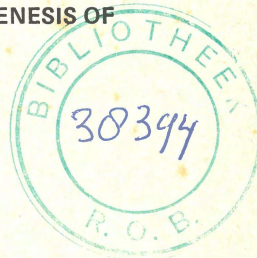


THE CALAIS DEPOSITS IN THE VICINITY OF WIERINGEN AND THE GEOGENESIS OF NORTHERN NORTH HOLLAND

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ABSTRACT

Based upon lithologic data and radiocarbon datings the lithostratigraphy of the Calais IV phase and existing subphases A and B is discussed. A subdivision of the Calais IV A subphase into two subunits 1 and 2 is introduced. The new subdivision solves the incompatibility between statements of various previous authors on the subject.

The data obtained are utilized to elucidate the genesis of northern North Holland.

Finally this new concept has been applied to the adjacent areas (part II). From the present state of knowledge it is evident that part of the previous work has suffered under the assumption of a too simple subdivision in Calais phases and has stepped into the pitfall of too much confidence in lithostratigraphy only (see also Ente, 1971).

PREFACE

In 1965 and 1966 investigations have been carried out by the soil section of the Lake IJssel Polders Development Authority (Rijksdienst voor de IJsselmeerpolders) in the areas Balgzand and Breehorn (fig. 1). About 800 borings have been carried out into the Pleistocene sand. Full details were already given by Ente (1969). In short the results are given in part I.

During this survey the need was felt to establish the relations between the sediments of this, in a certain geological way, rather isolated area and of those of other areas and their stratigraphy. A section was extended from the Balgzand area towards a profile dated by means of radiocarbon in the Anna Paulowna polder (du Burk, 1960). Although the geology of that area as far as known could be regarded as simple, the radiocarbon dates did not seem to fit very well in the existing models. Therefore other sections were made across the somewhat better known and geologically more interesting Wieringermeer, where the predecessors of the first author had made soil surveys (Zuur, 1936) and had already encountered Calais deposits of different phases (see also Pons and Wiggers, 1959).

Subsequent palynologic investigations and radiocarbon datings necessitated an emendation of the subdivision of the Calais phases. A new concept is introduced in the paragraph on the stratigraphic classification.

Part I

THE CALAIS DEPOSITS FROM THE SOUTHERNMOST PART OF THE DUTCH WADDEN SEA (BALGZAND AND BREEHORN) WITH SOME REFERENCE TO THE WIERINGERMEERPOLDER

LITHOLOGY

Introduction

In the coastal area of the western Netherlands the Holocene deposits show the following general succession. At the basis a peat layer (Lower Peat) is present overlain by a series of sandy and clayey layers, deposited in a lagoonal and tidal flat area (old tidal flat deposits: Deposits of Calais); on top again a peat layer occurs (Upper Peat: Holland Peat) and finally at several places another series of sandy and clayey layers (young tidal flat deposits: Deposits of Dunkirk) forms the topmost part of the succession (Jelgersma, 1961; Hageman, 1963).

Also, it is known that the marine beds were deposited during a number of separate transgression phases. This matter will be dealt with in particular in the paragraph on the stratigraphic classification.

Finally, it is a well-known fact that the relief of the Pleistocene has had a great influence on the development of the Holocene. A discussion of the genesis of the Pleistocene deposits is therefore necessary to understand the development of the Holocene sedimentary sequences.

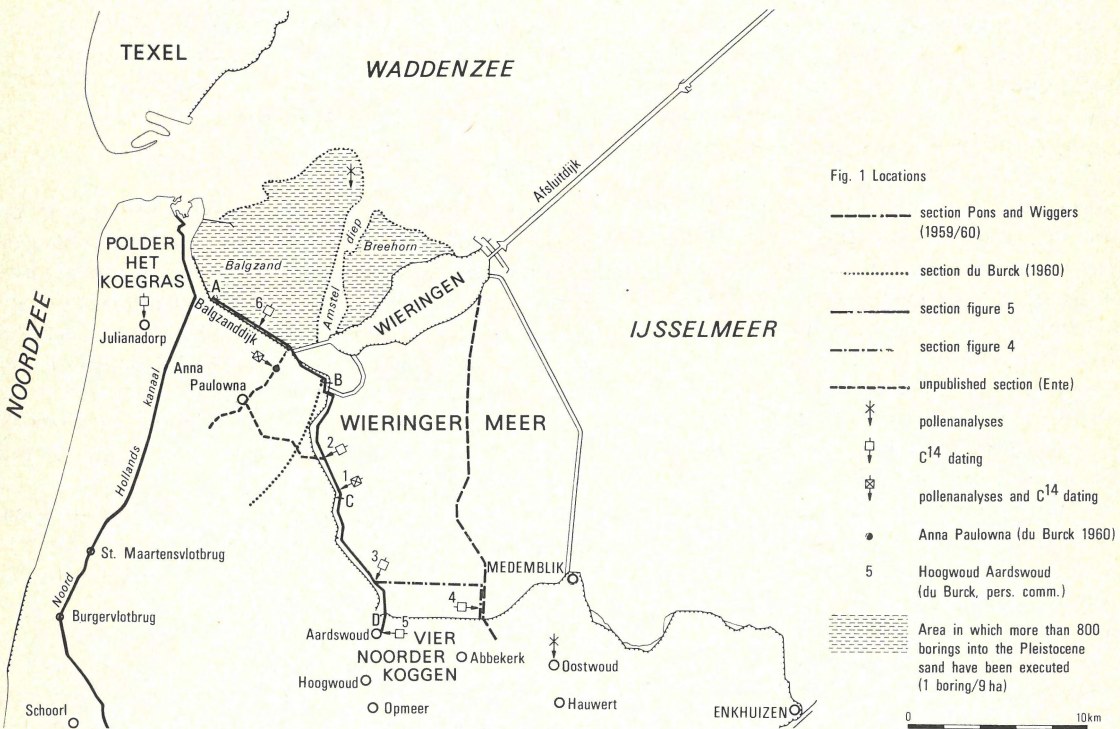
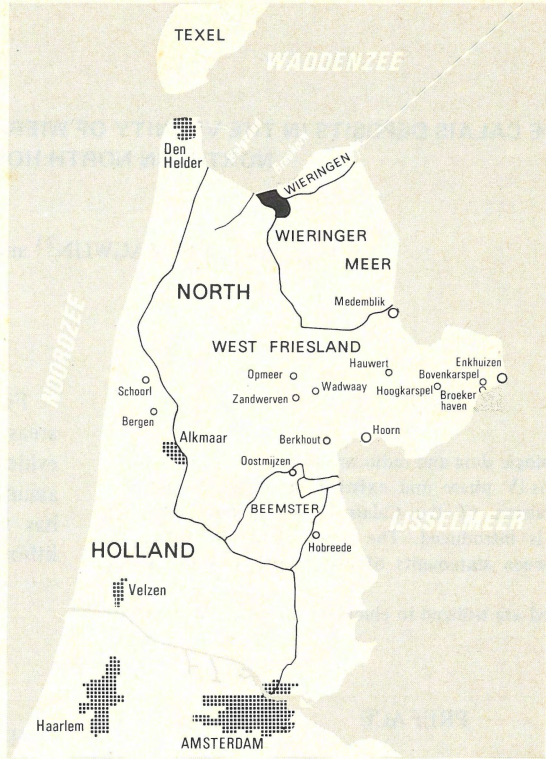
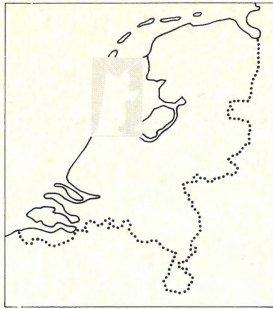
The Pleistocene fundament

