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SEDIMENTARY GEOLOGY OF THE HOLOCENE IN LAKE IJSSEL REGION

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ABSTRACT

Topics of the Holocene sedimentary geology based upon detailed investigations in the third polder of the Zuyderzee project are presented.

They comprise distribution, composition and dating of sediments of the Calais-transgression phases, strongly bound to the evolution of the western Netherlands. Mainly after the first Duinkerke-transgression phase the development evolves towards a separate history of the Zuyderzee. Its evolution from a complex of lakes towards a brackish-saline lagoon is shown by the described sediments of different composition. The development of the delta of the river IJssel is brought into relation with that of the lagoon. The displacement of sands along the coast by wind/wave effects is shown, together with the phenomenon of numerous megaripples present at the edges of the sand masses.

INTRODUCTION

In the Zuyderzee project, at present called the Lake IJssel project, many investigations of a sedimentological/geological nature have been carried out. Wiggers (1955) dealt extensively with this type of data from the North-East Polder. Investigations have been continued in the younger polder Eastern Flevoland – since 1957 – and have almost been completed by now. Some topics are presented here and compared with the older investigations.

The future polders have been roughly surveyed under water before 1960, the results of which have already been published (Pons and Wiggers, 1959/1960). They have been inserted in a more general framework by Pons, Jelgersma, Wiggers and De Jong (1963) which publication can be taken as a background for the present article.

TOP OF PLEISTOCENE

Figure 1 shows contours of the Pleistocene surface with regard to the Late Pleistocene braided-river systems of IJssel and Vecht, accompanied by river dunes, as well as with regard to the surrounding, contemporaneous coversand area. Pons, Jelgersma, Wiggers and De Jong (1963) gave the general contours for the lower part of The Netherlands. They stressed the great influence of the Pleistocene relief upon the development of the Holocene coastal history.

HOLOCENE

Until roughly 2000-1500 B.C. the sedimentation in the Lake IJssel region generally reflects that of the western Netherlands (fig. 2) but particularly it can be characterized as representing the marine-perimarine border (Hageman, 1969). It should be noticed however that this borderline shifted in course of time viz. has moved upwards (eastwards) as a consequence of the relative rise of the sea level (Jelgersma, 1961).

In the Middle Atlantic the marine influences

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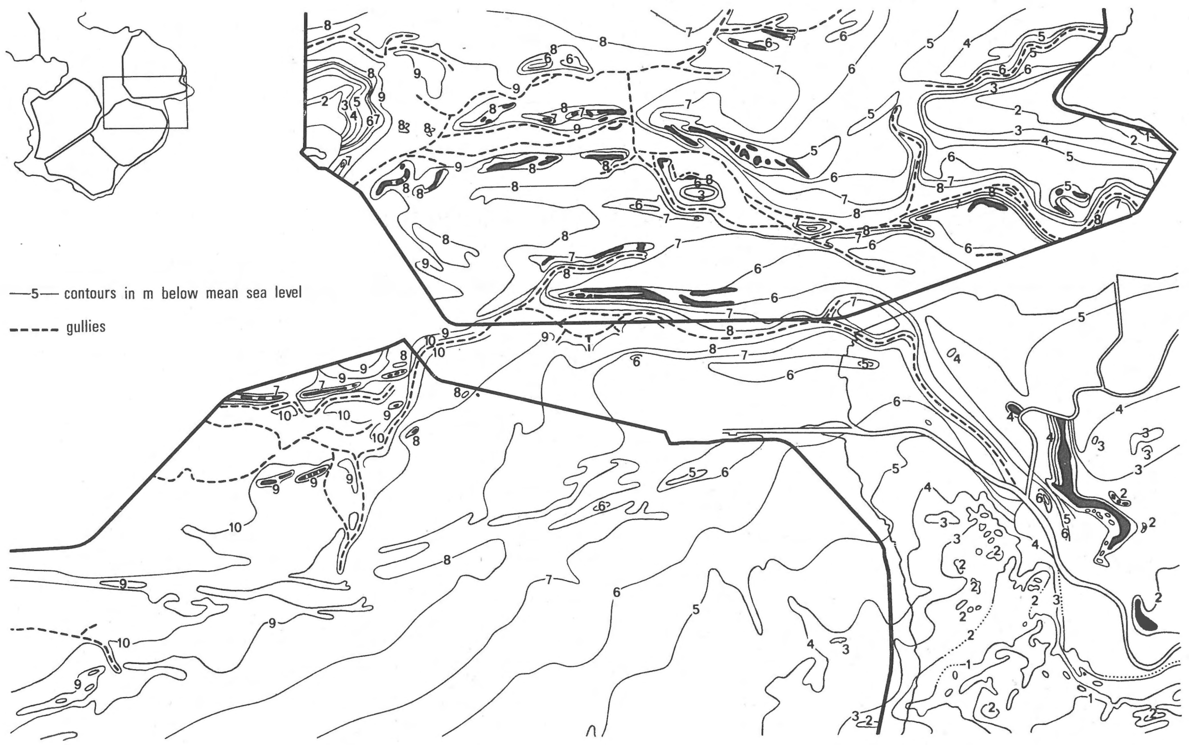

