APPENDIX I

POLLEN DIAGRAMS

For the purpose of reconstructing the environment around the settlement Hienheim, we made two pollen diagrams: one of the Heiligenstädter Moos and one of the Grosse Donaumoos. The diagrams are included in the enclosure which belongs to this publication. The description of the sampling sites, profiles and diagrams is given below.

THE HEILIGENSTÄDTER MOOS

The Heiligenstädter Moos (48°48′N, 11°47′E, 349 m above NN) is situated in the valley of the Donau river, just east of Neustadt a.d. Donau and adjacent to it. The fen covers a surface of 65 ha in the Holocene river valley. The western, southern and eastern limits of the deposit are formed by the terrace edge of the Late Pleistocene Lower Terrace. The situation of the fen between the surrounding settlements is shown in figure 21. The map is a simplification of a sheet of the geological map of Bayern 1:25000 No. 7136 Neustadt a.d. Donau (Schmidt-Kaler 1968). The same figure includes a profile through the peat, which has been taken from figure 27 of the explanation of this geological map. The profile was made by Laforce and Karglseder. It is obvious that the Heiligenstädter Moos is not a continuous entity, but consists of a series of channels which are filled up with organic deposits. We are undoubtedly dealing with abandoned river channels. According to Laforce and Karglseder, the river channels were filled up mainly with Carex-Phragmites peat, which changes downwards into calcareous gyttjas or into lake marl (Laforce and Karglseder, quoted in Hohenstatter and Vidal 1968).

The fen is drained superficially by a system of ditches. About two thirds of the surface are used as hayfield. There are also a few fields where maize and potatoes are grown. The rest is covered by a waste of shrubs and tall herbs: the remains of a fen carr. Rather large quantities of peat were cut in the past. This activity continues up to the present day.

As the Heiligenstädter Moos lies relatively close to Hienheim, namely at 8 km from this place, this fen was selected as the first site for palynological investigation. According to Dr. E. Hohenstatter, such an investigation had not been conducted before (Hohenstatter 1970, written information). For the sampling we selected the deepest channel found by Laforce and Karglseder. Of course this choice is arbitrary: we could not know beforehand which channel would contain sediments from the period we are looking for.

The sampling was done with a Dachnowsky corer. Figure 21 shows the point where the sample was taken. The series of organic deposits turned out to be 545 cm thick at the chosen spot. The stratigraphy is as follows:

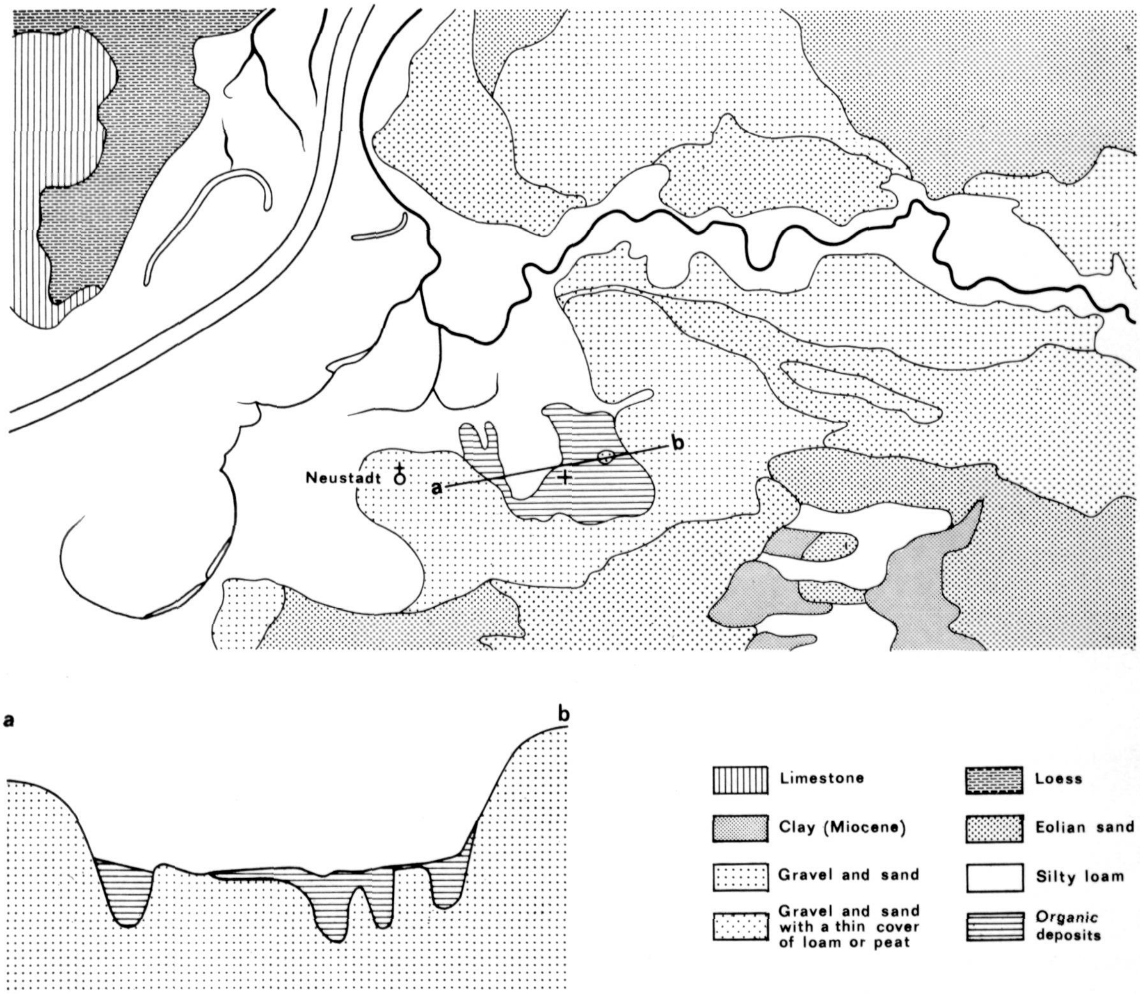

Fig. 21. The Heiligenstädter Moos: position, surroundings and section. The cross indicates the place of sampling. Map, scale 1:50000; section, horizontal scale 1:20000 verticale scale 1:400.

cm	
0– 30	amorphous peat with some sand
31–244	Carex peat with occasional Phragmites fragments becoming more numerous at base; Carex utricles and nuts; Menyanthes seeds; gradual transition to
245–287	swamp peat with a few molluscs (fragments and complete specimens); Cladium nuts; Menyanthes seeds; a piece of Salix or Populus wood; gradual transition to
288–324	complex of peat and calcareous gyttja; molluscs (fragments and complete specimens); gradual transition to
325–367	calcareous gyttja with molluscs (fragments and complete specimens); Menyanthes seeds; Potamogeton natans fruitstones; gradual transition to
368–474	calcareous gyttja with molluscs (fragments and complete specimens); at circa 405 cm a Potamogeton natans fruitstone; gradual transition to
475–545	lake marl
546–558	sand and gravel

It should be noted that the deposits between 245 and 545 cm contain a little mineral material. In the laboratory the core was cut into slices of 1 cm thickness. Each tenth cm was reserved for further analysis. Thus the distance between the analyzed samples is rather great. When the diagram was elaborated, it appeared that the curves of the different pollen types show a relatively stable course. We think that a sampling at each five centimeters or at each centimeter would not essentially change the course of the curves. In our opinion, an ample distance between the samples is sufficient in the case of the Heiligenstädter Moos to reach the goal set: a reconstruction of the vegetation in the surroundings of the fen.

