A BOTANICAL ANALYSIS OF A LATE-PLEISTOCENE AND HOLOCENE PROFILE IN THE RHINE DELTA

by

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The post-Glacial history of the forests in the Netherlands has been reconstructed fairly well by pollen analysis of several bogs. At the same time stratigraphical investigations shed some light on the way in which these bogs had been built up, i.e. on the plants by which, in the various forest periods, peat was formed. Though these data are quite interesting, they do not give a good impression of the entire synchronal herbaceous flora, as they are limited to the peat-building plants. As yet very little is known of the rest of the vegetation (water-, marsh- and land-plants) of the late-Pleistocene and Holocene periods. We must look for their remains in other deposits, particularly in clay and sand, wherein however few land plants will be found, as their chance of preservation is very small. The best strata for an investigation of this kind lie, as a rule, beneath the groundwater level, and this is a great handicap for collecting samples. Deep pits have been dug lately by the "Rijkswaterstaat" (Government office for the maintenance of dikes and canals) and as they are kept dry by intensive pumping, they are very useful for our purpose. The construction of a lock near Wijk bij Duurstede, province of Utrecht, gave us an opportunity for studying a profile extending from 4.70 m —NAP (i.e. 4.70 m below Ordnance Datum of Amsterdam) to 3.75 m +NAP (i.e. 3.75 m above O.D.). From this ± 8.5 m high profile, a complete set of samples was taken for pollen analysis, and larger quantities for macroscopical investigation. A special word of thanks is due to the technical staff of the "Rijkswaterstaat" for their kind assistance at the field work.

Wijk bij Duurstede is situated in the Rhine delta, where the "Kromme Rijn", now but a backwater of a formerly important river arm of the Rhine, branches off to the NW (see map, fig. 1). The youngest sediments consist of river clay, deposited in the broad valley of the Rhine, measuring here ± 25 km in width. About 6 km to the NE the Utrecht hill range, a push moraine dating from the Riss glacial epoch, rises up.

Fig. 1. Map of the Netherlands, showing Wijk by Duurstede and other localities referred to in the text.