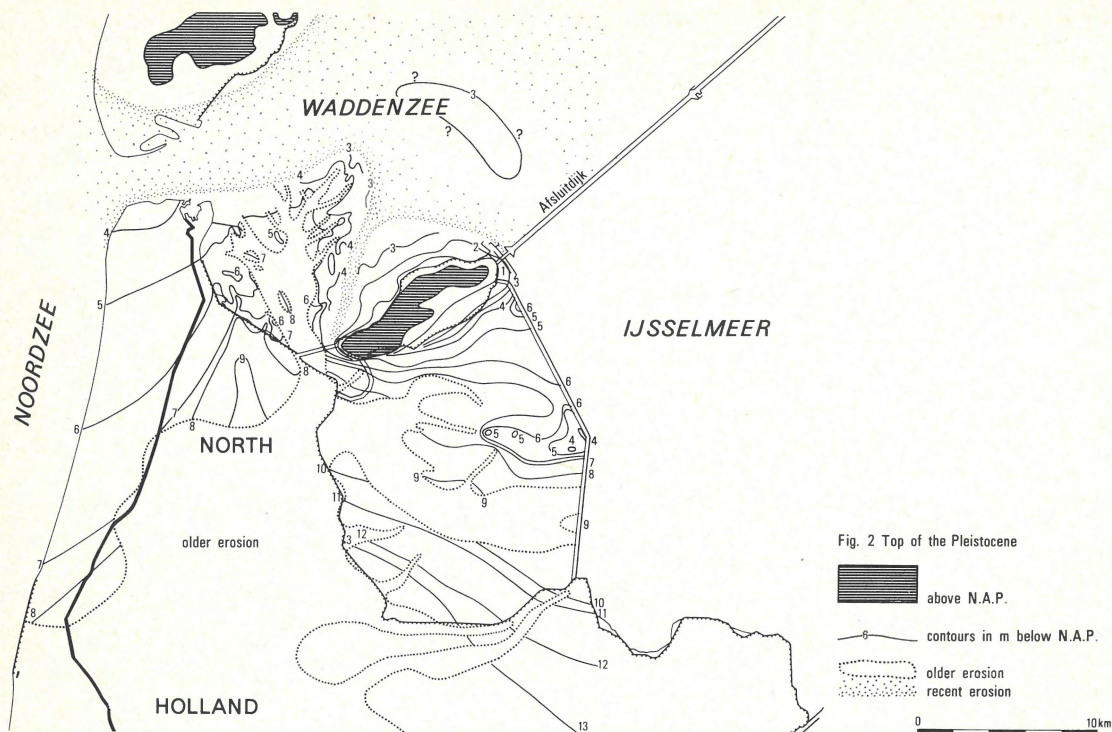
At the end of the Pleistocene the surface in the area studied consisted of wind-blown sands (coversands), still

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roughly representing the topography of the older Saalien landscape with ice-pushed hills and glacial tongue-basins (Ter Wee, 1962). The contours of figure 2 are based upon those sites that represent the original surface, indicated by the presence of a soil profile often covered by Lower Peat. The map largely corresponds with the one of Pons and Wiggers (1958).

In the centre of the Balgzand area the Pleistocene has been strongly subjected to subsequent marine erosion. The sea has penetrated the area from the lowest sites, as may be expected, and this is clearly demonstrated by the contours of not eroded "islands". In the north the top of the Pleistocene is relatively high. The map suggests that the Pleistocene surface gently dips up towards the centre of Texel.⁴⁾

The lithological succession in the Balgzand and Breehorn areas

On top of the Pleistocene sands peat accumulated, which is called Lower Peat in those areas where it is covered by Calais deposits. In the Balgzand area the Lower Peat is nearly

always present, except locally where the Pleistocene has been eroded in a later phase. The thickness of the Lower Peat rarely exceeds 30 cm. It consists of reed-sedge peat, locally containing remains of wood.

The older Calais deposit (it will be shown later that it belongs to a late Calais III transgression phase) is of minor importance in the surveyed area. It is only found along the southern part of the Balgzanddijk in a small strip with a width of a few hundred metres where the top of the Pleistocene is below 6 m minus N.A.P.⁵⁾

The deposit is thin and consists mainly of decalcified rather heavy clay with many root remains. On top of it a rather thin layer of peat is present.

The younger Calais deposit (from a later discussion it will appear that it belongs to the Calais IV B transgression phase) covers a considerable part of the Balgzand area. It is present also in the adjacent part of North Holland. It is absent where the top of the Pleistocene is above 3-3½ m below N.A.P. (Breehorn area and north-eastern part of Balgzand area). The contours of the top of the Pleistocene and particularly the erosional pattern in the Pleistocene sand surface suggest a sediment supply from the south. This is contrary to the views of Pons and Wiggers (1959/60) and Pons et al. (1963).

The top of the younger Calais deposit is at 2.2-3.0 m below N.A.P. The thickness varies and is greatest (> 5 m) at places where large gullies are supposed to have been present due to erosion of the Pleistocene sands. Outside these areas

⁴⁾ This seems to be contradicted by one boring at the southend of Texel (Archive Geol. Survey). At this location the gully "Spanjaardsgat" was present in 1712, according to Westenberg (1961, fig. 5). Therefore the clay found in this boring should be regarded as a recent gully filling.

⁵⁾ N.A.P. = Dutch ordnance datum = about mean sea level.



Fig. 3

Aerial photograph of a part of the Wieringermeer (see also fig. 4). The creek system showing a dark centre and light coloured margins is bound to the clayey reed marsh facies at the surface (Calais IV A 2), as is known from field work and indicated on the section Oudelandeweg. A similar creek system was regarded as representing Wieringermeer deposits by Pons and Wiggers (1960, fig. 26). The photograph also shows that the creek system with the dark centre and the light margins was probably at some places the predecessor of the younger intersecting creeks. The younger intersecting creeks are sprung from the northern gully, as was deduced from some field work. In the present state of knowledge it has to be accepted that the fill of this northern gully is nowhere younger than the Calais IV A 2 phase, so that all systems shown on this photograph are confined to the Calais IV A 2 phase. Photograph Ordnance Survey.

the thickness is mostly 2-3 m. In a strip along the Amsteldiep the thickness is even less (in the north due to wedging out; in the south due to rather recent erosion).

