2.1   Introduction

One of the main approaches in the present study is palynological research. In this research, pollen grains and spores are the objects of study. These particles are produced by flowering plants, ferns and other cryptogams. Pollen grains and spores are identifiable to more or less low taxonomical levels (often to families or genera, sometimes to species). These different taxonomical levels will in the following be referred to as taxa.

A major part of the pollen and spores produced by plants do not fulfil their natural function of fertilization. In an environment deprived of oxygen, they can be preserved for a long time. Examples of pollen-containing sediments are peats and lake-deposits. After chemical treatments, the pollen contained in such deposits can be studied.

The pollen and spores preserved in a sediment are a reflection of the vegetation that prevailed during deposition of the sediment. The composition of a pollen spectrum is largely determined by the composition of the vegetation that produced it, although pollen production and pollen dispersal differ considerably between different taxa (see further 2.3).

The pollen that is transported by air is generally referred to as the airborne component (pollen rain). Part of this airborne pollen derives from the close vicinity of its place of deposition. This component is referred to as local pollen (*sensu* Janssen 1973). It is usually transported less than 25 m. Pollen transported over greater distances, up to several kilometres, is referred to as regional pollen. In our region, such airborne transport over relatively great distances mainly occurs in tree pollen. The share of local and regional pollen in the pollen deposition in any given location depends not only upon the pollen production of the local vegetation but also upon the size of the basin in which the pollen is deposited. In an extensive body of *Sphagnum* peat or a lake, the contribution of the regional pollen deposition is much greater than in smaller basins.

Some pollen types are extremely well adapted to long-distance dispersal (e.g. *Pinus*), relatively low amounts of such pollen types in a deposit may have derived from sources tens to hundreds of kilometres away. This component is referred to as extra-regional.

Apart from airborne pollen, some sediments also contain pollen transported by water (waterborne pollen). The origin of waterborne pollen may be far away from the site of deposition, especially where large river basins are concerned. Waterborne pollen may especially be present in clayey sediments. Owing to its origin far distant from the site of deposition, waterborne pollen distorts the information on the environment of the sampling site as provided by the local and the regional airborne components. As a result, a pollen spectrum from clayey sediments is much more difficult to interpret than one from a raised bog, where waterborne pollen can be excluded. Together with waterborne pollen which is produced just prior to its transportation by water, the water may also contain pollen eroded from older sediments. The presence of pre-Quaternary pollen is indicative of such redeposited pollen.

For palynologically based environmental reconstructions of the Iron Age and Roman Period, pollen containing deposits from these times are required. On Voorne-Putten, the peaty layers present between the different Dunkirk deposits offer good possibilities. The Dunkirk clay deposits themselves also contain pollen, but some of this is waterborne or even redeposited. These factors render the interpretation of pollen spectra from Dunkirk clay much more complicated than those from peat. In places where Dunkirk I sediments are present, no peat is formed during clay sedimentation. Since habitation is often correlated with these Dunkirk I sediments (see *1.3*), this is an important restriction. Besides, the top of the peat that predates the clay sedimentation may have been eroded during transgression of the sea and consequential flooding of the peat.

2.2   Previous investigations

In the framework of the investigations relating to the geological map 37 West (Van Staalduinen 1979), several sections containing Holland peat on Voorne-Putten were analysed by the *Rijks Geologische Dienst* (R.G.D.; Geological Survey of the Netherlands).

The questions which the R.G.D. investigations tried to answer were of a geological nature. Dating of the layers of peat and clay were of primary interest. Such dating of Holocene sediments is possible by means of pollen analysis, using the different times of arrival of the tree species after the increase in temperature following the last ice age (Weichselian). Figure 10 shows the palynological criteria

Chronostratigraphy (Palynological periods)	Pollen (sub) zones	Main pollen-analytic features		Archaeological periods	Conventional ^{14}C age in years BP	Dendrochronological age (calibrated radiocarbon age in solar years)	Periods of transgression C=Calais, D=Dunkirk / periods of regression (Zagwijn & Van Staalduinen 1975)
HOLOCENE — Subatlantic	Vc		Increase of Pinus	Recent	0	1950	
	Vb2	Fagus > ca 5%	Increase of Secale	Middle Ages	1000	1000	D III
	Vb1		Carpinus > 1%	Roman	2000	0	D II
	Va		Carpinus < 1%	Iron Age			D I
					3000	1000	
Subboreal	IVb	Fagus > 1%		Bronze Age		2000	D0
	IVa	Ulmus low; agriculture		Late (Neolithic)	4000	3000	C IV
				Middle (Neolithic)	5000	4000	C III
Atlantic	III	Ulmus > 5% Alnus and Quercus important; Pinus low		Early (Neolithic)	6000	5000	C II
				Mesolithic	7000		C I
					8000		
Boreal	II	Alnus very low; Pinus dominant; Quercus, Ulmus, Corylus			9000		
Preboreal	I	Pinus, Betula dominant Corylus, Quercus etc. very low					

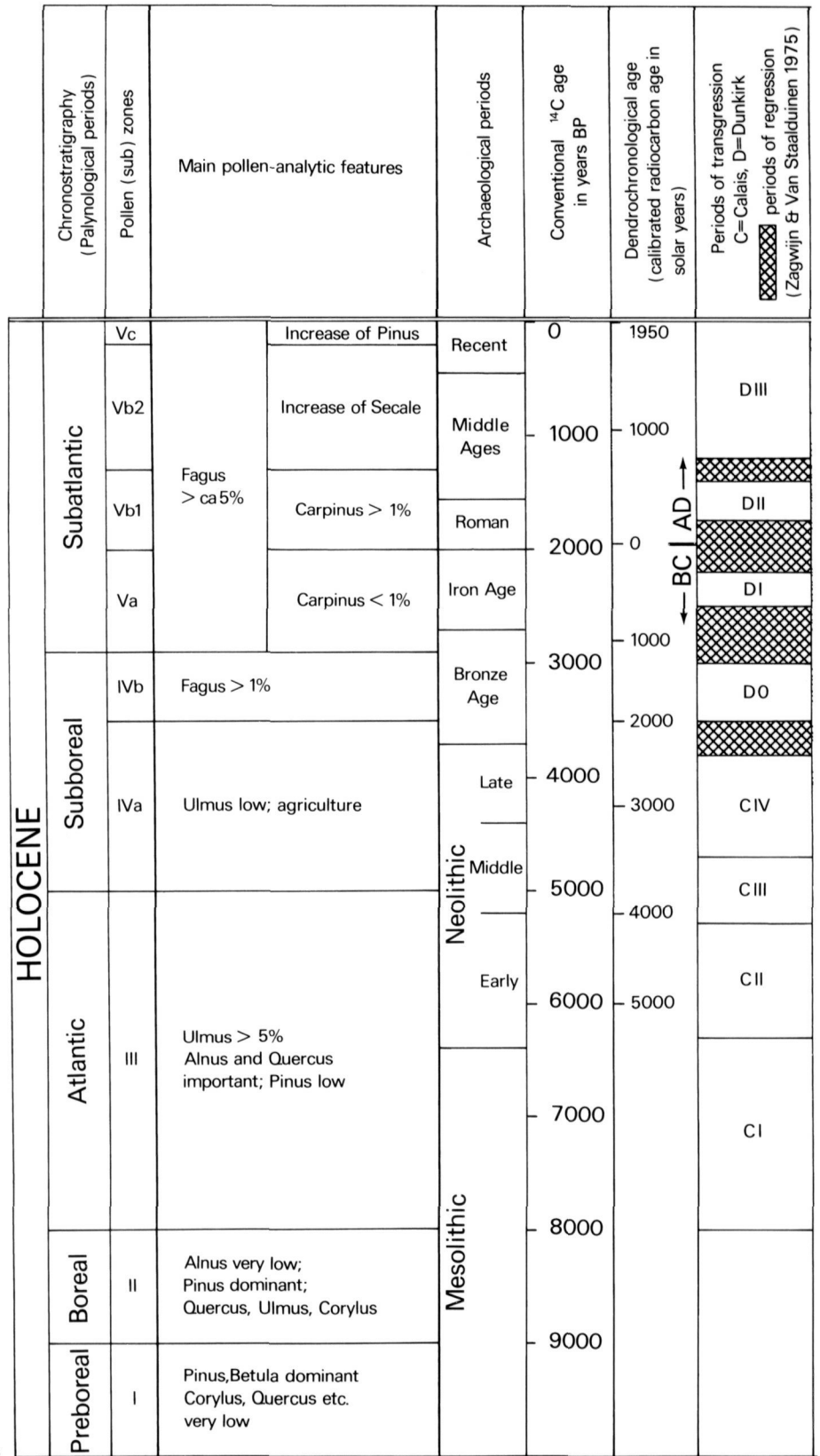(BC | AD indicated on the ^{14}C / dendrochronological axis, with → AD above and BC ← below.)

Fig. 10 Palynological criteria for distinguishing the different periods of the Holocene (after Berendsen/ Zagwijn 1984).

used to distinguish the Holocene periods in the Netherlands (after Zagwijn 1975; Berendsen/ Zagwijn 1984). The dispersal of trees after the withdrawal of the last glacial ice cover is the main determining agent to the succession observed. The arrival and spread of *Fagus* is the key characteristic of younger (Subboreal and Subatlantic) deposits. According to the R.G.D. criteria, the start of the Subatlantic period is characterized by a rise of *Fagus* above 5%, relative to a pollen sum comprising all tree pollen (arboreal pollen sum). Within the Subatlantic deposits, the spread of *Carpinus* after the start of the Christian era is significant in the Netherlands. According to the R.G.D. criteria, the presence of *Centaurea cyanus*, *Fagopyrum* and *Secale* characterize deposits dating from the Middle Ages or later. Notwithstanding the fact that occasional earlier finds of *Secale* (cf. Janssen 1972) and *Fagopyrum* (cf. Janssen 1972; Eland 1984) do exist, are the R.G.D. criteria very useful to estimate dates of pollen diagrams.

Several of the R.G.D. pollen diagrams from Voorne-Putten cover part of the Subatlantic period. They are highly relevant to the researches at hand. Especially the diagrams from Geervliet (De Jong 1961), Lodderland (Jelgersma 1957b), Brielle-Tinte (Zagwijn 1955) and Heenvliet (Zagwijn 1955) are important. The first three contain the first part of the Subatlantic. The Holland peat in these sections is covered by Dunkirk I deposits, which terminated peat growth around 2400 BP. In Heenvliet, peat growth continued into the Roman Period, which is exceptional in the southwest of the Netherlands (see 2.7). All data in these diagrams, published in internal R.G.D. reports, have been placed at my disposal by Ing. J. de Jong and Prof. Dr. W.H. Zagwijn.

These R.G.D. diagrams also provided part of the basis for the palaeogeographical reconstructions by Zagwijn (1986) discussed in chapter 1.

2.3   Methods used in the present research

For a detailed reconstruction of the environment during Early and Middle Iron Age habitation, and for any human influence upon vegetation, several sections near excavations were sampled. For sampling, monolith tins, measuring 50 × 5 × 4.5 cm were used, unless otherwise indicated.

In the laboratory, each section was cut into slices of one cm in thickness. Pollen samples were obtained from the central part of these slices. The samples were treated following Fægri *et al.* (1989), a bromoform-alcohol mixture (s.g. 2.0) was used to separate organic and mineral material, thus omitting the corrosive HF. Except for a few samples very poor in pollen, analysis was carried out until at least 300 pollen grains from upland trees were counted. This upland tree pollen constituted the pollen sum. As a rule, every second centimetre of the sampled column of sediment

was counted. This appeared to provide enough detail, rendering the counting of every centimetre unnecessary.

For the identification of pollen and spores, the following publications were used: Fægri and Iversen (1975), Punt (1976), Punt and Clarke (1980, 1981, 1984), Erdtman *et al.* (1961, 1963), Moore and Webb (1978), Culhane and Blackmore (1988) and Van Leeuwen *et al.* (1988). Identifications were additionally checked with the aid of the I.P.L. reference collection. Dr. W. Punt identified and checked some problematic grains. Other microfossils, such as algae, fungi, etc. (Types *sensu* Van Geel 1978), were identified following the publications by Van Geel (1978), Van Geel *et al.* (1982), Pals *et al.* (1980) and Bakker and Van Smeerdijk (1982).

Palaeo-environmental reconstruction, which is the aim of palynology in an archaeological perspective, requires a greater density of spectra within the stratigraphical column than geological investigations usually necessitate. By analysing spectra with small vertical distances, more subtle changes in the pollen record through time, and thus indirectly in the vegetation, can be monitored.

The aims of the investigations also influence the pollen sum which underlies the diagrams. The R.G.D. diagrams are based on a pollen sum comprising all trees. For the present study, it was decided to deviate from this pollen sum. The composition of the vegetation on the mineral deposits (the "upland" component of the environment) and in the peaty landscape ("wetland") are of such relevance to the economic possibilities of prehistoric inhabitants that any changes in both these environments should be as clear as possible in the pollen diagrams. In a pollen sum comprising all trees, changes in wetland components like alder (*Alnus*) influence the percentages of upland trees. Especially when alder is locally present during deposition of a sediment, the disturbing effect may be enormous (see also Janssen 1959). This is considered undesirable in the present study, hence a pollen sum consisting of upland trees only was used as the basis for calculations. A result of this deviation from the R.G.D. pollen sum is that the level of 5% in *Fagus* may be achieved earlier, since the percentages of upland trees will be higher in the pollen sum used in the present study.

Contrary to Iversen's upland pollen sum (1947, cited in Janssen 1974), in this study herbs have been excluded from the pollen sum. Nearly all herbaceous pollen types found either played a role in the local succession (although they are often considered "upland" pollen, e.g. Umbelliferae, Compositae) or they possibly indicated marine influence (e.g. Chenopodiaceae). Inclusion of these pollen types in the pollen sum would result in grave distortions of other curves in those parts of the diagrams in which they occur abundantly. By excluding wetland trees and all herbs, changes observed in pollen of upland trees can only be caused by changes in the composition of the upland forests themselves (see also Fægri *et al.* 1989). None the less, changes in the

wetland components can be detected relative to the upland pollen sum.

