the beginning of the Holocene. Furthermore, a regressive vegetation development caused by a deterioration in climate is considered to be synchronous. For instance, the *Pinus* fall recorded in many pollen diagrams, marking the end of the Allerød in The Netherlands is considered to be a good time marker. Even fluctuations in *Betula* percentage during the Lateglacial in The Netherlands might be synchronous (Hoek 1997a).

Major shifts in the main pollen taxa, radiocarbon dated in several pollen diagrams distributed over The Netherlands, are used to construct a regional zonation. Only those taxa that determine the vegetation aspect and may reflect regional trends are used for biostratigraphical zonation of the diagrams. In the present study, most important in the zonation are the fluctuations in *Betula* and *Pinus* percentages. Shifts in the percentages of Arboreal Pollen (AP), Non Arboreal Pollen (NAP), *Salix*, *Juniperus*, *Populus*, *Artemisia* and *Empetrum* were also used for the zonation. The zonation of the pollen diagrams used in this study sometimes differs from that given by the original authors, who were at that time not able to use many locations for regional comparison and often used different pollen sums or zonation concepts. The biostratigraphical zones are named following Hedberg (1976), therefore adjectives such as Early and Late are used instead of Older and Younger. The use of this terminology, which has been used since van der Hammen (1951) presented his Lateglacial overview of The Netherlands, has the advantage that no confusion with the chronozones presented by Mangerud *et al.* (1974) can be made (see also Walker, 1995).

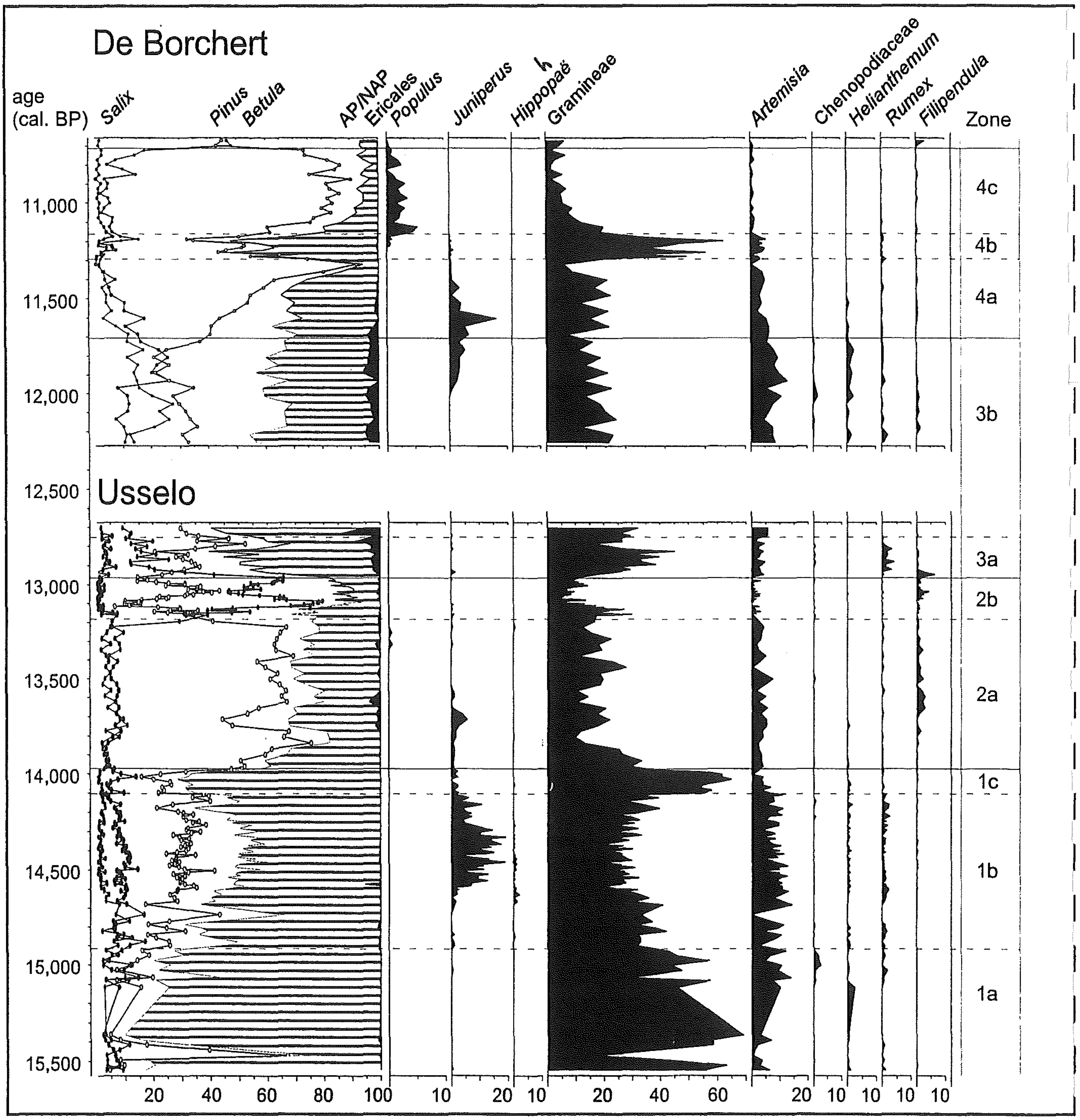

Figure 2 Pollen diagrams De Borchert (van Geel et al., 1981) and Usselo (van Geel et al., 1989) plotted against a calibrated radiocarbon time-scale.

The following Pollen-assemblage zones can be distinguished in The Netherlands for the Lateglacial and Early Holocene. Some of these zones can be divided into sub-zones at different levels of biostratigraphic resolution. A summary of the zonation scheme with zone codes and the main palynological characteristics of zones and sub-zones is given in Table 1. Changes in percentage are presented as arrows, with a relatively big change represented by double arrows.

LP	NAP Pollen-assemblage Zone (Late Pleniglacial)
1	*Betula-Salix* Pollen-assemblage Zone (Early Dryas *s.l.*)
2	*Betula-Pinus* Pollen-assemblage Zone (Allerød)
3	NAP-*Empetrum* Pollen-assemblage Zone (Late Dryas)
4	*Betula* Pollen-assemblage Zone (Early Preboreal)
5	*Pinus* Pollen-assemblage Zone (Late Preboreal)

Table 1 Regional pollen zonation for the Lateglacial in the Netherlands. Zone boundaries according to Hoek (1997a) have been calibrated to calendar years BP (Stuiver *et al.*, 1998).

^{14}C age BP	**cal. years BP**	**Zone**	**pollen percentage characteristics**	**Biozones**
		5		Late Preboreal
9,500	10,710	---------	*Pinus* ↑↑	--------------------
		4c		
9,750	11,175	---------	*Betula* ↑, *Populus* ↑	
		4b		Early Preboreal
9,950	11,300	---------	*Betula* ↓, Gramineae ↑, AP ↓	
		4a		
10,150	11,745	---------	*Betula* ↑↑, *Juniperus* ↑, NAP ↓↓	--------------------
		3b		
10,550	12,750	---------	*Empetrum* ↑	Late Dryas
		3a		
10,950	12,980	---------	*Pinus* ↓, AP ↓, NAP ↑	--------------------
		2b		
11,250	13,165	---------	*Pinus* ↑↑	
		2a2		Allerød
11,500	13,455	---------	*Betula* ↓, *Pinus* ↑, *Juniperus* ↓	
		2a1		
11,900	13,960	---------	*Betula* ↑↑, *Salix* ↓, AP ↑↑, NAP ↓↓	--------------------
		1c		Earlier Dryas
12,100	14,100	---------	*Betula* ↓, *Salix* ↑, *Juniperus* ↑, NAP ↑	--------------------
		1b		Bølling
12,450	14,885	---------	*Betula* ↑, AP ↑	--------------------
		1a		Earliest Dryas
12,900	15,530	---------	*Artemisia* ↑	--------------------
		LP		Late Pleniglacial

Zone LP (older than 15.5 ka cal.BP)

Zone LP (NAP PaZ), represents the end of the Late Pleniglacial, the period preceding the Lateglacial. Only a very few locations contain organic deposits belonging to zone LP. Most samples from this zone are relatively poor in pollen, indicating low pollen production or high sediment accumulation rates. The palynological characteristics of this zone are high percentages of NAP, mainly Gramineae, and very low percentages of *Artemisia*. In some cases relatively high percentages of *Pinus* occur, probably as a result of long distance transport. Reworking from older deposits also causes *Pinus* and thermophilous trees to be found in relatively high values, especially in those frequent cases where the Late Pleniglacial deposits consist mainly of mineroclastic waterlain sediments. Palynological indications for this zone suggest a herbaceous vegetation type consisting mainly of grasses and sedges.

Zone 1 (15.5 – 14.0 ka cal.BP)

Zone 1 (*Betula-Salix* PaZ) is characterized by an increase of *Artemisia* percentages and AP rising towards 50%. High percentage values of other heliophilous herbs as *Helianthemum* and *Plantago* are indicative for this zone. Cyanobacteria of the *Gloeotrichia*-type supposedly played a major role in the fixation of nutrients (van Geel *et al.*, 1989) while algae might have initiated stabilization of the substrate. Pollen of shrubs such as *Hippophaë rhamnoides* and *Juniperus communis* as well as *Betula* and *Salix* trees appears sequentially during this zone. The low AP percentage and abundance of heliophilous herbs during zone 1 indicates an open vegetation type. Zone 1 can be divided into three sub-zones.

The first sub-zone, 1a (15.5 – 14.9 ka cal.BP), is characterized by an increase in the *Artemisia* pollen percentage. Van der Hammen (1951) noted that the beginning of the Lateglacial could be defined palynologically by the rise in the *Artemisia* curve. The percentages of arboreal pollen types are still low with values below 20%. The low arboreal pollen percentages indicate an open landscape with some *Betula nana* shrubs. In plant formational terms this sub-zone reflects a transition from tundra towards shrub-tundra. Sub-zone 1a can be considered equivalent to the Earliest Dryas zone as defined by van Geel *et al.* (1989).

The second sub-zone, 1b (14.9 – 14.1 ka cal.BP), starts with an increase in *Betula* tree pollen. During this zone the percentage of arboreal pollen types rises to values round 50%. The rise in arboreal pollen values is mainly the result of expansion of dwarf birch shrubs (*Betula nana*) and birch trees. This develops towards a vegetation type of small birch copses within a predominantly open landscape. Sub-zone 1b can be considered equivalent to the Bølling zone, Bølling *sensu stricto*, as defined by van Geel *et al.* (1989).

At the start of sub-zone 1c at 14.1 ka cal.BP *Betula* decreases in percentage while NAP values rise. Towards the end of this sub-zone *Salix* percentages rise, in many cases towards values higher than those of *Betula*. The percentages of *Juniperus* also reach a maximum towards the end of this sub-zone. The palynological evidence suggests that the vegetation again became more open. A minerogenic influx in this period supports the palynological indication of a more sparse vegetation in a relatively open landscape. The relative importance of *Salix* (willow) shrubs during the later part of this sub-zone may indicate wetter conditions in the basins towards the start of the next zone. Sub-zone 1c can be considered equivalent to the Earlier Dryas zone as defined by van Geel *et al.* (1989).

Zone 2 (14.0 - 13.0 ka cal.BP)

Zone 2 (*Betula-Pinus* PaZ) is characterized by a strong rise in AP to over 80%, while NAP percentages decreased. Heliophilous herbs became less important. Based on differences in the AP composition zone 2 can be divided into two sub-zones; 2a or *Betula*-phase and 2b or *Pinus*-phase. Zone 2 as a whole can be considered equivalent to the Allerød zone as defined by van Geel *et al.* (1989).

At the beginning of sub-zone 2a (14.0 ka cal.BP) *Juniperus* pollen is relatively important but subsequently *Betula* is the main tree-pollen component with percentages rising to over 60%. In vegetational terms, juniper scrub developed, preceding the for this sub-zone characteristic open birch forest (Bohncke, 1993). In this sub-zone two minor temporary decreases in *Betula* percentage can be recognized, by which the sub-zone is subdivided into 2a1 and 2a2.

From the start of sub-zone 2a2 (13.5 ka cal.BP), at the second and most frequently found decrease in *Betula* percentage, percentages of *Pinus* rise to 15%. Towards the end of sub-zone 2a2 *Pinus* percentages again decrease to low values in favour of *Betula*. The fluctuations in *Betula* percentage are more clearly expressed in diagrams with high amounts of *Betula* pollen than in other diagrams. The decreases in *Betula* tree pollen percentage in favour of NAP at 13.7 and 13.5 ka cal.BP imply that the birch forest opened. *Pinus* pollen occurs with higher percentages in the second opening of the forest caused by long distance transport of pollen from pine trees that had migrated into areas further to the southeast and were already relatively near. In some locations during this phase a sandy influx in the organic deposits is registered, also indicating opening of the vegetation cover.

In sub-zone 2b *Pinus* is relatively important. The rise of *Pinus* percentages to values which are constantly higher than 20% indicates the start of sub-zone 2b; *Pinus* percentage varies between 20-60% over The Netherlands. The start of sub-zone 2b, marked by the arrival of *Pinus sylvestris* which migrated from the south-east into The Netherlands, is set at 13.2 ka cal.BP. *Pinus* pollen percentages exceed the rational limit of 20%, indicating that pine was actually growing locally (Lang, 1994).

Zone 3 (13.0 – 11.7 ka cal.BP)

Zone 3 (NAP-*Empetrum* PaZ) is characterized by a drop in AP percentages and can be divided into two sub-zones; 3a and 3b. Low percentages of thermophilous tree pollen may be present during this zone as a result of reworking from older deposits. Zone 3 as a whole can be considered equivalent to the Late Dryas zone as defined by van Geel *et al.* (1989).

The opening of the forest vegetation at the onset of the Late Dryas stadial is set at 13.0 ka cal.BP; the area of pine reduced at the start of this zone. In the diagrams where *Pinus* percentages are relatively high in the preceding sub-zone 2b, the strong decrease in *Pinus* indicates the start of sub-zone 3a. At locations where pine was a relatively unimportant species, a reduction in birch coverage took place at this time. With this opening of the birch forest, however, the influence of long-distance pollen transport increased. In some cases, therefore, no decrease in *Pinus* percentages and in some occasions even an increase in *Pinus* may be seen. In this situation the start of sub-zone 3a is marked by a decrease in *Betula* (Hoek, 1997b).

The start of sub-zone 3b round 12.7 ka cal.BP is characterized by a rise in *Empetrum*, while AP percentages fluctuate at a low level. *Empetrum nigrum* (crowberry) was an important species in the vegetation, especially in the northern Netherlands during the second phase of the Late Dryas stadial. The expansion of crowberry coincides with the influx of aeolian sandy material recorded in many pollen diagrams, indicating that the vegetation cover became less dense.

Zone 4 (11.7 – 10.7 ka cal.BP)

Zone 4 (*Betula* PaZ) is characterized by an increase in AP percentage, especially *Betula*, to high values. Birch forests became more dense with the start of the Holocene in large areas in NW-Europe (Paus, 1995). This is expressed by high percentages (over 80%) of *Betula* tree pollen in The Netherlands during this period. At some locations the development of juniper scrub occurred preceding the birch forest. Zone 4 can be considered equivalent to the Preboreal zone, as defined by Behre (1966), or the Early Preboreal and first part of the Late Preboreal as defined by van Geel *et al.* (1981). The zone can be divided into three sub-zones; 4a, 4b and 4c.

Sub-zone 4a (11.7 – 11.3 ka cal.BP) starts with a rise in *Betula* percentages towards values of 80%; *Juniperus* percentages are also relatively high during the beginning of this sub-zone. This sub-zone can be considered equivalent to the Friesland oscillation or phase defined by Behre (1966) and van Geel *et al.* (1981), respectively.

Sub-zone 4b (11.3 – 11.2 ka cal.BP) begins with a decrease in arboreal pollen in favour of Gramineae, with Gramineae percentages almost as high as those of *Betula*. The birch forest opened for a short period during this phase. Towards the end of this sub-zone *Populus* percentages increase. Sub-zone 4b can be considered equivalent to the Rammelbeek phase as defined by van Geel *et al.* (1981).

Sub-zone 4c (11.2 – 10.7 ka cal.BP) begins with a prolonged rise in *Betula* percentage towards values as high as 80%. The percentages of *Populus* are the highest during this sub-zone. *Populus tremula* (aspen) may have been an important forest constituent. As *Populus* is not always recognized, especially in older investigations, its absence in the samples cannot always be interpreted as a real absence in the vegetation.

Zone 5 (10.7 – 10.2 ka cal.BP)

Zone 5 (*Pinus* PaZ) is characterized by a rise in *Pinus* percentages to values exceeding 80%. Vegetation development continues after this zone with the appearance of *Corylus* round 10.2 ka cal.BP as the first thermophilous species from the Holocene closed deciduous forest. Although this zone is beyond the scope of the present investigation, it is used here because it is a clear marker in the biostratigraphic record. Zone 5 can be considered equivalent to the latter part of the Late Preboreal zone as defined by van Geel *et al.* (1981).

Teleconnections

Although based on different chronologies, calibrated ^{14}C years and annual layers respectively, the correlation between the regional trends in vegetation development in The Netherlands and the isotope shifts in the GISP2 bidecadal $\delta^{18}O$ curve (Stuiver *et al.*, 1995; Meese *et al.*, 1997) is remarkably high (Fig. 3). For instance, an apparent relation exists between the oxygen-isotope shift at the beginning of GI-1e at 14,670 cal. BP and the start of sub-zone 1b (Bølling) at 14,885 cal. BP, defined by the first rise of *Betula*. This would suggest no time lag between vegetation development and the isotope signal. The position of sub-zone 1c (Earlier Dryas), dated between 14,100 and 13,960 cal. BP coincides with the small $\delta^{18}O$ event round 14,100 cal yrs BP (GI-1d). Remarkably, the more extreme ice-core event GI-1b seems not to be reflected in the vegetation development in The Netherlands, though it is possibly obscured by the relatively high *Pinus* values between 13,165 and 12,980 cal. BP.

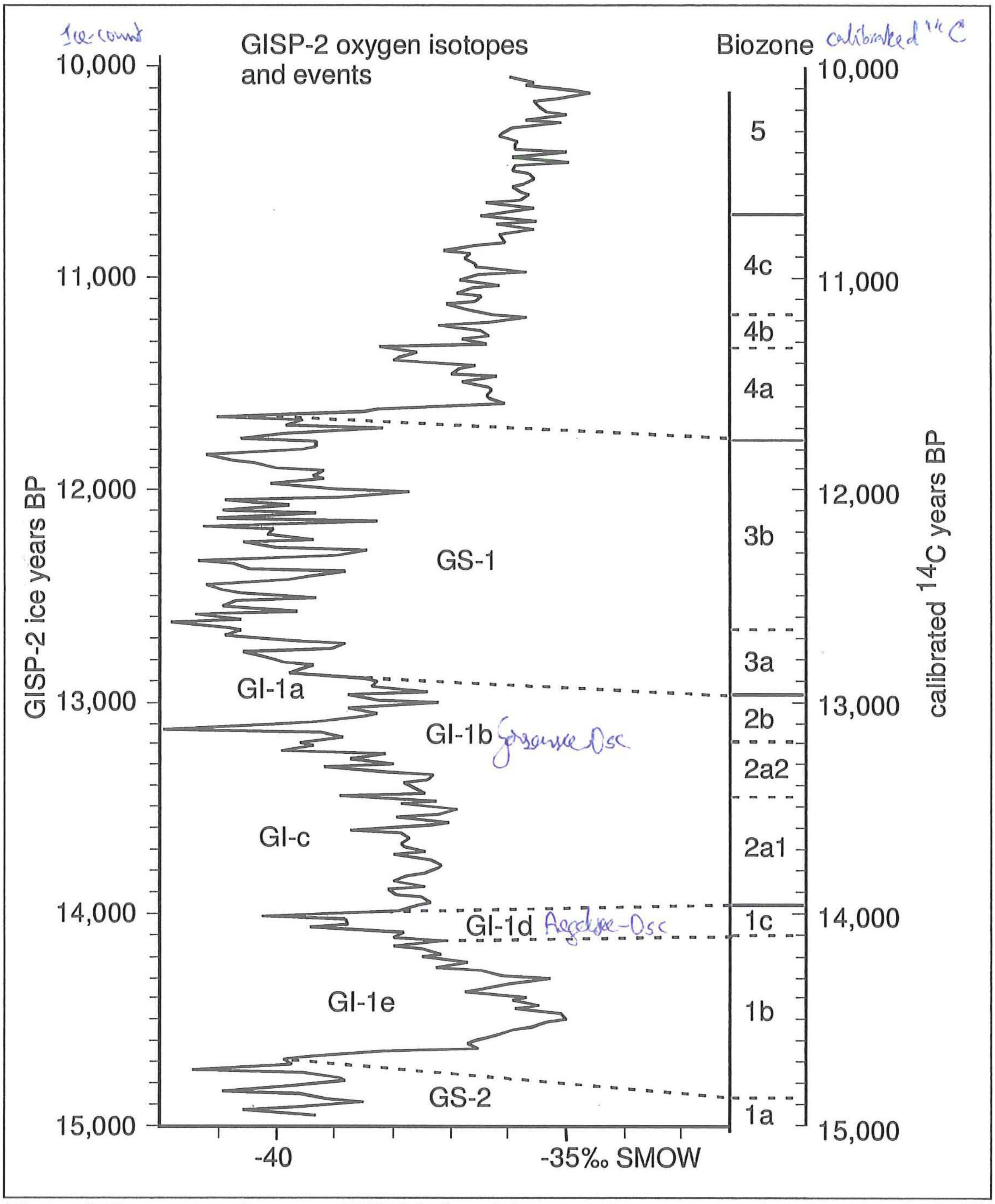

Figure 3 Comparison between GISP2 bidecadal oxygen-isotope record (Stuiver et al., 1995; Meese et al., 1997) and biozones for The Netherlands (Hoek 1997c) on an INTCAL98 calibrated time-scale (Stuiver et al., 1998). The INTIMATE event stratigraphy (Björck et al., 1998) is presented together with the ice-core record.

Ice-core event GS-1, the Younger Dryas cold event, starting at 12,900 BP, is the most pronounced climatic cooling recorded by oxygen-isotopes. The fluctuation reflected in pollen zone 3, starting at 12,980 cal.BP, is likely to be caused by this climatic cooling. The beginning of the Holocene, zone 4 at 11,745 cal. BP almost equals the oxygen-isotope transition round 11,650 ice-years BP in GISP2.

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17 The Regeneration of Fens in Abandoned Peat Pits Below Sea Level in the Netherlands

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SUMMARY

1. Restoration for nature protection involves the application of ecosystems as ecodevices. Similar ecodevices may produce different results as the environment differs. Restoration applies to the ecodevices as well as to the environment. Target states should represent a proactive optimisation of requirements with regional opportunities.
2. Critical switches in the regeneration of fen vegetation in peat pits 70–250 years old, below sea level in the Netherlands are analysed, based on previously published data and on management experience. Many sites today are of great value for nature protection, although no restoration plans have been applied.
3. Due to the depth and the steep sides of the pits, a swamp phase usually results from the formation of a floating raft, rather than from rooted, littoral vegetation.
4. Water table fluctuations relative to the vegetated surface are small in floating rafts. This promotes the development from swamp to fen, and subsequently to scrub and carr. Unless the body of mire water is brackish, open-fen vegetation on the rafts can only be maintained by harvesting.
5. When protected from drought, both harvested and non-harvested vegetation, in time, develop in to some type of poor fen. In particular, the ericaceous phase of harvested fen includes micro-sites resembling ombrogenous bog. A development of mature bog sites might occur within the next century, but there is no clear evidence so far.
6. The occlusion of ditches results in a decreasing supply of base-rich water and a rapid formation of poor fen. In surface-water-fed fens, the ditch water itself supplies bases. In groundwater-fed fens, ditches receive a lateral surface discharge, which is necessary to sustain the flow of base-rich groundwater.
7. With cyclic management regimes, problems of peat and litter disposal should be expected. Such problems can greatly reduce restoration success.
8. A hierarchical planning and realisation of restoration is suggested. The macro-level (landscape or ecological-field level) applies to the required amounts and composition of brackish or base-rich water. Opportunities for the development of various seres of succession can be assessed at this level.
9. The meso-level (ecodevice level) pertains to the gradient of base supply in the main

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part of the root zone. At this level, the surface-water network can be designed so as to control atmotrophiation (ombrotrophication).
10. The micro-level (vegetation, soil and management) concerns the micro-relief and local measures, such as harvesting, scrub removal, sod cutting and pool digging. These factors control vegetation structure, succession rates, micro-site variation, and species composition in more detail. More research is needed in order to quantify the role of management in determining succession rates through the development of root systems and through the accumulation of peat.

INTRODUCTION

The natural development of fen vegetation in abandoned turbaries provides spontaneous examples of wetland 'restoration'. As regards the scope of restoration, a formal approach is followed here.

Restoration for nature protection: what it is about

Restoration defined

The drive for restoration is inspired by public concern about the impoverishment of regional floras and faunas, and by the disappearance of 'wild' landscapes. In this contribution, 'restoration for nature protection' means the re-establishment of the conditions needed to balance extinction rates and evolution, especially of higher organisms, using two main approaches: (1) to create reserves for contemporary organisms, where their populations can survive in wildlife communities, and (2) to adjust environmental conditions so that these populations can extend as far outside the reserves as we allow. Consequently, by the restoration of wetlands is meant the creation of 'functional' wetlands, rather than the restoration of particular former wetlands to some bygone state. The continuation of appropriate management is not restoration. However, some forms of management are powerful tools in the restoration of degraded wetlands.

Restoration concerns functional ecodevices for nature protection

Planning, conservation, and restoration represent deliberate human efforts to 'protect' nature from other, supposedly adverse, human influences. Certain qualities of nature are considered to be in danger through autonomous processes of human society. Nature reserves are considered to be successful when they help to protect these qualities. The reserved areas thus represent applied (sub)ecosystems: ecological devices (*ecodevices*, van Leeuwen, 1982; van Wirdum, 1982, 1986) for nature protection. By contrast with eco*systems*, eco*devices* can fail, since their application requires targets to be set for them. Accordingly, management may be needed to balance a reserve's inputs and outputs where self-regulation falls short.

Most ecodevices provide material resources and profit for human society, as in urban and agricultural land use. Such human ecodevices are distinguished from ecodevices for nature protection by using the terms *natecs* and *humecs* respectively (for definitions, see van Wirdum, 1986).

The location of a *natec* sets limits to the possible exchange of control 'currency', for example, of water, species, tourists, carbohydrates or phosphorus, with the surrounding *ecological field* (Figure 1). Too high or too low a field potential may cause a device malfunction, a defect, or excessive wear. In such situations, the device owner should consider a 'functional' restoration, rather than a 'cosmetic' restoration of insufficiently saved species assemblages. Often, the ecological field also has to be restored or adjusted, thereby minimising the need for active management and facilitating an extension of the beneficial effects over the ecological field, especially its potential flora and fauna. Running ecodevices is not a purpose in itself!

Device design should match expected field characteristics

Natec functionality can be assessed according to rather rough criteria, for example, in terms of sustained biodiversity. In the absence of any human influence the quality of nature results from unmodified ecosystems, or 'raw' *natecs*. Through the ages the most successful types of such *natecs* have varied with geological, geomorphological and human influences. Van Wirdum (1993a) emphasises that the Dutch wetlands have changed from the predominance of large areas of natural mires in prehistoric times, through the harvesting of (semi-)natural ecosystems by man, to intentional land improvement for specific human-determined functions. The dominance of human control in the latter phase has led to a wide range of alarming side-effects. Wetland restoration is one of the efforts intended to increase positive human control.

The first period distinguished in the analysis of the past is the prehistoric one. In the Netherlands the emphasis is on the Holocene, especially the subboreal and subatlantic periods, *i.e.* from about 5000 BP. Most geomorphological forces still operate today, although the hydrological ones in particular have been tamed through social demand (van de Ven, 1993). Early human influences were not too

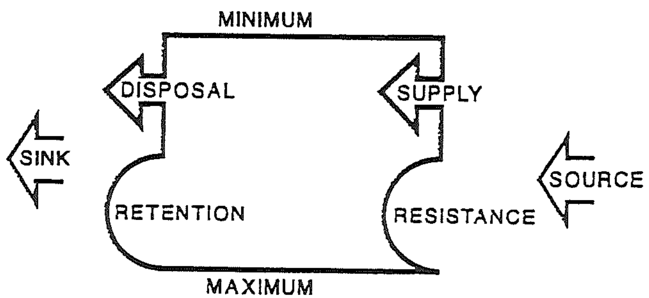

Figure 1. An ecodevice is controlled between minimum (required) and maximum (tolerated) levels by four exchange functions as regards the surrounding ecological field. After van Leeuwen (1982) and van Wirdum (1982).

different from those exerted by other large mammals. Lasting biodiversity at the country scale was controlled by the balance between the large and coherent mass of mire *versus* marine transgressions, river floods, and rising groundwater levels (see Pons, 1992).

The subsequent, historical, period in the Netherlands falls between about 1000 BP and 100–50 BP. The mass and coherence of mires was strongly diminished by flood protection, water management and land use. The human population had grown to the extent that it needed the harvest of the whole country; the landscape developed a pattern typical of human biology (Holling, 1992). However, no less diverse a flora and fauna spontaneously settled in ecosystems characterised by a large-scale and exhaustive harvesting regime.

Especially during the last century, technology enabled humans to 'squeeze' ecosystems even further, to increase their productivity artificially, and turn them into strictly-controlled *humecs* with narrowly-defined functions and with an impoverished fauna and flora. Derelict and exhausted wastelands still serve as a refuge for nature. Under stress through overfed and leaking *humecs*, they have now been 'reclaimed' as nature reserves (Gorter, 1986). Abandoned turbaries are just one example. Human artefacts and regulations overrule biological features in the resulting new landscape, but in this context it may be possible to start a third, modern period. The amount of change seen today should decrease when the planned system of ecodevices for the new period is in operation, and when we successfully control our population numbers. As the potential flora and fauna have been identified as a major concern, some room will be reserved for *natecs*. Hence the quest for restoration, not for the museum, but for the most appropriate nature that fits the future. Since the sequence from the prehistoric to the future template for nature is basically irreversible, restoration should refer to functional values rather than exact states. In national and international planning strategies, the best opportunities are sought for such restoration. A location thus may well end up with some target state which is new to it. Note, however, that there will be nature anyway; 'good' and 'bad' nature are defined only by the chosen goals of nature protection.

What can be learned from the abandoned turbaries?

Although abandoned turbaries cover only a limited range of mire morphology and extent, they do span a relatively wide range of hydrological-field and device-variable values, and of management. We can use the relevant data in assessing opportunities for restoration according to geographic factors, starting conditions and management with formulae of the type

$$\text{Value} = f(\text{ecological field, ecodevice}).$$

The ecological-field function concerns the local values of the driving forces for, *inter alia*, the flows of water and solutes. It includes rainfall and evapotranspiration, and the potential flora and fauna. Hence it is a *positional* function. The device function describes the storage and transformations of 'currency' by which an ecodevice interferes with the driving forces; it is a *conditional* function.

Internal management is thus in the device function, but the social support required is in the ecological field. Value is the *operational* result, weighted by human standards derived from a comparison with fen vegetation in other environments and with palaeoecological records. This approach should result in specific local goals and in the design of optimal *natecs* and management plans to achieve these. The known variety of turbary vegetation permits some estimation of the results that can be achieved over a limited time-span, even in the absence of any purposeful planning, (the abandoned turbaries were never dug with restoration of fen vegetation in mind). The emphasis in the main part of this paper is on the device function. In the final section, attention is given to the various levels, starting with positional variation, that should be addressed in restoration planning.

Background data

Detailed floristic, vegetational and environmental data can be found in the literature cited. Species names follow van der Meijden *et al.* (1983) and Dirkse, van Melick & Touw (1988); phytosociological names follow Westhoff & den Held (1969). The discussion is based on conditions in the Netherlands where there are mild winters (mean January temperature 2°C), cool summers (mean July temperature 16°C), and a precipitation surplus (rainfall and evapotranspiration 765 and 450 mm a^{-1}, respectively, with *c.* 100 mm water deficit during April–July). The Netherlands is a low-lying country on the coast of the North Sea, with strong marine influences, which can also be traced in the water system.

THE EXAMPLE OF TURBARIES

The detailed records of den Held, Schmitz & van Wirdum (1992), and the succession schemes and ecohydrological data of van Wirdum, den Held & Schmitz (1992), together provide an extensive analysis and description of the types of vegetation in terrestrialising turbaries in the lower part of the Netherlands. These turbaries are quite different from the peat pits in bogs in the more elevated parts of the country. In the lowland turbaries, moss peat was dredged from below the regional drainage level. The original bog surface had become almost flooded owing to the post-glacial rise in sea-level and to land use. As a result, the pits filled with relatively calcareous or even brackish water, rather than base-poor bog water. This has produced base-rich, but not necessarily eutrophic, fen environments (van Wirdum, 1993a).

In the summary scheme (Figure 2) the types have been related (i) to marine influences (strong for the bulrush, less for the reed, and virtually absent for the slender-sedge sere); (ii) to mire succession from a lake phase, via swamp (semi-aquatic) and fen (rich-fen or brown-moss phase and poor-fen including sphagnaceous and ericaceous ('fen–bog') phases) to (supposedly) a bog phase; and (iii) to harvesting (scrub and carr *vs.* open vegetation). A variety of species listed in the Dutch *Red Data Books* for vascular plants and bryophytes (Weeda, van der

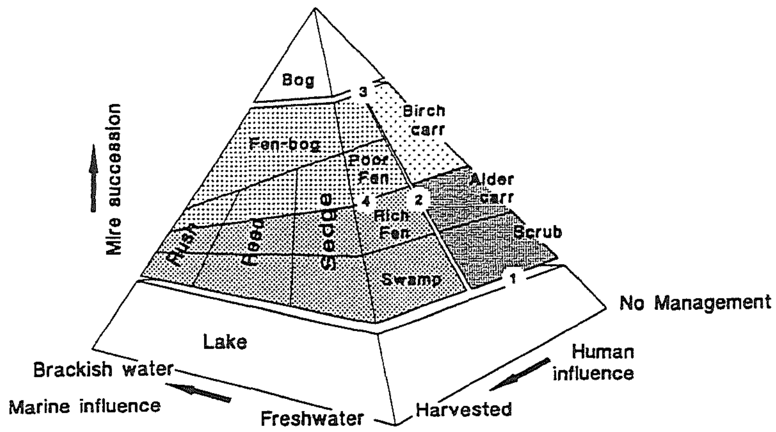

Figure 2. Ecological grouping of fen vegetation in terrestrialising turbaries, as depending on salinity (bulrush (*Scirpus lacustris* spp. *tabernaemontani*), reed (*Phragmites australis*), and slender-sedge (*Carex lasiocarpa*) seres), harvesting (open fen *versus* scrub and carr), and succession (lake, swamp, rich fen, poor fen, fen–bog (= ericaceous phase poor fen), and bog). 1–4: breaks and transitions (lake to swamp, open fen to carr, fen–bog to bog, and rich to poor fen, respectively). After van Wirdum (1993a).

Meijden & Bakker, 1990; Siebel *et al.*, 1992) is present in the terrestrialising vegetation. Many of them (Table 1) must be considered principal rich-fen species in the Netherlands, and most of them also occur in Wheeler's (1988) list of principal rich-fen species for the UK. Although several of these species are almost entirely restricted to the terrestrialising turbaries, they are by no means common in them. The brown-moss phase of the slender-sedge sere, with similarities to CARICION DAVALLIANAE vegetation, and traditionally mown in summer, yields by far the greatest number of sites for *Red Data Book* species, but contributes less than 100 ha of the sum total of *c.* 12,000 ha of terrestrialising turbaries. However, the remaining area is no less vital to the Dutch populations of the majority of commoner principal rich-fen species.

Three main breaks are shown in the scheme (Figure 2): transitions from (1) the lake to the swamp phase; (2) open fen to carr, and (3) fen to bog. The breaks reflect both major ecological switches and gaps in present knowledge. In addition, of particular concern within the open-fen environment is (4) the transition from rich fen to poor fen. These four points are discussed below, particularly based on the experience of managers and researchers (see Smittenberg, 1974; van Wirdum, 1979a). As experience forms the basis of day-to-day management, it is intentionally included in this treatment, with scepticism and warnings where appropriate. More formal scientific documentation is badly needed to help define ecological ground-rules more sharply. A summary such as that produced by George (1992) for the Norfolk Broadland does not exist for the Dutch fens. In this

Table 1. Sample of 'Red Data' concerning fen species in *kragge* vegetation, arranged according to phases and seres of terrestrialisation. *Red Data Book* (RDB) codes (Weeda, van der Meijden & Bakker 1990: Siebel *et al.* 1992): 1, endangered: 2, most vulnerable; 3, vulnerable; 4, rare. Seres (van Wirdum, Den Held & Schmitz 1992): B, bulrush sere; R, reed sere; S, slender-sedge sere (= quagfen sere *sensu stricto*): ( ) weak preference: – no preference. * *Kragge* fens are vital to the survival of these species in the Netherlands.

Species	RDB Code	Preferred sere
Swamp (and early brown-moss) phase:		
Calliergon giganteum	2	S–R
Eleocharis quinqueflora	2	S*
Rhizomnium pseudopunctatum	2	S–R*
Riccardia multifida	2	–
Althaea officinalis	3	R (brackish area)
Cladium mariscus	3	S–R
Cochlearia officinalis	3	R (brackish area)
Fissidens adianthoides	3	S–R
Linum catharticum	3	S–R
Pedicularis palustris	3	S*
Plagiomnium elatum	3	S–R
Sparganium minimum	3	S
Brown-moss phase:		
Bryum neodamense	1	S*
Campylium elodes	1	S*
Drepanocladus lycopodioides	1	S*
Drepanocladus sendtneri	1	S*
Eriophorum gracile	1	S*
Philonotis marchica	1	S*
Scorpidium cossoni	1	S*
Scorpidium scorpioides	1	S*
Utricularia intermedia	1	S*
Campylium stellatum	2	S*
Liparis loeselii	2	S*
Sphagnum contortum	2	S*
Dactylorhiza incarnata	3	S(–B)*
Parnassia palustris	3	S
Sagina nodosa	3	(S)
Calamagrostis stricta	4	S
Sphagnaceous phase:		
Hammarbya paludosa	1	(B–R)*
Sphagnum imbricatum	1	R* (still present?)
Sphagnum subsecundum ssp. *subsecundum*	2	S*
Sphagnum fuscum	4	S–R*
Sphagnum riparium	4	–
Sphagnum russowii	4	–

contd

Table 1. *continued*

Species	RDB Code	Preferred sere
Derived types:		
Carex pulicaris	2	–
Cirsium dissectum	2	–
Carex buxbaumii	4	–

respect a further exploration of palaeoecological and historical data sources, and their placing in an international context, such as given by Tallis (1983), would be most helpful.