The samples were treated subsequently with 10% KOH, 18% HCl, acetolysis and bromoform-alcohol sp. gr. 2.0. The conservation condition of the pollen turned out to be excellent.

We chose an upland pollensum for calculating the curves in the pollen diagram. This pollensum comprises all plants which grew outside the fen. The criteria for the classification of the plants are based on the recent habitat of the species that were retrieved. As we deal with older deposits, this method becomes more and more unreliable. In this respect we fully agree with the remark made by Janssen in a 1970 article (Janssen 1970): "One may ask whether the recent ecologic groups existed in the same way in the early Holocene." After enumerating arguments against such a hypothesis, Janssen arrives at the following conclusion: "All in all the conclusion must be that the use of pollen types as indicators of vegetation types works for the later part of the Holocene with a flora not too different from the present one. Before the Atlantic period the application of the present ecological tolerances may be of doubtful value." (Janssen 1970 p. 194). As we make the diagram in order to learn about the vegetation during the Atlantic and as the deposit starts in the Atlantic, as will appear further on, we think that we may use an upland pollensum. In the composition of the pollensum, we have left out of the sum all pollen types that might have originated from wet, eutrophic and mesotrophic locations, up to and including the Alnetum glutinosae and its seral communities. Plants from the Alno-Padion, in as far as not belonging to afore-said category, were kept within the sum. We have taken the data concerning the habitats of the plants in question from Bodeux and from Oberdorfer (Bodeux 1955, Oberdorfer 1970). Of course, the classification often presents problems. The pollen of the Cerealia-type was included in the pollensum, because the large numbers in the top of the profile originate from Secale. But as far as the rest is concerned, it is not clear which grass species provided the pollen. It could be Glyceria pollen, in which case the pollen type would not belong in the upland pollensum. Viscum is usually kept within the sum. We, however, left this pollen out of the sum, because Viscum can also occur on Salix. Hippophae has been left out of the sum, because we assume that this shrub was the pioneer on sand- and gravel-flats at the time that the meanders were abandoned by the river. The pollen of Hippophae namely occurs only in the bottom of the diagram. It is true that the shrub cannot have stood on the sampling place, because this lay under deep water at the time, but it could have grown in its immediate vicinity.

The zonation of the diagram is based on changes in the curves of the upland pollen. The most important of these curves are included in the main diagram. As the course of the curves, and more particularly the course of the tree pollen curves, shows a clear similarity with the curves in other South German diagrams, we feel that we should not introduce a numbering of our own in the nomination of the zones, but rather use the zonation by Firbas. However, we have placed a capital H before the Roman numerals. This will be explained later. The zones in the Heiligenstädter Moos are defined as follows:

H VI	Betula, Corylus, Quercus, Ulmus and Tilia have constant values. The curves of Fagus, Picea and Pinus are discontinuous. Abies is absent. A C14 date of 8000 ± 210 B.P. (GrN-7139) falls within this zone.
Boundary H VI-H VII:	First increase of Pinus, Picea and Fagus, strong decline of Ulmus. The boundary has been dated at 6250 ± 110 B.P. (GrN-7541).
H VII	Betula and Corylus have constant values, though slightly lower than in H VI; *Quercus and Tilia also have constant values, though slightly higher than in* H VI. Fagus and Picea are constantly present in low values. The curve of Abies is discontinuous.
Boundary H VII-H VIII:	The boundary is not sharp, it lies somewhere between pollen spectra 301 and 331. In the diagram a line has been drawn at the second increase of Fagus. This has been done because in many other diagrams the curve of Fagus is used to indicate the zonation. The second increase of Picea and Pinus takes place somewhat earlier. Abies becomes continuous slightly later. Tilia declines strongly at the same time as the increase of Picea and Pinus, an event dated by C14 to 5495 ± 65 B.P. (GrN-7140).
H VIII	Betula, Corylus, Quercus, Ulmus and Tilia are present in much lower percentages than in the preceding periods. Pinus, Picea and Abies show a maximum. Fagus continues to increase. Carpinus occurs for the first time.
Boundary H VIII-H IX:	Strong expansion of pollen of the Cerealia-type, which here belongs entirely to Secale. This is combined with a strong expansion of Plantago lanceolata and Chenopodiaceae. Pinus, Picea, Abies and Fagus decline.
H IX	This zone is characterized by distinct influences of human activity.

For zones H VI and H VII the correspondence with the zonation by Firbas is satisfactory. However, the boundary between H VIII and H IX and the description of H IX are different. The period Firbas IX is characterized by a constant, high percentage of Fagus pollen. In the Heiligenstädter Moos the continuous rise of the Fagus curve towards the maximum (the characteristic of Firbas zone VIII is interrupted by a series of phenomena which we interpret as deforestation. We think that the Fagus expansion in the area near the Heiligenstädter Moos could not reach its maximum, because the area was too densely populated by then. Firbas zone IX is considered generally to comprise, among others, the La Tène period and the Roman Age. The very large oppidum Manching at 20 km west of the Heiligenstädter Moos and the oppidum at Kelheim at 12 km north-east of the fen, date from the La Tène period. The inhabitants of the oppidum at Kelheim were concerned with the extraction and processing of iron-ore (Schwarz, Tilmann & Treibs 1965/1966). In addition to these two large centres, we know of occupational traces of minor extent from the La Tène period. For the Roman Age, suffice it to say that the Limes Rhaetica starts near Hienheim. Therefore traces of the Roman Age are predictably numerous. Remains of Roman buildings can be found, among other places, in Bad Gögging, at a distance of 1.5 km from the Heiligenstädter Moos.

Much wood was undoubtedly needed for human activities during the said periods. We assume, therefore, that the usual criterion for the nomination of zone IX cannot be applied in this area. To illustrate the deviation from the standard zonation, we have placed a capital H before the Roman numerals, which indicates that we are dealing with a local zonation.

As mentioned above, the Heiligenstädter Moos consists of a series of curved, long and relatively narrow sedimentation basins. We assume that these elongated lakes were not filled up simultaneously. In our opinion, the basin in which our pollen landed did not cover 65 ha, which is the recent extent of the fen, but a much smaller area. The width of the filled-up channel is circa 100 metres. We therefore consider the original ox-bow lake as one of the small lakes in the sense of Tauber. This means that Tauber's effective area, that is the area from which 80% of all pollen originates, has a radius of 300 to 1000 metres (Tauber 1965). There are two types of substrates within this area: the Holocene river-valley of the Donau and the Late Pleistocene Lower Terrace of the Donau and its tributary the Abens. The former consists of fine sandy sediments which are rich in nutrients, and was flooded more or less regularly by the river until recently (see p. 23). In the vicinity of the fen the latter consists of quartz sands and gravels, which are poor in loam and nutrients; moreover, it belongs to the dry part of the Lower Terrace (see p. 42). We expect that the upland pollen originates mainly from these two substrates. Further, a part of the pollen will have come from some distance, carried by the wind, but initially perhaps also by river-water, since the deeper sediments show an addition of mineral particles.