The curves for each taxon still will be influenced by other taxa in relative pollen diagrams. The following theoretical example may illustrate this point. Two species, A and B, are the only ones present in the pollen sum. Both have a comparable pollen production. In the first spectrum, both types occur in equal quantity, so a score of 50% for each is recorded. Then, the forest composition changes; species A remains steady, there is no change in the number of trees, hence not in pollen production and -deposition either. Species B, however, is twice as common at the time of the second spectrum. Consequently, the pollen spectrum shows 33.3% for A and 66.7% for B. Seemingly there has been a decrease in species A when comparing the two spectra. However, this is entirely due to the increase of species B. In the same way a decrease of species B will result in a relative increase of species A. Evidently, the percentages of the taxa included in the pollen sum are not independent of each other. It can be demonstrated that the same applies to taxa which are not included in the pollen sum (see also Tauber 1965: 44).

To meet these objections, assessments of the absolute number of pollen grains may be made (Benninghoff 1962; Stockmarr 1971), following the procedure described below. For each spectrum, 1 cm³ of sediment is processed. To this volume of sediment (and the pollen contained in it), a known number of exotic pollen or spores (viz. 12,100 *Lycopodium* spores) are added. By means of the number of *Lycopodium* spores retrieved in the analysis, the original number of a given taxon can be assessed as follows:

$$\frac{\text{counted pollen taxon A}}{\text{counted spores } Lycopodium} = \frac{\text{original number of taxon A}}{\text{added number of } Lycopodium}$$

From this equation follows:

$$\text{original number of taxon A} = \frac{\text{counted pollen taxon A} \times 12,100}{\text{counted spores of } Lycopodium}$$

Thus, the absolute number of pollen of each taxon per 1 cm³ of sediment can be graphically represented as pollen concentration diagrams. Unfortunately, this method too has a major drawback. The 1 cm³ of sediment used, represents a certain amount of vertical sedimentation which is related to time. Fluctuations in the numbers of a taxon may be caused by fluctuations in its presence in the landscape, but alternatively, it may be due to fluctuations in the rate of sedimentation. By means of a series of radiocarbon datings, possible fluctuations in sedimentation can, at least roughly, be assessed and corrected. This way, the pollen concentration diagram is converted into a pollen influx diagram (cf. Fægri et al. 1989). These pollen influx diagrams are probably the best reflection of pollen deposition. As Fægri et al. (1989) stated,

"conceptually, pollen influx data are much simpler and more direct representations of the natural vegetation, and therefore permit a more penetrating analysis, leading to more meaningful results. It opens the possibility of a (semi-) quantitative evaluation of former vegetation. (...) This does not mean that the old methods have become obsolete or redundant. Percentage presentations are inherent parts of all quantitative numerical pollen analyses and are automatically obtained. To transform them to concentration data costs very little, but to add the datings necessary for influx data may be impossible in some sediments, expensive and cumbersome in others".

As, moreover, relative diagrams dominate the literature (see also Birks/ Gordon 1985), I have decided to present mainly relative diagrams. Only for Spijkenisse 17-30, a pollen influx diagram will be presented.

Both relative pollen diagrams and pollen influx diagrams are based on the deposited numbers of pollen. However, it should be pointed out that there is a large discrepancy between pollen deposition and the number of a species/ taxon in the pollen catchment area of the site. This is due to the differential pollen production of various species. Pollen production is heavily dependent on the pollination strategy of a species. For instance, the pollen production of the insect-pollinated lime (*Tilia*) is substantially lower than of wind-pollinated species like oak (*Quercus*) and alder (*Alnus*), and pollen of pine (*Pinus*) is very well adapted to wind-pollination and long-distance transport.

To investigate the importance of differential pollen production in various tree species, Andersen (1970, 1973) compared the numbers of tree pollen in cushions of moss in Danish forests with the area covered by the crowns in the surrounding vegetation. This research revealed that there is a linear relation between these parameters. The more commonly a species occurs in the vegetation, the more it contributes to the pollen rain. The ratio of pollen percentage/crown area percentage is called the R-value. Trees with a low pollen production thus also have low R-values, a high pollen production similarly results in a high R-value. As a result, these R-values express the over- and under-representation of the species in individual pollen spectra. This difference in representation is exclusively due to differential pollen production.

R-values are not comparable from site to site, because they differ in various combinations of species and vary with the frequency of species (Andersen 1973: 110). Davis (1963) showed that the ratios of the R-values to the R-values of a reference species do offer the possibility of comparing different sites. The example presented by Birks and Gordon (1985: 185) may serve to illustrate this point (see *table 1*).

From this table it will be clear that the taxa have different R-values in different sampling sites, but their R_{rel}-values are the same.

Andersen used *Fagus* as a reference species. The resulting

Table 1. Hypothetical correction factors for pollen production (R-values) for three locations with three taxa each (after Birks & Gordon 1985).

Taxon	Vegetation	Pollen	R-value	R_{rel}-value
A	0.4	0.8	2	10
B	0.1	0.1	1	5
C	0.5	0.1	0.2	1
A	0.2	0.5	2.5	10
B	0.3	0.375	1.25	5
C	0.5	0.125	0.25	1
A	0.68	0.85	1.25	10
B	0.22	0.1375	0.625	5
C	0.10	0.0125	0.125	1

Table 2. Correction factors for pollen production (R_{rel}-values) of various tree species relative to *Fagus* (after Andersen 1973).

Taxon	R_{rel}-value
Quercus, Betula, Alnus, Pinus	1:4
Carpinus	1:3
Ulmus, Picea	1:2
Fagus, Abies	1:1
Tilia, Fraxinus	1×2

R_{rel}-values can be used for a correction of pollen spectra, in which the percentages of the different trees indicate the crown area percentages. The correction factors found by Andersen are shown in table 2. According to these data, the percentages of *Quercus* for instance should be divided by four to correct differential pollen production.

The R_{rel}-value of *Corylus* presents additional problems. For hazel in full light, Iversen (1947, cited in Andersen 1973) suggested a correction factor of 1:4, while under a tree canopy the factor may be 1:1 (Andersen 1973: 111).

Andersen's research related to local pollen deposition within forests. The pollen largely came from vegetation within a 20-30 m¹ radius of the place of sampling. Thus, the pollen production of different trees is of much greater importance than their pollen dispersal. In lakes and bogs, in contrast, the pollen spectra derived from vegetation from a much larger area and consequently, differential pollen dispersal plays a considerably larger role than in Andersen's studies.

In medium or large basins, the share of regional pollen is much greater than the local pollen component (*sensu* Janssen 1973). One may wonder how far pollen is generally dispersed from its source. According to Birks and Gordon (1985: 233), who cite several sources, medium- or large-sized lakes or bogs (at least 250 m in diameter) have pollen source areas of at least 1000-2000 km², which corresponds to a radius of 18-25 km. However, the distance pollen can bridge differs from taxon to taxon. Some produce large amounts of

light pollen, which is widely dispersed (e.g. *Pinus, Betula*), while others have a low production of heavy pollen, which is poorly dispersed (e.g. *Acer, Tilia*).

Janssen (1981) described recent pollen deposition in the Vosges (France). He concluded that the local effect of trees is felt over relatively short distances from the forest edge. This local effect is usually negligible at distances beyond 150 m from the pollen source. For herbs, Gramineae probably excluded, this distance is much shorter, usually not more than a few metres.

The pollen deposition in large basins is further complicated by the fact that pollen deposition decreases gradually, rather than abruptly, with distance, and at different rates for different species. These complications necessitate the incorporation of a "background component" in the calculation of R-values. This background component represents pollen produced outside the area for which the tree crown coverage was estimated. The fact that different taxa differ in their pollen dispersal capabilities and depositional characteristics, which are related amongst other things to size, shape and weight, complicates the relation between vegetation and pollen deposition even more (Birks/ Gordon 1985: 186). These authors (p. 187) conclude that

"size and type of the basin should be standardised as far as possible in any attempt to estimate R-values, and should be similar to the sites from which fossil stratigraphical data of interest are available. It is this problem of defining realistic pollen source areas that has perhaps resulted in the R_{rel}-value model being discarded by many palynologists".

One may conclude that at present there are still many difficulties in the use of R_{rel}-values. The results obtained could show a misleading precision. For this reason, I have not used any pollen representation factors to convert my percentage diagrams.

2.4   Pollen diagrams

2.4.1   THE POLLEN DIAGRAM OF SPIJKENISSE 17-30

The location of this section is indicated in figure 11. The section has been sampled near the Early Iron Age site of Spijkenisse 17-30, it lies 6 m northeast of the excavated farmstead. The stratigraphical position of the sampled part of the section is indicated in figure 12. The section had been cut especially to obtain material for palynological research by the excavators of the B.O.O.R. The top of the peat is strongly decomposed, the transition to the overlying clay is gradual.

Figure 13 represents the relative pollen diagram of Spijkenisse 17-30². Throughout the diagram, Gramineae and monolete psilate fern spores (*Thelypteris* type) are predominant. *Sphagnum* and Ericales are rare. This shows that we are dealing here with eutrophic fen peat.

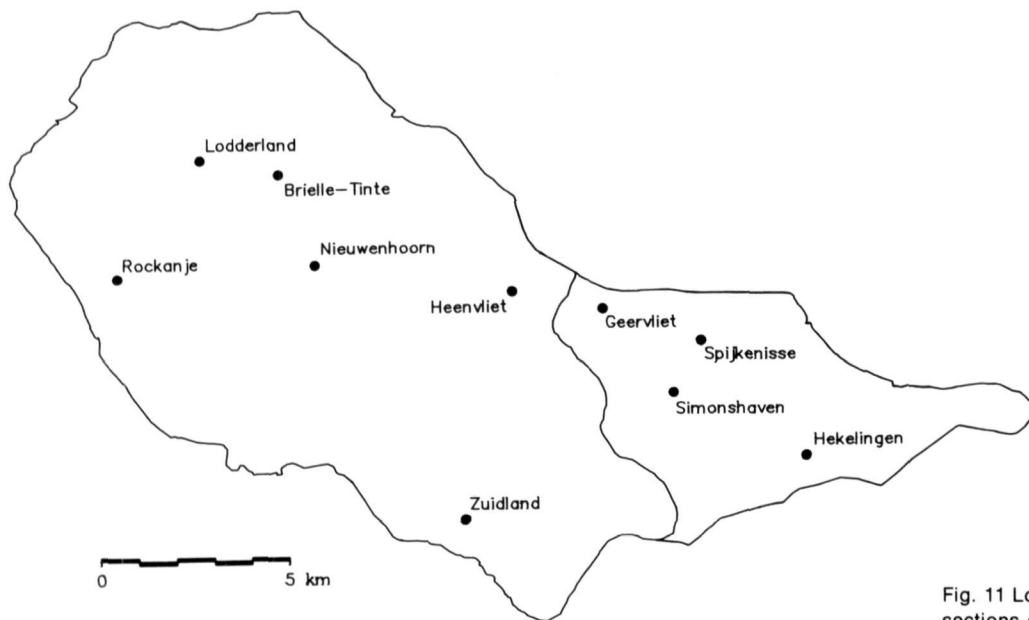The first local zone (A) is characterized by relatively high

Fig. 11 Location of the palynological sections on Voorne-Putten, scale 1:2000.

proportions of *Quercus* (oak) and *Fagus* (beech). *Corylus* (hazel) is present in lower percentages in comparison with the following zones. Already at the base of the diagram, *Fagus* exceeds 5%. Although the pollen sum used here deviates from that of the R.G.D., most probably the whole diagram can be dated to the Subatlantic period (compare *fig. 10*). This is confirmed by a ¹⁴C dating of 2625 ± 40 BP (GrN-15222) from the base of the peat. *Carpinus* does not attain values of 1% in a closed curve, so the whole section predates the Christian era. The algae *Pediastrum* and *Spirogyra* attain their maximum values in the first zone, the same applies to *Lythrum*. The algae indicate the presence of stagnant, fresh water.

In local zone B, *Quercus*, *Fagus* and *Tilia* show a marked decline, *Corylus* increases strongly in the relative diagram. The declining taxa are all trees of primary forests, whereas *Corylus* is a pioneer species of secondary forests (cf. Smith 1978). The remarkable changes in the composition of the upland pollen rain may have several causes.

In view of the peak of Chenopodiaceae pollen at the end of zone A, increased marine influence is the first possible cause of deforestation. A rising water table, connected with increased marine influence, probably had its effect upon the upland trees, which are sensitive to high water tables in the growing season. However, *Corylus* is likely to be affected by these circumstances in the same way. Consequently, the apparent increase of *Corylus* remains unexplained. The drowning of the upland forest would most probably also result in the expansion of *Alnus* in these parts of the land-

scape (see also Willerding 1977). In the pollen diagrams, however, *Alnus* shows a steady decline, more or less following the curve of *Quercus*. A further argument against a wetter phase during zone B is the decline of aquatic taxa like *Pediastrum*, *Spirogyra* and cf. *Potamogeton*, and the increase of Umbelliferae and Compositae tubuliflorae. Similar changes in these taxa occur in the *Assendelver Polder* section, investigated by Witte and Van Geel. They also point to drier local conditions to account for these changes (Witte/Van Geel 1985: 250).

A second option for the interpretation of the changes in upland tree pollen can be found in the study by Van der Woude (1983). His study concerns part of the Rhine-Meuse basin in the Alblasserwaard near the Hazendonk (upstream from Voorne-Putten). Here clayey layers, in comparison to peat, show notably higher values of *Fagus*, *Picea*, *Abies* and, to a lesser extent, of *Pinus*, *Tilia* and *Quercus*. This is explained by river-transported pollen of these six taxa. In periods of inundation, together with the sedimentation of clay, pollen from the hinterland is deposited. Florschütz and Jonker (1939) already postulated aquatic long-distance transport of pollen of *Pinus*, *Picea* and *Abies* to account for high values of these taxa in clayey sediments along the Rhine. In the case of Spijkenisse 17-30, the same might play a role in zone A and termination of riverine influence in zone B would result in the decline of these species. However, several observations invalidate this explanation. Firstly, *Pinus* shows regular percentages throughout the diagram, and *Picea* and *Abies* are hardly or not at all represented.
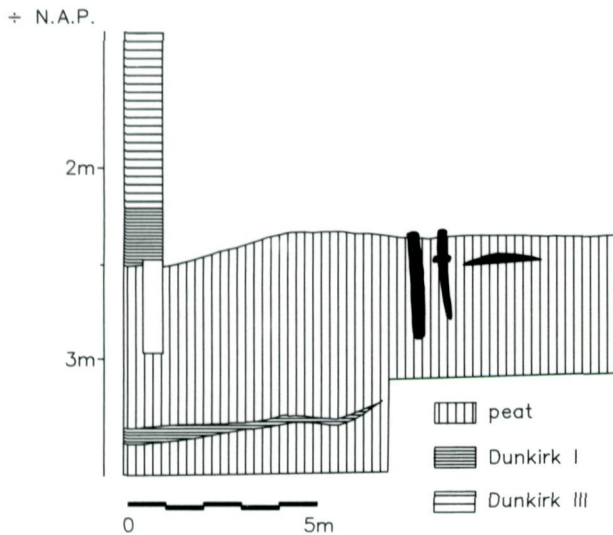
÷ N.A.P.

