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2. History of Vegetation and Biostratigraphy

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With 1 figure and 1 table

1. Pliocene

For the Quaternary biostratigraphy the climate changes during the Pliocene in general and the development of the climate during the Upper Pliocene in particular are of special interest.

New paleobotanical data concerning the Pliocene stratigraphy have come from studies in NW-Germany, especially on the isle of Sylt and at Oldenswort/Schleswig-Holstein (AVERDIECK 1971, HINSCH & MENKE 1972, MENKE in prep.).

Close parallels to the situation in the Netherlands (ZAGWIJN 1960) can be found in the Pliocene vegetation and facies development of Oldenswort - however, the Susterian (Oldenswort 9, ca. 420—600 m) is underlain by older strata with definitely Pliocene pollen assemblages, namely a) the "Garding-Stufe" (type locality Oldenswort 9, ca. 600—800 m, MENKE in prep.) which is probably the equivalent of the "Morsum-Stufe" defined on faunal evidence (GRIPP 1964), and b) the "Bredstedt-Stufe" (type locality Oldenswort 9, ca. 800—1000 m) which is contemporaneous, at least in part, with the faunally defined "Sylt-Stufe" and perhaps also the "Gram-Stufe" (GRIPP 1964). The change from the Miocene type flora to the Pliocene type one probably occurred during the Gramian, which is defined by marine faunal evidence. This floral change was probably caused by a considerable climatic cooling during the Gramian, which was followed by a re-warming during the Gardingian.

The Gardingian flora indicates a warm-humid climate (e.g. *Itea, cf. Clethra, cf. Palmae).* During the Susterian the flora obviously became poorer in species because of another climatic cooling. The Brunssumian flora again contains a greater number of thermophilous taxa, however, unlike the Gardingian flora, there is a predominance of conifers *(Taxodiaceae, Cupressaceae, Pinaceae).* In the Brunssumian sediments of Oldenswort pollen of *Calluna* and *Bruckenthalia*-type *("Blaeria*-type" of MENKE 1970) occurs for the first time. These are frequent in Quaternary sediments. In addition an increase of the Ericales, *Sphagnum* and *Lycopodium inundatum* values can be shown for the Brunssumian. This trend continues during the Reuverian, which generally is characterized by a definite decrease of thermophilous taxa in the pollen flora. The major climatic changes of the Pliocene apparently took place over millions of years (table 1).

Whether besides them minor climatic fluctuations existed during the Pliocene — as are characteristic for the Quaternary — cannot yet be safely deduced from the Oldenswort data. Actually the general climatic trend of the Pliocene can only be ascertained from longer profiles.

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Table 1

Pliocene and Quaternary stratigraphy of NW Europe. For "Känozän" (Cenocene) compare Fig. 1. Dates according to Zagwijn, v. Montfrans and Zandstra (1971), Hinsch & Menke (1972) and Menke (in prep.), partly changed.

			Holocene	Holozän	
10.000 B.P.					
about 70.000 y.	Weichsel glacial period		Younger	Jung-	Quaternary Quartär
	Eemian interglacial				
about 85.000 y.?					
	Saale-glacial periods: ? Warthe-glacial period		Middle Pleistocene	Mittel-Pleistozän	
	Saale-glacial periods: ? Treene thermomer				
	Saale-glacial periods: ? Lippe glacial period				
	Wacken-(Dömnitz-)interglacial				
	Mehlbeck-(Fuhne-)kryomer				
	Holstein interglacial				
	Elster glacial period				
	Harreskov interglacial ?		Older	Alt-	
? 400.000 y.	"Cold period B" ?				
	Rhume interglacial				
? 700.000 y.	"Cold period A"				
	Osterholz interglacial				
	Elbe kryomer				
	numerous climate oscillations (fig. 1)		Cenocene	Känozän	
	"Pretiglian" (Duration:				
? 2—2,5 m y.	about 0,3—0,5 m. y. ?)				
? about 3 m y.	Reuverian		Pliocene	Pliozän	Tertiary Tertiär
? about 5 m y.	Brunssumian				
	Susterian				
about 7 m y.	Gardingian	Morsum			
about 9 m y.	Bredstedtian	Sylt			
about 11 m y.		Gram			
	Fischbachian	Langenfeld	Miocene	Miozän	

2. The Tertiary - Quaternary boundary and the "Cenocene"

The Tertiary-Quaternary boundary (=Reuverian/Pretiglian, ZAGWIJN 1960) is present in the profiles of Oldenswort (Oldenswort 9, ca. 155 m; Old. B I, ca. 140 m) and Lieth (Schleswig- Holstein, Lieth B II, ca. 89 m, MENKE in prep.). At Oldenswort the oldest Quaternary sediments, some 40 metres representing the Pretiglian (Old. 9, ca. 110—155 m; Old. B I, ca. 100—140 m) are underlain, apparently conformably, by a complete series of deposits extending through the Pliocene into the Miocene. At Lieth, however, the Pretiglian horizon (Lieth B II, ca. 59—89 m) is overlain by a very complex series of sediments dating from the oldest part of the Quaternary (MENKE 1969b, 1970, 1972, in prep.), which also shows no major unconformities. The Pretiglian pollen spectra of Lieth and Oldenswort (Barmstedt-Stufe of MENKE 1972, see fig. 1) are dominated by nonarboreal pollen (NAP) types, mainly by pollen of *Ericales, Poaceae (Gramineae), Cyperaceae* and some herbs. Fern and *Sphagnum* spores also occur in abundance. Pollen of definitely thermophilous taxa, especially of those characteristic of the Tertiary, is practically absent. Arboreal pollen (AP) comprises mainly the taxa *Pinus* and *Betula,* but pollen of the *Alnus glutinosa*-Type and of *Myricaceae* is also of some importance. Values of *Quercus, Ulmus, Salix, Larix, Picea* and *Osmunda* are low. *Alnus viridis*-type pollen, occasionally found in Pliocene sediments, is much more frequent in Pretiglian samples. In addition the first, but very rare spores of *Selaginella selaginoides* occur. *Artemisia* pollen is becoming more frequent, too, but its values remain much below those reached during Weichselian late glacial times for example.