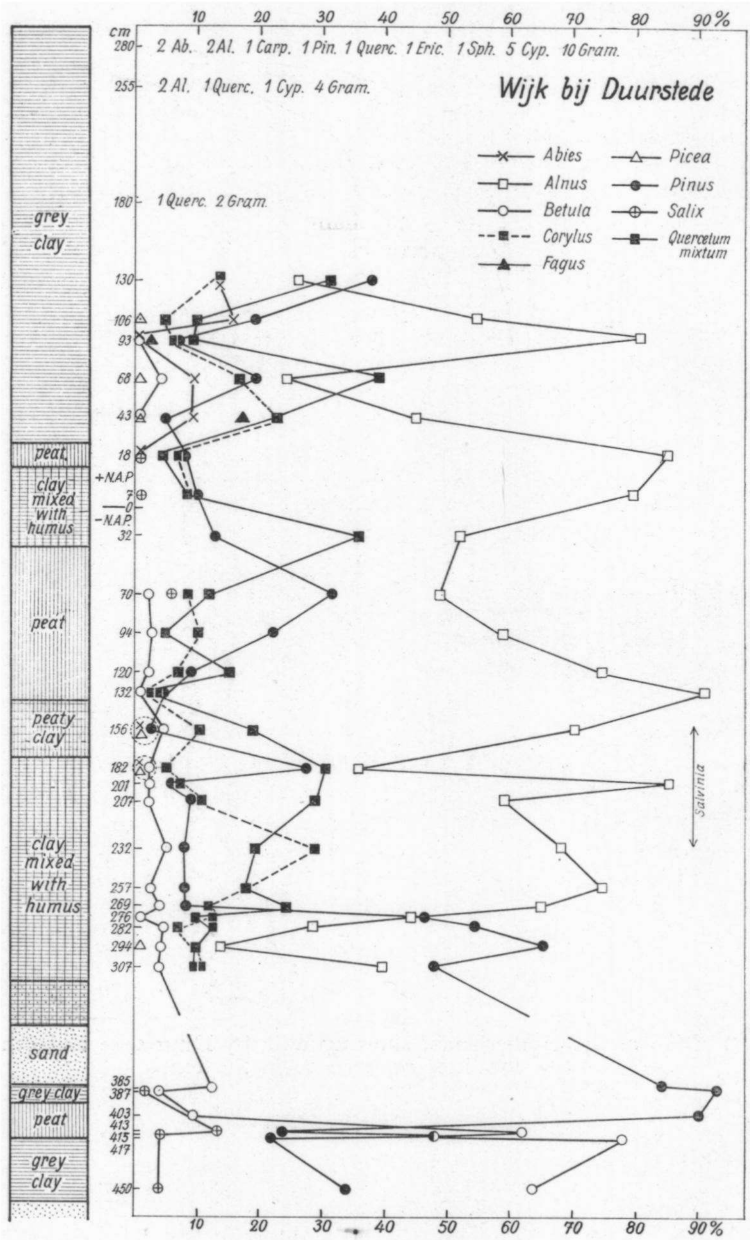

Fig. 2. Pollen-diagram.

Description of the profile. The lowest layer disclosed in the pit consists of coarse sand with pobbles up to 1.5 cm in diameter; it extends from the bottom (4.70 m —NAP) to 4.56 —NAP. On this lies a 40 cm thick layer of grey, calcareous clay, succeeded upwards by peat, about 20 cm thick. This is followed by grey clay, about 15 cm in height, which passes into a layer of sand extending to 3.40 m —NAP, covered by clayish, humic sand, gradually changing into humic clay. At 1.80 m —NAP this clay is replaced by peat and at 0.38 m —NAP the peat changes again into humic clay, and subsequently the latter becomes more peaty. The profile ends with a thick layer of grey, calcareous clay. The profile shows therefore alternating coarser and finer grained sediments of anorganic and organic origin, deposited either in the river bed itself, or in the marshes, developed in the old bed when the river had changed its course. In figure 2, a special column describes the nature of the layers.

Pollen analysis. Only a part of the sediments proved to be suitable for pollen analysis; the coarser sands at the base of the profile and some of the clay layers, especially the upper light-grey ones, contained too few pollen for calculating a spectrum. Even in the peat the pollen was not abundant, at least in comparision with the peat of raised bogs, formerly analysed. Although for some of the spectra 150 pollen grains were not available, a fairly satisfactory pollen-diagram could be made (fig. 2).

In the lower parts the diagram quite agrees with what was already known about the forest history of the Netherlands. The clay between 4.56 m—NAP and 4.15 —NAP and the peat, resting on it, were formed in the second phase of the late-Glacial period, that of the pure birch and pine woods. In the pollen spectra of the clay *Betula* dominates, while in the peat the *Pinus* values become high. *Salix* pollen is present in a small percentage, but grains of thermophilous trees are entirely absent. Only in one case the non-tree pollen ecxeeds 200 %. The woodless period, i.e. the first phase of the late-Glacial period, was obviously not found. Perhaps the upper part of the sand underneath the clay, below 4.56 m —NAP, was deposited at this time, but as the sand is coarse grained, it is more probable that it forms part of the Lower River Terrace, and dates from the Würm Glacial period.

The first appearance of thermophilous trees, i.e. the beginning of the third phase of the late-Glacial period, was not met with in the pollen spectra. Probably the sand between 3.83 m and 3.13 m —NAP, which contained too little pollen for analysis, was deposited at this time, though the upper part might perhaps have been formed in the Boreal period; in this case the boundary between Pleistocene and Holocene would be found in this layer. Whilst the humic clay was formed, the thermophilous wood has already grown considerably in importance, but the pine is still dominant in the diagram. The *Alnus* pollen attains 40 %, descends to 15 % and rises suddenly to intersect the descending *Pinus* line at 45 %. It is generally accepted that the Atlanticum begins here, apparently with a rise of the groundwater level, so that in the lower districts the pineta were ousted by alneta.

