

PROBLEMS OF HOLOCENE LITHOSTRATIGRAPHY

–with examples from the Central Netherlands–

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ABSTRACT

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Many lithostratigraphic units have been introduced in the geological literature without clear definitions. This has led to serious problems, especially in cases where various authors have used the same name with apparently different meanings. Holocene lithostratigraphy knows the same problem, but there are two more important disturbing factors:

- (1) many sedimentary units are still being formed, thus prohibiting a unit delineation on the basis of both the lower and the upper boundary;
- (2) much field work is carried out by scientists who are interested in the ecological and sedimentary development of the area or in the land-use potential rather than in its purely stratigraphic aspects. This implies that the existing definitions are often based upon a non-lithostratigraphic aspect.

In order to solve these problems it is suggested that Holocene lithostratigraphic units should be defined by their lower boundary and their lithological characteristics. Some examples are mentioned to illustrate the practical and theoretical possibilities.

INTRODUCTION

Lithostratigraphic classification is a tool for practical work (i.e. mapping purposes), rather than for theoretical analyses. As a result, many (or even most) geologists use it in a 'practical' way, paying insufficient attention to clear definitions. This has resulted in much confusion, especially when a specific unit received different names from different authors, or when the same name was used for roughly the same unit, but with varying lower and/or upper boundaries.

Even though this is often considered as only an inaccuracy (and not as a real problem) it is clear that serious problems may arise when, for instance, the micropalaeontological content of a unit is used for correlation purposes. The most extreme situation in this respect may be formed by correlation on the basis of numerical dating of the unit's boundaries: if the boundary is not well-defined, dating *must* lead to problems.

C-14 analyses in the Holocene

Numerical dating of sedimentary units is a quite uncommon (and usually impossible) procedure. Only in the youngest

Quaternary deposits (late Weichselian and Holocene) is this commonly done by means of C-14 analyses of layers which contain organic material *in situ* (mainly peat).

In fact, the reconstruction of the Holocene history is mainly based on C-14 analyses in coastal areas, where the vertical succession of interfingering marine clays and peat layers has resulted in a detailed insight of the trans- and regressions which characterized the fluctuations in the post-Pleistocene sea-level rise. The more datings which became available, the more complicated this history appeared: an increasing number of trans- and regressional events were needed to explain the sedimentary succession.

Sedimentary facies and sea-level movements

Rather surprisingly, the sedimentological aspect has long been neglected during investigations of Holocene coastal areas. Only in (the last part of) the seventies has this discipline considerably contributed to a better understanding of the geological history and the lateral facies distributions.

One of the most important consequences of this sedimentological help is the insight that a succession of alternating marine clays and peat layers need not to be the result of sea-level movements: *lateral facies changes may be responsible,*

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especially in intra-littoral environments or where river influence is important.

Now it is clear that the 'lobes' of a peat body, even when found in a vertical succession above each other, may be ascribed to facies changes which may be independent of sea-level changes (though it becomes more and more clear that an interaction exists between fluvial processes and marine activity). This implies that peat horizons need not to have any formal stratigraphic significance at all. The choice of one of them as a boundary for a lithostratigraphic unit is therefore rather arbitrary; correlation of such peat layers in remote areas should certainly be avoided. Even when they show the same C-14 age, it is no proof at all of an identical lithostratigraphic position. On the other hand, peat layers with different ages in separated areas may correlate lithostratigraphically; they even may have been formed contemporaneously, but show different C-14 ages as a result of different botanical compositions.

HOLOCENE UNITS IN THE NETHERLANDS

How problematic Holocene stratigraphy may be in practice, is well shown by the present situation in The Netherlands. The Holocene development of the Dutch coastal area has resulted in a rather complicated succession, the main deposits of which are marine clays, peats, coastal (and dune) sands and fluvial deposits. Simplified the succession shows:

- (4) an upper unit of marine clays
- (3) an upper peat layer, which in places is connected to the deeper peat. This upper peat is underlain by
- (2) marine clays, (in principle) covering
- (1) a peat layer upon an undulating Pleistocene substratum which rises towards the S and E.

This general picture is complicated not only by interbedded beach, dune and fluvial deposits, but also by more or less continuous peat horizons within the marine clays.

Previous lithostratigraphic names

The various lithological units which can be distinguished have been given many names in the past. It seems beyond the scope of this paper to review them in detail; nevertheless it is appropriate to mention some names of the four most important units (peat/clay/peat/clay) in order to show why it is so difficult to know at present what is meant by the various names.

Some data about this same subject have been published by ROEVELD (1974) and GRIEDE (1978). Their reviews, however, lack a clear analysis of the problems and a suggestion of how to solve them.