Fig. 1
Contours of the top of the Pleistocene (higher upstream some river dunes might belong to the Holocene; supplemented with data from the Soil Survey Institute).

reached the eastern Lake IJssel region. Drainage channels in the perimarine peat area – largely related to the Pleistocene relief – served as inroads for these influences. It can be assumed that the best developed perimarine drainage channels were those related to the most pronounced Late Pleistocene gullies and that they served as the inroads for the earliest transgression phase found here. With this in mind the older Calais phase was assumed to be present in the northwestern part of Eastern Flevoland and the southern part of the North-East Polder. The Calais Deposits farther south and farther north were supposed to be younger (P o n s et al., 1963). This has to be modified, as will be shown.

From 2000-1500 B.C. the sedimentation in the Lake IJssel region deviates clearly from that of the western Netherlands. Sedimentation then takes place in an extending lagoon, connected towards the north with the North Sea by an ever widening entrance.

Existing processes were suddenly halted in 1932 when the entrance was dammed off.

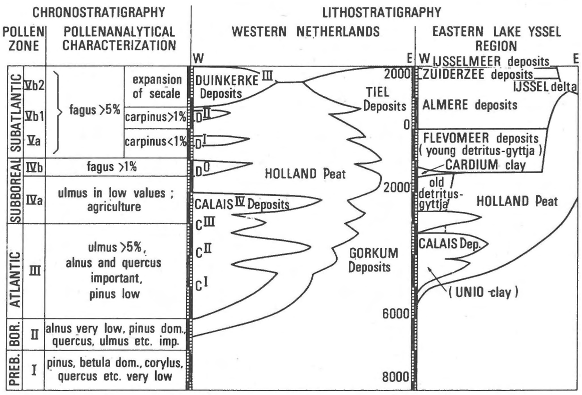

Fig. 2
Holocene stratigraphy (after Jelgersma, 1961; Hageman, 1969; Verbraeck, 1970).