Alnus is dominant in the rest of the diagram but its percentage undergoes great fluctuations. This in itself however is not deviating from the Atlantic and younger parts of the pollen diagrams of Dutch peat-bogs. The really important differences lie in the percentages of pollen with a smaller frequency. Our attention is at once drawn to the *Pinus*-curve, which rises more than once to as much as ± 30 %, though in normal diagrams of the Atlantic and later periods it stays, as a rule, under the 10 %. This phenomenon has also been found in similar profiles as the one studied at Wijk bij Duurstede, i.e. profiles consisting of peat, mostly alderbogpeat, and clay. OVERBECK and SCHMITZ (1931) published diagrams showing profiles from alternating marine clay and peat. The high *Pinus* percentages, up to 40%, were typical for the clay spectra. In the peat both below and above the clay, they were normal, i.e. usually less than 10 %. They had to deal with peat layers, which were covered by marine clay, which in its turn was overlaid by peat. OVERBECK and SCHMITZ explained the abnormally high percentage of *Pinus* by assuming that during marine transgressions, when the clay was deposited, the alderbog was drowned, whereupon the *Pinus* percentage rose at the cost of the *Alnus* percentage. They do not, however, wish to eliminate the possibility that some kinds of pollengrains decay sooner than others and that a selection is brought about in this way. Miss POLAK (1936) who also emphasises the high *Picea* percentage (up to 9 %) and the occurrence of *Abies* pollen in the "young marsh" near Schokland, explains the aberrant character of the spectra by assuming that the clay received an admixture from material derived from older layers. Although we do not wish to eliminate this possibility, in our case at Wijk bij Duurstede we feel another explanation to be more obvious. It struck us, that in the upper parts of the diagram, some *Picea* pollen and quite a number of grains of *Abies* and occasionally of *Fagus* were present next to the varying percentages of *Pinus* pollen grains. Taking into consideration the fact that the clay was brought there by the Rhine, we think that perhaps pollen might have been washed

LIST OF OBSERVED PLANT REMAINS

f = fruit(s); l = leaves; s = seed(s); w = wood.

Height with respect to NAP (in cm).	Characters of the layers	Herbaceous plants	Woody plants
25+ — 240+	grey clay	*Alisma* s *Carex* f *Gramineae* f *Lycopus* s *Nuphar* s *Ranunculus sceleratus* s *Rumex* f *Urtica* s *Musci*	*Alnus* f, w, remains of ♀ catkins
135— — 25+	peat humic clay peat	*Alisma* s *Carex* f *Lycopus* s *Mentha* s *Montia* s *Nuphar* s *Nymphaea* s *Ranunculus Lingua* s *R. sceleratus* s *Urtica* s *Scirpus* f *Stellaria* s *Stachys pal.* s *Musci*	*Alnus* f, w & remains of ♀ catkins *Solanum Dulcamara* s
150— — 135—	peaty clay	*Alisma* s cf. *Anagallis* s *Mentha* s *Lycopus* s *Ran. Lingua* s *Scirpus* f	*Alnus* f, w & remains of ♀ catkins
245— — 150—	peaty clay humic clay	*Alisma* s *Batrachium* s *Carex* f *Chara* oosp. *Comarum* f *Lycopus* s *Mentha* s *Nuphar* s *Nymphaea* s *Phragmites* l, stems *Potamogeton* f *Ran. Lingua* s *R. sceleratus* s *Rumex* f *Salvinia* macr. sporan. micr. sporan. *Scirpus* f *Sparganium* s *Stachys pal.* s	*Alnus* f, remains of ♀ catkins *Solanum Dulcamara* s
313— — 245—	humic clay	plant fibres	
380— — 313—	humic clay humic, clayish sand sand	*Chara* oosp.	