At the places of the original large gullies the deposit is sandy in the lower parts and clayey in the upper. The thickness of the clay varies from more than 5 m in the south to 3 and $1\frac{1}{2}$ m in the north. Outside the areas of the large gullies no sand occurs. The clay content varies from 30 to 40% in the upper part.

The clay is generally of subaquatic character. The upper part, however, contains roots from vegetation that was

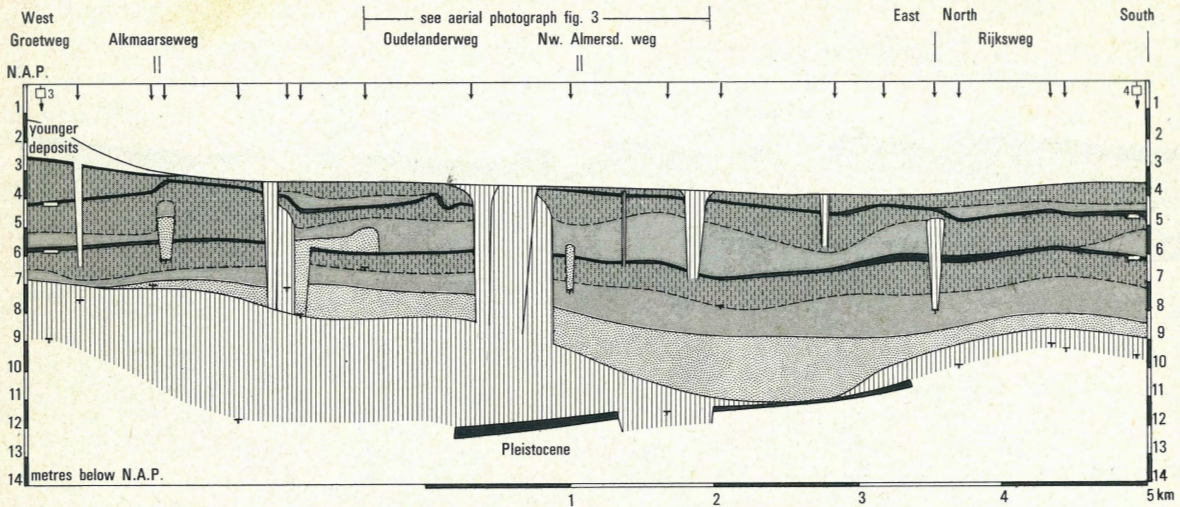
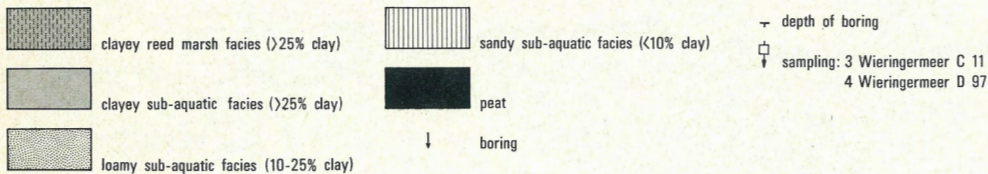


Fig. 4 The Calais deposits in the section Oudelandeweg (see note under „the lithological succession of the Wieringermeerpolder”)



present during the last stage of the sedimentation and thereafter, for which reason the upper 20-50 cm are mostly decalcified.

The younger Calais deposit is in most places covered by that part of the Holland Peat that escaped abrasion during late medieval times. The peat is mainly reed-sedge peat.

Since medieval times the area was flooded again by the sea and a relatively thick sequence of sediments was formed, deposition of which is still progressing.

The lithological succession in the Wieringermeerpolder

The surface of this polder mainly consists of Calais deposits. All the overlying peat, previously present, has been eroded since medieval times.

Zuur (1936, using soil mapping data from van Steen) discussed the composition of the polder soils extensively. He distinguished laminated, very calcareous, sparsely rooted, lighter textured soils, the so-called flats, and often decalcified, strongly rooted, heavier textured soils, the so-called salt marshes. In the so-called salt marshes creeks and gullies, forming an intricate pattern, were filled up later with light textured sediments.

Both the flats and the salt marshes were covering large, rather homogeneous areas, with transitional zones in between.

Zuur was aware of different phases of sedimentation. In the western part of the Wieringermeerpolder he mentioned the occurrence of a continuous clayey layer with much more autochthonous reed remains than were found in the normal

salt marsh soil. The layer even becomes peaty in some places or merges into one peat layer. According to botanical analyses the peat layer may be assumed to represent a brackish water formation. This layer was found at depths between 3 and $4\frac{1}{2}$ m below N.A.P., a maximum variation of more than one metre, which Zuur (l.c. fig. 3) considered striking.

In the south-east he mentioned the occurrence of two more or less parallel peaty layers (see also photograph fig. 25 in Pons and Wiggers, 1960). Botanical analyses revealed a fresh water depositional environment for the upper and a brackish one for the lower layer.

Zuur noticed a certain transgression of calcareous more silty sediments over the peaty layer, which covers more clayey sediments. On the other hand he stated that the broad subdivision in areas with flats and areas with salt marshes must have existed already during the older Holocene, at least in the north-eastern part. Consequently, the sedimentation roughly counterbalanced the rise of the sea level and therefore generally took place without much environmental change.

Pons and Wiggers (1959/60) correctly remarked that during some time a part of the fore mentioned salt marshes were tidal reed marshes. Here, subsidence may have been important. It should be remarked, however, that subsidence may have been restricted to basins of the tidal reed marshes, because the levee soils were presumably less liable to compaction (Ente, 1963; Ente, 1971).

With the exception of the westernmost part — where the younger Holland Peat is still present — at least a few dm of