The beginning of the filling up of the channel has been established by a C14 date at 8000 $\pm$ 210 B.P. (GrN-7139). The large error is due to the low suitability of lake marls for C14 dates (Mook 1974, written information). The beginning falls in our zone VI which, as far as the curves of the tree pollen and more particularly the low presence of Fagus is concerned, is comparable with Firbas zone VI. It is generally assumed that this period lasted from circa 7600 B.P. to circa 6000 B.P. (amongst others mentioned by Janssen 1974 figure 30). Since zone VI is a biostratigraphic unit, it need not start or end everywhere at the same time. The fact that our date is on the early side, allows no more than the conclusion, that zone VI began early at this place.

The vegetation of the surroundings of the Heiligenstädter Moos is dominated by deciduous trees during zone VI. Besides, there are shrubs, but in very low percentages. They are: Crataegus sp., Rhamnus cathartica, Ligustrum vulgare, Cornus sanguinea, Viburnum sp. and Sambucus nigra. The herbs that could be considered as forest flora are small in number. They are: Pulmonaria sp., Adoxa moschatellina, Pleurospermum austriacum and Melampyrum sp. The other upland herbs belong to vegetations of clearings. It is conspicuous that the Rumex acetosa type, Artemisia and Chenopodiaceae are predominant among the herbs. These plants are usually related to human activities. In our case one could think of the influence of a Mesolithic population, but in our opinion it is not necessary to attribute the presence of "ruderal plants" in the diagram to man. It is possible that the plants grew on spots that were kept open by animals. The size and the position of the clearings cannot be given.

The percentage of herbs is so low that we may assume that the surroundings of the ox-bow lake which was being filled up, were covered with dense forest, apart from the above-mentioned open spots which cannot be defined more precisely. It is difficult to distinguish between the vegetation of the river-valley and that of the dry sand area. The identified shrubs and the herbs Pulmonaria, Adoxa and Pleurospermum, however, only grow on soils with a certain loam content, richness in nutrients and sufficient moisture. We assume for that reason that they were present in the river-valley. They may have been part of a vegetation that we would class nowadays in the Alno-Padion. All trees belonging to zone VI possibly fit in such river-valley forests. It seems possible to us that the different forests which are considered to belong to the recent Alno-Padion, existed already in this period, and grew in the Donau valley. It is conspicuous, however, that little Fraxinus pollen was retrieved. This tree accounts, at least nowadays, for a considerable part of the forest population in a river-valley. Fraxinus should be represented reasonably in a diagram like that of the Heiligenstädter Moos, even when the bad distribution of the pollen is taken into account. We wonder therefore whether the ash had an important share in the river-valley forests. If this was not the case, the Alno-Padion was different from nowadays.

The vegetation on the high sand and gravel area of the Lower Terrace cannot, as far as we can see, be reconstructed from the diagram. We can imagine that the Betula pollen, a part of the Corylus and Quercus pollen and perhaps also some Tilia pollen had their origin in this area. Pinus is absent in this vegetation. At least we see no reason in the discontinuous Pinus curve to assume that this tree occurred locally.

During zone H VII the vegetation remained about the same as in zone H VI. The only conspicuous difference is the percentage of Ulmus pollen. The elms decline rapidly at the transition from H VI to H VII. We are certainly not confronted here with the classic phenomenon, because that is dated between 5800 and 4500 B.P. with a climax around 5100 B.P. (Godwin 1961, Sims 1973). The Ulmus decline in the Heilgenstädter Moos took place at a much earlier period, set by a C14 date at 6250 $\pm$ 110 B.P. (GrN-7541).

We tried to find out which elm species was responsible for the decline. For that purpose we examined a series of elm species by means of a scanning electron microscope, namely: Ulmus carpinifolia Gled. (two origins), Ulmus glabra Huds. (two origins), Ulmus glabra Huds. exoniensis and Ulmus laevis Pall.* Unfortunately it appeared to be impossible to point out differences between the pollen of the examined species. Neither was it possible to divide the subfossil pollen from before the Ulmus decline into groups; mutual differences are practically absent. It is not very clear either by which tree Ulmus was replaced; it could have been Quercus. The interpretation of the sudden elm decline also presents a problem. We see no reasons to explain the phenomenon as a result of a change in the local edaphic conditions. None of the other species from the Alno-Padion show a comparable reaction and the local vegetation does not show changes either. Any evidence for possible fluctuations in the width of the riparian zone (see p. 161) is absent precisely in that part of the diagram where the Ulmus decline occurs. Besides an edaphic cause, a climatological reason could be considered. The elm decline coincides with a pollen zone boundary which

* A part of the examined pollen was gathered for us by Ir. H.M. Heybroek of Wageningen.

is characterized by the first increase of Pinus, Picea and Fagus. Everywhere in Southern Germany the increase of Fagus is used to indicate the zone boundary VI-VII (Firbas 1949), but the phenomenon has never been connected with a climatological change. Moreover it has been observed nowhere so far that the coming of the beech coincides with the disappearance of the elm. The decline appears to be a local event. Therefore we consider a climatological explanation not very acceptable for our elm decline. We do not wish to engage in a discussion about a third possibility: an elm disease, because evidence thereof is very hard to find. On the other hand, we do wish to discuss a fourth cause: we mean the influence of certain human activities. It appears, namely, that the elm decline in the Heiligenstädter Moos coincides more or less with the beginning of the Neolithic occupation of the area concerned. The oldest C14 dates available at the moment for this occupation are 6155 $\pm$ 45 B.P. (GrN-7156), 6235 $\pm$ 45 B.P. (GrN-7557) and 6220 $\pm$ 45 B.P. (GrN-7558) from the LBK settlement at Hienheim. Although the coincidence might be chance, we think now that intervention by man is the most plausible cause of the rapid elm decline. Of course, the correlation between the first Neolithic inhabitants and the elm decline will have to be observed in more places in Southern Germany, before a real relation can be spoken of. We refer to p. 76 and to p. 77 for a further discussion of the elm decline.

After zone H VII there are major changes in the pollen assemblage which reached the Heiligenstädter Moos. The first changes start at a level which has been dated by C14 to 5495 $\pm$ 65 B.P. (GrN-7140). Ulmus and Tilia have become rare; the numbers of Betula, Corylus and Quercus drop rapidly. On the other hand, Pinus, Picea, Abies and Fagus increase strongly. But Abies is present in such a low percentage that we wonder whether the tree occurred locally. We think that the Abies pollen was carried by wind from a place rather far away. Transportation by river water is impossible; at least the sediment at this level no longer shows mineral particles which could indicate that the fen was flooded regularly. Picea is also present to a moderate extent only, but this tree could have stood in the vicinity. The values in which Pinus and Fagus occur indicate that these two trees were of importance in the vegetation. We assume that both grew outside the river-valley and replaced Betula, Corylus, Quercus and Tilia there. At least we cannot imagine that Pinus and Fagus were present in the relatively wet river-valley. Usually, both trees are represented poorly on more or less regularly flooded places and on places that are influenced strongly by the ground-water. We think that the growth conditions in the Holocene river-valley were still favourable for an Alno-Padion.

Although Pinus and Fagus stood, in our opinion, on the higher places, we do not assume that they were part of one and the same forest. We may visualize the beech growing on the drier parts of the Lower Terrace, whereas the pine stood further away on the eolian sands. The limit of these eolian sands is at a distance of 1 km from the sampling point. Pollen that originates from a distance of 1000 metres, and certainly Pinus pollen, can be found in large quantities in small basins (Berglund 1973). We think indeed that the percentage of Pinus pollen reflects to some extent the influence of the eolian sands around the Abens. These sands are covered nowadays with a pine forest (see p. 41), which has been described extensively by Hohenester (Hohenester 1960). If our opinion is correct, this means that the present pine forests did not develop until the beginning of zone H VIII, therefore around 5400 B.P. Anyhow, they were not present yet during zone H VI, since the Pinus curve would then have been continuous.