Height with respect to NAP (in cm).	Characters of the layers	Herbaceous plants	Woody plants
395— — 380—	grey clay	*Carex* f *Chara* oosp. *Menyanthes* s *Potamogeton* f *Scirpus* f	
417— — 395—	peat	*Carex* f *Chara* oosp. *Comarum* f *Hippuris* s *Mentha* s *Menyanthes* s *Myriophyllum* s *Nymphaea* s *Potamogeton* f *Ran. Lingua* s *Scirpus* f *Sparganium* s *Musci*	*Arctostaphylos* s *Betula* f *Pinus* l
456— — 417—	grey clay	*Alisma* s *Batrachium* s *Carex aquatilis* f *Carex* spec. f *Ceratophyllum* s *Chara* oosp. *Comarum* f *Filipendula* s *Heleocharis* f *Hippuris* s *Menyanthes* s *Myriophyllum* s *Oenanthe* f *Potamogeton* f *Ran. Lingua* s *Scirpus* f *Selaginella* macrosp. *Zannichellia* f	*Arctostaphylos* s *Betula* f *Pinus* l *Salix* f, l, twigs
below 456—	sand	*Alisma* s *Batrachium* s *Carex* f *Chara* oosp. *Comarum* f *Hippuris* s *Menyanthes* s *Myriophyllum* s *Nymphaea* s *Potamogeton* f *Ran. Lingua* s *Scrirpus* f *Selaginella* macrospores *Sparganium* s *Stachys pal.* s *Zannichellia* f	*Arctostaphylos* s *Betula* f *Pinus* l, s *Salix* buds

down from the woods of the upper Rhine. In the pollen diagrams of the Schwarzwald published by BROCHE (1929), *Picea*, *Abies* and *Fagus* obtain a great spread in the Atlantic and Subboreal periods. We would like to suggest that at Wijk bij Duurstede the pollen contents of the grey clay above NAP have been partly brought down from the upper Rhine region, partly because the vegetation in the near vicinity will also have played its part, e.g. in the *Alnus* percentage. The pollen in these layers is therefore, according to our opinion from mixed origin: allochthonous and grown in the near vicinity. If this interpretation should prove right, then this would be a means whereby the diagram might be further devided: the late-Atlantic and Subboreal part of the profile would fall between 0 and 130 cm +NAP, so that the upper 250 cm consisting of clay, very poor in pollen, would have been formed in the same periods or in the Subatlanticum.

Stratigraphy. The character of the layers, their height, and the macroscopically visible plant remains are found in the accompanying list. As the lowest clay strata, according to their pollen contents have been formed in the second phase of the late-Glacial period, the sand just below them must date from the same period or even from on earlier one. As mentioned above we would like to reckon this fairly coarse sand to the Lower Terrace, in which case it would date back to the Würm Glacial period. In comparison to what was found in similar deposits in Twente, we might have expected plant remains derived from a tundra flora. The tundra flora of the eastern part of the Netherlands consists of a mixture of true tundra plants, with *Dryas octopetala*, *Salix herbacea*, *Polygonum viviparum*, *Armeria arctica* and *Thalictrum alpinum* as typical representatives, of subarctical plants as *Betula nana*, *Selaginella selaginoides* and *Arctostaphylos Uva-ursi* and marsh and water plants. The true tundra plants had already disappeared in Twente in the late-Glacial period, when peat was formed, but the subarctic plants were still there. In a single case (Vriezenveen-Bruinehaar) macrosporae of *Selaginella* were found in Boreal deposits (FLORSCHÜTZ u. WASSINK, 1935); *Betula nana* was present in West Germany in the Atlantic period (OVERBECK und SCHNEIDER, 1938) and still occurs in the Lüneburger heath, while a few years ago *Arctostaphylos* was discovered still growing wild in the Netherlands (FLORSCHÜTZ, 1931). But even so we wish to consider these three species as typical for the late-Glacial period in the Netherlands.