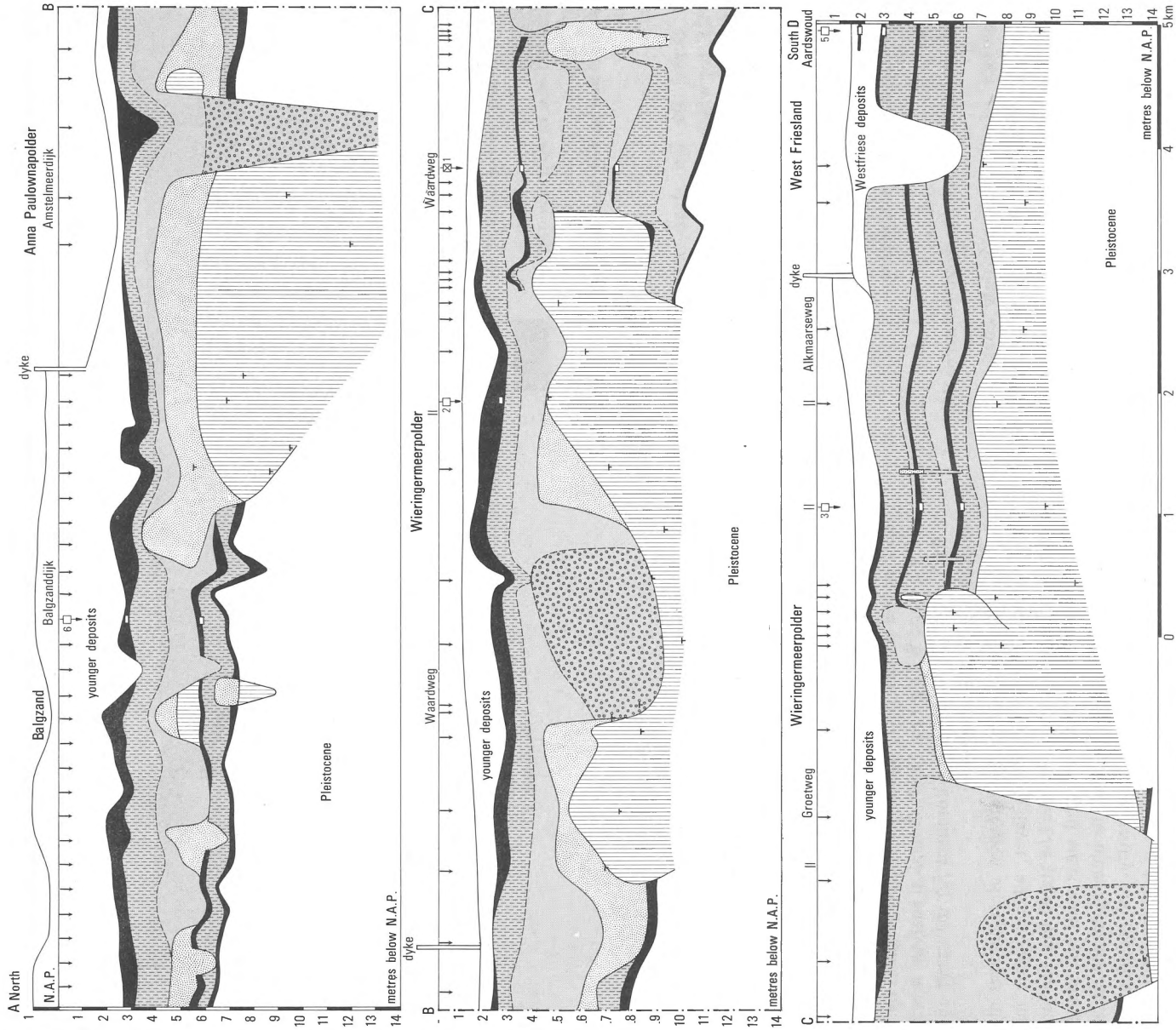


Fig. 5 The Calais deposits in the section Baigzand-West Friesland

the deposits have been removed by younger erosion in the western part, and most probably more has been eroded in the eastern part, as is clearly demonstrated by Zuur. This rather substantial erosion, brought older sediments near the present surface. For this reason, areal photographs of this area show different intersecting creek systems. Buringh (1948) was the first who drew attention to this phenomenon.

Pons and Wiggers have studied the photographs of an area in the southeast, where according to Zuur the two parallel peaty layers occur. They distinguished three intersecting systems (l.c. fig. 26). A similar photograph is shown here on figure 3 (partly overlapping the one published by Buringh). Its location is in the middle of the section Oudelandeweg (fig. 4).⁶⁾ At least two intersecting systems are visible and it is questionable whether the younger one may be subdivided. As apparent on the section (fig. 4) this "subdivision" can also be traced in the field. Both the photograph and the section Oudelandeweg show that the uppermost layers have outside the gullies a facies of salty marshes and reed marshes. In this area the sands and clays (clay is predominant) of deeper layers are found in subaquatic facies, though interrupted at a level of about 6 m below N.A.P. by beds with a reed marsh facies. Still deeper the subaquatic facies is predominant throughout. The sediments are more sandy here, sand is predominant in the western part of the section.

Similar features are present in the section Balgzand-West Friesland (fig. 5). However, as compared to the above discussed section (fig. 4) the presence of important gully fill deposits should be mentioned. For a considerable part these deposits consist of dark grey to black (due to staining with iron-sulphides) homogeneous clays. The section suggests that these gullies have been active during the sedimentation of all Calais phases here present and finally have silted up rather abruptly.

To summarize it may be stated, that in the Wieringermeer area deposits of three Calais transgression phases can be distinguished. The lowermost deposit is complex and contains fairly thick beds of clay and sand, in which peaty intercalations are only locally present. The upper two deposits are more clayey and in several places a peat bed occurs at their base.

DATING AND STRATIGRAPHIC CLASSIFICATION

Balgzand and Wieringermeer

The radiocarbon datings are listed in table 1; some other radiocarbon datings from the adjacent area are given in table 2. The sampling locations are shown in the sections figure 4 and 5 and in figure 1. The datings are in accordance with the local lithostratigraphical concept.

⁶⁾ In making the sections, the top soil map (Zuur, 1936) and aerial photographs were used to locate the borings on the crucial spots. Especially in the section Oudelandeweg hand-auger and spade have been used. The latter to clean ditch sides at several locations.

It can be concluded, that in the Wieringermeer area the latest Calais phase ended around 4100 years B.P. (before present), as indicated by the datings GrN 5945 (4040 ± 45) and GrN 5555 (4160 ± 65). In the Balgzand area the latest Calais phase ended around 3900 years B.P. as indicated by the datings GrN 6313 (3920 ± 55) and GrN 819 (3865 ± 85).

The dates GrN 5904 (4480 ± 45), GrN 5946 (4360 ± 45), and GrN 5948 (4385 ± 45) indicate the end of the preceding phase, which consequently was at about 4400 B.P.

The top of the oldest phase was dated in the Balgzand area by GrN 6314 (4630 ± 40) and GrN 820 (4605 ± 85) and in the Wieringermeer by GrN 6315 (5045 ± 60) and GrN 5947 (5015 ± 45), indicating its end around 5000 B.P. Finally a peaty lens, intercalated within the deposits of the oldest phase, provided a date 5685 ± 40 (GrN 5905).

TABLE 1
Radiocarbon datings Balgzand and Wieringermeer.

Location	Number GrN	Dating in years B.P.	Description	End of phase Calais
Wieringermeer B8/9 ¹⁾	5904	4480 ± 45	vegetation band	IV A 1
Wieringermeer B8/9 ¹⁾	5905	5685 ± 40	vegetation band	?
Wieringermeer B1	5945	4040 ± 45	base of upper peat	IV A 2
Wieringermeer C11 b	5946	4360 ± 45	base of peat layer	IV A 1
Wieringermeer C11 c	6315	5045 ± 60	base of peat layer	III
Wieringermeer D97 a	5948	4385 ± 45	base of peat layer	IV A 1
Wieringermeer D97 b	5947	5015 ± 45	base of peat layer	III
Balgzandijk km 6.3 a	6313	3920 ± 55	base of peat layer	IV B
Balgzandijk km 6.3 b	6314	4630 ± 40	base of peat layer	III

¹⁾ samples: Geological Survey; other samples: R.I.J.P.

TABLE 2
Relevant radiocarbon datings of border of Balgzand and Wieringermeer.