(1) The transition from lake to swamp

The swamp and fen phases are not necessarily continuous with the lake phase

In most present turbaries, the open water was created 70–250 years ago. These basins, *petgaten*, have a very particular morphology (*cf.* van Wirdum, 1991, 1993a): rectangular, with steep sides, *c.* 10–50 m wide, 100–1000 m long, and 0.7–4 m deep. *Petgaten* are separated by baulks of standing peat with sandy or clayey top-spit material, 2–10 m wide. On one or more sides of a *petgat*, baulks may be missing or have gaps. In many cases, terrestrialisation only started 30–100 years ago. In one large area, this late start can be attributed to an improved water management, resulting in more stable water levels and favourable conditions for aquatic macrophytes (van Wirdum, 1991). Many accounts (*cf.* Segal, 1966) suggest a vegetation of aquatic macrophytes at the start of a continuous line of terrestrialisation, but more extensive inventories raise doubts about the general applicability of this scheme. In particular, the 'classic' development of floating plants in a dense *Stratiotes* vegetation may represent a phase of desalting coincident with increased application of fertilisers in Dutch fenlands between 1920 and 1960 (van Wirdum, 1979b, 1991). In peat deposits from the far past, a comparable hydroseral development has been found associated with rising water levels in alder carr (Gotjé, 1993). Van Wirdum *et al.* (1992) and van Wirdum (1993a) no longer regard the swamp and fen phases as necessarily continuous with the lake phase.

Raft formation

The swamp phase in the peat pits mostly starts with the formation of a floating raft (*kragge*) by such species as *Typha angustifolia*, *Phragmites australis*, *Scirpus lacustris* ssp. *tabernaemontani*, *Equisetum fluviatile*, *Thelypteris palustris*, *Cicuta virosa*, *Menyanthes trifoliata*, and *Carex* species. The *kragges* in the peat pits are *c.* 30–70 cm thick. Their development may constitute: (1) an overgrowth of the lake starting from its banks (van Donselaar-ten Bokkel Huinink, 1961; van der Toorn, 1972); (2) a settling during extreme droughts (van der Toorn, 1972); or (3) floating bottom peat or old sods returned to the *petgaten* after excavation (*cf.* Rodewald-Rudescu, 1974); or it represents (4) an outgrowth of floating plants, either incidentally arriving from elsewhere or formed in dense vegetation of *Stratiotes aloides* (van Zinderen Bakker, 1942); or (5) a regrowth of remaining, uprooted, or intentionally introduced (Haans & Hamming, 1954) rhizomes. Even when starting from rhizomes at the pit bottom, *Phragmites australis* sometimes forms a floating raft through adventitious roots and rhizomes just below the average water level. *Typha angustifolia* rafts have been reported to rise after an initial growth on the pit bottom (Havinga, 1957; in former river beds: van Donselaar-ten Bokkel Huinink, 1961). Virtually all terrestrialising peat pits thus belong to the floating fens or quagfens, the fen, as opposed to bog, type of quagmire (van Wirdum, 1991). A period of some tens of years may be needed for *kragge* formation in these unfavourably formed basins. Aquatic vegetation in the lake phase may be helpful, but it is not a *conditio sine qua non*.

The occurrence of rafts in natural mires: terrestrialisation in hostile environments

Van Donselaar (1961) and van Donselaar-ten Bokkel Huinink (1961) extensively reported on hydroseral vegetation, partly with floating rafts, in former river beds in the Netherlands. Gotjé (1993) associated prehistoric *Carex–Menyanthes* quagfens in the Noordoostpolder region of the Netherlands with phases of increased sea level rise, at a rate of *c.* 2.5 mm a^{-1}. Other palaeoecological records (*e.g.* Witte & van Geel, 1985) document the formation of a non-floating swamp phase in shallow water, and this seems to have been the most common succession in the past. Rodewald-Rudescu (1974) and Pallis (1916) discuss the formation of rafts of *Phragmites australis* up to 2 m thick, locally called *plaur*, in the Danube delta. Some are considered to be thousands of years old. Their formation is linked with the intricate geomorphology and history of the delta. Base-rich quagfen is generally associated with sheltered basins exceeding 0.5–1 m in depth, or with rapidly rising water tables. Succow & Kopp (1985) and Succow (1988) provide evidence of the association of raft formation in Germany with badly eutrophicated lakes and with acidic pools. The available data thus suggest that raft formation is a property of somewhat hostile environments for aquatic vegetation. The succession in peat pits resembles that in less anthropogenic environments, but it certainly is not representative of the main character of these.

Basin morphology, restoration and cyclic management

An initial basin width of *c.* 30 m seems most suitable for swamp and fen development. Narrower basins will terrestrialise more easily, but edge effects often remain dominant. Larger basins have more difficulty passing through the lake phase due to wave action. Gently sloping or stepped banks will accelerate the swamp start. As will be shown later, deeper basins more easily maintain a water regime favourable to fen and bog vegetation. The trade-off of their slower recolonisation has to be accepted.

Present expertise concerning the restoration of lake and swamp phases is based mainly on the removal of swamp and fen peat from already terrestrialising peat pits, rather than from new pits. Such restoration was designed as part of so-called 'cyclic' management regimes, prescribing a re-digging of peat pits after about one century (Smittenberg, 1974) and was started in the mid 1960s. The aim was to achieve a fresh formation of aquatic and swamp vegetation, hopefully developing into brown-moss-phase quagfen. Until now both the results and their documentation have been poor. While it is true that the area of late stages of succession is ever-increasing over the more transient stages of swamp and fen vegetation, there is still a large resource of lake-phase sites with almost no macrophyte vegetation. Since it is much easier to dig away a raft with open fen vegetation than it is to remove a late carr-stage *kragge* fen, insensitive application of the concept of cyclic management locally has contributed to an even further decrease of species-rich mid-successional vegetation. Moreover, in the Netherlands and some other countries, regressions from the swamp phase back to the lake phase, and a strong decline of aquatic macrophyte vegetation have been observed and attributed to various causes (van Wirdum, 1979b; de Nie, 1987; George, 1992). Problems concerning the disposal of the dredged material (see (4) below) further support the suggestion that the cyclic concept should be rethought in view of its practical applicability, side-effects and aims.

(2) The transition between open fen and carr

Floating open fen today: a (valuable) management artefact?

With the possible exception of brackish fen, fen vegetation in the Netherlands presently only remains herbaceous when regularly harvested. Most available data concerning scrub and carr formation have been summarised by Wiegers (1985, 1992). *Salix cinerea* agg. and *Alnus glutinosa* can invade wetlands even as early as the swamp phase. *Frangula alnus*, *Salix pentandra*, *Myrica gale*, *Populus tremula*, *Betula pubescens* and *Sorbus aucuparia* establish in the brown-moss and sphagnaceous fen phases. Other tree species, including *Quercus robur*, *Fraxinus excelsior* and *Pinus nigra* rarely survive the juvenile stage. The exotic *Aronia* x *prunifolia* is locally a pest, especially in desalting brackish fens in the sphagnaceous phase. Open fen undoubtedly belongs to the most species-rich types of vegetation, and it represents the main foothold for many rich-fen species (Wheeler, 1988; van Wirdum, 1991; Prins, 1993). On the other hand, scrub and carr are very important for many bird species, and mature carr may be considered a more 'balanced' type of ecosystem as regards the presence of various functional groups of organisms.

Natural factors that can keep fen vegetation open

In the past, thick layers of brown-moss-sedge peat and other sorts of herbaceous-fen peat have been formed in the absence of any strong human influences

(Stiboka, 1965). As far as we are aware, this must have been favoured by conditions no longer applicable to the Netherlands, such as (i) marine transgressions and (ii) a rapid post-glacial rise of sea and groundwater levels, not compensated for by water management. Direct climatic effects are thought likely to emphasise these, since tree growth currently occurs in fens in regions with much harsher winters and shorter growth periods (*cf.* Palczynski, 1984; Moen, 1990) than the Netherlands had for most of the postglacial period. Fire was probably an important factor locally in the pre-historical period in Dutch wetlands (Witte & van Geel, 1985). Gotjé (1993) reports extensive ash layers in swamp and fen deposits formed thousands of years ago. Grazing by large wild herbivores will have had local effects, as it has today. However, quagfen *kragges* only become solid enough to support large grazing mammals in the brown-moss phase. Experimental grazing of fjell cattle on derelict fen *kragges* at best slowed down scrub and carr development (Oosterveld, personal communication). Tomaszewska (1988) gives evidence that the same holds true for quite dense populations of elk in the Biebrza valley mires (Poland). However, present-day evidence relates to sites showing a combination of grazing effects and post-management relaxation (see below) rather than to unmanaged sites.

The quagfen water regime does not prevent scrub and carr formation

Gotjé (1993) provides palaeoecological evidence that scrub and carr are formed especially during geogenetic phases of a reduced rise of the groundwater table, coincident with rather large seasonal fluctuations of water level. In more stable conditions during periods with an increased groundwater-level rise, *Carex* peats were formed in his study area. In some instances carr returned to open fen or swamp due to a change in the regional drainage conditions and the question has been raised whether groundwater discharging from underlying aquifers could re-create similar conditions. Even though a strong discharge of groundwater is more common now than it was in the prehistoric period, there are no present instances where such an outflow maintains the open-fen state in peat pits. The quagfens, while floating, provide a very stable water table relative to the peat surface, which prevents the water table from drowning the surface available for tree settlement, especially on tussocks. Hence, a groundwater discharge probably maintains open fen only on solid peat deposits subject to impeded drainage, as was once the case in mires in valleys of the Pleistocene districts in the Netherlands. A higher rainfall, harsher winters, long periods of inundation in spring, and lower solute concentrations may allow for open quagfen vegetation elsewhere (*cf.* Tallis, 1983).

Management regimes and post-management relaxation

The above considerations suggest that, if we want to preserve the open-fen environment in peat pits as a refuge for the appropriate species, we will have to consider active management at selected locations. Mowing and harvesting, either in winter or in summer, or burning will do the job (Smittenberg, 1974). Mowing in

summer is often considered 'best' when considering such criteria as fen-plant species frequencies and species diversity,. In management plans, summer mowing is usually combined with other measures to accommodate birds and insects. The main difference between mowing in summer and mowing in winter is that the latter does not affect below-ground development of such species as *Phragmites australis*. More nutrients remain within the system since they have already been stored in rhizomes and fallen leaves when mowing is started. The root systems of various species of *Carex*, *Salix cinerea* agg., *Salix repens* and *Betula pubescens* apparently do not suffer from mowing in summer. The slender-sedge sere, of mesotrophic conditions, requires a summer mowing regime, *i.e.* a harvest preferably in July, but certainly before mid-September. Upon dereliction, the advanced below-ground development may cause a rapid transition to carr, for which the term *post-management relaxation* is appropriate.

Field experience indicates that post-management relaxation of swamp and early rich fen after *c.* 25 years results in a loss of most characteristic fen species. Until then it is often possible by clearing to restore species-rich open fen within 2–10 years. Of course, scrub and carr both have their own intrinsic value.

(3) The transition from fen to bog

Formation of a 'mature bog', if any, requires some 250 years

With a wetland water regime, carr, scrub and harvested open fen all develop, by natural succession, into some type of poor fen. This is due to the formation of a rainwater lens in the uppermost layers of the peat (*atmotrophiation*, van Wirdum, *et al.*, 1992). In particular, the ericaceous phase of harvested fen in some respects comes close to wet-heath or bog vegetation. Brackish fens are known for the early establishment of such embryonic bog. Even before this phase is reached, *Sphagnum* species characteristic of bogs, such as *S. fuscum*, *S. imbricatum* and, more often, *S. papillosum* and *S. magellanicum*, can establish. A sphagnaceous acrotelm of 15–20 cm is formed by *S. palustre* and *S. recurvum* in 20–40 years (*cf.* van Wirdum, 1993a,b). After this rapid initial growth, peat accumulation slows down owing to slightly drier conditions at the acrotelm surface. The embryonic bog sites mature as the deeper layers of fen peat are sealed down by a sphagnaceous catotelm (*sensu* Ingram, 1983), which forms from acrotelm in about 100 years at a depth of *c.* 25 cm. Mature bog vegetation is characterised by the absence of species requiring mineral nutrients in excess of those provided by precipitation. Some of the more demanding species, helophytes as well as trees, survive in the terrestrialising *petgaten* until the fen peat layers explored by their root systems are buried below *c.* 20 cm of sphagnaceous catotelm. Adding another 100–150 years for this process (*cf.* Malmer & Holm, 1984), a sum total of *c.* 250 years is suggested for maturation of a bog embryo in a brown-moss-phase *kragge* fen (van Wirdum, 1993c). In some sites suggestive of an advanced succession, old moss peat or functionally-equivalent materials may have accelerated the process.

Witte & van Geel (1985) report the transition from CALTHION fen *via* MOLINION fen and 'wet heath' to bog vegetation in a coastal mire in about 300 years. Their detailed palaeoecological analyses suggest very slow growth, which compares well with field impressions from recent ericaceous poor-fen sites where the ericaceous phase is almost stationary! While this may contribute to the sealing properties of the catotelm, it is uncertain to what extent it automatically causes the poorer drainage conditions typical of bogs. Since most ericaceous poor-fen sites are small and freely draining into a well-maintained ditch system, there is some suspicion that bog development is arrested because of inefficient detention of rainwater.

Kragge scrub and carr apparently go through intricate cycles of atmotrophiation, eutrophication and mineralisation, but clear evidence of bog formation is missing (Wiegers, 1992). The relatively few detailed palaeoecological analyses of carr-bog sequences in peat profiles in the Netherlands (*cf.* Gotjé, 1993) are not unequivocal as regards the undisturbed and direct nature of such transitions and their applicability to floating fens. We really do not know to what extent carr is a more or less stable state, or whether it will develop into either bog or woodland.

Management for bog development

Whilst there is no clear evidence of ongoing bog formation at present, monitoring may provide important clues within one century. If the ericaceous and carr phases of poor fen prove to be almost stationary stages, a slightly improved retention of rainwater may stimulate bog growth. The 30 m width of the peat pits may now prove too small for a water regime similar to that of bogs. Where bog is the aim, a removal of baulks may be necessary in this phase.

There is no clear evidence of management facilitating bog maturation. The ericaceous phase of harvested fen is of low productivity. A gradual discontinuation of the harvesting regime, when applied, should be considered. I have seen some examples where roe deer have adequately controlled tree growth for several years in ericaceous poor-fen vegetation. Other fens became overgrown by *Betula pubescens* as a result of post-management relaxation (see above) or, in some cases, as a result of too drastic a removal of remaining trees, thereby providing bare peat spots suitable for their re-establishment.

(4) The transition from rich fen to poor fen

Different rates and causes of acidification

The transition from brown-moss (rich-fen) to sphagnaceous (poor-fen) phases has been discussed elsewhere (van Wirdum, 1991, 1993a,b; van Wirdum *et al.*, 1992; Kooijman, 1993a). Rather than the 'normal' slow atmotrophiation, a rapid transition to poor fen with a strong dominance of *Sphagnum recurvum* and *Polytrichum commune*, associated with a very species-poor vegetation (Figure 3) is often seen. The relevant sphagnaceous phases are quite different from the well-known *Carex lasiocarpa–Sphagnum* quagfen with *Sphagnum subnitens*, *S. teres*, and *S. contortum* (Segal, 1966; Westhoff & den Held, 1969; den Held *et al.*,

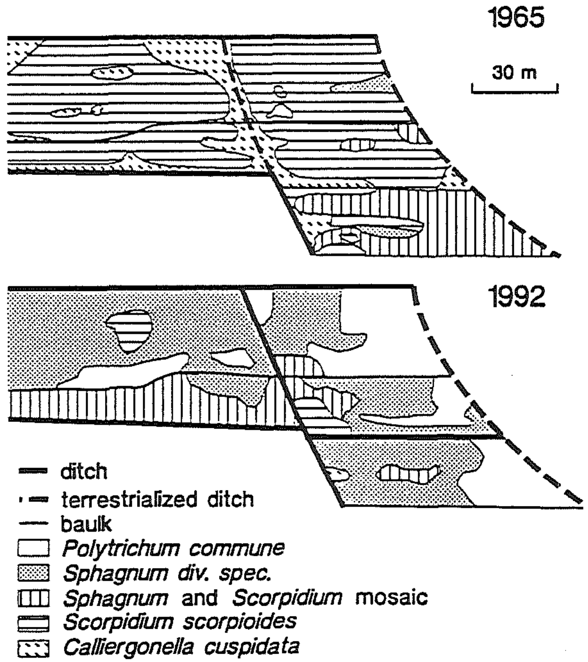

Figure 3. Atmotrophiation (*Sphagnum*, *Polytrichum*) of rich fen (*Scorpidium*, *Calliergonella*) accelerated by the terrestrialisation of ditches in a part of De Weerribben nature reserve. Terrestrialisation of ditches was in an advanced stage already in 1965, but the vegetation lagged behind; in 1992 ditches had been cleaned out and partially dug anew, but this is not yet reflected in the vegetation pattern. After van Zon-van Wagtendonk (1965) and van Wirdum (1993b).

1992), although intermediate types are common. Three causes of this rapid atmotrophiation have been suggested: (1) the exhaustion of bases, due to an increased hydrological isolation of sites, as identified by van Wirdum (1991); (2) an increased supply of nutrients due to enrichment of precipitation and surface water, followed by an expansion of *Sphagnum squarrosum* (Kooijman, 1993a, in press), which then acidifies the site; (3) an increased loss of nutrients and organic acids from plant material decomposing on the peat surface after imperfect harvests. The various causes may be linked with a changing vegetation, as with the increased abundance of *Carex elata* in a harvest-damaged moss layer first suggested by van Zon-van Wagtendonk (1965) and analysed by van Wirdum (1993b). Rather than building typical hummocks, the centrifugal growth of the shoots of *Carex elata* in mown quagfens gives way to slightly raised central pans. Rainwater and humus in the pans encourage an expansion of *Sphagnum* species, especially when coincident with a decreased supply of base-rich surface water.

The ditch system as a key to atmotrophiation control

Although the detail of the transitions discussed above are not known, there is no doubt that the supply of bases by groundwater or surface water is a primary requirement for the prolongation of the rich-fen phase. Base supply by surface water into the mire water beneath *kragges* was studied in detail by van Wirdum (1991). The relevant hydrological model can also be applied to groundwater supply (van Wirdum *et al.*, 1992). In groundwater-fed quagfens, ditches should provide for some surface drainage, so as to sustain an upward flux of base-rich groundwater. For this purpose they should be shallow enough to prevent diverting the main flow of groundwater before it reaches the *kragge*.

Whilst the existing evidence concerns the control of succession rates by ditch management, the model mentioned above and various agrohydrological formulae can also be used to determine an optimal layout of the ditch system in restoration plans. Monitoring of the water composition, for example with sounding rods (van Wirdum, 1991), can provide the information needed to fine-tune the system. Obviously, the beneficial effects of a base supply with surface water must be balanced against possible eutrophication. In the Netherlands today, groundwater is often eutrophicated as well.

Warning against possible side-effects and ineffectiveness of restoration

It is not self-evident that ditching alone is likely to be sufficient to restore strongly-acidified *kragges* back to base-rich fen, as suggested by Beltman & van den Broek (1993). Poor-fen *kragges* have to be removed, at least in part, in order to get full results from a restored ditch system, since brown-moss phase vegetation requires base-rich water.

This type of restoration initiative in existing nature reserves produces much organic material, which is often dumped, either on existing baulks or in carr, leading to potential eutrophication problems through mineralisation, and to a forced transition of fen sites into 'dry' peatland with common types of vegetation and few rich-fen species. Management authorities and dredging companies have only recently made progress towards solutions to these problems (Op't Hof, personal communication) and no records of vegetation response are available as yet. In particular, in a fairly eutrophic environment there is little chance that the early phases of terrestrialisation will really develop the vegetational properties aimed at (van Wirdum, 1983; Kooijman, 1993b). In such cases it may be much more appropriate to stimulate the development of sphagnaceous-phase vegetation to generate ericaceous poor-fen and possibly bog sites. The types of vegetation characteristic of such sites have become very rare in the Netherlands, and it has proved difficult to recreate them on cut-over bog surfaces. In many of these sites the surface peat has changed to the extent that it now provides some of the worst starting points for bog formation. In this respect, sphagnaceous phase vegetation in fens is not a 'plague' to be combated. However, where the present state is fertilised farmland, it makes sense to restore eutrophic swamp.

THE ECOLOGICAL-FIELD, ECODEVICE AND MANAGEMENT LEVELS OF RESTORATION

Three levels of scale are suggested for the planning and realisation of restoration projects. The first level (macro-level, ecological-field or landscape level) determines the properties of the ecological field with which *natecs* have to match. This level is rarely given due attention in restoration plans. Most often information about the past is tacitly considered reliable enough to assess restoration opportunities. An attempt to consider this level based on a hydrological characterisation of the ecological field is given below. The second level (meso-level or ecodevice level) particularly concerns a *natec*'s side of the same match: how much of what 'currency' (see Introduction) is exchanged with the ecological field, and which parts of a *natec* are involved. It is sufficiently illustrated by the ditch-system design mentioned above. In addition to the attention paid to management in preceding sections, the third level (micro-level or vegetation level) calls for a short discussion of micro-site patterns within the vegetation and of management control of succession rates. The higher levels provide boundary conditions for the lower ones, but it should be clear that the lower levels allow additional control over the higher ones (feedback control).

Opportunities at the ecological-field level

II 129

Mire regeneration reflects geomorphology and hydrology

Vegetation records have shown the existence of different successional seres (van Wirdum *et al.*, 1992), the main variance in the Netherlands coinciding with the saltwater–freshwater gradient (Figure 2). If the quite different succession in moorland pools and peat pits in the more elevated parts of the country is added to this, the current distribution pattern of the various seres is not very dissimilar to that of mire types earlier in the post-glacial period (Stiboka, 1965; Pons, 1992; see also van Wirdum, 1993a). This is a robust pattern suggestive of the influence of geomorphology and large-scale hydrology, which determine the water balance and water chemistry for whole mire areas. This macro-scale or landscape level apparently concerns the ecological field of the ecodevices. In spite of the overall robustness of the pattern suggested, the present situation is also strongly influenced by polders and the infiltration of polluted surface water (see also Schot & Molenaar, 1991; van Wirdum, 1980, 1991). This must be considered in the selection of suitable sites for restoration and of the environmental control measures needed. Measures may be needed to ensure the availability of the right amounts of water with appropriate chemical characteristics for the ecodevices to be restored. They include a possible restriction of land use, such as the application of fertilisers, drainage, and groundwater abstraction. The slender-sedge (*Carex lasiocarpa*) sere is particularly demanding as regards water factors.

The water cycle as a basis for planning

The connection of restoration opportunities with regional hydrology has been taken into account in planning in the Netherlands since the late 1970s according to a scheme proposed by van Wirdum (*cf.* 1980, 1991). In the hydrologic cycle, water consecutively passes through the atmosphere, the lithosphere and the ocean. Reference compositions of atmotrophic, lithotrophic and thalassotrophic water have been determined for water changed by residence in the atmosphere, lithosphere and ocean, respectively. Concise archives of water analyses suitable for the estimation of hydrological conditions at the national scale at present exist only for groundwater. Even with this limited material it is possible to determine opportunities for fen restoration according to the following rationale:

(1) In cases of an outflow of groundwater, its composition provides a good estimation of the type of water to be expected in existing or future wetlands;

(2) In cases of a substantial infiltration of water from wetlands towards the underlying body of groundwater, the latter will reflect the type of water apparently supplied from the surface-water system;

(3) When the groundwater is of the rainwater type, this is probably caused by a substantial infiltration of water in the absence of additional water sources. In the Dutch climate this indicates well-draining sites, where it will be difficult to maintain groundwater levels high enough to restore wetland conditions. However, there may still be regions with a potential for bog development (see 4);

(4) Atmotrophic water is available everywhere; where drainage is poor, measures can contribute to increase the local storage and accumulation of rainwater.

Prins (1993) compared a map of groundwater composition (Figure 4) with the present occurrence of seven main groups of fen vegetation. She found similar relations as had been found previously within individual fen sites (van Wirdum *et al.*, 1992). This means that the terrestrialising peat pits foreshadow the regional perspectives for restoration of the relevant types. A full application requires additional ecological understanding of the slender-sedge (*Carex lasiocarpa*) sere. This sere presently is almost confined to base-rich freshwater (lithotrophic situations), but van Wirdum (1991) provides evidence that it may also develop in desalting mires in the peri-marine area of the Netherlands. Other, more casual, data in support of this relation have since become available.

In the recent Nature Policy Plan for the Netherlands (Ministerie van Landbouw Natuurbeheer en Visserij, 1990) the network of existing nature reserves and projected nature reserves (derived by restoration) is based upon this scale level. This has shown a need for reliable methods to predict the likely response of plant species to restoration measures. Among the methods developed for this, the ICHORS model (Barendregt *et al.*, 1986; see also van Wirdum, 1986) should be mentioned particularly. Based on statistical relations between present species occurrences in the same region and measured water-related site factors, ICHORS estimates the probability of occurrence of species for any given set of site data supposed to apply after restoration.

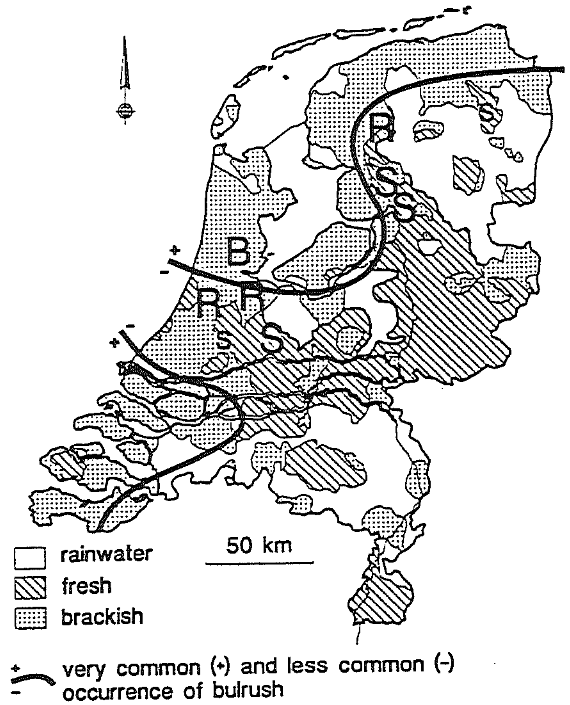

Figure 4. Dominant types of groundwater in the Netherlands, in relation to main sites of terrestrialisation (B bulrush sere, R reed sere, S slender-sedge sere). Groundwater map compiled by ir. H. Houweling (IBN, see Prins 1993), simplified. Commonness of bulrush (*Scirpus lacustris* ssp. *tabernaemontani*) roughly according to van der Meijden, Plate & Weeda (1989).

Management control of succession rates

Kragge *accrual and site heterogeneity respond to management*

On other occasions (see van Wirdum, 1991) I have drawn attention to the micro-relief in quagfen sites and its influence on ecological site heterogeneity. In particular, hummock–hollow patterns locally determine the existence of atmotrophic–lithotrophic and atmotrophic–thalassotrophic gradients expressed in the distribution of plant species. Vegetation on floating rafts is strongly influenced by the physical properties of the rafts, such as their thickness and their buoyancy. When the rafts become thicker a gradient develops between the hummocks and the hollows. Such stages are usually very rich in species of vascular plants, bryophytes and desmids due to the controlled presence of microsites with an intermediate base status. As the thickness of *kragges* increases further, they ultimately loose their capacity to follow water-level fluctuations immediately, since they are anchored to the baulks of the *petgaten*. Mineralisation then becomes more important, and a tall-herb vegetation often replaces the peat-forming mire vegetation. Alternatively, mire succession proceeds to poor-fen and embryonic bog stages as discussed previously. In both cases, site heterogeneity decreases due to the decreased presence of oligo-mesotrophic base-rich microsites (van Wirdum *et al.*, 1992; van Wirdum, 1991, 1993).

The rôle of vegetation management in the local control of raft development is very important to restoration initiatives, since the mowing of the vegetation has an obvious (but hardly studied) influence upon the thickness and buoyancy of *kragges*. When mown in winter, many helophyte species, such as *Phragmites australis*, have re-allocated above-ground nutrients to their root systems. This contributes to the accrual of below-ground biomass and peat. The relevant *kragges* usually develop faster towards the poor-fen and ericaceous phase than do summer-mown *kragges*. They also seem to suffer more from summer droughts and surface mineralisation, as mentioned above.

Experimental approach required

In the Netherlands, managers of nature reserves have a fairly good appreciation of the impact of harvesting on the succession of the vegetation (Smittenberg, 1974). However, there is a lack of understanding of the below-ground development of root systems and of peat-accumulation rates. Such understanding is of vital importance for restoration planning and to management of wetlands for long-term success. We should be aware that the expertise currently available is based on a limited set of alternatives fortuitously supplied through traditional land-use, especially peat winning and vegetation harvest. Experimental management switches and dereliction have presented puzzling examples of post-management relaxation. The accrual of *kragge* peat has been shown to interfere with the supply of water and bases at the ecodevice level, but until now no better solution has been invented than a cyclic application of old land-use methods. Rather than advertising a wide application of this unverified solution, I suggest that researchers, planners and managers should invest in the documentation of existing and new experiments and historical cases, and in the planning of new ones.

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131

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H 132

G. van Wirdum 1994

The Atmotrophiation of Floating Rich-Fens

in: Institute for Land Reclamation and Grassland Farming,
Conservation and Management of Fens.

Institute for Land Reclamation and Grassland Farming, Falenty, 457-466

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Abstract: In The Netherlands open rich-fen succeeds into wooded poor-fen when not harvested. Due to human control hydrological factors capable of maintaining and regenerating fen conditions in the far past no longer apply. Even if restoration works for fens, slowing down the natural succession into poor fen requires management. During succession the supply of bases with groundwater and surface water to fen sites decreases, and this furthers succession (atmotrophiation). Related water and soil factors are given for a study site in terrestrializing turbaries. The gradient between rich-fen and poor-fen in the study site relates to the distance of the fen from a ditch supplying base-rich water. When the bodies of surface water are allowed to terrestrialize in such floating fen mires, atmotrophiation eventually takes hold of the whole area, as demonstrated with monitoring results.

Keywords: floating fen, succession, base state, water flow

INTRODUCTION

Open fen: a natural loser in The Netherlands today

Mire succession in The Netherlands leads to raised bog, but marine and fluvial influences held a substantial area of mire in the fen stage during most of the Holocene. Early land use along with an increased liability to flooding and erosion reduced the bogs' area in favour of marshes and fens from 2000 years ago onwards. Scrub and carr became common features of the mire landscape. During the last thousand years humans harvested large areas of fen, and thus enlarged the area of open fen relative to scrub and carr.

Presently, 96% of the land surface is intensively cultivated. A natural development of fen mire is restricted to the rather artificial landscape of abandoned turbaries below sea level, with a relatively large area of floating fens, and to a narrow belt of solid fen peat along some small rivers. Due to the controlled regional hydrology, and to a cessation of harvesting, both types are subject to a natural succession from open rich-fen to wooded poor-fen.

III 134

The conservation problem: balancing restoration and management

From the point of view of nature protection, the formation of poor-fen and of scrub and carr leads to a convergence of mire vegetation and, hence, to a loss of specific natural values. Poor-fen and scrub in themselves represent valuable types of nature, but their area has increased to such an extent that other valuable types, such as *Caricion davallianae* open rich-fen, have become very rare and threatened. Conservation authorities seek methods of hydrological restoration to save the relevant types of fen with a minimal demand for vegetation management. In case such management is considered necessary, they want to be sure the water regime is suitable for the relevant types.

In this contribution attention is paid to the succession from floating rich-fen to poor-fen in abandoned turbaries, and to factors that can retard such succession.

THE GRADIENT IN DE STOBBENRIBBEN

Leaking turbaries with surface-water supply (Fig.1)

De Stobbenribben is an example of abandoned turbaries now terrestrializing. Because of their almost ideal lay-out for research they have been subjected to detailed hydrological and ecological investigations (Van Wirdum 1991). The particular turbaries described now are some 200 m long, 30 m wide, and 2 m deep. A c. 0.7 m thick floating raft supporting fen vegetation covers the surface of the turbaries. The peat "soup" underneath the raft constitutes a flow channel. It is connected to a ditch at one narrow end of the turbaries. The ditch is part of a large body of surface water with an artificially stabilized water level. The aquifer in the underlying sand bottom discharges in polders whose phreatic levels are kept at c. 2 m below the surface water level in the turbaries' area. This hydrostatic system maintains an average leakage from the body of mire water down into the aquifer at a rate of 2 m a^{-1}. The precipitation surplus is 0.25-0.5 m a^{-1}. The surplus water seeps through the floating raft into the flow channel. An additional influx of surface water from the ditch into the flow channel underneath the raft compensates for the remaining water deficit of 1.5 m a^{-1}. Due to the hydraulic resistance in the turbaries the water level slopes down from ditch level to c. 15 cm lower at a distance of 160-200 m from the ditch in dry periods. The raft follows the water level fluctuations with a slight delay and with a slightly reduced amplitude, since the rhizomes are anchored in solid peat baulks at

III 135

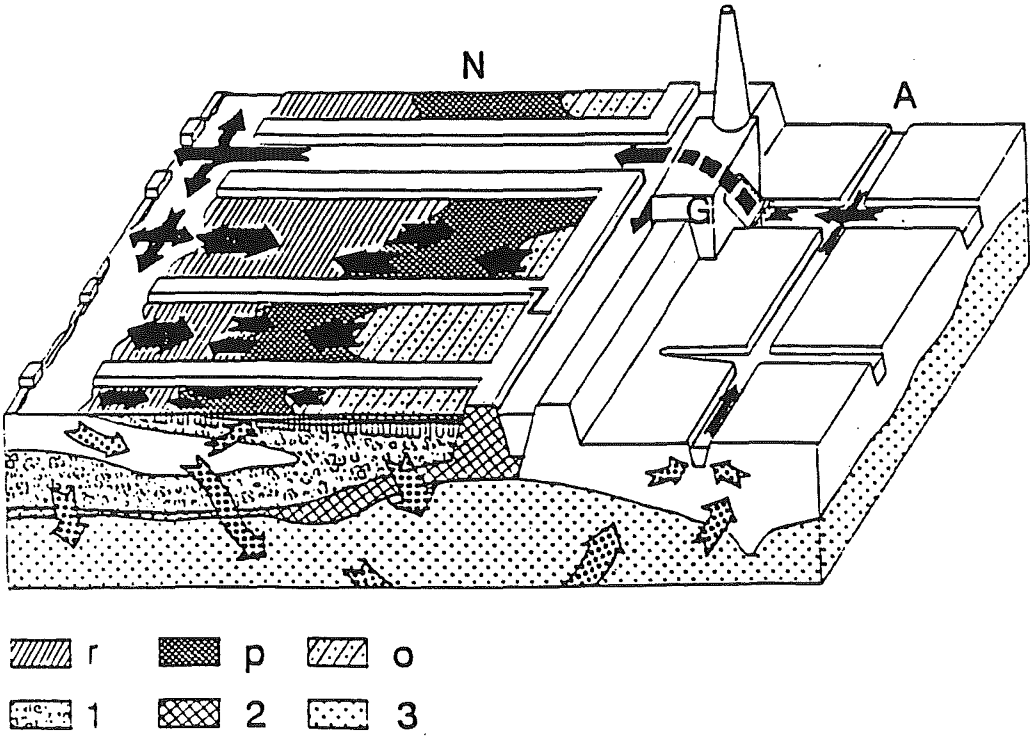

Figure 1. Schematic view of water flow (arrows) and vegetation pattern (r, p, o) in De Stobbenribben. Three vegetational zones have been indicated: brownmoss phase reed-sere(r) and slender-sedge sere fen (p), and spahgnaceous phase fen (o). Mud, remaining peat and the sand bottom are shown with the patterns 1, 2 and 3, respectively. The nature reserve (N) consists of abandoned turbaries separated by peat baulks (Z). To the right is a polder area (A) with a discharge pumping station (G). From Van Wirdum 1979

three sides. Drought causes the raft to fill with "groundwater" from the flow channel; substantial rain fall lifts the raft out of the body of groundwater.

