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DEVELOPMENT OF THE WESTERN PART OF THE NETHERLANDS DURING THE HOLOCENE

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GENERAL ASPECTS OF HOLOCENE STRATIGRAPHY AND CLIMATE

The genetic history of the coastal area of the Netherlands may be looked upon as almost completely governed by one main agent, the climate. This agent sometimes manifests itself directly – for instance in the dune area by means of an alternation of peaty or humic layers with sand blown layers – in many other cases indirectly by means of derived agents such as the absolute sealevel rising, the isostatic movements and river water content.

This is the only consideration on which we ever may expect to base a worldwide Holocene stratigraphy in which consideration we also have to incorporate the plausible starting point that, at least the main, climatic tendencies have their influences in some manifestation all over the world.

On the other hand – might this approximation come true – at least the main lines of this stratigraphy should be the same, as well in marine as in terrestic areas in contrary to older epochs where other agents, such as tectonics, with a regional character completely overrule the climate agent. In a way these considerations are valid for the whole Quaternary, but especially for the Holocene, because of its very big scale enlargement in relation to the geological perspective. In other words, we are studying a time space which is so small that the proceeding of long wave geological cycles is practically zero and that, in far most cases, we have to do with a single value proceeding caused by the agent climate.

Therefore the study of Holocene may be considered important as, from a certain point of view, it may be looked upon as the rare case in nature of one equation with only one unknown. Of course others than climatic influences also incidentally occur, and have their influences, such as vulcanism and earth quakes, salt tectonic etc., which prove that the long wave cycles are going on, but these events only locally have influenced the climatically reigned pattern of sedimentation.

The philosophy just mentioned above, raises the importance of a detailed study in a favourable region and gives it, especially with respect to a worldwide stratigraphy, a high general value.

INTRODUCTION

At the end of the Weichselian a vast and mainly sandy plain built up by fluviatile and periglacial deposits, slowly dipping from the southeast to the northwest, offered in the Dutch region the surface over which the sea rising in accordance to the melting of the inland ice – consequently transgressed from the northwest to the southwest.

This flat and poorly accidentated plain – especially by means of its very gently sloping character – formed a highly sensible area to registrate the proceeding of the post-Weichselian marine transgression.

The record of this sealevel movement, however, is only to be read in areas where sequences of stratified and determinal layers are fossilized. Such an area we now find behind the present Dutch coastal barrier.

Although the absolute sealevel rising, caused by the melting of the inland ice masses, formed the main factor of the Holocene marine transgression in the Dutch area, other factors, for instance the isostatic movements of the earth crust and also real tectonic movements, may have played an important role in the mechanism of the Holocene marine transgression in

DIVISION AFTER BLYTT-SERNANDER

Subatlantic	700 B.C.- Present
Subboreal	3000 B.C.- 700 B.C.
Atlantic	5500 B.C.- 3000 B.C.
Boreal	7500 B.C.- 5500 B.C.
Preboreal	8100 B.C.- 7500 B.C.
Weichselian	

Fig. 1

this area.

All these movements are accumulated in that single feature which we call the "relative sealevel movement".

In the Dutch coastal area this relative sealevel movement has formed an excellent registration due to the fact that the most important factors, absolute sealevel rising, isostatic movements and probable also the tectonic subsidence all worked in the same sense, that means enlarged the relative sealevel rising.

This enlargement of the vertical scale made it possible that younger layers not only could develop on top of the older ones, but even attain a thickness in which a complete cycle of sedimentation of the separate layer was expressed. The latter is important to split up the Holocene transgression as a whole into phases of increasing and decreasing transgressive activities.

However, the conditions just mentioned would not have been of any value if two other favourable conditions had not reigned in this area.

In the first place the development of a coastal barrier.

This barrier probably was erected already during the middle-Atlantic about at the place where it still exists. Due to the combined action of tidal streams, and deepness and shape of the sea bottom, it protected the weak sediments in the lagoon behind. Only under these protective conditions a "sedimentological record" of this type could be built up and be preserved. The second favourable condition was the fact that the above mentioned lagoon was partly fed with sediments and fresh waters of the rivers Rhine and Meuse which entered into the lagoon from the east. Not only the river inlets were important; these rivers also had their big estuary shaped outlets through the coastal barrier. These outlets formed the main connections through which the sea could come in at high tide and distribute its sediment through the relatively quiet lagoon.

These conditions made the Dutch coastal region even more sensible as a registration area, for the river outlets through the coastal barrier worked as a ventile.

During times of enlarged transgressive activities these ventiles admitted the sea water to come in in such amounts that the areas around the inlets turned from brackish to marine and more land inward areas turned from fresh to brackish. Accordingly the marine and brackish sediments as clayey sheets with sandy gulleys invaded eastward. Deep erosion only took place in the main gulleys. In general, however, we can say that the fresh water sedimentation and peat growing was pushed back, but not destroyed.

On the opposite, during decreasing aggressivity of the sea, the fresh water restored its influence almost until the river mouthes and humic and peaty layers "marched on" again from the east till in the coastal barrier area.