A subarctic type of vegetation, as assumed for the Pretiglian by ZAGWIJN (1960), cannot safely be deduced from the pollen spectra of Oldenswort and Lieth, the high NAP values rather being derived from the flora of vast swampy and boggy areas existing at that time (MENKE in prep.) as nowadays in boreal regions. Thus the Pretiglian can be characterized definitely as belonging to the Quaternary on the base of the pollen data, but not as a glacial phase as defined by ZAGWIJN (1960) with a subarctic vegetation in northwestern Europe. The palynological Tertiary/Quaternary boundary is therefore best placed at that level in NW-Europe, where certain pre-Quaternary taxa vanish (MENKE 1970). In particular this is true of *Sequoia*-type, *Liquidambar, Nyssa* and *Sciadopitys.* This corresponds with observations of the type profile at Meinweg (ZAGWIJN 1960).

The thickness of the sediments of the Pretiglian and earlier stages considered, together with the general character of the sediments, suggest a long duration for the Pretiglian, (at least 0.3—0.5 million years, estimated!).

The gradual climatic cooling continued from the end of the Brunssumian through the Reuverian — perhaps with some fluctuations — to the beginning of the Quaternary. Thus the Reuverian-Pretiglian transition, like the earlier Bredstedtian and Susterian, represents the final major phase of climatic cooling at the end of the Tertiary, with the Reuverian belonging definitely to the Tertiary, the Pretiglian, however, to the Quaternary.

A distinct increase of the pollen values of thermophilous taxa at the end of the Pretiglian at Lieth ("Meinweg-Thermomer" of MENKE in prep.) indicates a climatic warming, followed by the first true cold stage of the Quaternary (Ekholt-Kaltzeit, fig. 1) with a probably almost arctic vegetation (MENKE in prep.; diagrams 1 and 2 of the paper of MENKE 1969 b show the end of the Ekholt-Kryomer only).

A comparable period does not seem to exist in pollen diagrams from the Netherlands (ZAGWIJN 1960, 1963). The Ekholt cold stage is the first of a series of major and minor climatic fluctuations (fig. 1), which have local names (MENKE 1970, 1972).

Alternating interglacial and more or less boreal conditions prevail; definitely subarctic conditions, however, are relatively rare (mainly Ekholt, Krückau, Lieth, Elmshorn cold stages). It is not yet clear how to correlate the Lieth sequence with the earliest

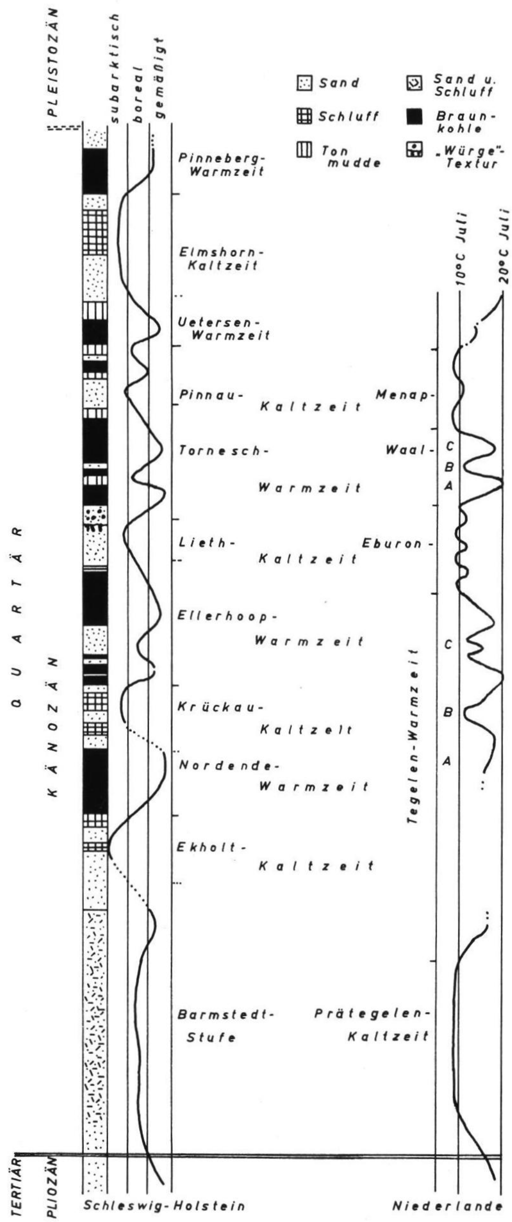

Fig. 1. Stratigraphy of the Oldest Quaternary ("Känozän" = Cenocene) in NW Europe. Dutch subdivision from ZAGWIJN (1960, 1963), North-German (Schleswig-Holstein) subdivision from MENKE (1972, and in prep.). Kaltzeit = kryomer, Warmzeit = thermomer. The middle part of the "Tornesch-Warmzeit" shows another thermomer, represented by the coal, covered by the central sand layer. The nearly almost erodet upper part of this coal contains a distinct thermophilous flora (MENKE, in prep.).

Quaternary of the Netherlands (Zagwijn 1960, 1963). One of the possibilities is shown on fig. 1. Here the Pinnau cold stage is correlated with the Menapian, what may be correct, provided that the division of the Waalian into 3 major temperate and 2 cool phases can be proven (v. d. Hammen, Wijmstra & Zagwijn 1971, fig. 1).

In any case, the Lieth series comprises more climatic fluctuations during the earliest Quaternary than the profiles from the Netherlands, notwithstanding that the Lieth profile is probably not complete in its uppermost section because of glacial erosion.

According to this the earliest Quaternary is much more complex than has been presumed until now. As proposed by Menke (1972), some general characteristics can be used to separate this period from the Pleistocene, as an equivalent unit, the "Cenocene" (Känozän), within the Quaternary era:

1. Floristic and climatic conditions during the Cenocene cold periods were different from those during the great Pleistocene glacial periods. Any attempt to distinguish "glacial" and „interglacial" periods in the Cenocene turns out to be a very subjective undertaking. Therefore it would probably be better to use the terms „kryomer" and "thermomer" (Lüttig 1965). By doing this the definition of interglacial and glacial periods of the Pleistocene is made easier. Because of the great number of Cenocene zones similar to one another, it will in any cases hardly be possible to correlate convincingly short profiles which have no clear connection with established earliest Quaternary horizons.