Fig. 12 Position of monolith tin in section of Spijkenisse 17-30. Black = wooden posts.

peat

Dunkirk I

Dunkirk III

0   5m

Secondly, a clayey enrichment of the sediment in zone A could not be found. Besides, pre-Quaternary pollen, often characteristic of redeposition in Holocene sediments (cf. Dimbleby 1985), are lacking in the Spijkenisse diagram.

The third possible explanation points towards an anthropogenic origin. Deforestation by man of the upland area can explain the decline of *Quercus*, *Fagus* and *Tilia*. The rise of *Corylus* in this case may have been due to better flowering or expansion of this light-demanding species, facilitated by the opening up of the formerly closed primary forest. The decline of *Alnus* may also have been due to felling, as this species was very regularly used for construction purposes during the Iron Age (see 3). Furthermore, *Alnus* is a predominating species in the charcoal from hearths (see Brinkkemper/ Vermeeren *in press*). The changes in the forest composition would in this case reflect a phenomenon with many parallels to Iversen's (1941) classic *landnam*.

The radiocarbon dating of the base of zone B, 2435 ± 45 BP (GrN-15223) is in perfect agreement with datings of construction wood belonging to the nearby Early Iron Age site of Spijkenisse 17-30 (c. 2450 BP; Van Trierum 1986). The ^{14}C dates for the pollen diagrams presented here were obtained from the same peaty material as was used for pollen analysis.

In view of these arguments, the changes observed in the composition of the upland forest can, in my opinion, only be attributed to anthropogenic causes.

In zone C, after a slight recovery of *Quercus*, a second decline is represented. The ^{14}C date of 2220 ± 30 BP (GrN-13236; Van Trierum 1986) fits in perfectly with the datings

of wood in Middle Iron Age constructions (c. 2200 BP; cf. Van Trierum 1986). The peak of *Myrica* in this zone may be explained by local peat development. In the sediment concerned, a strong decomposition of the peat can be observed. This is due to drainage of the peat, related to the first influences of the Dunkirk I transgression phase, which culminated in the sedimentation of clay on top of the decomposed peat. *Myrica* grows abundantly on this kind of peat as a result of the higher mineral contents generated by decomposition (see also Denys/ Verbruggen 1989). Thus, the strong increase fits in very well. Bakker and Van Smeerdijk (1982: 131) observed similarly high *Myrica* percentages in decomposing peat. In Behre's (1976b) diagram Ahlenmoor VI, *Myrica* shows high values after a level poor in pollen. This also seems to indicate the spreading of *Myrica* on decomposing peat. Apparently, this phenomenon is not restricted to the Dutch coastal area.

The high percentages of *Corylus* pollen recorded in the present diagram are conspicuous. In Iversen's (1941) publication, where the expression *landnam* is introduced, a peak of *Corylus* occurs during regeneration of the forest, in Iversen's case after *Betula*. Here, *Quercus* was also a major component, which was adversely affected by human influence. The species that play a role in the regeneration will amongst other things depend upon soil factors, which may account for the subordinate role of *Betula* in the present study.

The persistently high values of *Corylus* in the present diagram, however, cannot be explained by regeneration. The phase with hazel in the succession of a regenerating forest would not last several hundreds of years. The prolonged abundance probably points towards longlasting open spaces in the upland forest.

However, the pollen influx diagram reveals some unexpected perspectives in this observation. This diagram is based on absolute values per cm³, with differences in sedimentation rates corrected with the aid of ^{14}C datings. The diagram (*fig. 14*) shows convincingly that the relative maxima of *Corylus* are caused by the falling off of other upland trees. The absolute numbers of hazel pollen deposited per time unit remain constant. Consequently, the net pollen production of *Corylus* did not increase. The positive influence of better light conditions may have been offset by a reduction in the numbers of these shrubs.

The obvious interpretation of these data is that a considerable clearance of the primary forest on mineral deposits (the "upland") took place at the same time as Early Iron Age habitation in the area. After a short period of recovery, the next clearance phase is recorded in the pollen diagrams at the time of Middle Iron Age habitation.

In the last zone (D) of the relative diagram, *Quercus*, *Tilia* and *Fagus* recover again. In this case, the sedimentation of allochthonous pollen together with clay may explain this

phenomenon. In the clayey samples, there need not be any relation with the development of the upland vegetation on Voorne-Putten. The possibly renewed recovery of the forest cannot be observed owing to the sedimentation of clay during the Dunkirk I transgression phase. Therefore, the diagram does not contain information on the Late Iron Age and the Roman Period. Reliable ^{14}C dates cannot be obtained from the clayey sediment of zone D. Consequently, no pollen influx diagram can be drawn for this part of the section.

The changes in the tree pollen values are thus best explained by human influence upon the vegetation. It may be asked whether there are other indicators of human activities in the area discernible in the diagram. The repercussions of human activities in pollen diagrams have been subject to many studies, in which ranges of "anthropogenic indicators" have been suggested. These indicators may belong to two categories. Firstly, they may concern species cultivated by man, which Behre (1990c) referred to as primary anthropogenic indicators. Secondly, a range of non-cultivated anthropogenic indicators is mentioned in the literature on this subject, which Behre called secondary anthropogenic indicators.

As for the cultivated species, the curve of cereal pollen (Cerealia-type) has often been considered to provide useful information (cf. Beug 1986; Teunissen *et al.* 1987). In the diagram of Spijkenisse 17-30, Cerealia-type pollen is only recorded in one spectrum from the upper layer of clay. The absence in the Iron Age spectra is not as strange as it appears at first sight. The cereals cultivated during the Iron Age, viz. wheat species, barley and probably oats (cf. Van Zeist 1970; *ch. 4*), are all autogamous. As Iversen (1941, 1949) already observed, cereal pollen remains enclosed between the bracts, resulting in self-pollination. Only rye (*Secale cereale*) is a wind-pollinated species with good pollen dispersal. This species, however, did not come into large scale cultivation before medieval times (cf. Behre 1976a; Pals/ Van Geel 1976), although it does occasionally occur in the 3rd or 4th century (Behre/ Kučan 1986).

Regarding the Iron Age cereals, Heim (1970) demonstrated in recent situations that at a distance as short as 50 m from the fields, cereal pollen can no longer be demonstrated. Diot (1992) studied the pollen dispersal of bread wheat (*Triticum aestivum*) and the wild ancestor of emmer wheat (*T. boeoticum*). Within a cultivated field, ca. 10% of cereal pollen was found in the uppermost centimetre of the soil. This percentage decreased to ca. 3% at 10 metres' and 1.4% at 50 metres' distance. Hall (1988) even reported a drop in grain pollen to 1% at a distance of only 1 m from the edge of cultivated fields.

In the plough marks of a Bronze Age field near Haarlem (the Netherlands), C. Vermeeren (*pers. comm.*) found only three Cerealia type pollen grains (1%), amidst reasonably

well-preserved material. In the peaty sediments next to this field, she could not demonstrate any cereal pollen at all.

As Ralska-Jascewiczowa (1968) already demonstrated, most of the pollen of autogamous cereals is released during threshing. Considerable numbers of cereal pollen (except *Secale*) in pollen diagrams mostly, if not always, consist of this "threshing pollen" (see also Robinson/ Hubbard 1977). This phenomenon is very convincingly demonstrated by Vuorela (1973), who monitored the pollen rain around cultivated fields (with the cereals *Hordeum* and *Avena*). By means of pollen traps inspected monthly, she established that most cereal pollen is found in the latter part of August, i.e. harvest time. During flowering time, hardly any cereal pollen was found. The combine harvester, by scattering the chaff, dispersed the pollen. Welten (1967) published pollen diagrams from a transect leading away from a Neolithic lake-village in the Burgäschisee. In the settlement, he recorded 114% of Cerealia pollen, whereas at a distance of 29 m only 0.4%. The high amounts of Cerealia pollen in the settlement cannot have come from an arable field. They must be interpreted as threshing pollen and/or pollen from faeces.

Furthermore, cereal pollen cannot always be identified with certainty (see *2.4.8*). All in all, the very few Cerealia-type pollen grains found in the pollen diagram of Spijkenisse 17-30, whose sizes never exceed ca. 50 µm, may have come from coastal wild grasses. Their significance should correspondingly not be overrated.

Apart from cereals, some other cultivated species occur in the Iron Age. Linseed (*Linum usitatissimum*), gold of pleasure (*Camelina sativa*), cabbage species (*Brassica* spec.) and several pulses must be taken into consideration. *Linum* produces very characteristic pollen. However, this species is predominantly self-pollinated (Zohary/ Hopf 1988: 114) and thus very rare in pollen diagrams. The absence in the present diagram cannot be seen as evidence for a minor role of *Linum*. *Camelina* and *Brassica* produce pollen, which at present cannot be distinguished from several other Cruciferae species (cf. Behre 1981). Besides, *Camelina* is also self-pollinated (cf. Plessers *et al.* 1962). The different pulses (*Vicia faba*, *Pisum sativum* and *Lens culinaris*) do produce characteristic pollen. These legumes are insect-pollinated, so their pollen is also poorly dispersed, and very rare in pollen diagrams. In summary, we arrive at the conclusion that cultivated plants are very difficult to attest in pre-medieval pollen diagrams. Since medieval times, *Secale* has provided better opportunities.

Apart from these cultivated primary anthropogenic indicators, several other pollen types have been recognized as secondary anthropogenic indicators. Although not cultivated, these plants were favourably influenced by human activities. Behre (1981) gave a considerable stimulus to the use of these secondary anthropogenic indicators in

pollen diagrams. This theme is elaborated on by the various authors in the volume edited by Behre (1986a). In general, *Plantago lanceolata*, *Plantago major*, *Rumex acetosa*, Ranunculaceae and sometimes *Calluna* are regarded as indicators of pastoral farming. *Centaurea cyanus*, *Polygonum convolvulus*, *Spergula arvensis* and *Scleranthus annuus* are useful indicators of arable farming.

In the present diagram, the arable weeds are conspicuously absent. A closer examination of the species concerned reveals that, with the exception of *Spergula*, all belong to wintercrop weeds (equivalent to the present syntaxonomical class Secalietea). The study of botanical macroremains on Iron Age sites on Voorne-Putten demonstrated that only summercrop weeds (the present Chenopodietea) occurred. Seeds of *Spergula arvensis* have not been found either (see *ch. 4*). Thus, the absence of these arable indicators in the pollen diagram does not allow any conclusions to be drawn on the arable component of the economy as revealed by the pollen deposition. The scarcity of the "pastoral" indicators is probably linked to the type of soil. The species listed are useful in mineral environments. In the landscape around the Iron Age sites near the Bernisse, reed swamps and drier heathlands are the most likely environments for grazing (see also Witte/ Van Geel 1985). Here, the "pastoral" indicators probably could not play an important part. Behre (1976b) noted similar objections to pasturing on very poor soils. On such soils, extensive heathlands have been used for grazing sheep, but *Plantago lanceolata* does not occur in grazed heathlands.

Apart from these qualitative approaches of indicator species, quantitative ratios have been proposed by a number of authors as well. A very simple ratio is presented by Steckhan (1961) and Lange (1971). Cereal pollen forms the arable component and *Plantago lanceolata* the pastoral one. Their mutual share in pollen spectra was used to calculate the importance of arable and pastoral farming. However, as Behre (1981) pointed out, *Plantago lanceolata* may be absent in some types of pasture (heathlands, grazed forests, "*Hudewälder*"). Besides, *Plantago lanceolata* can recolonize fallow land, thus being an indirect indicator of arable land, especially before the introduction of the mouldboard plough, since the perennial *Plantago lanceolata* was probably not eradicated by the ard.

Turner (1964) proposed an arable/pastoral index, which is the ratio of *Plantago* grains relative to the total of *Plantago*, Compositae, Cerealia, Cruciferae, *Artemisia* and Chenopodiaceae. She claims that in recent situations,

"with one or two exceptions it is below 15% in the arable region and above 50% in the pastoral region" (Turner 1964: 81).

In his discussion on this ratio, Maguire (1983: 13) observed that on pollen sites close to the coast, *Elymus farctus* (= *Agropyron junceum*: Cerealia type pollen), *Aster tripolium*

(Compositae) and *Plantago maritima*[3] greatly influence the ratio, whereas none of them is indicative of anthropogenic activities. Besides, the same applies to Chenopodiaceae, a family also containing a whole range of salt marsh plants, and to *Artemisia maritima* (see also Behre 1976b: 113). Since the present pollen diagram originates from an area where coastal influences cannot be neglected, the calculation of this pollen ratio is hazardous.

Calculation of Turner's (1964) index for the spectra 277-281 cm (Early Iron Age) and 265-269 cm (Middle Iron Age) for the diagram of Spijkenisse 17-30 would result in ratios of 2.1% and 2.7%, which would indicate almost complete specialization in arable farming. In fact, these low ratios result from the low values of *Plantago* and the high ones of Compositae and Chenopodiaceae only.

Kramm (1978: 26) proposed a completely different approach. He established the proportions of Cerealia and (non-cultivated) Gramineae. He found a relative increase of Cerealia towards medieval times. The presence of *Secale* in medieval samples, however, seriously distorts the picture obtained.

Kramm's ratio would produce values of almost 100% pastoralism in the case of Spijkenisse 17-30. However, the local presence of *Phragmites* and the predictable scarcity of Cerealia do not hold much hope for the representativeness of these values either.

Riezebos and Slotboom (1978) modified Kramm's ratio, using:

(Gramineae + Papilionaceae + *Plantago lanceolata*) / (Gramineae + Papilionaceae + *Plantago lanceolata* + Cerealia + *Fagopyrum* + *Rumex* + *Artemisia* + *Centaurea*)

The objections raised by Maguire also apply to this index. As Behre (1981: 236) observed, the inclusion of *Rumex* in the arable component of this ratio is not undebated. Berglund (1969 cited in Behre 1981) for instance regarded *Rumex* as a pastoral indicator. For Spijkenisse, this ratio scores over 90% pastoralism during Early and Middle Iron Age.