The mixing gradient (Fig.2)

The surface-water demand of the whole length of each turbary, 300 m^3 m^{-1} a^{-1}, passes into the flow channel from the ditch end. The flow rate decreases towards the other end. In the flow channel, the ditch water mixes with the rain water seeping through the floating raft. In weak spots, there is almost now stratification of rain water above ditch water. Where the

III 136

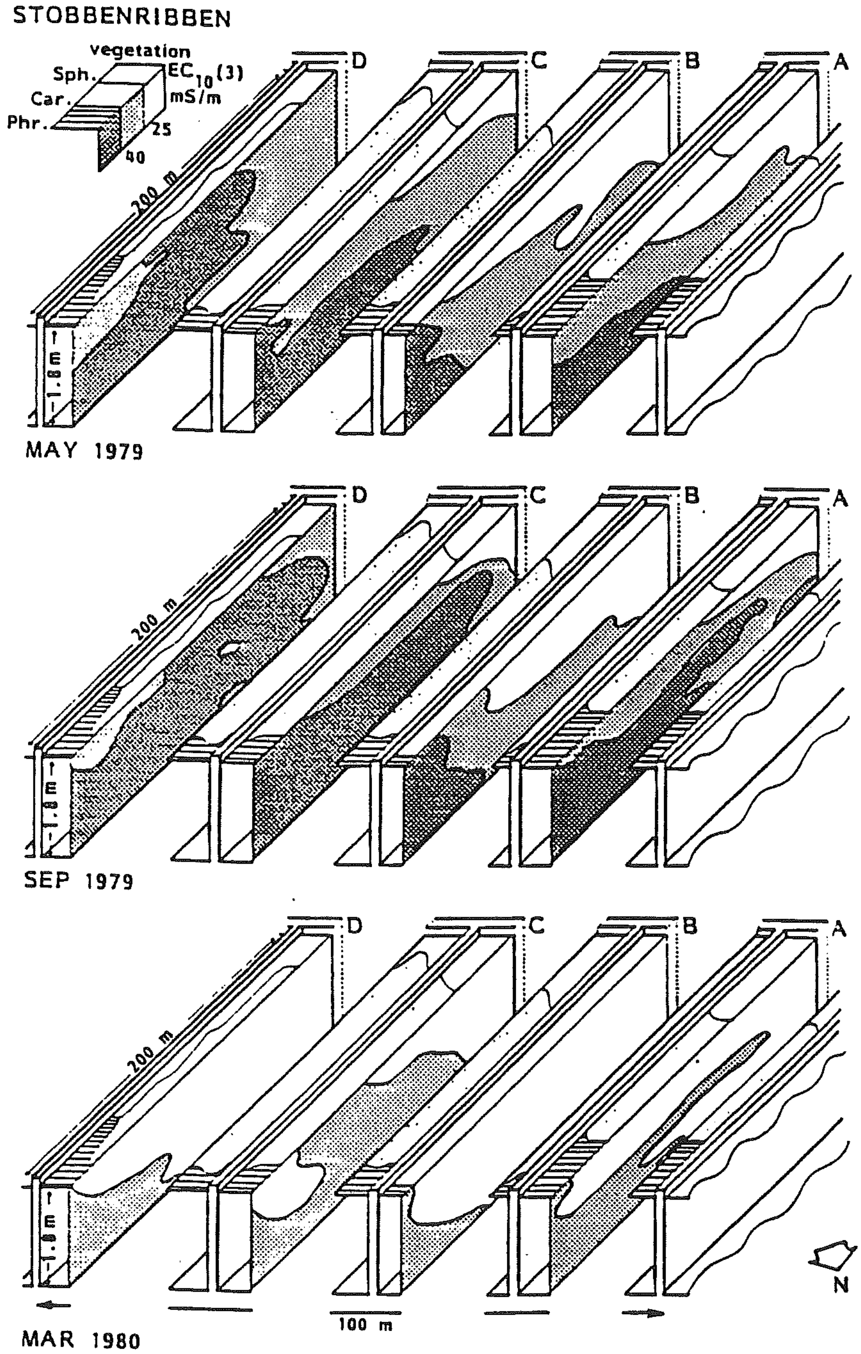

Figure 2. Electrical conductivity in four terrestrializing turbaries, as it changes with the seasons. The feeding ditch is in front of the depicted sections. Phr.: reed sere vegetation, Car.: slender-sedge sere vegetation, both in the brownmoss phase. Sph.: sphagnaceous phase vegetation. Conductivity values from measurement in peat "soup", calibrated with water samples. From Van Wirdum (1991)

raft is more solid, such a stratification exists to some degree, but drought periods and slight variations of the floating depth of the raft impede a strict stratification. Since the ditch water is base-rich as compared to the rain water, a measurement of the electrical conductivity of the saturated peat soil can be used to demonstrate the patterns of mixture. (Fig.2).

Vegetation and indicated base and nutrient states (Fig.3)

Due to the hydrologically determined gradient from the ditch end of the turbaries towards the other, "dead", end, a vegetational gradient has developed as well. In order to demonstrate this gradient ecologically a system of environmental indication on the basis of floristic composition was developed. The indicatory value attached to each species was derived from the international literature, rather than from local observations (Van Wirdum 1991), so as to exclude circular reasoning. Five combinations of ecological characteristics are used here:

LthOli: Litho-oligotrophic, base-rich and nutrient-poor;
LthMes: Litho-mesotrophic, base-rich and moderately nutrient-rich;
CirOli: Circumneutral-oligotrophic: moderately base-rich and nutrient-poor;
AtmOli: Atmo-oligotrophic: base-poor, nutrient-poor;
Rest: all remaining types of environment, especially the more nutrient-rich types.

The indicated environment is illustrated with radial diagrams in Fig.3. Near the ditch the vegetation (type A) indicates a relatively eutrophic and base-rich environment ("rest" indication relatively important), with *Phragmites australis* as a dominant species in the herb layer, and *Calliergonella cuspidata* in the moss layer. This belt of productive vegetation extends 10-40 m from the ditch. The intermediate part of the rafts is covered with a vegetation (type B) characterized by an abundance of *Carex diandra* and *Carex lasiocarpa* in the herb layer, and *Scorpidium scorpioides* in the moss layer. The species composition is indicative of a litho-oligotrophic environment. At greater distance from the ditch a type of vegetation (type C) with a moss cover of various species of *Sphagnum* and some *Polytrichum juniperinum ssp. strictum*, and with a sparse herb layer with *Erica tetralix* as a remarkable element is found. This indicates an atmo-oligotrophic environment. Type D vegetation is derived from type C, but it contains some species characteristic of slightly dryer conditions, and also species spreading from the surrounding peat baulks.

III 138

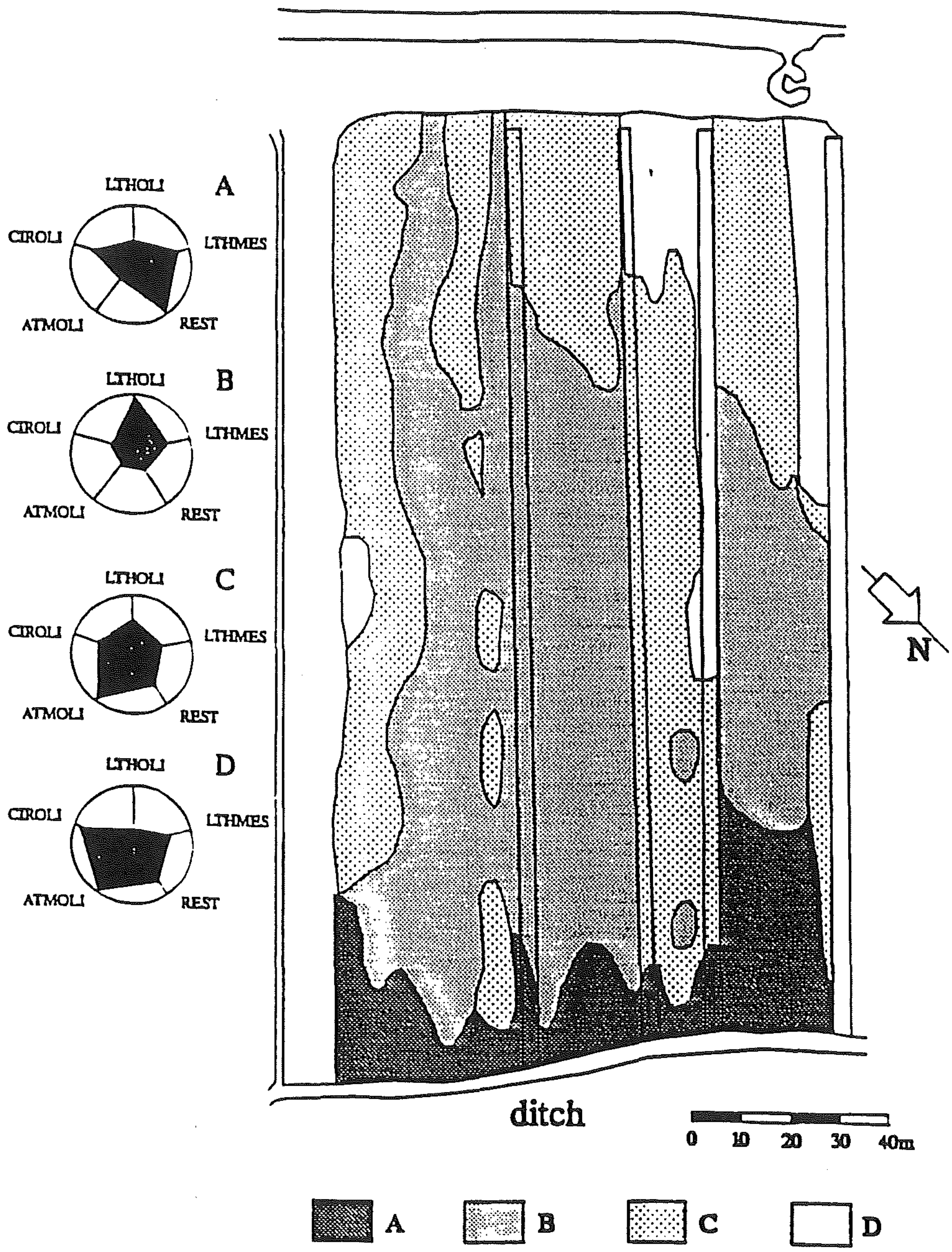

Figure 3. Zonation of the vegetation in De Stobbenribben, from the feeding ditch (below) towards the "dead" ends of the turbaries. A, B: brownmoss phase vegetation of the reed and slender-sedge seres, respectively, C: sphagnaceous phase fen, D: slighly drier contact community derived from sphagnaceous phase fen. Radial diagrams show the environmental differences indicated by the floristic composition of the vegetation. From Van Wirdum 1991, 1993a

Age, phase and environment

Terrestrialization in De Stobbenribben started c. 80 years ago, shortly after the turbaries were abandoned. According to Van Wirdum, Den Held & Schmitz (1992) types A and B vegetation constitute brownmoss phase fen in the reed and slender-sedge seres, respectively. The more productive type A vegetation is usually harvested in winter for thatching reed, whereas type B vegetation is mown in summer, for conservation only. In the past type B vegetation was harvested for additional fodder. Types C and D constitute sphagnaceous and ericaceous phase poor-fen. The difference between seres of succession is no longer prominent at this more advanced stage.

Age in itself is no reason for the phase difference. While sphagnaceous phase fen can develop within 15-20 years in early swamp phase fen, brownmoss phase fen of type B has been present in De Stobbenribben for fourty or more years already. As terrestrialization proceeds into the open, the oldest fen is liable much faster to succeed into poor-fen due to an increasing insulation from the base-rich water: priority, associated with insulation, is at least as important as age.

With insulation, the amount of base-rich water mixing with infiltrating rain water decreases, inparticular at the raft surface. This is shown in Table 1. The process is not a matter of mere mixing. Calcium, magnesium, sodium and potassium are exchanged against hydrogen ions; hence the saturation with bases of the exchange complex decreases from 100% near the ditch, with about 5% rain water, to about 30% in the sphagnaceous phase fen, with 84% rain water and a dominance of *Polytrichum* at the sample site. The specific exchange capacity depends on the peat structure; the absolute capacity varies further with the peat density and the thickness of the floating raft.

THE ATMOTROPHIATION IN DE WOBBERIBBEN

The process of atmotrophiation has been followed in quite some detail in De Wobberibben. De Wobberibben is another group of abandoned turbaries, close to De Stobbenribben. While the ditch feeding De Stobbenribben is more or less regularly cleaned up, the ditch system in De Wobberibben has been neglected during most of the time this research was done. Fig.4 illustrates the ongoing atmotrophiation resulting from this neglect. It should be mentioned that various factors relating to the vegetation management have increased the effects on the vegetation. The pattern nevertheless demonstrates that the effects depend on the distance from the ditches: insulation is a master

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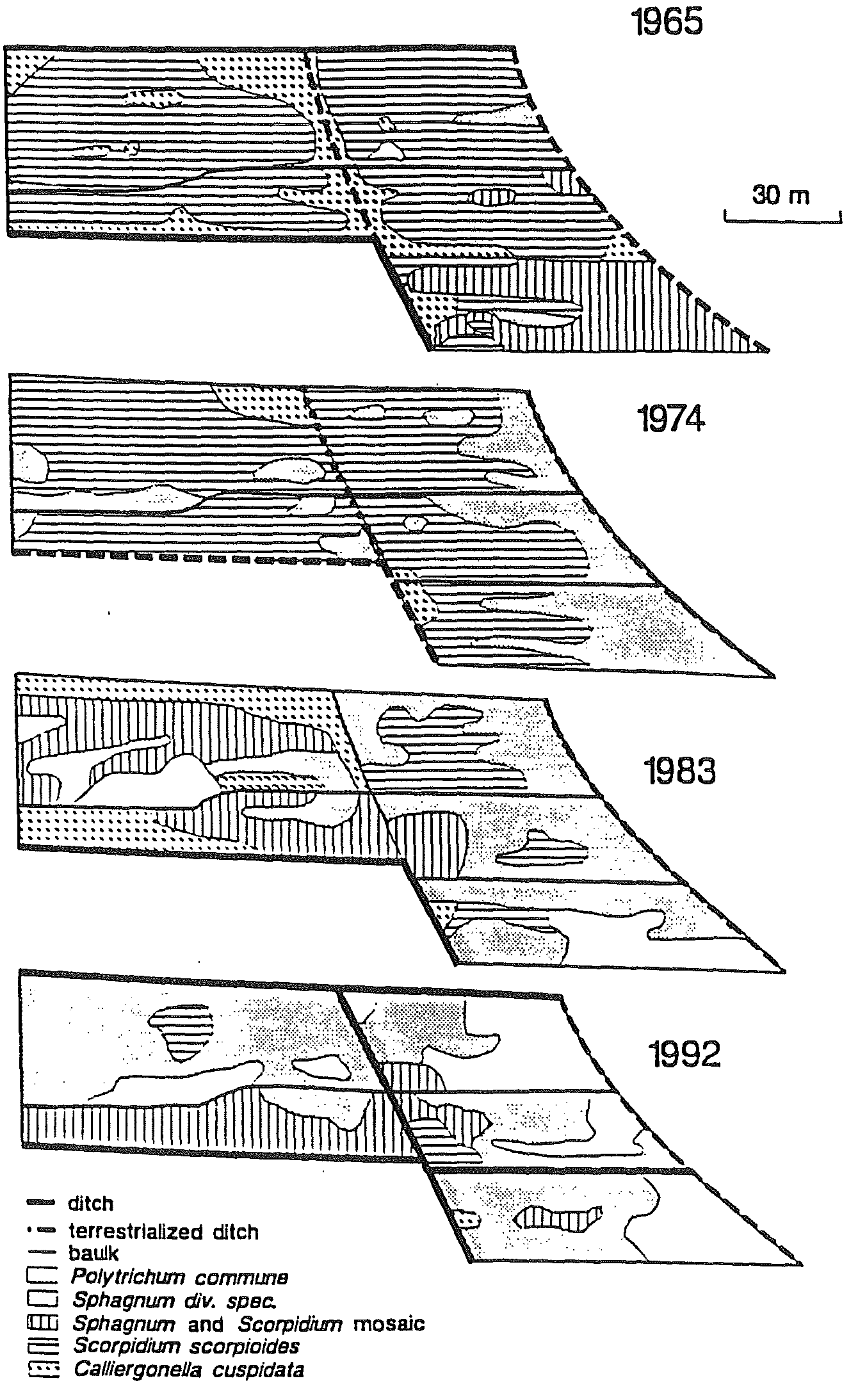

Figure 4. Atmotrophiation (*Sphagnum*, *Polytrichum*) of rich-fen (*Scorpidium*, *Calliergonella*) in De Wobberibben accelerated by the terrestrialization of ditches. Terrestrialization was in an advanced stage already in 1965, but the vegetation lagged behind; in 1992 ditches had been cleaned up and partially dug anew, but this is not yet reflected in the vegetation pattern. After Van Zon-Van Wagtendonk (1965), G.J.M. Ruitenburg (unpublished), Calis & Van Wetten (1983), Van Wirdum (1993b).

factor. Very recently ditches have been cleaned up again, and some sitches have been dug anew. The vegetational effects are being followed further. It is expected that (1) sphagnaceous phase fen will not be replaced by brownmoss phase fen in the near future, but (2) that the remaining brownmoss phase fen will not be replaced by spahgnaceous phase fen in the near future either.

Table 1. Selection of analytical results. Water sampled in upper part (uppr) of raft and below raft (lowr), soil sampled at 5-15 cm (uppr) and 30-40 cm (lowr) depth in raft. EC_{25}: electrical conductivity at 25C, Ca-loss: Ca deficit at comparison with properly mixed sample of ditch and rain water, CEC: cation exchange capacity, base sat.: saturation of exchange complex with calcium. magnesium, sodium and potassium. After Schouwenberg 1992 and Van Wirdum 1991.

		ditch	rain	*Sphagnum*		*Polytrichum*		*Scorpidium*	
				uppr	lowr	uppr	lowr	uppr	lowr
Water:									
pH		7.6	4.2	6.5	6.5	4.5	5.5	7.9	6.4
EC25	mS m^{-1}	61	5	24	46	11	20	58	60
Ca	mg l^{-1}	70	0.4	21	50	5	17	45	65
Ca loss	%			29	12	55	22	14	7
Cl	mg l^{-1}	76	3.0	33	62	14	25	57	76
N_{inorg}	mg l^{-1}	0.82	2.09	0.25	0.25	0.21	0.39	0.17	0.41
Rain water	% vol.	0	100	59	20	84	70	26	1
Peat exchange complex:									
Ca	mg g^{-1}			6.8	10.0	2.4	5.0	14.9	16.1
CEC	cmol kg^{-1}			62	74	62	102	95	91
Base sat.	% CEC			66	78	30	33	90	102

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IV 143

Proceedings of the 19th workshop

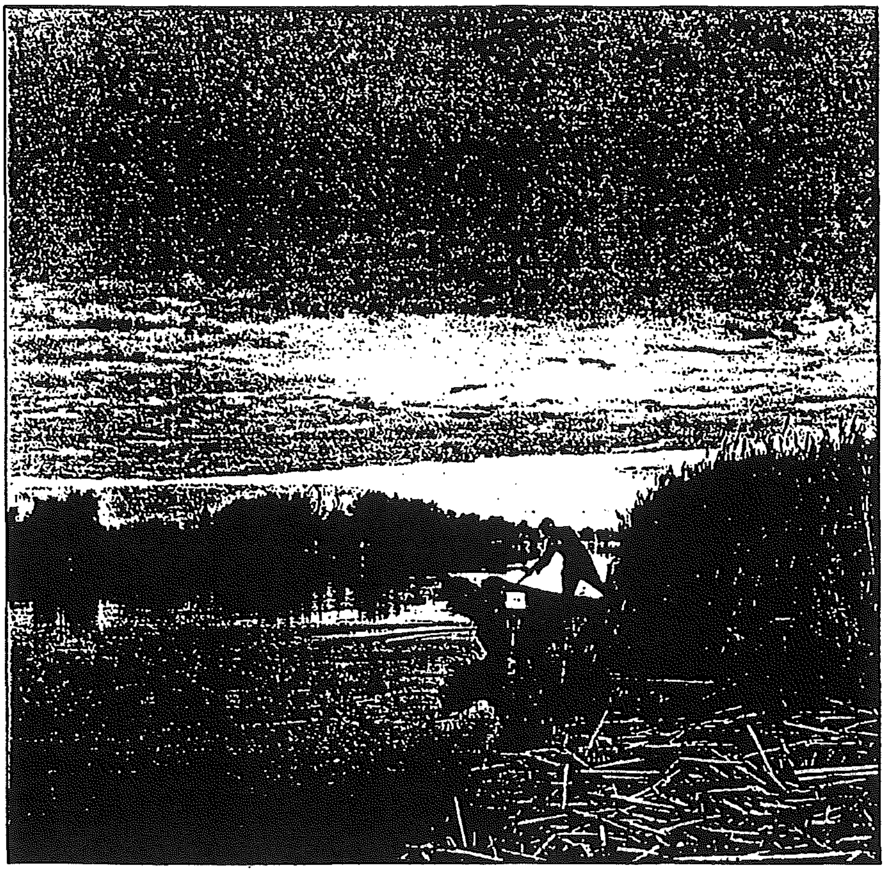
Compte-rendu du 19ème atelier d'EUROSITE

EUROSITE

VAN WIRDUM

The Management of Water Levels and Quality in and around Conservation Areas

La gestion de la qualité et du niveau de l'eau dans et autour des Zones de Conservation



May / mai 1994

Nationaal Park "De Weerribben"

-Nederland-

Résumé : Les problèmes liés à la gestion de l'eau dans le Parc National des "Weerribben"

par Geert van Wirdum, Département de l' Ecologie de la Végétation, IBN-DLO

La conservation de la nature, et la restauration des zones humides sont des formes d'occupation de sol qu'il faut négocier avec les autres utilisateurs du sol. Pour bien négocier, il convient de faire une estimation des coûts et des avantages pour chaque partie, pour tous les scénarios possibles.

Des études de l'hydrologie sont particulièrement importantes, quand il s'agit des zones humides, étant donné que les niveaux et la qualité d'eau sont vitaux pour ces espaces. Des études récentes; réalisées par l'auteur ont montré qu'il y a une percolation vers la nappe phréatique, contrairement à ce qu'on aurait cru ; par conséquent, il a dû adapter les mesures de gestion.

Quand la zone de conservation est étendue, le gestionnaire peut plus facilement maintenir les niveaux dessinés dans sa réserve ; toutefois, il dépend de l'extérieur. Actuellement, dans les "Weerribben", les niveaux des nappes phréatiques sont maintenus en fonction de la nature. C'est pour cette raison que les gestionnaires des réserves ont l'obligation morale de définir correctement les objectifs pour les réserves et, en fonction de ces objectifs de gérer l'eau à l'intérieur des réserves.

Il est particulièrement important de maintenir les différents types de tourbières dans "les Weerribben", ainsi que tous les stades de la succession naturelle. De ce fait, il faut surtout combattre l'acidification. L'enlèvement des résidus est vital pour ça. Toutefois, l'auteur recommande de ne pas trop aller à l'encontre des processus naturels.

Water Management and related problems in " De Weerribben" National Park

by Geert van Wirdum
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Introduction

Water management for nature protection in wetlands can be considered at three levels of scale: the regional, local, and sub-local level. Some main issues at each level are introduced below, with reference to the North-West Overijssel mire reserves, De Weerribben in particular. The need for an integration of planning and execution of the water management with other interests is emphasized in view of sustainable results.

The regional level

Conservation, restoration, or even creation of wetlands for nature, are forms of land use. The relevant wetland areas are "eco-devices" used to sustain biodiversity. Regional hydrology determines the range of possible results, or: targets set define requirements. Measures are necessary when the present hydrological conditions fall short to support reasonable conservation results. At this point the conservation authorities have to negotiate about their demands with other land users in the same area. Such negotiations require a comparison of alternative plans, at least through a ranking of costs and benefits for various parties.

Hydrological studies are often needed here. However, hydrological studies for nature conservation usually need to be precise and reliable for different variables and ranges than studies for other forms of land use have to (Van Wirdum, 1986). Fluctuations of the water level near the boundaries of the conservation area (inclusive of its bottom!), and near the main in- and outflows in particular, and the chemistry of the water are key factors for marshes, fens and bogs (Van Wirdum, 1993). In this context one must distiguish between nutrient state and base state of the water, respectively. Gradients between rain water, calcareous ground- or surface water, and sea water are primarely determined by the base state and salt concentrations in the water. All can be oligotrophic, mesotrophic, eutrophic, or even hypertrophic.

As the conservation area is larger, the manager has more freedom to maintain gradients within the area (an aspect of the local management level; see below). At least one end of the gradient is determined by the water management at the regional level. A precipitation surplus, for example, can only be used to maintain a gradient from base-rich to base-poor water when base-rich water is available as well. When the water near the boundaries of the conservation area is base-poor, as is rain water, there is nothing to vary upon, and base-rich fen will usually not be in the range of sustainable types of vegetation. As a general rule, polluted and eutrophic waters exclude many sensitive species of plants and animals, although most vertebrates avoid clearly oligotrophic conditions. A supply of base-rich water increases the opportunities for a large variety of wildlife, but it restricts bog communities to the most insulated rain-water fed parts of the wetlands involved.

Figures 1 and 2 summarize the regional hydrology of De Weerribben and De Wieden. It is important to note that both reserves are fen areas, which by definition will become poor-fen or bog, or will suffer from drought, when no water comes in from outside: fen depends on its surroundings. Until the early 1970s it was widely believed that the conservation area received groundwater discharging from the main aquifer through the bottom of the reserves. My eco-hydrological studies (Van Wirdum, 1991) rather proved a considerable downward leakage of mire water into the aquifer, and a vital base supply with surface water supplied at the reserves' surface boundaries. This made obvious that a conservation of rain water, in order to keep pollution out, would diminish the base supply and thus favour a development of Sphagnum-dominated poor-fen and bog at the cost of brownmoss-dominated rich-fen.

IV 146

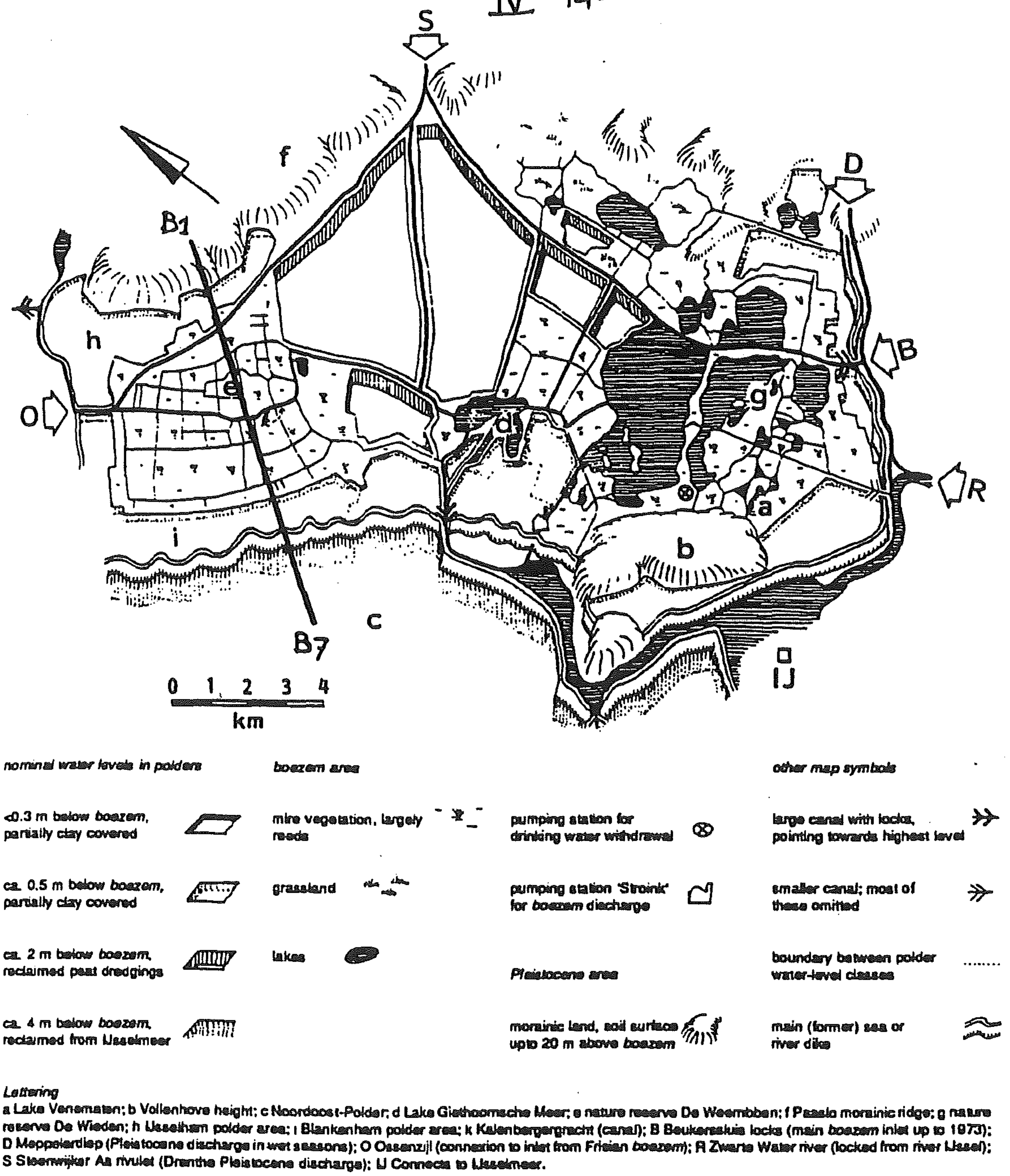

Fig.1 Hydrographic situation of the North-West Overijssel mire reserves. Pseudo-shadowing suggests the high elevation of the water table in the mire reserves as compared to the various polders.

The increased understanding of the hydrology at the regional level opened new views on problems of eutrophication and acidification within the reserves, and on optimal water management. However, nobody was obligued to see the new views since they had not been extended to specific user interests other than nature protection. The present quantitative hydrological modelling (Post, 1994) aims at a comparison of policy scenarios for various forms of land use in the larger region, and at the raising of a broad public support. The model should form part of the agreed basis (common sense) for forthcoming political negotiations (Corporaal, 1994). Conservation and restoration of wetlands are explicitly considered in it. Emphasis is given to the transformation of polders used for agriculture into essentially new wetlands. This can improve the regional hydrology so as to save the existing mire reserves, and it will increase the total area of wetland such that more species will be able to found a sustainable population. In conclusion, regional hydrology must be considered in order to assess the opportunities for the conservation of specific types of wetland, and its consequences for other relevant types of land use must be considered in order to organise a broad support for the long-term aims to be decided.

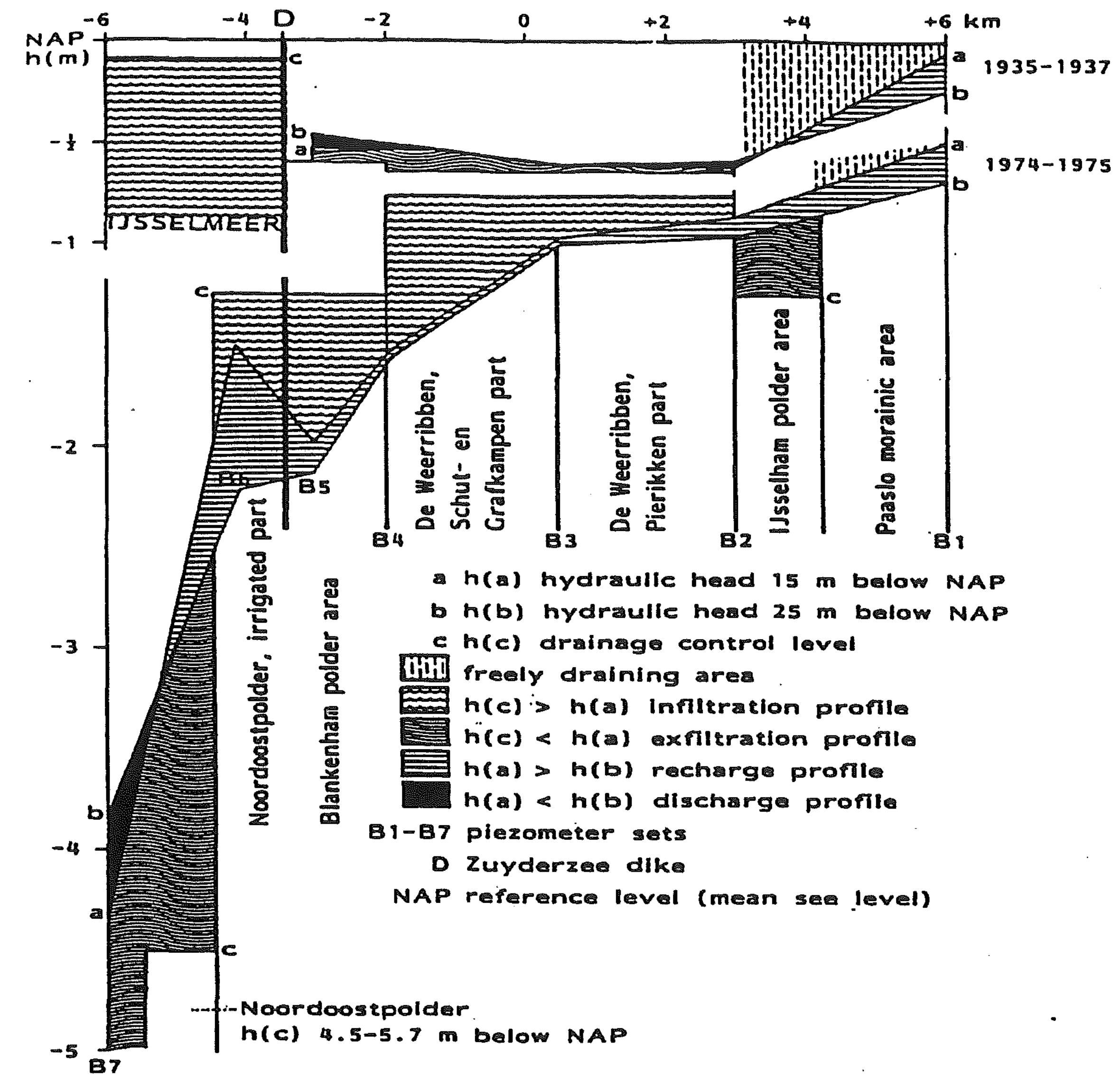

Fig.2 The alteration of the hydraulic head gradient in the B-transect, 1935-1975. The distance of the piezometers from the centre of the mire area has been indicated along the axis. Note the dramatic drop of the hydraulic head at 15 and 25 m below NAP. The alteration was largely due to the construction of various polders. In the 1930s the mire received mainly surface water, although some groundwater discharge may have been present locally and no infiltration to the deeper aquifer occurred. Nowadays, the mire is recharged with surface water and leaking water towards the underlying aquifer.

The local level

Within the conservation area, the surface-water network determines how much of a possible rain-water surplus is discharged from the various wetland parts, and how much surface-water can penetrate into them (Van Wirdum 1991,1994a). The individual parts of the reserves can be considered smaller ecodevices themselves here. The local water system and management determine gradients between rich-fen and poor-fen with very species-rich types of intermediate fen. It is important that the manager sets more detailed goals for the conservation area and accordingly draws a plan for the maintenance of water courses. This is no longer a private choice to be made by the reserve owners. As the regional water management is tuned to the requirements of conservation areas, and as this potentially restricts other land use, it is a social responsibility of the owners and managers to make the best of the opportunities. The natural succession of the ecosystem, e.g. from rich-fen to poor-fen, must be taken into account (Van Wirdum 1993). While in general stabilization of gradients (Fig.3) will be best for biodiversity, it makes no sense, and a lot of disturbance, to heavily counteract natural processes, rather than just delay them. Long-term stability enables the natural community to reach species saturation.

IV 148

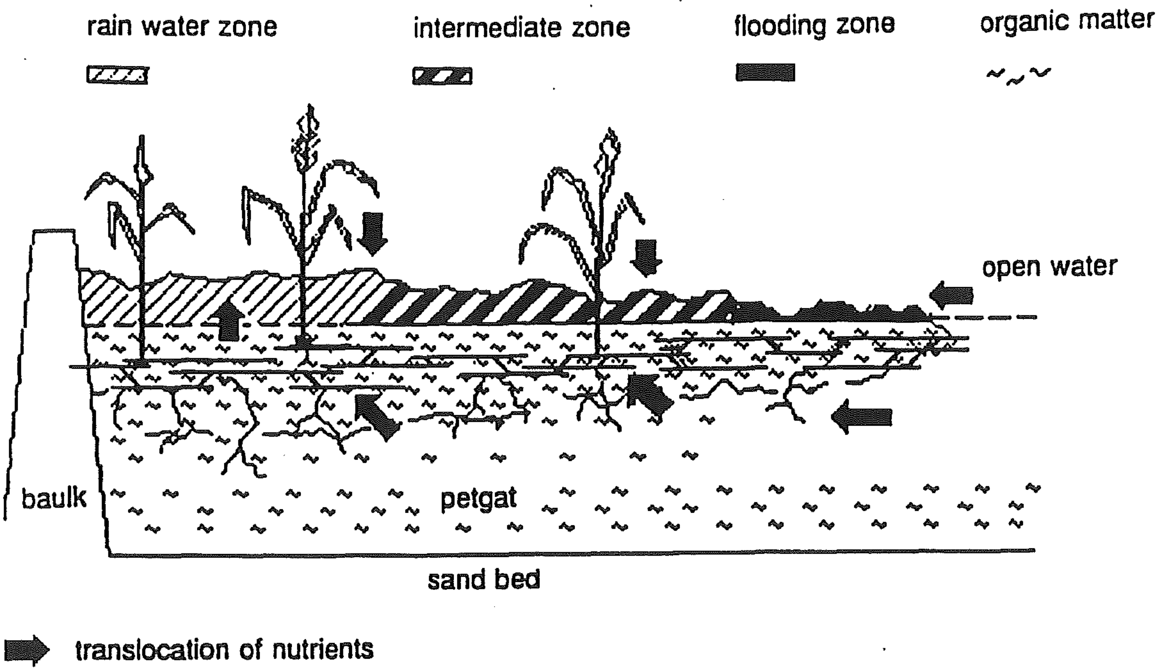

Fig.3 Different scales of environmental homogeneity in a quagfen. The picture shows a floating raft (kragge) adapted to a certain type of water supplied from below. Within the kragge three hydro-environmental zones have developed according to the decreased influence of flooding and the increased influence of rain water as the distance from the body of open water increases. Hummocks and hollows are present in each zone. Micro-zonation is not shown. From Van Wirdum (1991).

In De Weerribben, a policy is followed to keep part of the canals and ditches open, so as to delay the succession to poor-fen. This has resulted in the conservation of some of the best examples of rich-fen still available in The Netherlands. Highly threatened rich-fen types are also developing anew in early phases of terrestrialization elsewhere in the reserve. Reedbed management, inclusive of irrigation with wind pumps, is usually considered a positive factor in the maintenance of open rich-fen. In the very long run these factors will prove unable to stop poor-fen development (Van Wirdum, 1994b). In due time, part of the area will perhaps acquire a bog character. When irrigation and reed exploitation are continued long they will become disturbing rather than sustaining factors at this stage: post-management relaxation will then lead to scrub and carr development or to a mineralization of peat, rather than to the development of embryonic bog sites.

