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LITHO-, BIO-, AND CHRONOSTRATIGRAPHY OF THE HOLOCENE DUTCH "SLOEF" (ALMERE MEMBER OF THE GRONINGEN FORMATION)

by

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A Holocene lagoonal sediment, usually indicated by the lithostratigraphical name of "sloef", is exposed in two reclaimed areas of the Dutch IJsselmeer (the former Zuiderzee). It is now proposed to name this deposit the Almere Member of the Groningen Formation. A stratotype is described and a reference section is indicated.

In both polders seven beds can be distinguished with specific lithological properties. Not all beds have an equivalent in the other polder. Correlation is therefore mainly based on datings. Dating is possible by several archaeological finds that indicate a depositional age of 0 - 1600 A.D.

Macrofossils are scarce, in contrast to an abundance of ostracods, diatoms and forams. These indicate a slightly brackish environment surrounded by vegetated marshes.

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SAMENVATTING

In de wanden van sloten die voor drainagedoeleinden gegraven zijn in de Noordoostpolder en Oostelijk Flevoland, is de z.g. "sloef" ontsloten. Dit is een Holoceen lagunair sediment met interessante sedimentaire strukturen. Teneinde de warrige en vaak incorrecte nomenclatuur, die op de "sloef" is toegepast, in de toekomst te kunnen vermijden, wordt thans de stratigrafische naam "Almere Member van de Groningen Formatie" ingevoerd. Een stratotype wordt aangewezen, evenals een referentie profiel.

Het materiaal van de Almere Member bestaat voornamelijk uit silt en klei, met als voornaamste overige bestanddelen $CaCO_3$ en humeus materiaal. Desondanks kunnen op grond van specifieke lithologische eigenschappen zeven "beds" (lagen) worden onderscheiden in beide polders. Deze zijn niet zonder meer te correleren.

Correlatie berust grotendeels op archeologische vondsten. Deze tonen aan, dat de Almere Member gevormd werd tussen ca. 0-1600 n. Chr. De fossielinhoud is niet voor alle beds identiek. Macrofossielen zijn schaars, maar ostracoden, foraminiferen en diatomeeën komen in verscheidene beds rijkelijk voor. Zij wijzen op een licht brak milieu, omgeven door kwelderachtige oevers. Dit komt overeen met de sedimentologische en paleogeografische interpretatie van een lagunaire afzetting.

INTRODUCTION

The so-called "sloef" is exposed in ditches, excavated in polders, reclaimed in the IJsselmeer (fig. 1). Since the sides of the ditches are densely vegetated, investigations can only be made when new ditches are dug. This recently happened in the Noordoostpolder in the neighbourhood of the village of Emmeloord. The exposed sections have been indicated in a previous paper (van Loon & Wiggers, 1975a).

The recent exposures showed abundant sedimentary structures, which partly could originate due to the typical grain-size distribution in these sediments (Wiggers, 1955; Wiggers *et al.*, 1962; van Loon & Wiggers, 1975b). Most typical is the low lutum content in respect to the 0 - 16 µm fraction, although hardly any material coarser than 75 µm is present.

Since sedimentary structures in lagoonal sediments are not very well known, and since the "sloef" (which is a lagoonal deposit) shows so many beautifull structures (plate 1), we decided to publish a series of papers on this subject. A paper on erosional features will soon be presented (van Loon & Wiggers, in press).

It seems necessary to add some stratigraphical information to the other papers. Therefore we will give here a review of the present state of stratigraphic research. Many data are not generally accessible, since they are mainly contained in internal reports, usually written in Dutch. These reports show that both in a lateral and in a vertical sense the properties of the sloef change. This permits the reconstruction of a fairly accurate picture of the sedimentary history of this lagoonal area.

LITHOSTRATIGRAPHY

In publications on Quaternary deposits the correct use of stratigraphic nomenclature is often neglected. This is partly due to the specific problems of this field. On the other hand research in Quaternary geology is often carried out by investigators with an insufficient theoretical-stratigraphical background.

The stratigraphic description of the "sloef" forms no exception. This deposit has been mentioned in literature as:

"sloef" (Muller & van Raadshoven, 1947; van Voorthuysen, 1951);
"sloefafzetting" (or: sloef deposit)(Ente & Segeren, 1969);
"sloefafzettingen" (or: sloef deposits) (Wiggers, 1955; Koopstra, 1962);
"sloeflaag" (or: sloef layer) (Muller & van Raadshoven, 1947);
"sloeflagen" (or: sloef layers) (Zuur, 1954; Ente, 1973);
"sloef sediments" (Middelhoek & Wiggers, 1953);
"Almere(-)afzetting" (or: Almere deposit) (Koopstra, 1961; Ente *et al.*, 1965);
"Almere(-)afzettingen" (or: Almere deposits) (Pons & Wiggers, 1959-1960; Wiggers, 1963);
"Almere lagen" (or: Almere layers) (Ente, 1973).

This deposit is usually considered as a - non specified - part of the Duinkerke deposits (de Jong, 1967; Zonneveld, 1974). In a more recent paper by de Jong (1971) both the terms "Duinkerke deposits" and "Duinkerke Member" are used. In spite of the English text de Jong used the Flemish name "Duinkerke", where other English texts often use the term "Dunkirk" (*e.g.* Louwe Kooijmans, 1974). The Duinkerke Member was considered by de Jong (1971) to be a member of the North Sea Formation, which name he introduced to replace the name "Holocene North Sea Formation", which was introduced by Brand *et al.* (1965). De Jong - correctly - rejected this latter name as nomenclaturally incorrect. Before that, de Jong himself (1965) had used the name "Holland Formation" for these same deposits.

A recent paper by Roeleveld (1974) divides the Holocene from western and northern Holland (where it lies disconformably upon Pleistocene sediments) into a Wold Formation (peat *in situ*) and a Groningen Formation (other sediments) which he combines into the North Sea Group. We believe that this new terminology offers great advantages, and therefore we propose to redefine the "sloef" as the "Almere Member of the Groningen Formation". A description of the stratotype is given below.