To all these ratios, the reservations expressed by Groenman-van Waateringe (1988a: 10) are in force. She observed that

"as long as the criteria for identifying arable and pastoral indicators are not clearly defined, and directly relevant to prehistoric agriculture, it is impossible to expect to be able to translate an arable/ pastoral ratio in terms of past economies or subsistence practices".

Behre (1981: 240) vented similar reservations. According to him, a precise assessment of the relative proportions of crop and animal husbandry has so far been not possible by pollen analysis alone. The applicability of these ratios for Voorne-Putten will be given further attention in the discussion on the economy of the sites (*ch. 6*).

2.4.2   THE POLLEN DIAGRAM OF SPIJKENISSE 17-34

The section of Spijkenisse 17-34 was sampled by the B.O.O.R. with monolith tins. The section is located ca. 12 m east of a Middle Iron Age site. The distance towards the pollen section of Spijkenisse 17-30 is ca. 250 m. As in Spijkenisse 17-30, the section consists of fen peat, covered with clay. The top of the peat is strongly decomposed, the transition to clay is gradual. The location of the monolith tins in the section is indicated in figure 15.

In the diagram (*fig. 16*), *Quercus* shows only one distinct minimum at 268-260 cm below NAP[4], *Tilia* and *Ulmus* show synchronous minima. Again, *Corylus* at the same time shows a (relative) increase. [14]C dates of the peat in the upper part of the diagram show a reversed sequence, the uppermost sample has an older dating (2485 ± 40 BP; GrN-14176) than the lowermost (2330 ± 60 BP; GrN-14175), the middle sample also has the middle dating (2415 ± 50 BP; GrN-16328). We are dealing with a period of strong wiggles in the ^{14}C calibration curve (cf. Baillie/ Pilcher 1983), which results in all three datings spanning a range between ca. 750 BC and 400 BC. Baillie and Pilcher (1983: 58) in this respect stated that the calibration curve is essentially flat between 800 and 400 BC. The dates in the pollen diagram only allow the conclusion that the top of the section is not younger than 400 BC.

An argument for assuming that peat growth ceased before the Middle Iron Age is presented by archaeological research.
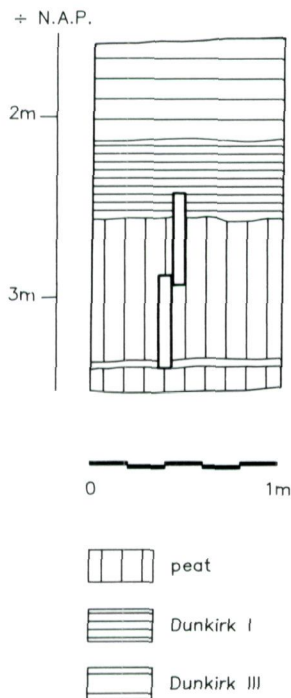

Fig. 15 Position of the monolith tins in section of Spijkenisse 17-34.

The traces of habitation in the nearby Middle Iron Age site of Spijkenisse 17-34 were on top of a thin layer of clay. This indicates that sedimentation of the clay started before habitation took place, and thus that the peat under the clay was formed before the Middle Iron Age (i.c. before c. 2200 BP). The decline of *Quercus* in the pollen diagram of Spijkenisse 17-34 thus seems to have occurred during the Early Iron Age.

During this oak decline, a transition can be observed in the stratigraphy from peat to clay. The possibility of rede-posited pollen (deposited with the clay) must thus be taken into consideration. As stated above, redeposition of pollen is often characterized by increasing values of *Pinus, Picea, Abies, Quercus, Fagus* and/or *Tilia*. In the diagram, *Picea* and *Abies* are absent, *Pinus* is constant and *Quercus, Fagus* and *Tilia* show a decline. Redeposition thus fails to explain the shifts observed in the tree pollen percentages. In view of the proximity of the Spijkenisse 17-30 diagram, the same anthropogenic influence may be expected here. The Middle Iron Age *landnam* is not represented, as peat formation ceased prior to habitation. As in Spijkenisse 17-30, the anthropogenic indicators are hardly discernible in Spijke-nisse 17-34.

2.4.3   THE POLLEN DIAGRAM OF HEENVLIET

The pollen diagrams discussed above are both from an area situated close to human settlements. In order to assess the extent to which human influence occurred, another site for pollen analysis had to be selected. This site should prefer-ably be at some distance from settlements. It was therefore decided to sample a section near Heenvliet. Despite several surveys, no traces of Iron Age or Roman habitation have been found here.

Heenvliet is the site where Zagwijn's palaeo-geographical map of the Netherlands shows a raised bog area during the Iron Age and where peat accumulation did occur during the Roman Period. This appears to be a unique situation in the southwest of the Netherlands, most of the peat being desic-cated before the Christian era during Dunkirk I influences. Near Heenvliet, only DIII deposits occur on top of the peat. The complete lack of traces of Iron Age habitation in the Heenvliet polder is in accordance with continuous growth of *Sphagnum* peat. In consequence, by analysing the pollen contents of this peat, an insight into the environmental development of an uninhabited area may be gained. It should also offer data on the landscape during the Roman Period. The presence of *Sphagnum* peat further indicates that all pollen recorded will be airborne, if not originating from the local vegetation.

For the diagram which resulted from the R.G.D. invest-igations (Zagwijn 1955), ^{14}C dates have been obtained from the bottom and the top of the peat. The spectra mostly have distances of 5 cm. Both these facts render this diagram less

suitable for detailed and dated reconstructions of human influence. The decision to sample this site anew was thwarted as the location of the Heenvliet section studied by the R.G.D. is not exactly known (Zagwijn/ De Jong *pers. comm.*).

For sampling it was deemed best to select a site where (sub)recent disturbances could be ruled out. A medieval site lying *in situ* on top of the peat would demonstrate that the peat could not have been disturbed after the medieval habitation. In practice, it appeared that the exact location of the selected site (Heenvliet 10-75; Van Trierum *et al.* 1988) could no longer produce useful samples as it had been trench-ploughed only a few weeks before our arrival. As an alternative, the peat below the neighbouring meadow was sampled. The upper part of the section could be examined in the slope of a ditch. The top of the peat below the Dunkirk III sediments did not show any disturbance and the site was sampled by means of a corer for taking peat samples (Ø 6 cm).

The diagram (see *fig. 17*) shows considerable fluctuations in the curves of *Quercus* and *Corylus*. Before *Fagus* attains values over 5%, *Quercus* shows an obvious decline, compensated by *Corylus*. The Subboreal ^{14}C dates of this part of the diagram are in accordance with the *Fagus* curve. The Holocene mean sea level curve of Van der Plassche (1982b: 176) shows a gradually rising mean sea level between 3900 and 3800 BP, corresponding to the Calais IVb transgression phase. The changes in the composition of the upland forest can be thus accounted for. The rise of *Alnus* would be in agreement with the environment becoming wetter.

However, an alternative explanation may be given for these changes in the tree pollen. The ^{14}C dates point to the synchroneity of this oak decline with habitation during the Vlaardingen culture. The oak decline was therefore probably caused by man. Neolithic occupation of the Rhine-Meuse estuary is known from levees only (cf. Louwe Kooijmans 1974). Along the Meuse, these levees are no longer present owing to medieval erosion by Dunkirk III transgressions (see *2.5.2*). Neolithic habitation can therefore not be attested. The natural vegetation of these levees will have consisted of upland forests containing oak. The forests were probably felled by the neolithic inhabitants. However, it is beyond the scope of the present study to investigate this Subboreal oak decline any further.

After the first oak decline, the upland forest recovered again. Then a series of fluctuations in the *Quercus*, *Corylus* and *Fagus* curves can be observed. Unfortunately, ^{14}C datings reveal that the upper 45 cm of the diagram shows a repetition of the chronological sequence. Apparently, peat growth stopped during the Early Iron Age and redeposition of a vast amount of peat occurred. The only possible explanation (apart from highly improbable laboratory failures)

is that an island of peat, after being torn loose during a rising water table, has floated to the pollen site and settled there as a result of lowering of the water table.

Floating peat has often been noticed in pollen diagrams during periods of increased marine influence (first by Polak 1929). Normally, the floating peat mat remains attached to the main body of peat and only hinges. This mechanism results in intercalated layers of clay, deposited under the floating peat. These layers of clay are much younger than the peat below and above them (so called *Klapp-Klei*: Behre 1970; Grohne 1957a: 26; Jelgersma 1960). In such cases, the stratigraphy of *Sphagnum* peat is only interrupted by a clayey layer. Above the clay, the sequence continues. Even today, this phenomenon of floating peat can be observed in the Sehestedter Moor (Behre 1990a: 92, 1991c: 51).

In the Heenvliet diagram, in contrast, no intercalated clay has been observed and the ^{14}C dates do not show a continuing sequence. This can only be explained by redeposition of an island of peat right upon a contemporaneous body of peat. The absence of clay in between is very remarkable in view of this explanation.

Later, a second attempt was made to sample peat formed during the Roman Period near Heenvliet in the hope that the phenomenon described above would be of spatially restricted importance. Before chemically treating the samples and the subsequent time-consuming counting of pollen, it was decided to await the ^{14}C date of the top of the peat. This appeared to be 2395 ± 30 BP (GrN-18054), so further processing of this core was abandoned.

In view of these two experiences, the upper ^{14}C date of the R.G.D. pollen diagram near Heenvliet (1830 ± 110 BP) was given additional attention. It was measured before the Suess-effect became known (cf. Vogel/ Waterbolk 1963). The reference number of the Heenvliet dating is Gro-308 (De Jong *pers. comm.*). It must be corrected by 0 ± 20 years to account for the Suess-effect (Vogel/ Waterbolk 1963). Calibration[5] of 1830 ± 130 BP results in a 1σ interval of 30-340 AD and a 2σ interval of 110 BC-460 AD and 480-530 AD. As a result, the top of the peat in the R.G.D. section indeed is -in an absolute sense- younger than the top in the present two sections, since their 2σ ranges span 762-402 BC (for 2425 ± 35 BP) and 754-398 BC (for 2395 ± 30 BP). Regrettably, this peat-growth during the Roman Period could not be re-analyzed in the present study.

2.4.4   THE POLLEN DIAGRAM OF SIMONSHAVEN
This section was analysed by L.I. Kooistra (1984). It was sampled by means of two monolith tins (50 × 5 × 5 cm) in a section at ca. 70 m distance from the excavated Roman site of Simonshaven 17-24 (see also Van Trierum 1986).

The *Sphagnum* peat at the base of this diagram shows relatively high percentages of *Fagus*, which indicates a

Subatlantic age for this base (see *fig. 18*). Next to *Fagus*, *Quercus* and *Corylus* are the predominating upland trees. *Pinus* shows low values, its pollen will have arrived through long-distance transport. *Alnus* has relatively high percentages. *Myrica* shows a remarkable maximum in the top of the *Sphagnum* peat. This is a strong indication of decomposition of the peat. Most likely, this decomposition is caused by desiccation owing to the increased marine influence that finally resulted in the deposition of the clayey layer on top of the *Sphagnum* peat. The high values of Chenopodiaceae in this clay deposit are in agreement with this observation.

The *Sphagnum* peat has been ^{14}C-dated at two levels. One date was obtained from a level with abundant fungal spores and hyphae. Kooistra (1984) assumed that this level would represent the Early Iron Age surface, which is covered by renewed peat growth as was already known from excavation of Early Iron Age sites around the Bernisse (see *ch. 1*). The ^{14}C date, viz. 2490 ± 30 BP (GrN-12217; cf. Van Trierum 1986), indicates that the level does indeed correspond to the Early Iron Age. The top of the peat yielded a date of 2355 ± 30 BP (GrN-12216).

The clayey deposit covering the *Sphagnum* peat belongs to the Dunkirk I sediments. The high percentages of *Pinus* and Cerealia-type in the clayey sediment illustrates the effects of aquatic long-distance transport. The peat on top of this deposit is fen peat in which *Phragmites* roots predominate. Alder (*Alnus glutinosa*) seeds are also present. The very high maximum of *Alnus* pollen is another indication of the local presence of alder carr on this site. It is the reason why *Alnus* has been excluded from the pollen sum. The upland tree pollen percentages in this part of the diagram show fluctuating values of *Quercus*, low numbers of *Corylus*, and a relatively high share of *Fraxinus*. *Pinus* values sometimes exceed 10%. *Carpinus* shows a continuous curve above the 1%-level, which is indicative of a dating after the beginning of the Christian era. The calibrated ^{14}C dates obtained from this *Phragmites* peat reveal that it was deposited between 248-384 (base) and 608-668 AD (top; both 2σ ranges; see *2.6*). Thus, the peat was mainly formed after the Roman inhabitation on Voorne-Putten.

The upper clayey layer again shows increased values of Chenopodiaceae, confirming the marine origin of this deposit, which belongs to a Dunkirk III transgression phase.

2.4.5   A POLLEN SPECTRUM FROM ZUIDLAND

A section from Zuidland was sampled by means of a corer. The analysis has not yet been completed. Since the spectrum from the top of the peat is relevant to the reconstruction of the environment during the Early and Middle Iron Age (see *2.5*), this spectrum has been included in the present study (see *table 3*, which concerns counted numbers).

Table 3. Pollenspectrum from Zuidland. Analysis W.J. Kuijper.

Spectrum	150
Upland trees	
Quercus	54
Corylus	17
Tilia	–
Ulmus	6
Fraxinus	33
Betula	63
Fagus	36
Pinus	8
Carpinus	12
Pollensum	229
Wetland trees	
Alnus	307
Myrica	99
Salix	–
Herbs	
Artemisia	1
Chenopodiaceae	3
Cruciferae	1
Cyperaceae	95
Ericaceae	184
Gramineae	42
Plantago lanceolata	3
Rubiaceae	1
Sparganium erectum	5
Urtica	1
Spores	
Monoletae psilatae	23
Sphagnum	9

2.4.6   THE POLLEN DIAGRAM OF ROCKANJE II[6]

This section was sampled with a corer (Ø 3 cm) at ca. 350 m southeast of the excavated settlement of Rockanje II. The section was studied by L. Duistermaat (1986). The main goal of the investigation of this section was to provide data about the development of vegetation during Roman habitation. This information was to have been obtained by analysis of a section through the so-called "Roman peat" near the excavation (see further *2.6*).