In general, a cessation of reed irrigation and reed cutting is advised before the floating rafts have terrestrialized far enough to loose their capacity of floating up and down with the water level. As the conservation area until now has been the working area for commercial reed cutters, this once again is a political item: after-use has to be considered timely. Many types of nature in wetlands have in part developed as a result of various forms of agricultural land use. When it is considered essential for nature conservation to continue or to stop such land use the relevant decision needs social support. The long-term demand for wetland products, and the opportunities for their production in harmony with nature, have to be estimated in order to settle a sustainable conservation strategy. A slightly lower level of ambition for short-term conservation results may well contribute to a better long-term result..In the end, the present polders may well become the main areas for species characteristic of rich-fen and of reedbed communities. After the regeneration of wetland conditions in these polders they will be less liable to an accumulation of rain water.

In conclusion, the local management involves both water management and harvest strategies. It is good practice to tune these to the highest aims for nature conservation in relatively small areas or sub-areas. In large areas sustainability can only be reached when the management required, either a harvest or strict "self-regulation", contributes to a functional land-use as felt so by the larger public. The use of a wild crop, recreation, or just set-aside for nature should be recognized as opportunity factors when the targets are set.

The sub-local level

Even within sites which are homogenous as regards their position in the prevailing gradients, a pattern of hummocks and hollows, pools and slightly elevated sites often exists. Such a pattern may be responsible for a co-occurrence of a great number of species (Fig.4). The higher spots will usually show a more acidic character, while the pools are still base-rich, depending on the position in the water-chemistry gradient. Vegetation management has an influence on the formation of these sub-local patterns, but their formation is beyond the scope of direct control. If it were not, nature management would risk to reduce to nature gardening.

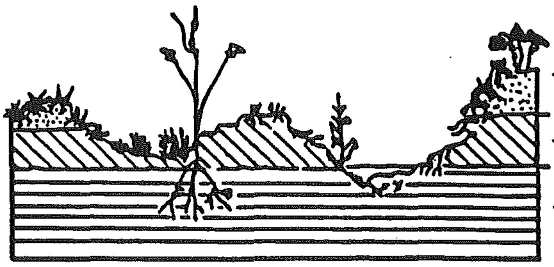

Fig.4 Microrelief and the fluctuation of the water table determine the type of water various species meet in the below-ground environment.

Indirect control in De Weerribben includes the removal of the annual above-ground production of biomass, so as to prevent a fast accumulation of plant litter. Such accumulation would stimulate hummock formation and surface acidification. It would thus counteract the water management at the local level, which strives after a supply of base-rich water. The use of large and heavy machinery can easily destruct an almost stable natural micro-relief, and replace it with an artificial pattern year after year. A balance has to be sought with practicable management for open fen between the return in terms of species-saturated micro-gradients and a sustainable yield. This essentially comes back to the conclusion formulated about the local-level management above.

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V 150

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Rapid Communication

The timing of last-glacial periglacial and aeolian events, Twente, eastern Netherlands

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ABSTRACT: Sequences of last-glacial age contain valuable palaeoclimatic information but are often difficult to date because the environment has been unfavourable for deposition of datable organic material. This paper presents age-estimates, determined by optically stimulated luminescence, for sediments from the type site of the so-called 'coversands' (periglacial aeolian deposits) in The Netherlands. These improve the chronology of this type site considerably, allowing age limits (22–17 kyr BP) to be set, for the first time, for the important phase of widespread permafrost degradation and aeolian deflation recorded in these deposits. Aeolian deposition occurred intermittently for most of the Last Glacial Maximum and the Late-glacial phases. Based on luminescence dating, sand-sheet deposition was concentrated between ca. 17–14 kyr ago, and dune formation was dominant during the Younger Dryas. The Younger Dryas was sufficiently cold to allow the first stages of ice-wedge-cast development in The Netherlands. Copyright © 1999 John Wiley & Sons, Ltd.

Journal of Quaternary Science

KEYWORDS: luminescence dating; permafrost degradation; coversands.

Introduction

Many Last Glacial Maximum sequences in Europe have a paucity of material suitable for radiocarbon dating because at this time vegetation and organic production was low and subsequently preservation of organic matter has been poor. The Lutterzand section (Twente, eastern Netherlands, Fig. 1) is the classic type site for the Late Weichselian aeolian deposits in northwest and central Europe (Van der Hammen, 1971; Wijmstra and Schreve-Brinkman, 1971; Doppert *et al.*, 1975; Vandenberghe and Van Huissteden, 1989). It also contains evidence of permafrost degradation and deflation, features that have been identified over large areas of the northwest European lowlands (Kolstrup, 1980; Vandenberghe, 1985). These features have never been dated accurately because of the lack of datable organic material. In this paper we present the first comprehensive application of optically stimulated luminescence (OSL) to sediments of the Lutterzand section, establishing a chronostratigraphy of the aeolian and associated permafrost degradation events.

Stratigraphy and depositional environments of the Lutterzand section

The Lutterzand section is a natural section along the Dinkel river (Fig. 1), which reveals a sequence of fluvial and aeolian sands (Wijmstra and Schreve-Brinkman, 1971; Van Huissteden, 1990). The important palaeoclimatic proxies in this section (Fig. 2) are described below.

Aeolian deposits of Late Pleniglacial to Holocene age

The base of the section (Beverborg Member, Twente Formation) consists of cross-bedded coarse fluvial sands,

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Contract grant number: JRP385

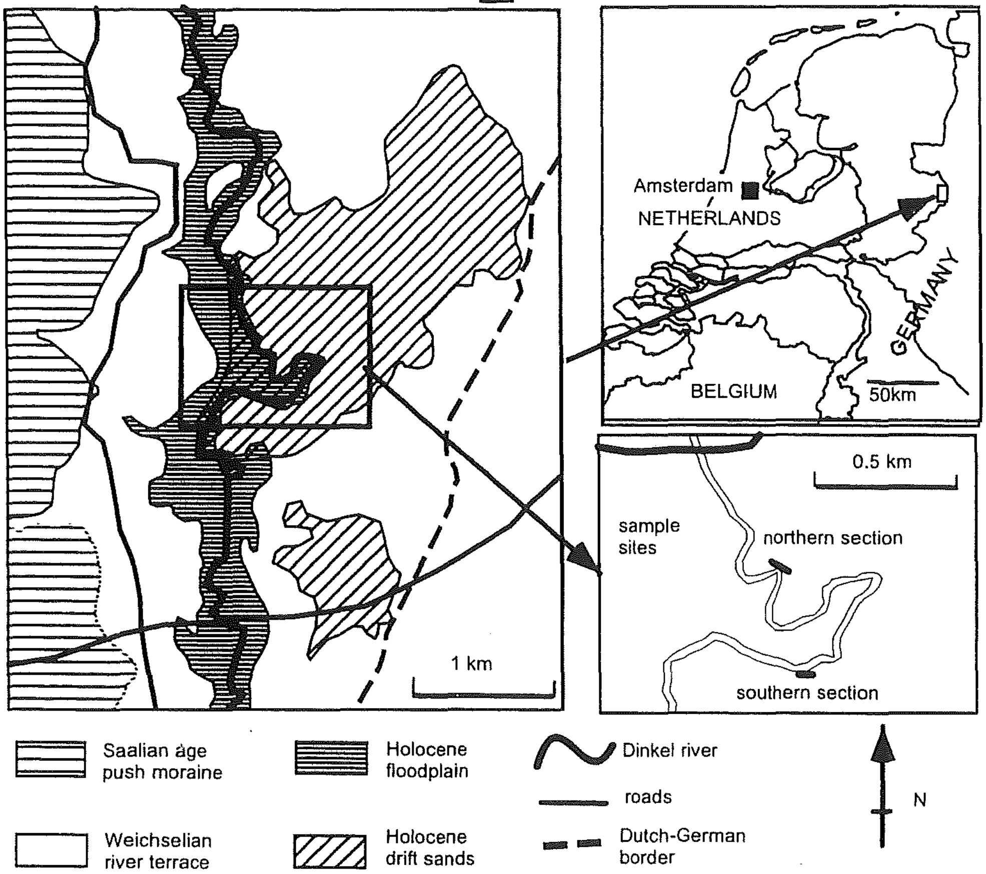

Figure 1 Location map of Lutterzand site, and sections sampled.

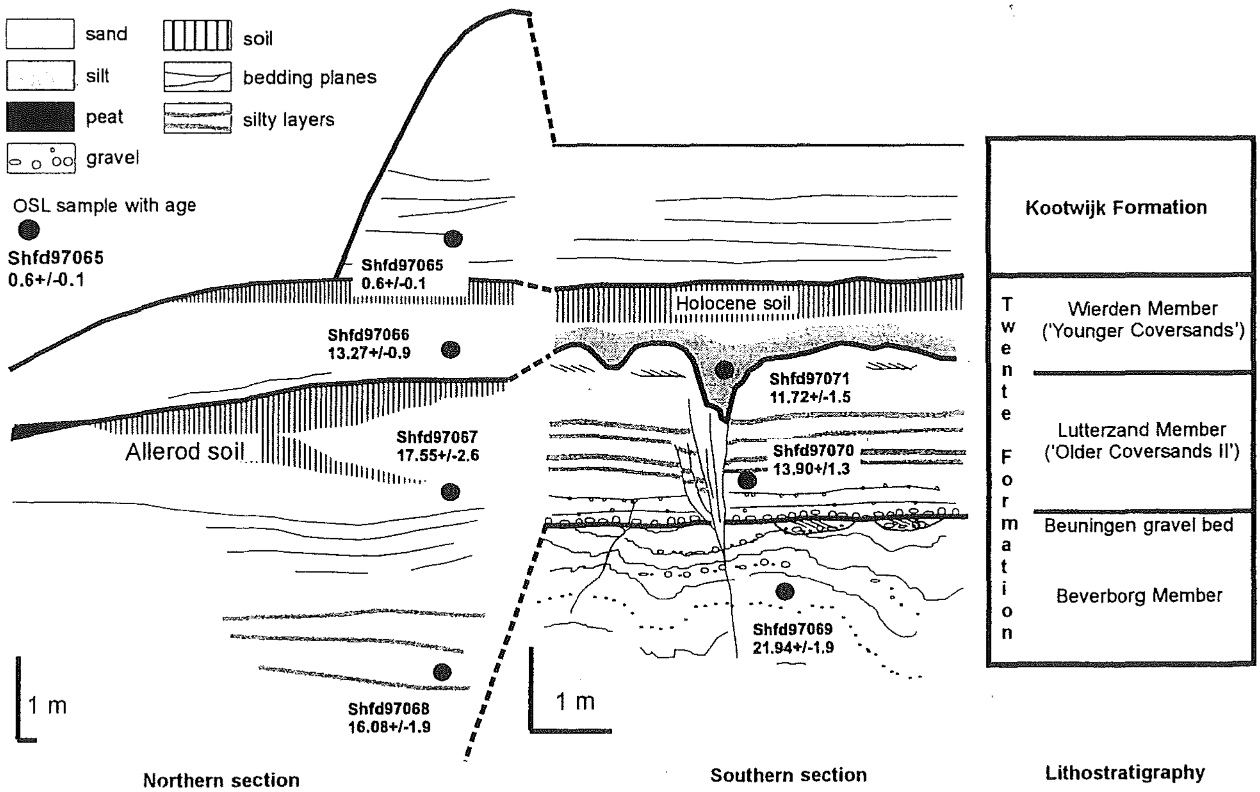

Figure 2 Stratigraphy and sedimentological structures found in the Lutterzand exposure, with detailed stratigraphical logs of the two sections sampled in the Dinkel valley showing sediment type, bedding structures, stratigraphical assignment and OSL sample locations and age determinations (in kyr from the present day).

intercalated with horizontally bedded finer sands, interpreted as the result of fluvial and aeolian interaction on a river floodplain (Vandenberghe and Van Huissteden, 1988). Towards the top of this unit, the proportion of aeolian deposits increases. The overlying Lutterzand Member (or 'Older Coversands II', Wijmstra and Schreve-Brinkman, 1971) represents the classic 'coversand', an aeolian sand-sheet, with predominant horizontal bedding (Koster, 1982; Schwan, 1986, 1988; Kasse, 1997). The Wierden Member is separated from the Lutterzand Member by a soil or a cryoturbated silt layer, and consists of well-sorted, cross-bedded sands displaying a distinct dune relief ('Younger Coversands II'; Wijmstra and Schreve-Brinkman, 1971). The uppermost unit, the Kootwijk Formation, is represented by small dunes with distinct cross-bedding.

An Aeolian deflation lag or desert pavement

This layer (the 'Beuningen gravel bed') consists of a few strings of gravel, which truncates the Beverborg Member. The erosion is attributed to aeolian deflation (Wijmstra and Schreve-Brinkman, 1971) and, in part, to erosion by surficial runoff (Van Huissteden, 1990). The Beuningen gravel bed is an important stratigraphical marker that has been found in Belgium, The Netherlands and northwest Germany (Kolstrup, 1980; Vandenberghe, 1985). It is always associated with the periglacial features described below.

A permafrost degradation phase of Late Pleniglacial age

The top of the Beverborg Member is heavily cryoturbated, with large cryoturbations showing an amplitude of 1 m in some cases. Structures of this size are thought to originate from permafrost degradation (Vandenberghe, 1988). The cryoturbations are truncated by the Beuningen gravel bed. In the Lutterzand section, the gravel bed is associated with frost fissures that post-date the cryoturbation outlined above.

Incipient ice-wedge casts and cryoturbation structures, presumably of Late-glacial age

The silt at the base of the Wierden Member has been deformed by small amplitude (< 50 cm) cryoturbations with large frost fissures penetrating down into the silt from above. Downfaulting of the adjacent sediment and a secondary infilling of sand and silt point to the erstwhile presence of wedge ice. The fissures, however, lack the characteristic width of ice-wedge casts.

Existing chronology

The age of the Beverborg Member is constrained only by the age of organic silts that were found 7–8 m below its top in a borehole section 1 km north of the Lutterzand exposure. These were radiocarbon dated at 27 500 ± 250 ^{14}C yr BP (GrN 11523, Van Huissteden, 1990). Organics found in channel deposits overlying ice-wedge casts at Staphorst (some 70 km to the west of the Lutterzand) are assumed to be a lateral equivalent of the Beuningen gravel bed (Kolstrup, 1980). The age determined from a humic extract of these organics was 19 100 ± 180 ^{14}C yr BP (GrN 8506, 8594), although there are some uncertainties because it was reworked material.

The Lutterzand Member pre-dates the Bølling–Allerød interstadial (Van Geel *et al.*, 1989). A radiocarbon date from a channel fill (14 000 ± 150 ^{14}C yr BP, GrN 8509) marks the start of the sedimentation of the Lutterzand Member in an exposure near Epe, 100 km to the west of the Lutterzand (Kolstrup, 1980). The dating, however, was on *Potamogeton* fruits and therefore it may have been affected by hard-water error.

The Wierden Member is thought to be of Late-glacial age (Allerød), based on pollen from a peaty silt in a channel fill. Correlation with the nearby Usselo site (Van der Hammen, 1951; Van Geel *et al.*, 1989) indicates an age of at least 12 930 ± 210 ^{14}C yr BP (Ua-382, Van Geel *et al.*, 1989) for the base of the Wierden Member. The Younger Dryas Stadial, during which the 'Younger Coversands II' are thought to have been deposited, is dated to between 10 950 ^{14}C yr BP and 10 150 ^{14}C yr BP (Hoek, 1997). On top of the Wierden Member a well developed podsol soil of Holocene age occurs, which has been dated at 7535 ± 50 ^{14}C yr BP (GrN 5180, Wijmstra and Schreve-Brinkman, 1971).

The Kootwijk Formation is thought to owe its existence to soil degradation during medieval times (Koster, 1988; Castel, 1991; Koster *et al.*, 1993).

Luminescence dating

Luminescence has been applied to the Lutterzand site in a number of studies (Smith *et al.*, 1990; Dijkmans and Wintle, 1991; Stokes, 1991; Dijkmans *et al.*, 1992). All have failed, either through methodological problems or lack of samples, to establish a good chronostratigraphy for this site. The most systematic approach using thermoluminescence on feldspars was undertaken by Dijkmans and Wintle (1991) and Dijkmans *et al.* (1992), but it was found that these dates underestimated the age of the samples by 20–50% when compared with the existing chronology. Although only two in number, the OSL age-estimates reported by Stokes (1991) showed good agreement with the radiocarbon age for the Usselo layer. Accordingly the use of quartz and OSL has been adopted for this study.

Experimental details

Seven samples were collected. As the luminescence dating technique has been proven to best suited to aeolian sediments (e.g. Aitken, 1998), samples were taken from stratigraphical positions where sedimentological evidence indicated the presence of aeolian-derived material (Fig. 2). A summary of the sample preparation procedures and equipment used for the luminescence measurements can be found in Bateman and Catt (1996) and Thomas *et al.* (1997).

Both multiple aliquot and the single aliquot methods were used to derive the palaeodose (D_e) of the samples (Duller, 1994; Aitken, 1998). For the multiple aliquot approach each sample was split into four subgroups, three of which underwent various lengths of laboratory irradiation ranging up to 10 times the estimated D_e. Each disc was preheated to 220°C for 5 min before being stimulated for 120 s at 50°C. Interdisc normalisation was by way of the total equivalent dose method (Stokes, 1994). All samples exhibited low interdisc scatter and consequently the single saturating exponential regression growth curves established using an integral of the first 30 s of data were plotted with a high degree of confidence (Fig. 3).

For the single aliquot approach the preheat correction method was used (Duller, 1994). All discs were preheated for 120 s at 220°C and OSL measurement times were 0.5 s at 50°C. All growth curve extrapolations to establish the D_e were found to be linear (Fig. 3). Repeat measurements at the maximum dose point were tightly clustered, indicating that the preheat correction method worked well. Up to 17 replicate D_e measurements were made for each sample and the D_e values presented in Table 1 are the resultant means and standard deviations from these replicates.

Total dose rates were calculated from the concentrations, as analysed by Inductively Coupled Plasma (ICP) mass spectrometry (U and Th) and ICP Atomic Emission Spectroscopy (K), using published conversion data (Aitken, 1998), taking into consideration attenuation resulting from palaeomoisture contents, which were assumed to be the same as present-day values. The cosmic dose contribution was calculated using published equations (Prescott and Hutton, 1994).

Results and discussion

The final D_e estimates can be seen in Table 1. For four of the samples where both multiple and single aliquot approaches were used the D_e values are in close agreement with each other. Only Shfd97070 has a significantly lower single-aliquot-derived D_e. It was noted that the plateau test for this sample showed a gradual rise of D_e with stimulation time, perhaps indicating the incorporation of less well-bleached material (Fig. 3). As the single aliquot approach uses only the signal from the most light-sensitive traps, and has a high reproducibility, as shown by the low scatter around the mean $D_e(S_n$ value), the single aliquot D_e has been used in the final age calculation. Using the single aliquot data, none of the samples showed the systematic correlation between OSL signal and D_e and all showed low scatter around the mean D_e, thereby indicating sufficient bleaching prior to deposition (Duller, 1995; Clarke, 1996). The dates derived therefore should not include a significant overestimate of age resulting from an antecedent geological OSL signal.

The final OSL age determinations are presented in Table 2 expressed as years before present (1998), with errors of one standard deviation. From these it can be seen that aeolian deposition at Lutterzand has occurred, albeit intermittently, throughout the Late Pleniglacial and Late-glacial periods.

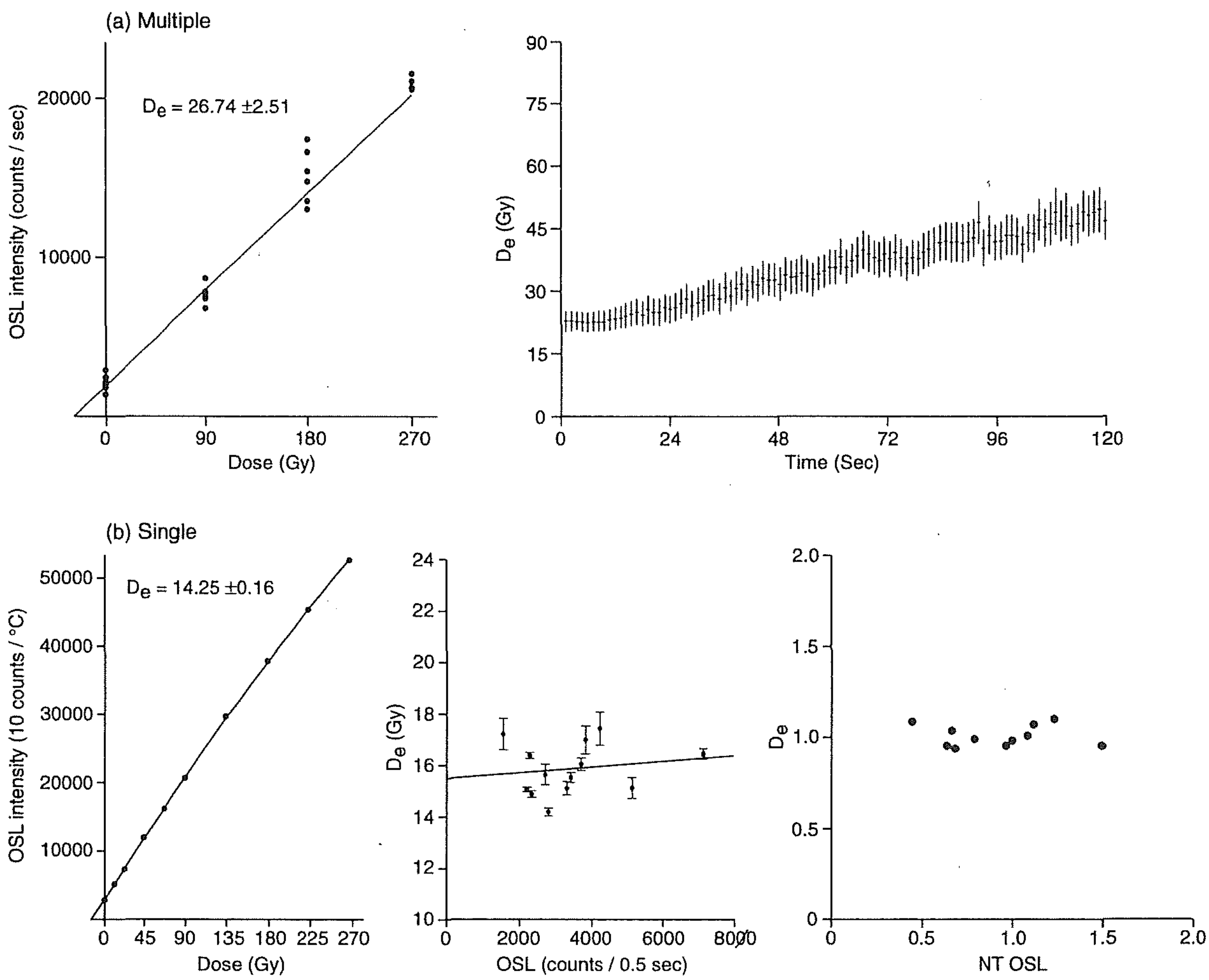

Figure 3 Example of OSL data (Shfd97070). (a) Multiple aliquot approach showing the low interdisc scatter and good fit of the growth curve used to calculate the D_e. Also shown is the plateau test for this sample. (b) Single aliquot approach showing the good fit of the growth curve to the data points, the lack of correlation between the naturally aquired OSL signal and D_e (after Duller, 1995) and the good clustering of the D_e values from the replicate measurements around the mean OSL signal and mean D_e value (after Clarke, 1996).

Table 1 Optically stimulated luminescence sample details, concentrations of uranium (U) and thorium (Th) as determined by ICP mass spectrometry and potassium (K) as measured by ICP Atomic Emission Spectroscopy. Cosmic dose calculated from published expressions (Prescott and Hutton, 1994). The total dose was calculated by converting the concentrations to activities using published algorithms (Aitken, 1998), making allowances for grain size, density and a palaeomoisture level based on present-day moisture. The palaeodose was determined by the total bleach additive dose method (Aitken, 1998) using both multiple aliquot and single aliquot techniques (Duller, 1994)

Site	Sample details			Dosimetry details					Palaeodose details		
	Number	Depth (m)	Moisture (%)	U (p.p.m.)	Th (p.p.m.)	K (%)	Cosmic dose (Gy kyr^{-1})	Total dose (Gy kyr^{-1})	Multiple D_e (Gy)	Single D_e (Gy)	S_n
Northern section	Shfd97065	1.40	2.0 ± 5.0	0.51	1.54	0.70	0.160 ± 0.008	1.08 ± 0.07	1.09 ± 0.09	0.65 ± 0.09	0.138
	Shfd97066	2.25	2.4 ± 5.0	0.75	2.44	0.90	0.150 ± 0.007	1.44 ± 0.09	–	19.02 ± 0.34	0.018
	Shfd97067	3.05	6.0 ± 5.0	0.53	1.80	0.96	0.130 ± 0.007	1.27 ± 0.09	22.74 ± 4.74	22.27 ± 2.97	0.133
	Shfd97068	4.15	6.0 ± 5.0	0.51	1.68	0.96	0.110 ± 0.006	1.24 ± 0.09	23.86 ± 4.86	19.88 ± 1.86	0.095
Southern Section	Shfd97071	1.25	15.0 ± 5.0	1.73	5.20	1.49	0.140 ± 0.007	2.10 ± 0.15	39.17 ± 4.76	24.56 ± 2.50	0.102
	Shfd97070	1.85	9.0 ± 5.0	0.51	1.54	0.85	0.150 ± 0.008	1.14 ± 0.08	26.74 ± 2.51	15.90 ± 0.99	0.006
	Shfd97069	2.45	6.0 ± 5.0	0.95	2.64	1.02	0.170 ± 0.008	1.50 ± 0.10	–	32.94 ± 1.78	0.054

Table 2 Comparison of the OSL dates presented here with the existing chronology for the Lutterzand area. Optically stimulated thermoluminescence ages are quoted from the year of measurement (1998) with errors of one standard deviation. All radiocarbon dates have been calibrated using the CALIB V3.0 software of Stuiver and Reiner (1993), except the older dates, which use the data of Kitegawa and Van der Plicht (1998)

Stratigraphical unit	Older stratigraphical terms	OSL age estimates		Existing chronology (Cal kyr BP)
		Age (ka)	Laboratory code	
Kootwijk Formation	Younger Drift Sands	0.60 ± 0.1	Shfd97065	< 1.0
Wierden Member	Younger Coversand I and II	13.27 ± 0.9	Shfd97066	11.8–15.3
		11.72 ± 1.5	Shfd97071	
		12.50 ± 1.1	Average	
Lutterzand Member	Older Coversand II	17.55 ± 2.6	Shfd97067	15.3–16.8
		16.08 ± 1.9	Shfd97068	
		13.90 ± 1.3	Shfd97070	
		15.84 ± 1.8	Average	
Beverborg Member	Older Coversand I	21.94 ± 1.9	Shfd97069	22.5–30.5

Moreover, the OSL dates compared favourably with the existing independent chronology and do not show any stratigraphical reversals.

The sample from the Kootwijk Formation (Shfd97065) gives an age of 0.6 ± 0.1 kyr before the present-day, which conforms to the estimated medieval age of this formation and also to the TL ages derived by Dijkmans and Wintle (1991). Sample Shfd97070, which has the poorest independent age control, agrees very well with the known radiocarbon dating of the Beuningen gravel bed according to Kolstrup (1980). Similarly, samples Shfd97068, Shfd97069 and Shfd97071, all from the Lutterzand Member, have a mean age of 15.8 ± 1.8 ka, which compares well with the 16.8 to 15.3 kyr BP calibrated radiocarbon age range for the Lutterzand Member at this site.

Given the problems associated with the independent chronology associated with the Beverborg and Lutterzand Members (outlined above) the strongest confirmation of the luminescence results comes from the Wierden Member, which has much better radiocarbon age control. Samples Shfd97066 and Shfd97072 have a mean age of 12.5 ± 1.1 ka and so fall within the 15.3 to 11.8 kyr BP calibrated radiocarbon age range assigned to this formation. As both radiocarbon and luminescence ages agree for the Wierden Member we may suppose that the luminescence dates of the underlying Lutterzand Member are equally reliable.

These new luminescence results have a number of implications. The three OSL dates from the Lutterzand Member (Shfd97068, Shfd97069 and Shfd97071) and the one from the Beverborg Member (Shfd97070) set, for the first time, provisional limits of ca. 22 to 17 ka for the Beuningen gravel bed and its associated large cryoturbation structures. The age range of the luminescence dates for the Lutterzand Member may also indicate that sedimentation started earlier at low-lying locations, e.g. at the northern section of Fig. 2, which is at a former river channel margin. As the error limits are overlapping, however, it is impossible to rule out the possibility that all three dates represent a narrower age range of deposition.

An additional point to note appertains to the Shfd97066 sample collected from what were thought of as Younger Coversand II deposits. These deposits are considered elsewhere to be of Younger Dryas age (Kolstrup *et al.*, 1990; Bateman, 1995, 1998; Bateman *et al.*, 1999). Although the OSL age from Shfd97066 deviates from the maximum age of the Younger Dryas in The Netherlands by less than 0.5 kyr, it could pre-date the Younger Dryas Stadial. As this sample originates from the cryoturbated silt that has been displaced into the incipient ice-wedge cast of Fig. 2, it is probably of Allerød age (which is well within the error limits of Shfd97066). This would make the incipient ice-wedge casts of Younger Dryas age.

V 155

Conclusions

1 Optically stimulated luminescence has been shown to provide a reliable and independently tested chronology for the Lutterzand sediments, thereby demonstrating the appropriateness of applying OSL dating to cold-climate aeolian/fluvio-aeolian contexts.
2 For the first time the stratigraphical marker of the Beuningen gravel bed complex can be assigned tentatively to the period 22–17 ka. The Late Pleniglacial permafrost degradation also must have occurred within this time period.
3 From the OSL chronology it can be seen that aeolian sedimentation has occurred at Lutterzand intermittently for most of the Late-glacial period.
4 Initiation of the Lutterzand Member may have been diachronous, with initiation starting earlier in low-lying contexts close to the river.
5 The dates also suggest that Younger Dryas climatic conditions permitted initial stages of ice-wedge-cast development.

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V 156

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VI 157

Proceedings of the Prehistoric Society, 61, 1995, pp. 1–36

Patterns of the peasant landscape

By H. T. WATERBOLK[1]

In a slightly different form this paper was given as the Europa Lecture for 1994

The subject of this contribution is the origin of the diversity in the 19th century peasant landscape in the northern Netherlands. The first goal of the paper is to introduce a British audience to a line of research, which so far has been mainly reported on in Dutch and German. The second goal is to lay my finger on some basic properties of peasant landscapes elsewhere in the world. The third goal of my efforts in landscape archaeology is to identify ancient structures in today's landscape, which explain their identity, and to present this information to all those who are concerned with landscape conservation and landscape planning in the study area.

INTRODUCTION

The study area is the northern Netherlands north-east of the Zuyder sea, between the rivers Vecht and Ems. It comprises roughly the provinces of Friesland, Groningen, and Drenthe (Fig. 1). In terms of physical geography, five zones can be distinguished in this area (Fig. 2):

1. The uplands of pleistocene boulder-clay with a more or less thick cover of Lateglacial sands, comprising the Drenthe plateau and a number of isolated moraine outcrops. The highest part, 25 m above sea level, is in the south-east. From there a watershed runs in a north-westerly direction. Brook valleys, cutting into the plateau, drain the area to the north and the south. In the downstream part of these valleys there are river dunes of pleistocene age.
2. The peat zone, consisting of raised bogs on the plateau, along the valleys and in a broad belt between the uplands and the clay marshes. Little is now left of these bogs (Fig. 2, 5). Their original extent is apparent from a palaeogeographic reconstruction for the early medieval period (Fig. 1).
3. The river clay marshes, occurring only in the downstream part of the valley of the Ems, in German territory.
4. The sea clay marshes along the coast, intersected by estuaries and a dense network of creeks, and now largely contained within dykes.
5. The coastal barrier with a number of dune islands and some clay marshes.

Landscape

In this paper I shall use the word 'landscape' in a restricted sense: for the non-urban cultural landscape, by which I mean the ordered structure man has imposed on his natural environment, and which manifests itself in the pattern of settlements, cemeteries, fields, grazing grounds, roads, canals, and dykes, in the architecture of the houses and accessory buildings, in the lay-out of the settlements, and in the parcelling of the fields and the form of the field boundaries.

The diversity of the landscapes in the northern Netherlands can best be illustrated by sections of the ordnance survey map of *c.* 1850 (Fig. 3), in combination with cadastral abstracts of *c.* 1830 (Fig. 4). On most maps I have indicated the boundaries of the village territories. On the central Drenthe plateau we find a landscape of nucleated villages with open arable fields, called *es* (plural *essen*), a ladder-like parcelling of the meadows and hay fields in the brook valleys, and large heath commons (Fig. 3, 1; Fig. 4, 1, 2; Fig. 23; Fig. 24). An *es* is a conglomerate of blocks of parallel parcels, with so few roads that most parcels could only

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VI 158

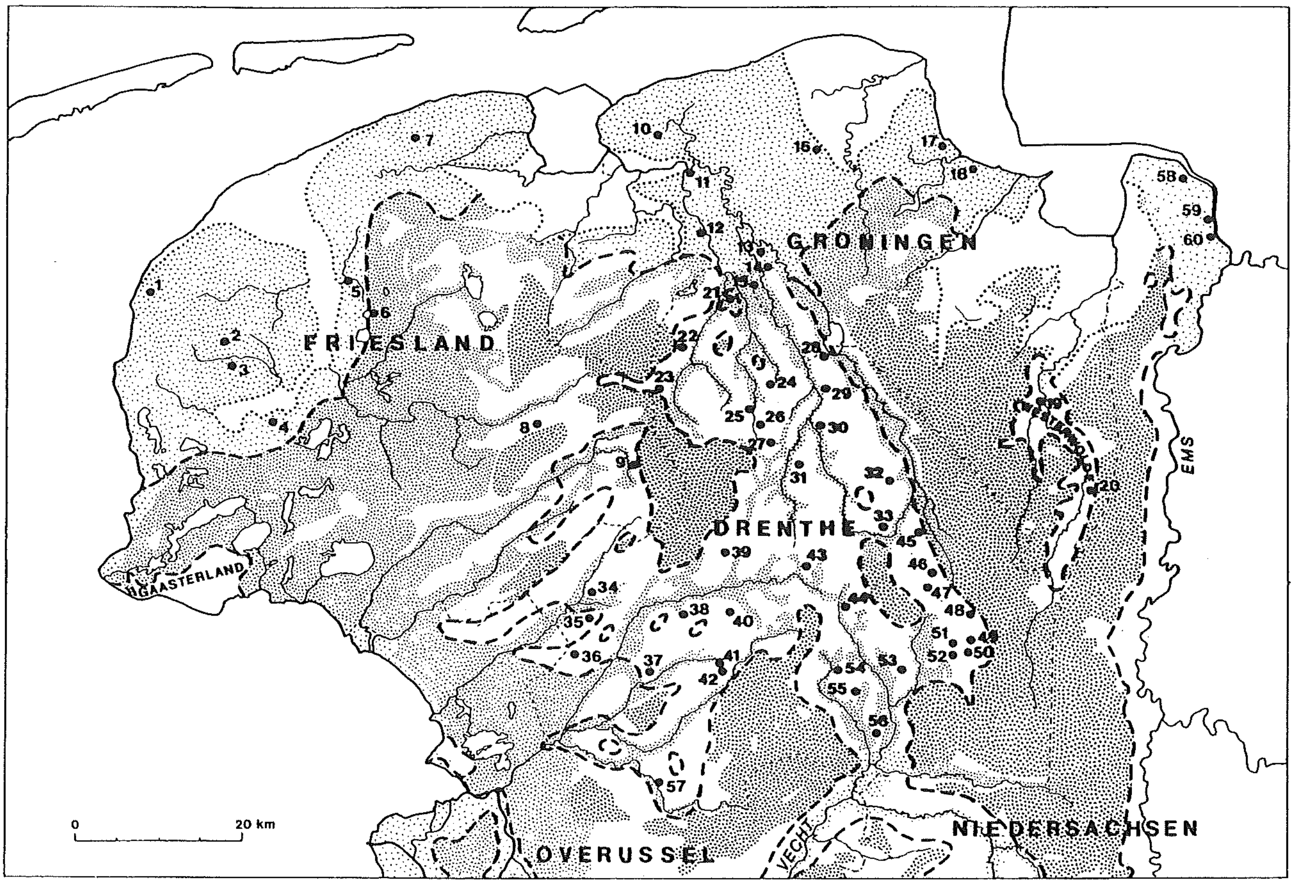


Fig. 1

The northern Netherlands with provincial boundaries and sites mentioned in the text. Different shadings for raised bogs (extension *c.* 1500 AD), valley deposits and fen peat, and marine clays.
Heavy dotted line: estimated maximum extension of raised bogs (*c.* 800 AD). Light dotted line: medieval marine ingressions, now reclaimed.