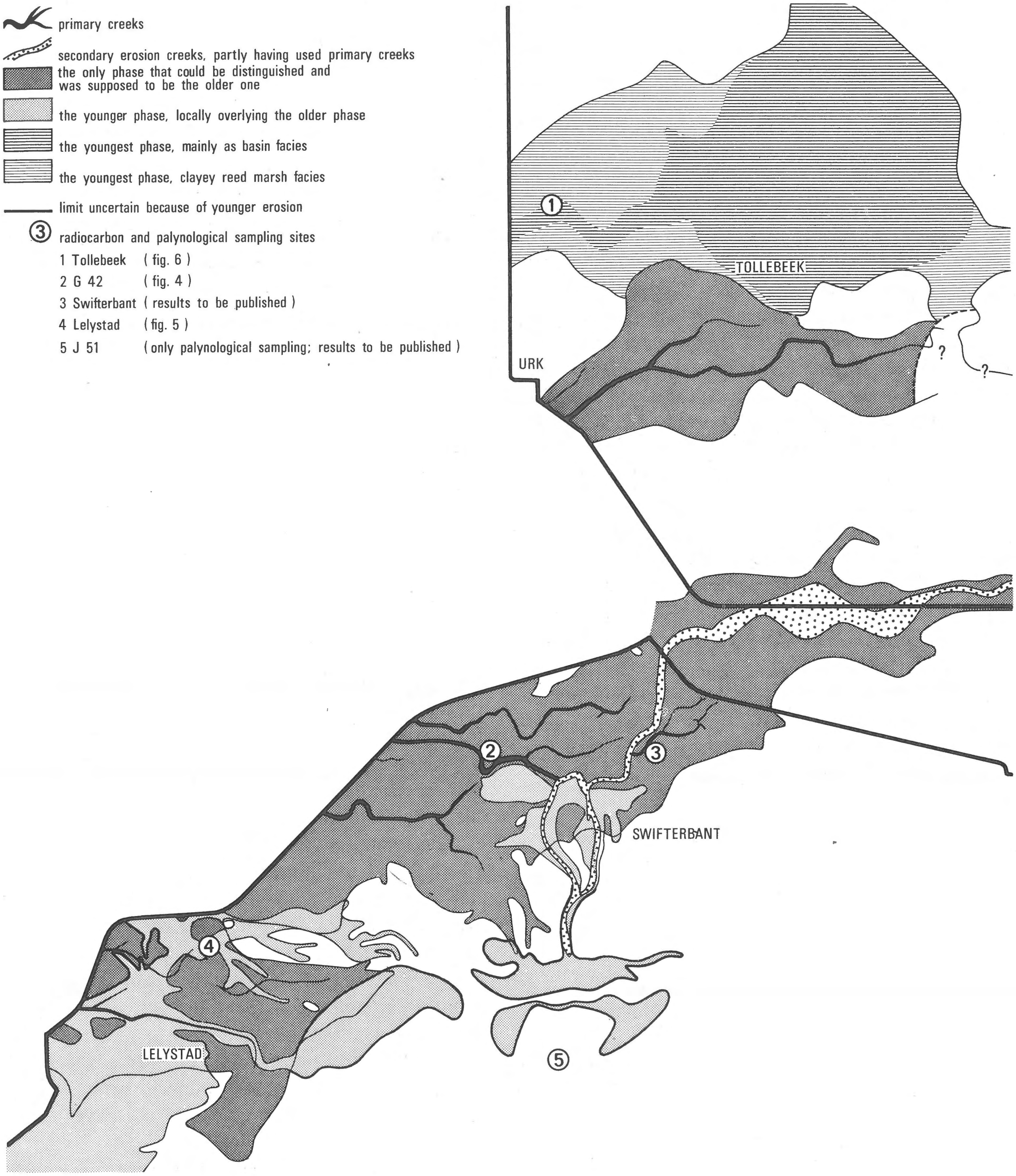

Fig. 3
The Calais Deposits.

Facies of the Calais Deposits. The different occurences of the Calais Deposits are here successively described.

A well developed system of creeks with levees and backswamps existed in the northwestern part of Eastern Flevoland (fig. 3 and fig. 4). The levee deposits are compact to a great depth (down to $8\frac{1}{2}$ m below mean sea level), in contrast to the backswamp deposits which are very soft. The compactness of the levee deposits can be explained by the higher position and consequently the better drainage during sedimentation, together with the evapo-transpiration due to climate and vegetation at that time. Simultaneously decalcification of the top layers has taken place. The soft backswamp deposits are relatively rich in organic matter (up to 20%) partly consisting of clearly distinctable debris of reeds. In the original situation they must have reached to a higher level (Ente, 1964). Compression of the clays and the underlying peat has lead to the present situation (in contrast to the levees which can be regarded as being almost insusceptable for compression). Both, levees and backswamps consist of clay, generally containing 40% of particles smaller than 2 micron. The clay was derived mainly from the west. Minor amounts of clay might have been supplied by the rivers, which certainly supplied larger quantities of fresh water, for

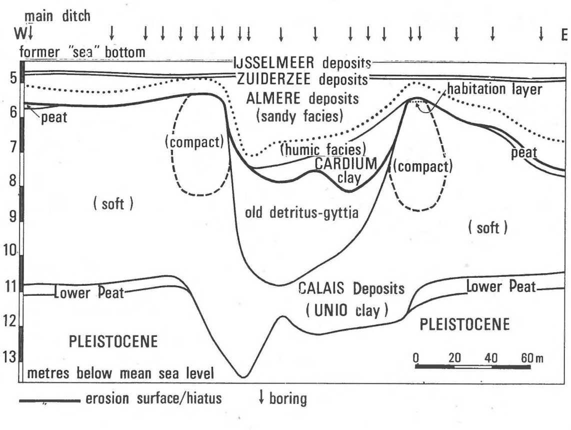

Fig. 4
Radiocarbon sampling and archeological investigation on levee of Calais Deposits, ditch G 41/42, near Swifterbant.
GrN 5443 (Oostelijk Flevoland, G 42^{a}; charcoal):
5300 ± 40 B.P. = 3350 ± 40 B.C.
On the erosion surface a part of a Bell-Beaker of Veluwetype (± 1800 B.C.) has been found.

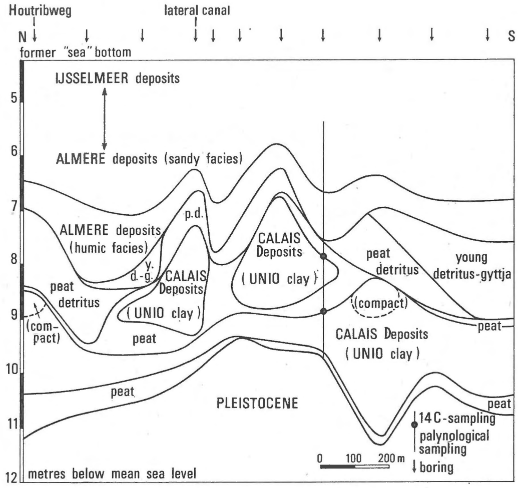

Fig. 5
Radiocarbon and palynological sampling "Beginweg", parcel A 70, near Lelystad.
GrN 5081 (Lelystad I):
5330 ± 60 B.P. = 3380 ± 60 B.C.
GrN 5348 (Lelystad I^{b}, resampling of I):
5265 ± 75 B.P. = 3315 ± 75 B.C.
(GrN 5390 extract of I^{b})
(5315 ± 65 B.P. = 3365 ± 65 B.C.)
GrN 5082 (Lelystad II):
6150 ± 130 B.P. = 4200 ± 130 B.C.