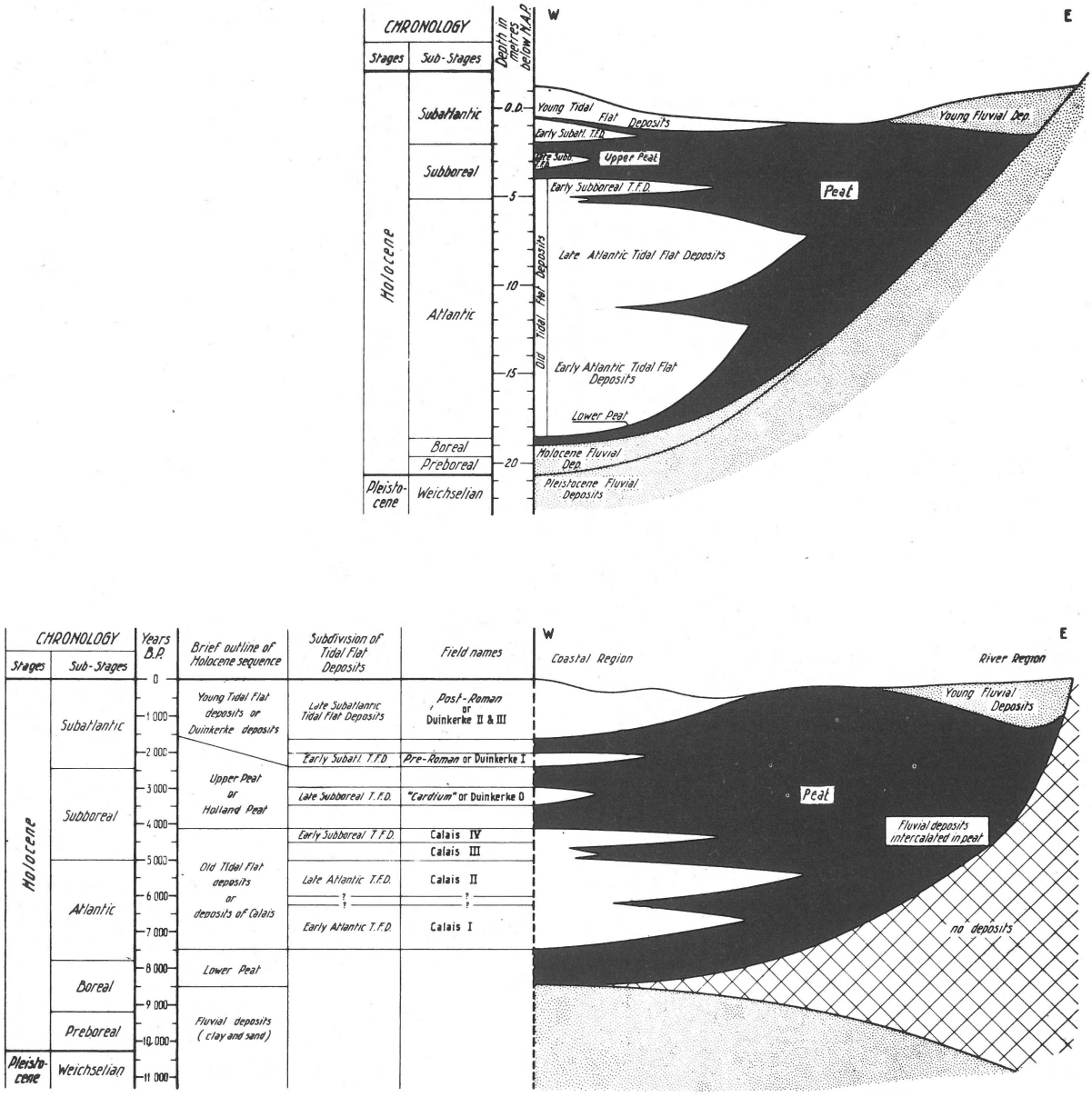
THE HOLOCENE DEPOSITS AT THE BASE OF THE HOLOCENE SEQUENCES

At the end of the glaciation the restoration of oceanlevel started. The Northsea area became again a sea during the Early Holocene period. (Boreal and Preboreal.) At the end of the Boreal (± 5500 years B.C.) the coastline of the Northsea approached the present coastline of the Netherlands.

In front of the invading sea the groundwater table got related to the rising sealevel instead of to the inland conditions and started to rise. This relatively sudden break of the groundwater equilibrium had several consequences. The most important was the drowning of a wide landstrip, along the transgressing sea.

By means of both factors, the improved climate and the higher groundwater level, a backswamp area in front of the invading sea came into being. As the sea went on rising, the peat layer, originated in the backswamp area, got covered by marine sediments and the backswamp moved upward over the gentle slope towards the east.

Another probable consequence of the break of the



After Pons, Jelgersma, Wiggers and de Jong.

Fig. 2

equilibrium of the groundwater surface and the sudden rise of a part of it, was the genesis of numerous springs at the feet of the ice-pushed hills (pushed during the Saale glaciation) at the eastmost boundary of the backswamp area. These springs may also have fed the backswamp area with eutrofic water which stimulated the vegetation and formed the origin of the local drainage pattern.

As to the datings of this so called "basis peat" layer in the deeper western part of the coastal area, the peat growing started during the late-Boreal, whereas in the more shallow eastern part the first

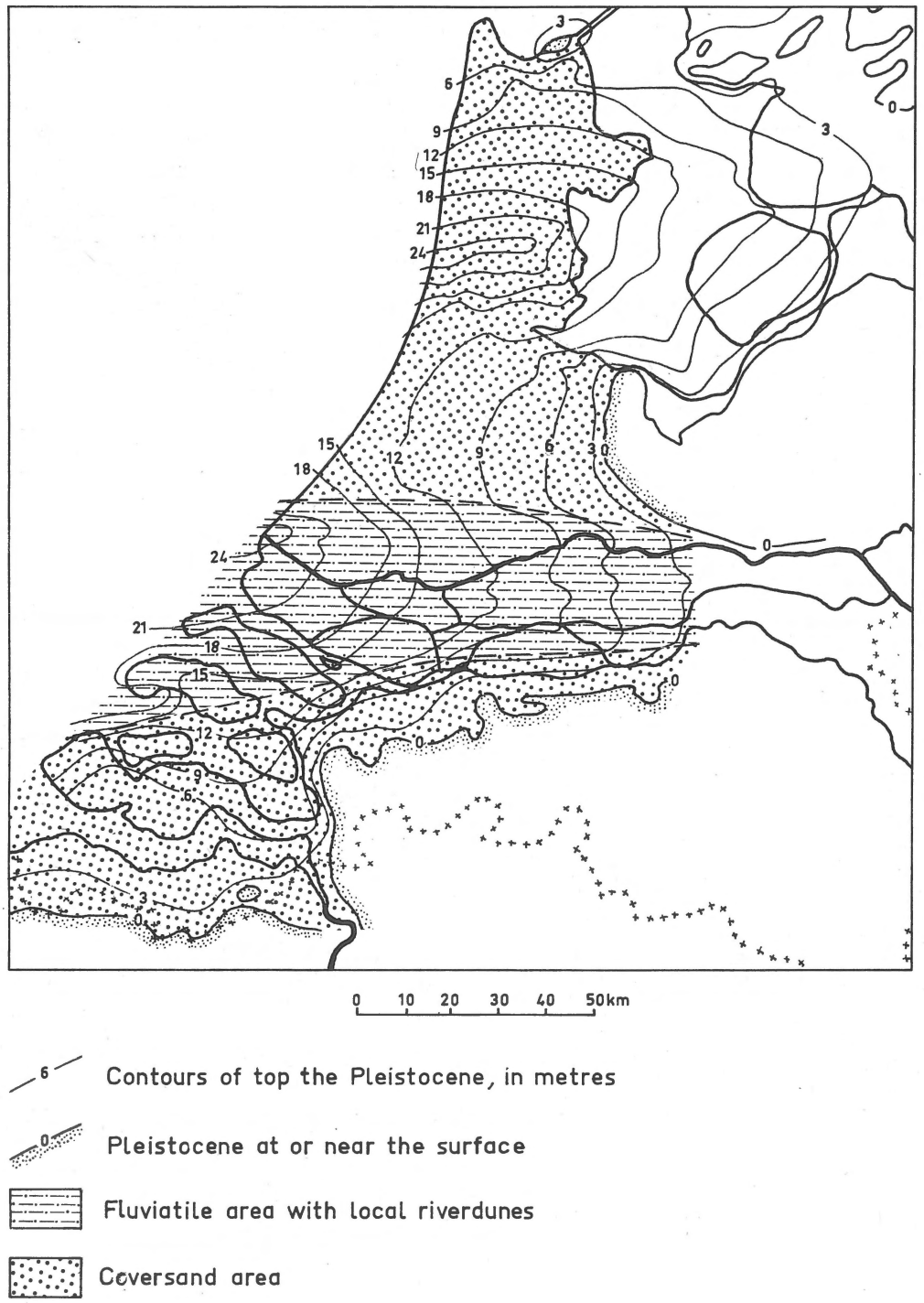

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0 10 20 30 40 50km
6
Contours of top the Pleistocene, in metres
0
Pleistocene at or near the surface
Fluviatile area with local riverdunes
Coversand area

Fig. 3

appearance of the "basis peat" layer has to be placed in the second half of the Atlantic (see figure 2).

The datings and depths of the base of this "basis peat" layer have been used to reconstruct the early part of the relative sealevel rising curve. In order to use this hypothesis of fixed relation between peat growing and relative sealevel movements one has to be sure that the relative sealevel rising was the only agent which started the peat growing. This example may also be looked upon as a demonstration that many times a development starts not because some factors are present in a unlimited amount, but because of the fact that the most limiting factor has become more favourable and that the intensity of the development depends on this factor.