The deposits on top of the Almere Member, which have been defined as the "Zuiderzee deposits" and the "IJsselmeer deposits" should for the same reasons be named the "Zuiderzee Member" and the "IJsselmeer Member", the former being a part of the Groningen Formation as well. The underlying "Flevomeer deposits" (detritus-gyttja) should be named the "Flevomeer Member".

In the Noordoostpolder the Almere Member can be divided into seven beds, as distinguished by Wiggers (1955) on the basis of variations in composition. The sedimentary petrographical properties of these seven beds are dealt with in other papers (van Loon & Wiggers, 1975a, 1975b).

These seven beds are:

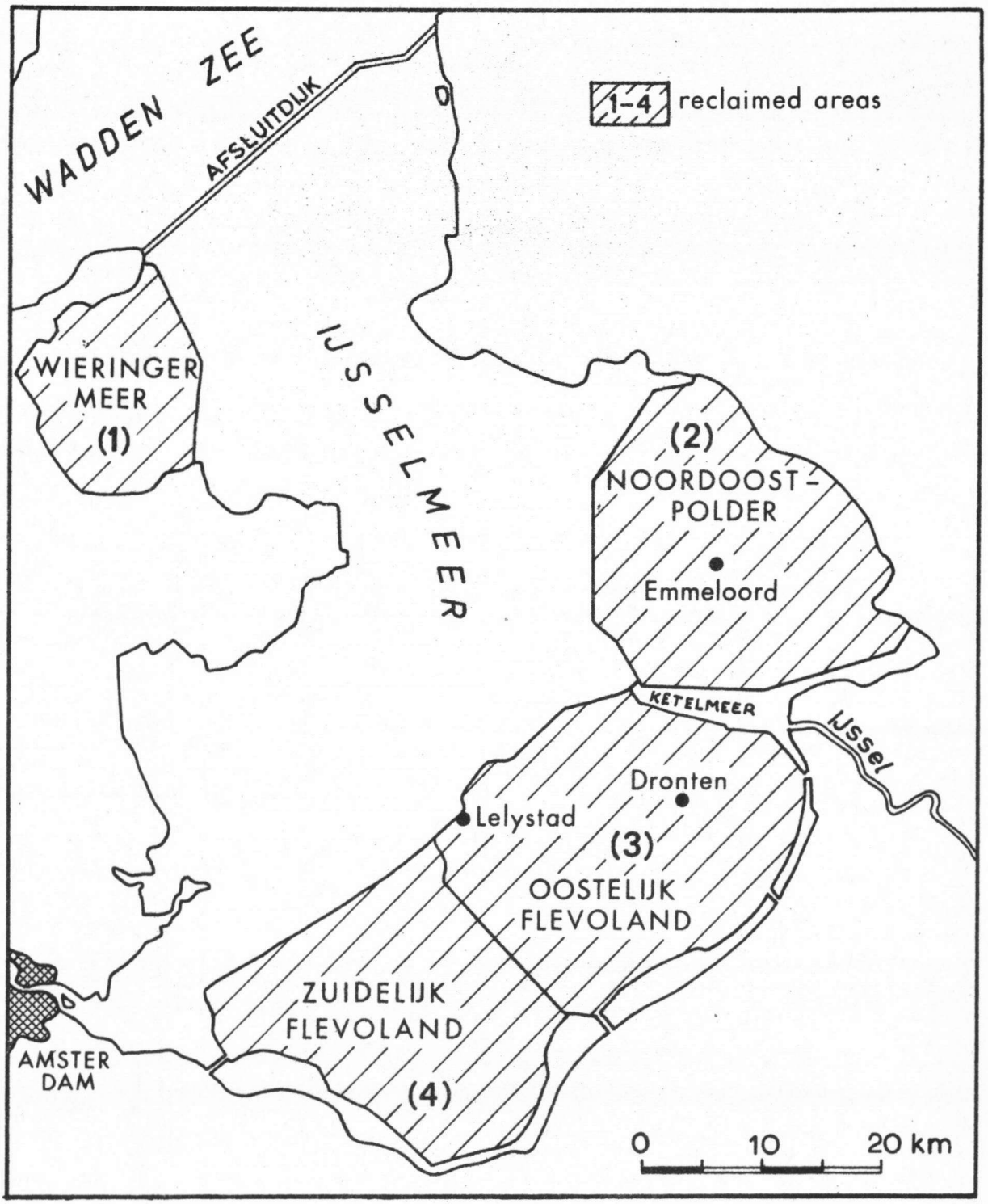
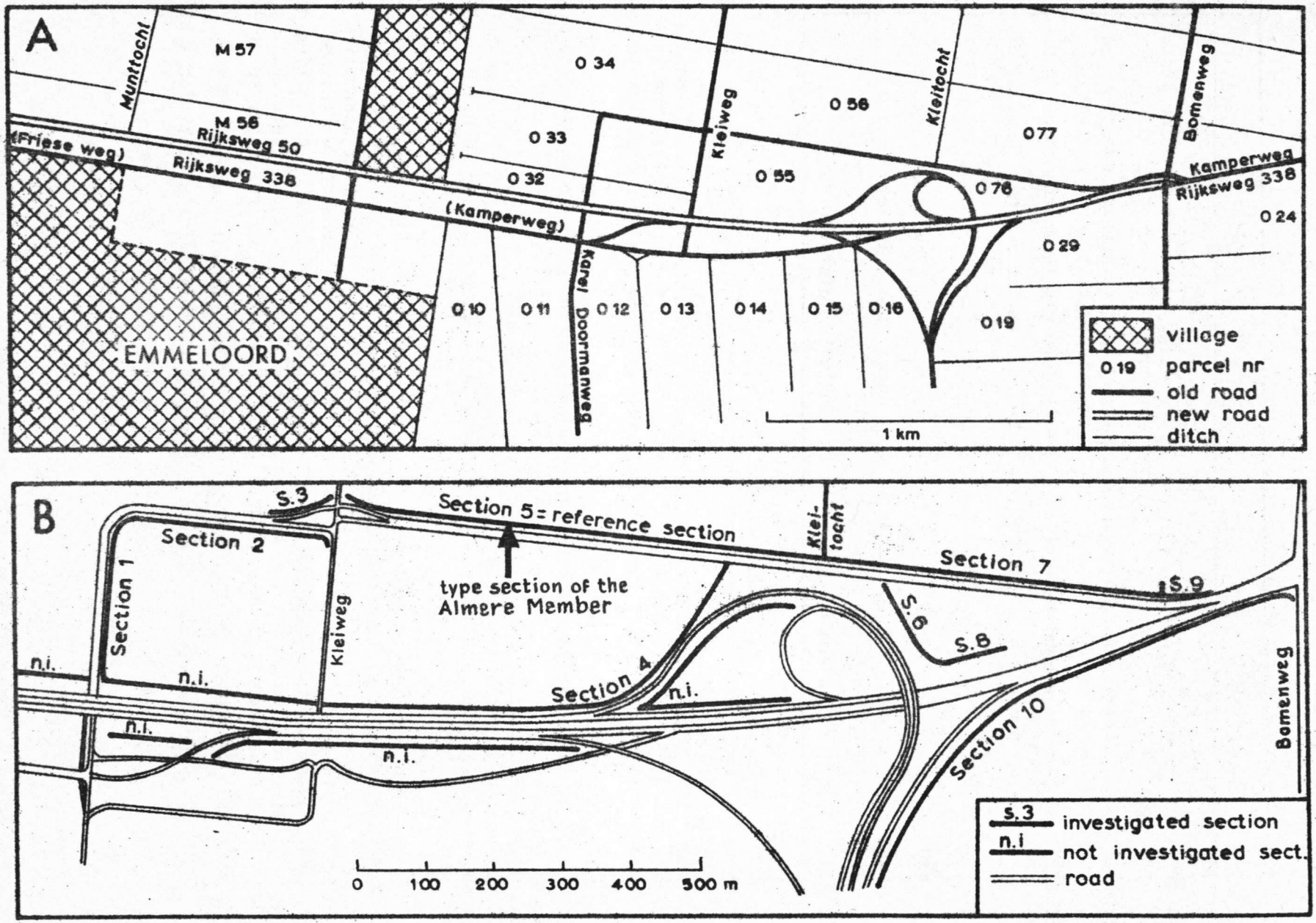