diatoms have indicated a fresh-brackish environment (Gulinck and van Voorthuysen, 1961). This is in agreement with the numerous remains of reeds present and the possibility for habitation by man (fig. 4).

The compactness i.c. the physical "ripeness" (Pons and Zonneveld, 1965) of the levees down to 2-3 m below the top, points to a very gradual silting up, keeping pace with the rising sea level during the latter part of this phase. For the first part a more rapid sedimentation can be assumed, resulting in subaqueous deposits without remains of vegetation near the later creeks.

From the levees towards the edges the Calais Deposits gradually become thinner, whilst the relatively thin underlying reed-sedge peat layer, either remains thin or becomes thicker.

Before dealing with the two phases being present somewhere in the abovementioned area, other occurrences are firstly treated.

The same situation as described above is found near the southern limit of the North-East Polder. Besides, recent investigations have shown that, in contrast to the ideas of Pons c.s., the region near the former island of Urk has to be devided into two areas, the southern one of which corresponds with the situation described above, with regard to both properties and level and the assumption of the oldest phase being bound to the most pronounced Late Pleistocene gullies.

The older phase found in the southern area near Lelystad, displays the same features, however, less expressed (fig. 5). A creek system with compact levees and soft backswamps is present. The levees only reach to about $7\frac{1}{2}$ m below mean sea level. The compact top part of the levees is only 1 m thick. The lower limit of compactness ($8\frac{1}{2}$ m below mean sea level) is surprisingly at the same level as in the northwestern part of Eastern Flevoland.

The younger phase of the southern area near Lelystad consists of soft homogeneous clays with only occasionally some sandy layers. The deposits reach to 6 m below mean sea level. In the upper metre they show remains of a vegetation. The southern part gives the impression of a basin being silted up. Somewhat to the north a weakly developed creek system exists, lying scattered over the backswamps of the older phase (fig. 5). Occasionally the same creeks have been used in both phases.

In the east the creek pattern ends into a basin in which the clay layers are relatively thin and not overgrown. The clay is embedded in a kind of course peat-detritus gyttja. Here seems to be found the starting point of the complex of lakes that gave rise to the later Lake Flevo, which up to now always has

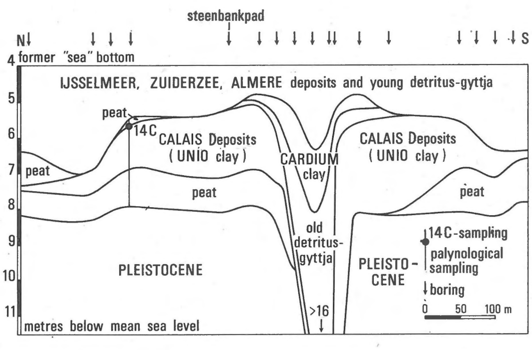

Fig. 6
Radiocarbon and palynological sampling Westermeerweg, parcel D 8/9, near Tollebeek.
GrN 5391 (Tollebeek I):
4630 ± 90 B.P. = 2680 ± 90 B.C.
(GrN 5349 extract:)
(4370 ± 40 B.P. = 2420 ± 40 B.C.).

been thought to have originated in the Duinkerke 0 trangression.

Somewhat more to the east a same kind of basin is found. Here a connection exists with the younger phase found in the northwestern part of this polder. Much of the reed-sedge peat surrounding these areas has been eroded later on.

The northernmost area is the best studied of the North-East Polder (W i g g e r s, 1955). Mostly clays have been deposited here in a basin below the water table. The deposits reach locally to 5 m below mean sea level. The upper part shows much reed debris. In the bottom layers a great number of Unio tumides has been found, showing the fresh-water character of the environment of deposition. Since then the name Unio Clay was used. The basin must have been fed through a western entrance (fig. 6).

Dating of the Calais Deposits and correlation with other regions. The results of recent radiocarbon datings are given in the figures 4, 5 and 6. Palynological analyses (Z a g w i j n, pers. comm.) have only partially been completed.