In this particular case, the climatic conditions were already favourable, just as the surface was rich in minerals, and peat growing only was waiting for an adequate groundwater level. (This considerations about the limiting factor is based on a well-known law of the economics, the law of the "minimum factor".)

Only in sectors where the genesis of the peat layer is of the just described type, the datings of the base of the peat layer can be used to reconstruct the relative sealevel movement.

In general such conditions are found in the drowned cover sand areas; similar conditions also occur against the flanks of the late-Weichselian and earliest Holocene river dunes.

In the areas where the late-Weichselian Rhine and Meuse sought their way to the sea, the development was different (Fig. 3.)

About the transition of the Weichselian into the Holocene the late-Weichselian braided river system carried less and less water and vast parts of the fluviatile area got covered with a lightgrey clay layer of some decimetres in thickness. This clay layer was deposited during short periods when exeptional high river water levels completely or partly irrigated the degenerated braided river plain. This clay layer on top of the braided river system got covered partly by a peat layer, partly by old Holocene river deposits and on some spots by wind blown sands from the river valleys which formed river dunes.

The time of coming into being of the oldest peat layers in this area cannot directly be related to the relative sealevel movement, because the groundwater conditions in this area depended on other factors such as the level of the river water and false water levels on top of clay layers. The time of their origination herefore can be rather different from place to place without consequent relations to their depth situation.

THE HOLOCENE SEQUENCES IN THE THREE MAIN MARINE INFLUENCED AREAS

In order to discuss the further development of the Holocene sedimentation in the western and northern part of the Netherlands, we have to divide the whole area into three main landscapes.

A. Lagoonal and tidal flat area.
B. Perimarine area
C. Beach and dune area (see fig. 4).

Description

With the term "Perimarine area" is meant the area where the sedimentation or seditation took place under the direct influence of the relative sealevel movements but where marine or brackish sediments themselves are absent.

Perimarine conditions mainly reign in the backswamp areas and in that part of the fluviatile areas where the downflowing river-waters have been pushed up by the rising sea, thus giving rise to the development of thick fluviatile clay layers, alternating with peat layers cut by fossil gulleys, filled up with sand.

A. The lagoon and tidal flat area

Main lithostratigraphic units of the lagoonal and tidal flat area. – According to the rapid sealevel rising of approximately 50 cm a century during the Atlantic, a relative thick sequence of lagoonal and tidal flat layers came into being. In the western part of the area corresponding to the deeper position of the Pleistocene surface, this thickness amounts to about 15 metres.

During the late-Atlantic and early-Subboreal, the speed of the sealevel rising diminished (figure 5) and at about 1800 B.C. the marine sedimentation in practically the whole area came to an end.

The lagoonal and tidal flat deposits got covered by a peat layer. This sequence of lagoonal and tidal flat

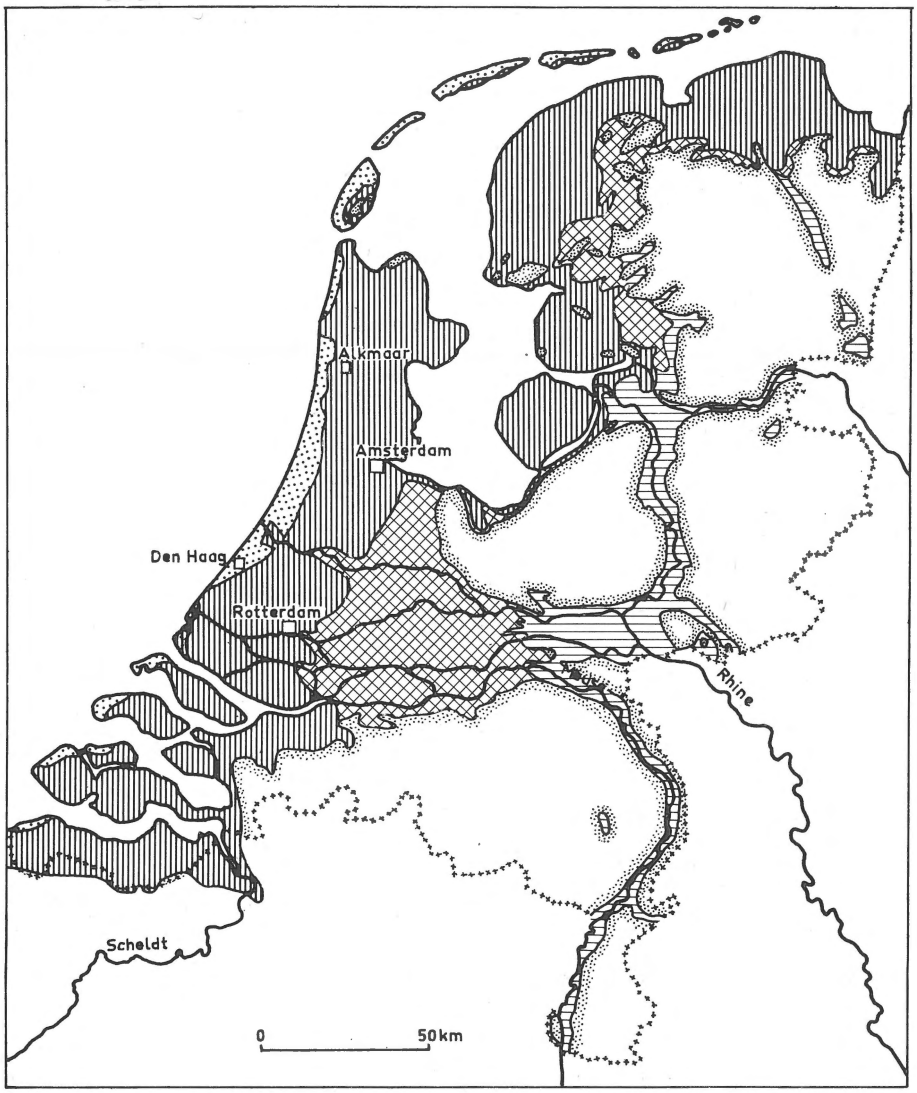

Alkmaar
Amsterdam
Den Haag
Rotterdam
Rhine
Scheldt
0
50km
Peri marine area
Holocene fluviatile deposits
Lagoonal and tidal flat area
Beach and dune area
Outcropping Pleistocene and older formations

Fig. 4

deposits overlying the basis peat layers and covered by the main peat layer of the "Holland peat" (± 1800 B.C.) we call the "Calais deposits" (figure 6).

The coming into being of a rather reliable barrier system combined with the retardation of the relative rise of the sealevel during the Subboreal to approximately 15 cm a century were the causes of a practically complete freshening of the lagoon resulting in an almost general peat growing. More eastward the agressivity of the sea during the sedimentation of the Calais deposits was so strongly diminished and the peat growing, stimulated by fresh water infiltration from the high Pleistocene landscape at the eastern edge, went on so fast, that in general the conditions for peat growing were in favour.

Via a transitional zone of interfingering, the whole profile in the eastmost part therefore consists of peat, the so called "Holland peat". As figure 6, profile A_1-A_2 shows, this Holland peat which forms almost the whole profile in that part of the perimarine area, sends its fingers according to the fresh water situation in the lagoon more or less far into the lagoon and tidal flat area. As to the stratigraphy, these "peat fingers" are the "hold fasts" for our stratigraphical subdivision.