The influence of man begins to show in zone H VIII. The curve of Plantago lanceolata becomes continuous half-way through the zone. We do not wish to attribute a special significance to the few pollen grains in the preceding zone. They could belong to the open spots already mentioned. Nor do we wish to emphasize the presence of two Plantago media or P. major pollen grains. In agreement with Groenman-

Van Waateringe, we think it risky to interpret such sporadic presences as human influence (Groenman-van Waateringe 1968).

To what extent man was responsible for the change in the composition of the forests, cannot be said. The really major interventions are not found until zone H IX. This zone is characterized by the decline of all tree pollen curves, with the exception of Betula. Betula usually profits by the light which becomes available when shadow-casting trees are cut. Moreover, the tree grows quickly in open spaces. The curves of a large number of herbs rise steeply during zone H IX. This phenomenon can also be observed in the diagram of the "local" and "ecologically indeterminable" pollen types. These categories apparently include species which were favoured by man. Particularly Plantago lanceolata, Chenopodiaceae, Compositae, Umbelliferae and Cruciferae propagate themselves rapidly. Moreover, the first crop plants, Secale and Cannabis, are observed in zone IX. All Cerealia type pollen belongs to the Secale type. We suggested already that zone H IX with its large scale deforestation would coincide with the La Tène Period or the Roman Age. Unfortunately this suggestion cannot be supported by means of a C14 date, because the peat layer in the top of the sediment contains too many roots. Unfortunately there are no younger peat layers from which the mediaeval vegetation history might be deducted. Perhaps they were removed by the cutting of peat.

The diagram of the local pollen types of course shows only the strictly local vegetation history. The curves with parallel courses were placed beside each other, and were arranged according to the habitat of the plants in question. In this way we obtained stratigraphic-ecological pollen groups. On the basis of the diagram drawn in this way, we reconstruct the history of how the ox-bow lake was filled up as follows:

Initially the water was too deep to enable the growth of higher water plants. The local pollen types, which occur in the bottom of the diagram, are not local in the very strict sense, but originate from the bank of the basin. We assume that there was a belt of alder and willow around the lake. Dry sand- and gravel-flats were covered with a Hippophae-brushwood. The cross section of the lake shows clearly that the riparian zone cannot have been very wide: the slopes are very steep. This could also explain the initial absence of a reedbelt with the tall plants, such as Sparganium, belonging thereto. At a somewhat later stage, namely around spectrum 31, this belt is observed for the first time. At the level of spectrum 61, the lake was filled with lake marl to such an extent that Myriophyllum spicatum or M. verticillatum could begin to grow in the lake. Myriophyllum spicatum occurs in waters of 1–5 m deep and M. verticillatum in waters of 0.5–3 m deep (Oberdorfer 1970). We are dealing probably with M. spicatum, because this plant is more common than M. verticillatum in calcareous water. Since the sediment is calcareous, the water must have been calcareous too. In addition to Myriophyllum, we have found a few grains of Nymphaea and Nuphar. These few grains could have been carried in by river water during inundations. But it is also very well possible that Nymphaea and Nuphar grew on the spot. The seed of Potamogeton natans was found twice at the same level, although the pollen of this plant has not been observed. Nymphaea, Nuphar and Potamogeton, together with Myriophyllum, may have belonged to a syntaxon from the Nymphaeion Oberd. 1957 em. Neuhäusl. 1959. These plant communities occur nowadays in eutrophic waters of 0.5–3 m deep which are sheltered from the wind, a description which entirely fits our picture of the Heiligenstädter Moos in the period concerned. Algae from the genus Pediastrum apparently also do well in this quiet water, considering the remains found.

From spectrum 171 on, riparian plants, with, however, the exception of Alisma and Sagittaria, begin to manifest themselves again. For one reason or another they were observed only in small numbers for a while. We shall return to this later. The plants of open water are replaced gradually by Equisetum (E. fluviatile?), Potamogeton sp., Sparganium sp. and Typha latifolia. When these plants became predominant, the lake had a depth of 250 cm at the most. We can imagine that the lake had become overgrown with plant communities which must be considered as belonging to the Phragmitetalia W. Koch 1926 em. Pignatti 1953 denuo em. Segal et Westhoff.

Finally the reed-swamp passed into a sedge-fen. Simultaneous with the rise of the Cyperaceae-curve, we found Cladium mariscus seeds. The pollen of this plant was also observed frequently. As Cladium occurs together with Menyanthes trifoliata, Monoletae (with, among others, spores of Thelypteris palustris), Lysimachia vulgaris type (to which belongs Lysimachia thyrsiflora, among others) and Rubiaceae (Galium palustre), we could be witnessing the beginning of the sedge predominance with a Cladietum marisci (Allorge 1922) Zobrist 1935. Later the Cladium-swamp probably passes into other associations of the Magnocaricion W. Koch 1926. The nature of the sediment changes at this level. The gyttjas pass gradually into Carex-peat with an addition of Phragmites.

However, there is something conspicuous in this transition zone, which does not fit in the succession Nymphaeion – Phragmitetalia – Magnocaricion, namely a temporary expansion of the alder carr between spectra 251 and 301. It would seem that the zone with alder and willow extended itself almost to our sampling site. Salix (c.q. Populus) wood has been found at this level. At a later stage, the belt seems to contract again: at least, far less pollen grains of this vegetation are found. A temporary change of the water-level could be the cause. Besides, the diagram gives us the impression that the width of the riparian zone has been subject to several more changes. The zone seems to have been very narrow between spectra 121 and 251. Between 131 and 171, even riparian plants as Sparganium are absent. Also after the major extention, that is after spectrum 301, the belt seems to narrow first, then to widen, and then to narrow again. When the Alnus-curve increases, the Cyperaceae-curve decreases, and vice versa. A large number of herbs fluctuate together with the Alnus-curve. This could mean that the alder forest was not very dense, but had numerous clearings. A number of the herbs found belong to the normal undergrowth of the Carici elongatae-Alnetum W. Koch 1926 em. R.Tx. et Bodeux 1955. But there are also herbs which are not listed by Bodeux, such as Compositae non Cirsium, Sanguisorba officinalis and Polygonum bistorta (Bodeux 1955). These plants are found in wetter or drier grasslands. We assume therefore that around the lake, later fen, there were a number of grasslands between wet and dry. These spots belong perhaps to the same phenomenon as the open spots on the dry grounds, which were found in the upland pollen. It is possible that beavers were responsible for the open spots.

Not only pollen, but also molluscs give indications of the local environment in the Heiligenstädter Moos. The molluscs which appeared during the treatment of the peat- and gyttja-samples, have been gathered and identified by W.J. Kuijper. He writes about these molluscs: "The finds comprise the following species: Valvata cristata Müller, Valvata piscinalis (Müller), Bithynia tentaculata (L.), Physa fontinalis (L.), Radix peregra (Müller), Planorbis carinatus Müller, Anisus vorticulus Troschel, Gyraulus albus Müller, Gyraulis laevis Alder, Armiger crista (L.), Segmentina cf nitida (Müller), Acroloxus lacustris (L.), Pisidium sp. and the land snail Succinea sp. The largest numbers are at circa 290–350 cm beneath the surface. As the size of the examined samples was only a few cm^3, no more than a few dozens of specimens were found. The fauna which lived here, was undoubtedly richer in species. Above species indicate that the sedimentation took place in still, clear, freshwater with much vegetation. The depth of the water cannot be reconstructed through the species found, but most of the above-mentioned animals do not survive a drying-out of their habitat, even if this is temporary, so that a very shallow water is not possible. A land snail of wet terrain (Succinea sp.) occurs in the entire shell-containing part of the sediment. This proves that there was always a bank nearby" (Kuijper 1975).