Fig. 1 (above). Location of the IJsselmeer area and the four reclaimed polders.
Fig. 2 (right). Detailed map of the neighbourhood of Emmeloord (A), and location of the investigated sections (B). Section 5 is the proposed reference section of the Almere Member, and includes the type section (indicated by an arrow).


A
Munttocht
M 57
M 56
Rijksweg 50
(Friese weg)
Rijksweg 338
(Kamperweg)
0 34
0 33
0 32
Kleiweg
0 56
Kleitocht
077
Bomenweg
Kamperweg
Rijksweg 338
0 55
0 76
0 24
0 29
Karel Doormanweg
0 10
0 11
0 12
0 13
0 14
0 15
0 16
0 19
EMMELOORD
1 km
village
0 19 parcel nr
old road
new road
ditch
B
S.3
Section 5 = reference section
Kleitocht
Section 2
Section 1
Kleiweg
type section of the
Almere Member
Section 7
S.9
S.6
S.8
n.i.
n.i.
Section 4
n.i.
n.i.
n.i.
Section 10
Bomenweg
0 100 200 300 400 500 m
S.3 investigated section
n.i not investigated sect.
road

code	Dutch name	English translation
Sl I^a	droge sloef	dry sloef (dry, due to a low lutum content)
Sl I^b	vette sloef	greasy sloef (greasy, due to a relatively high lutum content)
Sl II^a	droge bandjessloef	dry, clearly laminated sloef
Sl II^b	humeuze bandjessloef	humic, laminated sloef (laminae of organic matter)
Sl II^c	humeuze sloef	humic sloef
Sl III^a	magere sloef	meagre sloef (low lutum content)
(with a shell band, the so-called Valvata layer, upon, in, or beneath it: Koopstra, 1962)		
Sl III^b	sterk humeuze sloef	highly humic sloef

In Oostelijk Flevoland another subdivision into beds has been made. On the basis of similar variations as in the Noordoostpolder Koopstra (1961) originally distinguished seven beds, indicated by the codes Al^{a1}, Al^{a2}, Al^b, Al^{c1}, Al^{c2}, Al^{c3} and Al^{c4}. During later surveys the beds Al^{c2} and Al^{c3} were usually mapped together as Al^{c2+3}, since the only difference between these two beds consists of a variation in colour, which does not reflect really different properties (Koopstra, 1962).

It is impossible to correlate the beds in the two polders directly, since they are absent or cannot be mapped in the region (Ketelmeer) between these two areas. According to Ente (1973), the best method to correlate the two polders is via the area of the IJssel deposits near the village of Kampen (the nearshore area). Koopstra (1962), however, claims that correlation can also be based upon the humus and lutum content.

Ente & Segeren (1969) arrived at the same correlation results as Koopstra (1962). They state that the boundaries between the various beds represent partly isochrones, partly facies boundaries. No arguments for their assumption are given. Although some boundaries might be slightly diachronous, we see no reason to speak of facies boundaries: the relatively short time of deposition and the wide distribution of various beds strongly suggest that the differences between the beds are based on sedimentary conditions that varied rather suddenly in time.

Koopstra and Ente & Segeren arrived at the following correlation scheme:

Noordoostpolder	Oostelijk Flevoland
Sl I^a	no equivalent
Sl I^b	$Al^{a1} + Al^{a2}$
no equivalent	Al^b

S1 II^a	Al^{c1}
S1 II^b	Al^{c2}
S1 II^c	Al^{c3}
no equivalent	Al^{c4}
S1 III^{a+b}	no equivalent

This scheme would implicate that sedimentation in Oostelijk Flevoland started later than in the Noordoostpolder, or that the lowermost beds were eroded. We have no reason to believe that these assumptions are correct.

In the recently reclaimed polder "Zuidelijk Flevoland" (fig. 1) the excavation of ditches started only few years ago, and entrance is difficult. Therefore mapping has not been finished as yet. It is known (Ente & Wiggers, 1963), however, that the Almere Member is present over this entire polder, but a subdivision into beds has not been made until now. For that reason no comparison can at present be made between the beds in this new polder and in the two older polders.