As in most areas, the Holocene lithological units in The Netherlands were originally only defined by descriptive terms (like 'old blue sea clay'). Since their lithological characteristics may change laterally, this kind of definition was rather

inappropriate for correlation purposes (although most authors were not aware of this). An additional complication was formed by the language: papers about the Dutch and adjoining Belgian coast were mainly published in Dutch and French, but later English (and to a lesser extent also German) became important. To the confusing terminology in the original papers, was added the problem of translation. In this paper all original terms will be translated into English; the French term 'Assise', the Dutch term 'Afzetting(en)' and the German term 'Sequenz' will all be translated as 'Member'.

The lower peat unit – The first attempt to establish lithostratigraphic units with clear names was made by DUBOIS (1924). He considered the lowermost Holocene peat level as the upper part of the Ostende Member, which he made equivalent to the lower part of the Flandrian. In fact this formed the beginning of a real problem: the more that authors used the term 'Flandrian' (Flandrien), the more unclear it became whether it was meant to be a litho- or a chronostratigraphic unit.

Other authors have used the following (translated) names: non-marine member (TESCH, 1930, 1942), deeper peat (FLORSCHÜTZ, 1944; TAVERNIER, 1947, 1948; PANNEKOEK, 1956; DOPPERT, 1957), basal peat (DE JONG ET AL., 1960), lower peat (DE JONG, 1960), organic basal member (BARCKHAUSEN ET AL., 1976). None of these authors described these members (or unnamed units) as parts of a more embracing formation.

By various other authors, however, the peat was considered to be part of a named formation indeed. BRAND ET AL. (1965) and DE JONG (1960, 1967) consider this 'basal peat' as an informal unit of the (Holocene) North Sea Formation. Later DE JONG (1971) described this unit as the 'Holland peat Member' of the North Sea Formation.

At present two terms exist which are frequently used to indicate this peat level. ROEVELD (1974) considers it an unnamed part of the entire 'coastal' peat deposits which together form the Wold Formation. This terminology has been followed by various other authors (e.g. GRIEDE, 1978). Another terminology is followed by the Dutch Geological Survey, as indicated by ZAGWIJN & VAN STAALDUINEN (1975). They name the entire peat unit (both the basal and the higher parts) 'Holland peat', which they consider a part of the Westland Formation.

The nomenclature of Roeleveld and of Zagwijn & Van Staaldunin will be dealt with in more detail.

The lower marine unit – Ever since DUBOIS (1924) these deposits (which mainly have a near-shore, lagoonal or tidal-flat facies) have been known as the Calais Member; authors who used this terminology are, for instance, TAVERNIER (1947, 1948) and DE JONG ET AL. (1960). Nevertheless, purely descriptive terms have also long been used: old marine clay (EDELMAN, 1950), older tidal flat deposits (ZWART, 1951), old sea clay (HAANS, 1954) and old blue sea clay (TESCH, 1942).

More formal names are: Calais Subformation (of the (Holocene) North Sea Formation: BRAND ET AL., 1965; DE JONG,

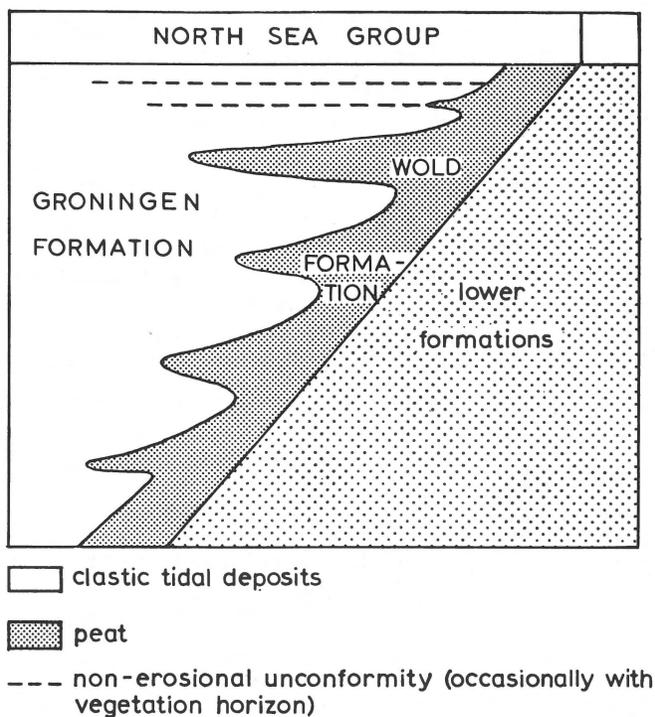


Fig. 1
Lithostratigraphic position of the North Sea Group, subdivided into a marine Groningen Formation and a Wold Formation with peat in situ (after Roeleveld, 1974). Both formations form part of the Westland Formation, introduced by the Dutch Geological Survey.