From these results and from those of the preceding paragraph the following might be concluded (from young to old):

1. no indications have been found that the Calais IV phase ever has penetrated into the eastern polders;
2. the extent of the Calais III phase is limited to the northernmost area in the North-East Polder;
3. the Calais II phase exhibits the greatest extent viz. covers the area from Urk to Lelystad;
4. the Calais II phase either shows a subphase in the neighbourhood of Lelystad and in the southeastern part of the area in Eastern Flevoland, or this subphase has to be regarded as the Calais I phase whilst in the northwestern part of Eastern Flevoland the Calais I phase and the Calais II phase unnoticedly merge into each other.

The date for the older subphase resp. phase comes rather near to those of Nieuwe Wetering (GrN 1620, 6320 ± 70 B.P. –9 m below mean sea level; J e l g e r s m a, 1961) and Pampus (GrN 1628, 6240 ± 90 B.P. –9.20 m below mean sea level; P o n s and W i g g e r s, 1959) as cited by R i e z e b o s and D u S a a r (1969). The latter authors preferred to appoint the deposits in question at Nieuwe Wetering and Pampus as the Calais I phase. The highest sedimentation level they found southwest of Amsterdam was

$8\frac{1}{2}$ m below mean sea level. The higher level in Eastern Flevoland ($7\frac{1}{2}$ m below mean sea level for some levees) does not seem to support the preference of Riezebos and Du Saar. A gradient giving a higher water level upstream might be assumed as an explanation for these differences in highest levels. However no such gradient could be detected, for the only date-depth figure locally available (Swifterbant, GrN 5067: 5610 ± 60 B.P. –6.15 m below mean sea level) exactly fits into Jelgersma's time-depth graph of the relative sea-level changes in the western Netherlands.

In favour of the preference of Riezebos and du Saar is the fact that there has been no indication of the presence of peat layers at a distinctly lower level in the neighbourhood (Southern Flevoland). Besides these authors might have missed the highest possible level either because of change of facies or because of erosion. Otherwise the dating remains the strongest support for their preference.

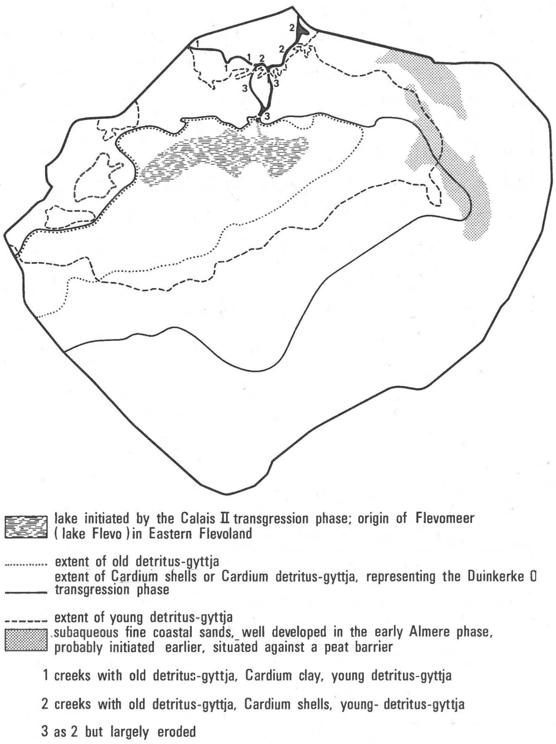

Fig. 7
Mainly lake resp. lagoon sediments formed from the end of the Atlantic till the Middle Subatlantic in Eastern Flevoland (including those of the initial Flevomeer phase, Duinkerke 0 phase, Flevomeer phase and early Almere phase -partly-).

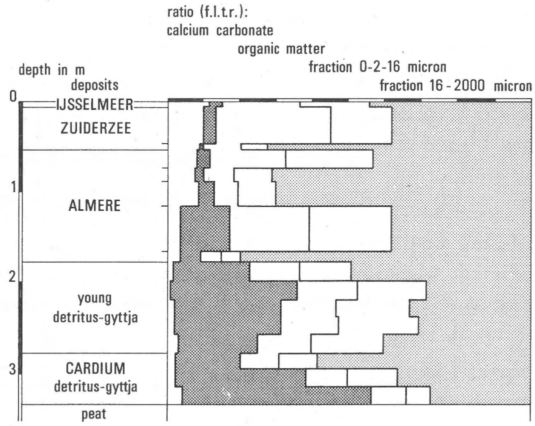

Fig. 8
Granulometric composition of a profile in the centre of Eastern Flevoland (parcel J 81/82).

Holland Peat and old detritus-gyttja. During the regression phases the Holland Peat must have regained some of the lost territory. However, some areas, creeks as well as basins, remained open water in which old detritus-gyttja was formed (figures 4, 6 and 7). There exists vague archeological evidence that in the neighbourhood of some creeks peat land was inhabited (fig. 4).