2. The typical middle-European forest succession of the Pleistocene and Holocene is not well developed during Cenocene time, and there are some particular Tertiary relics recorded for this period having typical positions in the middle European Cenocene forest succession.

3. A number of Tertiary relics connect the Cenocene with the Pliocene to which certain profiles were once assigned which are now considered to be of Cenocene age (e.g. Tegelen and Lieth). Among these relics are *Eucommia, Magnolia, Actinidia, Pterocarya, Carya, Juglans,* cf *Castanea,* cf *Ostrya, Decodon, Meliosma, Parthenocissus, Ampelopsis, Proserpinaca, Tsuga, Neogenisporis* (cf. *Gleicheniaceae),* some types of *Retitriletes* (cf *Lycopodium),* and cf *Ophioglossaceae.* There are taxa which were found in Cenocene levels in NW-Germany only, for example *Selaginella sibirica,* and there are taxa exclusively known from the Netherlands as *Liriodendron* and *Menispermum.* Some pollen types could not yet be determined.

Some of these relics spread during cenocenic times, probably because of changed conditions of competition, especially *Alnus* cf *viridis,* cf *Ostrya* and *Eucommia.* Of the aforementioned relics only *Eucommia* (Osterholz interglacial period) and *Pterocarya* (at the end of the Holstein interglacial period) occured for certain also during the Pleistocene s. str., at least in northwestern Europe. The faunal assemblages of sections proved to be of Cenocene age by palynological investigations are considered Villafranchian (e.g. Tegelen, Rippersroda, Leffe) in age.

4. Radiometric and paleomagnetic data (Zagwijn, van Montfrans & Zandstra 1971) suggest that the Cenocene and the Pleistocene lasted for about the same time, although these measurements have not yet really reached the degree of reliability one would like.

Lithologically the sediments of Oldenswort and Lieth belong to the "Pliocene" "Kaolinsandformation". (For this reason the Quaternary age of the long-known profile of Lieth was not realised earlier). The deeply weathered "kaolin sands" were redeposited during the cenocenic kryomers, however, but apparently without resulting in any recognizable improvement in the nutrient status for the vegetation.

Accordingly the cenocenic vegetation of Schleswig-Holstein is of a distinctly oligo- or dystrophic character, a situation, which was only changed during the Pleistocene glacial periods. Numerous taxa indicate a strong oceanic influence on the cenocenic climate (see MAI, MAJEWSKI & UNGER 1963, **9**[1])). In distinguishing a Cenocene and a Pleistocene period the Cenocene/Pleistocene boundary needs discussion.

At the Tertiary/Quaternary boundary the Cenocene/Pleistocene boundary should — in NW Europe — be placed at a level where relics are vanishing, i.e. where the basic pattern of the Pleistocene forest succession starts to develop. This would be equivalent to the beginning of a glacial period. In any case, it must be situated between the Pinneberg and the Osterholz interglacial periods (fig. 1). Whether this glacial period is identical with the Menapian appears to be in doubt, as long as the correlation proposed in fig. 1 is used.

3. Pleistocene

Compared with the Cenocene the Pleistocene is characterized in NW-Germany by the lack of almost all Tertiary relics and by the middle-European succession of forest development, though the latter shows a degree of variation from one interglacial period to another. It is mainly these differences in vegetational development, which seem to follow a particular trend during Pleistocene time, which form the basis of the Pleistocene into an Older, Middle and Younger Pleistocene.

An older phase, which is more or less dominated by Quercetum mixtum (QM) pollen assemblages with much *Ulmus* as well as *Quercus*, but less *Tilia*, and a younger phase characterized by a mixed forest of *Carpinus* and conifers, are common to the Older Pleistocene interglacial periods. The Middle Pleistocene interglacial periods are distinguished by a continuous conifer-dominance, whereas for the Younger Pleistocene (and the Holocene) again an older QM-dominated phase is characteristic with much *Corylus* at the base and with more or less much *Tilia* in its younger part.

Picea and *Abies* reached their maximum expansion during the younger Older Pleistocene and the older Middle Pleistocene. During the Younger Pleistocene they are more restricted to mountainous regions and appear later in NW-Europe. *Taxus* was an important constituent of the forests during the Middle and Younger Pleistocene, *Tilia* during the Younger Pleistocene only.

Lower Pleistocene

Definitely of Older Pleistocene age in NW-Germany are the interglacial deposits of Osterholz and Bilshausen. The vegetation development of the completely recorded Osterholz interglacial period (GRÜGER 1967) is strongly reminiscent of the Cenocene of Lieth especially in the lack or sparse occurrence of *Abies, Taxus, Tilia,* in the low *Corylus* values, and the occurence of *Eucommia.* This apparently is the oldest interglacial period of the Pleistocene. At the Bilshausen site (H. MÜLLER 1965; "Rhume" interglacial period, LÜTTIG & MAARLEVELD 1962, **11**) the vegetation development shows from its very beginning a stronger participation of *Picea* and — in an early phase — also of *Abies* with *Abies* spreading earlier than *Carpinus. Tilia* and *Corylus* are present, but do not reach high values. There is no indication of *Taxus* and *Eucommia* (GRÜGER 1967, H. MÜLLER 1965, and pers. comm.). The Rhume interglacial period is being compared with the deposits of Westerhoven (ZAGWIJN & ZONNEVELD 1956, **7**, **11**). Judging from varve counts MÜLLER concluded that this interglacial lasted for about 30,000 years.

Whether an how the deposits of Voigtstedt (GDR, ERD 1965, **7**, 1970) can be correlated with the two NW-German deposits, cannot be decided, mainly because of the great sampling intervals at Voigtstedt.

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1) **9** = cited in **9** of the bibliography.