1960, 1967), Calais Member (of the North Sea Formation: DE JONG, 1971) and Calais Formation (HERBER ET AL., 1981).

In the terminology of ROELEVELD (1974) this unit forms the lower part of the Groningen Formation. ZAGWIJN & VAN STAALDUINEN (1975) consider it the Calais Member of the Westland Formation.

The upper peat unit – Informally this peat is known as ‘peat at shallow depth’. It has also been called ‘surface peat’ (TAVERNIER, 1947, 1948), ‘intermediate peat’ (TESCH, 1930, 1942), ‘upper peat’ (DE JONG, 1960) and Holland peat.

DUBOIS (1924) did not describe this peat as a separate unit, but placed it within the top part of his Calais Member. BRAND ET AL. (1965) and DE JONG (1960, 1967) called it ‘Holland peat’ and considered it to be an unofficial unit of their (Holocene) North Sea Formation. DE JONG (1971) made it the upper part of his Holland peat Member (of the North Sea Formation).

ROELEVELD (1974) considers it as the upper part of his Wold Formation whereas the Geological Survey (ZAGWIJN & VAN STAALDUINEN, 1975) names it Holland peat and considers it to be an informal part of the Westland Formation.

The upper marine unit – Informal names like ‘young sea clay’ and ‘young sea sand’ have long been used (e.g. TESCH, 1930, 1942; PANNEKOEK, 1956), even after DUBOIS (1924) introduced it as the Dunkerque Member. In a more or less similar interpretation it has been used by various authors (e.g. TAVERNIER,

1947, 1948), but often with a different spelling: Duinkerken Member (DE JONG ET AL., 1960) and Duinkerke Member (of the North Sea Formation: DE JONG, 1971). It has also been mentioned as the Dunkirk Beds (DE JONG, 1960) and as the Dunkerque Subformation (of the Holocene North Sea Formation: BRAND ET AL., 1965).

At present it is usually referred to as the upper part of the Groningen Formation (ROELEVELD, 1974) or as the Duinkerke Member of the Westland Formation (ZAGWIJN & VAN STAALDUINEN, 1975).

INVENTORY OF THE PROBLEMS

From the above-mentioned data it will be evident that the terminology is rather confusing. But there are several more problems:

- (1) most authors neither describe lateral facies changes, nor do they consider diachronous sedimentation;
- (2) definitions (or even descriptions) of the units under consideration are often vague or even completely absent. This also holds for stratotypes etc.;
- (3) in the studies mentioned it is not clear to which units some minor deposits should be assigned; this concerns, for example, thin peat layers or isolated peat lenses within the marine clastic units;
- (4) apart from ROELEVELD (1974) and his associates no distinction is made between autochthonous and reworked peat.

Geology is a discipline which uses data of which more and more get lost in the course of time. Therefore Holocene geology has the best chance of unravelling problems at a high level of resolution and it is considered a necessity to do so. That goal can only be achieved when a proper lithostratigraphic scheme is available, allowing a very exact exchange of detailed information about Holocene lithostratigraphy, apart from a chronostratigraphic framework.

Since at present the stratigraphic approaches by the Geological Survey and by Roeleveld are the ones most commonly applied, we will discuss their lithostratigraphic units in some more detail.

The Westland Formation

The Dutch Geological Survey (DOPP ET AL., in ZAGWIJN & VAN STAALDUINEN, 1975) introduced the Westland Formation in a rather unfortunate way. In the first place the introduction was realized in the ‘Explanation to general geological maps of The Netherlands’, published a year after the thesis by ROELEVELD (1974) who introduced other names. It may be true that the Geological Survey used the name ‘Westland Formation’ earlier in informal papers; but the formal introduction of a new formation name, even without referring to the earlier publication by Roeleveld, should be considered as an unfortunate result of insufficient communication.

There are more important objections against the use of this formation name:

(1) The authors give no unequivocal definition, but only a description which (in translation) goes as follows: 'The unit consists of alternations of coarse to fine sands, light to heavy clay and peat; almost all possible combinations of the lithostratigraphic units may occur. Coastal deposits, marine, estuarine, lagoonal and perimarine deposits are all included in the formation'. This rather vague description will prevent any objective distinction from other adjacent formations.

(2) Within the Westland Formation various members ('afzettingen') are distinguished which have hardly been defined at all: only reference is made to earlier publications (e.g. DUBOIS, 1924, for the Calais and Duinkerke Members), but, as shown before, those earlier publications are often of rather confusing nature.

(3) It is nowhere stated which rock units underlie the Westland Formation. It is evident that the authors only place Holocene deposits in this formation, but it is not clear how these should be distinguished from, e.g., Eemian marine deposits. It should be realized that the micropalaeontological arguments cannot be valid, since formations are units which should allow lithostratigraphic mapping in the field.