1. Wijnaldum
2. Tritsum
3. Wommels
4. Sneek
5. Leeuwarden
6. Warstiens
7. Foudgum
8. Wijnjeterp
9. Fochteloo
10. Leens
11. Ezinge
12. Aduard
13. Paddepoel
14. Groningen
15. Neerwolde
16. Middelstum
17. Biessum
18. Heveskesklooster
19. Wessinghuizen
20. Sellingen
21. Peizerwold
22. Roden
23. Een
24. Vries
25. Zeijen
26. Rhee
27. Peelo
28. Midlaren
29. Schipborg
30. Gasteren
31. Balloo
32. Gasselte
33. Borger
34. Wapse
35. Wapserveen
36. Havelte
37. Ruinen
38. Lhee
39. Hijken
40. Wijster
41. Eursinge
42. Pesse
43. Elp
44. Zweeloo
45. Buinen
46. Exloo
47. Odoorn
48. Weerdinge
49. Emmerhout
50. Angelsloo
51. Emmen
52. Noordbarge
53. Sleen
54. Gees
55. Wachtum
56. Dalen
57. Bloemberg
58. Hatzum
59. Jemgum
60. Bentumersiel

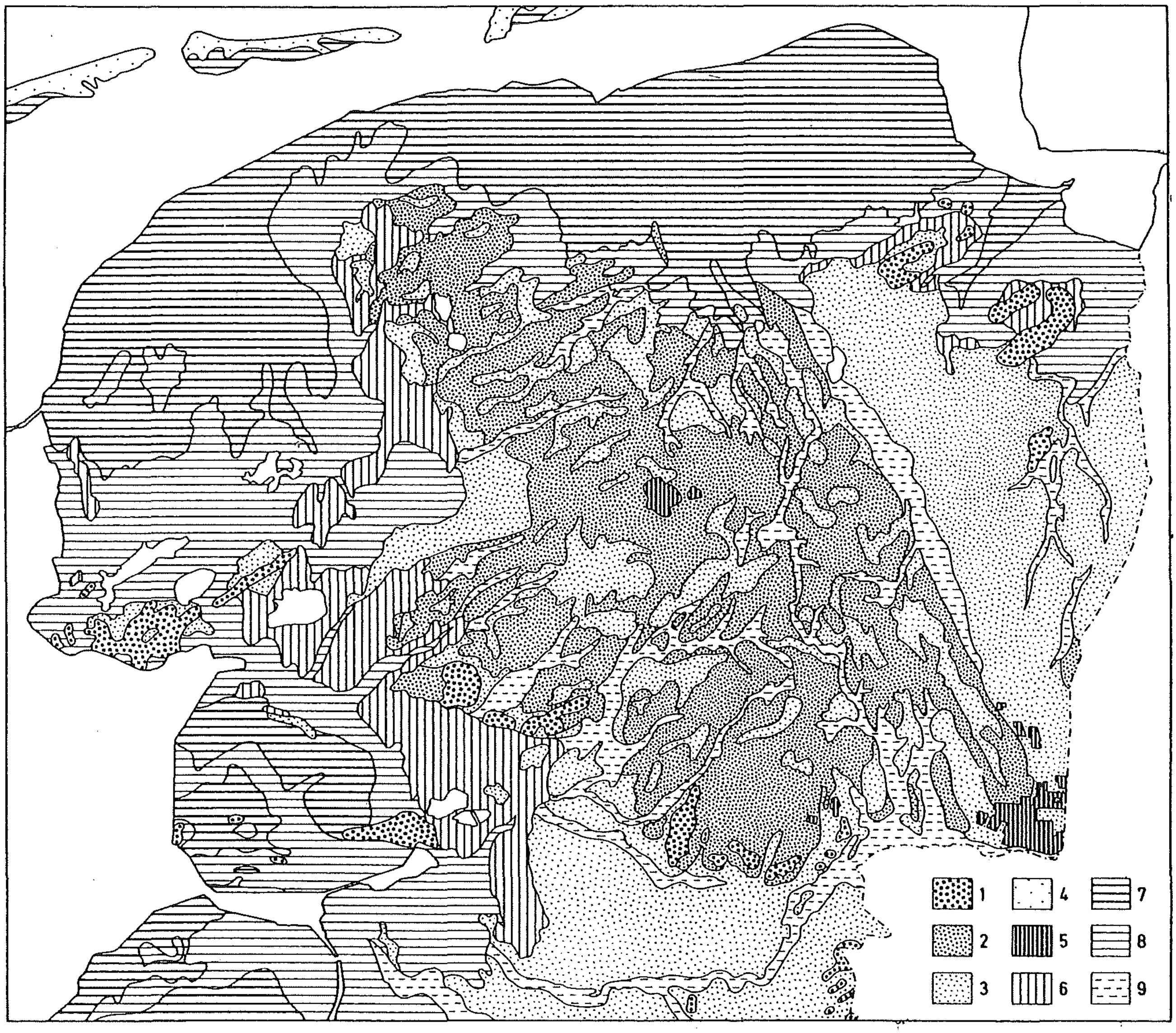


Fig. 2

Simplified geological map of the northern Netherlands. Legend: 1. ice-pushed deposits; 2. ground moraine, melt water deposits, and glacial deposits; 3. cover-sand; 4. dune and shore deposits; 5. raised bog remains; 6. (fen) peat; 7. marine clay; 8. clay on peat; 9. brook deposits.

be reached over neighbouring land. *Essen* are situated on natural elevations. They have a thick humus layer, resulting from sheep manure mixed with sods.

Around the plateau and all over the former peat zone the so-called *streek* villages dominate. Here the farms stand in an often irregular line along a road or path. Elongated strip holdings stretch over the whole breadth of the village territory (Fig. 3, 2; Fig. 4, 3).

Locally, at the periphery of the plateau, and along some moorland brook valleys, we find the landscape of the *es* hamlets with isolated farms or farm groups, and small *essen* (Fig. 3, 3). On the isolated moraine outcrops in the peat zone various intermediate forms between the *es* and *streek* villages occur. For Drenthe in its medieval form — which included parts of the adjacent provinces — a map of the village territories (Fig. 5) will serve as a background for some of the distribution maps plotted below.

In the clay marshes, settlements on artificial mounds called *terp* or *wierde* predominate. In the 19th and

VI 160

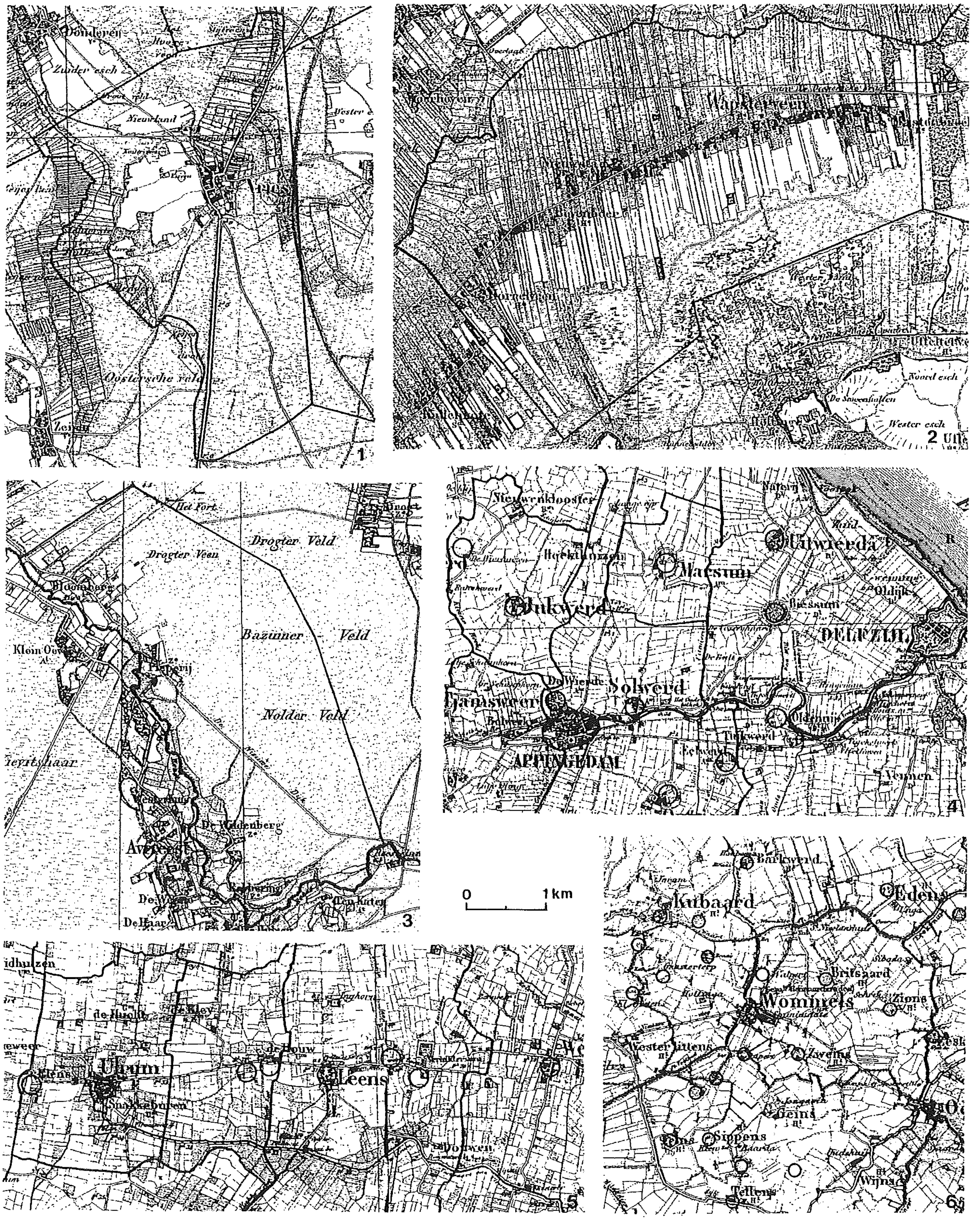


Fig. 3

Excerpts of the first topographical map of the Netherlands (*c.* 1850), showing various types of historic landscapes. Heavy line: border of village territory.

1. *Es* village of Vries; 2. *streek* village of Wapserveen; 3. *es* hamlet complex of Bloemberg; 4. *terp* landscape with radial parcelling of Biessum and surroundings; 5. *terp* landscape with rectangular parcelling of Leens and surroundings; 6. *terp* landscape with irregular parcelling of Wommels and surroundings (borders of village territories not indicated).

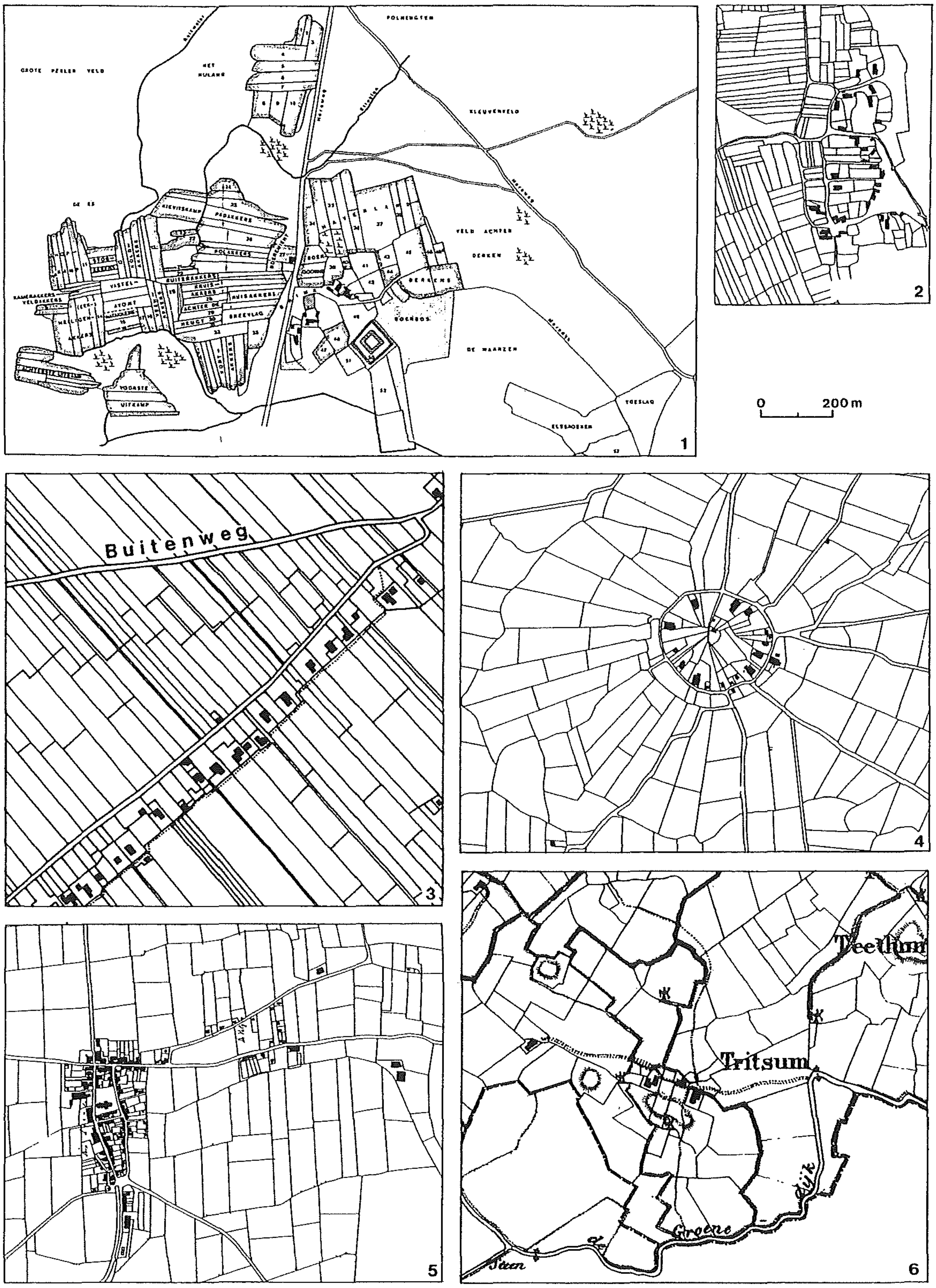


Fig. 4

Excerpts of the first cadastral maps (*c.* 1825). 1. small *es* village of Peelo with names of field complexes (moated site dates from the 16th century); 2. large *es* village of Zeijen with adjacent parts of the *es*; 3. part of the *streek* village of Wijnjeterp; 4. *terp* village of Biessum with radial layout; 5. *terp* village of Leens with rectangular layout; 6. *terp* hamlet of Tritsum with irregular layout.

VI 162

Fig. 5

The county of Drenthe in its reconstructed early medieval extension with the historic territorial boundaries. Heavy dot: primary *es* villages; open circle: daughter *es* settlements and *es* hamlets; block lines: *streek* villages.

early 20th centuries the phosphate-rich *terp* soil was systematically dug away to be used as a fertiliser for the sterile moorland soils in the hinterland. As to the structure of the landscape, four types can be distinguished: first, round *terpen* with a circular road and a radial parcel pattern extending into the surroundings (Fig. 3, 4; Fig. 4, 4), second, *terpen* with a regular north–south/east–west pattern of roads and parcels extending into the surroundings (Fig. 3, 5; Fig. 4, 5), third, elongated *terpen* with a central road — a type more common in northern Germany —, and fourth, mostly smaller *terpen* with an irregular layout both on the mound and in the surroundings (Fig. 3, 6; Fig. 4, 6). As a sample area I shall use the marsh area north-west of the town of Groningen, which itself is situated on a spur of the plateau (Fig. 6). Finally, on the islands, we find nucleated villages with semi-circular ring-dykes protecting the vital parts of the village territory.

Excavations

In this area the results of many excavations tell us about the structure of the landscape in the past. In the

VI 163

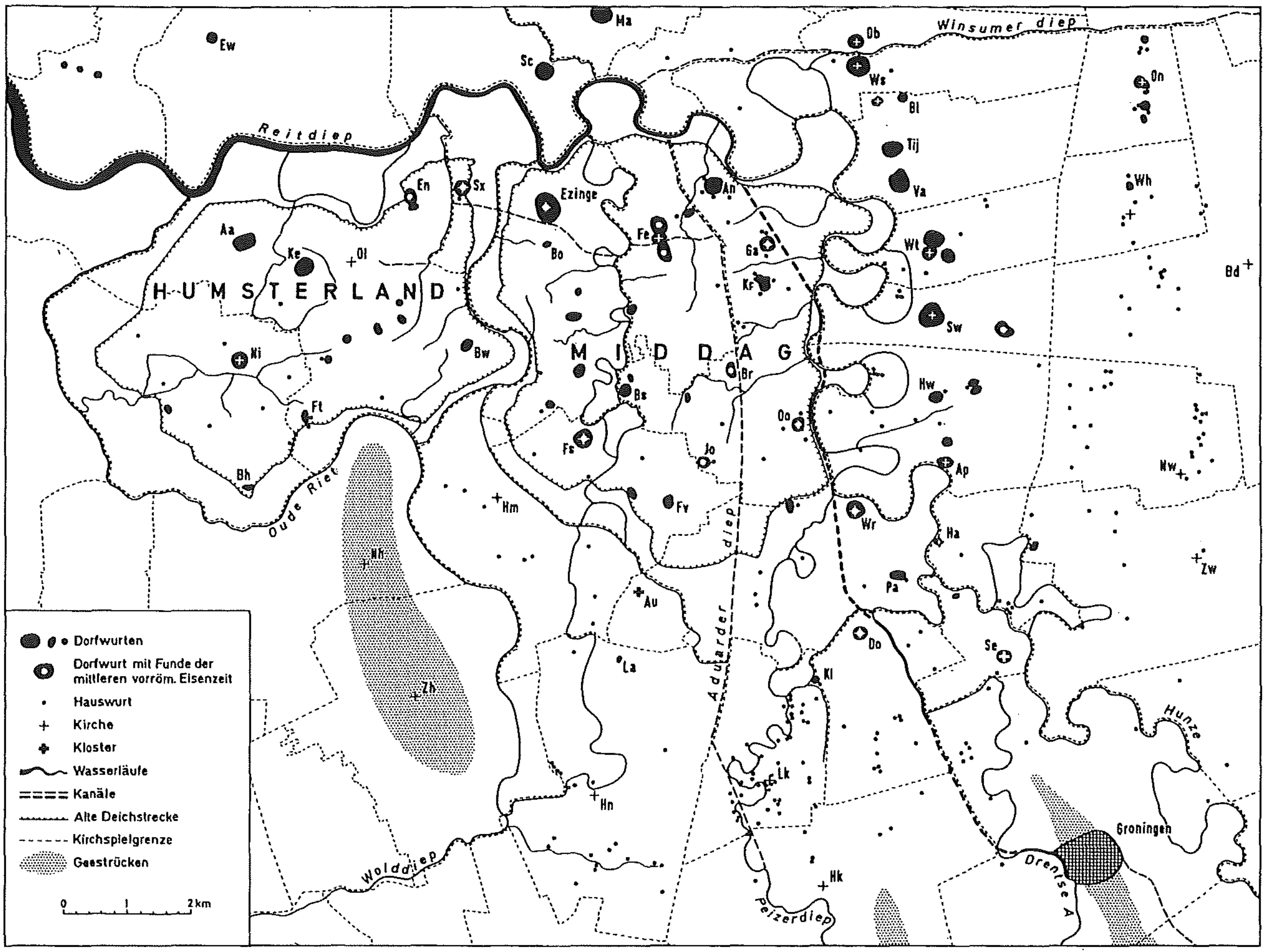
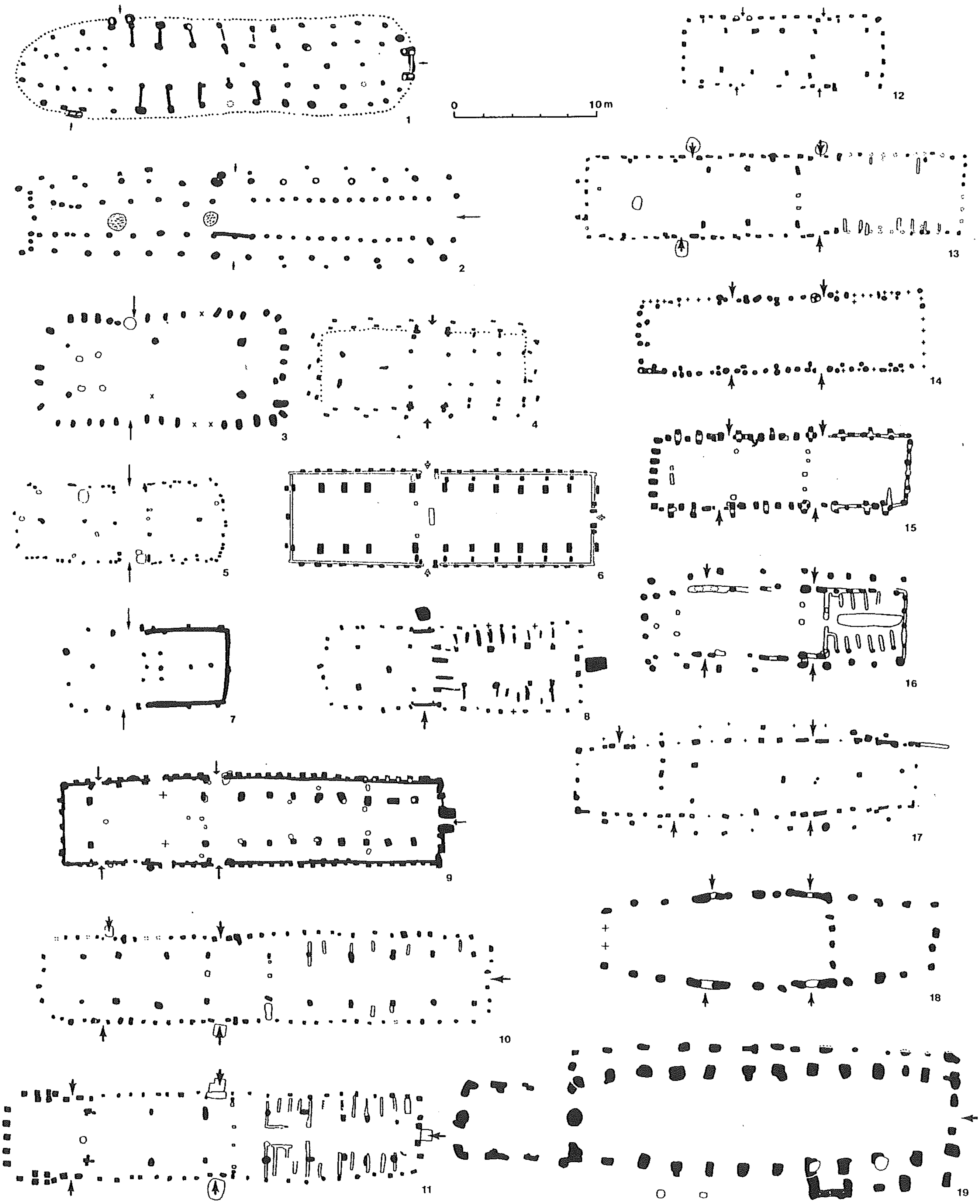


Fig. 6

Map of the clay marsh area north-west of Groningen. Translation of legend: 1. village *terpen*; 2. village *terpen* with finds going back to the Middle Iron Age; 3. house *terpen*; 4. church; 5. monastery; 6. rivers and creeks; 7. canals; 8. ancient dykes; 9. parish boundary; 10. sand ridge.

first half of the present century my predecessor, van Giffen, was a very active excavator (Waterbolk 1973a; 1976; 1989a). His excavations in the early 1930s of the Iron Age dwelling mound of Ezinge in the clay marshes north of Groningen, with its well preserved house remains and succession of village plans (van Giffen 1936a; Waterbolk 1991a) are famous (Fig. 10). Equally important are his settlement excavations, of the late 1930s, on the sandy plateau south of Groningen, for example at Fochteloo, where soil traces of post-holes allowed the identification of clear plans of aisled houses of the Late Iron Age with surrounding ditches and fences (van Giffen 1958). Other important sites excavated by van Giffen in the period include Zeijen (van Giffen 1936b), Rhee (van Giffen 1940a), and Sellingen (van Giffen 1939). In those years of massive unemployment van Giffen was able to use state-paid labour, allowing him to open up large areas. Succeeding him in 1954, I soon saw the opportunity for further large-scale settlement excavations on the plateau, now with the aid of draglines, bulldozers, and other machinery. After an interesting walled enclosure at Vries (van Es 1958; Waterbolk 1977), our first major object was Roman period Wijster, which produced detailed house plans and a great deal of evidence on the structure of the settlement (van Es 1967; Fig. 19). After this we excavated Bronze Age settlements at Elp (Waterbolk 1964; 1986; 1987a; Fig. 8), Emmen–Angelsloo/Emmerhout (van der Waals & Butler 1976), Hijken (Harsema 1992; Fig. 10), and Dalen (Kooi

VI 164



VI 165

1991); Iron Age settlements at Hijken (Harsema 1992), Noordbarge (Harsema 1980; Fig. 13) and Peelo (Bardet *et al.* 1983; Kooi 1994a; Kooi & de Langen 1987); another Roman period settlement at Peelo (Kooi *et al.* 1987; Fig. 18); and medieval sites at Odoorn (Waterbolk 1973b; 1991b; Fig. 20), Eursinge (Lanting 1977), Gasselte (Waterbolk & Harsema 1979; Fig. 22), Pesse (Harsema 1984), and again Peelo (Kooi 1986; 1995; Fig. 25). In the clay marshes, where van Giffen had, in 1940, excavated the early medieval site of Leens (van Giffen 1940b; Fig. 21), the sites of Tritsum (Waterbolk 1961), Sneek (Elzinga 1962), Warstiens (Elzinga 1970), Paddepoel (van Es 1970), Foudgum (de Langen 1992), Leeuwarden (van Es & Miedema 1972; de Langen 1992), Middelstum (Boersma 1983; Fig. 15), and Heveskesklooster (Boersma 1988) produced interesting new evidence. For the peat zone can be mentioned the sites of Peizerwold (van Giffen 1944), Wijnjeterp (de Langen 1992; Fig. 26), and Neerwolde (Casparie 1988).

The research has involved the participation of many colleagues, co-workers and students and this paper is presented with thanks for, and due hommage to, their hard work. I have endeavoured to list them in my acknowledgements.

I start my overview with the Middle Bronze Age. It is only from that period onwards, that information is available on house and settlement structures. For the earlier periods the nature of the soil allows the recognition of post-holes, fences, etc, only in exceptional cases. But we do, of course, have our Middle Neolithic megalithic tombs and Late Neolithic and Early Bronze Age burial mounds, as well as material from settlement sites of these periods. Figure 7 is a summary chart of the main house types excavated on the Drenthe plateau. For a study of their reconstruction see Huijts (1992).

MIDDLE AND LATE BRONZE AGE

In the Bronze Age, habitation was restricted to the Drenthe plateau and the morainic outcrops and dunes along the river Westerwoldse A in the eastern part of the province of Groningen. It is in this latter area that van Giffen in the 1920s discovered the famous timber circles around the Middle Bronze Age barrows (van Giffen 1938). In 1928 Gordon Childe came expressly to see these Dutch circles, which were so reminiscent of the British henge monuments (van Giffen 1960). Personally I remember with pleasure our display of such a barrow at Elp in 1960, when the Prehistoric Society visited our country. It contained two successive timber circles and a total of 12 graves.

Having come across some additional post-holes at the north-eastern foot of this barrow, excavation continued in the following years and found, in an area of only 6000 m², the plans of 10 aisled houses, most of them with distinct living and byre sections — now known as the Elp type (Fig. 7, 2) —, 12 granaries, 4 small and 2 large accessory buildings, remains of at least 2 cattle kraal fences, and a group of 7 flat graves (Waterbolk 1964; 1986; 1987a). Radiocarbon dates show that only the early phases could be contemporary with the barrow interments and the flat graves. The site is divided into two parts, one of which had been occupied six times, the other four. Corrected radiocarbon dates, most of which cannot be related with certainty to specific houses, cover over 800 years. If we assume a duration of 30 years for each phase, at least 500 years are unaccounted for. Other sites can therefore be expected in the neighbourhood, probably at the edge of the same brook valley west of the village, close to a Late Bronze Age urn cemetery that may have succeeded our barrow. Two phases are emphasised on Figure 8.

Fig. 7 (*opposite*)
Major house types from Drenthe.

1. Type Emmerhout (Emmerhout, Middle Bronze Age)
2. Type Elp (Angelsloo, Late Bronze Age)
3. Type Een-Angelsloo (Peelo, Early Iron Age)
4. Type Hijken (Hijken, Middle Iron Age)
5. Type Dalen (Noordbarge, Middle Iron Age)
6. Type Fochteloo A (Fochteloo, Late Iron Age)
7. Type Noordbarge (Noordbarge, Late Iron Age)
8. Type Wijster A (Wijster, Early Roman period)
9. Type Fochteloo B (Peelo, Early Roman period)
10. Type Peelo A (Peelo, Late Roman period)
11. Type Wijster B (Wijster, Late Roman period)
12. Type Peelo B (Peelo, 5th century AD)
13. Type Eursinge (Eursinge, 5/6th century AD)
14. Type Odoorn A (Odoorn, *c.* 6th century AD)
15. Type Odoorn B (Odoorn, *c.* 7th century AD)
16. Type Odoorn C (Odoorn, *c.* 8th century AD)
17. Type Odoorn C (Gasselte, 9th century AD)
18. Type Gasselte A (Peelo, 10th century AD)
19. Type Gasselte B (Peelo, 11–14th century AD)

VI 166

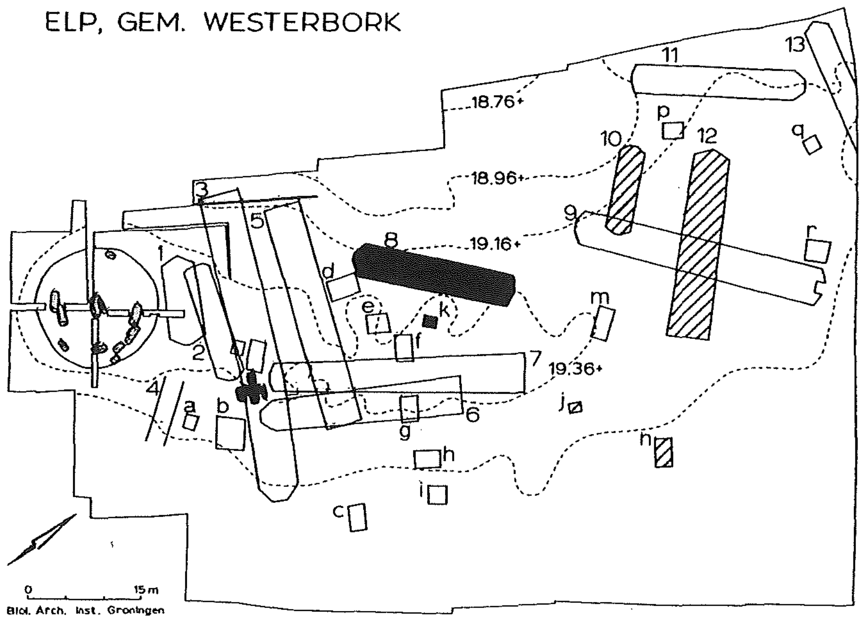


Fig. 8
Elp. Barrow, flat grave group and settlement. Black: phase d (house 8 of Emmerhout-type, granary k and flat graves; Middle Bronze Age). Hatched: phase f (house 12 of Elp type, barn 10, granaries j and n; Late Bronze Age).

More evidence on the area within which houses and fields shifted is available from Zeijen, Hijken, Angelsloo, and Emmerhout. At Zeijen, Middle Bronze Age barrows and secondary burials in Neolithic barrows all lie near an ancient historic trackway, the *King's Road*, along a stretch of *c.* 1000 m (Waterbolk 1985; Fig. 9). To the east of the barrows is a large Celtic field. Here one would expect to find the house sites and fields. That this is indeed probable is demonstrated at Hijken (Harsema 1992; Fig. 10). At this site Middle Bronze Age barrows, in two groups, follow another ancient road which, as at Zeijen, is already indicated by an alignment of Late Neolithic barrows. In the south-western part of the adjacent Celtic field an area of 30,000 m^2 was opened up. In addition to Iron Age house plans it contained the plans of ten Middle Bronze Age houses of a type first discovered at Emmerhout (Fig. 7, 1). The houses follow the main orientation of the Celtic field banks, at right-angles to the road.

The richest settlement evidence has been obtained at the neighbouring sites of Angelsloo and Emmerhout in the south-east corner of the region near the expanding town of Emmen. Here some 60 Middle and Late Bronze Age house plans, 25 barrows, and 3 urnfields were excavated. A few house plans are from the Early Iron Age. In the immediate vicinity are two large Celtic field systems. Among the Bronze Age house plans is the eponymous plan of the Emmerhout type, with the central cattle stalls (Fig. 7, 1). One of the Elp-type houses was well preserved; it had two fire places (Fig. 7, 2). Among the buildings at Angelsloo, three, succeeding each other, stand out by their length — up to 60 m — and the absence of any indication of cattle stalls. A report on the excavations is being prepared by P. B. Kooi. Rich bog and grave finds in the area (Butler 1993), such as the necklace of Exloo with beads of amber and segmented ones of tin and fayence, or the string of amber beads and bronze pins in a grave at Weerdinge, show the prosperity and international orientation of this part of the plateau. Perhaps the long halls were central meeting places.

At the site of Dalen (Kooi 1991), Emmerhout-type houses show clear evidence of repair, whereby one end of the house was pulled down while at the other end a new part was added. In one case this happened three times. Such repair patterns are also observed in Elp-type houses at Angelsloo and Emmerhout. More

VI 167

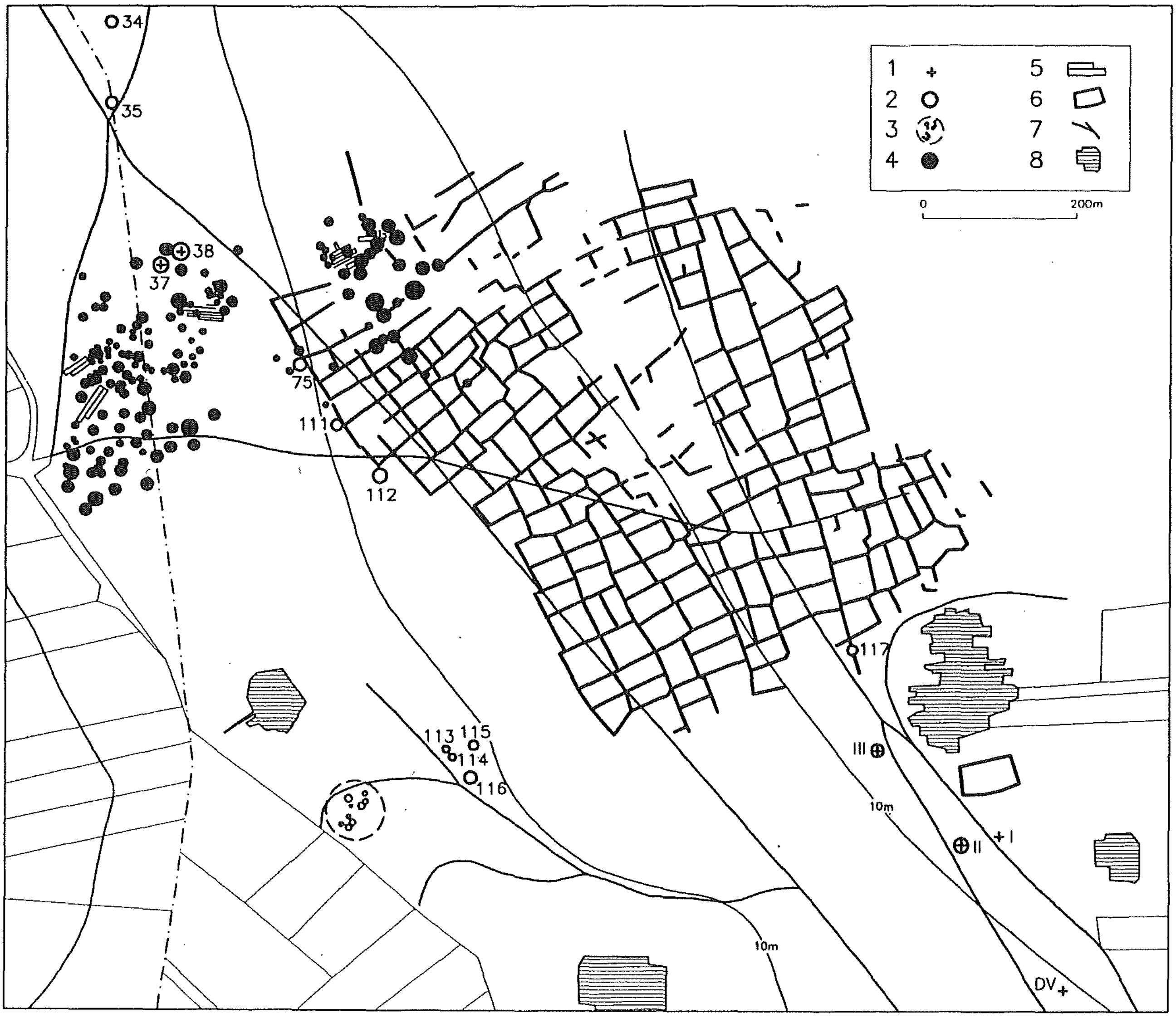


Fig. 9

Zeijen. Celtic field, barrows, urnfield, walled enclosure, and road tracks. Legend: 1. Neolithic megalithic grave, barrows, and flat graves; 2. Middle Bronze Age barrows and secondary interments in Neolithic barrows; 3. Late Bronze Age urnfield; 4. Iron Age cremation barrows (and undated barrows); 5. Iron Age long barrows; 6. Late Iron Age walled enclosure; 7. major cart tracks; 8. peat cuttings.

recently, good Bronze Age settlement evidence has been obtained at Roden (Harsema 1993) and Borger (excavations by P. B. Kooi 1995).