Location ¹⁾	Number GrN	Dating in years B.P. ²⁾	End of phase Calais
Anna Paulowna	819	3865 ± 85	IV B
Anna Paulowna	820	4605 ± 85	III
Anna Paulowna ³⁾	824	5665 ± 105	—
Aardswoud	5554	3440 ± 90	IV B
Aardswoud	5555	4160 ± 65	IV A 2

¹⁾ samples: du Burck (Aardswoud, pers. comm.).

²⁾ obtained by applying correction to original Gro-numbers (Vogel and Waterbolck, 1963).

³⁾ top of peat layer; other samples represent base of peat layer.

TABLE 3
Some other relevant radiocarbon datings.

Location ¹⁾	Number GrN	Dating in years B.P.	End of phase Calais
Velserbroekpolder (II a) boring 1	5907	3850 ± 55	IV B
Velserbroekpolder (III) boring 1	5663	4140 ± 30	IV A 1
Velserbroekpolder (IV) boring 1	5664	4735 ± 55	III
Velserbroekpolder (V) boring 2	5665	4595 ± 40	III
Velserbroekpolder (VII) boring 3	5915	3715 ± 55	IV B
Schoorl-beach (III)	5668	3770 ± 40	IV B
Schoorl-beach (IV) ²⁾	5669	4045 ± 40	3)

1) all samples: Geological Survey.

2) top of peat layer; other samples represent base of peat layer.

3) base of Calais IV B sedimentation phase.

Concepts on the subdivision of the Calais deposits

Originally the classification of the so-called Calais beds, was mainly based on palynological evidence. This resulted in the following subdivision: Early Atlantic, Late Atlantic, Early Subboreal tidal flat deposits (Hageman, 1960; Jelgersma, 1961). This scheme was also used by Pons et al. (1963).

A different approach was that of Pons and Wiggers (1959), who discerned a number of units, which by nomenclature reveal that they actually represented lithostratigraphic units (e.g. Wieringermeer deposits, Beemster deposits), although it was not stated explicitly. These authors also used radiocarbon datings by means of which units were attributed to certain transgression phases.

Later Hageman (1963) introduced a subdivision of these deposits on a lithostratigraphic basis. They were classified within one member: the Deposits of Calais (as opposed to the younger Deposits of Duinkerke). The Calais deposits were subdivided into four units: Calais I, Calais II, Calais III and Calais IV.

However, for interregional correlation radiocarbon dating is an invaluable tool. This was realised by Hageman and Jelgersma (in Brand et al., 1965) and by Hageman (1969) and resulted in the following scheme:

Calais IV	4550-3750 B.P. (2600-1800 B.C.)
Calais III	5250-4750 B.P. (3300-2800 B.C.)
Calais II	6250-5250 B.P. (4300-3300 B.C.)
Calais I	7950-6450 B.P. (6000-4500 B.C.)

In this scheme it is supposed that there are time-intervals between the various Calais phases, corresponding to times of peat accumulation. It is obvious, that in areas with entirely or partly continuous sedimentation, also marine deposits dating from these intervals occur. On the basis of data from Pons and Wiggers (1959) the Calais IV phase has been subdivided, as proposed by Hageman (1963) as follows: Calais IV A (between about 4550 and 4000 B.P.) and Calais IV B (between about 4000 and 3750 B.P.).

The scheme of dating of the Calais phases of Hageman and Jelgersma (loc. cit.) is based on the fairly great number of radiocarbon dates available from various parts of the south-western and northern Netherlands (Jelgersma, 1961) and on the data from North Holland (Pons and Wiggers, 1959). Later data of various authors, fully discussed by Rieboos and du Saar (1969), proved to corroborate the general validity of the scheme.

Some more relevant data will have to be discussed, especially with regard to the dating of the sub-units Calais IV A and Calais IV B.

The Calais IV B deposits and their age

In West Friesland at Hauwert Pons and Wiggers (1959) described four claybeds superimposed and separated by peat-bands. From top to bottom these four beds at this locality were named: Westfriese II, Westfriese I, Wieringermeer, Beemster. It should be noted, that the latter two names have been applied to beds that are assumed to be correlative with those in the type area elsewhere.

The radiocarbon datings (table 5) show, that the Westfriese II deposit was formed around 3200 B.P. (GrN 617) and therefore belongs to the Duinkerke deposits of Hageman.

The age of the Westfriese I deposit is between 4090 ± 120 (GrN 610) and 3750 ± 120 (GrN 609). This deposit was later correlated with Calais IV B by Hageman.

The so-called Wieringermeer deposit at this site was formed between about 4700 (GrN 605 and 2070) and 4100 (GrN 610), and the lowermost beds, called Beemster beds, were deposited before 4700-4900 B.P. (GrN 605 and 2070). In other parts of the western Netherlands, especially in the southwest, strata formed during the Calais IV B phase are not well developed; perhaps some beds at Vlaardingen and Hekelingen are of this age, although they differ in lithostratigraphic position (Pons in Altena et al. l.c.: 15-18: 23-29: 235-240). Further data recently acquired from North Holland, however, corroborate the existence of a transgressional phase between 4100 and 3750 years B.P. (table 3).

Near Schoorl on the present beach in a boring a clay-bed has been found, at the base of which a peat-layer occurs. The top of this layer has been dated at 4045 ± 40 (GrN 5669), whereas the base of the overlying peat yielded the date 3770 ± 40 (GrN 5668). Borings in the Velserbroekpolder, north of Haarlem, at the border of the former IJ, revealed the existence of many transgressional phases in this former estuary. They are represented by clay-beds separated by thin peaty horizons. One of these beds is bracketed by the following dates: 3850 ± 55 (GrN 5907) and 3715 ± 55 (GrN 5915) at the top, and 4140 ± 40 (GrN 5663) at the base.

These dates from Schoorl and Velserbroekpolder perfectly match the dates obtained earlier from the Westfriese I deposit at Hauwert. The conclusion therefore is, that in North Holland at several places beds of a transgressional phase can be found, which date from the time between about 4100 and 3750 B.P. This is the Calais IV B phase.

TABLE 4
Crucial statements and assumptions by previous authors on the stratigraphy as classified according to the present concept.

Concept of this paper		Pons and Wiggers				du Burck			Local alternative (restricted)
C ¹⁴ dating in years B.P. (end of sedimentation)	lithostratigraphic units	boring Hauwert	area Wieringermeer	area Beemster	aerial photograph Wieringermeer	area Vier Noorder Koggen	boring Aardswoud (gem. Hoogwoud) ⁽¹⁾	boring Anna Paulowna	West Friesland Wieringermeer Balgzand Beemster
3800	Calais IV B	Westfrieze I deposits**			Westfrieze II deposits	Westfrieze I deposits**	Westfrieze I deposits**	Westfrieze I deposits	Westfrieze I deposits
4100	Calais IV A 2	Wieringerm. deposits*	Westfrieze I deposits		Westfrieze I deposits Wieringerm. deposits	Wieringerm. deposits	Wieringerm. deposits*		Wieringerm. deposits
4400	Calais IV A 1		Wieringerm. deposits**	Beemster deposits**					Beemster deposits
4700 à 5000	Calais III	Beemster deposits*	Beemster deposits					Beemster deposits(?) ⁽²⁾	Hoofddorp deposits

* by means of radiocarbon dating
** by lithologic definition

(1) personal communication

(2) regarded by Pons and Wiggers as Wieringermeer deposits

Classification of the beds in the Wieringermeer area and surroundings

In this area the oldest beds probably belong to more than one phase in the scheme of H a g e m a n (1963), as a peaty intercalation in their lower part dates from approximately 5700 B.P. (GrN 5905), which means that this part of the sequence belongs to the Calais II beds. The upper part of this sequence, however, is in many places covered by peat-beds formed at about 5000 B.P. or in a younger time. Therefore, these beds belong to the Calais III deposits.