(4) As the upper boundary of the formation the local land surface is given. This is certainly incorrect, since it is not excluded that the sediments are locally covered by other deposits, e.g. recent fluvial sediments belonging to the Betuwe Formation. Furthermore, a proper definition of local land surface is lacking. Does it imply the surface of 1975 or that in any other year that is suitable for the investigator?

(5) The variation in lithology has led the authors to introduce three stratotypes. According to the commonly accepted rules for stratigraphic nomenclature (see, e.g., the International Stratigraphic Guide, edited by HEDBERG, 1976) this is unacceptable since it is only allowed to establish one holostatotype and various (but subordinate) para- or hypostatotypes. The authors give no indications for such distinctions, neither do they present criteria which are required for establishing a para- or hypostatotype in the sense of HEDBERG (1976).

(6) Although the authors mention three stratotypes, they in fact only indicate three type areas without selecting a proper type locality for the stratotype.

(7) For the establishment of a stratotype there should be an adequate description which constitutes the standard for the definition and recognition of the unit concerned. Various aspects should be described (cf. HEDBERG, 1976), including a lower boundary.

(8) The authors mention a Holocene age for this formation, and within the framework of their publication it is evident that older deposits are excluded. This introduces a chronostratigraphic characteristic, which is not allowed.

In view of the above objections, the formal introduction of the Westland Formation should have been avoided. An analysis of the objections shows that, apart from an inadequate definition, a major problem is formed by the combination of two units with quite different lithologic properties and genesis (autochthonous peat and clastics). The unfortunate introduction of this formation most probably is the result of detailed mapping in the area where these two lithologies are interfingering as a result of facies changes.

The North Sea Group

ROELEVELD (1974) recognized the problem of the two different lithological units and introduced a Wold Formation (autochthonous peat) and a Groningen Formation (clastics), which he combined into the North Sea Group (Fig. 1). Although this offers less problems in comparison with the terminology used by the Geological Survey, other ones remain unsolved. For instance, Roeleveld did not properly define his formations, nor did he establish stratotypes, only type areas for both formations being indicated. Furthermore Roeleveld did not state whether small and/or autochthonous peat lenses and vegetation horizons within the clays belong to either the Groningen or the Wold Formation.

Roeleveld does not indicate whether or not lithostratigraphic units of a lower rank can be discerned in his formations. In fact it is even unclear whether his Groningen Formation contains all marine clastic sediments of the Westland Formation of ZAGWIJN & VAN STAALDUINEN (1975). It might be supposed that this is not the case: the Westland Formation is meant to be a unit recognizable throughout The Netherlands whereas the Groningen Formation is established mainly as a stratigraphic tool for mapping purposes in the northern coastal area of the country. But such a difference in applicability is substantiated by neither the Geological Survey, nor Roeleveld.

In spite of these shortcomings, Roeleveld's concept is accepted as basically correct. Therefore it is suggested that stratotypes for both the Groningen and the Wold Formations should be established, with descriptions and definitions according to the international criteria (HEDBERG, 1976). This should be done on the basis of (hand)borings on localities with characteristic properties in an area where interfingering of the two units does not occur.

Afterwards an attempt could be made to subdivide these formations into units of a lower rank (e.g. members), where necessary or useful from the point of view of mapping or lithostratigraphic correlation.

As far as the term 'North Sea Group' is concerned, it seems necessary to stress that a new possibility for future confusion is

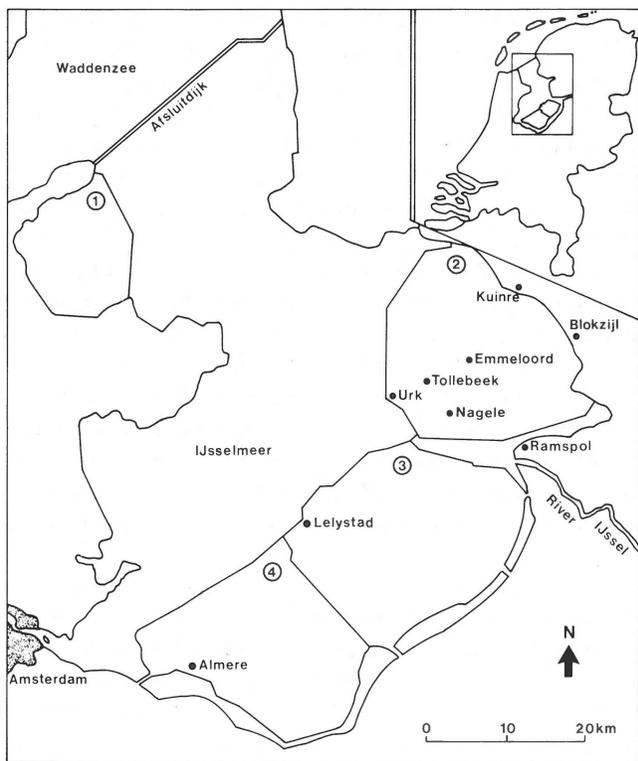


Fig. 2
Location of the IJsselmeer area with polders (1 = Wieringermeer; 2 = Noordoostpolder; 3 = Oostelijk Flevoland; 4 = Zuidelijk Flevoland) and localities mentioned in text.

already present. While ROELEVELD (1974) uses this name to combine his post-glacial formations in the coastal areas, the Geological Survey (VAN STAALDUINEN ET AL., 1979) uses this term to combine many more formations, including various ones with a Pleistocene or even Tertiary age.