The lowermost part of the section, which consists of *Sphagnum* peat, was not the part of greatest interest in the original study. However, it does provide data that are relevant to the present research. Although no ^{14}C dates have been obtained from this *Sphagnum* peat, it is of Subatlantic age, in view of the *Fagus* percentages and the fact that the peat is covered by Dunkirk I sediments.

The strongly declining *Quercus* values in the lower part of the section (see *fig. 19*) are reminiscent of the pollen diagrams from Spijkenisse. However, Early and Middle Iron Age habitation has not or only sparcely been demonstrated on western Voorne. The pollen of *Quercus* most likely originated from oaks in the Older Dunes (see *2.5*), which

were situated further west than the present coast line of
Voorne (see *ch. 1*). To the south and north of Voorne, these
Older Dunes were demonstrated to have been relatively
densely inhabited during the Iron Age (Van Heeringen
1992). It is highly probable that the Older Dunes on Voorne
were inhabited, too. This habitation may have caused the
decrease of pollen production of oaks, through felling. As in
Spijkenisse, *Corylus* shows a (relative) increase. Whether this
is in fact only a relative increase cannot be proved, absolute
countings have not been undertaken. The familiar peak of
Myrica just prior to the sedimentation of Dunkirk I deposits
can also be observed in this diagram.

The high values of *Rumex acetosa*-type that occur during
the decline of *Quercus*, also point to an anthropogenic
influence. As the pollen of this herb will not be dispersed
far, this is an indication that human influence did occur in
the western part of Voorne during the Early or Middle Iron
Age. The maxima of *Lotus uliginosus* and *Hydrocotyle vul-
garis* coincide with the *Quercus*-minima. The same correla-
tion can be observed in the diagram of Spijkenisse 17-34.
Probably, these herbs are also favourably influenced by
anthropogenic activities.

As the ¹⁴C dates demonstrate, the upper peat is mainly
"post-Roman", as in Simonshaven (see further *2.6*). The
upland trees in the post-Roman peat show a decrease in
Corylus pollen and an increase of *Fagus*. The upper clayey
sediment shows a higher level of *Corylus*, but this is most
likely redeposited. Chenopodiaceae also reach a high
percentage in this upper spectrum.

The large numbers of *Menyanthes* pollen in the post-
Roman peat indicate mesotrophic conditions in this peat.

2.4.7 EIGHT POLLEN SPECTRA FROM NIEUWENHOORN

Another attempt to obtain palynological information about
the Roman Period was made near Nieuwenhoorn. In the
vicinity of an excavated Roman settlement, peat occurred on
top of Dunkirk I sediments, corresponding to Van Staaldui-
nen's "Roman" peat. The section was sampled by means of
a corer (Ø 6 cm), the stratigraphy is given in figure 20. The
eight spectra analysed (see table 4) show that the spectra
from 256 cm upwards are of Subatlantic age, seeing the
share of *Fagus*. The corresponding ¹⁴C date is rather old. In
view of the relatively high share of *Pinus*, part of the *Fagus*
pollen in this spectrum may have derived from aquatic long-
distance transport. ¹⁴C dates further demonstrate the upper
peaty sediment to belong to the peat formed after the
Roman inhabitation. Again, an attempt to obtain truly
"Roman" peat failed.

2.4.8 THE POLLEN DIAGRAM OF ROCKANJE 08-52

This section was sampled by means of a monolith tin (50 ×
15 × 10 cm). *The section is located at a distance of ca. 2 m
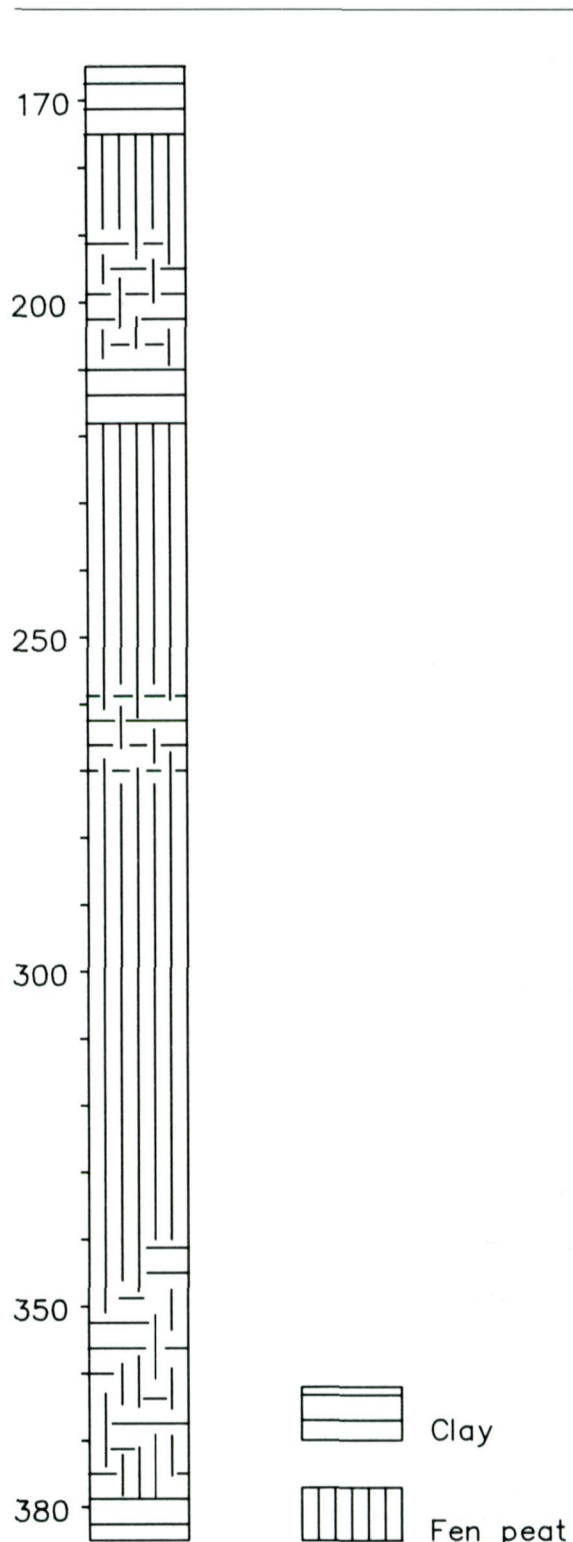outside the excavated houseplan on this site. There was ca.*

Fig. 20 Stratigraphy of the coring of Nieuwenhoorn.

Table 4. Pollen spectra from Nieuwenhoorn. To each spectrum, one tablet containing 12,100 *Lycopodium* spores was added.

Spectrum (depth ÷ N.A.P.)	390	364	334	304	286	254	238	218
^{14}C date				3355 ± 40	2910 ± 40	2515 ± 40		1695 ± 30
GrN-number				15224	15225	15226		15227
Upland trees								
Quercus	54.9	28.4	39.7	43.2	15.5	22.0	18.6	37.8
Corylus	12.6	13.6	27.6	24.0	11.3	35.0	5.1	14.3
Tilia	4.0	6.8	0.9	2.6	–	1.0	–	1.0
Ulmus	1.1	–	2.6	2.6	4.2	3.0	2.5	–
Fraxinus	8.6	3.4	3.4	5.7	2.8	11.0	1.7	7.1
Betula	4.6	34.1	20.7	21.9	45.1	16.0	61.9	31.6
Fagus	0.6	1.1	–	–	7.0	6.0	3.4	6.1
Pinus	12.6	12.5	5.2	–	14.1	6.0	6.8	1.0
Picea	0.6	–	–	–	–	–	–	–
Carpinus	–	–	–	–	–	–	–	1.0
Hedera	0.6	–	–	–	–	–	–	–
Pollensum (n)	175	88	116	192	71	100	118	98
Lycopodium (n)	42	31	181	36	44	32	7	33
Wetland trees								
Alnus	16.6	75.0	44.8	42.7	139.4	61.0	84.7	79.6
Myrica	6.3	3.4	6.0	2.6	–	–	–	–
Salix	1.1	–	–	2.6	–	2.0	6.8	–
Herbs								
Artemisia	1.1	1.1	0.9	1.0	5.6	2.0	1.7	3.1
Calystegia	3.4	–	–	–	–	–	–	2.0
Caryophyllaceae	–	14.8	18.1	–	–	1.0	0.8	1.0
Chenopodiaceae	8.6	25.0	–	51.6	42.3	8.0	28.0	6.1
Compositae lig.	–	1.1	–	–	–	6.0	13.6	–
Compositae tub.	1.1	1.1	–	3.6	4.2	3.0	11.9	2.0
Cruciferae	–	4.5	–	8.3	1.4	1.0	1.7	–
Cyperaceae	136.0	28.4	59.5	41.1	142.2	28.0	17.8	91.8
Ericaceae	1.1	10.2	–	0.5	4.2	64.0	48.3	7.1
Filipendula	0.6	–	–	–	–	–	0.8	–
Gramineae	165.7	68.2	87.1	103.1	400.0	132.0	55.9	479.6
Lotus uliginosus	1.1	–	–	–	–	–	–	–
Lythrum	2.3	–	–	–	–	–	–	1.0
Malvaceae	–	2.3	–	–	–	–	–	–
Mentha-type	1.1	–	–	–	–	–	–	–
Monoletae psilatae	22.9	39.8	24.1	31.2	15.5	12.0	–	1.0
Plantago lanceolata	1.1	–	–	–	–	–	0.8	3.1
Plantago major/media	–	–	–	–	1.4	–	–	–
cf Potamogeton	5.1	–	–	–	–	–	–	1.0
Rubiaceae	18.9	–	2.6	1.0	–	–	–	–
eu-Rumex	–	1.1	–	–	–	–	–	10.2
Rumex acetosa-type	–	1.1	2.6	–	–	–	–	–
Sparganium emersum-t.	–	–	–	0.5	–	–	–	–
Sparganium erectum	10.9	4.5	1.7	–	–	–	2.5	5.1
Sphagnum	–	2.3	–	3.6	5.6	–	39.8	2.0
Stachys-type	0.6	–	–	–	–	–	–	–
Succisa	–	1.1	–	–	–	–	–	–
Triletae psilatae	2.3	–	–	3.1	–	–	–	–
Typha latifolia	0.6	–	0.9	–	–	–	–	–
Umbelliferae	–	4.5	2.6	0.5	–	–	2.5	5.1
Urtica	–	–	–	–	–	–	0.8	1.0

Additional ^{14}C date: 178 cm below surface: 1500 ± 30 BP (GrN-15228)

55 cm of *Phragmites* peat on top of a Calais IV clay deposit below the sampled part of the section. Then followed 25 cm of Dunkirk 0 clay, which was covered by 30 cm of fen peat with *Phragmites*. Upon this fen peat came a 7 cm thick layer of slightly decomposed *Sphagnum* peat. This layer in its turn was covered by a layer of strongly decomposed *Sphagnum* peat of 14 cm in thickness. The upper 6 cm of this strongly decomposed *Sphagnum* peat was present at the base of the sampled part of the section. Above this strongly decomposed *Sphagnum* peat occurred a 19 cm thick deposit of settlement waste.

On top of this anthropogenic deposit lay a Dunkirk I sediment, which was peaty at its base. The presence of a Dunkirk I deposit above a Late Iron Age level is of great chronostratigraphic importance. The implications were discussed in *1.2.1.3*. The Dunkirk I deposit in the pollen section became more clayey towards the top. These Dunkirk I sediments contained Roman pottery sherds in the upper part. Above this sediment, another peaty layer occurred, which was covered by Dunkirk III deposits. This peaty layer is presumably equivalent to the "post-Roman" peat that was already investigated in the diagrams from Simonshaven and Rockanje II (see *2.4.4*; *2.4.6*). It has therefore not been included in the present diagram.

The presence of the strongly organic Dunkirk I sediment between a Late Iron Age deposit and one from the Roman Period provided a means of obtaining palynological information on the decades around the beginning of the Christian era. In view of the rarity of this period in pollen diagrams on Voorne-Putten, it has been included in the present study. It should be kept in mind that the layer concerned is clayey, which implies that part of the pollen may have been transported by water over a long distance. Redeposition of pollen may potentially have occurred, too.

The inclusion of the present section, which was sampled in October 1991, was only possible thanks to Mrs. Drs. M.J. Alkemade-Eriks, who undertook the counting of most of the samples. The resulting diagram is shown in figure 21.

The base of the diagram, which consists of *Sphagnum* peat (zone A), shows relatively low values of *Quercus*. *Betula* reaches high values compared to the diagrams discussed above. *Fagus* shows a decline, which continues through the following zone (B), consisting of the anthropogenic deposit. *Alnus* shows high percentages at the base of the diagram.

The anthropogenic deposit shows high values of Compositae, Cruciferae, Umbelliferae and Gramineae, all of which most probably have their origin in synanthropic vegetation types. Partly they may have been brought to the site by man. Remarkable is the occurrence of several indicators of high salinity, such as *Plantago maritima*, *Spergularia* and Foraminiferae. Apparently, the environment has a saline component in the vicinity of the site. Most strikingly, the spores of *Sphagnum* hardly occur in the *Sphagnum* peat and strongly increase in the anthropogenic deposit.

The peaty base of the Dunkirk I deposit (zone C) shows increased values of *Quercus*. Unfortunately, *Pinus* shows values between 12 and 25%, an indication that part of the pollen is transported by water. The marine type 116 is another indication for transport by water. This type is found numerously in zone C. This may also apply to the *Quercus* pollen, especially in view of the corresponding trends in the curves of *Quercus* and *Pinus* from the second zone onwards. The consequence of this observation is that the increased values of *Quercus* between the Late Iron Age and the Roman Period cannot be considered a reliable indication of the greater importance of oak on Voorne in this period. Therefore, this pollen diagram does not permit a reliable reconstruction of the vegetation during the Roman Period.

The Dunkirk I deposit shows relatively high values of Cerealia-type. The interpretation of this Cerealia-type need not simply that we are dealing here with grain. As was already concluded by Firbas (1937: 463-464), cereal pollen can readily be demonstrated, if hexaploid wheat species (with comparatively large pollen grains), such as bread- and clubwheat (*Triticum aestivum* s.l.) or if *Secale* and *Avena sativa* are present. However, more uncertainties arise, where barley (*Hordeum vulgare*/*distichum*) and emmer (*Triticum dicoccum*) are concerned, because their pollen resembles that of some wild grasses. Einkorn (*Triticum monococcum*) is even more similar to wild grasses (see also Diot 1992). Thus, the Iron Age cereals, mainly barley and emmer, do not differ much in size from particular wild grasses. Later investigations into this problem made use of phase contrast microscopy. Here, not only size, but also microsculpture of the grain has been considered (Grohne 1957b; Beug 1961). However, no unambiguous identification criteria for cereal pollen have so far been drawn up.