The beds of the next two overlying units are, according to their radiocarbon datings, part of the Calais IV A deposits. Evidently, in this area this phase actually includes two sub-phases, which may be named the *Calais IV A 1* and *Calais IV A 2* sub-phases. Calais IV A 1 ends at about 4400 B.P. and Calais IV A 2 terminates at about 4100 B.P.

The section Balgzand-West Friesland (fig. 5) reveals that the Westfrieze I and II deposits of West Friesland overlie the beds which correlate with those belonging to the Calais IV A 1 and Calais IV A 2 sub-phases in the Wieringermeer area. As discussed before, the lowermost part of these Westfrieze deposits is correlative with the Calais IV B beds.

Discussion of previous concepts concerning the stratigraphy

Based on the results discussed, the existing literature contains several conflicting assumptions. Particularly in stratigraphic interpretation, the use of the lithostratigraphic

terms Beemster and Wieringermeer deposits as defined by P o n s and W i g g e r s (1959) may produce conflicting results.

In the table 4 the terms Westfrieze I, Wieringermeer and Beemster as used by previous authors to interpret the stratigraphy in various parts of North Holland is presented and compared with the present concept on the classification of the Calais beds.

The present correlation indicates that the beds at the surface in about half of the Wieringermeer area should be named Wieringermeer deposits if this name has to be retained. These beds were included into the Westfrieze I deposits by P o n s and W i g g e r s (1959) and they assigned the term Wieringermeer deposits to the underlying clay-beds of an earlier phase, which has no counterpart in the boring Hauwert. In fact the whole problem arose, because there appeared to be one more phase in the area than was actually recognized at that time. This phase, which cannot be recognized separately at Hauwert, contains the Beemster deposits of the type area, as based on the radiocarbon datings at present available from the Beemster area (K w a d e t al., 1965).

In this line of reasoning the beds, formerly called Beemster deposits at Hauwert and belonging to the Calais III phase are correlative with the Hoofddorp deposits (R i e z e b o s et al., 1969 l.c.: 91).

At the extreme righthand side of table 4 is shown in which way the names introduced by Pons and Wiggers should be used in the present concept. However, in view of the

existing confusion with regard to the use of the mentioned names the authors prefer the scheme with the subdivision into Calais IV B, IV A 2, IV A 1, III etc.

The chronostratigraphic and lithostratigraphic position of the deposits found in boring Anna Paulowna (du Burck, 1960) has always been somewhat confusing when compared with other beds dated by radiocarbon – for instance those of Hauwert (Pons, 1957; Pons and Wiggers, 1959/60). However, the data from Balgzanddijk – it should be noted that sampling of this boring located about 2 km away from the site of boring Anna Paulowna, was carried out some 10 years later – are surprisingly similar to those of Anna Paulowna (compare table 1 and 2). Consequently confusion remained to some extent.

Regarding the older phase at Anna Paulowna with its dating of about 4600 B.P. for the end of the sedimentation, there may be some preference to classify this phase as a younger part of the Calais III phase. This also seems to be supported by the altitude of the top of these deposits. Overlying are about 20 cm of reed-sedge peat. The accumulation of a bed of this thickness can be estimated to cover some 300 years. This indicates that beds of the Calais IV A 1 phase must be absent here.

The end of the sedimentation of the younger deposits is at about 3900, which is about 150 years earlier than at Hauwert. These dates presently correspond with the dates determined for the end of the Calais IV B phase. Apparently, there is no reason for the assumption of a late Calais IV A 2 phase in the case of the sediments near Anna Paulowna and Balgzand.

However, a discrepancy still remains between the datings in the Balgzand area and the dating of 4040 B.P. for the end of the sedimentation in the southern part of the northernmost large gully in the Wieringermeer area. This gully always has been correlated with the topmost Calais beds in the Balgzand area. Perhaps in the northern gully of the Wieringermeer locally a still younger filling is present, which has been overlooked so far.

Part II

THE GEOGENESIS OF NORTHERN NORTH HOLLAND DURING THE LAST FEW CALAIS TRANSGRESSION PHASES

Introduction

In the foregoing a new interpretation is presented for the succession of beds in the areas Balgzand-Breehorn and Wieringermeer. The neighbouring areas are dealt with incidentally. In the following an attempt is made to apply the new concept on the stratigraphy systematically to adjacent areas. Furthermore all knowledge is combined to arrive at the genesis of the northern part of the province of North

Holland, with special reference to the younger Calais phases. As the conclusions described are not based on a systematic survey of the entire area they should be regarded as tentative only (fig. 6).

Initial development of coast and hinterland

The development of the late Holocene beach barrier coast of Holland has been extensively treated by van Straaten (1965; see also Zagwijn, 1965; Jelgersma and van Regteren Altena, 1969; Jelgersma et al., 1970). Since a long time a complex of more or less parallel beach barriers has been distinguished. Van Straaten suggested that before about 5300 B.P. a (first?) beach barrier, accompanied by tidal flats, had already been formed. Afterwards this beach barrier was abraded completely, though the tidal flat deposits were at least partly preserved. Similar observations were made by Riezebos and du Saar (1969).

It is tempting to bring the interruptions in the sedimentation in the hinterland into some relation with the formation of beach barriers. Indications for older interruptions in the sedimentation have been found locally e.g. at Hoogkarspel and Broekerhaven (Pons et al., 1963: Soil Survey Institute, unpublished) and in the Wieringermeer (this publication). However, the localities are few, and cannot be linked lithologically, as intermediate areas do not have such clear indications for interruptions in the sedimentation. Furthermore the datings show some variation. Therefore, the data for these older phases should be considered with some reserve.

In the hinterland of Eastern Flevoland sediments of a slightly younger Calais phase have been found (Ente, 1971). The datings indicate that this phase of sedimentation ended about 5300 B.P. This dating relates these deposits to the former beach barrier postulated by van Straaten. Correlative sediments have not yet been demonstrated in the area of northern North Holland.

Van Straaten distinguished two major phases of barrier formation, following the hypothetical minor phase before 5300 B.P. The beach sediments formed during these two major phases are still present in the coastal area between Hoek van Holland and Bergen. The first major phase started about 4800 years ago and terminated before 4100 B.P. The second major phase started, according to Jelgersma et al. (1970), before 4200 years ago and probably ended 3500 years ago. Formation of successive beach ridges took place from east to west. Locally inlets were present, which connected the tidal flat areas behind the barriers with the sea.