SUBDIVISIONS OF (SUB)RECENT FORMATIONS

Quaternary, and especially Holocene, formations offer an ideal possibility for detailed mapping. This advantage may be used for discerning various separate subunits which, according to the rules of nomenclature, should be called members; if such members can be further subdivided, this may be done by naming separate beds, the smallest formal lithostratigraphic units. Such a detailed subdivision at first sight may seem useless, but in practice it may contribute considerably to a better understanding of the palaeogeographic development in the area under study.

It should be emphasized that *only lithological characteristics* should be taken as a criterion. This implies, for instance, that it is impossible to subdivide the Wold Formation into members, only on the basis of different ages for the various peat tongues. However, for the Groningen Formation with its varied lithology, such a subdivision into members is possible.

Since this special issue of *Geologie en Mijnbouw* is dedi-

cated to Prof. Dr. A. J. Wiggers, it seems appropriate to show the possibilities for a subdivision in the area where he worked for a long time and where he was concerned with lithostratigraphic problems during mapping.

The IJsselmeer area

The IJsselmeer, in the central part of The Netherlands, became a lake after the construction of a dam in 1932. Before that time it had been a lagoon, originating from a peat-lake area, formed 6000-2000 years ago.

Within the IJsselmeer area four large polders have been reclaimed; the first was the Wieringermeer (1930). In the fresh-water stage (so after 1932) the Noordoostpolder (1942), Oostelijk Flevoland (1957) and Zuidelijk Flevoland (1968) were reclaimed (Fig. 2). Wiggers has carried out various investigations in these polders (and adjoining areas), partly before they became dry (e.g. WIGGERS, 1955, 1963; SMITS & WIGGERS, 1959; PONS & WIGGERS, 1959-1960; ENTE ET AL., 1961; WIGGERS ET AL., 1962; ENTE & WIGGERS, 1963); the most important data were derived from the Noordoostpolder. In a later phase Wiggers and the present author carried out both sedimentological and stratigraphic investigations in the IJsselmeer area, again with emphasis on the Noordoostpolder (VAN LOON & WIGGERS, 1975-a, b, c, d, 1976-a, b, c, 1977, 1979). The data gathered resulted in the proposition of two formal units: the Almere Member and the Nagele Member, both belonging to the Groningen Formation.

It is beyond the scope of this paper to describe the geology of the IJsselmeer area in detail, but a few factors should be mentioned:

- (1) The Pleistocene substratum mainly consists of cover sands (Twente Fm.), fluvial deposits with occasionally river dunes (Kreftenheye Fm.) and boulder clays (Drente Fm.).
- (2) After a varied history the area became covered with Holocene peat, in which lakes were eroded. These gradually grew together to form one large lake (Flevomeer). Subsequently, a connection with the sea was formed, changing the lake into a slightly brackish lagoon (Almere). About 1600 A.D. this lagoon suddenly attained an almost full-marine character (Zuiderzee), which lasted till the dam was closed in 1932 forming a new lake (IJsselmeer).
- (3) In Holocene times clastic sediments were supplied (a) by erosion of the bottom and the borders, (b) from the North Sea via the Wadden Sea, and (c) by the river IJssel which gradually built out a delta.

On the basis of these data and field observations, it is proposed to distinguish between various lithostratigraphic units in this area. Since the scope of this paper is restricted to the Holocene, only those units will be dealt with that are at least partly of Holocene age.

The author is well aware that the following suggestions cannot be considered as formal proposals for the establishment of new units; for most of them much more field work and laboratory analyses should be carried out to fulfill all require-

ments. The main intention, however, is to show the possibility of relevant subdivisions on a lithostratigraphic basis, and to encourage investigations of this type in the IJsselmeer area and elsewhere.

Wold Formation – This is the most easily defined unit. It contains all peat *in situ*. Since peat growth is an important facies indicator, it is suggested that all thin and/or isolated peat bodies are included, even vegetation horizons. As mentioned earlier, a stratotype of this formation still has to be established; this may be done in the Wold area as indicated by ROELEVELD (1974).