Renewed marine aggressions along the coast since about 1500 B.C. caused new transgressions, which however show a different generation of deposits, the "Dunkirk deposits". These deposits mainly occur at the weakest spots in the coastal barrier system. Such spots often are the river outlets, furthermore the coastal sectors where the barriers only fragmentary occurred, such as in Zeeland and in the northernmost areas.

The Dunkirk deposits only incidentally reach average thicknesses of more than two metres; they mainly consist of clay sheets cut by a dendritic system of sandy filled gulleys of which the branches originate from the sector where the sea broke in.

Subdivision of the lithostratigraphical units "Calais deposits" and "Dunkirk deposits". – The section of the "Calais deposits" gives evidence of a certain cyclicity, an alternation of transgressive phases expressed by the cyclic occurrence of lagoonal and tidal flat deposits and peat layers in the vertical column.

The transgressive phases of these cycles are dated as follows:

Calais IV	2600 – 1800 B.C.	(C_{IV})
Calais III	3300 – 2800 B.C.	(C_{III})
Calais II	4300 – 3300 B.C.	(C_{II})
Calais I	6000 – 4500 B.C.	(C_I)

As can be derived from figure 6, profile A_1-A_2, these datings only have to be considered as time limits between which the particular transgression took place. The more eastward we move on the profile, the later the transgression came to expression in the sedimentation and the sooner the transgressive tendency vanished and peat growing was restored.

According to this we have a preference for these regions with the more quiet development to date the cycles of the "Calais deposits".

At the more levelled part of the curve (during the Subboreal and Subatlantic) the periodic fluctuations show a real temporarily elmination of the transgressive tendency. This phenomena also we find expressed in the sedimentation and schematically reflected in profile A_1-A_2 of figure 6. In this profile we see how the main peat layer of the Holland peat reaches the westernmost part of the sea. This peat layer can be found almost everywhere directly behind and within the coastal barrier system. The roles are reversed now and during the Subboreal and early-Subatlantic the peat growing is only temporarily and locally interrupted by the Dunkirk transgressions.

These Dunkirk transgressions have been dated as follows:

Dunkirk III	800 A.C. and later	(D III)
Dunkirk II	250 – 600 A.C.	(D II)
Dunkirk I	600 – 100 B.C.	(D I)
Dunkirk 0	1500 – 1000 B.C.	(D 0)

B. The perimarine area and its lithostratigraphic units

The term "Perimarine area" has already been defined. The fluviatile clay layer which partly covers the late-Weichselian braided river system and which originated around the transition of Weichselian into Holocene is present at the profile B_1-B_2 (figure 6), just as the river dunes (donken) which are partly syngenetic, partly postgenetic to the covering clay layer.

During the Preboreal, Boreal and early-Atlantic the relative sealevel rising yet hardly influenced the fluviatile sedimentation in this area and at that time

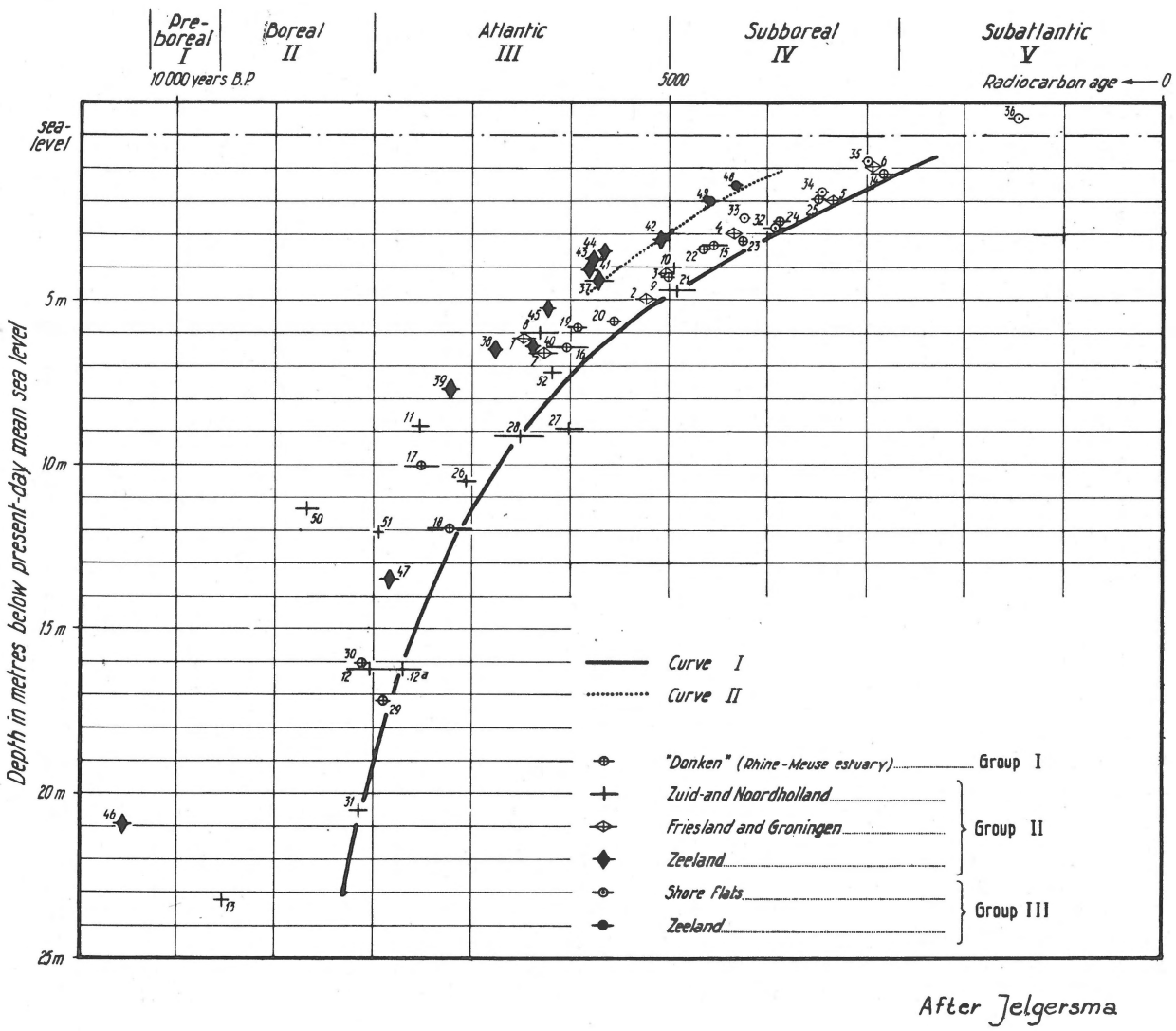


Fig. 5

the rivers deposited along the gulleys at times of high fluvial water levels, a heavy dark bluish grey clay often rich in humic material (see figure 7).

According to the fact that we only seldom met the dark clay on top of the light greyish one, but in general at a position slightly lower than the light greyish clay, we have to conclude that during that time accumulation not yet took place (figure 7). On the contrary, a tendency to build erosion terraces is still to conclude until the early-Atlantic.

During the middle and late-Atlantic however, the shore line quickly approached this region, the rising sealevel pushed up the water in this region which suddenly had become to be the utmost lower coarse of the river system.