The results of the malacological analysis are in agreement with those of the pollen analysis. The level with the most abundant mollusc remains falls within our Nymphaeion: a plant community that also points to still, clear freshwater. According to Kuijper, species that are characteristic for this environment were not found, probably because the size of the sample was far too small.

As was to be expected, the vegetation in the former lake developed entirely independently of the vegetation on the dry grounds. The only zone boundary found back in the local pollen as well, is the boundary H VIII – H IX. The human influence apparently extended itself beyond the edges of the fen. The observed hydrosere passes through the sequence which is normal for this type of basins: predominantly open water, floating-leaved macrophytes, reedswamp, fen. The fen carr stage, if reached, could not be observed, probably because a part of the deposit is missing. In the Heiligenstädter Moos too it appears that "The essential nature of the autogenic sequence seems not to have changed throughout the Postglacial" (Walker 1970 p. 137).

THE DONAUMOOS

The Donaumoos (48°42′N, 11°15′E, ± 380 m above NN) is also called the Grosse Donaumoos, to distinguish it from the Kleine Donaumoos near Günzburg. It is a vast fen that covers circa 18000 ha south-west of Ingolstadt. The peat deposits developed in a funnel-shaped basin orientated from the south-west to the north-east. The "stem" of this funnel is located near Pöttmes (Ldkr. Aichach), the "mouth" merges into the valley of the Donau. As is shown on a peat depth chart from 1900, the thickest peat deposits are found in the "stem" and in its forward extention. The surroundings and the subsoil of the peat consist mainly of loamy sands, sandy loams and clays of the Upper Miocene freshwater Molasse (Schmid 1969). At the west side of the fen, a few patches of loess-loam are found on top of the Miocene deposits. To the north, there where the basin merges into the Donau valley, the fen is not adjacent to Molasse deposits, but to deposits of the Lower Terrace of the Donau.

According to Schmid, the Donaumoos-basin developed under the influence of a big river: "The south-west to north-east orientated funnel-shape of the Donaumoos-basin and the ± 100 m difference in altitude between the basin and the Tertiary hills west of the basin, allow no other conclusion than that the downcutting of the Donaumoos-basin was caused by a mighty river system" (Schmid 1969 p. 228 our translation). The valley would have developed in the Early Pleistocene. Schmid thinks that the Donaumoos-basin represents perhaps the former course of the Lech river. It is strange, however, that no river gravel was found at the base of the peat (Schmid 1969 p. 229), but the gravel deposited by the Lech could be buried by solifluction material during the Würm ice age. The Lech would have left the valley before the last ice age. The funnel-shape of the basin would have been emphasized by solifluction phenomena. During the Würm ice age the basin was closed at the north side by the deposition of gravel by the Donau. The dam of terrace material built in this way disturbed the drainage of the basin. According to Schmid, the edaphic conditions were already favourable for peat formation in the last stages of the Würm ice age. "The peat formation (Quellmoor) which with certainty started already in the Late Glacial and which continued until recently, was interrupted only in 1790 by the drainage started under Kurfürst Karl-Theodor" (Schmid 1969 p. 230 our translation). The Donaumoos has been reclaimed systematically since 1790.

Before the reclamation the fen consisted of a landscape dominated by tall sedges and willows, which was so wet that even in normal summers it could not be used as hayfield (von Aretin 1795). Spöttle writes that already before 1790 attempts were made to improve the drainage, but these were not very succesful (Spöttle 1896). Since 1791, however, the area has been drained permanently. It is used mainly as arable. The reclamation caused a considerable lowering of the surface. The level of the fen at Ludwigsmoos, where there is a gauge, has dropped 300 cm in the last 175 years. 100 cm of this difference in altitude must be attributed to peat-cutting, the remaining 2 metres are caused by compaction and wind erosion. Nowadays, compaction and wind erosion still have a strong influence. In a 1932 dust storm, 5 cm of the dried-out and pulverized peat disappeared within 24 hours (Seithz 1965 p. 18). For the future, a loss of level of 1.5–2.0 cm per year is taken into account (Scmid 1969 p. 224).

Paul tried in 1939 to make a pollen analysis of the Donaumoos. This attempt failed because the pollen turned out to be too corroded (Seitz 1965 p. 14). No attempt has been made since to examine the fen by means of pollen analysis (Hohenstatter 1972, written information). As the fen lies next to loamy deposits, which are somewhat like loess in as far as their potential vegetation is concerned (Seibert 1968), and as we failed at the time to find peat in the vicinity of loess, (see p. 38), we decided to try again to make a pollen diagram of the Donaumoos. In the preparation and execution of this plan, the "Bodenkulturstelle Mittelbayern" of the Bayerische Landesanstalt für Bodenkultur und Pflanzenbau was very helpful to us. After consulting a peat depth chart which was made in 1900 and which is available in this "Bodenkulturstelle", we selected a place near the village Walda, Ldkr. Neuburg a.d. Donau. Boring on this spot had two advantages: first, the greatest thickness of the peat had been measured here, and second, this site is at a distance of only 200 m from a slope consisting of sandy loam. The latter fact led us to expect that the vegetation on the loam would be represented in the sedimented pollen in any case.

The sampling took place by means of a Dachnowsky corer. The stratigraphy of the deposits at the site is as follows:

cm	
0– 35	amorphous peat with sand
36–185	Cyperaceae peat; Carex utricles and nuts; in the lower half of the deposit some molluscs (fragments and complete specimens); more or less gradual transition to
186–365	complex of Cladium peat, calcareous gyttja and lake marl with molluscs (fragments and complete specimens); few Carex utricles and nuts; many Cladium nuts; Chara oosporangia; gradual transition to
366–484	complex of Cladium peat, calcareous gyttja and lake marl with molluscs (fragments and complete specimens); many Cladium nuts; remains of Scorpidium scorpioides; abrupt transition to
485–555	compact, amorphous peat; fragments of Betula and Salix wood; remains of Scorpidium scorpioides; few Carex nuts; at the base of the deposit some Potamogeton sp. fruitstones and Menyanthes seeds; more or less gradual transition to
556–568	calcareous gyttja with plant remains and molluscs; remains of Scorpidium scorpioides; Menyanthes seeds; Chara oosporangia; gradual transition to
569–602	lake marl with few plant remains and some molluscs; remains of Scorpidium scorpioides; Najas marina fruit; fruitstones of Potamogeton sp. and Carex sp. nuts

603–607	sand and lake marl; molluscs; roots of Cyperaceae; Carex nut; few remains of Scorpidium scorpioides; some Chara oosporangia
608–617	sand

The core was treated in the same way as the core from the Heiligenstädter Moos. At the bottom, a spectrum was made of each cm of sediment; from 474 to 556 cm each fifth cm was counted, and beyond that each tenth cm. The pollen appeared to be very well preserved.