Among van Giffen's early discoveries are the Late Bronze Age and Early Iron Age urn cemeteries with their variety of post-settings and peripheral ditches (Waterbolk 1962). In contrast to the loose structure of the preceding barrow cemeteries, the urn fields are always dense concentrations of interments. A good example was excavated at Noordbarge (Kooi 1979). The situation was complicated by the presence at the same place of Iron Age house remains and medieval reclamation ditches. A narrow free zone through the cemetery suggests an ancient road. Such road indications are common. If we find them in adjacent cemeteries as well, the regional road network may be

VI 168

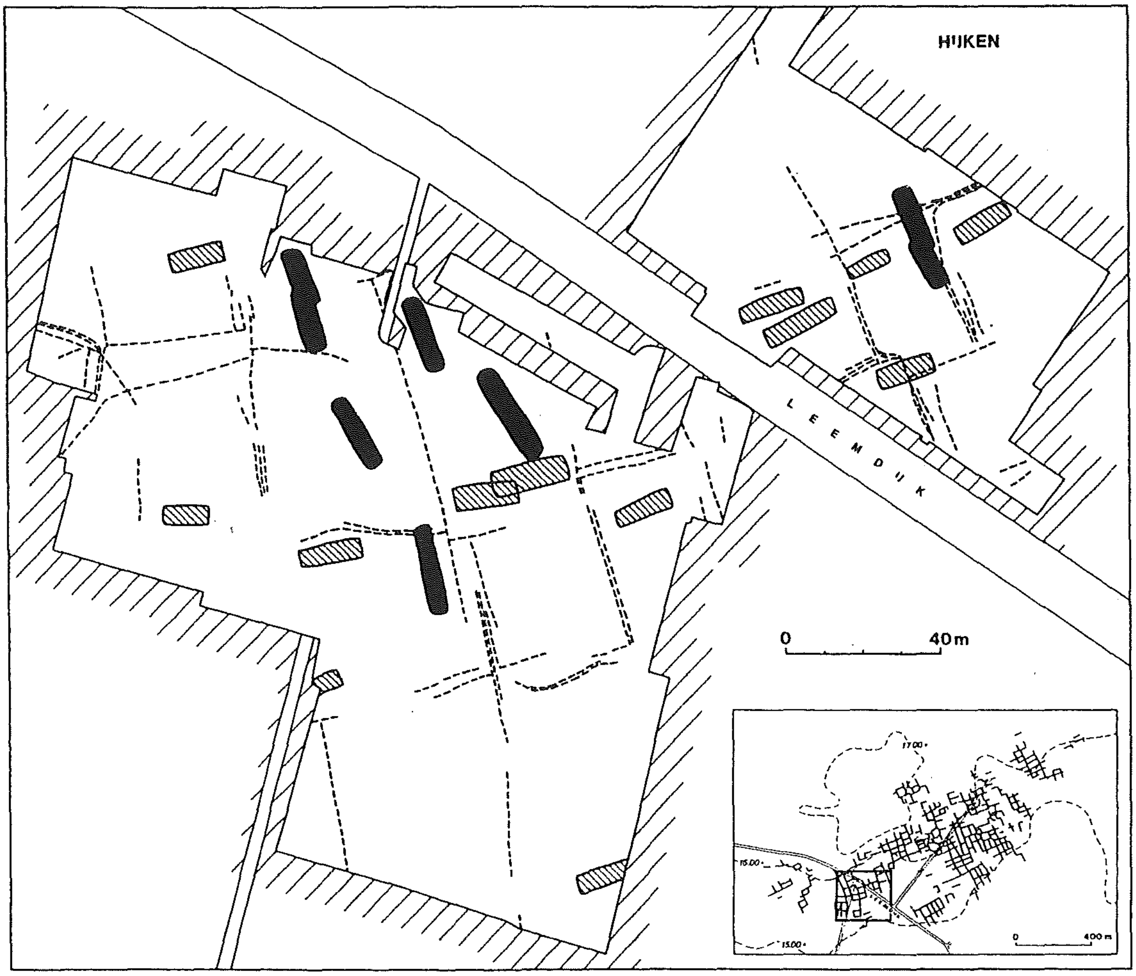


Fig. 10
Hijken. Excavated part of Celtic field. Black: Middle Bronze Age houses of Emmerhout-type; hatched: Middle and Late Iron Age houses of Hijken- and Fochteloo A-type; dotted lines: stake fences.

reconstructed, as has been done by Kooi (1979) in south-east Drenthe. Some of these roads, too, roughly coincide with historic roads. Indeed, it may well be that the regional road network is one of the oldest elements in the historic peasant landscape.

Figure 11 is a distribution map of Middle Bronze Age barrows (Waterbolk 1987) and Figure 12 of Late Bronze Age urnfields combined with the Celtic fields. For the purposes of easy comparison, individual dots represent all occurrences within 1000 m for barrows, within 500 m for urnfields, and within 1500 m for Celtic fields — if not separated by brook valleys. On both maps we see occupied areas that later became overgrown with peat. Leaving these aside, we find in more than half of the historic village territories only one Middle Bronze Age barrow cemetery. When there are two, an adjacent small territory may be empty. Hiatuses can be explained by the medieval *essen*, covering potential findspots and by some large drift-sand areas which developed in the 18th century AD. In contrast, there are at least twice as many urnfields. Since most barrow cemeteries have an adjacent urnfield, this must mean that new urnfields were established. Very often the distance between urnfields and Celtic fields is less than 1500 m, which suggests that they belonged together. If we include isolated occurrences of both categories, and take into account the obvious hiatuses, we arrive at a total for the Drenthe plateau of *c.* 250 settlement units in the Late Bronze Age — $2\frac{1}{2}$ times as many as the Middle Bronze Age

VI 169

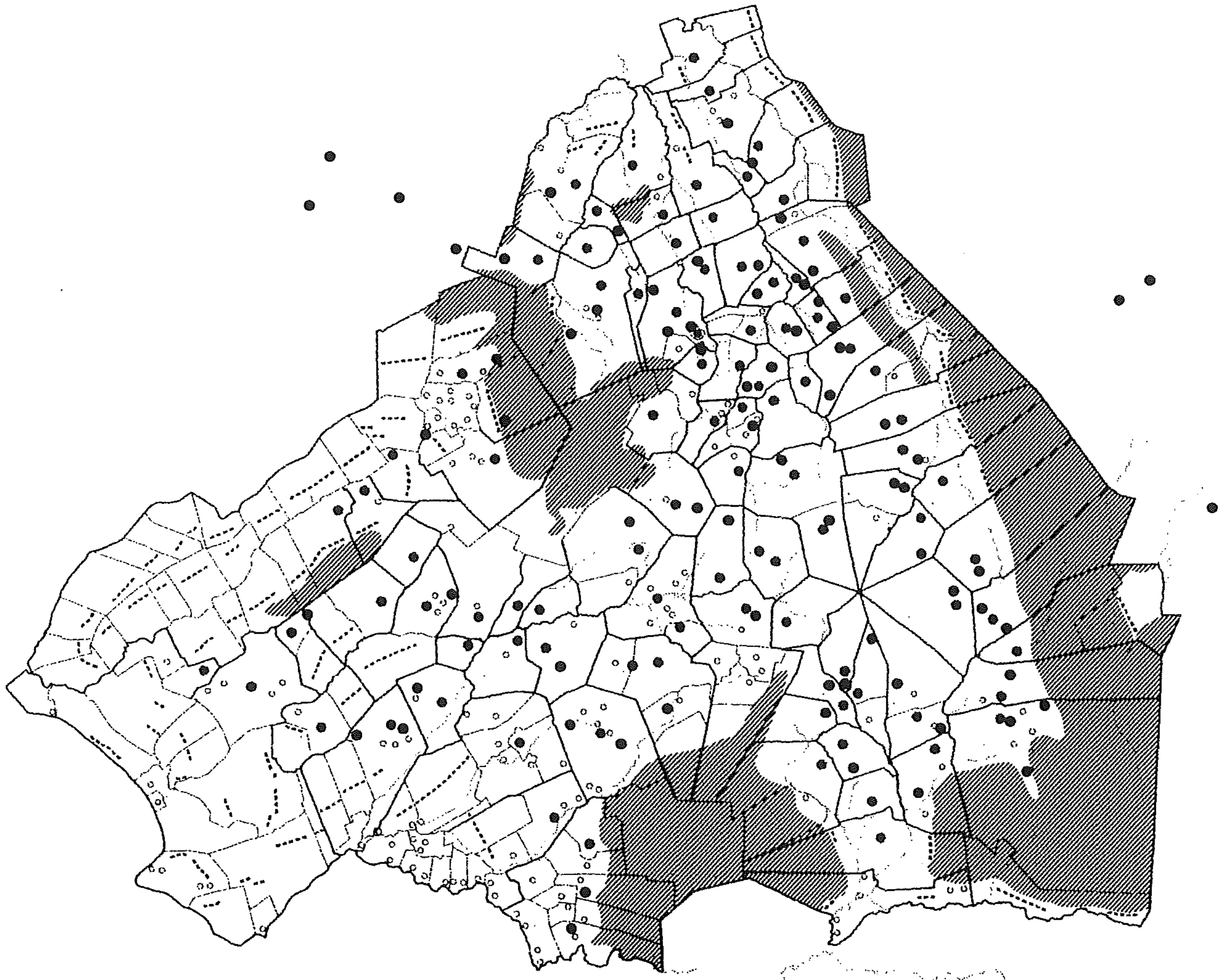


Fig. 11
Distribution of Middle Bronze Age barrow cemeteries on the Drenthe plateau and in Westerwolde.

barrow cemeteries and the historic village territories. The internal expansion in the urnfield period is explained by the occupation of those parts of the boulder-clay plateau that had only a shallow cover of sands and had been avoided in the preceding periods (Spek 1993). Perhaps the Late Bronze Age tools were better suited for dealing with heavier vegetations and soils. Another factor might be the increased need for grazing grounds. The Late Bronze Age Elp-type buildings could house many more cattle than the Middle Bronze Age buildings of Emmerhout-type.

In a pattern of shifting fields and settlements and with increased need for grazing grounds, a growing population might easily result in the splitting off of daughter settlements, which would mark their relative independence by starting a cremation cemetery of their own. It may well be, though, that for certain activities they kept in touch with the parent settlement and with the barrows of their remote ancestors. Frequently one finds isolated Late Bronze Age or even Early Iron Age burials in the top of the barrows (Waterbolk 1962).

The Late Bronze Age map shows four concentrations of habitation, roughly coinciding with the main drainage systems and separated by the watersheds and the growing raised bogs. There is some evidence for a differentiation in material culture. Key-hole shaped ditches of Westphalian types only occur in south-east Drenthe and Westerwolde; north Drenthe has in its material culture much affinity with the north German coastal area. Whilst a road network linked the

VI 170

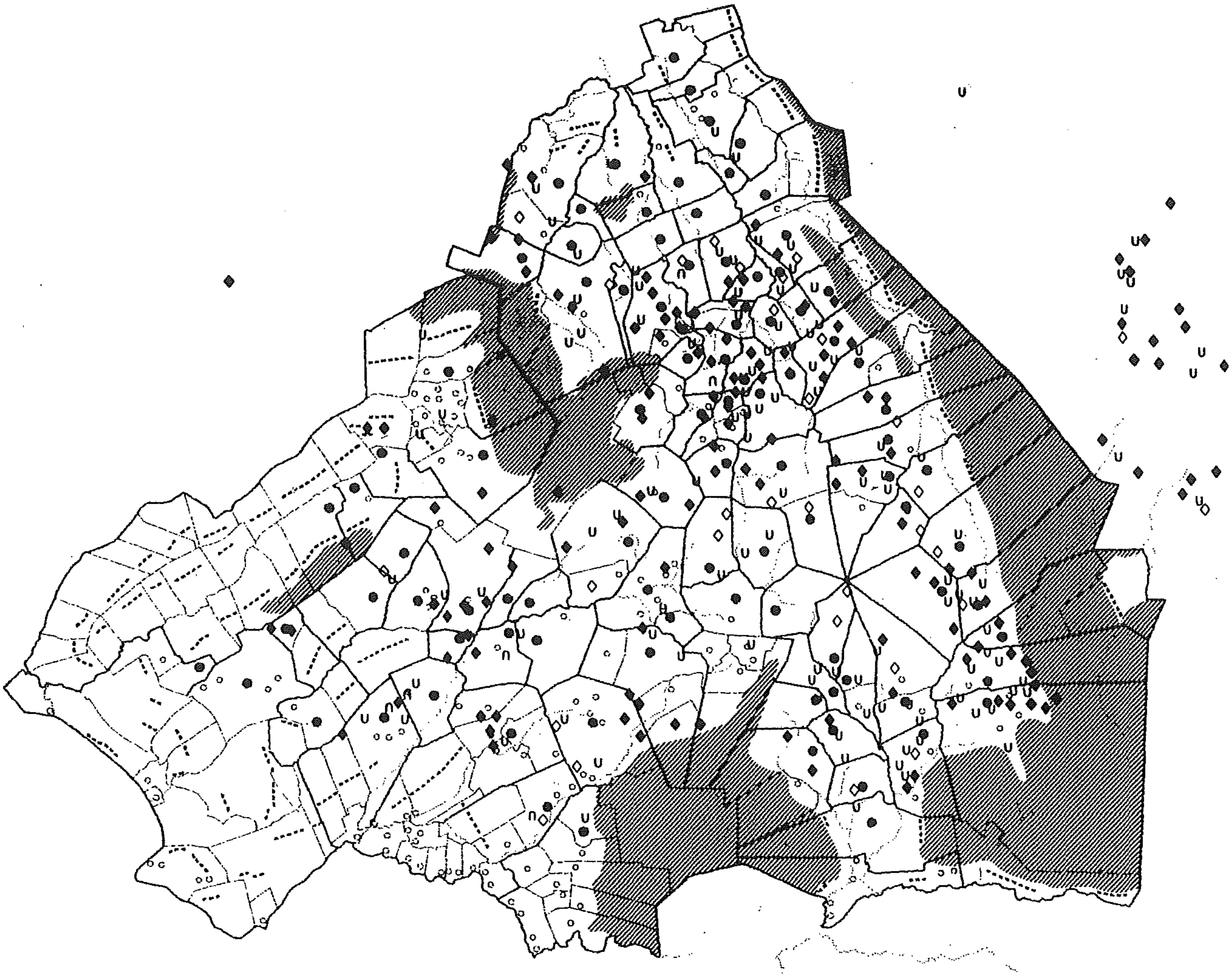


Fig. 12
Distribution of Celtic fields (lozenges) and Late Bronze Age/Early Iron Age urnfields (u-signs) and additional Middle to Late Iron Age *Brandhügel* cemeteries (n-signs) on the Drenthe plateau and in Westerwolde.

settlements on the plateau, contact with the outside world mainly depended on the waterways, and these were of course very different for the four regions.

How many people lived in a settlement? How many houses co-existed at any given moment? Assuming that all children over a certain age and all adults were buried in an urnfield, and assuming a life expectancy of 30 years, we can calculate a mean population per completely excavated cemetery. Such calculations lead to estimates of 5–25 people, that is one to three or four houses. In some cemeteries detailed study of the burial sequence confirms this calculation. At Wessinghuizen (van Giffen 1938) and Noordbarge (Kooi 1979) the evidence suggests two contemporaneous farms; at Sleen (Kooi 1979) three. The two barrow groups at Hijken suggest two contemporaneous groups in the Middle Bronze Age population, which would mean that, of the ten houses in the excavated area, no more than two would have co-existed. The urnfield of Hijken has been localised but not excavated.

IRON AGE

Most Late Bronze Age urnfields remained in use in the Early Iron Age. Single circular ditches prevail, but urn interments without a peripheral ditch predominate locally. Good examples have been excavated at Wapse (Waterbolk 1957), Havelte (Kooi 1979), Gasteren (van

Giffen 1945), and Balloo (van Giffen 1935). In the Middle Iron Age a change takes place. The deceased are still cremated but the cremated bones, together with the charcoal, are left on the spot of the pyre, which is covered by a, usually, low mound surrounded by a circular or square ditch or stake fence. The cemetery of Ruinen (Waterbolk 1965) is a good example. Later in the Iron Age mounds are generally higher and are constructed of piled up sods. Such barrows, called *Brandhügel* always lie close together.

Gasteren and Balloo are examples of cemeteries that remained in use from the Middle Bronze Age until well into the Middle Iron Age. Many urnfields, however, had been given up already in the course of the Early Iron Age. Among them were quite a few that had been founded in the Late Bronze Age, like the one at Buinen. Because of the lack of closely datable finds and grave forms it is difficult to assess the process of depopulation in detail. But we do get a picture of the resulting settlement pattern if we map the cemeteries with earth-covered pyre remains of the Late Iron Age. The result (Waterbolk 1979) is a neat 1:1 relation to the present village territories. In many cases there is even some sort of systematic siting just outside the *es*, opposite the village. In the northern and eastern periphery of the region some territories appear to have been deserted.

Though the cemeteries are generally very poor in finds, there are a few notable exceptions, such as the dagger and horsegear of Havelte (Jope 1961; Kooi 1983), suggesting the continuous presence of an elite in contact with the outside world.

It is in the Early Iron Age that the banks of the Celtic fields attained the height that make them so clearly detectable in air photographs (Brongers 1976). These banks must have grown out of the unharvested plant remains with adhering earth that were thrown aside after the harvest. Their great width, often more than 5 m, resulted from trampling by cattle and sheep when the plots were used for grazing.

Good examples of Early Iron Age house plans (Fig. 7, 3) with accompanying granaries have been excavated in the Celtic fields of Sellingen and Peelo (Kooi & de Langen 1987). Some 13 Middle and Late Iron Age houses (Fig. 7, 4), all oriented east–west, and with many surviving details, have been excavated in the Celtic field of Hijken (Fig. 10). Here palisade fences were found both in and under the banks which suggests that they served to protect the fields and the farmyards when the plots were in use. Other Early Iron Age

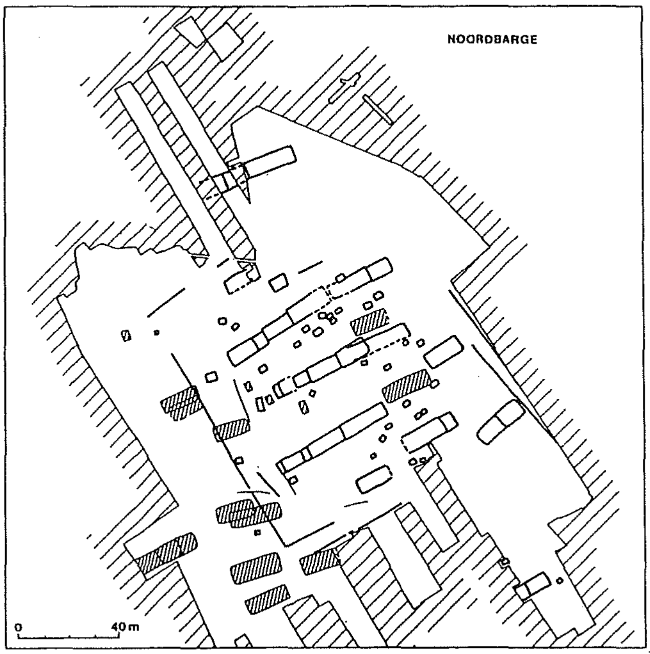


Fig. 13
Noordbarge. Middle and Late Iron Age houses (hatched) of Hijken-, Dalen-, and Fochteloo A-types and fenced village of the Late Iron Age/early Roman period with houses of Noordbarge-type.

houses have been excavated at Een (van der Waals 1963), Angelsloo, and Emmerhout. At Noordbarge (Fig. 7, 7; Fig. 13) a group of Middle and Late Iron Age houses were succeeded in the Late Iron Age by a fenced settlement of five houses, set at equal distances, three of which were repeatedly rebuilt. The site has a parellel at Rhee (Waterbolk 1977, where I probably wrongly attributed the enclosure to the group of walled enclosures to be discussed below). Here we have the first instance of a structured semi-permanent settlement, a real village. The sunken huts between the houses are another innovation.

New also is the occurrence, so far only at Zeijen and Vries in north Drenthe, of small walled and palisaded enclosures dating to the Late Iron Age and perhaps the 1st century AD (Waterbolk 1977). Though they only contain barns and granaries and no houses, pottery and quern finds point to domestic activities. Our provisional interpretation is that they were staple places, but they may have served religious purposes as well. Whether the defences had a real function or were just symbolic is difficult to tell. Details of entrances and peripheral structures are reminiscent both of the

VI 172

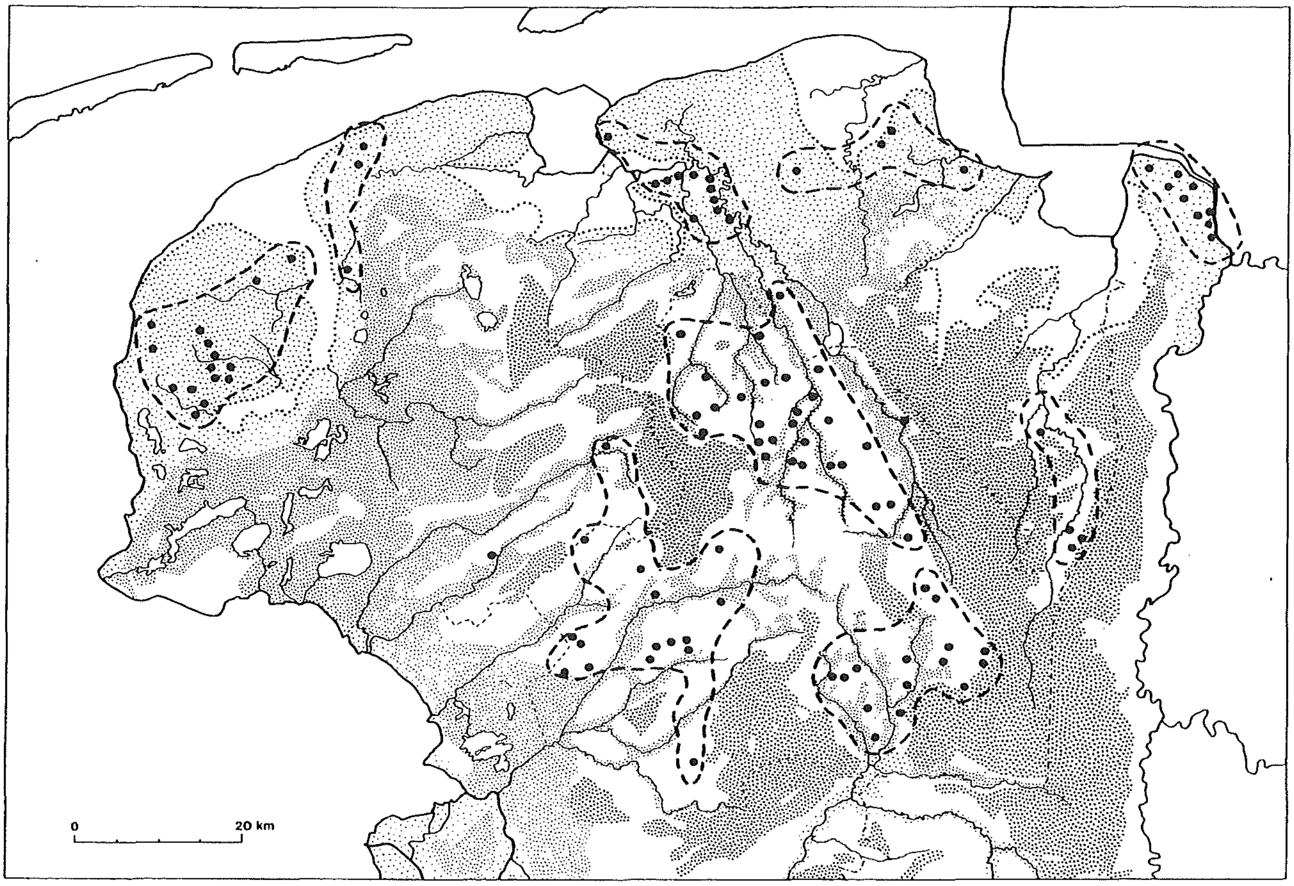


Fig. 14
Distribution of Middle Iron Age pottery types RWI and RWII. Dotted lines enclose supposed nuclear regions.

Iron Age hillforts and the square-walled offering sites in the La Tène world to the south.

A major event in the occupation history was the colonisation of the clay marshes, which had gradually silted up and become habitable as the sea level rise slowed down in the Bronze Age (Waterbolk 1959; 1966). A distribution map of the two main pottery types of the Middle Iron Age (Fig. 4) illustrates what happened. In addition to the four plateau regions we now also find four concentrations of habitation in the sea marshes and one on the Ems river marshes. This sudden colonisation took place in the early part of the Middle Iron Age, around 500 BC, and must have had a prelude. We assume that in the preceding Early Iron Age transhumance had taken place from the plateau (van Gijn & Waterbolk 1984). We have seen that in the course of the Late Bronze Age the whole plateau had become settled and that cattle were numerous. At the same time the rise of the water table and the expansion of the raised bogs continued. On the drier parts, however, in use since the Neolithic, sand dunes formed. In the course of time, they not only covered Celtic fields and house sites after they were ploughed over, but also the grazing grounds with intact soil profiles. All this must have meant a serious reduction of the quality and quantity of the grazing grounds, to which transhumance might have been an answer. Yet it is difficult to find proof of our hypothesis. In the western part of the base level of the marsh site of Middelstum (Boersma 1983) which, given the radiocarbon dates, may well go back to the Early Iron Age, small huts were discovered which can be interpreted as summer dwellings (Fig. 15). Experiments may have shown that it was possible to grow and harvest various summer crops, and at a certain stage a massive emigration took place, so that in a relatively short time all the best marshes were occupied, each by a group of adjacent settlements, as in the homelands. In Westerwolde the whole population left for the marshes (Groenendijk 1993).

In the area north-west of Groningen (Fig. 6) eight *terpen* have produced finds from the Middle Iron Age. The Ezinge excavations (around the churchyard) provided settlement evidence (Boersma & Waterbolk 1976; Waterbolk 1991a; Fig. 16, 1–2), which unfortunately was rather incomplete. In period I an aisled house with three large granaries stood within a rectangular palisade fence, and in period II the byre section of a large farmhouse was revealed, standing on a low mound, with an unusual number of accessory buildings. For both periods the rest of the settlement remains hidden under the 7 m-high village mound bearing the church and modern cemetery. The lay-out of the contemporaneous site of Boomborg, one of a series of settlements on the banks of the Ems, is more regular. In period III there were 5–6 contemporary houses, each accompanied by a single granary or accessory building (Haarnagel 1969; Fig. 17). This site, as well as the neighbouring site of Jemgum (Haarnagel 1957), were excavated by our German colleagues from Wilhelmshaven. Maybe van Giffen in Ezinge hit upon a relatively important settlement — after all it was to become the largest *terp* in the area. At Middelstum the pioneer phase with the supposed summer dwellings was followed by a fenced area on a low mound without houses, but with many granaries and sheds — like a small hillfort (Fig. 15, 2). Among the stray finds is a pottery mask enforcing the suggestion that here, too, we may be dealing with a rather special situation. The mound was deserted in the Late Iron Age.

THE ROMAN AND MIGRATION PERIODS

The Roman expeditions to the Elbe in the decades around the beginning of the Christian era must have passed through the northern Netherlands (van Es 1990). Early Roman military finds from Bentumersiel on the Ems (Brandt 1977) and a few other places document the short-lived Roman presence. In AD 69 the Rhine was made the frontier of the Roman Empire. Our area was close enough to be of interest to the Romans for procuring food, clothing, and soldiers, and maintaining good relations. Trade is attested by finds of Roman pottery, glass, coins, and bronze statuettes. We may assume strong Roman influence on all aspects of society and technology. House types (Fig. 7, 8–11) show many new features. On the Drenthe plateau the ancient Celtic field economy came to an end. Within the old territorial structure we see a general shift of fields, settlements, and cemeteries to new locations, often close to the present villages (Waterbolk 1980; 1982). Zeijen and Hijken are good examples. The burial ritual in the beginning is inconspicuous: ash and charcoal with at most a few burnt remains of grave-goods are collected from the pyre and deposited, perhaps in a container of organic material, in a small pit. This is sometimes accompanied by a setting of four posts, as at Wijster (van Es 1967). Few of these cemeteries have come to light, and mostly as an admixture to the more conspicuous inhumations, in coffins with intact grave-goods, that start in the 4th century AD.

Two types of settlement are in evidence. The common form seems to be the loose group of 1–3 farmsteads, each of which consists of a rectangular fenced area with a large house and a number of accessory buildings. Fenced fields lie directly adjacent. Examples have been excavated at Fochteloo (van Giffen 1958) and Peelo (Kooi *et al.* 1987; Fig. 18). Houses again accommodate large herds of cattle. At Wijster (van Es 1967), however, we are faced with a large structured village (Fig. 19, b–c), with fenced, isolated farmsteads or groups of farmsteads, and a system of parallel roads and side-roads, which must have led to a large field system. Houses without cattle stalls suggest the presence of specialised craftsmen. The westernmost farmstead stands out by the size of its main building, its variety of accessory buildings, including a huge multi-store granary, and a separate heavily built dwelling with a monumental entrance — certainly the seat of the leading family. The nearby cemetery contains a grave of around AD 400 with all the equipment of a German soldier in the Roman army.

Wijster must have been a central place, if not for the whole of the Drenthe plateau then at least for the south-western part. The exceptional position of the site is also evident from ample signs of habitation in all phases of the Iron Age (Fig. 19, a), from the houses of the leading family being set exactly on the site of two Late Iron Age houses, and from the unusual position of the adjacent cemetery near and over a Late Iron Age barrow cemetery. The soldier's grave was dug into the top of one of these barrows.

In the 5th century Wijster looses its special position. Houses become smaller and more uniform and do not differ from a contemporary settlement at Peelo (Fig. 7, 12). In the 6th century the settlement moves out of the

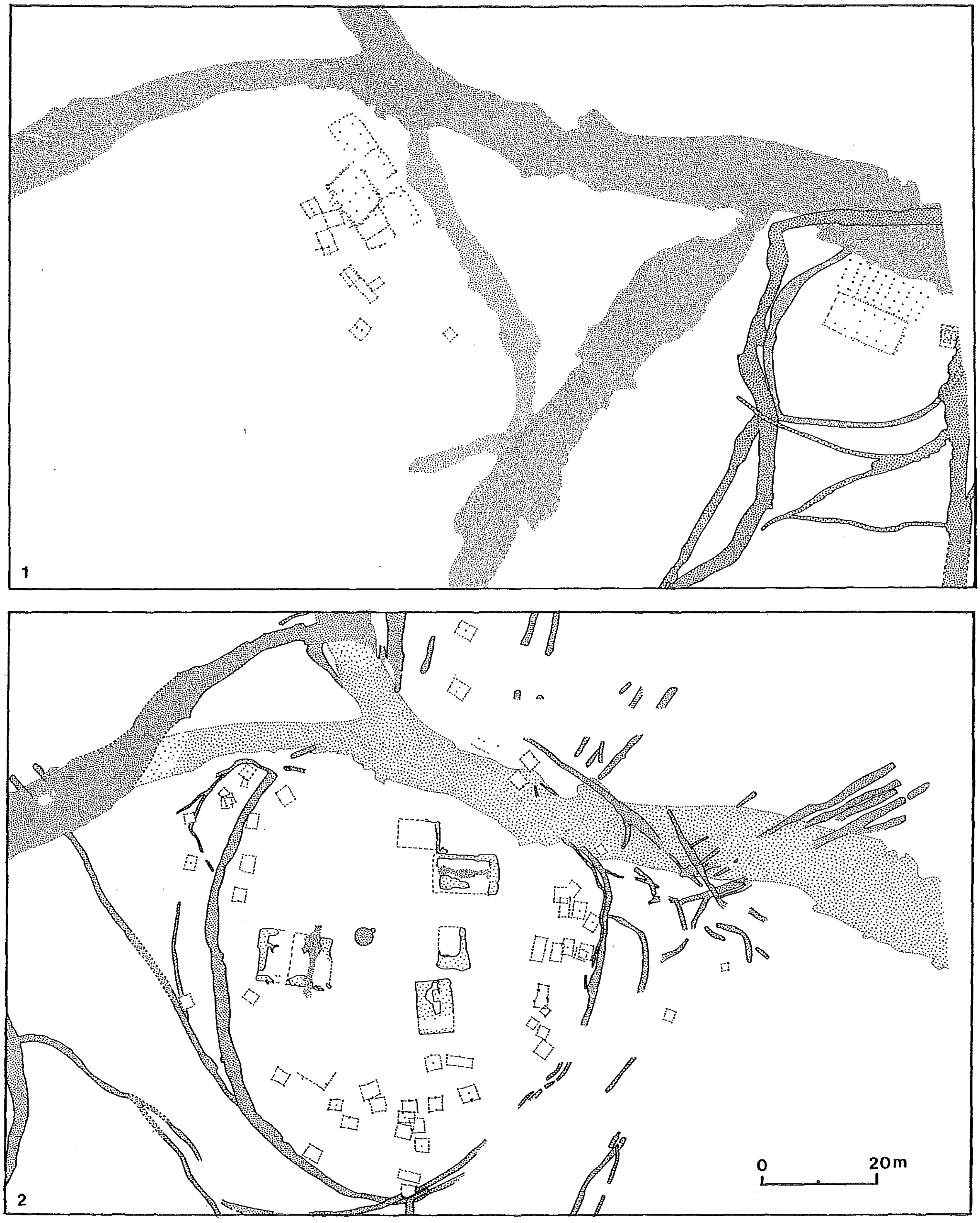


Fig. 15

Middelstum-Boerdamsterweg. 1. Phase 1; western part: summer dwellings and sheds along natural creeks, eastern part: house with adjacent large platform (probably not contemporary) within system of field ditches (Early/Middle Iron Age). 2. Phase 2: low mound with remains of small buildings and many granaries, surrounded by ditches and fences (Middle Iron Age).

VI 175

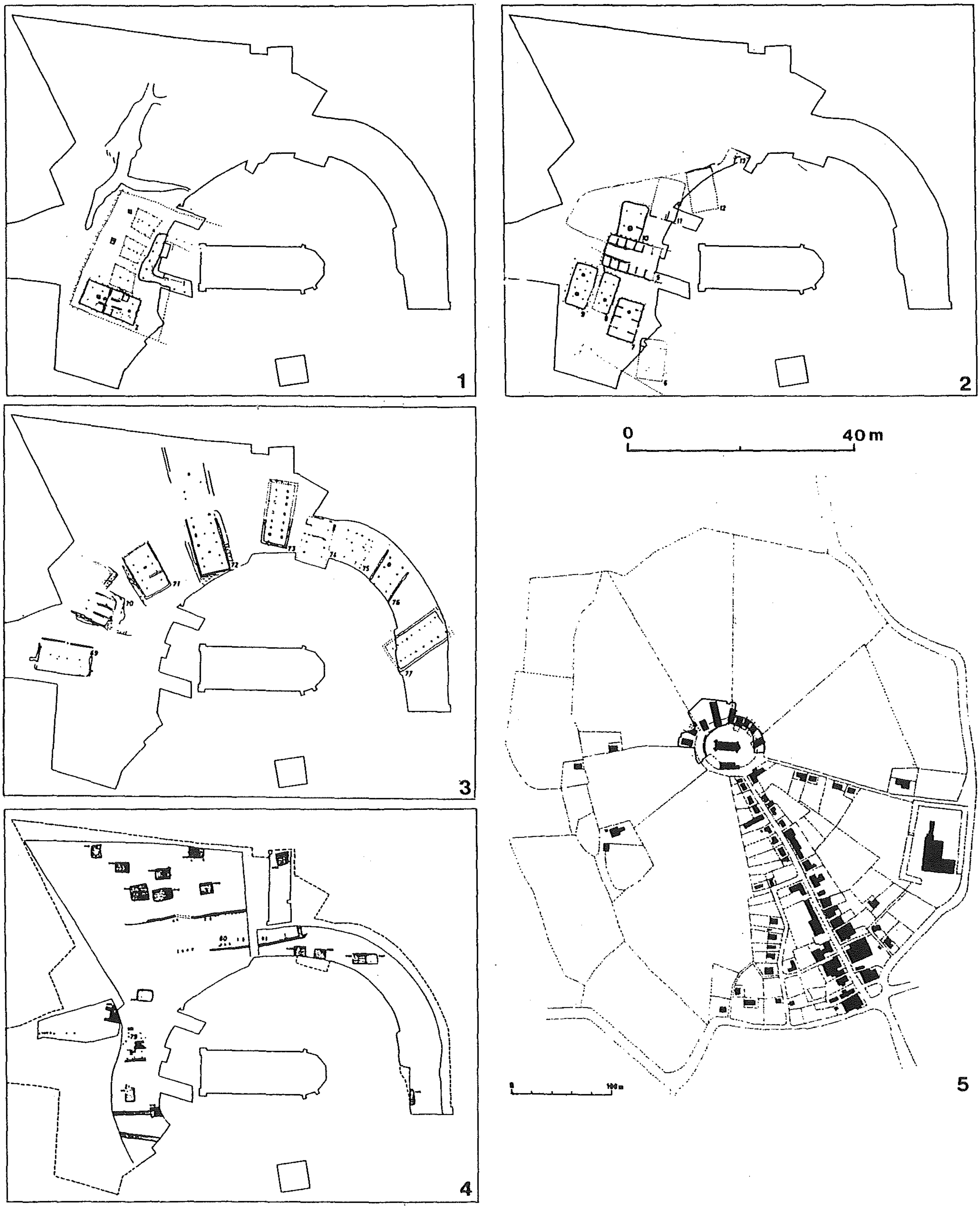


Fig. 16

Ezinge. 1. Phase Ib (Middle Iron Age); 2. Phase IIb (Middle Iron Age); 3. Phase VIa–e (Roman period); 4. Phase VIIb (Late Roman/Migration period); 5. Phase VIa–e, projected on cadastral map (*c.* 1930).

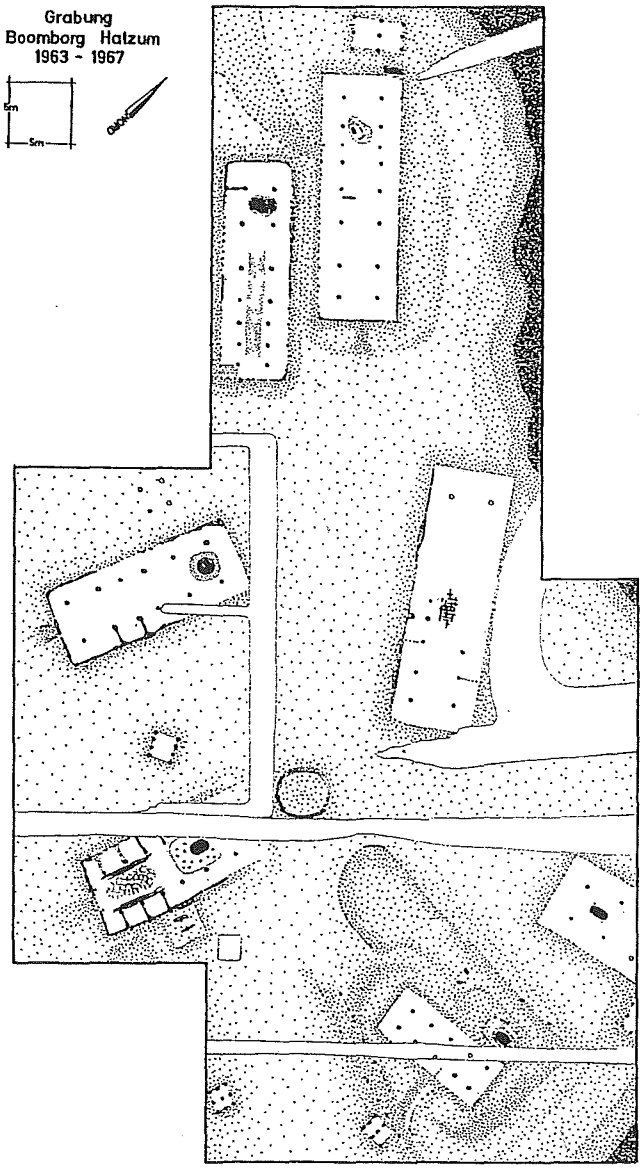


Fig. 17
Hatzum-Boomberg (D.). Phase III (Middle Iron Age)
(after Haarnagel 1969).

excavated area (Fig. 19, d). The cemetery remained in use until the 9th century. At Peelo the 5th century habitation is situated west of that of the 3rd and 4th centuries. Lack of preserved fences unfortunately precludes the delineation of the individual farmsteads. Houses have room for very few cattle. A good example of a fenced farmstead was excavated at Rhee (Waterbolk 1991b). At Zweeloo the 5th century grave of very rich woman came to light (van Es & Ypey 1977).