This led to a series of sedimentological consequences. The length of the lower course, which was at that time pushed back to this region already, was now quickly shortened by the invading sea. Consequently the distance over which the sedimentated material had been distributed was pushed together. Too much material sedimentated over too short distances, the gulleys got quickly stooped up and formed bypasses, thus forming a river pattern resembling a braided system, but mainly built up at low velocities and as a consequence consisting of fine sand and clayey ma-

terial. But not only the minerogene sedimentation was stimulated in a relatively narrow area; the high levelled river waters, pushed up by the rising sealevel and widely distributed by the stopping up of the gulleys, procured the whole area with fresh eutrophic water which stimulated peat growing along the gulley systems.

In this way this perimarine area got rapidly built up by fluviatile sandy and clayey deposits and peat layers in accordance with the relative sealevel rising which is schematically characterized in figure 8.

The same mechanism in principle functioned during the first half of the Subboreal, also in accordance with the levelling of the sea rising curve, in a decreasing intensity.

During the late-Subboreal and the Subatlantic, the diminishing relative rising speed of the sealevel allowed a returning to more equilibrated situations.

By means of an adequately filling up of the gulley bottoms upstream and a restoration of the dynamic equilibrium between the gulley profile and the average river water discharge, the rivers reobtained a meandering character in a more stable pattern.

Figure 7-III shows the continuation of the building up of the system in the schematic section.

In figure 7-IV the rounding off of the whole sequence till the present days has been given. According to the levelled character of the sealevel rising curve, the Subatlantic sediment layer is relatively thin and at some places did not even cover the highest ridges of the early subboreal system.

Main lithostratigraphic units of the perimarine area. – Besides the Holland peat, which unit, in a way, can be considered as a kind of "trait d'union" between the "lagoonal and tidal flat area", the "perimarine area" and the "beach and dune area", the perimarine area has two main lithostratigraphic units, the "Gorkum deposits" and the "Tiel deposits". Both units consist of fluviatile sediments.

The "Gorkum deposits" are to be regarded as the perimarine counterpart of the "Calais deposits" in the lagoonal and tidal flat area. These "Gorkum deposits"