ZAGWIJN, v. MONTFRANS & ZANDSTRA (1971) report three Older Pleistocene interglacial periods ("Cromerian" interglacial I—III), the oldest of which they believe to be equivalent to the Osterholz because of the occurrence of *Eucommia.* The second interglacial is being correlated with Westerhoven, whereas the youngest is not yet firmly established. The Harreskov interglacial (ANDERSEN 1965, **7**) is the only known interglacial of Older Pleistocene of Denmark. Unlike NW-German sites it is characterized by high *Taxus* values and by relatively much *Corylus.* That *Carpinus* and *Abies* are missing might be the effect of its more northern position. Because of these differences the Harreskov interglacial cannot definitely be correlated with any of the NW-German ones. It could be possible, that it is younger than the Rhume interglacial.

A comparison of the deposits on the continent with the English Cromerian is considered to be premature according to many specialists (SCHNEEKLOTH 1969).

Of the Older Pleistocene glacial periods, especially of their limits of glaciation, less is known, of course, than of the interglacial periods.

Whether the "Elster" complex contains indications of more than one glaciations must still be studied.

Middle Pleistocene

Despite the above mentioned reservations the boundary between Older and Middle Pleistocene can be drawn at the beginning of the Elster glacial period, the deposits of which have been found at many places in the north European, formerly glaciated region. Of special importance is the "Lauenburger Ton" (dutch "Potklei" = Peelo Formation), which comprises Elster time clayey ice lake sediments of wide distribution.

At many places in Schleswig-Holstein they lie directly below the marine clay of the Holstein interglacial.

More recently palynological investigations of NW-European Holsteinian deposits have been carried out on sediments from Hummelsbüttel (Hamburg, limnic-marine, HALLIK 1960), Wiechel (Niedersachsen, limnic, HALLIK 1960), Klieken (GDR, limnic, MAJEWSKI 1961, **5**), Tornskov (Jutland, marine, ANDERSEN 1963, **5**, **10**), Vejlby (Jutland, limnic, ANDERSEN 1965, **5**, **10**), Tönisberg, (Niederrhein, limnic, KEMPF 1966, **5**), Lüneburg (Niedersachsen, brackish-marine, BENDA & MICHAEL, 1966), Wacken (Schleswig-Holstein, marine, MENKE 1968 b, **10**), Pritzwalk and Granzin (GDR, limnic-brackish-marine, ERD 1970) and Fahrenhorst (Schleswig-Holstein, marine-limnic, MENKE unpubl.). Characteristic of the NW-European Holsteinian vegetation development are a uniform *Pinus-Alnus*-dominance during most of the interglacial period, the relative unimportance of the QM (mainly *Quercus,* but only little *Tilia),* relatively little *Corylus,* a considerable, early expansion of *Taxus* (as during the Old Pleistocene Harreskov interglacial), an almost contemporaneous spreading of *Carpinus* and *Abies* (with *Carpinus* expanding earlier than *Abies,* and thus different from the situation at Bilshausen), high *Abies* values in the younger parts of the interglacial, and furthermore the occurrence of some distinctly thermophilous and exotic taxa such as *Azolla, Salvinia, Stratiotes intermedius, Pterocarya, Celtis, Euryale, Aldrovanda, Crataegus acuticarpa, Buxus, Trapa, Vitis,* some of which were able to expand far into Jutland (ANDERSEN, 1965, **5**, **10**, ERD 1966, cp 1970, **10**, KEMPF 1966, **5**). By this and by the conifer dominance, the Holsteinian interglacial is to a certain degree similar to the Pliocene. At Wacken (MENKE 1968 b, **10**, 1970, DÜCKER 1969, **10**) and Prignitz (ERD 1970) a younger Middle Pleistocene interglacial was proven, which is separated from the Holsteinian by a period with subarctic conditions (Mehlbeck or Fuhne kryomer). The "Saalian" interstadials of Vejlby (ANDERSEN 1965, **5**, **10**) belong perhaps to this Mehlbeck kryomer. The deposits of the Holstein interglacial, of the Mehlbeck or Fuhne kryomer and the Wacken or Dömnitz interglacial period were found at Wacken and at Prignitz to be present in a more or less coherent series, which was ice-pushed at Wacken.

The vegetation of the Wacken or Dömnitz interglacial was very similar to that of the Holsteinian, except for *Abies,* which is missing. *Picea* spread relatively late, at about the same time as *Carpinus,* but remained unimportant. *Carpinus* expanded earlier than in Holsteinian so that the QM phase is less developed. *Azolla filiculoides* was present during both interglacials.

The Saalian glacial period cannot yet be subdivided biostratigraphically because of the lack of suitable, pollen containing deposits. Picard (1959, **5**, **6**) and Stremme (1960, **6**, 1964, **5**) studying fossil soils in Schleswig-Holstein postulated the existence of a "Treene" interglacial, which they consider subdivides the Saalian glacial complex into a "Drenthe" (or "Lippe") and a "Warthe" glacial period. However, palynological data are still too scarce to support or refute this view. The unimportant "Wandsbek interstadial" of the Hamburg area with its allochthonous sediments, which contain a pre-Quaternary pollen flora, belongs to this period according to Grube (1967).

The diatomite sediments ("Kieselgur") of the "Ohe" interglacial (v. d. Brelie 1955, **5**) were placed in the Holsteinian by Hallik (1960) using palynological criteria.

The "Gerdau interstadial" (Lüttig 1958, **6**) is probably of Eemian age (Benda, Lüttig & Schneekloth 1966, **7**), Erd (1970) published the pollen diagram of a "Rügen" interglacial, which for lithostratigraphical reasons was placed in the Saalian complex by Cepek (Erd 1970). The pollen diagram is very similar to those of the Wacken or Dömnitz interglacial. A complete profile of the "Saalian" late-glacial has only been made known by Menke & Ross (1967) from a site in Schleswig-Holstein. Contrary to the "Weichselian" late-glacial it shows a continuous transition — without any recognizable climatic fluctuations — from an open grassland vegetation via a pioneer phase rich in *Hippophaë* and *Salix,* to a spread of *Juniperus,* followed by the *Betula* phase of the Eemian.