TYPE SECTION OF THE ALMERE MEMBER

A characteristic type section of the Almere Member is at present difficult to be found. The member is best known in the Noordoostpolder, and also shows its most characteristic facies there, especially in the central eastern part. Therefore the search for a type section has been restricted to this area.

The sediments here are exclusively exposed in the sides of ditches, of which the first detailed mapping (Bodemkundige Code- en Profielenkaart van de Noordoostpolder, 1947-1956) unfortunately only concerned the uppermost 140 cm, sometimes even only 100 cm. The older beds of the Almere Member are, as a result, often not indicated on the maps. A renewed mapping is hardly possible, since most sides of the ditches are covered by avalanched material from the surface, and because they are now densely vegetated.

For these reasons investigations had to be restricted to a few rather recent ditches, which have been excavated in the neighbourhood of Emmeloord (van Loon & Wiggers, 1975a). These ditches together have a length of about 6 km, but only at a single locality all seven beds were found above each other. This rare occurrence is in agreement with the tendency shown on the older maps.

We propose to locate the type section of the Almere Member at the place, where we found all seven beds together. This spot is situated in parcel O 56, in the northern side of the ditch, that forms our section 5 (fig. 2). This ditch runs along a nameless road between the roads "Bomenweg" and "Kleiweg", and the type section lies at a distance of about 245 m from the Kleiweg.

The rapid lateral facies changes in these sediments result in some beds of the type section not showing their most typical character. At other localities in this same ditch, however, all beds frequently can be found in their most characteristic lithofacies. For this reason we suggest that this entire ditch

(length about 800 m) should serve as a reference section.

In the near future vegetation will prevent an easy access to these sediments. Therefore a lacquer peel of the type section has been prepared. It is stored in the Institute of Earth Sciences of the Free Reformed University in Amsterdam, where it will be available for future studies.

A short description of the type section, as it was visible in the field during the first months of 1975 (plate 2) follows beneath.

Underlying sediments

At the water level in the ditch (113 cm below surface) the top part of a peat layer (belonging to the Wold Formation) is visible. A few erosive depressions in the peat are present, which have been filled up with coarse peat detritus. This must be considered as a local and coarse development of the Flevomeer Member of the Groningen Formation. These isolated depressions have a lowermost base at 105 cm below surface, and a maximum thickness of 5 cm.

Bed S1 III^{b}

Lower boundary: 102 - 96 cm below surface.
Contact: erosive.
Thickness: 8 - 11 cm.
Material: alternating laminae and thin layers of very humic silt and silty peat detritus.
Characteristics: few laminae of very fine sand, wedging out within a few cm and rarely showing very small-scale scour-and-fill structures. Wood fragments frequent.

Bed S1 III^{a}

Lower boundary: 92 - 90 cm below surface.
Contact: erosive.
Thickness: 17 - 25 cm.
Material: laminae of very fine sand and humic silt. Scattered shells.
Characteristics: irregular lamination, small-scale current ripples and load casting. Various lenses of nearly pure peat detritus.

Bed S1 II^{c}

Lower boundary: 75 - 66 cm below surface.
Contact: erosive.
Thickness: 6 - 7 cm.
Material: laminae with humic silt at the base and silty detritus at the top. A few sand lenses.
Characteristics: sedimentation started after an erosive period. Probably sedimentation from suspension in a few phases.