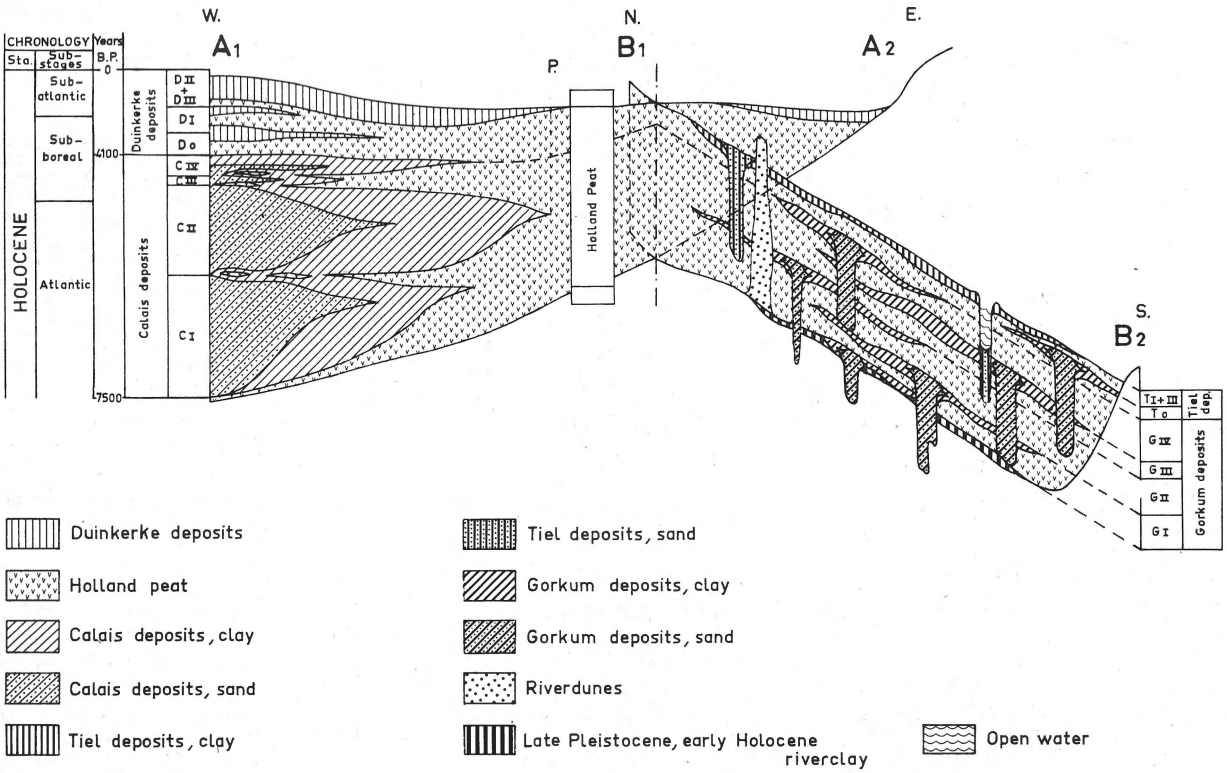


Fig. 6

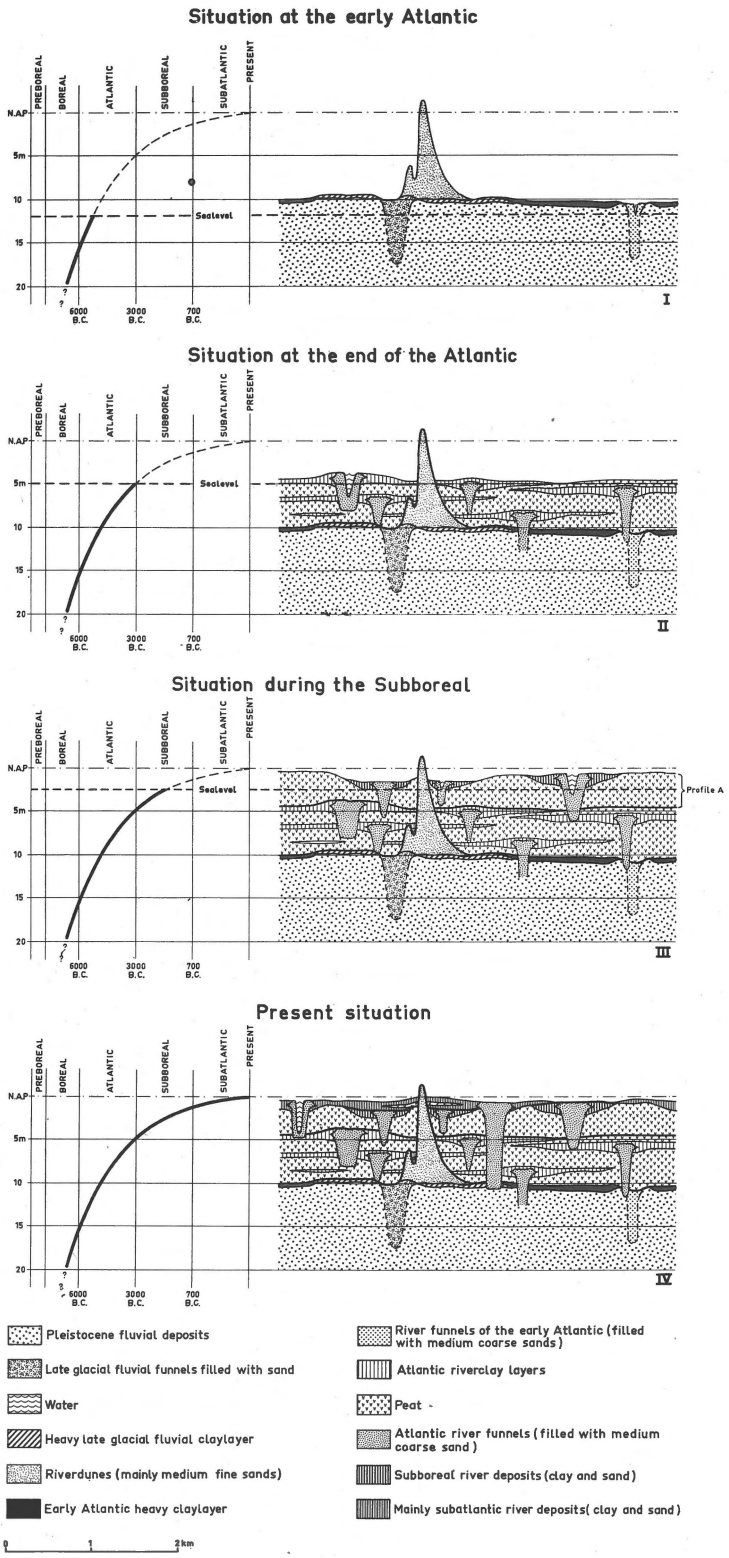

Situation at the early Atlantic
PREBOREAL
BOREAL
ATLANTIC
SUBBOREAL
SUBATLANTIC
PRESENT
N.A.P.
5m
10
15
20
Sealevel
6000 B.C.
3000 B.C.
700 B.C.
I
Situation at the end of the Atlantic
II
Situation during the Subboreal
Profile A
III
Present situation
IV
Pleistocene fluvial deposits
Late glacial fluvial funnels filled with sand
Water
Heavy late glacial fluvial claylayer
Riverdunes (mainly medium fine sands)
Early Atlantic heavy claylayer
River funnels of the early Atlantic (filled with medium coarse sands)
Atlantic riverclay layers
Peat
Atlantic river funnels (filled with medium coarse sand)
Subboreal river deposits (clay and sand)
Mainly subatlantic river deposits (clay and sand)
0
1
2km

Fig. 7

also originated during the period of strong sealevel rising, and consequently show a relative strong development of distinct phases overlying each other. They too end during the middle-Subboreal (at about 1800 B.C.).

The genetic relation between the "Calais deposits" and the "Gorkum deposits" is demonstrated in figure 8. This figure suggests a direct correlation between transgressive phases in the lagoonal and tidal flat area and periods of increasing fluviatile sedimentation in the perimarine area.

The effect however, is different in both areas. When in the lagoonal and tidal flat area vast sheetlike deposits came into being, in the perimarine area an irregular and complicated system originated of sandy filled gulleys and clay strips, interweaving and alternating with peat layers.

The "Tiel deposits" show a similar character as the "Dunkirk deposits", in so far that they also are relatively thinly developed and that the distinct phases of the "Tiel deposits" are separated either by very thin peat layers or only by a dark humic horizon.

Each distinct layer of the "Tiel deposits" can horizontally be subdivided into two main different lithogenetic units, the stream deposits and the basin deposits (or decantation deposits), the former consisting of coarse to medium fine sandy material, the latter of often very heavy clays. These two extremely different types of sediments are, as a rule, separated by narrow but well developed levees along the gulleys. Furthermore crevasse deposits and so called "wash over deposits" often occur. The latter can be considered as a catastrophical kind of crevasse, ori-

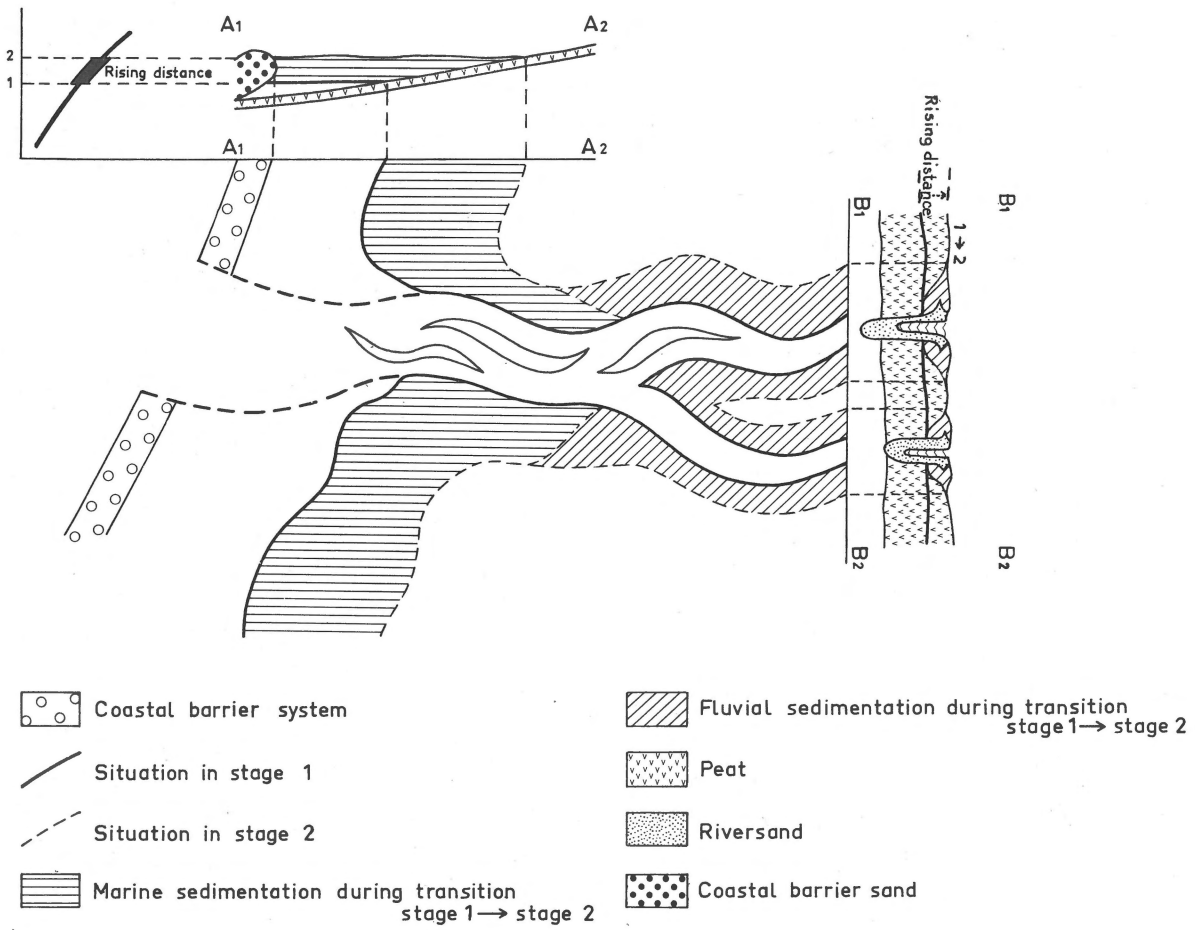
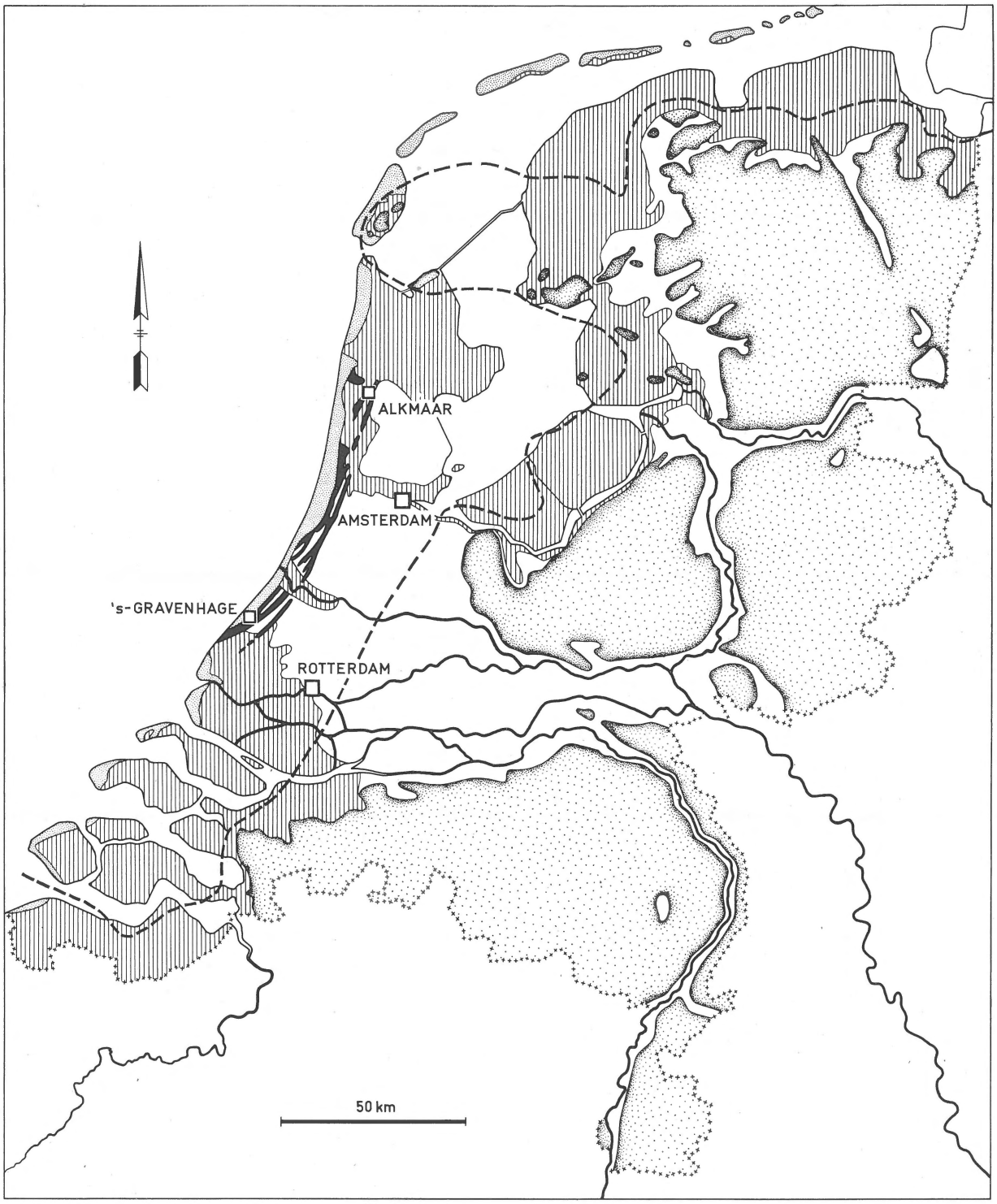