Younger Pleistocene

The boundary between the Middle and the Younger Pleistocene is drawn at the very beginning of either the Saalian glacial or — more common — of the Eemian interglacial. During recent years so many NW-European sites of Eemian age have been studied palynologically that it is impossible to mention all of them at this place (Hallik 1957, **2**, Selle 1957, **2**, 1962 a, **5**, Müller 1958, **5**, Behre 1962, Menke 1967, **10**, 1970, Averdieck 1967, a, b and others).

The aim of these studies was to gain more detailed informations on the Eemian forest history, the fundamentals of which had already been worked out by Jessen and Milthers (1928, **2**). Thus the vegetation development during Eemian time is now fairly well known. It is recorded from many places in NW-Germany. Of especial interest are the finds of macrofossils of *Tilia tomentosa* (together with *T. cordata* and *T. platyphyllos)* in the Hils Mountains (Rabien 1953, **2**) and the pollenanalytical evidence of *Taxus* (Behre 1962, 1970 a, Menke 1967, **10**, 1970, Menke & Ross 1967, **10**, Averdieck 1967 a, b), the pollen curve of which is mostly parallel to that of *Tilia,* sometimes reaching values as high as 40 % of the AP (Helgoland, Behre 1970 a).

In contrast to the Holocene the Eemian forest development was rather uniform everywhere as shown in many pollen diagrams. That might be due to similarities in quality of the soils, which contained fresh material at the beginning of the Eemian throughout all the glaciated area. Also, unlike the Holocene, thermophilous genera such as *Ulmus, Quercus, Cladium, Viscum* and others had already immigrated before the end of the *Pinus* expansion, whereas *Corylus* spread distinctly later, when the QM was already developing, although it did then reach very high pollen values.

The Eemian pollen assemblage zones are — contrary to those of the Holsteinian for example — clearly separated from one another. The vegetational changes were caused — except for climatic changes and the sequence of immigration — probably in the first place by competition, especially competition for light (MENKE 1967, **10**) and not — at least not during the older phases — by the leaching of the soils. At many sites with freshwater lake marls in the region of the Lüneburger Heide (SELLE 1962 a, **5**) and in Schleswig-Holstein (MENKE 1970 and unpubl.) the sedimentation of calcareous material continued throughout the *Carpinus*-phase, and also increasingly eutrophic conditions persisted until the end of the interglacial in the lakes forming the Kieselgur deposits of the Luhetal, as is known from diatom studies (BEHRE 1962, BENDA 1963, **5**).

In smaller lakes and bogs especially on outwash plains, however, a development of oligo- and dystrophic conditions can be recognized, starting with the *Carpinus*-phase (ANDERSEN 1966, 1969, **10**, DÜCKER & MENKE 1970, MENKE 1970) or even earlier.

Several attempts have been made to subdivide the Eemian on the base of vegetational changes (JESSEN & MILTHERS 1928, **2**, SELLE (3 different proposals) 1941, 1951, 1953/57, **2**, HALLIK 1953, **2**, BEHRE 1962).

The differences in the zonation schemes result mainly from the exclusion or inclusion of the "Saalian"-late-glacial and from the importance attached to the *Picea* curve. A separate "Fichten-Zeit" (*Picea* zone) was recognised by earlier workers. It could be shown, however, that the *Picea* expansion was not synchronous, but strongly depended on edaphic factors (as forming of *Picea* swamp forest). Therefore a separation of a *Picea* zone appears to be unreasonable and was omitted in the last mentioned subdivision.

The development of the Eemian climate can be approximately deduced from the vegetational development. Apparently an initial warming occurred very early, but thermophilous deciduous trees expanded later.

Then, the climate was uniform, summer-warm and winter-mild, for a long time, but with higher temperatures than during the Holocene, as finds of *Tilia tomentosa* (see above), *Buxus* (Denmark, ANDERSEN 1966), *Viscum, Cladium* and several *Najas* species (macrofossils of the last three taxa occurring frequently and in great quantities) indicate. *Viscum,* an indicator of warm summers had its maximum distribution during the QM-phase, but also occurred during the *Carpinus*-phase. *Ilex,* indicating mild winters, was well represented in both phases and is even found in sediments of the end of the Eemian. *Viscum* spread distinctly earlier than *Ilex.* The climatic change at the end of the interglacial period probably resulted first in decreasing summer temperatures, but the expansion of *Abies* during late Eemian times with its northwestern limit of distribution running through Schleswig-Holstein could be explained by winters which were still mild.

Studies on the Islands of Sylt (AVERDIECK 1967) and Helgoland (BEHRE 1970 a), regions close to the North Sea, indicate the decrease of summer temperatures by very low values of *Tilia* and especially by the lack of *Viscum* on the island of Helgoland. On the other hand, high *Ilex* values at Helgoland indicate mild winters. In Denmark, too, *Tilia* is missing (ANDERSEN 1965, **10**, 1966).

The Eemian North Sea transgression corresponds well with the above climatic interpretation. Unlike the Holocene no peats are intercalated in the marine sediments of Eemian time, thus indicating uniform climatic conditions. The maximum sea level stand was reached at the end of the *Carpinus* phase or later (v. D. BRELIE 1954, **6**, GRIPP 1964), an observation that well coincides with the persistance of *Ilex.*

The transition from the Eemian interglacial to the Weichselian glacial period is shown in many pollen diagrams, represented by increasing values of herbaceous plants like *Artemisia* and dwarf-shrubs and with *Pinus* and *Betula* among the tree pollen. Usually the profiles end with sediments which are still organogenic.