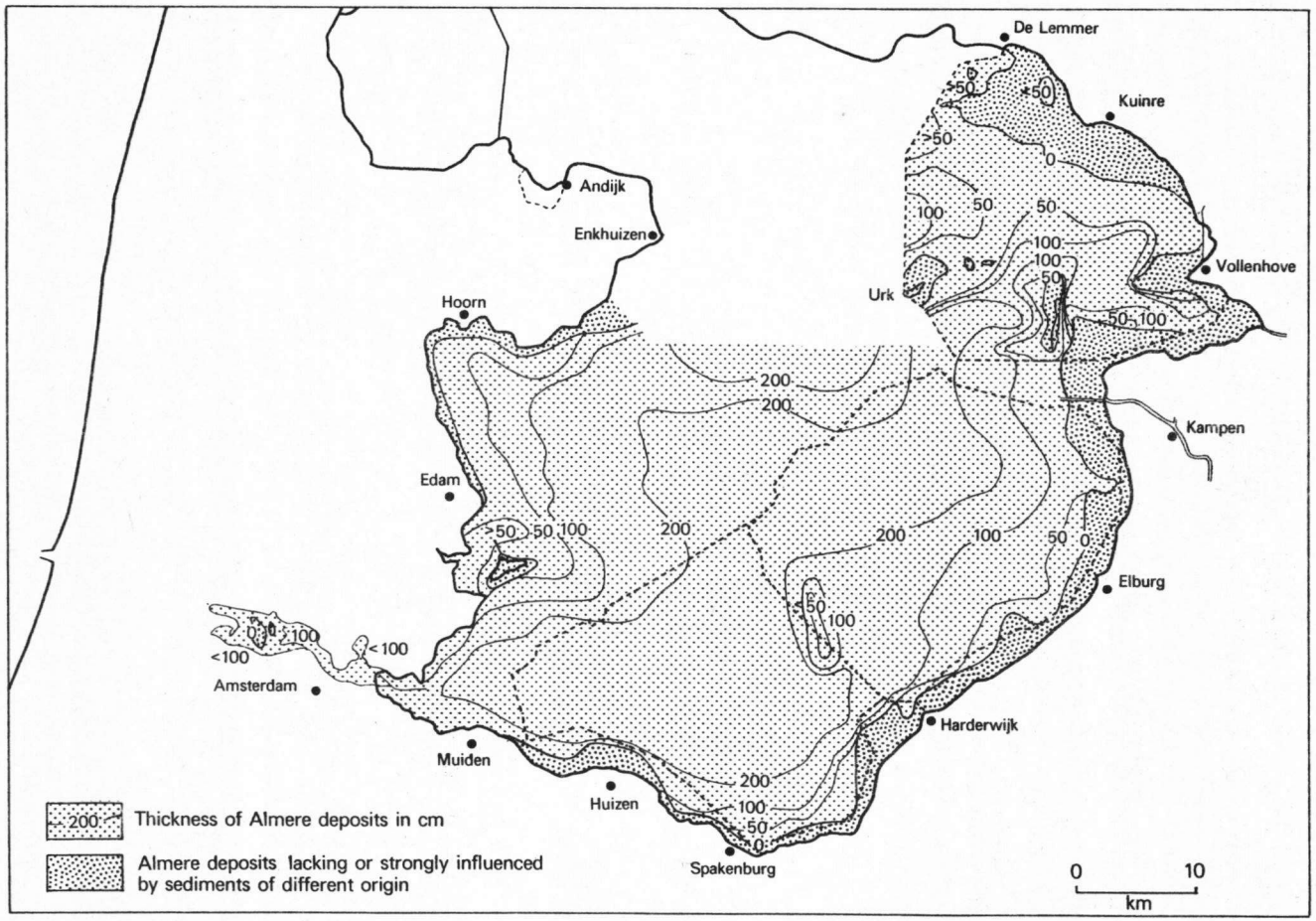


Fig. 3. Distribution and thickness of the Almere Member. After Pons & Wiggers, 1959-1960.

Bed S1 II^{b}

Lower boundary: 62 - 56 cm below surface.
Contact: normal.
Thickness: 17 - 19 cm.
Material: alternation of humic silty laminae and sandy laminae.
Characteristics: fairly regular lamination. Humic laminae dominate, filling up depressions. Especially in the sandy laminae some small-scale current ripples and scour-and-fill structures.

Bed S1 II^{a}

Lower boundary: 52 - 50 cm below surface.
Contact: erosive.
Thickness: 13 - 17 cm.
Material: same as in bed S1 II^{b}, but no real humic laminae.
Characteristics: some laminae are thicker than 1 cm (layers). Scour structures are common.

Bed S1 I^{b}

Lower boundary: 36 - 34 cm below surface.
Contact: erosive.
Thickness: 12 - 16 cm.
Material: alternation of "greasy" parts with sandy and silty horizons.
Characteristics: irregular bedding, especially in the clayey parts. Possibly some flow and escape structures. Irregular sand lenses.

Bed S1 I^{a}

Lower boundary: 25 - 23 cm below surface.
Contact: normal.
Thickness: 4 - 6 cm.
Material: alternating sandy and silty laminae.
Characteristics: irregular, wavy lamination.

The sequence ends 18 - 21 cm below surface, since ploughing has disturbed the material above that level. On the basis of comparisons with the bed S1 I^{a} elsewhere, and taking into account the previous mapping, it may be assumed, however, that the bed S1 I^{a} is practically complete in this type section.

DISTRIBUTION

Sedimentation of the Almere Member took place in a lagoon, the location of which roughly corresponds to that of the present IJsselmeer. Mapping of this area started more than a century ago, when it was still covered by the waters of the Zuiderzee. In 1865 van Bemmelen made a comparison between the bottom sediments and those of arable lands, based on lutum content and coarseness of the

sands (Zuur, 1958). A private Zuiderzee Society ordered the mapping of the Noordoostpolder area in 1874 and of the Wieringermeer area in 1880 (Ente, 1966). This underwater mapping is still in progress in the areas that have (so far) not been reclaimed. The methods for this kind of mapping are described by Smits & Wiggers (1959).

Thus in Oostelijk Flevoland (about 540 km^2), for instance, 430 underwater borings were made. After these first attempts more advanced preliminary mapping was carried out by means of 5400 borings when the area was reclaimed (de Jong, 1957). By far the most data, however, became available during the subsequent mapping of the sides of excavated ditches. Therefore, much data are available about the Noordoostpolder and Oostelijk Flevoland, while knowledge is relatively poor about the other areas that are not reclaimed, or in which ditches have not been dug as yet.

On the basis of our present knowledge, mainly based on the results of mapping, as shown on the "Bodemkundige Code- en Profielenkaart van de Noordoostpolder" (1947 - 1956) and on the "Bodemkundige Code- en Profielenkaart van Oostelijk Flevoland" (started in 1968), and on the data published by Pons & Wiggers (1959-1960), the following - schematic - sketch of the distribution can be given (fig. 3). A decrease in grain-size is found from NW to SE. In the northernmost and southernmost parts of the IJsselmeer the grain-size distribution is therefore not very characteristic. The most typical sediments can be found in the middle part, like in the Noordoostpolder and the northern part of Oostelijk Flevoland. In most places the Almere Member is present with a thickness of 50 - 400 cm, usually 50 - 150 cm (fig. 3). The present depth below surface is 15 - 90 cm in Oostelijk Flevoland (de Koning & Wiggers, 1955), 25 - 50 cm in the Noordoostpolder (Wiggers, 1955) and 35 - 60 cm in Zuidelijk Flevoland (Ente & Wiggers, 1963). Subsidence after reclamation can be significant (de Glopper, 1973). The rate of subsidence mainly depends on the amounts of lutum and organic matter, the drainage conditions, the climate, and the clay minerals present.

BIOSTRATIGRAPHY AND PALEOECOLOGY

Relatively little attention has been paid to the fossil content of the Almere Member, especially during the last decade. Most investigations have been carried out in the Noordoostpolder, among others by Muller & van Raadshoven (1947), van Voorthuysen (1951), Middelhoek & Wiggers (1953), Wagner (1957) and by Ente *et al.* (1961).

Most striking is the almost total absence of large shells. In addition, the macrofauna present strongly differs from that in the underlying and overlying deposits.

Generally a distinction has been drawn between the Sl III (especially the Sl III^b) and the younger beds. The Sl III^b contains specimens of the fresh-water snail *Valvata piscinalis* (Müller) and of the fresh-water mussel *Unio tumidus* Philipsson. Forams are in the bed Sl III^b totally absent (van Voorthuysen, 1951), but ostracods are present, though sometimes only sporadically. Wagner (1957) mentions:

Cyprideis torosa (Jones)(smooth specimens)	: oligohaline to mesohaline
Darwinula stevensoni (Brady & Robertson)	: fresh to oligohaline
Candona neglecta Sars	: fresh to oligohaline
Cytheromorpha fuscata (Brady)	: oligohaline to β-mesohaline
Ilyocypris gibba (Ramdohr)	: α-mesohaline
Limnocythere inopinata (Baird)	: fresh to oligohaline

These species may be partly absent in several localities (Ente *et al.*, 1961).