Fig. 8



1 Subatlantic marine deposits

2 Subatlantic coastal dunes

3 Landward limit of the Calais deposits

4 Late Atlantic and Subboreal coastal barriers

5 Outcropping Pleistocene and older formations

Fig. 10

ginating when a dike broke through.

Lithostratigraphic subdivision of the "Gorkum deposits" and the "Tiel deposits". – In the foregoing a correlation between the lithogenetic development in both areas – the lagoonal and tidal flat area and the perimarine area – has been made plausible. Considerations on the basis of these lithogenetic conformities led to investigations which had to decide whether for the Gorkum deposits a parallel lithostratigraphic subdivision could be used as for the "Calais deposits" in the lagoonal and tidal flat area.

These investigations were carried out by means of long sections from the lagoonal and tidal flat area far into the perimarine area, on which sections many probes were taken and elaborated on pollen and C14.

In accordance to the findings of these investigations the "Gorkum deposits" indeed have been subdivided completely indentical to the Calais deposits as follows:

Gorkum IV	2600 – 1800 B.C.	(G_{IV})
Gorkum III	3300 – 2800 B.C.	(G_{III})
Gorkum II	4300 – 3300 B.C.	(G_{II})
Gorkum I	6000 – 4500 B.C.	(G_{I})

As to the "Tiel deposits", similar considerations also led to the same lithostratigraphic subdivision as were already used for the marine equivalent, the "Dunkirk deposits".

This subdivision shows up as follows.

Tiel III	800 A.C. and later	(T_{III})
Tiel II	250 – 600 A.C.	(T_{II})
Tiel I	600 – 100 B.C.	(T_{I})
Tiel 0	1500 – 1000 B.C.	(T_{0})

C. The beach and dune area

Figure 9-I-II-III-IV shows how the successive stages of the coastal barrier system could have developed.

Figure 9 (I-II) characterizes the period in which the barrier system was pushed ahead by the sea. These processes can be compared with the working of a bulldozer and may be regarded as characteristic for the period of relative quick sealevel rising in the Atlantic. During these processes the quantity of the material pushed together in the barrier system increases. It is plausible that the eastward movement of the barrier system came to an end on the one hand because of the decreasing aggressivity of the sea according to the levelling of the sea rising curve, on the other hand by means of the increased resistance of the accumulated sand mass in the barrier system.