Jelgersma has pointed out that between Bergen and Alkmaar an important inlet existed for a long time. As Pons et al. (1963) suggested, the coast north of the Bergen inlet bent outwards in the direction of the present-day Pleistocene outcrops at Texel. The contours of the top of the Pleistocene may confirm this suggestion.

The stable inlet near Bergen fits better into the data

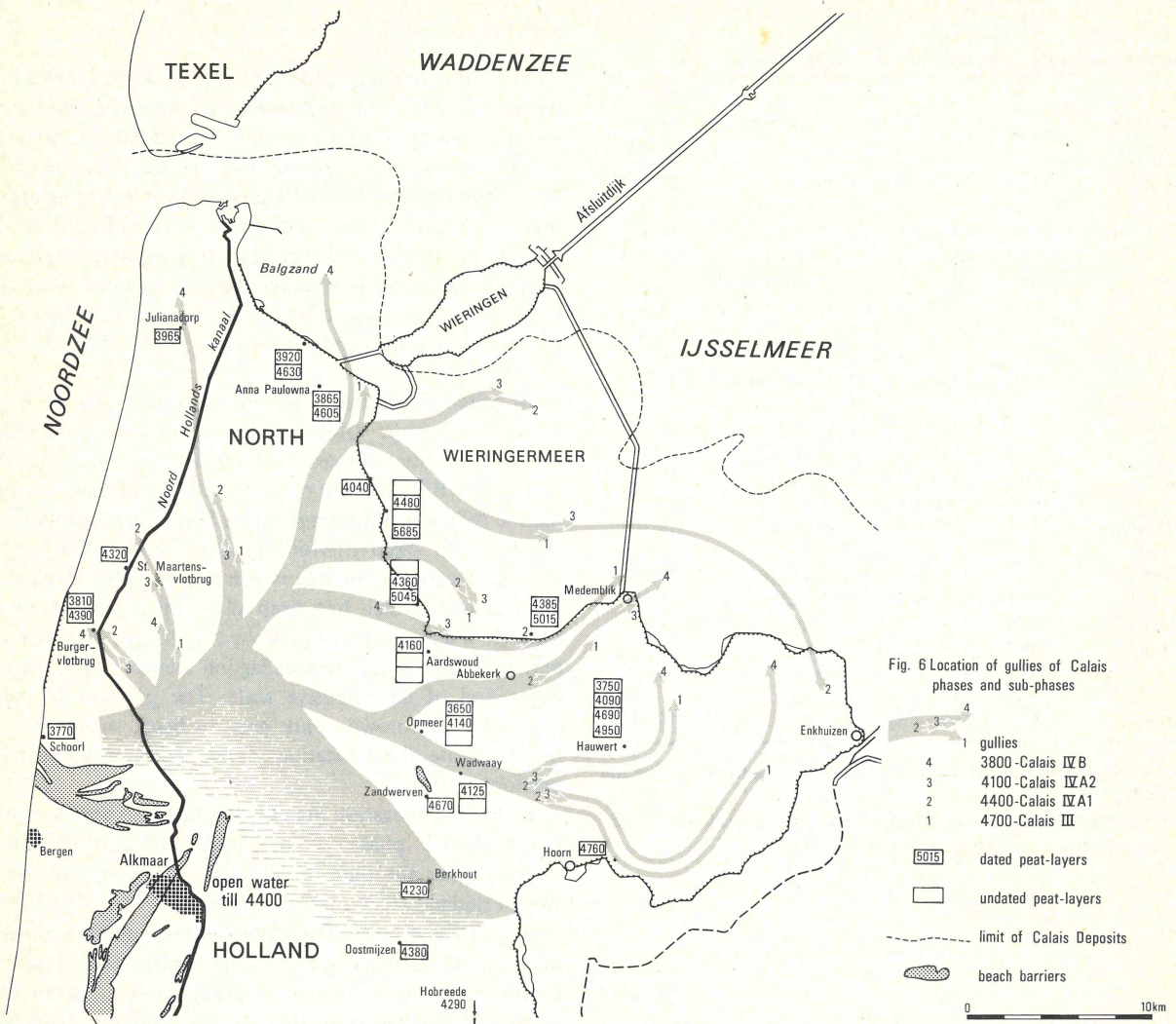


Fig. 6 Location of gullies of Calais phases and sub-phases

discussed in chapter I concerning the situation near Wieringen than the working hypothesis of Pons and Wiggers (1959/60) who assumed subsequent breaches in coastal barriers. Near Wieringen evidently gullies were present which have been active during the sedimentation of all Calais phases. The larger gullies remained relatively stable and open. They were silted up only at the very end of Calais sedimentation.

Calais III phase

Landinwards of the inlet near Bergen the presence of sandy tidal flats and muddy tidal flats may be assumed. In the north-eastern part of the area the presence of salt marshes and peat, dated around 5000 B.P. indicate that a large part of the area was silted up above mean sea-level of that time, this is during the Calais III sedimentation phase. Similarly near Zandwerven a sand barrier, most probably an aeolian formation on the eastern edge of a sand flat, was formed. Its age is known from a radiocarbon dating of

marine shells, underlying the dune at a level of about 3 m below N.A.P. The age was 4670 B.P. (table 5; Altena, 1958; see also Pons and Wiggers, 1959/1960, p. 142, and Kwad, 1961).

In the south-western part of the area, this is west and south of Zandwerven, open water conditions must have prevailed longer, as assumed by Kwad et al. (1965). Du Burk (1968) also arrived at this conclusion (see later).

The tidal flat area was adjacent to accumulating peat in the north and the east. The boundary between the tidal flats and the peat areas was mainly controlled by the altitude of the sea-level and the configuration of the Pleistocene sand surface (Jelgersma, 1961; Pons et al., 1963). Generally the boundary may be assumed to have been rather smooth; locally however, complicated boundaries may have existed (e.g. Eastern Flevoland, Enté, 1971).

The radiocarbon datings of the top of the Lower Peat near Julianadorp, in the north (table 5: Koegras), indicate that marine influence has been apparently almost absent prior to 5000 B.P. A similar dating from Anna Paulowna (table 2)

TABLE 5
Relevant radiocarbon datings in northern North Holland.