According to Beug, *Hordeum* type amongst other things comprises cultivated and wild *Hordeum* species, *Agropyron* species, *Glyceria fluitans* and several *Bromus* species. *Triticum* type comprises *Ammophila arenaria* and probably some *Bromus* species and some grains of *Elymus arenarius*. *Avena* type includes only species of this genus, but also the wild *Avena fatua*. *Zea mays* and *Secale cereale* can be recognized unambiguously, although a small number of *Secale* grains belong to the *Hordeum* type. Küster (1988: 17) also dealt extensively with the identification of Gramineae pollen. According to him, most of Beug's cereal-like grass pollen (*Bromus*, *Glyceria*) can be distinguished from true cereals. He also separates *Elymus* from cereals which, however, is not supported by material in our reference collection. *Ammophila* is not included in his study. Andersen (1979) also stated that *Ammophila arenaria*, *Agropyron* species, *Elymus arenarius* and *Glyceria* species cannot be distinguished from *Hordeum*-type pollen, which furthermore includes *Hordeum vulgare* and *Triticum monococcum*.

In view of the proximity of the coast near Rockanje, the Cerealia-type pollen grains may well have originated from

wild grasses. Besides, aquatic long-distance transport of Cerealia-type pollen may have occurred as well.

2.5 Reconstruction of the Early and Middle Iron Age environment.

2.5.1 THE LOCAL ENVIRONMENT AROUND THE IRON AGE SITES

Peat near two excavated Iron Age sites near Spijkenisse (17-30 and 17-34) has been analysed for pollen. Both these sites are situated in the vicinity of the Bernisse. The palynological data provided by these sections will be used as models for all Early and Middle Iron Age sites around the Bernisse.

Local environment can be reconstructed with the pollen diagrams of Spijkenisse 17-30 and 17-34. Supplementation of these data is possible with botanical macroremains recovered in the various sites. These will be discussed in a following chapter (*ch. 4*).

Local vegetation can be reconstructed by means of the pollen deposition it produced. In the peaty area concerned, local pollen mainly originates from herbaceous plants. The pollen diagrams of Spijkenisse reveal that Gramineae and Cyperaceae are the most important herbs throughout the sections, ferns are also well represented. Ericaceae and *Sphagnum* are scarce. These data indicate that we are dealing with eutrophic fen peat here. Especially the macroremains indicate the presence of reed vegetation types (Phragmitetea).

There are three possible developments in the natural vegetation succession of eutrophic fen peat (Westhoff *et al.* 1971: 71-76). Firstly, this type of peat may develop into an alder carr. There, alder (*Alnus*) occurs as a local component, leading to *Alnus* percentages into several hundreds if outside the pollen sum, or a complete domination of the pollen sum if included in it. Secondly, eutrophic fen peat vegetation may show a development into oligotrophic raised bogs, especially during lowering (!) of the water table, which brings the vegetation out of reach of the mineral-rich ground water (Behre 1987, 1990a). Thirdly, a natural development of ruderal vegetation types may occur.

The development of an alder carr is not recorded in either diagram; local alder carrs did not occur near Spijkenisse. A raised bog, which would show high values of Ericaceae and *Sphagnum*, was clearly not present near Spijkenisse either in the period concerned. The development of ruderal vegetation types will mainly express itself in an increase in tall herbs (e.g. *Lythrum salicaria*, *Valeriana officinalis* and *Thalictrum flavum*: Westhoff *et al.* 1971), which does not show up clearly in the pollen diagrams, although the peak of *Lythrum salicaria* in both diagrams of Spijkenisse may point to such a development. Continuous presence of fen peat is only found when a steadily rising water table occurs. If this

rise stagnates, oligotrophic bog would develop, if the water table rises too fast, the fen peat is drowned, as can be seen in the top of the two Spijkenisse diagrams.

Apparently, man had settled in those parts of reed swamps which had fallen dry. These swamps were part of an open landscape, in which trees did hardly or not occur within several hundred metres of the site. These dried-out reed swamps were to be found along the natural water courses that caused the drainage. All the known Iron Age sites around the Bernisse are situated in the vicinity of creeks (Van Trierum *in press*). These creeks apparently did not drain the peat to such an extent that peat formation ceased everywhere during the Early Iron Age. This is demonstrated by the continued peat growth in the sections of Spijkenisse 17-30 and Simonshaven.

Total drainage of the peat is connected with the Middle Iron Age. Decomposition of the peat gave rise to large-scale colonization by *Myrica gale*. This phenomenon is probably indicative of the approaching transgression. Increasing marine influence finally resulted in the deposition of Dunkirk I sediments in the area around the Bernisse.

Near Heenvliet, the transition to an oligotrophic raised bog did take place. Already before the start of the Subatlantic, a raised bog dominated by *Sphagnum* and Ericaceae had developed here.

Since the pollen dispersal of practically all herbs is limited, it is very difficult to assess the horizontal distribution of eutrophic reed swamps, oligotrophic raised bogs and the intermediate mesotrophic peat types, amongst other things characterized by *Menyanthes* and Cyperaceae. Only by means of a dense grid of corings in combination with ^{14}C datings, can this problem be (partly) solved.

To what extent *Alnus* occurred locally in the peaty landscape is another important topic. As is shown by the section of Simonshaven (see *2.4.4*), during the first half of the first millenium AD local alder carr developed at that site, resulting in 1295% of *Alnus* pollen (of course excluded from the pollen sum). Such high values have not been recorded in the diagrams discussed above. Only one of the pollen diagrams of Voorne-Putten produced by the R.G.D. shows extremely high *Alnus* values. In their diagram "Spijkenisse" (Jelgersma 1957a), *Alnus* reaches values exceeding 80% (within the pollen sum) in carr peat. Alder predominated here from Subboreal times onwards into the Subatlantic up to the Roman Period.

In view of the scarcity of Subatlantic diagrams with high *Alnus* values, the landscape during the Early Iron Age in all probability showed a very patchy distribution of *Alnus*, depending upon factors such as human influence and the distribution of *Sphagnum* peat, where *Alnus* does not grow (cf. Grosse-Brauckmann 1976). Reed swamp vegetation types in an early stage of succession will also have been too wet to allow growth of *Alnus*.

2.5.2   THE LOCATION OF UPLAND FORESTS

The upland forests will have been restricted to mineral soils, with relatively low water tables during the growing season. These drier, mineral soils are very interesting from an arable point of view. The landscape during the Early and Middle Iron Age on Voorne-Putten was dominated by peat. It is highly probable that the mineral soils were the only soils suited to the cultivation of some arable products (see *ch. 6*). The location of these mineral soils in relation to the Iron Age sites is crucial for the economic possibilities of these sites. Therefore, the following reasoning, developed by Turner (1975) is of great interest. She argued that the share of a particular type of vegetation in the pollen rain is large close by this vegetation and diminishes with increasing distance. If pollen diagrams from different sites are compared, the curves for a particular (set of) species can give hints for their location in relation to the pollen sites. The following example, focussed on the situation on Voorne-Putten, may serve to illustrate this.

If we assume that the upland forests, where oak and hazel predominate, are located in the dune area on western Voorne (see *ch. 1*), the share of the upland trees relative to the wetland species will decline in pollen spectra from west to east. The most important upland component is oak (*Quercus*), whereas alder (*Alnus*) is the dominant wetland tree species represented in the pollen diagrams. Since the upland trees constitute the pollen sum, they do not decline from west to east in the example given, but in this case *Alnus* increases.

To investigate the location of the upland forests, twelve pollen diagrams are now available. Apart from the eight discussed above, we also have the diagram from Hekelingen, analysed at the I.P.L. (Schuller 1981), as well as the R.G.D. diagrams from Geervliet, Brielle and Lodderland. Unfortunately, it is impossible to compare the twelve diagrams directly, the data must be made more manageable first.

Firstly, a synchronous and relevant time-slice has to be selected. Eight of these diagrams have produced ^{14}C dates roughly between 2400 and 2500 BP. In most cases, we are concerned with the top of the peat below Dunkirk I sediments. Only in two places, Spijkenisse 17-30 and Rockanje 08-52, has peat growth continued considerably after 2400 BP. For this reason, the top of the peat below DI sediments in the sections that have not been ^{14}C-dated are considered as being of comparable age. This time-slice has an additional advantage in that it represents the situation at the start of Iron Age habitation on Voorne-Putten.

The time factor has another effect. In one year, the weather may be (dis)advantageous to a particular species, resulting in a difference in the yearly pollen production. Fortunately, since the spectra used cover generally a time span of at least 20 years, such effects are smoothed out.

After we have chosen a time-slice, indicative taxa still

have to be selected. Following Turner's (1975) reasoning, I have used the percentages of *Alnus* and *Quercus* as keys here. The relevant pollen diagrams were produced by different institutes and this has resulted in different pollen sums, relating to the underlying questions. To circumvent the difficulties in the comparison of these diagrams, the ratio of *Quercus* and *Alnus* is calculated for the spectra concerned. This is of great practical value, since this ratio is not influenced by the pollen sum (nor by the use of absolute numbers of pollen grains), as the following example will show. At a given pollen sum, the percentages are the numbers of *Quercus* (X) and *Alnus* (Y) found, divided by the pollen sum (ΣP) and multiplied by 100. Thus the ratio is:

$$\frac{X.100}{\Sigma P} : \frac{(X+Y).100}{\Sigma P} = X : (X + Y)$$

The use of *Quercus*, the dominant upland component, and *Alnus*, the dominant wetland component, in a ratio has another advantage in that their pollen production seems to be comparable. Their representation factor, according to Andersen (1973) is 1:4 relative to *Fagus* for both species.

Another factor which is important in the interpretation of these ratios is the dispersal capacity of the taxa concerned. If for instance pollen of *Alnus* is on average dispersed further than that of *Quercus*, and both are located in one single area, the number of *Alnus* relative to *Quercus* will increase with distance from this area. As Fægri *et al.* (1989: 122) stated,

"to control the effects of different dispersal one must also establish gradients from the pollen source outwards. Such data are not freely available anywhere".

Pollen dispersal over greater distances would also result in a greater "background component" in R-value models, incorporating such components. Direct measurings of background levels in R-value models are unknown to me. The pollen dispersal capacity of *Alnus* and *Quercus*, however, is indirectly indicated in some publications.

One parameter that has a great influence on pollen dispersal is the weight of the pollen grains. According to Janssen (1974), the average weight of *Quercus robur* pollen is 18.16 µg, that of *Alnus glutinosa* 9.37 µg. The falling speed of *Quercus* is also almost 1.5x greater than that of *Alnus*. Both these data suggest a better pollen dispersal on the part of *Alnus*.

Contrasting results have been obtained by several other investigators. Randall *et al.* (1986) studied the recent pollen rain on a treeless island in the Outer Hebrides, west of the Scottish mainland. They observed in total eight *Alnus* grains, in four samples, while the nearest forest with this tree is 40 km away. *Quercus* was recorded nine times, in two samples and the nearest location is more than 50 km away.

This is an indication that *Quercus* is dispersed at least not worse than *Alnus*.

Heim (1970: 158 ff) discussed the contribution to the regional pollen rain of tree species in Belgium. He regarded pollen that travelled distances of 500 to 10,000 m as regional pollen. On the basis of 552 locations for *Alnus* and 232 for *Quercus*, he concluded that *Alnus* on average contributes 1.8% (0.1-3.3%) to the regional pollen rain, while *Quercus'* share is 5.9% (0.6-12.0%). As in the study of Randall *et al.*, *Quercus* would seem to have better dispersal capacities than *Alnus*. Heim compared his data with those obtained by Janssen (1966) in the U.S.A. and found a seemingly great similarity. However, knotty problems arise when the question is asked what these contributions to the regional pollen rain in fact mean. They will be mainly determined by the abundance of the relevant species in the "regional" environment. If *Quercus* is ten times as common as *Alnus* in the regional vegetation, and the contribution to a location's regional pollen rain is twice as high for *Quercus*, than *Alnus* has a five times higher background component, provided that their pollen production is truly the same, as Andersen found it was. In view of the unknown quantities in the regional vegetation, the corresponding data for Belgium and the U.S.A. do not indicate a world-wide constant contribution to the regional pollen rain, but a mere coincidence.

Kalis (1984) published highly relevant data on pollen dispersal in the French Vosges. He compared the recent distribution of the tree species with the pollen deposition in a transect. He stated (p. 282) that *Alnus* pollen is present in comparable percentages in the whole transect, both in areas with many *Alnus* trees as well as in areas where they are lacking. This points to very good wind dispersal capacities of *Alnus* pollen. The relatively high pollen percentages in relation to the rather small distribution area of *Alnus* trees also points to large pollen emission for *Alnus*[7].

For *Quercus*, Kalis (1984: 293) observed that the dispersal capacity is extremely efficient. From the tree limit to the top of the "Kastelberg", the relative proportion of *Quercus* in the pollen deposition rises from 12% to 30%. At 5-15 km distance from forests with oak, *Quercus* pollen still reach 8-16%. The pollen emission (= pollen production s.l.) of *Quercus* is only moderate, according to Kalis. He also stated that the combination of a moderate pollen emission and the extremely good dispersal renders the interpretation of pollen percentages virtually impossible. Only percentages higher than ca. 20% can, according to Kalis, be interpreted with some certainty as an indication of the presence of *Quercus* in the surrounding forests, at least within forested areas and in the present circumstances. In conclusion, the pollen dispersal of *Alnus* and *Quercus* are both very good. However, in view of the contrasting data, it must be concluded that the precise effect of dispersal cannot be assessed at present.

The proportions of *Quercus* and *Alnus* in pollen diagrams

might also be influenced by differential preservation of both species. Havinga (1984) published results of a 20-year study of the differential corrosion in various soil types. He concluded that *Quercus* is more susceptible to corrosion than *Alnus*. Havinga also demonstrated that corrosion is the least in *Sphagnum* peat. Six of the sites discussed here comprise this *Sphagnum* peat. For all relevant samples I have seen, the pollen preservation is good, also in fen peat. Only the R.G.D. material has not been checked in this respect. An additional indication of the minor role of corrosion is presented by Geervliet and Heenvliet, situated close to each other. In Geervliet, we have *Phragmites* peat and in Heenvliet *Sphagnum* peat. Still, both sections produced highly similar ratios. Furthermore, the *Sphagnum* peat sections have a more southerly distribution. If selective corrosion of *Quercus* should play a role, this would result in lower ratios in the northern fen peat diagrams. This is the exact opposite of what is recorded in the present study (see below).