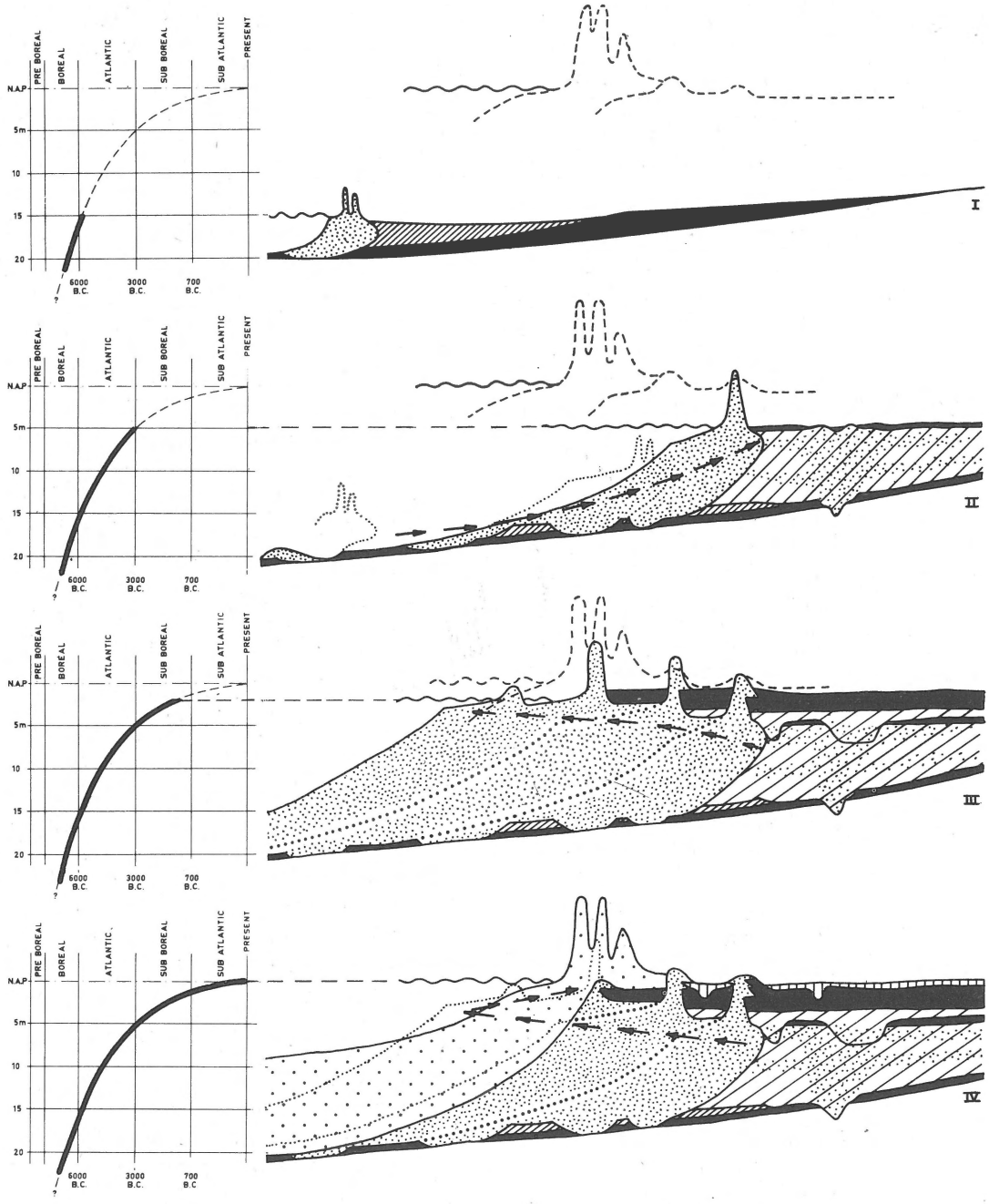
Using the term resistance we have to distinguish between the resistance of a barrier system against long shore drift or longitudinal drift and the transversal drift caused by the waves running against the beach.

The resistance against long shore drift is about zero, for the current carries the sandy material away; meanwhile the resistance against transversal wave attack is high, as the material is mainly reworked in the breaking zone but stays in the attacked sector, killing the energy of the waves. From this point of view it is plausible to consider the transversal wave effect as the main agent building the barrier system. This might already have happened during the early stage (figure 9-I) when the breaking waves collected the initial sandy material from the slightly dipping Pleistocene surface to accumulate a ridge.

The low resistance of a barrier system to erosion by means of long shore streams means that the barrier system in this area, where tidal currents occur, can only be formed in directions consequent to these stream directions, in other words in an equilibrium with the tidal current pattern. An almost perfect accordance between the current pattern and the shape of the coastal barrier system therefore does not mean that the long shore had to be the most important building agent. It only means that these directions, because they were not subdued to erosion, were the only ones in which the barriers have been allowed to come into being.

It is clear that the "bulldozing" actions of the waves mentioned before must have been most successful on a regular slightly dipping surface. But, in regions where the Pleistocene surface had an irregular shape, for instance as a result of river gulley patterns, the coördination of the wave activities along one line were destroyed and formation of single accumulations might have occurred. Resuming it may be that only in the central part of the Dutch coast, as a consequence of a favourite Pleistocene topography, a more or less continuous reliable system of barriers ever existed.

Figure 9-II characterizes the turning point in the development of the coastal barrier system (± 3000



Sealevel

Present sealevel

Present morphology

Former morphology, fossilezed

Former morphology, eroded

Peat

Old dune sand

Young dune sand

Calais deposits, heavy clay

Calais deposits, sandy clay

Calais deposits, sand

Dunkirk deposits

Partly after v. Straaten

Fig. 9

B.C.). From now on accumulation is in favour. The decreasing speed of relative sealevel rising causes a less quick passing of the deepest part of the offshore strip – which strip provides the material to be pushed up by wave actions towards the coast – beneath the critic level where wave action no longer attacks the seafloor. This means an enlargement of the "active" part of the offshore strip.

Moreover, according to the decreasing speed of sea level rising, the space to be filled up between two level stages is growing less and the accumulation surplus starts building barriers in front of the former ones.

From that time on the barriers are fossilized. The slacks in between the barriers got filled with peat layers.

The easternmost slack also has partly been filled with clays of the Calais IV transgression (figure 9-IV). This means that already at that time the second barrier, counted from the east, must have existed and have protected the easternmost slack against the sea.

In figure 9-III a phase near the end of the Subboreal development of the coastal barrier system is characterized. This system of barriers and slacks as a whole is called the "Older Dunes" and is supposed to have been built up between 3000 and 1800 B.C. After that time a phase of standstill followed, which may correspond with a period of equilibrium between accumulations at the shore line and the relative sealevel rising. This period lasted until about 1200 A.D., when a new type of dune building started, which form the so called "Younger Dunes" (see figure 9-IV).

We do not know much about the reason of the origination of this system of the "Younger Dunes", maybe a change in the pattern of the tidal streams was due to it. Indications in that direction can be derived from figure 10. This figure indicates that, especially in the south-western part of the coastal area, large parts of the "Older Dunes" system have been cut away by the sea. Referring to what has been said about the resistance against erosion of such a system of sand barriers, it is likely to accept for this feature erosion by means of long shore tidal streams.

In other words, the elongation of the system of the "Younger Dunes" should be in accordance with a new tidal current pattern as it came into being between 1000 and 1200 A.D.

This new current system showed a less curved line along the coast and therefore completely cut away the outwards bending parts at the extremities of the Older Dune system, which system was built up consequently to the former tidal current pattern.

The changing of the tidal current pattern might have affected the process in a double way. In the first place erosion took place of large strips of the coastal barrier system. In the second place the eroded material was transported and sand accumulated on the near shore strips of the offshore platform. At that time transversal transport of the sand from the newly provided near shore sand depots to the beach by means of the wave actions again got an immense impuls. The "Younger Dunes" system nowadays witnesses, by means of its high and broad development at several places, that big amounts of sands were available in front of the beach at the time the system was originated.

Another indication that at the time between 1000 and 1200 A.D. a considerable sanddrift passed along the coast can be derived from the fact that also about 1000 A.D. the mouth of the river Rhine near Katwijk (north of The Hague) silted up completely.

Figure 9-IV is a schematic section at a place where the barrier system of the "Older Dunes" partly has been eroded; it has to be considered to be located somewhere around The Hague. At other places, near Haarlem for instance, as shown by figure 10, the "Older Dunes" may scarcely have been attacked by the new tidal current pattern.

About the detailed stratigraphy of the "Older Dunes" and "Younger Dunes", mainly due to climatic cyclicity, is dealt with in the article of Jelgersma and Van Regteren Altena in this issue.

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