Not a trace of the true tundra plants was found West of the river IJssel. There is, of course, the possibility that the tundra did not stretch further westwards, though remains of tundra animals were found at Rotterdam (FLORSCHÜTZ en V. D. VLERK, 1939) and periglacial phenomena appeared even in the southernmost part of Zeeland (Zeeuwsch Vlaanderen) (FLORSCHÜTZ, 1939*a*).

In congruence with the results obtained from other parts of the province of Utrecht (Soestdijk etc.) the late-Glacial deposits of Wijk bij Duurstede (clay and peat) also contained *Selaginella* and *Arctostaphylos*, but *Betula nana* was absent. That the sandlayers at the base do not contain remains of the true tundra plants might be due to the sand not being deposited before the late-Glacial period, i.e. in a time that the true tundra plants had already disappeared. The peat layer between 4.17 m—3.95 m —NAP, consisting chiefly of hydrophilous *Musci*, might be called "peat-at-greater-depth" ("veen op grotere diepte").

This geological expression has been accepted for a layer of compressed peat or humic clay, as found practically always at a depth of 10—20 m in the west of the Netherlands. Originally this layer was taken for the lowest Holocene sediment, but later studies (VERMEER-LOUMAN, 1934; FLORSCHÜTZ, 1939*b*) have shown that this peat can also be formed in the late-Glacial, Boreal and old-Atlanticum, thus covering a considerable period and can hardly be taken as a geological level.

Between 3.80—3.40 m —NAP (sand) and 3.40—3.15 —NAP (sandy clay) only oosporae of *Chara* were found.

The plant remains, brought to light by the study of the slightly humic clay between 3.13 m and 2.76 m —NAP dating from the Boreal period, were not recognizable. The same may be said of the 30 cm Atlantic deposits (to 2.45 —NAP). The next meter, however, of clay becoming more peaty higher up, contained a number of marsh and land plants, in which *Salvinia* was prominent. This waterfern was present from 2.25 m to 1.50 m —NAP, and especially abundant from 1.85 m to 1.65 m —NAP, micro- as well as macrosporangia were found.

Up to this time *Salvinia* was only known from the Netherlands in Pleistocene interglacial and interstadial deposits. The finding of one macrosporangium in the Holocene layers beneath the Cathedral Square at Utrecht (FLORSCHÜTZ en JONKER, 1936) created the supposition that even in Alluvial deposits *Salvinia* was to be found in Holland. This supposition was proved to be right, when great quantities of *Salvinia* remains emerged from the clay at Wijk bij Duurstede. The possibility of transport of *Salvinia* from the upper Rhine regions by the river, must be excluded for the following reasons: in the first place, the fragile, reticulated sporangium wall was often intact, and it is unlikely that this could withstand a long transport by water; in the second place the occurrence of *Salvinia* is limited to the small zone of 2.25—1.50 m —NAP, but here it is found in every sample. Moreover the quantity increased gradually in the higher parts beginning at 2.25 m —NAP, reached a maximum between 1.85—1.65 m —NAP and gradually dimished till 1.50 m —NAP, whereabove no more *Salvinia* spores were found. Even though the occurrence of *Salvinia* is here confined to the old-Atlanticum, this does not mean that it need be limited to this period in other parts of our country. At present, *Salvinia natans* does not occur North of the upper Rhine region but from there it is transported from time to time by woodrafts to Holland, where it sometimes maintains itself a few decennia.

In the pure peat following on this clay, as already mentioned, *Salvinia* does not occur. This peat was obviously formed in an *Alnus* bog (wood, fruits, remains of female catkins, etc.). In the higher part the percentage of *Alnus* remains gradually decreases, rests of fresh water and marsh plants taking their place. These do not need a more detailed discussion.

Above 2.40 m —NAP traces of human influence were found: pieces of brick etc.; these layers were therefore not examined further.

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