Late-Subboreal and Subatlantic

Duinkerke 0 phase. The forementioned complex of lakes and creeks in the peat land has been greatly enlarged because of the transgressive Duinkerke 0 phase. Formerly its deposits were called Cardium Clay, based upon the numerous relicts of Cardium edule locally present. The calcareous, homogeneous, rather heavy clay is present in a subaqueous facies, mainly in creeks (figures 4 and 6). Only in the North-East Polder it also has been found in a basin overlying a part of the Calais III basin. The higher situated borders have been overgrown there. In other places the Duinkerke 0 phase is present as an erosion surface paved with more or less numerous Cardium shells and sometimes as a detritus-gyttja (figures 7 and 8).

After the complete silting up of the estuary in the western Netherlands (Westfrisian estuary) an enlarged complex of lakes remained.

Flevomeer phase. In the enlarged complex of lakes young detritus-gyttja – a mixture of clay, silt, peat detritus and remains of water plants, plankton, etc. –

has been deposited under quiet and fresh-water conditions (figures 7 and 8). Based upon palynological evidence, both in the North-East Polder and Eastern Flevoland, the upper limit of the young detritus-gyttja has to be placed at the beginning of the Christian era.

The Romans mentioned a Lake Flevo (= Flevomeer) and pointed at a connection between this lake and the North Sea. Though at that time this connection might have been still unimportant, the widening of this northerly inlet must have led to the next phase.

Almere phase. The lower part of the Almere deposits shows a humic facies (fig. 8) of a rather equal thickness. This humic facies is overlain by a sandy facies, at least in the central part of the Lake IJssel region. Towards the east the sandy facies grades into a silty facies, along with thinning and merging into the upper part of the humic facies in Eastern Flevoland. In the North-East Polder the silty facies reaches for the IJssel mouth. The IJssel might have delivered a part of the silt and clay. This hypothesis seems to be supported by fig. 9, but it cannot be proved. Granulometric composition of the sandy