Middelhoek (*in*: Middelhoek & Wiggers, 1953) mentioned also the occurrence of ostracods. Unfortunately his interpretation and nomenclature were not very careful, as pointed out by Wagner (1957). Therefore, we will not use Middelhoek's data.

Apart from allochthonous specimens the diatoms in the humic facies of the Almere Member (probably: Sl III^{b}) contain the following species (Ente *et al.*, 1961):

Actinoptychus undulatus (Bailey) Ralfs	: marine to brackish
Melosira moniliformis (Müller) Agardh *Nitzschia punctata* (W. Smith) Grunow *N. scalaris* (Ehrenberg) W. Smith *Scoliopleura tumida* (de Brébisson) *Caloneis amphisbaena* (Bory) Cleve var. *subsalina* (Donkin) *Campylodiscus clypeus* Ehrenberg *C. echeneis* Ehrenberg *Cyclotella striata* Kützing *Diploneis interrupta* (Kützing) Cleve *Nitzschia circumsuta* (Bailey) Grunow *N. navicularis* (de Brébisson) *Thalassiosira balthica* (Grunow) Ostenfeld	├ brackish to marine ├ brackish
Coscinodiscus lacustris Grunow *Cyclotella meneghiniana* Kützing *Nitzschia tryblionella* Hantzsch *Fragilaria construens* (Ehrenberg) Grunow *Meliosira granulata* (Ehrenberg) Ralfs *M. italica* (Ehrenberg) Kützing *Pinnularia maior* Kützing *Stauroneis phoenicenteron* Ehrenberg *Stephanodiscus astraea* (Ehrenberg)	├ brackish to fresl ├ fresh to brackish
Pinnularia cardinalis (Ehrenberg) W. Smith *P. nobilis* Ehrenberg	├ fresh

These indications for variations in salinity support the sedimentological and paleogeographical interpretation of a lagoonal environment.

The bed Sl III^{a} at many localities contains a band with a lag deposit on a intraformational erosional surface (van Loon (Wiggers, in press). Since a concentration of *Valvata piscinalis* is present, this band is known as the Valvata layer, which forms a good marker horizon. *Unio tumidus* is also frequent.

The younger beds in general contain somewhat more fossils than the Sl

III. Muller & van Raadshoven (1947) mention the following molluscs:

Valvata piscinalis (Müller) *Unio tumidus* Philipsson *Theodoxus fluviatilis* (L.) *Bithynia tentaculata* (L.)	abundant
Sphaerium solidum Normand *Sphaerium corneum* (L.) *Pisidium supinum* Schmidt *Pisidium amnicum* (Müller)	in smaller quantities

According to our own observations *Anodonta cygnea* (L.) and *A. piscinalis* (Nilsson) are also present. Ente *et al.* (1961) mention the local occurrence of juvenile forms of *Cardium edule* L. in the uppermost part. Only this latter species indicates a more marine environment. All other species indicate rather fresh water, although they can resist slightly brackish conditions. This is in accordance with the environmental conditions of the ostracods in the younger beds, mentioned by Wagner (1957): *Cyprideis torosa* (Jones) - both smooth and ornamented specimens -, *Cytheromorpha fuscata* (Brady), *Candona neglecta* Sars, *Darwinula stevensoni* (Brady & Robertson), *Limnocythere inopinata* (Baird), *Loxoconcha elliptica* Brady, *Hirschmannia viridis* (Müller), *Leptocythere* sp., *Microcytherura fulva* (Brady & Robertson, *Semicytherura nigrescens* (Baird) and *Xestoleberis* sp.

The foraminiferal faunas studied by van Voorthuysen (1951) are often abundant in specimens. The assemblages are dominated by *Streblus beccarii* (L.) - at present named *Ammonia beccarii* (L.) -, which species occasionally may form the entire fauna, *Nonion depressulus* (Walker & Jacob) - probably a synonym of *Protelphidium anglicum* Murray, see Murray, 1971 *Elphidium excavatum* (Terquem) - probably *E. articulatum* (d'Orbigny) - and arenaceous forms (mainly *Trochammina* and *Haplophragmoides* spp.). They all indicate shallow marine, brackish conditions, and the arenaceous species are especially indicative of hyposaline tidal marshes (Murray, 1971).

Van Voorthuysen considered the almost continuous presence of considerable quantities of the arenaceous forms as an indication of poorly oxigenated conditions. Comparison with more recent literature (*e.g.* Lutze, 1968), however, shows that these types prefer the shallower parts of tidal marshes, covered with vegetation, which is a different interpretation.

Ente *et al.* (1961) also mention *Streblus batavus* Hofker, which they consider a possible geographic variety of *Streblus beccarii* (now: *Ammonia beccarii*), and also *Trochammina inflata* (Montagu), *T. magrescens* Brady and *Haplophragmoides canariensis* (d'Orbigny). They consider these species as characteristic for an estuarine-lagoonal environment. All ostracods mentioned by Ente *et al.* belong to the same species mentioned before by Wagner (1957). The autochthonous diatoms that they describe from this part of the Almere Member are the same as those in the underlying (humic) beds, while the following species are also present:

Caloneis formosa (Gregory) Hustedt *Synedra tabulata* (Agardh) Kützing	brackish
Caloneis permagna (Bailey) Cleve *Nitzschia sigma* (Kützing) W. Smith	brackish to fresh