During recent years some localities with Early Weichselian sediments have been discovered and studied (Hallik & Kubitzki 1962, **1**, Selle & Schneekloth 1965, **1**, Schneekloth 1966, Averdieck 1967 a, Schütrumpf 1967, **10**, Menke 1970, Behre 1973), revealing two great interstadials, from thick peat and gyttja layers. The older of them is equivalent to the Danish Brørup (Andersen 1961). Its vegetation is dominated by *Betula, Pinus* and *Picea (excelsa* and *omoricoides).* Recent studies at Keller (Schleswig-Holstein, Menke 1970) and Osterwanna (Niedersachsen, Behre 1973) have shown that temporarily *Larix* (in Osterwanna also with macrofossils) must have been of considerable importance. The quantity of the — partly certainly autochthonous — pollen of thermophilous woody species in almost all profiles is surprisingly small. Frenzel's (1967, p. 218) assumption that "die Vegetation die Klimagunst vielleicht nicht ausschöpfte" ("that the vegetation perhaps could not fully take advantage of the better climatic conditions") is probably not correct, for the interstadial lasted for a time long enough to allow the deciduous trees reimmigration to northern Germany from their — according to the pollen finds — not too far away refugia.

The repeated deforestation following the Brørup is best proven in Odderade (Niedersachsen, Averdieck 1967 a). Here and at Oerel (Niedersachsen, Selle & Schneekloth 1965, **1**, Schneekloth 1966) a second, similarly well developed interstadial has been found above the Brørup. It was called Odderade.

Its vegetation development resembles that of the Brørup. Somewhat higher NAP values during the *Betula* phase and a *Picea* curve, which is beginning later here than in Brørup diagrams, are the only (shaky, of course) features to distinguish the two interstadials.

At several localities during the Brørup interstadial-and as far as we know also during the Odderade interstadial-thick *Sphagnum* peat layers have been formed as was the case at the end of the Eemian. A characteristic pollen type, occurring especially at the beginning of the growth of the raised bogs, is that of *Bruckenthalia (Ericaceae;* Keller: *Blaeria*-Typ, Menke 1970; Osterwanna: numerous seeds, Behre 1973), a dwarf shrub which is known from recent vegetation of the Balkans. In earlier studies this pollen type, which has been found in great numbers in Cenocene (perhaps a different species) and Middle Pleistocene sediments (Menke 1970) and occasionally also in Eemian deposits (Menke unpubl.) has not been distinguished from *Frangula* and partly not even from *Cornus* pollen. Correlating the North German with the Dutch and the Danish biostratigraphy of the Early Weichselian it turns out that nowhere in NW-Germany that smaller thermomer preceding the two great interstadials could be found, which Andersen (1961) described as "Rodebaek" interstadial. It might be possible that the NW-German and the Danish Brørup is equivalent to the Dutch "Amersfoort" and that the Odderade corresponds with the Dutch "Brørup". The precision of radio-carbon datings unfortunately is not sufficient to solve this question, especially considering the great age of these deposits.

Only very few organogenic deposits of Weichselian pleniglacial times are known in NW-Germany. The algal gyttja from Kollau (Hallik 1955, **1**) might be of this age. Several times fossil soils have been described (Dücker 1967, **10** and others), the pollen frequency, however, is unsufficient in most cases and radiocarbon datings are not applicable. Schütrumpf (1967, **10**) described organogenic sediments from Geesthacht, having a radiocarbon age of 26,600 years. How problematic radiocarbon dates may be, however, can be demonstrated at Ostrohe ("Ostrohe interstadial", DÜCKER 1967, **10**), where a humus layer of a fossil podsol gave a radiocarbon date of 32,200 ± 600 (Gro 1551) years, but where the pollen flora (DÜCKER 1967, p. 48) does not differ from that of the Brørup or the Odderade interstadials. According to ZAGWIJN (pers. comm.), the older Groningen dates of the Early Weichselian have been proved to be not correct (too young).

Thus the existence of the "Ostrohe interstadial" seems to be doubtful, at least at its type locality. According to all available informations it seems to be unlikely that there existed forests in northern Germany in the time span between the Odderade interstadial and the Late-glacial of the Weichselian.

The first recognizable climatic warming of the Late-glacial has been detected at Glüsing and Meiendorf in Schleswig-Holstein. It was called "Meiendorf Interval" (MENKE, 1968, **10**). It is indicated by changes in the NAP composition and can be synchronized with the "Hamburg culture" of young paleolithic age at the type locality of this culture. According to C-14 dates (ca. 13,500—14,000 BP) it is most probably contemporaneous with the "Raunis interstadial" of NE-Europe (DREIMANIS 1970). The subsequent climatic detereoration ("Grömitz-interval") is followed by the Bølling interstadial, in the course of which trees *(Betula)* appeared in the area for the first time after the glaciation (DIETZ, GRAHLE & MÜLLER 1958, **3**, ALETSEE 1959, **3**, SELLE 1962 b, MENKE 1968,**10**). At this time *Pinus* grew already in Middle Germany (MÜLLER 1953, **5**). The younger phases of the Weichselian Late-glacial period have been recorded in numerous pollen diagrams. Apparently the Older *Dryas* time was of short duration in NW-Germany. The Allerød is preceded in Niedersachsen (BEHRE 1966, **3**) as in the Netherlands (CASPARIE & VAN ZEIST, 1960, **3**) by a *Juniperus* phase with much *Hippophaë* (see also SCHNEEKLOTH 1963, **3**).

In Schleswig-Holstein, however, almost no significant *Juniperus* expansion at this time has been proved. Similar it was in Denmark, where it appeared at the beginning of the Holocene only (IVERSEN 1954, **3**).

During the second half of the Allerød *Pinus* spread; in the Hamburg area (SCHÜTRUMPF 1955, **6**, AVERDIECK 1957, **3**, **8**) pine had high values at this time, it reached its northwestern limit of distribution, however, not far away in northern Holstein (ALETSEE 1959, **3**). The Laacher tuff, an important horizon for synchronization is found in the southeastern part of Niedersachsen, e.g. the Hils Mountains (FIRBAS 1954, **3**) and the surroundings of Hannover (DIETZ, GRAHLE & MÜLLER 1958, **3**), and northeastwards as far as Mecklenburg (MÜLLER 1965). Besides limnic and telmatic deposits, soils, dating from the Allerød have been discovered at many places in NW-Germany, often called the "Usselo-Horizont" (ERBE 1958, DÜCKER & MAARLEVELD 1958, **10**, and others).