The analysis clearly shows that, as Schmid assumed, the formation of the organic deposits already started in the Late Pleistocene. the base of the compact peat (550–555 cm) was dated at 10440 ± 95 B.P. (GrN–7141). The fact that Late Pleistocene, as well as Early Holocene and also Late Holocene vegetation periods are represented in the deposit, raises problems in the choice of a pollensum. The criteria for the choice should be different at the bottom and at the top of the deposits. We think that a pollensum as used for the Heiligenstädter Moos cannot be applied directly to Late Pleistocene deposits (see p. 155). This gave us reason to show the deposits of the Donaumoos not in a single pollen diagram, but rather in two diagrams with different calculating methods. We publish only one diagram here, namely the part within which the Atlantic falls. The older part lies outside the scope of our present investigation and will be published elsewhere.

We chose an upland pollensum for the younger part of the deposit. The criteria for the composition of this sum are the same as in the case of the Heiligenstädter Moos diagram (see p. 155). The choice of the pollensum is not quite correct as far as zone D IV and the beginning of zone D V are concerned, which will be defined below, because it is almost certain that Betula and Pinus of spectra 96 through 131 were part of the local vegetation: a carr. Both zones, however, have been included in the diagram to give a sharp lower limit to the Atlantic: zones D VI and D VII.

As usual, the diagram has been divided into pollen assemblage zones, for which purpose we used the zonation by Firbas. As we did for the Heiligenstädter Moos, we added a letter to the Roman numerals to indicate that the zones are not necessarily simultaneous with the same zones elsewhere. The zonation is as follows:

D IV	Pinus dominates, thermophile trees are absent.
Boundary D IV–D V:	occurrence of the first thermophile trees: Corylus, Ulmus and Picea. Quercus and Fraxinus follow slightly later.
D V	this zone is characterized by the increase of thermophile trees. Tilia appears. On the basis of the curves of Corylus, Quercus and Ulmus, this zone can be divided into three subzones.
D Va	a subzone in which these three trees increase rapidly; they reach a first maximum, to which belongs a C14 date of 9250 ± 100 B.P. (GrN–7142).
D Vb	during this subzone the percentages, in which Corylus, Quercus and Ulmus occur, decrease again, to increase permanently in DVc.
D Vc	(This subzonation is not according to Firbas)
Boundary D V–D VI:	most pollen curves increase or decrease no further.
D VI	a zone without important changes.
Boundary D VI–D VII:	the curve of Fagus becomes continuous, first occurrence of Abies.

D VII	very much like D VI, only Betula, Corylus, Quercus, Ulmus and Tilia decrease gradually and Pinus increases. Fagus is present in very low percentages. A C14 date of 5840 ± 80 B.P. (GrN–7143) falls within this zone.
Boundary D VII–D VIII/IX:	rapid increase of the Fagus curve.
D VIII/IX	zone VIII of Firbas cannot be distinguished separately because of the very fast increase of Fagus. Zone IX is a period in which Fagus dominates and Quercus, Ulmus and Tilia decrease strongly. Corylus recovers. Further, Plantago lanceolata and Plantago major occur for the first time.
Boundary D IX–D X:	Fagus decreases and Pinus increases.
D X	is hardly represented. Pinus dominates.

The Donaumoos at the sampling site can be compared with a small fen, rather than with a vast sedimentation basin. We made our bore-hole in a lateral valley of the large, funnel-shaped basin in which the fen formed itself in the course of time. The plan and the profile show that the fen lies as a tongue between slopes. Therefore we wish to interpret our pollen diagram as a diagram of a small sedimentation basin, in which most upland pollen had a relatively local origin and came from the vegetation in an area with a radius of some hundreds of metres or at the most some kilometres around the fen (Tauber 1965, Berglund 1973). We expect that most pollen relates to the vegetation of the slopes around the fen. These consist mainly of sandy loams and loamy sands. The regional vegetation will not have been different from the local upland vegetation, because there are similar sediments everywhere in the surroundings (figure 22).

At the level where the diagram shown here begins, thermophile trees are still absent. We cannot well judge the vegetation of the upland in this period, since the fen carried the same trees as we would expect on the upland (see p. 164).

Most of the thermophile trees appear during zone D V. However, the expansion of the first thermophiles: Corylus, Quercus and Ulmus, does not take place gradually. The curves show a temporary decrease in subzone D Vb. This decrease, which took place just after 9250 ± 100 B.P., remains unexplained. We can point at no edaphic factor that might have caused a change in the course of the curves. The calculation of the curves is no longer influenced at this level by a wrongly chosen pollensum (see p. 164), since at the level of the decrease the plants that could have brought about such an effect, namely such trees as Pinus, had already disappeared from the strictly local vegetation. We think it improbable, to say the least, that there were trees in a Cladium fen. It seems premature to us to explain the decrease by a climate fluctuation. It is true that the Venediger oscillation occurred in this period (Patzelt 1972), but we feel that a phenomenon in the Donaumoos should not be correlated to one in the Eastern Alps. One should rather withold one's opinion until the phenomenon has become apparent in other diagrams from the same area.

Deciduous trees dominate zones D VI and D VII, but the pine has not disappeared from the landscape. We think that the pine held its own on the poorer soils and more specifically on the sands and the loamy sands. We may visualize an oak-pine forest here, possibly with hazel. The loams were covered, we suppose, with a richer deciduous vegetation which contained, besides oak, also lime, elm, ash, maple and hazel. In