PLATE 1

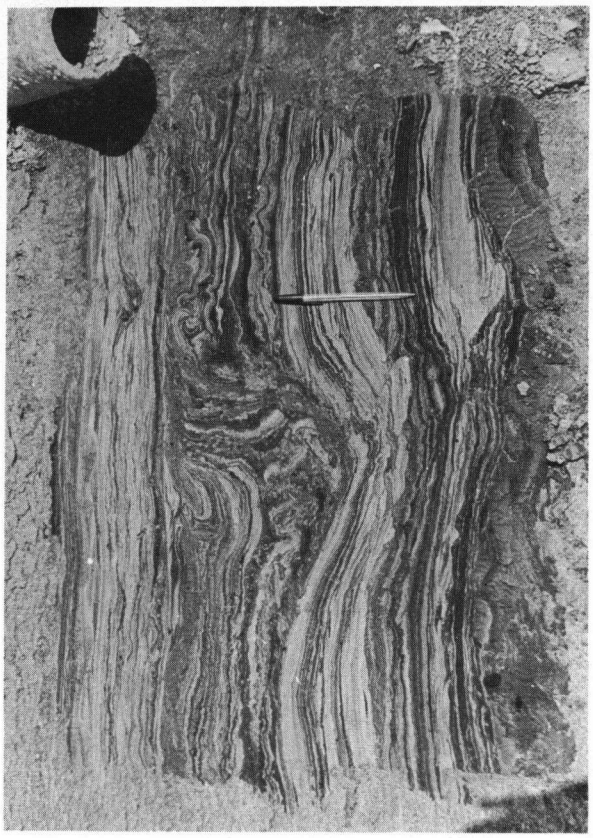
Fig. 1. Small channel-like wash-outs, indicative of bottom-currents.

Fig. 2. Relatively large channel, which has been filled in laterally. Black colour of various laminae is caused by a high content of humic material. At the base detritus-gyttja of the Flevomeer Member is exposed.

Fig. 3. Typical facies of the "sloef" with various kinds of sedimentary structures, *e.g.* small wash-outs (pre-sedimentary), current ripples (synsedimentary), plastic deformation, flow structures and faulting (probably all meta-sedimentary) and load-casting (postsedimentary).

Fig. 4. Detail of a metasedimentary-faulted structure. Some plastic deformation is also visible.

plate 1



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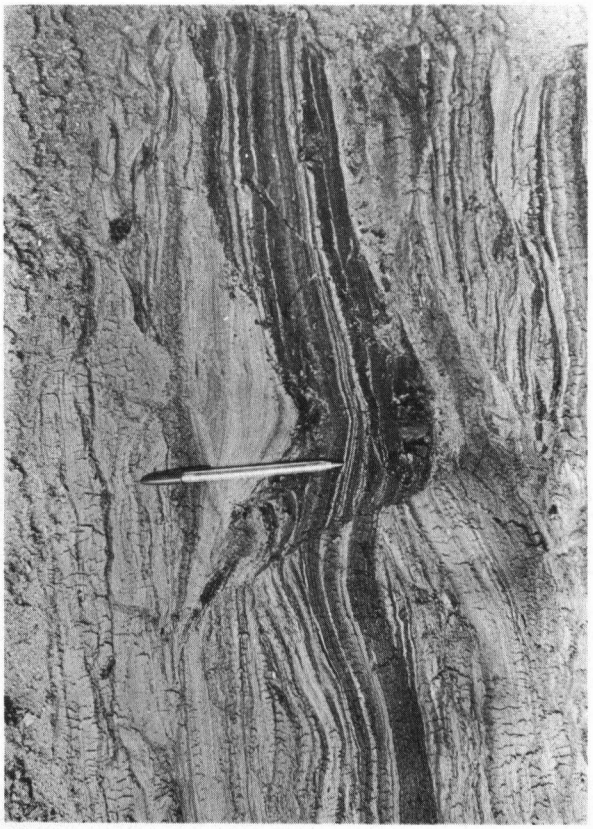

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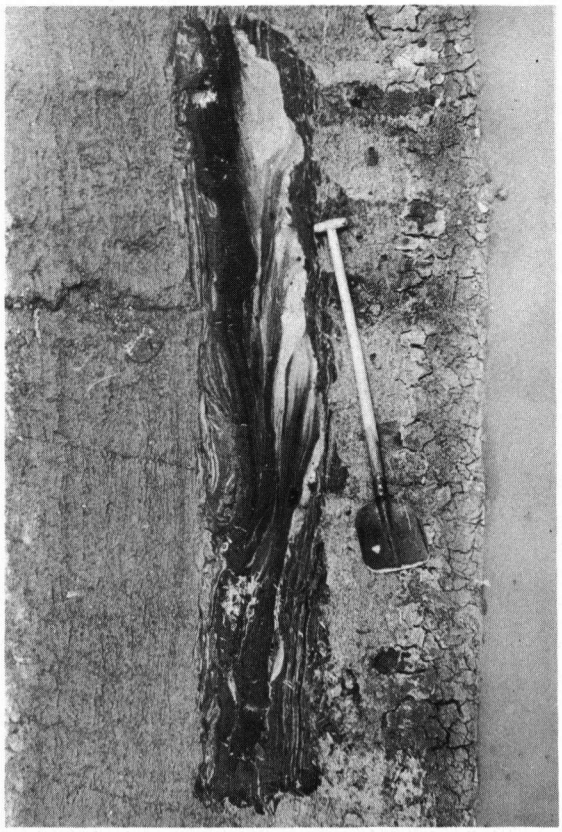

2

The ecological interpretations by the quoted authors of all the species mentioned above are based on comparisons with specimens living at present. This appears to yield a reliable interpretation. Nevertheless, some contradictions exist between the various fossil groups. This is discussed in more detail by Ente *et al.* (1961).

By combination of all data it may be concluded that during deposition of the Almere Member an oligohaline (0.3 - 2.00 ‰ of salt) to β-mesohaline (2 - 8 ‰) lagoonal environment existed (ostracods and diatoms), limited by vegetated marshes (forams).

CHRONOSTRATIGRAPHY

Direct dating of the various beds of the Almere Member by means of ^{14}C is impossible, owing to the fact that the organic matter is derived from older layers. Chronostratigraphic interpretation therefore is based on archaeological finds, that have been made in various beds.

Between the lowermost bed (S1 III^{b}) and the underlying Flevomeer Member a find from Roman times is mentioned by van der Heide (1955), so it may be assumed that sedimentation of the Almere Member started about 0 A.D. At the boundary of the S1 III^{b} and the S1 III^{a} beds a sarcophagus from the 12th century was found.