The Younger Dryas was a period of another, almost complete deforestation, with *Empetrum* heathers spreading on shifting coversands. Nevertheless, *Betula* as well as *Pinus* were still locally present in Niedersachsen (BEHRE 1966, **3**), so that they could spread rapidly — together with *Populus* — at the beginning of the Holocene.

4. Holocene

The number of papers on the vegetation history of northwestern Germany published during the last decade, is great and the problems they are dealing with, are numerous. It is impossible to give a complete summary of the results of these studies as space is limited in this paper. They focussed mainly on the following problems:

1. Zonation of pollen diagrams by pollen assemblages, absolute dating of pollenfloristical zone borders (mainly by radiocarbon dates), and general vegetation history

(Aletsee 1958, **8**, Grohne 1957, **4**, Kubitzki 1961, **12**, Menke 1969 a, Schneekloth 1967, Straka 1961, see also papers cited in 5.) Behre (1966, **3**, 1967) could detect a preboreal thermomer-kryomer-cycle (Friesland-oscillation, Piottino-oscillation).

2. Methodical studies preparing the reconstruction of fossil plant communities (Behre 1970 b, Grosse-Brauckmann 1962 a, **4**, 1962 b, 1963, **8**, 1968, 1969, Körber-Grohne 1967, Menke 1963, **4**, 1968 c, **4**, **9**, 1969 c, **9**, Trautmann 1969).

3. History of cultivated plants, way of life of early man and possible changes of the coastal regions of North Sea and Baltic Sea, rise of sea level (Behre 1970 b, Behre & Menke 1969, **10**, Dümmler & Menke 1970, Grohne 1957, **4**, Körber-Grohne 1967, Lange & Menke 1967, **9**, Menke 1968 c, **4**, **9**, 1969 a, 1969 c, **9**, Wiermann 1962, **4**, **9**, 1966 a, b, **9**).

5. Development of bogs, especially the problem of recurrence surfaces (Aletsee 1959, **8**, Averdieck 1957, **8**, Cordes 1967, **4**, Overbeck et al. 1957, **12**, Schneekloth 1963 a, b, **4**, 1968, 1970, Willutzki 1962).

Generally the authors focussed more or less on more than one of these and related problems. The close connection existing between vegetation history, geology and history of human settlements, appear to be very distinct in the coastal regions. This complex of problems being of more than local importance, particularly because it is closely related to sea level changes, will be discussed below restricting them to the North Sea coastal region.

Extensive geological mapping has made evident a series of lithological cycles found from Schleswig-Holstein to the Netherlands, which at some places of the coastal area have been interpreted as indicating transgressions (Brand et al. 1965, **4**, **9**).

The main geological question is: are these cycles local phenomena only or are they synchronous over larger areas? Were there periods with major or minor ingressions of the North Sea or differed the sea flooding according to local conditions? It is the task of vegetational history, especially of palynology, to date the sequences. The existence of a detailed pollenfloristic zonation (see point 1 above) and its continuous correction by further radiocarbon datings are necessary to do so.

Compared with the attempts to date intercalated peat layers by the C-14 method only (Geyh 1969) a paleobotanical study usually results in a great number of informations concerning the particular profile. It allows for example to recognize gaps etc. in the profile and to check the reliability of single radiocarbon dates by transferring dated marker horizons from different pollen diagrams. At the same time conclusions are possible concerning environmental conditions and their changes (mean water level, nutrient conditions, salinity and other factors), which are necessary for the interpretation of the ecologic rise of the sequences. Information derived from studies mentioned under 2 (see above) are needed for this purpose. It could be shown that taxa behave in about the same way now as they did in earlier times, and also that some plant communities, which nowadays are no longer present or which at least are very rare in the study area (e.g. *Cladium*- and *Phragmites-Thelypteris*-reeds, sedge and grassland communities partly of the recent *Molinion)*, were of great importance in the back swamps during the past.

Salix and *Frangula* shrub communities — since about 1800 BC *Myrica* shrubs too — were present in the region, but forests were scarce even in the hinterland, except along the rivers. It could also be shown that in certain areas special trends continued throughout centuries. For example a site poorly provided with sediments might have remained in this situation for a long time, and the relatively greater wetness becomes evident in the facies changes again and again. As large scale mapping has shown, this results from the fact that the river and creek systems of the hinterland did not change very much during such periods. Thus long-term changes in connection with ingression cycles are even better shown in these areas.

There are, however, also areas with a local development, different from the general trend, as swamp formation in the hinterland of coastal barriers, even during times of ingression.

The great marine ingressions occurred between 5200—4500 (4300) BC., 4000—3300 BC, 3000—(2800)—2400 (2200) BC., 1900—(1700)—1300 (1000) BC., 600 (500)—100 BC., 100 (200)—(800)—1100 AD.

The dates of the beginning and of the end of each ingression differ a little from place to place, which might partly be due to dating problems, i.e. to methodical difficulties.

The ingressions caused the forming, deepening and expansion of creeks (tidal channels) over larger areas in the hinterland, concurrent with the sedimentation of clay covers and with the forming of more or less extensive banks — poor in vegetation — along the rivers. They also caused the expansion of reeds, the eutrophication of raised bogs etc. These are phenomena which naturally follow the rise of the tidal high water level. The opposite is happening during the time between two ingressions (filling up of the creeks by reed peat, peat formation on clay covers, oligotrophication). Especially during subboreal times (ca. 2400—1900 BC and 1200—600 BC.) and about the time of the birth of Christ raised bogs started to develop, partly directly on tidal sediments.

During such periods vast banks, which had been poor in vegetation during the ingressions, must have been completely out of the reach of floods. When connecting in a time-depth-diagram, where considerable compaction cannot be expected, an almost asymptotic curve is resulting, similar to the one JELGERSMA (1961) has drawn for the Netherlands using the radiocarbon dates of the basal peat layers. This curve, however, can only very roughly correspond to the actual position of the water level, because it is based on — increasing — maxima, whereas phases of regression and standstill are not expressed.