One might consider the possibility of distinguishing members on the basis of the type of peat, as most types can be recognized in the field. This procedure can be useful since it will provide additional information about the conditions of the terrain. An objection against this type of subdivision might be that the formation would then consist of many bands and bodies, belonging to various named members, within a rather chaotic framework.

Flevomeer Member – This unit consists of (allochthonous) peat of the Wold Formation, reworked in a limnic environment. There may be coarse to fine well-recognizable peat fragments, but gyttja and dy are also common. The sediments directly overlie the autochthonous peat of the Wold Formation and usually are less than 25 cm thick. Since the nature of the sediment (detrital peat, gyttja or dy) does not provide additional information about the sedimentary environment, there seems no relevance in distinguishing these lithologies as separate beds.

This unit is called a member and not a formation. The main reason is that it, although easily mappable, is of very restricted thickness and (probably already from its origin) discontinuous, which characteristics make the unit improper for the rank of a formation.

This poses the question to which formation this member belongs. Obviously it cannot form part of the Wold Formation, since that one only comprises peat *in situ*. The Geological Survey (ZAGWIJN & VAN STAALDUINEN, 1975) do not mention this unit separately, but it is evident that they assign it to their Westland Formation. Apart from the formal objections against that formation, we think this an inappropriate solution.

There is no formation covering all limnic sediments in The Netherlands; the Geological Survey introduced the Griendtsveen Formation: "The unit predominantly consists of peat, in which *Sphagnum* peat dominates: furthermore some organogenic limnic sediments are present, consisting of dy and gyttja". For reasons which are beyond the scope of this paper, it seems not justified, however, to attribute the Flevomeer Member to this formation, so this problem remains as yet unsolved. But a stratotype of the Flevomeer Member could be selected and described properly.

Almere Member – This unit has been formally introduced by VAN LOON & WIGGERS (1975-b). These authors consider it as a part of the Groningen Formation which, however, has as yet not been defined and described properly according to the stratigraphic criteria. Van Loon & Wiggers mention no less than nine previously used names for this unit, together with some discussions about the terminology of 'Duinkerke deposits' etc.

The member consists of alternations of clayey, silty, fine-sandy and peaty laminae in a lagoonal facies with many deformational sedimentary structures. Macrofossils are extremely scarce, except in one erosional horizon where shells of *Valvata piscinalis* have been concentrated.

In this member seven beds have been distinguished in the Noordoostpolder; most of these beds can be traced over large distances in the IJsselmeer area, but elsewhere a few other beds may be present as well (KOOPSTRA, 1962; ENTE & SEGEREN, 1969).

The characteristics of this unit are clear: a fine-grained sediment deposited in a slightly brackish lagoon, and resting upon the Flevomeer Member or, where absent, on the Wold Fm., the Kreftenheye Fm., the Twente Fm. or the Drente Fm.

Zuiderzee Member – Although informally mentioned in earlier papers (e.g. VAN LOON & WIGGERS, 1976-a, 1977), this unit has not as yet been established correctly. It usually directly overlies the Almere Member; the most characteristic difference being the sudden appearance of macrofossils (e.g. *Cardium edule*) which indicate an abrupt increase in salinity, giving it an almost full-marine character. Consequently this member definitely belongs to the Groningen Formation.

The silt content is less than in the Almere Member; as a consequence the number of sedimentary deformational structures is much smaller. Within this member various beds can be distinguished (cf. WIGGERS, 1955); a stratotype should be located in a place where all these beds are present.

IJsselmeer Member – When the dam was closed in 1932, the 'marine' sedimentation in the lagoon stopped and the water gradually became fresh. Another result was that the sediment supply from the Wadden Sea was halted almost completely and the sedimentation rate decreased considerably. A new hydrographic pattern appeared which locally resulted in erosion; the eroded deposits were laid down elsewhere as fine-grained fresh-water sediments.

Since the change from a marine into a fresh-water environment is considered of importance, these fresh-water deposits are considered as a separate lithostratigraphic unit. The restricted thickness and discontinuous extent seem to prevent the establishment of a new formation, though sedimentation continues and may form a continuous sheet when the entire IJsselmeer will have been filled up completely. Nevertheless, at present it is considered more appropriate to treat this unit as a member. However, this raises the question of which formation this member belongs to. Up to now no formation