2.5.3   RESULTS AND CONCLUSIONS

In table 5, the locations as well as their *Quercus*/ *Quercus* + *Alnus* ratios are given. In figure 22, the lithology and ^{14}C dates, as well as the location of the pollen spectra analysed, are presented. Besides, a visual representation of these ratios is given in figure 22. Except for Heenvliet and Geervliet, these data show similar ratios for sites in east-west transects. In contrast, on Putten a steady decline of *Quercus* can be observed from north to south.

From the ratios it can be concluded that the upland forests in which oak occurred, were located in the north of Putten, stretching from east to west. Only if the dispersal of *Alnus* is significantly better than that of *Quercus*, this conclusion cannot be maintained.

Elevated levees along the Meuse are the only likely candidates for supporting these upland forests in the north of the area. The smaller levees along the Bernisse originated during the Dunkirk I transgression phase, so they did not yet exist during the time-slice discussed here. There is a deviation in the ratios in Heenvliet and Geervliet (located close to each other). This will be discussed below. The situation on Voorne will have differed owing to the vicinity of the Older Dunes. The low share of *Quercus* near Rockanje is remarkable. The *Quercus*/ *Quercus* + *Alnus* ratio in the uppermost spectrum of the peat of Rockanje 08-52 is exactly equal to the ratio of Rockanje II. This ratio is lower than the other ratios on Voorne, although Rockanje is situated closest to the dune area. The ^{14}C date of the spectrum from Rockanje 08-52 reveals that this spectrum is the youngest in the series chosen (see *fig. 23*). This may explain the lower share of *Quercus* in this spectrum.

Of course, *Quercus* is not the only species present in the upland forests. *Fagus*, *Corylus*, *Tilia* and *Ulmus* are also important constituents. Apart from *Corylus*, however, they
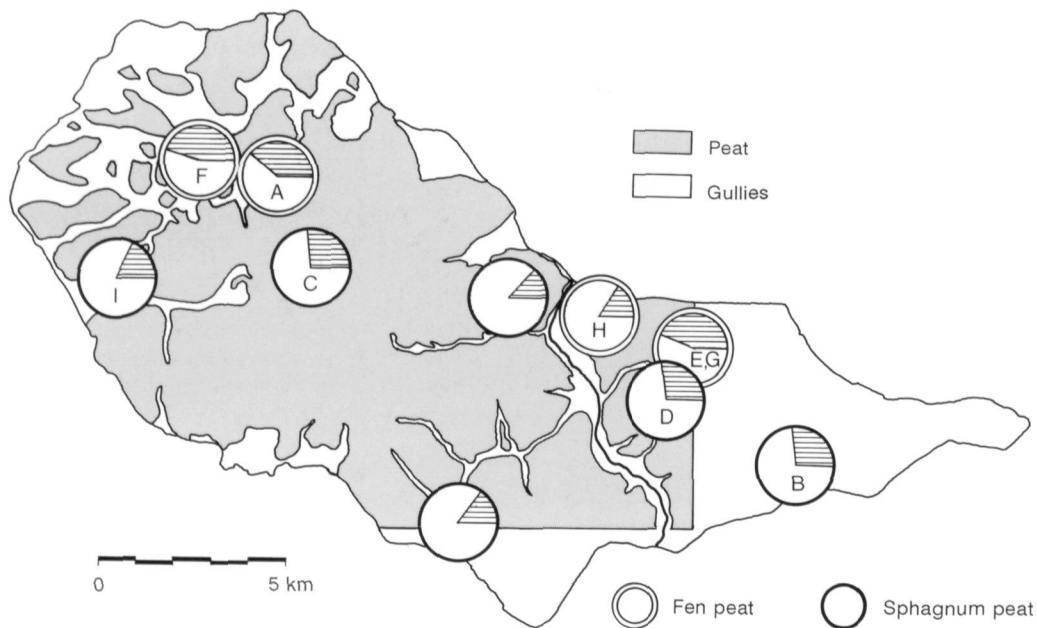
Fig. 22 *Quercus*/*Alnus* ratios of the pollen diagrams on Voorne-Putten, scale 1:2000. A - I: see table 5. Hatched = *Quercus*, White = *Alnus*.

occur in relatively small amounts, and do not offer a solid base for calculating a ratio. To obtain yet another ratio, with a profound base, the ratio *Alnus/ Alnus + Quercus + Corylus + Fagus + Tilia + Ulmus* has been calculated. Of course, this ratio should show a reverse trend when compared to the previous one. An increase of the ratio at increasing distances of the upland part of the landscape is expected. As table 5 reveals, the results of the *Quercus/ Quercus + Alnus* ratios are confirmed, only Hekelingen shows a considerable deviation. Most likely, the *Corylus* curve in this diagram still contains a high share of *Myrica*. The discrimination between these taxa presented great difficulties during the counting of this diagram (Vermeeren *pers. comm.*).

Nowadays, the levees reconstructed above, are not present along the Meuse. This can be ascribed to erosion during one or more Dunkirk III transgressions in medieval times. Further upstream, this erosion did not occur, and remains of levees are still discernible (Th. de Groot *pers. comm.*).

The actual natural vegetation of levees, and its pollen production, could provide important data for comparison with the past situation. It is a great pity that the natural vegetation types of the higher parts of levees in Europe have become very rare. This is due to the excellent arable conditions on these levee soils, where regular flooding causes natural fertilization. As a result of deforestation, recent parallels are hardly found, so we have to rely on reconstructions. In the northwest German coastal area, such a recon-

struction has been possible. Thanks to excellent conditions for preservation and to detailed research, forest vegetation could be reconstructed in great detail (Behre 1985, 1988). Here, the levees have not suffered large-scale erosion. The levee along the Ems was deposited during Dunkirk 0. It has a width of 1-2 km and was first inhabited during the Early Iron Age (Behre 1984a). Directly below the settlement
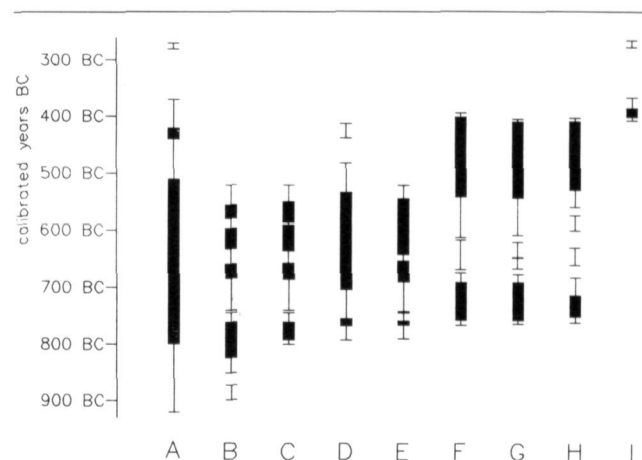

Fig. 23 Calibration of ^{14}C dates used in table 5 and fig. 22 (symbols as in table 5). Black = 1σ interval; line = 2σ interval.

Table 5. Pollen ratios in Early Iron Age peat on Voorne-Putten. * = probably too low (see text).

	Site	Depth ÷ NAP	^{14}C date (BP)	GrN-number	Q/Q+A	A/A+ΣAP	Reference
A	Brielle-Tinte	159 cm	2510 ± 130 yr	304	0.39	0.51	Zagwijn 1955
B	Hekelingen	271 cm	2580 ± 60 yr	10431	0.27	0.33*	Schuller 1981
C	Nieuwenhoorn	250 cm	2515 ± 40 yr	15226	0.27	0.48	This publication
D	Simonshaven	310 cm	2490 ± 30 yr	12217	0.27	0.46	This publication
E	Spijkenisse 17-34	265 cm	2485 ± 40 yr	14176	0.44	0.37	This publication
F	Lodderland	192 cm	2405 ± 65 yr	104	0.45	0.46	Jelgersma 1957
G	Spijkenisse 17-30	279 cm	2435 ± 45 yr	15223	0.44	0.27	This publication
H	Heenvliet	280 cm	2425 ± 35 yr	16333	0.13	0.66	This publication
I	Rockanje 08-52	180 cm	2310 ± 30 yr	18635	0.13	0.61	This publication
	Geervliet	290 cm			0.16	0.59	De Jong 1961
	Zuidland	210 cm			0.15	0.74	This publication
	Rockanje II	250 cm			0.18	0.72	Brinkkemper *et al.* in press.

Boomborg/Hatzum on this Ems levee, 22 tree stumps were found, which had obviously been felled to clear the ground for settlement. Of the 22 stumps, 18 belonged to *Alnus*, one to *Quercus*, one to *Ulmus* and two to *Fraxinus* (Behre 1970). Furthermore, Behre (1985) published a list of trees found near Rade on a levee of the Weser (northern Germany). Of the 71 stumps that were found there, seven were of *Ulmus*, *Quercus* occurred six times, *Fraxinus* 22 and *Alnus* 36 times. Three ^{14}C dates revealed that the trees were of Late Subboreal age. Apparently the levees were densely forested, although at present they are completely treeless. The vegetation appears to have consisted of several belts parallel to the river. Nearest to the river, there were reed vegetation types. The low-lying levels next to these reed belts were covered with willow shrubs (*Salix*), flanked by willow trees. The still higher lying forest (German: *Hartholz-Aue*) is mainly characterized by ash (*Fraxinus*) on lower and oak (*Quercus*) and elm (*Ulmus*) on higher grounds.

According to Behre (1970), *Fagus* did not grow regularly on the levees in northern Germany, as it is absent in the wood spectra of sites in the Ems area. He assumes the same for *Tilia* (Behre *pers. comm.*). This is in contrast to the observation presented here that *Quercus*, *Fagus* and *Tilia* decline simultaneously. It is highly probable that they also occurred in the same vegetation. In this respect, palynological research in a comparable area further to the north, near Swifterbant is significant. On the levees where Neolithic settlement has been attested, *Tilia* is also assumed to have occurred (Casparie *et al.* 1977: 50) in a landscape, which will have been quite similar to that in the Meuse Estuary. The absence of *Fagus* in Swifterbant, both among wood and pollen, will be a result of the Atlantic/Subboreal date of the deposit.

According to Behre (1985), the *Hartholz-Auen* occupied the elevated levees along the river banks downstream as far as the transition to brackish conditions. In this respect, the strong decline of the *Quercus/Quercus + Alnus* ratio between

Spijkenisse and Geervliet deserves further attention. It can be explained by assuming that the transition from fresh to brackish conditions during the Iron Age must be sought here. This area is situated at ca. 20 km from the former coast line. These data are well in agreement with those of Zonneveld (1960), when a high river discharge (to today's standards) is assumed. The upland pollen component in the diagrams on Voorne will mainly have come from the Older Dunes, since the levees there were in the salt to brackish tidal area.

Because of the scarcity of modern equivalents of these vegetation types, it is hardly (or even not at all) possible to collect modern pollen data and to relate them to modern vegetation. The pollen representation factors (to transform amounts of pollen to crown coverage in vegetation) can only be used with some confidence, if the modern situation closely matches the one in the past. Thus, for the present data, no adequate R_{rel}-factors can be obtained. As a consequence, reconstructions of former crown coverages are out of reach at the present state of research.

Behre (1970) published three pollen diagrams situated along a transect from the Ems levee into the backswamp area. Unfortunately, very few ^{14}C dates were obtained, so the only possibility of designating synchronous levels is with palynological datings. Behre's section RL7 is situated closest to the levee. Here, peat growth stopped at the onset of the Subatlantic period. In this spectrum, the *Quercus/ Quercus + Alnus* ratio is 39.4%. Behre's section RL 29 is located at ca. 5.3 km distance from RL7, the corresponding ratio at the Subboreal/Subatlantic boundary is 34.4%. Pleistocene deposits are at a distance of ca. 3 km from RL29, while a small Pleistocene "island" is ca. 1.5 km away. A third diagram has been obtained from the vicinity of this "island" (RL37). Remarkably enough, its ratio at the Subboreal/ Subatlantic transition is lowest, reaching 25.5%. It may be concluded that some diminishing trends in the *Quercus/ Quercus + Alnus* ratio in a transect away from the levee seem

Table 6. ¹⁴C-dates of "Roman peat" on Voorne-Putten.

Site	¹⁴C-date	GrN-number	Reference
Rockanje II (base)	1790 ± 65 BP	GrN-14594	Brinkkemper *et al. in prep.*
Lodderland	1725 ± 65 BP	GrN-1093	Jelgersma 1961
Simonshaven (base)	1720 ± 25 BP	GrN-12215	This publication
Nieuwenhoorn (base)	1695 ± 30 BP	GrN-15227	This publication
Nieuwenhoorn (top)	1500 ± 30 BP	GrN-15228	This publication
Rockanje II (top)	1470 ± 60 BP	GrN-14593	Brinkkemper *et al. in prep.*
Simonshaven (top)	1395 ± 30 BP	GrN-12214	This publication

to present themselves. The nearness of Pleistocene deposits probably bring about the relatively small decline in the ratio.

The ratio from RL7 is still rather low in comparison to the ratios found near Spijkenisse, in the northern part of Putten. This may be explained by the age of the deposits concerned. The Ems levee consists of Dunkirk 0 deposits (see above), the soils are thus relatively immature at the start of the Subatlantic period. This coincides with the small share of *Quercus* in the tree stumps found in Boomborg-Hatzum. On Voorne-Putten, the levees are most likely of greater age. In view of the scarcity of Dunkirk 0- and the commonness of Calais IV deposits, the levees were probably Calais IV deposits, which will have been much more matured in the period concerned. This will have allowed a greater extension of the "*Hartholz-Aue*" forests and a more common occurrence of *Quercus*, and probably of *Fagus* and *Tilia* as well.