In the clay marshes nearly all pioneer *terpen* remained occupied and expanded. Many new settlements had been founded in the Late Iron Age between the old ones and at the periphery of the area, and on new marshes (Miedema 1983). An example was excavated at Warstiens (Elzinga 1970). The relative prosperity of the marsh people, now called *Frisii* by the Romans, in comparison to the plateau people is evident from the distribution of the Roman imports (van Es 1960).

At Ezinge (Fig. 16) we see the evolution of a radial arrangement of farms, which, projected onto the cadastral map (Fig. 16, 5), strongly suggests that the present radial pattern goes back directly to the Late Iron Age. In the late Roman and Migration period there was an east–west oriented farm with sunken huts in the centre of the *terp*. It is here that much later the church was to be built. The radial arrangement was maintained at the periphery of the *terp*. With at least some of the *terp* settlements, together with the watercourses and the roads, going back to around 500 BC, we have here one of the oldest cultural landscapes in the Holocene part of the country, very much meriting the implementation of protective measures and careful management.

THE EARLY MEDIEVAL PERIOD

In the early medieval period there is a great contrast between the poverty and isolation of the Drenthe plateau and the wealth and international orientation of the clay marshes. Good evidence for the structure of the landscape between the 6th and the 9th centuries has been obtained from the southern *es* of Odoorn, close to the present village (Waterbolk 1973b; 1991b). A detailed house typology (Fig. 7, 13–17), intersections of fences, and some stratigraphic observations permitted us to follow the development of a part of the site (Fig. 20). After a period of agriculture in the Roman period, houses were built in the 6th century. The settlement has a clear Wijster-style structure with rectangular farmyards, separated by north–south and east–west roads. In the 8th century the houses were moved from the area probably to the site of the present village. The old farm yards were now cultivated again. Field sheds stood at the edges of the parcels. The road system had remained intact, and was even renewed. Later most roads and fences were given up and the whole area became part of the *es*, with only a few field

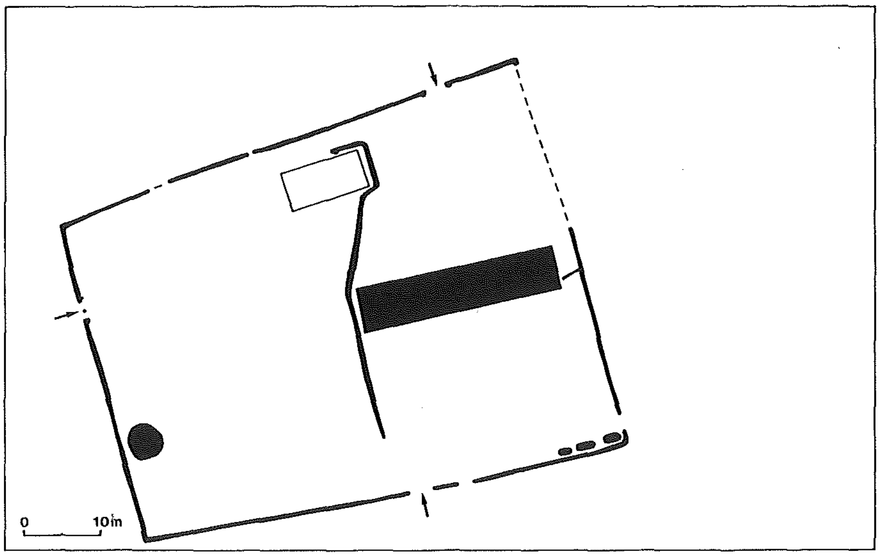


Fig. 18
Peelo. Isolated farmstead (phase 1) with house of Fochteloo B-type from the early Roman period, barn, well, and pits. For approximate location, see Fig. 4, 1:37.

boundaries and roads surviving from the old settlement (Fig. 20, 5). We can visualise an early medieval landscape with a fairly permanent plot pattern with east–west and north–south roads — remotely resembling Roman centuriation — within which a semi-permanent settlement could shift its position. Other early medieval sites yielding good house plans include Schipborg (excavated by van Giffen as early as 1921; Waterbolk 1989b), Sleen (Bruijn & van Es 1967), Eursinge (Lanting 1977), and Dalen (Kooi 1994b).

An Odoorn-style parcel and road structure is shown by the early 19th century cadastral maps of many villages in Drenthe (Waterbolk 1980; 1991b). A good example is Zeijen (Fig. 4, 2), where the main settlement lines continue into the adjacent *es* fields, where indeed early medieval finds have been made. On the small *es* of Peelo, equally with early medieval settlement finds, the parcels that have taken the place of the former roads still bear the name of *wendakker* (Bardet *et al.* 1983), that is, a headland where the plough could be turned (Fig. 4, 1 nos 11, 12, 14, 32).

After a period of increased marine activity in the late Roman period, when many peripheral and low mounds had to be given up, new habitable clay marshes were formed on the seaward side of the old marshes. They were colonised in the 6th and 7th centuries. At the site of Leens (Fig. 21) heavy sod walls caused the mound to grow quickly in height (van Giffen 1940b; de Langen 1992). All the time the houses maintain their north–south and east–west orientation, which still prevails in the surrounding landscape. Unlike the aisleless Odoorn houses, the contemporaneous *terp* houses are aisled in the traditional manner. Another example of an aisled house with sod walls was excavated at the foot of the radial *terp* of Foudgum (de Langen 1992) which had started its development in the early Roman period.

Recent excavations by the universities of Groningen and Amsterdam on the findspot of the famous brooch of Wijnaldum (Besteman *et al.* 1993) in Western Friesland have not yielded settlement data of any importance for our theme. The excavation was sparked off by the find of additional fragments of the brooch by amateurs with metal detectors. Here, too, houses had heavy sod walls.

Early medieval cemeteries occur on the main *terpen* themselves, often on the south-east slope or on deserted low mounds in the neighbourhood. Many cemeteries were destroyed in the period of the commercial digging of *terp* soil. Rich museum collections of Anglo-Saxon pottery, brooches and other ornaments, runic inscriptions, etc, show that the area formed part of what is sometimes called the North Sea culture. A stray find of a gold and almandine pin head at Ezinge (Mensonides 1958) shows that this village too was a link in the elite network.

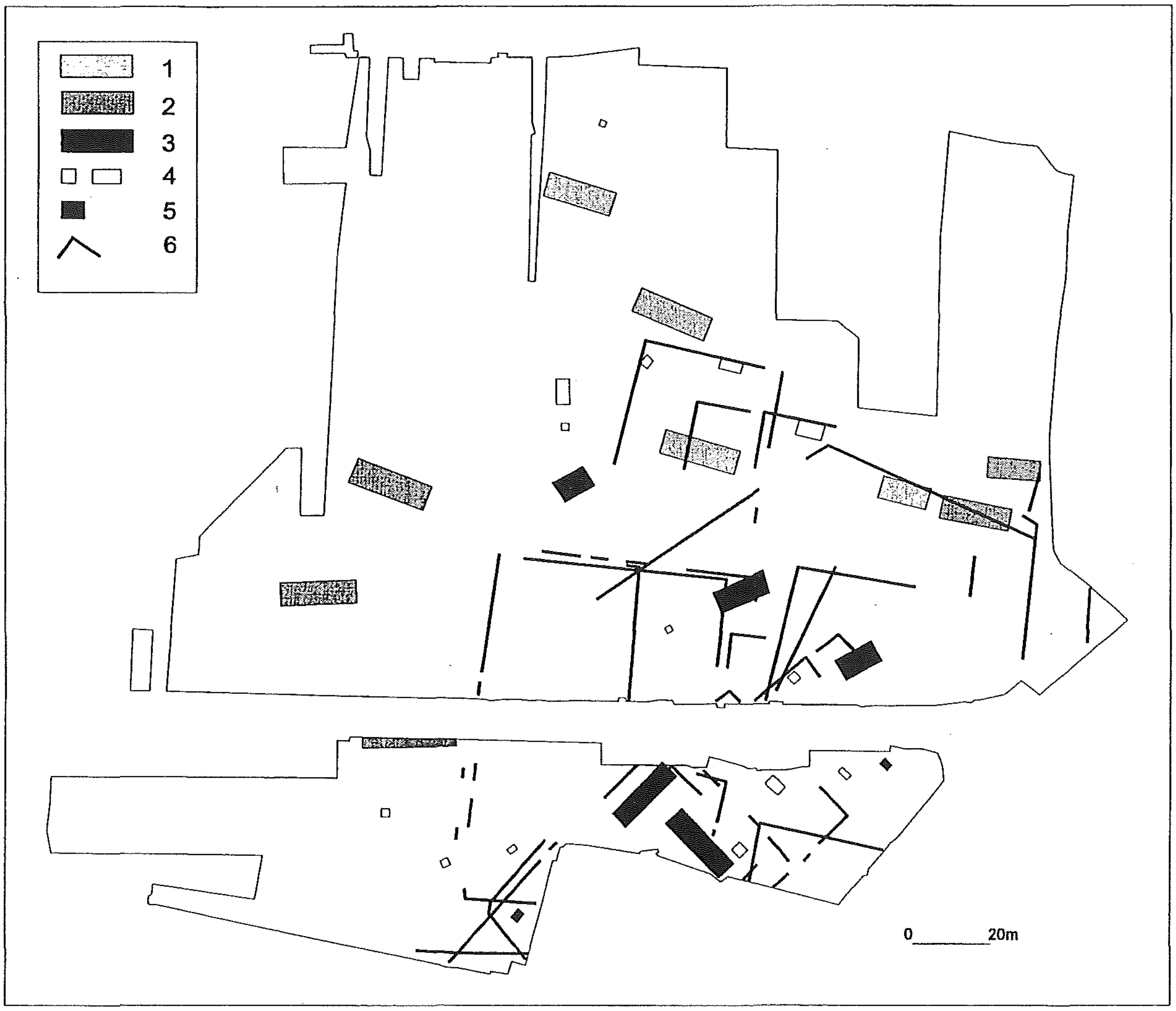


Fig. 19a
Wijster. Middle and Late Iron Age. Legend: 1. houses of type Hijken; 2. houses of type Fochteloo A; 3. houses of type Noordbarge; 4. granaries and sheds; 5. sunken huts; 6. fences.

THE LATER MEDIEVAL PERIOD

The 9th century saw the beginning of a development which brought new changes in the peasant landscape and gave it its final structure. Most Drenthe villages moved to their present locations. Improvement of agricultural methods, such as horse power, ploughs with mould boards, crop rotation, the mixing of manure with turf sods, drainage of the brook valleys, and a developing economy gave new impetus to farming. Long, narrow plots became an advantage. The introduction of the tie-beam frame made it possible to increase the width and height of the farm buildings. The accessory buildings, too, grew in size and number. At the site of Gasselte (Waterbolk & Harsema 1979) we have been able to draw up a house typology (Fig. 7, 17–19) and to follow the development of a row of 11 farms between the 9th and 11th centuries AD (Fig. 22). At first they were separated by roads, but these were given up in the last two phases. In fact, the excavated farms formed an extension of an early medieval village further east (Fig. 22, 5). For some reason, nine of the 11 farms were given up and probably rebuilt farther east, closer to the brook valley, where the earliest finds are from the 13th century. In other village plans such medieval extensions are still recognisable on the cadastral maps, for

VI 179

Fig. 19b
Wijster. Village of the early Roman period. Legend: 1. houses of type Wijster A; 2. houses of type Fochteloo B; 3. granaries and sheds; 4. sunken huts; 5. fences.

example at Gees (Fig. 23). On the plan of most *essen*, one can distinguish between a nuclear part with the remains of the early medieval lay-out, as discussed in the case of Zeijen and Peelo, and a peripheral part with large blocks of much longer parcels. In the plan of Wachtum (Fig. 24) the two field parts are separated as are the early medieval nucleus and the Gasselte-style extension of the village. At Peelo we were able to excavate the medieval precursors of the historic farmstead of Hovinge, directly behind its twin successors, one of which was built in 1629 (Kooi 1995; Fig. 4, 1; 26). This was possible because the buildings had moved from the centre of the yard to the edge. Such a shift is common throughout the area.

Another late medieval development is the foundation of daughter settlements, often at the opposite end of the *es*, but also elsewhere in the territory, and then with their own small *essen*. An example has been excavated near Zeijen (Waterbolk 1989b). Sometimes these daughter settlements grew to formal independence (Fig. 5). Settlements were also established far from the plateau on the sand dunes along the moorland brooks, for example along the Westerwoldse A. Here we have the origin of the *es* hamlet landscape (Fig. 3, 3).

Fig. 19c
Wijster. Village of the late Roman period. Legend: 1. houses of type Wijster B; 2. houses of type Wijster C (this type resembles type Wijster B but has only one pair of opposite entrances; not illustrated on Fig. 7) and derivates; 3. granaries and sheds; 4. sunken huts; 5. wells, some of which may (also) belong to the preceding phase and the following phase; 6. fences.

In the coastal marshes the main change was caused by the building of dykes. The first were built by one or a limited number of villages. They were low and only served to protect the summer crops. In the Groningen area (Fig. 6) two such ring-dyke systems can still be distinguished. They protect the areas known as Humsterland and Middag. Gradually the local systems were united and the dykes were made so high that they could also protect the area in winter. At this stage farms could move away from the *terpen* and spread over the higher parts of the surrounding marshes. Dyke building was not always successful and, for example in the Ems estuary, large tracts of land were lost and could only slowly be reclaimed by making polders.

We now come to the second major event in the occupation history of our area: the colonisation of the vast moorlands between the uplands and the coastal marshes (de Langen 1992; Groenendijk 1993). It began in the late 9th or 10th century and was largely completed in the 13th century. The process started both from the *terpen* back into the hinterland — often via sandy outcrops — and from the villages at the edge of the plateau down along the brook valleys or across them. In all cases Gasselte-style lines of farms were

VI 181

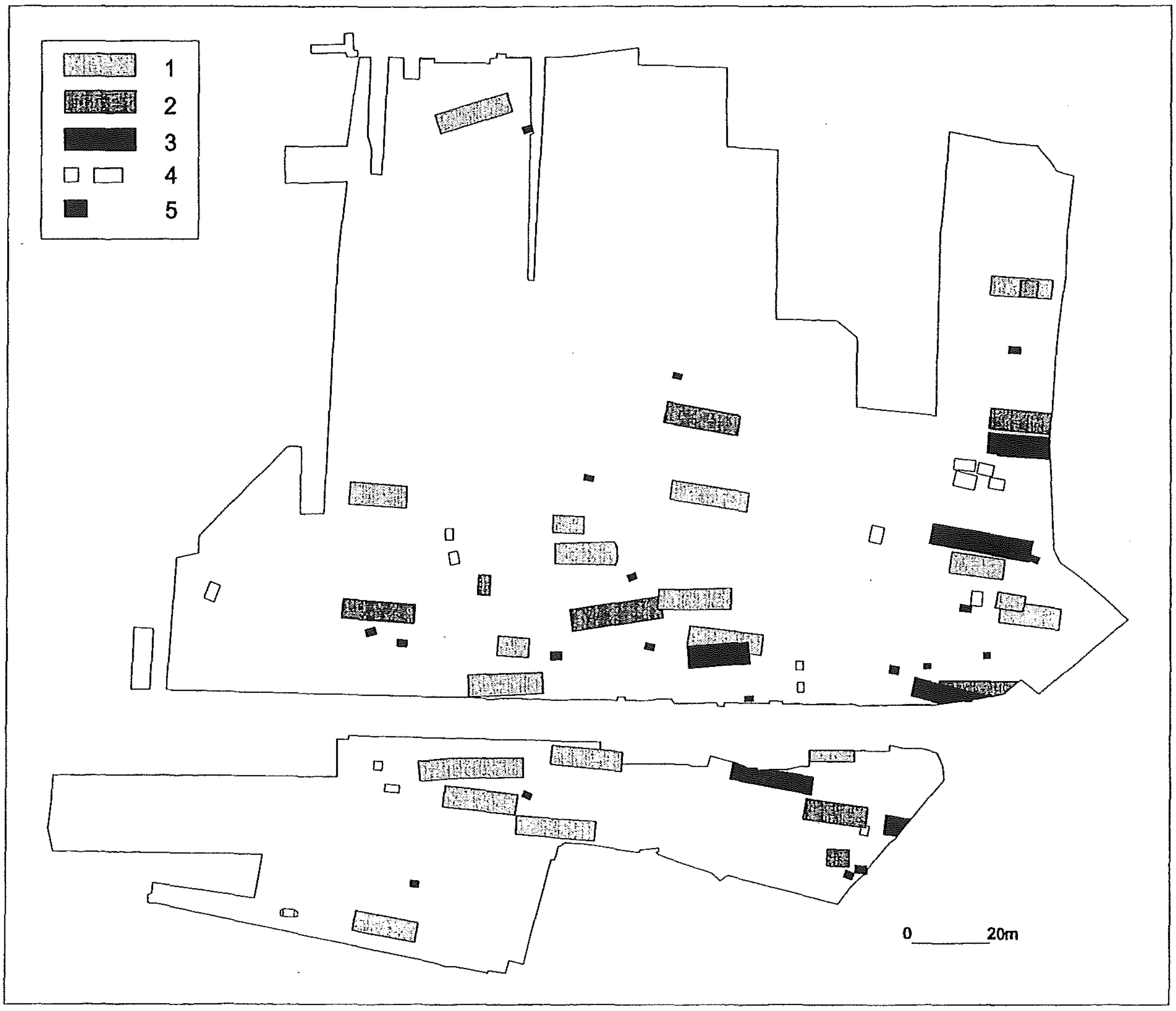


Fig. 19d
Wijster. Early medieval period. Legend: 1. houses of type Peelo B; 2. houses of type Eursinge; 3. houses of type Odoorn A; 4. granaries and sheds; 5. sunken huts.

built in relatively dry places, with parallel drainage ditches. In the *terp* margin area, water went towards the sea, via the natural drainage system of the marshes. At the plateau edges, farms were aligned parallel to the brooks, into which the drainage ditches emptied (Fig. 3, 2). In both types the settlements shifted their position repeatedly in response to the changes in hydrology caused by peat cultivation, peat cutting, and differential peat compaction. At Wijnjeterp (de Langen 1992; Fig. 4, 3; Fig. 27) a 13th century house site was excavated, far from the present village but in line with the position of an old churchyard. As most of the peat has been dug away it is rare to find intact house sites in the peat zone. Some have been excavated in the peat area south-west of the town of Groningen, at Neerwolde (Casparie 1988) and Peizerwold (van Giffen 1944; Waterbolk 1989b). Only the inaccessible parts of the large raised bogs, far from the natural drainage system, survived the medieval period (Fig. 2, 5).

Finally something should be said on the effect of Christianity on the landscape. It brought churches and monasteries, and a parish-deanery-diocese organisation on top of the old structure of village territories and nuclear regions (see below). Five to ten villages formed one parish in the central parts of the Drenthe plateau, and 1–2 at the periphery. Most churches were

VI 182

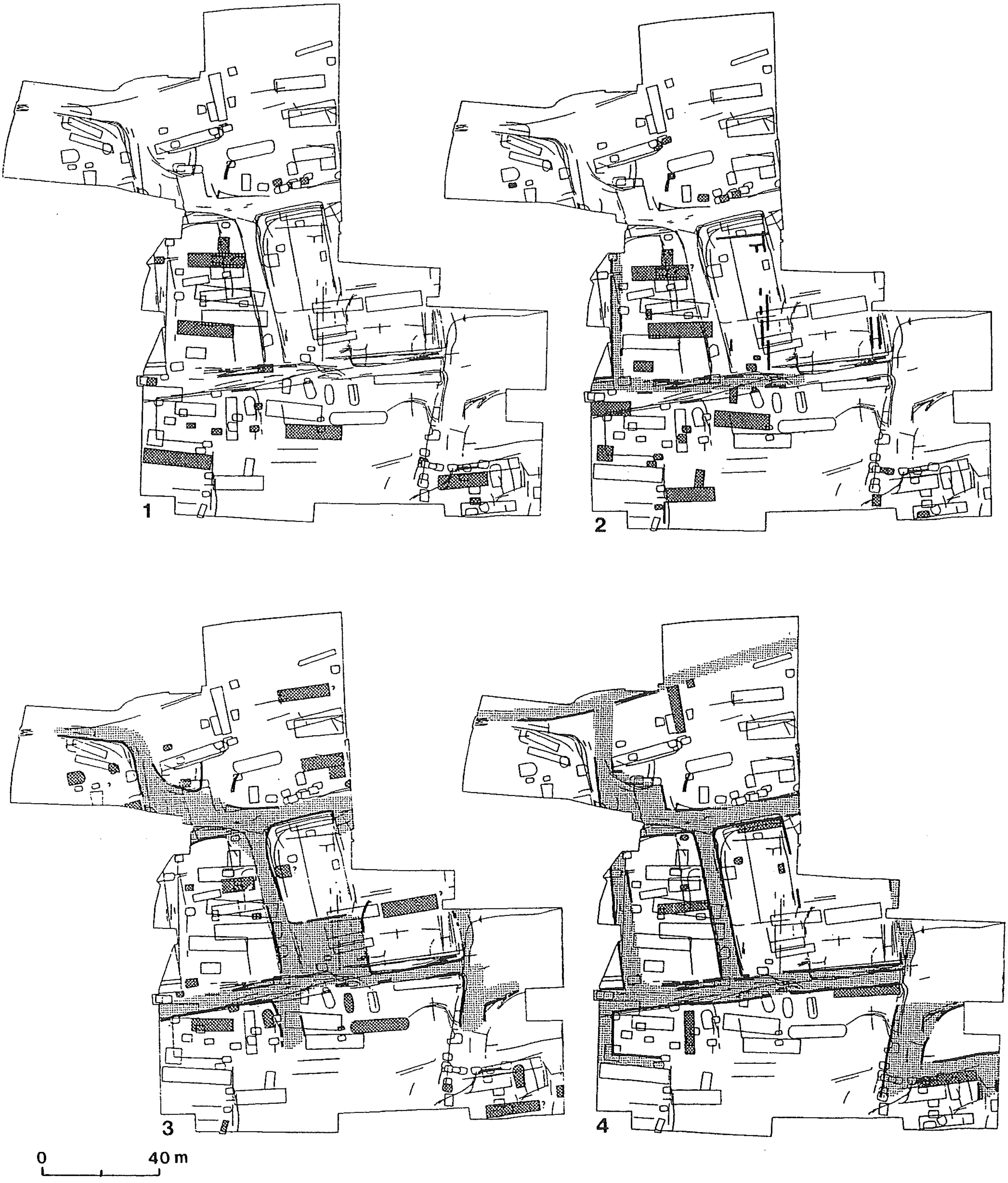


Fig. 20a

Odoorn. Early medieval village. 1. Phase 1b (house type Odoorn A); 2. phase 2 (house types Odoorn A and Odoorn B); 3. phase 4 (house type Odoorn C); 4. phase 6 (field sheds)

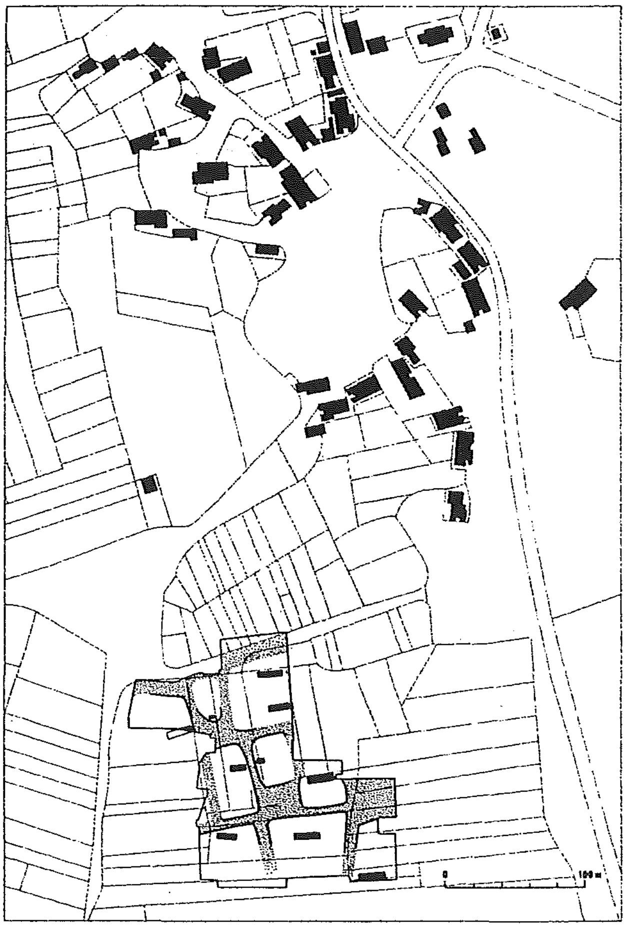


Fig. 20b
Odoorn. Early medieval village. 5. phase 4 projected on the cadastral map of *c.* 1830.

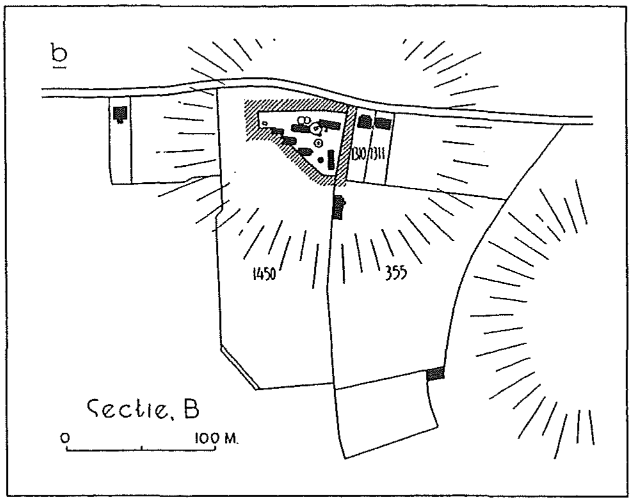


Fig. 21
Leens-Tuinster Wierde. Early Medieval *terp*. Excavated area with houses, projected on cadastral map (*c.* 1930).

built at the edge of the villages. Some moorland daughter villages, such as Wapserveen (Fig. 3, 2), became independent parishes, whilst the mother village remained in a large parish together with other villages. Many moorland villages even split and formed two parishes. If anything, this shows that the economic position of the plateau villages in the medieval period was relatively poor. In the clay marshes, too, the parishes mostly consist of one or two village territories. Examples in Figure 3, 4 are Marsum and Uitwierde + Biessum. It is interesting to note that in the area north-west of Groningen (Fig. 6) of the ten pioneer *terpen*, 7 became parish centres. Churches are normally built on the top of the *terp* (cf. Ezinge, Fig. 16, 5, and Leens, Fig. 4, 5). Monasteries, most of which disappeared after the Reformation, played an important role in the colonisation of the heaths. The monks of Aduard (Praamstra & Boersma 1978), for example, dug a straight canal through the low-lying marshes to improve the drainage of the hinterland (Fig. 6: Aduarder Diep; Au = Aduard). In some hamlets the sites of former monasteries have left their marks in the parcel structure.

THE POST-MEDIEVAL PERIOD

I shall be very brief on the changes in the peasant landscape that have taken place in the post-medieval period, for this is not the field of archaeology but of historical geography. For each of the three main zones I shall mention one major phenomenon. On the plateau the remaining raised bogs were systematically exploited from the 16th century by companies that invested capital in digging canals for drainage and transport and for preparing the land for agriculture. The town of Groningen, too, was a major investor. The result is a fully rational landscape without a territorial structure and with farms placed along the canals.

In the low-lying parts of the peat zone additional fuel peat was won by digging the peat from below the water table and drying it on narrow strips of land. These strips were, however, easily attacked by wave action, with the result that lakes were formed.

In the coastal zone the main change was the formation of successive polders, both in the estuaries,

VI 184

Fig. 22a

Gasselte. Late medieval village. 1. Phase 1: houses type Odoorn C'), barns, sunken huts, wells, and fences; 2. phase 2: houses (type Gasselte A), barns, wells, and ditches.

VI 185

Fig. 22b
Gasselte. Late medieval village. 3. phase 3: houses (type Gasselte B), barns, wells, and ditches; 4. phase 4: houses (type Gasselte B), barns, wells, and polygonal hay or corn stacks (according to a recent interpretation some of these stacks belong to the preceding phases).

VI 189

there had always been room for 4–5 territories with the same size and properties as those on the Drenthe plateau. Nuclear regions are comparable to tribal areas in pre-agricultural societies. Isolated populations must have a minimum size to produce suitable marriage partners, withstand diseases and other hazards, fulfill social obligations, etc. An educated guess (Waterbolk 1987b) leads me to put this minimum at 250–500 people, or 15–30 territories of the size normal in, for example, the Late Bronze Age of our area.

Another characteristic feature of the nuclear region is the high degree of standardisation in the size, form, and location of the territories, in the location of the settlements, fields, and cemeteries within the territories, and in the mode of exploitation of the natural resources. If an adaptive area consists of parallel zones with specific economic potential, the territorial borders are placed in such a way that all can use all zones. In the fertile clay marshes a mean distance of *c.* 1.5 km between the settlements is normal. On the Drenthe plateau it is at least double. North of Bremerhaven in Germany a *terp* area lies close to a high plateau. In both zones settlements are aligned, with mean distances of 1500 m in the marsh and 5500 m on the plateau (Haarnagel 1973). Of course, this uniformity does not preclude the existence of differently structured central places within the nuclear regions. In the Roman period Wijster may have been a case in point.

It is easy to find other examples of nuclear regions with these properties. Wherever new land is settled we find the occupation to begin with a number of contemporaneous settlements. Let me mention just one example from a totally different period and environment. Early Linear pottery occupation is restricted to loess soils. In the southern Netherlands there are a number of isolated loess plateaus, but only the larger one was occupied, by a series of 12 contemporaneous settlements, all located at the edge of the plateau (Bakels 1982). Such a pattern can only be understood with the aid of the nuclear region concept, which I think has considerable heuristic value.

With the medieval colonisation of the peat zone, the physical isolation of the different nuclear regions of course came to an end, but one can still recognise them, for they underlie the diversity of the peasant landscapes as documented on the 19th century maps, and many of them live on as low-level historical units with their own names and traditions.

Much that was characteristic of these landscapes has been lost in the 20th century through the reclamation of the heathland commons, afforestation, the introduction of modern farming methods, reallotment schemes, town expansion, motorway building, etc. One way of retaining something of the ancient diversity in the landscape is to concentrate on the preservation of its essential structures. For the older landscapes it is archaeology alone which can identify these.

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VI 186

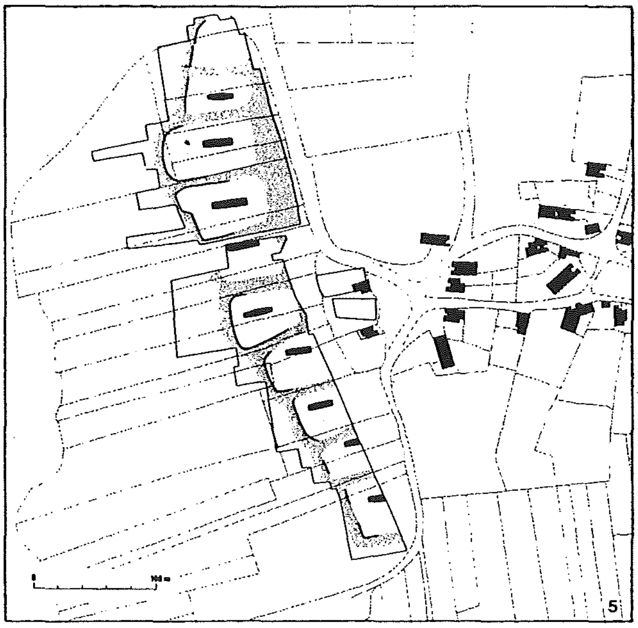

Fig. 22c
Gasselte. Late medieval village. 5. phase 2 projected on the cadastral map of *c.* 1815.

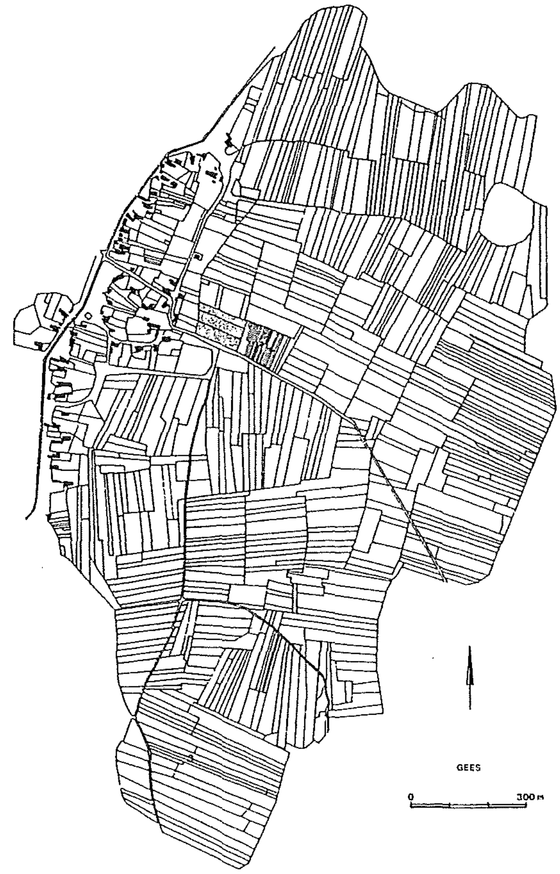

Fig. 23
Gees. Cadastral map (*c.* 1815) of village and *es*.

and seawards from the old dykes. Here too, a fully rational parcel pattern resulted.

Finally I should mention the residences of the local gentry with their barns, moats, parks, and woods. The estates were always small and contained within the structure of the village territories. They were most numerous at the periphery of the plateau, in the *streek* villages and in the clay marshes. Their *floruit* was in the 17th and 18th centuries, and many houses had already disappeared by 1850 when the first topographical maps were made. Often they left their marks in the local topography and parcel structure. Most of the surviving houses, parks, and woods are now in public hands. They are often a charming element among what, since 1850, has been left of the original peasant landscapes.

EPILOGUE

I think I have demonstrated that archaeology can contribute to our understanding of the nature and origin of historic peasant landscapes, and that the time-depth of certain structural features can be considerable. Continuity of structure appears at different levels.

At the level of the basic economic unit, it is the long house with dwelling and byre sections, accompanied by granaries or sheds, which we find in Drenthe from the Middle Bronze Age right up to the 19th century AD.

The next level is that of the settlement: the agglomeration of economic units that together exploit a territory. As to permanency of location, we can schematically distinguish three phases on the plateau: first the wandering settlements in the permanent Celtic field; then in the Roman and early medieval periods the semi-permanent settlement which shifted its position within a permanent framework of probably privately owned field plots with a regular road network; and finally the permanent settlement with a permanent field system, both containing many structural elements of the preceding phase. In the phase of the wandering settlements, permanent elements in the landscape included not only the Celtic fields, but also the roads and the cemeteries. In the Roman period a general shift in the location of settlements as well as fields and cemeteries took place, but this did not affect

VI 187

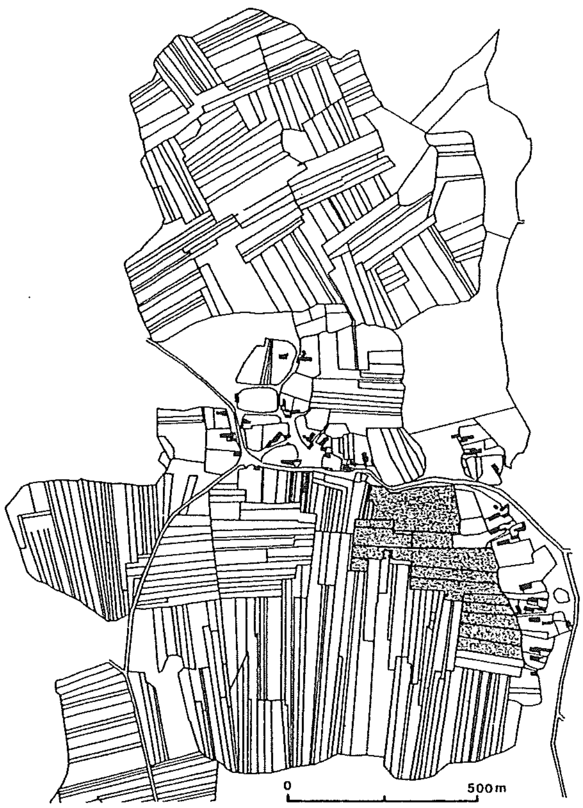

Fig. 24
Wachtum. Cadastral map (*c.* 1815) of bipartite village and *essen.*

the overall territorial structure and the main road network. The distance from the old to the new location was always much smaller than the distance between villages. In the clay marshes all settlements were permanent, provided that the surroundings remained suitable for agriculture. In their present lay-out many original elements can be recognised. In the peat zone changes in hydrology necessitated frequent shifts of the settlements, but these had to take place within the original framework of the elongated land holdings.