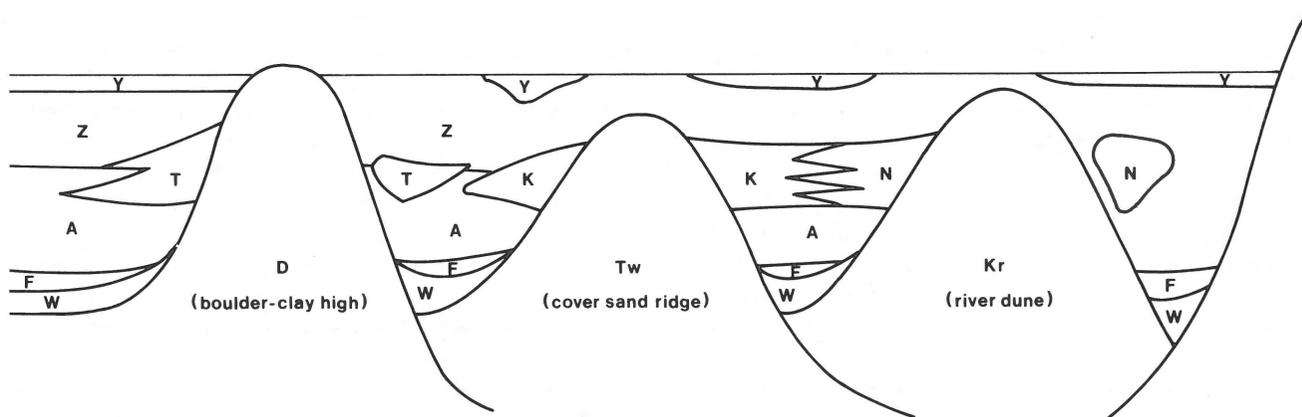


Fig. 3

Theoretical cross section through part of a polder in the IJsselmeer area, showing the main lithostratigraphic units. Vertical scale exaggerated. Y = IJsselmeer Member; Z = Zuiderzee Member; A = Almere Member; T = Tollebeek Member; K = Kuinre Member; N = Nagele Member; F = Flevomeer Member; W = Wold Formation; D = Drente Formation; Tw = Twente Formation; Kr = Kreftenheye Formation.

has been introduced by either the Geological Survey or other investigators for this type of deposit. Therefore it will be necessary to investigate whether all post-glacial lake deposits should be assigned to one formation (at present some of them are included in other formations like the Westland, Betuwe and Singraven Fm.), or whether another solution has to be looked for. In any case it will be required to describe a stratotype properly for both the IJsselmeer Member and the formation to which it belongs.

This unit lies on top of the Zuiderzee Member, locally on top of the Almere Member and it cannot be excluded that (in restricted areas) it lies on top of local units. The upper boundary, of course, is a problem; since the unit is still being formed, it is *the best possible proof that it is of no use to establish an upper boundary* for Holocene deposits.

Another interesting problem is of a more practical nature: a stratotype should be easily accessible and therefore preferably not under water. But in the reclaimed polders, where possibly relevant stratotypes have been present, the upper soil layer has been reworked by tillage. So it will be almost impossible to find a locality which fulfills all criteria for a stratotype.

Tollebeek Member – Especially in the lagoonal phase (in which the Almere and Zuiderzee Members were formed) abrasion, due to wave action, affected the Pleistocene 'highs'. In a few cases boulder clays of the Drente Formation were eroded, and the material became re-deposited in wedge-formed units, often elongated according to the predominant wave direction.

Such a situation is clearly visible near the village (on the former island) of Urk: the reworked material forms a long 'tail'. Especially since the Urk locality has yielded the best-developed sediments of this nature, the deposits have been informally known as Urk sands. That would suggest a formal name like Urk Member. In The Netherlands, however, there exists an Urk Formation of quite different nature. Since an

Urk Member might lead to confusion, it is suggested to name this unit after another village (Tollebeek) where similar deposits frequently occur.

The unit is easily recognizable, since it consists of the coarsest sands present in the IJsselmeer area, often with many boulders in it (up to a few dm). No similarity with the Drente Fm. exists, since the reworked sediments show abundant structures of subaquatic origin. In some places it is possible to distinguish various beds, e.g. on the basis of fossils present.

It is suggested that a stratotype be established near Tollebeek, if possible with a parastratotype (or holostratotype) near Urk. The obviously contemporaneous deposition with respect to the Almere and Zuiderzee Members, in which the Tollebeek Member is present as isolated bodies, indicates that it belongs to the Groningen Formation.

Nagele Member – Just as abrasion of boulder clays resulted in the formation of the Tollebeek Member, abrasion of late Weichselian to early Holocene river dunes (Kreftenheye Fm.) led to sandy deposits which have been combined into the Nagele Member. The grain size of the sands is very constant with a high percentage between 105 and 420 μm ; grains larger than 600 μm are almost completely absent.

The unit has formally been introduced by VAN LOON & WIGGERS (1977), who pointed out that it belongs to the Groningen Formation. They mention the occurrence of two beds which are, respectively, time-equivalent to the Almere and the Zuiderzee Members. It seems appropriate and useful to establish these beds in a formal way, since they may provide information on wave activity and availability of river-dune sand during the palaeogeographic development of the area.