2.6 Environmental reconstructions for the Roman Period.

The pollen diagrams discussed in paragraph 2.4 mainly cover the Subatlantic period up to c. 2200 BP. In most locations, peat formation ceased after the Middle Iron Age, preventing environmental reconstructions for the Late Iron Age and Roman Period. The scarcity of peat formation after deposition of Dunkirk I sediments has a parallel in the northwest German coastal area. Behre (1986b: 46) described the dominance of large-scale soil development in areas near the coast during this period. Further inland, a transition from eutrophic fen peats to oligotrophic bogs occurs on a large scale. Both these phenomena can be attributed to lowering water tables, correlated with a regression of the sea. Van Staalduinen (1979: 55) presented a map with the distribution of "Roman Peat" (see *fig. 7*), seemingly a good source of information about the Roman Period. So far, four of these locations with "Roman Peat" on Voorne-Putten have produced ¹⁴C dates (see *table 6*).

Calibration of the data (see *fig. 24*) reveals that peat formation did not start before ca. 200 AD. Roman habitation on Voorne-Putten continued to 260 AD at the latest. Therefore, peat formation started at the very end of or even after Roman habitation of the area (see also Van Trierum *et*

al. 1988). No palynological data on the landscape during the Late Iron Age, nor those on the influence of the beginning of Roman occupation, can be obtained. The term "post-Roman" peat would thus be more appropriate, at least from an archaeological point of view.

Environmental development after Roman habitation can be reconstructed by means of the diagrams of Simonshaven and Rockanje II. This is still relevant to the present research, since they may show regeneration of the forest. The top of the peaty sediment in these sections has been dated, 1395 ± 30 BP (GrN-12214) in Simonshaven and 1470 ± 60 BP (GrN-14593) in Rockanje II. Both diagrams show declines of *Corylus*, while *Carpinus* and *Fraxinus* increase in both diagrams. In Rockanje II, *Quercus* shows a gradual rise, and *Fagus* a conspicuous one, which is much less clearly expressed in Simonshaven. *Tilia* shows very low percentages in both diagrams, but is not absent. *Ulmus* shows a gradual rise in Rockanje II. In conclusion, the primary upland forest elements recover in both diagrams, more markedly so in Rockanje II. Rockanje is relatively close to the dune area, whereas Simonshaven is far from any upland parts of the landscape. This is supported by the large rise in *Alnus* in Simonshaven (up to 1295%). Near Rockanje II, *Alnus* also increases, but not beyond 90%.

The rising values of the primary forest elements *Quercus*, *Fagus* and *Ulmus* in Rockanje indicate that these trees had occupied considerably less than their potential area during peat growth at the base of the "Roman peat", i.e. the latter part of the Roman Period. Although the environment became increasingly wet, as is demonstrated by peat growth, the upland trees mentioned could increase. It is tempting to impute the reduction of the area of primary forest during the Roman Period to human activities. *Quercus* and to a lesser extent *Ulmus* are important construction elements in some Roman settlements (see *ch. 3*). Furthermore, it has been shown by dendrochronological research on the oaks of the native Roman settlement in Nieuwenhoorn that these oaks most probably came from mineral soils on Voorne-Putten. For the construction of the last house on this site, the inhabitants had to use oaks with a much more irregular growth, which points to worse growing conditions. This may point to exhaustion of the oaks of better quality (see *3.2*).

A last possibility for obtaining information on the "miss-
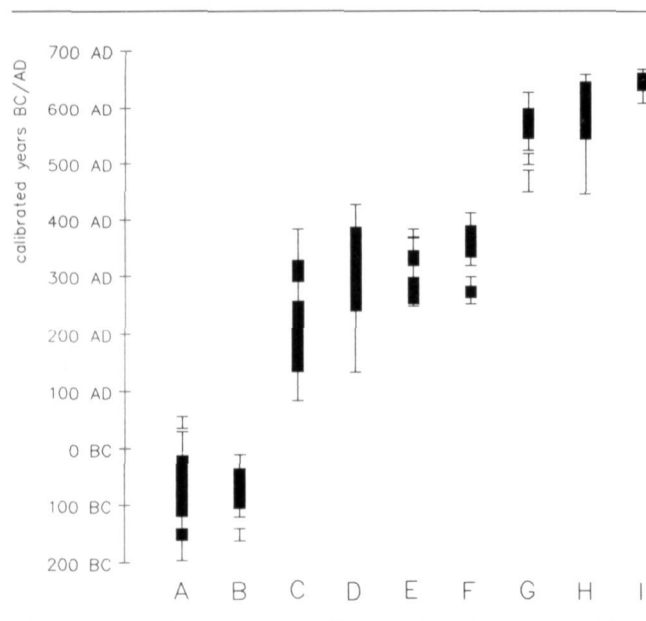
Fig. 24 Calibration of ^{14}C dates of a Late Iron Age post, the peaty base of the Dunkirk I deposit at Rockanje 08-52 and of "Roman peat". Black = 1σ interval; line = 2σ interval.
A = Rockanje 08-06   (2060 ± 50 BP; GrN-6401)
B = Rockanje 08-52-I   (2050 ± 30 BP; GrN-18634)
C = Rockanje II (base)   (1790 ± 65 BP; GrN-14594)
D = Lodderland   (1725 ± 65 BP; GrN-1093)
E = Simonshaven (base)   (1720 ± 25 BP; GrN-12215)
F = Nieuwenhoorn (base)   (1695 ± 30 BP; GrN-15227)
G = Nieuwenhoorn (top)   (1500 ± 30 BP; GrN-15228)
H = Rockanje II (top)   (1470 ± 60 BP; GrN-14593)
I = Simonshaven (top)   (1395 ± 30 BP; GrN-12214)

ing period" (Late Iron Age and Early Roman Period) is offered by the R.G.D. diagram from Heenvliet, where a ^{14}C date of the top of peaty deposit of 1830 ± 130 BP was obtained. Apart from the base of the peaty sediment, no further datings have been carried out. This diagram, which was kindly placed at my disposal by Ing. De Jong, is presented in figure 25. The lower part of the Heenvliet diagram analysed in the present study (see *2.4.3*) has been dated more thoroughly, but the sequence stops at 2425 BP. A possible solution to this problem is offered by comparing both diagrams by means of statistical methods. Birks and Gordon (1985) gave several examples of similar approaches in comparing two diagrams. Their method of sequence-slotting could not be used for the two Heenvliet diagrams since the software needed was not at our disposal. In the data sets of Birks and Gordon, Principal Components Analysis yielded results comparable to sequence-slotting. Unfortunately, this method appeared unsuitable for the two Heenvliet diagrams. Virtually all the spectra were located in one large cluster in which 41 of the 49 spectra occurred. This does not give a reliable indication about which spectra in both diagrams are most similar, since practically all the spectra are similar.

Therefore, it was investigated whether cluster analysis could yield results that were easier to interpret. Details on this method will be discussed in paragraph 4.7.1. In the present situation, the Euclidean distance was used for calculating the similarity between the samples. The results can be represented in a dendrogram, which shows clusters of variables (in this case pollen spectra) that are more similar to

each other than to variables in other clusters within the same dendrogram.

The dendrogram for the two Heenvliet sections is given in figure 26. Additionally, ^{14}C dates obtained from either of the two sections have been indicated next to the spectrum concerned. Subsequently, it has been assumed that a ^{14}C date for a given spectrum of my Heenvliet diagram can be assigned to a spectrum in the R.G.D. diagram if it occurs in the same cluster. Thus, spectrum "RGD60" is "dated" at 2425 ± 25 BP, "RGD75" as 2820 ± 50 BP and "RGD150" as 3945 ± 45 BP. The spectrum "HEEN158" (from my diagram) occurs in a cluster with two R.G.D. spectra (83 and 100). If the corresponding date of 3895 ± 45 BP was attributed to "RGD83", the stratigraphical lower sample "RGD88" would be younger. Therefore, this date has been assigned to RGD100. Apart from this ambiguity, all other inferred datings of the R.G.D. diagram are in stratigraphical order.

The spectra "HEEN148" and "HEEN134" correspond most closely with "RGD95" and "RGD88" respectively, but the very long branches of the dendrogram indicate that these spectra are not very similar. In consequence, these datings were not used, although both would fit in with the stratigraphical sequence of the datings that have been used. The original R.G.D. datings of the diagram are indicated by black rectangles, all indirect datings of the R.G.D. diagram are indicated without black rectangles.

The gratifying outcome of this exercise is that the uppermost, prolonged decline of *Quercus* in the R.G.D. diagram can be assigned to the Iron Age, while earlier, smaller
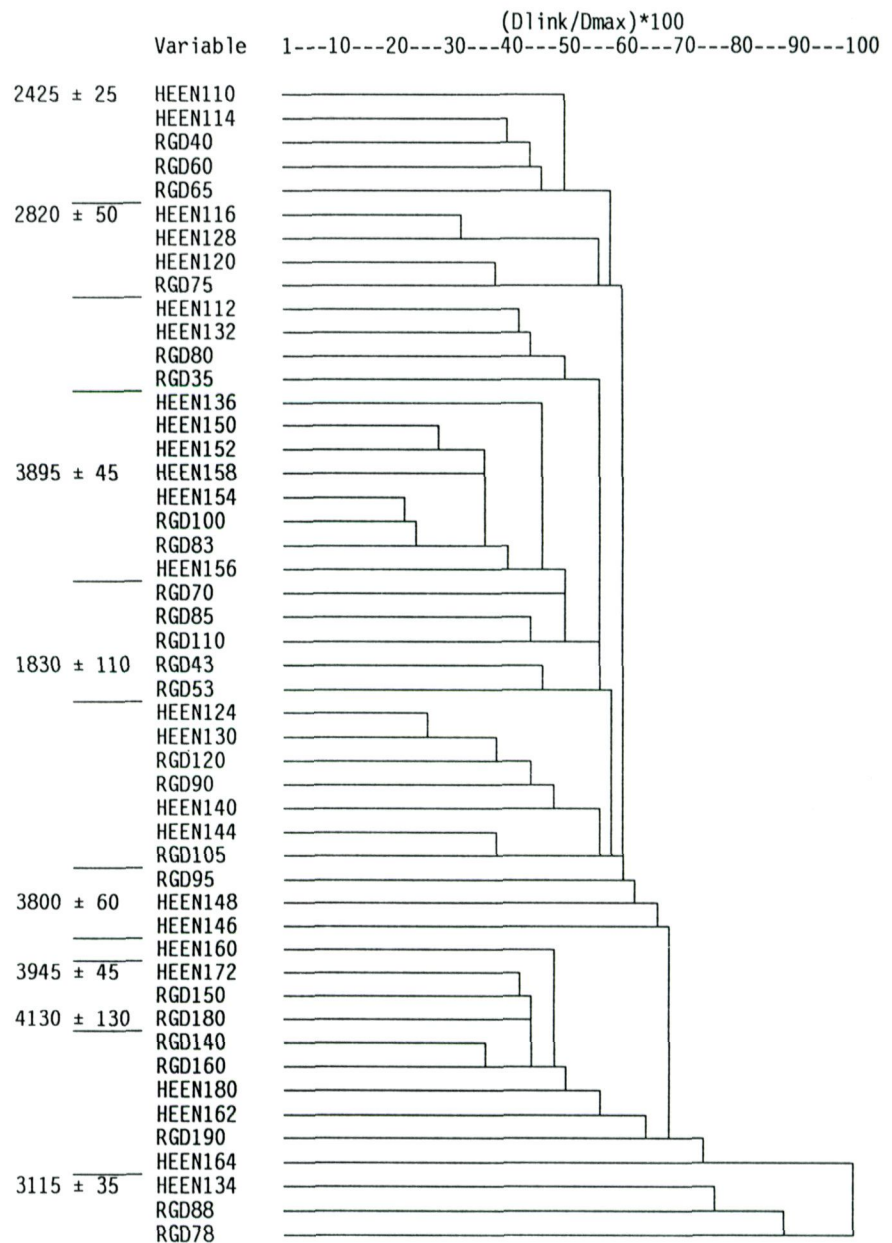
Fig. 26 The dendrogram of the cluster analysis of both Heenvliet diagrams.

declines are older. Furthermore, the diagram shows that after the Iron Age oak decline a gradual increase of oak occurred. However, the main rise occurs in the clayey sediment and part of the pollen may have been transported by water.

The Roman Period is covered by four spectra only in this diagram. This implies that it does not offer a reliable basis for the reconstruction of the landscape during Roman inhabitation.

2.7   Conclusions

The pollen diagrams discussed in the present chapter have revealed the presence of elevated levees along the Meuse, where forests of oaks, elms and other characteristic trees of

the so-called *Hartholz-Aue* forests occurred. During the Early and Middle Iron Age, the former primary forest was felled to a considerable extent. Since the levees concerned were eroded in medieval times, it cannot be assessed whether they were inhabited during the Iron Age and/or whether arable fields were laid out.

In the wetter part of the landscape on Voorne-Putten, trees were very scarce. It was an open landscape, which showed a mosaic of vegetation types, such as reed swamps and raised bogs.

Peat formation ceased practically everywhere on Voorne-Putten after increased marine influence. This marine influence is connected with a Dunkirk`I transgression phase, which took place in the last centuries before the Christian era. Locally, peat growth recovered from c. 200 AD onwards. As a result, the reconstruction of the Iron Age and Roman environment after deposition of Dunkirk I sediments is not possible. Notwithstanding that, the pollen diagrams that have been obtained from this "post-Roman" peat do show an increase in trees from primary forests. This implies that during the Roman habitation these trees occupied considerably less than their potential area.

Two sections, which were situated close to excavated Iron Age habitation sites, did not reveal any Cerealia-type pollen grains. Apparently, large-scale threshing of grain did not take place, at least not during the Early Iron Age.

notes

1 In the present study, "m" stands for metre(s), not mile(s).

2 Raw data of all pollen diagrams analysed in the I.P.L., including rare taxa, will be stored in the regional Dutch pollen database. Besides, raw data can be requested from the author.

3 Pollen of *Plantago maritima* closely resembles that of *P. lanceolata*, although the latter species has on average more pores (cf. Faegri *et al.* 1989).

4 NAP = *Normaal Amsterdams Peil*; Dutch Ordnance Datum.

5 All calibrations have been made by means of a computer programme (cf. Van der Plicht/Mook 1987).

6 Owing to the fact that "upland" herbs like Chenopodiaceae were excluded from the pollen sum, the diagram presented here (see fig. 19) is somewhat different from the diagram of the same section presented by Brinkkemper *et al.* (*in prep.*).

7 Kalis distinguishes between pollen production (sensu stricto) and pollen emission. *Tilia* is a moderately large pollen producer, but owing to the small emission of this insect-pollinated tree, it is a bad pollen producer in the conventional sense.