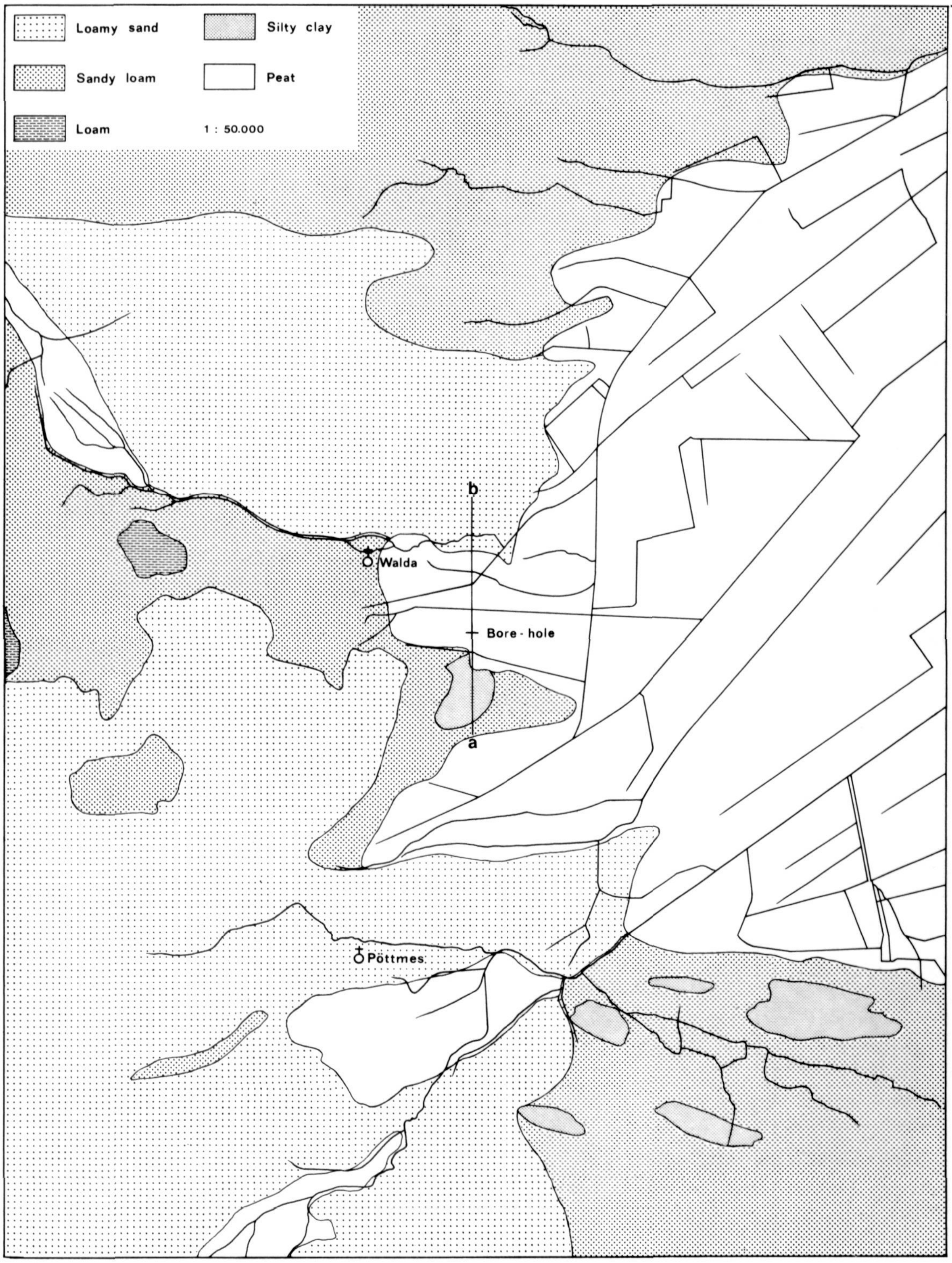

Fig. 22a. The S.W.-part of the Donaumoos and its surroundings. Scale 1:50000.

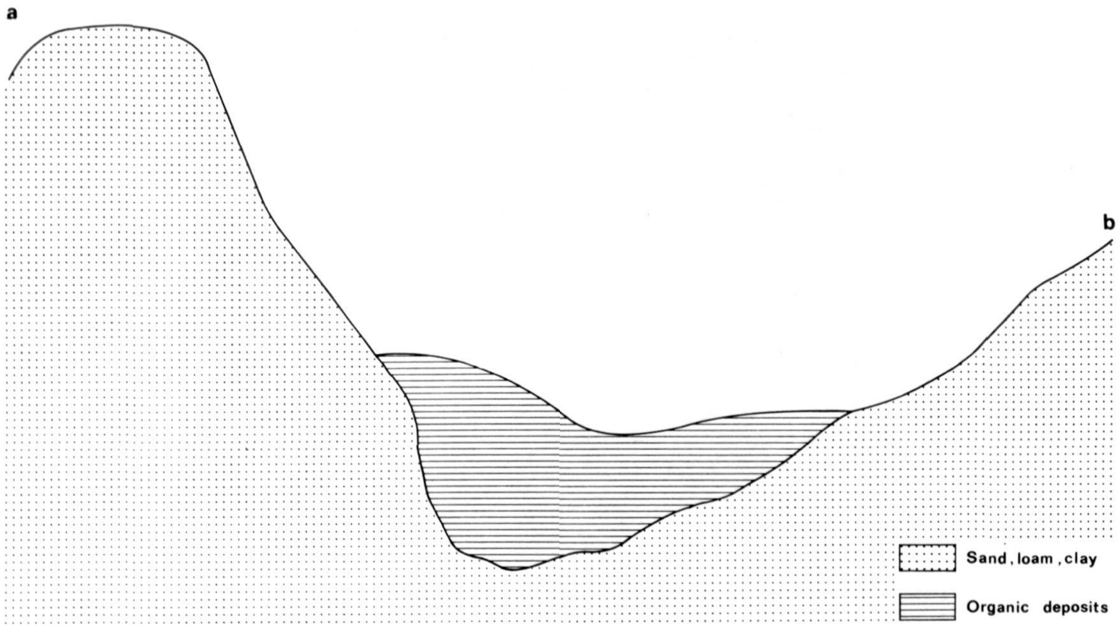

Fig. 22b. The S.W.-part of the Donaumoos, section, horizontal scale 1:12500, vertical scale 1:250.

contrast with our observations in the Heiligenstädter Moos, we find almost no shrub-vegetation. The typical forest plants are restricted to a single find of Pleurospermum and one of Melampyrum. The number of herb species which use to grow on clearings, is also smaller. Still, there is reason to assume that here too were some clearings. Artemisia occurs frequently and also Chenopodiaceae are found, be it sporadically. Spectrum 411 might represent a small clearing.

In the combined zone D VIII/IX the forests appear to change their composition. The beech becomes an important tree and seems to expand itself at the expense of the other deciduous trees, with the exception of Corylus. Ulmus disappears almost completely. As Pinus does not allow itself to be expelled, we assume that Fagus became a part of the forest communities on the loams. A beech forest, possibly a mixed beech forest, would then have developed on the loamy soils. This assumption is supported perhaps by the fact that in zone D X, that is the first zone in which human influence becomes apparent, it is precisely Fagus which declines strongly. Nowadays the loams are used as arable, and the sands for forestry. If we may assume that also in the period, in which zone D X falls, the loams were preferred for agriculture then this means that Fagus was rather common on the loams originally. Should this assumption appear to be incorrect, then of course this argument becomes void. Since we do not know the agricultural history of the area, we cannot prove our assumptions.

We think that the increase of Pinus should not be explained by the planting of pines, but by the disappearance of other pollen producers. Unfortunately zone X is virtually absent in the diagram, so that we miss the Middle Ages. We attribute this to the earlier mentioned loss of level by peat cutting and wind erosion.

The vegetation of the fen itself can be deducted not only from the lithology and the macroscopic remains, but also from the local pollen types. We have composed the local diagram in the same way as the diagram of the Heiligenstädter Moos, but the pattern is far less clear than in the latter fen.

The absence of indicators of open water is conspicuous: the sedimentation basin was never a lake, not even in the preceding period of which the diagram is not given here. During zone D IV and the beginning of zone D V, peat, now represented by a hard, compact, dark brown layer was formed in the basin. Remains of Salix and Betula wood were found in this layer. Closer to the edge of the basin we also found Pinus wood at this level; the latter finds were made during the borings for the cross section. In addition to wood remains, we found remains of the moss Scorpidium scorpioides and a few Carex-nuts in the peat.* We suppose that the deposit in question developed in a carr. Besides these macroscopic remains, the peat layer is characterized by the presence of pollen of Cruciferae, Lysimachia vulgaris type (to which belongs L. thyrsiflora, among others) and Gramineae. In the diagram, the Rubiaceae have been added to this group, because this pollen type, like the Cruciferae and the Lysimachia vulgaris type, is strongly correlated with Salix in the levels underneath. The peat layer passes rather suddenly, but not entirely without transition, into a deposit that must have developed under much wetter conditions. It is possible that the stratigraphy shows a hiatus here, but that cannot be seen clearly in the pollen curves. The peat is followed by deposits of calcareous gyttja, which alternate with spots of Cladium-peat. Until 366 cm beneath the surface, the Cladium-peat is mixed with remains of Scorpidium scorpioides. Higher up, almost no Scorpidium is found; Chara oosporangia are present instead. In the part of the deposit with Cladium-peat we found many Cladium pollen grains among the Cyperaceae pollen. This wet vegetation is undoubtedly also the origin of the sporadically found pollen of marsh plants: Potamogeton sp., Equisetum sp., Sparganium sp., Typha latifolia and Menyanthes trifoliata. All these plants could have belonged to the Cladietum marisci (Allorge 1922) Zobrist 1935 (sub nom. Mariscetum serrati). The Rubiaceae pollen (Galium palustre) and a part of the Gramineae and Monoletae undoubtedly were also part of the local plant community in which, by the way, we also wish to include Utricularia intermedia, although the single pollen grain of this plant was really found higher in the sediment. A subfossil Cladietum marisci as this one is described by Rybniček as Cladium mariscus subfos. comm. (Rybniček 1973). "It is characterized by the predominance of Cladium, while most of the other species are represented sporadically" (Rybniček 1973 p. 239). This agrees completely with our finds. From the structure of the sediment we gain the impression, in as far as such is possible from a small core, that the Cladium vegetation formed hummocks, between which there were open pools. The fact is that the Chara remains are always clearly separated from the surrounding off-white to light brown, strongly calcareous gyttjas. The Chara, which was found in large quantities in the upper half of the Cladium peat-calcareous gyttja deposit, could have grown in these pools. It is conspicuous that the oosporangia of Chara are absent in the lower half, but this could be coincidence.