Considering the hydrographic conditions during the growing season, which can be deduced from changes in the former plant communities (MENKE 1968 c, **4**, **9**, 1969 a) a much more complicated picture of ecologically important water levels is resulting. As there was no sedimentation over vast areas during the more or less regressive phases, but wide-spread peat and — at higher, i.e. dryer, sites — even soil formation (sometimes even in bogs, thus causing gaps), the regressive phases are taken only insufficiently into consideration when subdividing the Holocene in coastal regions lithologically (BRAND et al. 1965, **4**, **9**).

The process of filling up with sediments largely depended on the local conditions. Surfaces of the same age therefore must formerly have been on different niveaus, and are not the result of subsidence only. Along the river Eider and in other parts of the West coast of Schleswig-Holstein the main filling in with clastic sediments took place during the Calais ingressions (Atlanticum).

The highest sediment surfaces dating from about 2400 BC are situated between 1 m below recent sea level and sea level (Stapelholm, Eider), though this surface is usually found at the —2 to —3 m level. Its lowest position, however, is at 5.5 to 6 m below recent sea level (at a site on the W coast of Schleswig-Holstein). These differences of elevation can — according to the vegetational development — not only be explained by later compaction. On the other hand there are indications of the forming of an "Inversionslandschaft" (inversion landscape) by compaction during phases of regression and standstill (e.g. formation of lakes in the swampy hinterland, shifting of rivers, forming of inversion ridges in former creeks), especially about 2000 BC.

Behre (1970) and Streif (1971) have stated a very low position of the older layers for the area around the Dollart, which — at least partly — must be primary. Here mainly the Dünkirchen ingressions (Subboreal, Subatlanticum) caused the filling up with clastic sediments.

Despite the fact that very detailed studies are available for some regions it is still difficult to correlate vast areas — uncorrect conclusions are therefore still possible. For example Streif (1971; Woltzeten, Niedersachsen) did not correlate as one would have suggested the "middle peat layer" (D = 4395 ± 45 B.P.) with the main peat layer of the "Holland peat" (Streif 1971, p. 42), which marks the boundary between the sediments of the Calais and the Dünkirchen ingression, but he considered it to be older, to be contemporaneous with a layer between the Fiel and the Husum horizons (or C III/C IV of the Dutch subdivision, ca. 2800 B.C.). New dates from Schleswig-Holstein (Menke 1969a, tab. I and p. 41) indicate, however, that the "middle peat layer" most probably corresponds with the Calais/Dünkirchen boundary (= Husum/Meldorf boundary). (Peat formation began in Schleswig-Holstein after the Husum ingression at about 2500 B.C.). Therefore the younger "intercalated peat layer" (ca. 1700 B.C.) of Streif probably corresponds with a — even in Schleswig-Holstein — not very marked interruption of the Meldorf ingression (beginning at about 1900 B.C., see Menke1969 a, tab. I and p. 42).

The other dates, which have been published by Streif, can also easily be correlated with the results from Schleswig-Holstein: the "lower peat layer" (D = 5090 ± 33 B.P.) corresponds with the Eesch/Fiel boundary (Menke 1969 a, tab. I and p. 42), and the "upper peat layer" (D = 2905 ± 21 B.P., peat formation from about 1300 to 600 B.C.) with the peat layer formed between the Meldorf and the Schwabstedt ingression of Schleswig-Holstein (Menke 1969 a, tab. I and p. 42). The correlation problems are mainly caused by the fact that some of the dates published by Brand et al. (1965) must be considered to be approximate dates only, which have to be corrected (see Menke 1969 a, p. 31). Remains of settlements give evidence that for a long time man had to arrange p. 31).

Remains of settlements give evidence that for a long time man had to arrange himself with the changing influence of the sea. Plant remains are often found well preserved in these cultural layers. They are an excellent source of information concerning environment and man's way of life, but also concerning the degree of salinity affecting the vegetation.

Studies on the early iron age surface-level settlement Boomborg/Hatzum, in the marsh region of the lower river Ems (Behre 1970 b) showed that gallery-like alluvial forests (incl. the upper hard wood alluvial forest) grew on the banks of the river Ems during early Subatlantic times, but farming, too, was already practised (mainly *Linum*, *Vicia faba*, *Camelina sativa*, but also *Hordeum* and *Triticum*). Animal breeding dominated, however. At that time there was only freshwater vegetation. In the same period man began to settle on a fossil coastal barrier of Tating (Eiderstedt, Menke 1969 c, **9**, Bantelmann 1970). The next phase of ingression stopped the early iron age settlement at Boomborg/Hatzum. About the birth of Christ the colonization of the vast marshes began, mainly on the flat ground. The beginning of raised bog growth in the back swamps ("Sietland") of the river Ems region (Behre 1970 b), the peat formation and soil development on the Eiderstedt peninsula (Elwert 1972) can be interpreted as indicators of a further regression. Shortly after the birth of Christ (occasionally during the century before Christ, as in Jemgumkloster, Brandt 1972) the rise of the sea level forced man along all the southern coast of the North Sea to build "Wurten" (dwelling mounds to erect houses on them). At the same time the occupation on dunes of fossil coastal barriers of the Eiderstedt peninsula was intensified (starting about 100 to 200 A.D.), where man now also raised the settlements artificially. Plant remains from the dwelling mounds of Roman period (Feddersen Wierde, Körber-Grohne 1967, Jemgumkloster, Behre 1972, Tofting, Scheer 1955, **8**, Behre in prep.) indicate intensive agriculture *(Vicia faba, Linum, Camelina sativa, Hordeum, Triticum dicoccum, Avena* and *Panicum)*. Animal breeding, however, was always more important. In addition, the botanical studies showed that pastures along the Außenweser and Eider reached far into the salt marsh area. The region formerly covered by freshwater vegetation in the lower Ems region now for the first time showed a distinct influence of brackish water. All along the southern North Sea coast region the colonization of the marshes ended in the 4th/5th century AD. Resettlement started in the 8th century AD only, from its very beginning on dwelling mounds. According to botanical studies (Elisenhof/Eiderstedt, Behre in press) the marsh settlements of early medieval times reached far into the now marine influenced area. Animal breeding in the salt marsh area was more important at that time than agriculture on the river banks *(Vicia faba, Linum,* only little *Hordeum,* and *Avena)*.

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