Kuinre Member – Comparable to the Tollebeek and Nagele Members, this part of the Groningen Formation is due to abrasion of cover sands (Twente Fm.). In various localities the lithological characteristics (esp. the macrofossil content) indicate that two beds can be distinguished, again time-

equivalent to the Almere and Zuiderzee Members.

Informally these deposits are known as Kuinre Sands, but no formal proposal for a member name has been published as yet. Investigations are being carried out at present, however, to describe a proper stratotype near the former harbour of Kuinre.

Other possibilities – It is possible to distinguish even more lithostratigraphic units in the IJsselmeer area. An analysis of previous investigations (e.g. WIGGERS, 1955) shows that, for instance, the Ramspol Sands, the Blokzijl Sands and others could be treated as separate units.

It seems beyond the scope of this paper to go into such detail. It should be clear, however, that the lithological development of the deposits in the IJsselmeer area will allow an easy recognition of units with such specific characteristics that it seems appropriate to identify them as formal lithostratigraphic units (Fig. 3).

DISCUSSION

The aim of this paper is to show the possibility of establishing a correct and detailed lithostratigraphic nomenclature for areas where sedimentation is still going on. Suggestions have been made to establish new formal lithostratigraphic units, but this paper contains no formal proposals due to lack of adequate detailed information.

The suggestions are based on two main principles: (1) the lithology must be sufficiently characteristic to recognize the units in the field without problems; (2) the genesis must be considered (e.g. peat *in situ* versus reworked peat). Doing this, a few questions arise:

(1) When is a recognizable unit sufficiently sizeable to be mapped as a separate unit? In principle, the thickness or extent of a unit is not of any importance; in the USA, for instance, formations tend to comprise much more rocks than in Europe; young deposits tend to be split up in smaller units than older ones.

Nevertheless it is felt that the basic unit (the formation) should show both lithological and genetic characteristics which define it as a separate unit, plus a not too restricted (original) extent. In the IJsselmeer area these requirements seem to be matched by placing all units within three formations: a marine one, a limnic one and one consisting of peat *in situ*. All these three formations occur or have occurred over the entire IJsselmeer area.

Within each formation the members should be chosen on the basis of their lithological characteristics. Since, for instance, many small sand stringers may result from the abrasion of a boulder clay, it is felt that not each sand grain or even each sand lamina should form a separate member. Considering the thickness of the Groningen Fm. in the IJsselmeer area (less than 1 m to a few m), one might suggest mapping a

deposit as a separate member if it embraces all lithologically comparable parts of a formation, as far as these separate parts are at least about one dm thick.

Within a member the beds which can be distinguished may have any thickness. In order to avoid too many names, it is suggested to introduce formal beds only if they have an extent of at least several kilometres.

(2) How should the lower and upper boundary be defined? The last part of this question is most easily answered: the upper boundary should not be defined since sedimentation is sometimes still going on, and in other situations where it has stopped or is replaced by another type of sedimentation, the original circumstances may come back. So *the upper boundary in fact is only defined by the lower boundary of the next unit!*

This implies that the lower boundary is very important. But it cannot be stated that the lower boundary (in a specific locality) lies where, for instance, marine sedimentation turns to peat growth. For such an approach leads to extreme difficulties in areas where two main types of deposits interfinger (like peat and clays in Holocene coastal areas). On the level of members, this will lead to even more frequent problems than on the level of formations.

The best solution is to establish a stratotype in an area where no interfingering occurs. By definition, the lower boundary has to be clear in that stratotype. *The lower boundary of the unit can then be defined as the level that lithostratigraphically can be correlated with the lower boundary in the stratotype.* This is sufficient, for in an area where interfingering occurs, various levels above each other are all correlatable with one level (the base) in the stratotype.

Whenever a unit, e.g. a member, consists of isolated lenses, that should be mentioned explicitly in the definition.

(3) Where should a stratotype preferably be located? In contrast to most older units (especially those of hard-rock formations), most Holocene deposits are badly exposed. In many cases this implies that the stratotype will consist of a boring or a specific place in the wall of a ditch. Such localities should be chosen in such a way that there is a minimal risk for disturbance (e.g. by tillage) or for inaccessibility (e.g. by the construction of new roads, expansion of a city, etc.). Besides, it should fulfill the other requirements, e.g. a characteristic development and the presence of as many units of a lower level (e.g. members within a formation) as possible. The most suitable location is there, where in the stratotype of the formation also the stratotypes of the members (and possible beds) can be chosen.

If possible, the stratotype should be located at (or very near to) the geographical object from which its name is derived.

(4) What name should be given to the unit? In this respect there are no special rules or recommendations for Holocene units. One should follow the normal procedure, viz. choosing a name which can be found on maps. Choosing the name of a

geographic object which does not contain deposits of the considered unit at the surface or in the subsoil should be avoided as much as possible.

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