The third level is that of the settlement territory. According to the biologist Tinbergen (1982), man is an animal with a genetic pre-disposition towards splitting up into territorial groups and to inter-territorial hostility. The territorial structure of the peasant landscape is an expression of this pre-disposition. We may expect it to be one of its most constant and durable elements, and it need not surprise us that in the central Drenthe plateau we find it to go back with certainty to the Late Iron Age, and in all probability to at least the Middle Bronze Age.

There is a fourth level which is worth looking at. It is what I have called an adaptive area (Waterbolk 1974; 1979; 1984; 1987b; 1990), and which Heidinga (1987) calls a nuclear region (in Dutch, *kerngewest*): the

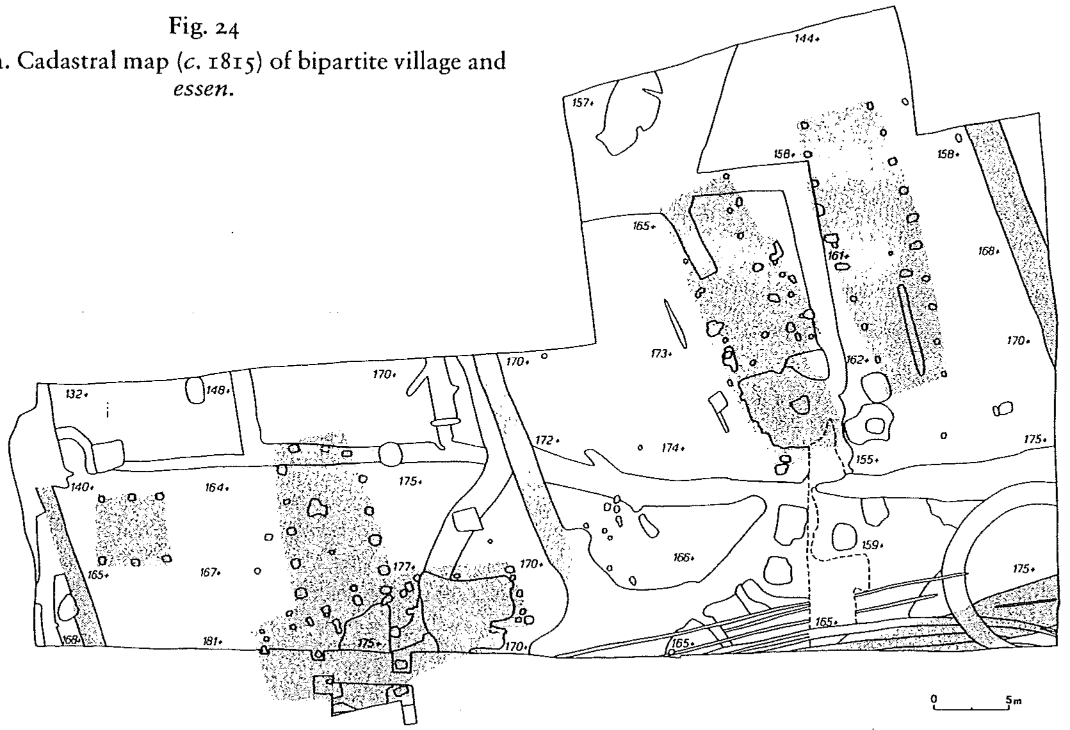

Fig. 25
Wijnjeterp. Two farmsteads from the 13th century. The distance to the present village (Fig. 4, 3) is *c.* 2 km.

VI 188

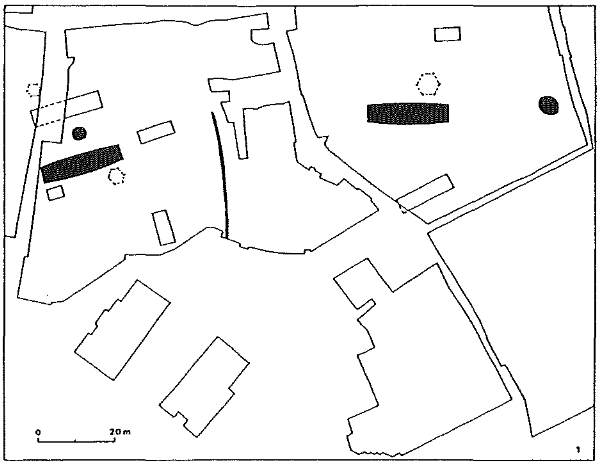

Fig. 26.1

Peelo. Schematic development of historic farmstead Hovinge. Two farmsteads of the 9th century with houses of type Odoorn C Black: houses, wells, and fences; open: barns; dotted: hay or corn stacks.

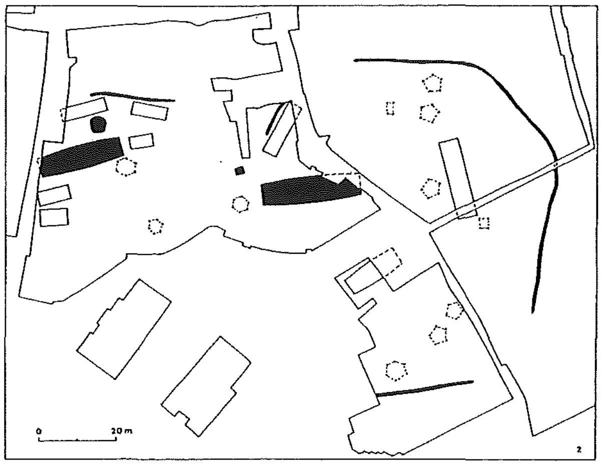

Fig. 26.2

Peelo (Hovinge). Two farmsteads of the 10th century with houses of type Gasselte A (for key see Fig. 25.1).

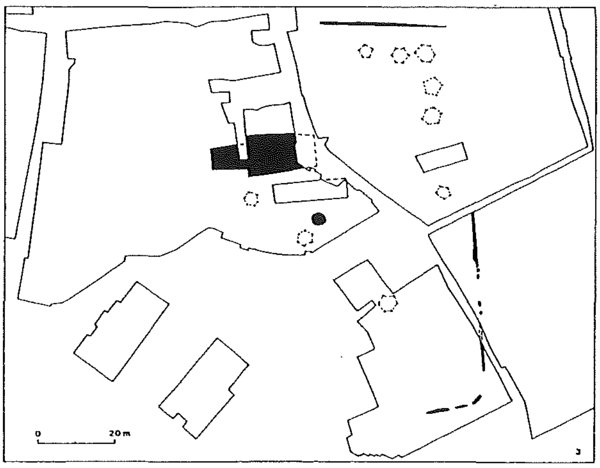

Fig. 26.3

Peelo (Hovinge). Single farmstead of the 11th century with house of type Gasselte B (for key see Fig. 25.1).

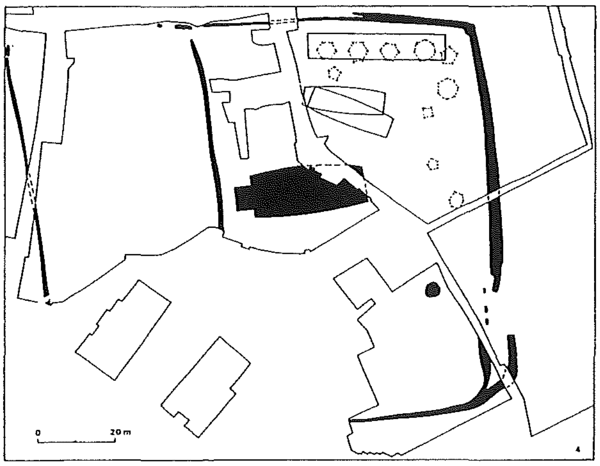

Fig. 26.4

Peelo (Hovinge). Single farmstead of the 12th/13th century (two sub-phases) with house of type Gasselte B (two building periods) (row of polygonal corn or hay stacks replaced by very large barn). For location of site see Fig. 4, 1:39–42 (for key see Fig. 25.1).

agglomeration of adjacent territories in a physical environment which is homogeneous as to the possibilities of human exploitation. In our overview we came across three such areas on the Drenthe plateau, one along the Westerwoldse A river, at least four in the clay marsh area, and one on the river clay banks of the Ems (Fig. 14). Such nuclear regions have a number of interesting properties, which are easily overlooked. First they appear to have a minimum size. Both in the well investigated areas north-west of Groningen and on the Ems bank, Middle Iron Age habitation starts with *c.* 10 contemporaneous settlements. Conversely, Westerwolde is deserted in the Roman period although there were certainly areas not covered with peat that could have housed 3–4 territories. A large morainic outcrop in Friesland, known as Gaasterland, which became isolated in the Late Neolithic, was not reoccupied until the medieval period, although here, too,

VI 190

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VI 192

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Waterland - Environmental and Economic Changes in a Dutch Bog Area, 1000 A.D. to 2000 A.D.

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Introduction

Waterland, the former raised-bog area just north of Amsterdam (Fig. 1), is part of Western Europe's belt of wetlands. It is a famous bird sanctuary, although its agricultural aspect is dominant. It presents the visitor with a cliché view of Holland: flat green polders, surrounded by massive dykes and divided by many glittering ditches. From this description it is immediately apparent that there is actually no 'nature' to be found; the landscape of Waterland is entirely man-made. The appearance of tranquil eternity is misleading.

Most of the landscape changes were directly or indirectly induced by people. Those changes had profound effects on economic and social life in the area, in turn causing new changes in the landscape (Fig. 2). Recent archaeological research (Bos 1985a, 1985b, 1986) has revealed that this resulted in relocation of the settlements. Hundreds of deserted Medieval and post-Medieval houses are scattered around the area, the waterlogging providing good conditions for the preservation of both archaeological and palaeoecological evidence. The potential for the study of the turbulent relationship between Waterland and the Waterlanders or between environment and occupants, is enormous. This was only very recently realized, and research programmes are now being formulated. The Dutch Ministry of Agriculture has asked the University of Amsterdam to map all relevant sites and to report on ways to preserve them and to harmonize agricultural and archaeological interests. These topics fall beyond the scope of this chapter. Here we are concerned with the vicissitudes of people in a changing cultural landscape.

The natural landscape

At the end of the Weichselian, sea-level rose as a result of melting inland-ice. During the Holocene, sandy beach ridges and dunes were formed in the western Netherlands. Clayey and peaty sediments were

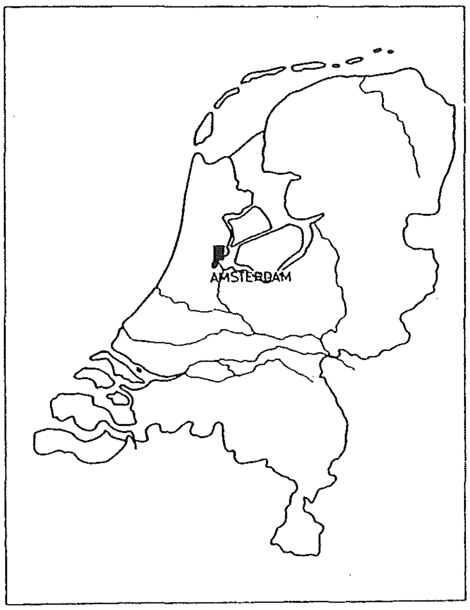


Fig. 1. Position of Waterland within The Netherlands.

deposited in the coastal plain, between the coastal ridges and the Pleistocene deposits of central and eastern Netherlands. Under the influence of several large rivers, the saline conditions changed to a freshwater environment. At many sites the eutrophic environment of marshes, fens and carrs gradually became more oligotrophic. When the vegetation became dependent solely on rain water for its nutrient supply, raised bogs developed (Pons & van Oosten 1974).

Palaeobotanical research (Polak 1929) showed the presence of submerged raised-bog complexes in the province of Noord Holland. Recently, their development and palaeoecology have been studied in detail (Bakker & van Smeerdijk 1982; Pals *et al.* 1983; Witte & van Geel 1985). At the Ilperveld (Bakker & van Smeerdijk 1982), situated in the former raised-bog complex of Waterland, peat growth started at *ca.* 4600 B.P. From *ca.* 4100 B.P. onwards, Ericaceae, *Sphagnum* and other oligotrophic taxa became dominant. During peat formation, especially during the raised-bog phase, which lasted more than 3000 years, the wet, open landscape was unattractive for human occupation.

In the 10th century, the natural boundaries of Waterland were strips of oligotrophic peat in the north, west and south, and Almere lake in the east. The area (Fig. 3) was drained by the Waterlandse Die river and its tributaries, running into Almere (de Cock 1975). The occurrence of many toponyms with the suffix *-woud* (forest) or *-broek* (carr) suggests that Waterland was once largely covered by forest (de Cock 1975). Palynological evidence does not corroborate this assumption. The *-woud* and *-brouk* toponyms may refer to small strips of woodland that were restricted to the river banks and were a striking element in the landscape. Since most transport was by water, the impression of a forested area would have been evoked.

There is no archaeological or palaeoecological evidence for human presence in Waterland before the 10th century. Earlier temporary Iron Age occupation of bogs is known only from areas nearer to the inhabitable coastal area (Brandt 1983). The first permanent bog reclamations in the western Netherlands occur in Carolingian times (Besteman 1974), but the great *hausse* began at the end of the 10th century. This is also the time of the reclamation of Waterland.

The impact of human intrusion

The exact circumstances which led to broad-scale reclamation activities are not yet known. However, changes in economy, technology, demography and social structure of the older settlements outside the bog area certainly interacted with the effects of climatic variation that made the 10th century a period of drought (Heidinga 1984). Maybe the formation of the Younger Dunes along the coast, which meant the loss of a considerable amount of arable land, was a stimulus for people to leave the dunes and invade the bog areas. A more important consequence of the drought, however, may have been the postulated end of bog growth. The upper peat is supposed to have dried out, thus making the area more accessible. Oxidation of the surface peat increased available nutrients, and the original raised-bog plants gave way to plants requiring meso- to eutrophic conditions (van Geel *et al.* 1983). With the insight and skills developed in the Carolingian reclamations, it was possible to construct drainage systems that allowed permanent exploitation and occupation.

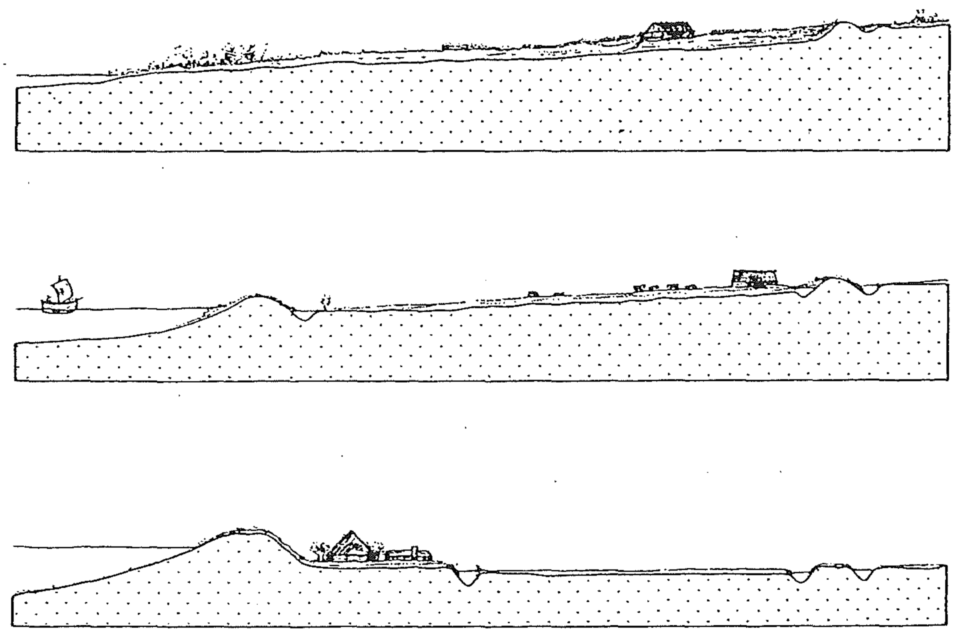


Fig. 2. The 3 main stages of landscape development in Waterland under human influence: (top to bottom) Arable land, shortly after the reclamation (11th-12th century); Extensively used pasture land enclosed by dykes (late 13th-16th century); Present-day intensively exploited pasture land, which has sunk below sea-level since the introduction of mechanical drainage in the early 17th century.
Drawing: B. Donker.

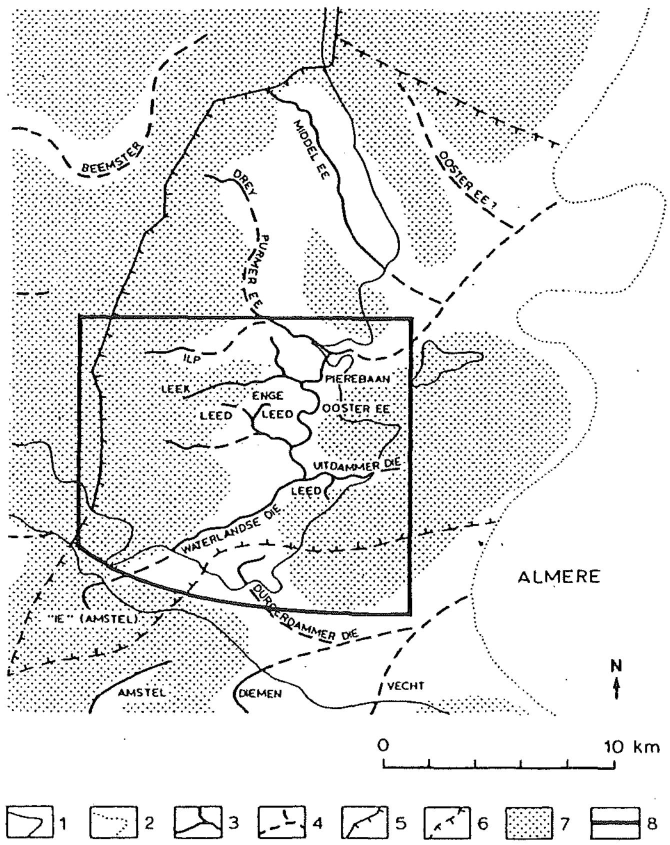


Fig. 3. Reconstruction of the natural landscape, adapted by H. A. Heidinga from de Cock (1975).
1 = present coast line;
2 = reconstructed Medieval coast line;
3 = natural rivulet;
4 = id., supposed;
5 = border of Waterland;
6 = id., supposed;
7 = oligotrophic peat;
8 = approximate outline of Fig. 4.

In a span of probably only a few generations most of Waterland was transformed into agricultural land. Drainage was so successful that the higher parts could be used as arable, mainly for rye cultivation (van Geel *et al.* 1983; van Geel 1984; Pals 1984). At this point a process was set into motion that proved to be irreversible and with consequences that are still felt even today (Fig. 2).

If water is removed from peat, the volume is strongly reduced, and this reduction is increased by oxidation of the plant remains. The surface starts to sink to a level nearer to the new water-table. Further drainage becomes imperative. The landscape sinks even further, and so on. It must have seemed as if the environment had become hostile. Although Waterland was not 'wrested' from the water like the later 'true' polders, it is certainly the case that a long struggle ensued.

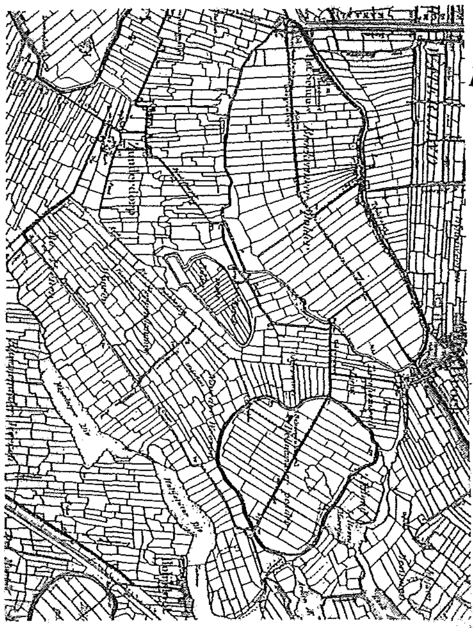
The subsidence allowed the surface water to attack the land successfully. Large parts of reclaimed land along the eastern coast of Waterland were washed away in the formation of the Zuiderzee (de Cock 1975). Dykes were constructed, but these were frequently breached. The one advantage of the floods was the deposition of a fertile layer of clay (Besteman & Guiran 1983). This advantage disappeared, however, as the water of the encroaching Zuiderzee became increasingly brackish, as shown by the occurrence of salt-marsh plants such as *Triglochin maritima* L. and *Spergula marina* (L.) Griseb./*S. media* (L.) C. Presl. in the centre of the bog area (van Geel *et al.* 1983). When this became a real problem, due to the continuing subsidence, the larger rivers, which all debouched into the Zuiderzee, were dammed, the dams being provided with an outlet sluice that could be opened at low tide. In this way the dyke ring was completely closed in the second half of the 13th century (Bos 1988). This did not solve the problem completely, as the dykes proved to be rather vulnerable. At the end of the 13th century there was an increasing tendency to build houses on *terpen* (artificial mounds); palaeoecological evidence points to problems with the loose subsoil as well as continuing problems with surface water (van Geel *et al.* 1983). The most extreme example excavated so far is the town *terp* of Monnickendam, where an infill of almost 5 m was achieved in one phase (Bos 1988). Floods became a lasting aspect of the history of Waterland. The present landscape has many scars that bear witness to that: larger and smaller lakes immediately behind the dykes where these were breached; and straight stretches of dyke, where land had to be given up after a flood and a new 'safe' dyke had to be constructed, etc. The last great flood occurred in 1916.

Not only the Zuiderzee caused floods and loss of land. The natural rivulets, swept up by the wind, increased in size to form lakes, the largest of which also had to be enclosed by dykes.

Re-orientation of the economy

The relative rise of the water-table during the first 3 centuries of occupation forced the people of Waterland to reorganize their economy. Crop growing became increasingly difficult after *ca.* 1300 A.D., as the available technology failed to provide adequate drainage. Waterland became a uniform pasture area (Fig. 2). Its inhabitants turned to new forms of subsistence and cereals had to be imported.

In the late 13th century towns such as Amsterdam and Monnickendam developed, where agriculture was secondary to craft, shipping and trade. This development was encouraged by the integration of Waterland into the powerful county of Holland in 1282, when the self-styled lords of Waterland, the Persijn family, sold their rights to Count Floris V, who was a man of truly international stature. During his reign, Holland became part of the newly developing Western European economy. The expansion of Holland in the second half of the 13th century was both territorial and economic. The people of Waterland needed to import certain necessities such as corn, and they found new means of making a living using the opportunities presented by a growing demand and supply system, in which money became the lubricant.



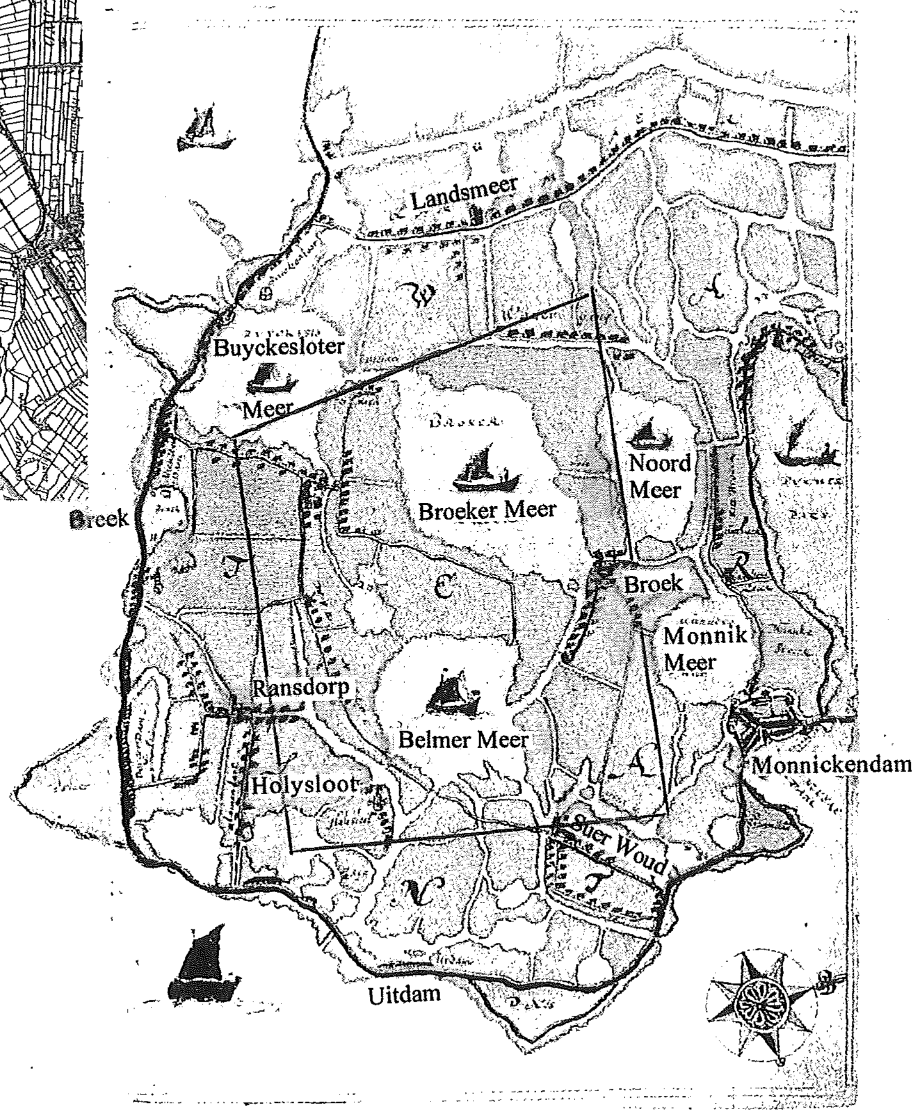


Fig. 4. Waterland in 1588 (North is 90 degrees to the right in relation to Fig. 3). Note the still elongated structure of the settlements. Map by B. de Vyll at the Rijksarchief Noord-Holland, Haarlem.

The new traders and seamen were independent of the nobility and the clergy. The new towns did not develop in the shadow of manorial or ecclesiastical residences, but mostly on the sites of the dams in the main rivers, which were readily accessible by ship, both from within and from outside.

Waterland in the 14th century is poorly documented, though we may assume that it was a period of transition and adaptation. Archaeological evidence suggests an initial decline in the population of the countryside; this was only partly mitigated by the increase in population of the urban centres.

Waterland 1000-2000 A.D.

Dairy farming is considerably less labour-intensive than crop growing. However, Waterland became no more than marginal land, even to the less demanding dairy farmer. Historical sources from the 15th and 16th century are eloquent on this point (although admittedly they are from tax declarations): "We can only use our lands from May to the middle of September, and then we have to stable our animals" (1544); "We can hardly get the hay properly off the fields once every three years" (1553); "Yes, we do keep cattle, but we can't make a living out of that" (1494); "Our lands hardly yield enough to pay the land taxes alone" (1556); "We have no way of making a living on our lands, except that some of our wives may keep one or two cows" (Bos 1985a).

It is therefore not surprising that the change from crop growing was not only to dairy farming. The people of Waterland switched mainly to craft, shipping and trade, without actually moving to the towns: "We make our living on the seas, sailing east and west, and some of us also engage in trade" (1514); "We are all fishermen and sea-faring people" (1543). In the first half of the 16th century almost half of all Dutch skippers sailing to the Baltic came from Waterland. All supporting craftsmen were to be found in the villages; the home-industry was principally spinning and sewing of clothes. Although the towns certainly profited by these activities of country people, competition was feared. Amsterdam issued dozens of regulations to curb rural activities. Such regulations have been preserved from the 15th century onwards (Bos 1985a).

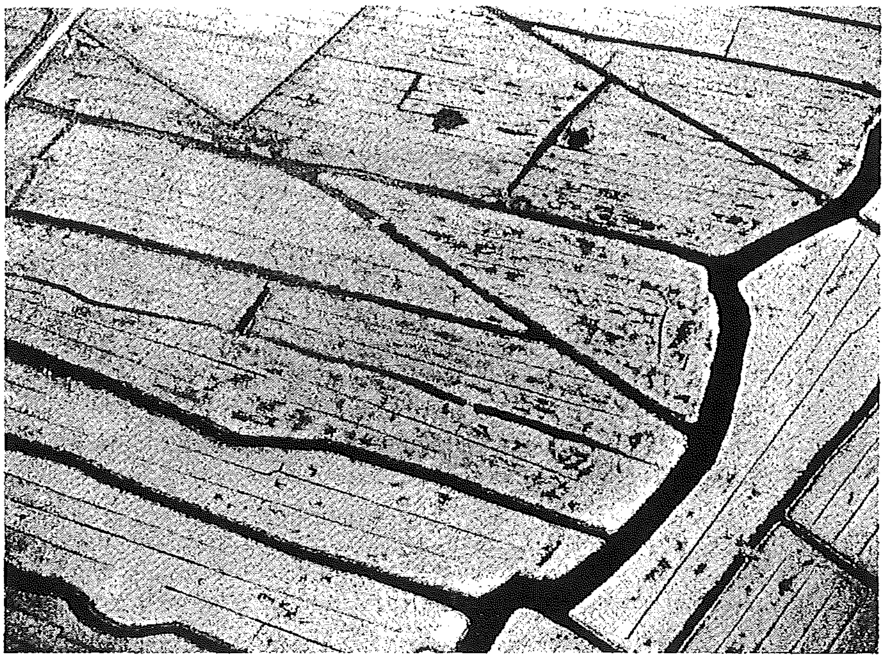


Fig. 5. In the lower left corner 2 house *terpen* can be recognized from the ditch pattern. As the *terpen* are still distinguishable as small mounds, the present farmer adapted the drain system to the difference in height.

The archaeological survey has discovered hundreds of houses which were deserted in the period of transition, from *ca.* 1250 to 1350 (Bos 1985a, 1985b). These desertions were not due to the decline in population alone; it is now apparent that almost all settlements were relocated. The former villages were all on the fields, forming long strips parallel to both the rivulets and the small dykes at the end of the reclaimed village-area. Now settlement shifted towards dykes, roads and waterways. This shift may not be due to drainage problems, but be related to the re-orientation of the economy; the focus shifted from fields to connections with the outside world (Bos 1985a, 1986). Not only was this more practical, it was also an expression of a changing attitude to the environment and to life in general.

The end of the 'urban' life in rural Waterland was quick. It was brought about, both directly and indirectly, by the war with Spain. The damage from the storm surges of 1570 was not completely repaired when the troubles began. In 1572 the Protestant Dutch raided parts of Waterland, but soon Waterland declared itself for the Prince of Orange. Amsterdam delayed till 1578. Waterland became the scene of many skirmishes. Villages were pillaged and burned. The dykes were breached in many places, but the disintegration had gone so far that these were not repaired. Many people fled from their homes. What was even worse, their ships were plundered, burned or confiscated throughout the country; their capital was destroyed. When the situation stabilized, it was Amsterdam that profited. It had a huge influx of capital, brought by the religious refugees from the southern Netherlands, and it had not suffered such severe losses as Waterland.

Two things happened. Amsterdam practically acquired a trade monopoly. In the process, it became a profitable market for agricultural products, as its population doubled in the following decades. The merchants of Amsterdam sought ways to invest their abundant capital. A new re-orientation of the economy of Waterland followed.

Return of the importance of agriculture

Land subsidence had not stopped since the end of the corn-growing period and the area had now almost lost its agricultural value. Helped by capital from the towns, the countryside was thoroughly reorganized. Dykes were repaired and reinforced. The larger lakes were drained, fishing and sailing water was transformed into pasture land. An important new feature was the introduction of windmills to pump out the water. These were also used to lower the water-table in the ditches of the old land, which resulted in better pastures and hay meadows, but also accelerated subsidence. From this time (*ca.* 1600) to the present day, Waterland has sunk at least a further 2 m. Only at this stage was the present 'typically Dutch' landscape formed (Fig. 2).

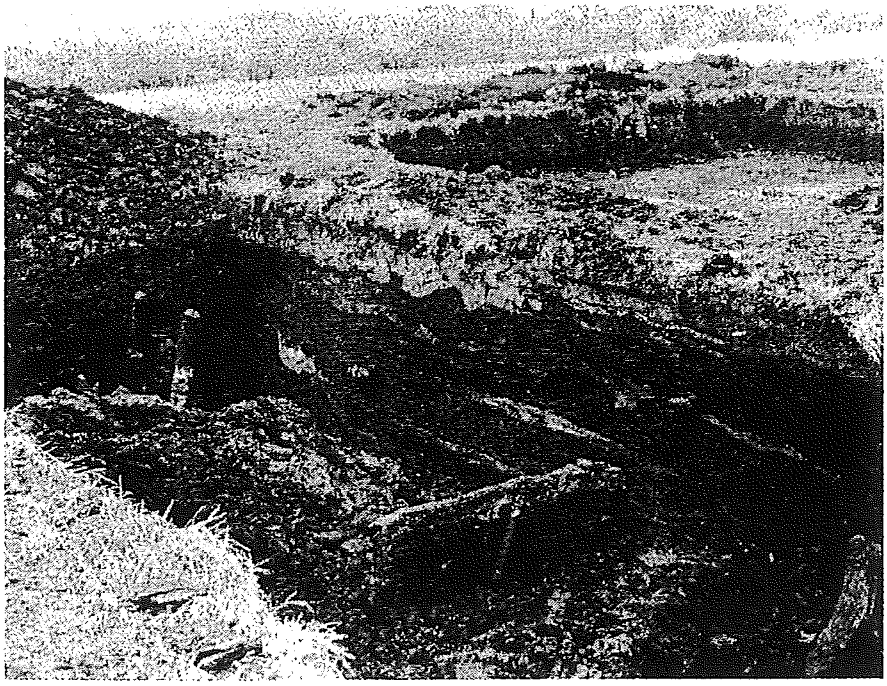


Fig. 6. Loam floors seal off the palaeoecological evidence from 5 successive phases of occupation, dating from the late 10th to the 12th century. When the first layer of infill (with the first farm house on it) had sunk into the peat, a second layer was added, the house was elevated or rebuilt and a new floor was spread. This process was repeated 4 times. Four of the 5 floor levels can be seen in this section.

Milk was brought to Amsterdam once or even twice a day; milk and cheese production became the major sources of income for most people in Waterland. The economy of the villages of Waterland completely changed. They no longer said: "Oh yes, that is true, our wives may have one or two cows" (see above); now it had become: "Our people occupy themselves almost exclusively with dairy farming", "The villages are solely concerned with the production of milk, which they bring to the market at Amsterdam" (1750) (Bos 1985a).

The shift from craft, sea-faring and trade to dairy farming was the second major change in the economy of Waterland, and for the second time some of the settlements were relocated. Some smaller hamlets disappeared completely, as did many scattered farms. The elongated structure of the villages (Fig. 4) was, in several instances, given up in favour of nuclei near the church (Bos 1983, 1986).

It is curious to see that at a time of growing importance of the land, the focus of the settlements turned inward. The background of this development is as yet unknown. Was it a matter of greater security to live closer together, or was it a matter of an 'urbanization' of thought? Much interdisciplinary research remains to be done. Another new element in the landscape was the half-land, half-water area in western Waterland, where peat was cut in large quantities for sale in towns. The peat cutting was, so to say, the last possible use of the land. These areas are now, for the most part, nature reserves. Peat cutting enriched the wildlife, but obviously it decreased the archaeological value, as many sites have been cut away. In some places we see a regeneration of peat growth. At others, humans have created a totally new landscape, as in the recreation area Twiske, where trees and hills abound as if the architect suffered from a *horror vacui*!

The housing developments of Amsterdam are also new. The multi-storied apartment blocks present a sharp contrast to the adjacent polder landscape of the remaining part of Waterland.

Today, dairy farming is still important in Waterland. Problems with the irreversible process of lowering the water-table, however, have not ended. During the present reallotment programme the water-table will be lowered by, on average, a further 60 cm. It can be predicted, looking at the past, that one day yet another phase in the landscape development can be expected: one day the continuous lowering of the water-table must come to an end.

Relics from the past

It will be clear that the most important historical monument of Waterland is the landscape itself. It comprises both the natural elements, such as the remaining original rivulets, and the cultural landscape, made through, and in spite of, human activities.

This landscape is furnished with many small monuments of the past. Many of the Medieval sites can be discovered by systematic field-walking (Bos 1985b), inquiries into field names (Bos 1983) and other such methods. Others are recognizable as features in the landscape itself. House *terpen* may sometimes be easily distinguished, although the general tendency of the peat is towards a level surface. *Terpen* that have sunk can be recognized by the way they seem to have diverted the ditches (Fig. 5). Each anomaly in the ditch pattern may result from the ditch being made around or along a former yard.

The remains of these former settlements form a very important outdoor archive. Their archaeological potential is self-evident, but their palaeoecological potential is no less great; each time a loam floor was spread or a layer of infill was added (Fig. 6), information about vegetation and landscape was sealed. Continuous waterlogging guarantees good preservation of organic material. The contrast between the original raised-bog vegetation and the successive later vegetation types is considerable. Many hundreds of house sites have already been mapped and described by means of cores. A programme for palaeo-ecological research of samples from a representative number of these sites has been established.

The landscape of Waterland not only bears witness to its own history. It is also an important source of information for the study of the rise of Holland as a commercial nation. It is therefore fortunate that the importance of this cultural landscape has been realized just in time to preserve it for the future.

Waterland 1000-2000 A.D.

Summary

(1) Integrated archaeological and palaeoecological investigations of Waterland, a former raised-bog area in the western Netherlands, have concentrated on natural and human-induced changes in the landscape (from raised bog to damp pasture area) and related subsequent shifts in economy and settlement pattern.

(2) Active growth of the raised bogs ceased in the 10th century, when the bog-surface dried out during frequent droughts.

(3) The bogs were colonized and crops grown until the end of the 13th century, when subsidence caused by drainage lead to flooding.

(4) From 1300-1600 the area was used as pasture, until continued subsidence lead to declining productivity. Local people took up crafts and trades such as sea-faring and fishing, and moved their settlements from fields to dykes and waterways.

(5) After 1600, war and technical innovations resulted in further drainage to permit profitable dairy farming, and the villages and landscape were again remodelled.

(6) The land surface is now below sea level, and subsidence problems will continue until all the peat has disappeared.