The so-called Valvata layer, which in most cases formed on top of the S1 III^{a} bed, was dated by Wiggers (1955) at about the middle of the 13th century; Ente (1973) concluded that the Valvata layer dates from the end of the 12th century.

The end of the period of deposition of the Almere Member could be established by many archaeological finds dating from the transition of the 16th to the 17th century. Some of the younger beds have been dated by means of ship wrecks (van Loon & Wiggers, 1975b). In the Noordoostpolder nearly 200 hulks have been discovered. These finds have in many cases been dated very accurately through special objects (*e.g.* coins) within the wrecks.

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Bodemkundige Code- en Profielenkaart van de Noordoostpolder, 1947-1956. Direc-

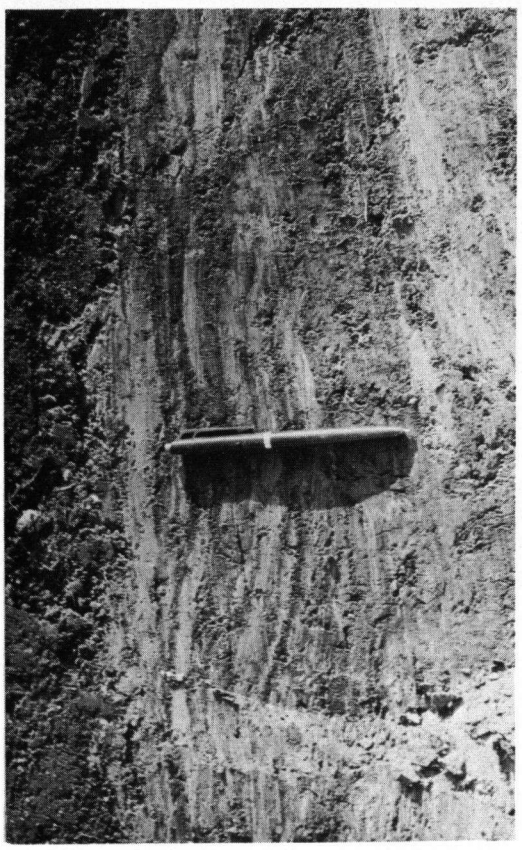
PLATE 2

Fig. 1. Proposed type section of the Almere Member. At the base some peat and detritus of older units is present. At the top bedding has been disturbed by ploughing.

Fig. 2. Detail of the type section, showing a part beneath the ploughing zone. Irregular, wavy lamination of the bed Sl I^a is visible in the middle, and "greasy" appearance of the bed Sl I^b can be seen at the base.

Fig. 3. Detail of the type section, showing the rather regular lamination of the bed Sl II^b (upper, light-coloured horizons), the humic character of the bed Sl II^c (light-grey band in upper half of photograph), and the coarse, irregular facies of the bed Sl III^a (lower part).

plate 2



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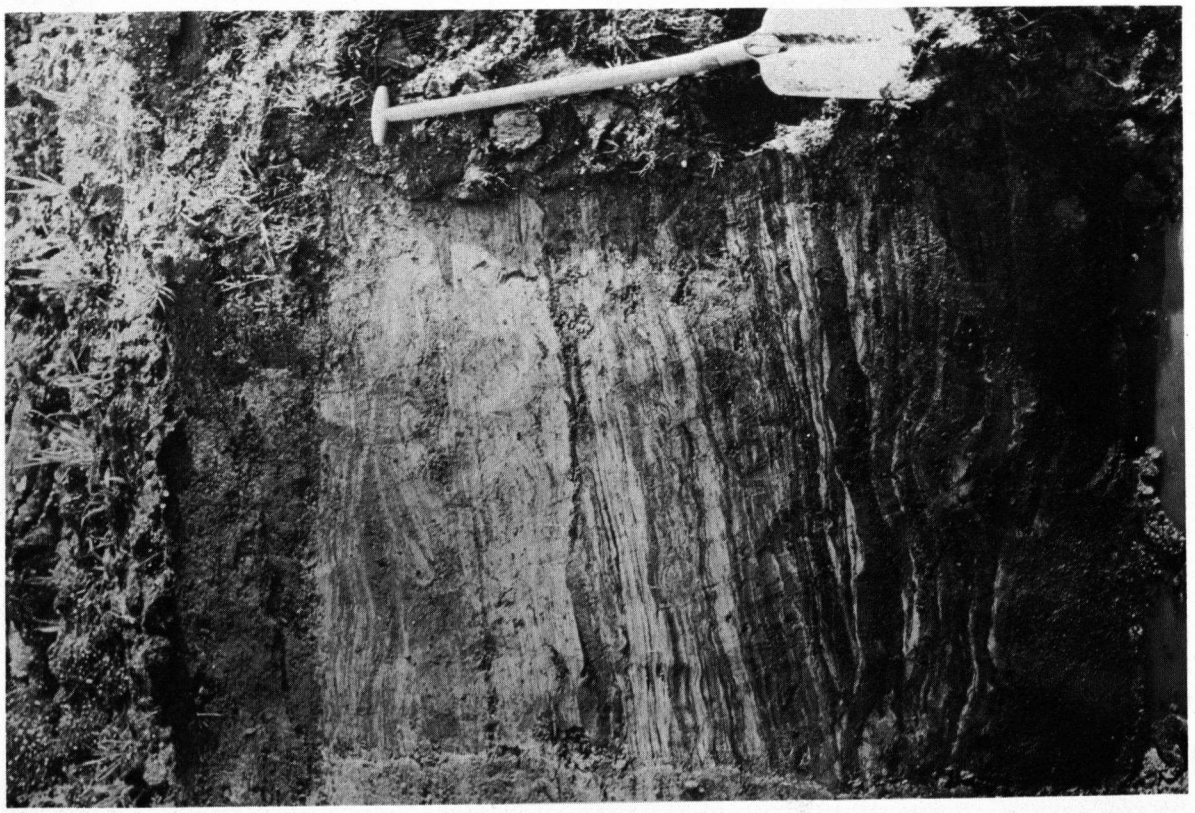

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