At circa 185 cm beneath the surface, the Cladium peat – gyttja complex passes gradually into a Carex fen. At circa 125 cm, the percentage of Parnassia pollen increases spectacularly. We think that the plant community Tofieldietalia Preising apud Oberd. 1949 established itself on the fen. This reconstruction corresponds completely with the vegetation which the Donaumoos would have nowadays if human influence were absent (Seibert 1968).

Besides the pollen which we may attribute to the local sere of vegetations, there are pollen types which come from plants growing on wet places, which cannot or hardly be placed in the strictly local flora. We

* The moss remains from the Donaumoos profile were identified by Dr. A. Touw, the wood remains by Dr. P. Baas, both of the Rijksherbarium of Leiden.

feel that they represent the marginal vegetation of the fen. When gathering the data for the cross section, we found many fragments of alder wood along the edge of the fen, at the foot of the slope. These remains were not restricted to the upper levels, but extended down to 275 cm. They are probably the remains of a narrow alder belt which stood along the marsh on the boundary between fen and drier land. We think that this vegetation is the origin of the pollen of the alder and the other plants of wet habitat.

As observed above, we arrived at the conclusion that the Donaumoos, at least at the sampling site, has never been open water. The growth of the thick peat deposit could take place probably because of the continuous trickle of water. Near the sampling site a small stream flows into the fen. As we found no mineral material mixed in the peat, however, we think that this stream had hardly any influence on the peat formation. Therefore we think of seepage.

Our finds are supported by the examination of the molluscs.

To obtain more material for the examination of molluscs, two additional borings were carried out with an Edelman corer. However, the samples are still of small size for a malacological analysis. Still, a picture of the mollusc fauna could be obtained. The molluscs were described by W.J. Kuijper. We quote the following from his report: "The good condition of the material (outer skin present, Pisidiums in doublets) proves that the animals lived on the spot and that no transportation from other environments took place. The following species were found in the deposits from 5 to 0 metres deep:

freshwater: Valvata cristata Müller, Valvata piscinalis (Müller), Hydrobiidae, Bithynia tentaculata (L.), Galba truncatula (Müller), Galba palustris (Müller), Radix peregra (Müller), cf Lymnaea stagnalis (L.), Planorbis planorbis (L.), Planorbis carinatus Müller, Anisus leucostomus (Millet), Anisus vorticulus (Troschel), Bathyomphalus contortus (L.), Gyraulus cf laevis (Alder), Armiger crista (L.), Hippeutis complanatus (L.), Pisidium milium Held, Pisidium nitidum Jenyns, Pisidium hibernicum Westerlund.*

land: Carychium minimum Müller, Cochlicopa lubrica (Müller), Vertigo angustior Jeffreys, Vertigo antivertigo (Draparnaud), Vertigo moulinsiana (Dupuy), Vertigo pygmaea (Draparnaud), Vallonia pulchella (Müller), Vallonia costata (Müller), Succinea elegans Risso, Punctum pygmaeum (Draparnaud), Vitrinidae, Nesovitrea hammonis (Ström), Limacidae, Euconulus fulvus (Müller), Helicigona arbustorum (L.).

The species of the Hydrobiidae could not yet be identified by means of the one fragment. Perhaps it is a Paladilhia (Belgrandia?) or Bythinella species.

Molluscs are absent in the peat layer deeper than 5 m and in the uppermost metre of the Carex-peat deposit.

The molluscs which were found in the top of the peat layer, that is from 5 to 4.85 m beneath the surface, indicate that the biotope at this place was wet with ground-water practically at surface level or slightly thereunder. Here lived the land snails Vertigo pygmaea, Vallonia pulchella, Succinea elegans and the water species Pisidium obtusale and Galba cf truncatula. The latter two species can live very well without water, in a wet environment. Above this level (4.85–4.77 m) the water molluscs become predominant. At the transition (4.85 m) a Vertigo antivertigo was found: a land snail of a very wet terrain with much vegetation. From the then following deposits (circa 4.60–1.50 m) are the remains of a fauna which must have lived in shallow, clear, still water with a rich vegetation. Moreover, this environment must have

* The Pisidiidae were identified by J.G.J. Kuiper of Paris.

included places which rose slightly above the water (e.g. sedge- or grass-hummocks). On these places lived the land snails, which are found frequently in the deposits. The water level was probably fairly constant throughout the year. Periods of drought did not occur: this is demonstrated by species which cannot tolerate desiccation (Anisus vorticulus, Planorbis carinatus). One obtains a picture of a constant marshy area without trees.

This changes from 1.50 m beneath the surface onwards. The numbers and species of land snails increase markedly, especially beyond 1.35 m, which proves that the area projecting above the water grows in size. After 1.20 m the aquatic species disappear and the fauna is a land fauna of wet terrain. The absence of molluscs in the uppermost metre was probably caused by an acidification of the biotope. Such an explanation may also apply to the absence of molluscs in the peat layer of circa 5.50–5.00 m.

The species of the Hydrobiidae, found at a depth of 4.25 m, could be an indicator of seepage. Most representatives of this family live underground in springs, in streams connected with springs and in places where seepage occurs, that is to say in places with few changes in temperature, water composition and the like." (Kuijper 1975).

If, finally, we compare the diagrams of the Donaumoos and the Heiligenstädter Moos with each other, there appear to be not only many similarities, but also differences. In the upland pollen curves, the difference resides mainly in the curve of Pinus and in the number of species found where the shrubs and herbs are concerned. In zones VI and VII Pinus plays a far more important part around the sampling site in the Donaumoos than in the Heiligenstädter Moos, where this tree was perhaps initially absent. On the other hand, the Donaumoos diagram lacks the rich shrub- and herb-flora of the Heiligenstädter Moos. We attribute these differences to differences in the substrate. Human influence is much more apparent in the diagram of the Heiligenstädter Moos than in the Donaumoos diagram. The reason is probably a difference in the intensity of the prehistoric c.q. protohistoric occupation in the immediate surroundings. The diagrams of the local pollen types indicate that the two basins were filled up in completely different ways. The Heiligenstädter Moos was a lake which was filled up "normally"; the Donaumoos remained a swamp, probably as the result of never-ending seepage.