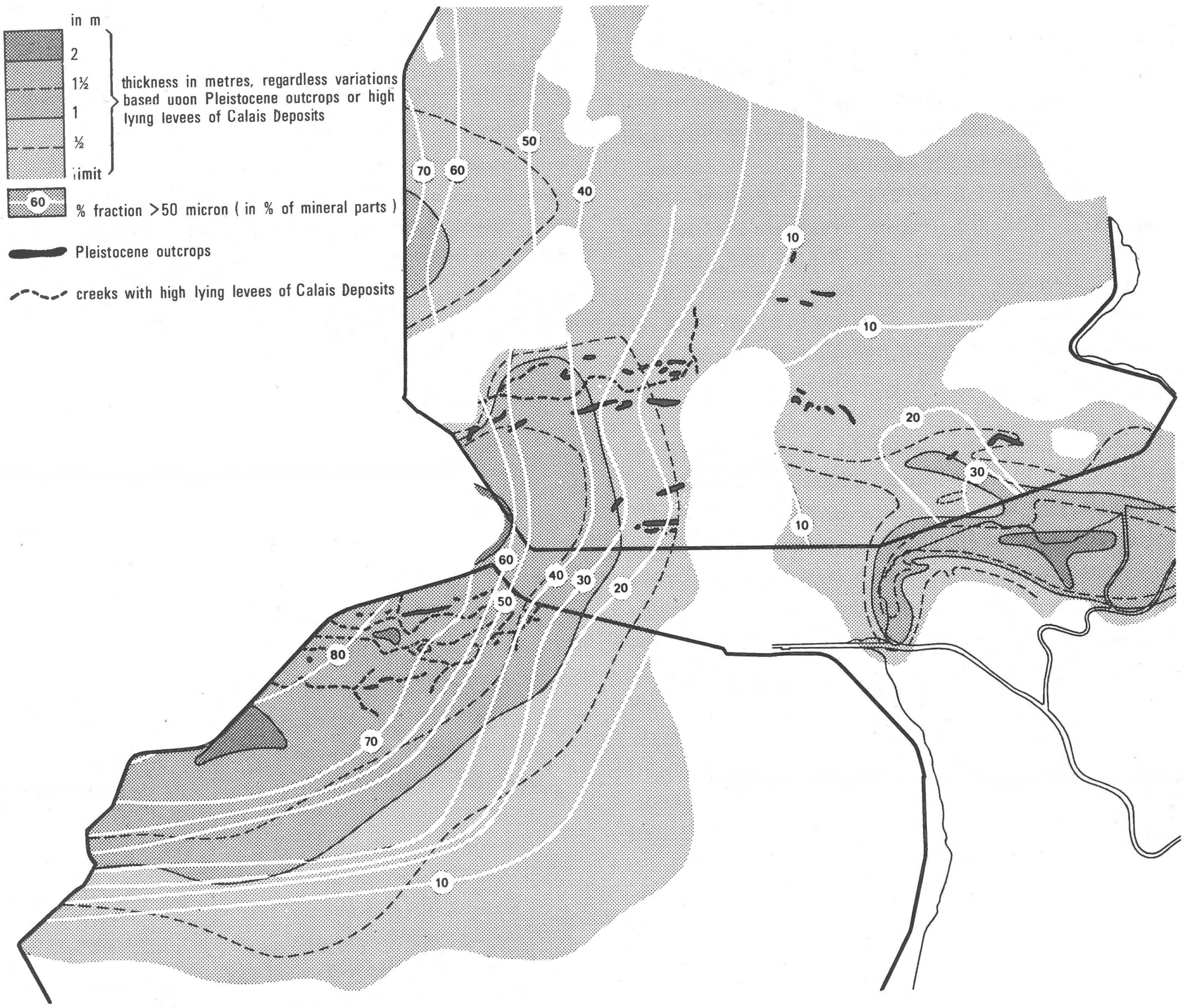

Fig. 9
Thickness and coarseness of the slightly humic sandy/silty facies ($Al^{c1} + Sl^{IIa}$) of the Almere deposits; coastal sands excluded.

facies anyway demonstrates that the main influx of coarse and fine sand, silt and clay (viz. the anorganic fraction) came from the north (fig. 9). This was already stated by Muller and van Raadshoven (cited and confirmed by Wiggers).

The sandy or silty facies contains some organic matter derived from the abrasion either of a peat bottom or of the surrounding peat land.

The sandy/silty facies varies in thickness depending on the variable softness of the subsoil (differential compaction, Ente, 1963).

The influx of sand and silt from the north must in general have taken place between about 1000 and 1400 A.D. The beginning is rather uncertain. Wiggers mentioned the found of a sarcophagus cover from the end of the 12^{e} century at the bottom of the sandy facies in the western part of the North-East Polder.

The upper part of the Almere deposits shows a clayey, relatively non-humic facies in the eastern half of the area, grading into a somewhat sandy one towards the centre of the lagoon.

Van Straaten (1963; citing Wiggers) extensively dealt with the relative shortage of the clay fraction (smaller than 2 micron) in the fresh to brackish Almere deposits due to the peptization of relatively large floccules of about 25 micron. In Eastern Flevoland this also plays a role, but to a far lesser extent.

Coastal features are found f.i. near the mouth of the IJssel. During the Almere phase embankment of the river IJssel was undertaken from about the 11th Century. The river bed was narrowed resulting in increased transport of at least sandy material. Thus a rather coarse sandy subaqueous delta platform was formed, flanked by peat areas and protruding into the Almere, partly covering Almere deposits (fig. 10). The upbuilding of the delta started about the 12th Century. About 1364 the delta had already largely extended, when a part had silted up and was given to the city of Kampen by the Archbishop of Utrecht. Around the 16th Century the delta had reached about its definite extension.

Other coastal features are found near Pleistocene outcrops (Wiggers, 1955) f.i. in the northeastern part of the North-East Polder and the southeastern part of Eastern Flevoland. These outcrops have led to subaqueous displacements of sand. In Eastern Flevoland, the position of the sand in relation to the source areas (fig. 11) points to a northward transport which

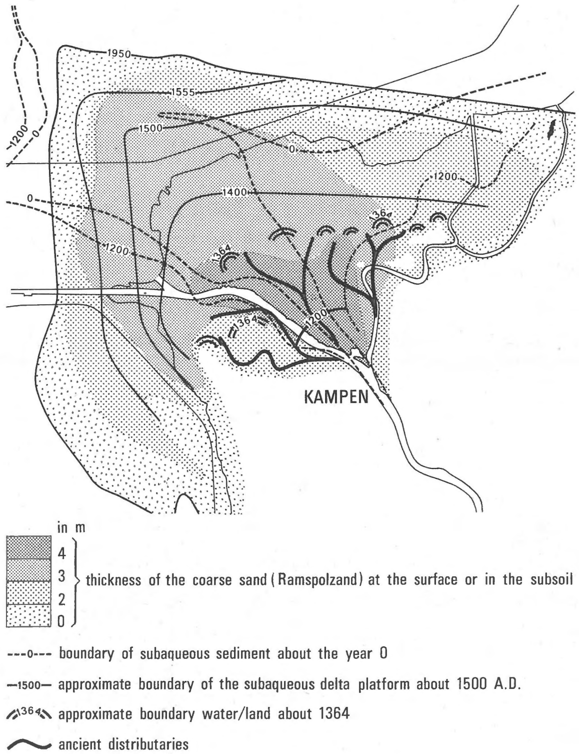

Fig. 10
The delta of the river IJssel.