Location	Number GrN	Dating in years B.P. ¹⁾	Author	End of phase Calais
Berkhout	2499	4230 ± 80	Pons (see Kwaad et al)	IV A 1
Burgervlotbrug	1934	3810 ± 80	du Burck (p.c.)	IV B
	1937	4390 ± 80	du Burck (p.c.)	IV A 1
Hauwert	617	3240 ± 140	Pons and Wiggers	—
	609	3750 ± 120	Pons and Wiggers	IV B
	610	4090 ± 120	Pons and Wiggers	IV A 2
	605	4690 ± 140	Pons and Wiggers	III
	2070	4950 ± 70	Pons and Wiggers (resampling of 605)	III
Hobreede	4474	4290 ± 60	Kwaad et al	IV A 1
Hoorn	2386	4760 ± 80	Kwaad	III
Koegras	460	3965 ± 110	Jelgersma	IV B
	1060	4960 ± 80 ²⁾	Jelgersma	—
St. Maartensvlotbrug	1135	4320 ± 65	Jelgersma	IV A 1
Oostmijzen	4619	4380 ± 85	du Burck (p.c.)	IV A 1
Opmeer II	4621	3650 ± 75	du Burck (p.c.)	IV B
Opmeer I	4620	4140 ± 85	du Burck (p.c.)	IV A 2
Wadwaay	2382	3935 ± 105 ²⁾	Kwaad	—
	2975	4125 ± 75	Kwaad	IV A 2
	2389	4420 ± 90 ²⁾	Kwaad	—
	1583	4670 ± 55	Altena	III

¹⁾ obtained by applying correction to original Gro-numbers (Vogel and Waterbolk, 1963.

²⁾ for top of peat layer; other datings refer to base of peat layers, excl. Hauwert 617 and Zandwerven, which refer to shells.

indicates, that the sea invaded that area some time after 5600 B.P. On the other hand in the midwest of the Wieringermeer the sea was rather near about 5700 B.P. (fig. 4) and salt marshes were already formed locally.

The end of the older sedimentation phase in the Balgzand area has been dated about 4600 B.P. Earlier in this publication this phase has been considered to be a late stage of the Calais III phase.

Not much is known about the pattern of sedimentation during the Calais III phase. The pattern probably had rather large dimensions with vague transitions. This does not contradict the concept of a tidal flat area. The location of the original gullies, however, is difficult to trace. In the section figure 4 it can be observed that the marine sand is found in the west at a higher level than in the east. If we look at the corresponding point in section figure 5, a relation is suggested between the sand in the subsoil and the presence of an older phase of the southern large gully of younger age. However, such a relation does not exist in the case of the northern gully of the Wieringermeer. This indicates the relative unimportance of the northern gully at that time, if this gully existed.

Calais IV A 1 phase

The transgression phase of Calais IV A 1, which terminated about 4400 B.P. seems to have brought no sediments towards the north into the Balgzand area. This conclusion has been derived from the thickness of the peat layer overlying the Calais III phase. It can safely be assumed that sedimentation has not taken place before 4300-4200 B.P., as the thickness of the peat layer requires at least a few hundred years of peat accumulation. Sediments of phase Calais IV A 1 are also absent at Hauwert and Hoorn in West Friesland (Pons and Wiggers, 1959/60; Kwaad, 1961).

In other places the sediments of phase Calais IV A 1 are present, however. Quite a few datings are available to demonstrate that a general regression occurred at about 4300-4400 B.P., leading to peat accumulation on top of the marine sediments (Wieringermeer, Berkhout, Burgervlotbrug, Hobreede, St. Maartensvlotbrug, Oostmijzen). The last three sites are located in an area which was regarded as part of an open lagoon, which had been silted up completely at that time (Kwaad, 1961; du Burck, 1968). The pattern of sedimentation in this former lagoon seems to have been very vague and of an extensive scale. The position of the last gullies is not known. Dark grey to black subaquatic clays may indicate their location, a possibility which has been overlooked so far.

In the north-eastern area the sedimentation pattern of the Calais IV A 1 phase is completely different, as may be inferred from the data of Balgzand, Wieringermeer and mid West Friesland (Kwaad, 1961; du Burck, 1968). For a large part these areas were dissected by numerous small and middlesized creeks. Some of the larger creeks may have followed the same course as creeks present in an earlier phase. This is probably true for the southern gully in the Wieringermeer, as discussed above. With regard to the northern gully an earlier gully having the same course is, however, difficult to trace. If such an earlier gully existed here, it must have been a relatively unimportant one. Moreover, the younger gully apparently had a great erosional power (see fig. 2), so that much of the older sediments may have vanished.

The evolution of the north-eastern sedimentation area during the Calais IV A 1 phase, fits in the general observation, that in areas where silting up has proceeded well above mean sea-level, creeks become deeper. In other words further evolution in a tidal flat area results in more prominent contrasts.

Calais IV A 2 phase

Many datings from peat beds on top of marine sediments have shown that a regression has taken place at about 4100 B.P., this is the end of the phase Calais IV A 2 (Wieringermeer, Aardswoud, Hauwert, Opmeer, Wadwaay). No deposits of the Calais IV A 2 phase seem to be present in the Balgzand

area, as was stated before. The same situation is presumed for the western area.

In the Wieringermeer area both the very large northern gully as well as the southern one present in the preceding phase, continued to exist. In the southern part also medium-sized creeks of the preceding phase, maintained themselves during the Calais IV A 2 phase. This means, that patterns of different phases in palaeographic maps will be similar. This contrasts with the strongly individual patterns suggested by Pons and Wiggers for each phase.

The fill of the northern gully in the Wieringermeer consists partly of dark grey to almost black subaquatic clay of rather considerable thickness. Probably this filling was deposited rapidly when the area was silted up. Generally speaking during phase Calais IV A 2 less sediment was transported than during the preceding phase. This diminishing of sedimentation in the Wieringermeer is a prelude to the following final regression, when peat accumulation in this area prevailed.

Calais IV B phase

Quite a number of datings of peat beds on top of marine deposits indicate the occurrence of a regression at about 3850 B.P. which is at the end of the Calais IV B phase (Balgzanddijk, Anna Paulowna, Aardswoud, Burgervlotbrug, Hauwert, Koegras, Opmeer). In the Wieringermeer and Vier Noorder Koggen, beds of Calais IV B are present near or at the surface. Here they clearly overly beds of the preceding Calais IV A 2 phase, as they are separated from them by a peaty layer. Furthermore the inversion ridge of Abbekerk is regarded by du Burck (1968) as being formed during this phase. At Hauwert in West Friesland strata of this phase are reasonably well developed. This is even better the case in eastern West Friesland (Ente, 1963, appendix 3), presuming that the thin vegetation-layer found here represents the end of this sedimentation phase.

With the exception of the south-eastern part no sediment of the Calais IV B phase has been found in the Wieringermeer, although its presence in the northern gully was left open for discussion.

In the Wieringermeer area it is supposed further that peat accumulation was predominant during phase Calais IV B. Presumably the marine beds of this phase wedged out in peat. However, all factual evidence for this presumption has apparently been wiped out by younger erosion.

In the Balgzand area only the top of the peat has been eroded. Here the wedging out of the sediments of the Calais IV B phase in the peat can still be found.

Dunkirk 0 phase

Following the Calais phases, sediments of the Dunkirk 0 phase are found in the area under discussion, which will be dealt with for completeness sake only. The presence of sediments from this phase is more restricted than of those of

all earlier mentioned phases. They occur in West Friesland only. Details of the sedimentation pattern have been published by Ente (1963). From the configuration in eastern West Friesland near Bovenkarspel it may be inferred that part of the creeks and gullies present during this phase existed during the preceding Calais IV B phase.

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