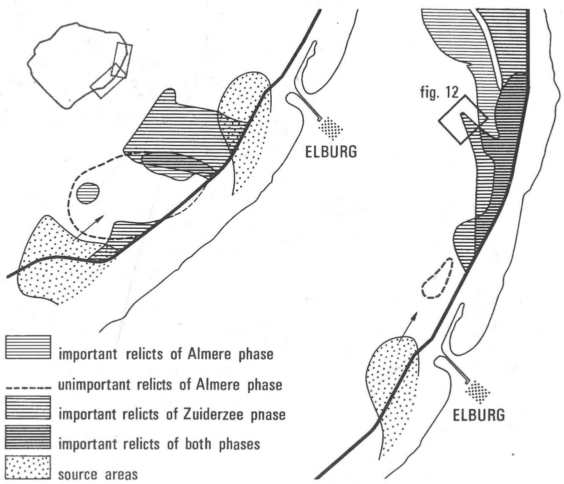

Fig. 11
Distribution of displaced sands of Pleistocene origin.

can only be explained by prevailing strong southwesterly winds. It is in accordance with the earlier findings of Haans and Maarleveld (1957) who held the same agent responsible for the increase in rounding and change in composition of the gravel found in beach bars along the same coast.

Zuiderzee phase. The Zuiderzee deposits show almost the same granulometric pattern (Pons and Wiggers, 1960) as the upper part of the Almere deposits. They are of a marine to brackish character and show consequently an abundance of marine molluscs, a.o. Mya arenaria. The coming up of Cardium edule and Mya arenaria almost occur at the same level. Both the presence of Mya arenaria (Hessland, 1946) and the archeological evidence (dated shipwrecks; van der Heide, 1955) fix this chrono-stratigraphic boundary between Almere deposits and Zuiderzee deposits in the eastern polders at about 1600.

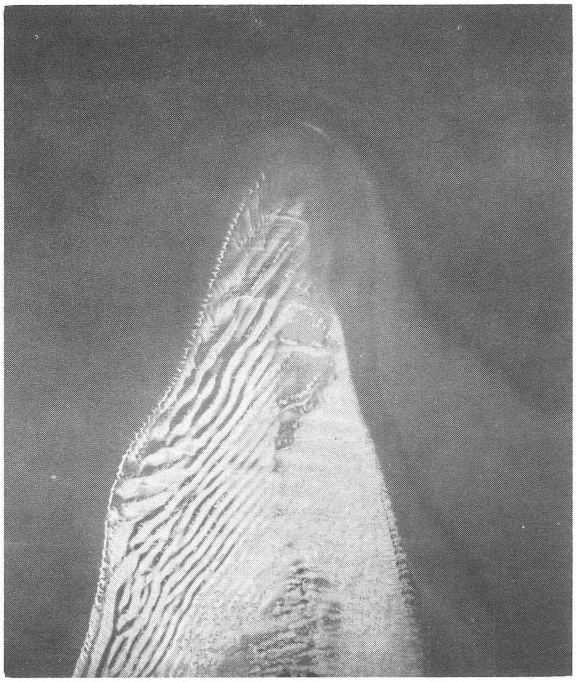

Fig. 12
Coastal sand, falling dry in January 1957 during the evacuation of the water from the polder Eastern Flevoland and showing many megaripples (for location see fig. 11). KLM-Aerocarto.

The historically known, diminished influence of the river IJssel (van der Heide, 1955) around the 17th Century can be considered as the main cause for the rapid salinisation of the eastern part of the former Zuiderzee, possibly in combination with a heavy storm surge in 1570.

During this phase the subaqueous IJssel delta platform has relatively little been reshaped.

The displacement of sands of Pleistocene origin continued (fig. 11). After the creation of the polders these sand masses, as well as the IJssel delta platform showed many "lows and balls" (Evans, 1940; van Straaten, 1953; King, 1959). On aerial photographs, taken in 1931, of the region of the delta platform could be seen that the ridges were lying in a "breaker" zone. Regarding the other areas, the ridges were found both inside the polder Eastern Flevoland and in the border lake. The great number of ridges (fig. 12) might be due to the faint slope together with the fact that in stormy periods the tidal differences (in quiet periods only some dm's) could be larger whilst the mean could be found at various levels.

IJsselmeer phase. The Zuiderzee phase came to an end in 1932, the moment of the damming off of the Zuiderzee. The IJsselmeer phase followed, during which only some displacement of clay, silt and sand took place.

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