

## THE MARINE PLEISTOCENE SEDIMENTS IN THE FLANDRIAN AREA

— a 'mise au point' on the nomenclature and stratotypes —

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### ABSTRACT

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A review of the Pleistocene marine stratigraphy of the Belgian coastal plain is given, including a critical discussion of the formerly used nomenclature. A stratigraphical revision of formations introduced in the first edition of the legend of the Geological Map of Belgium is made.

Hence the Oostende Formation (type locality Oostende) stands for marine deposits of Eemian age, the Herzele Formation (type locality Herzele in France) stands for marine deposits of both Holsteinian and 'Cromerian' age. In the Flemish Valley as well as in the eastern part of the coastal plain both formations are found to exist generally superposed. Here the Zeebrugge Member of the Herzele Formation is introduced to indicate marine deposits with *Corbicula fluminalis* and *Tapes senescens* var. *eemiensis*. Neither fossils are therefore considered as solely belonging to the Eemian stage.

### INTRODUCTION

The study of the geological evolution of the Flandrian coastal plain has a long but tedious background. Ever since A. Rutot (1895) introduced the connotation 'Flandrian' a hundred years ago its stratigraphical meaning has changed continuously from Lower Quaternary (= Diluvium) to recent or Holocene (PAEPE ET AL., 1976). It is partly due to the complexity of the stratigraphical structure of the coastal plain that the confusion has continued so long. Moreover, the lack of well described stratotypes respecting international rules of stratigraphic classification in our opinion contributed largely to this confusion. The lack of thoroughly separated litho-, bio- and chronostratigraphical stratotypes (mixed up in many cases with ill-defined terms of geomorphology) prevented a clear

picture of the geological sequences being seen (cf. VAN LOON, 1981).

In this area climatic changes frequently controlled facies changes (marine and continental), changes in sea level, in coastal configuration and in geomorphological development (varying from pediplanation under polar-desert conditions to landscape dissection during phases of temperate climatic evolution). Adequate separation of the various stratotypes is thus of basic importance.

The major mistake which characterises many former studies is an incorrect intermingling and over-subdivision of lithostratigraphical sequences of different regions as well as of various chronostratigraphical classifications. Correlation of even adjacent sites may be incorrect because of the impossibility of distinguishing between major and minor palaeoclimatic trends, leading to correlation of deposits of different age and genesis. An overestimated compilation of the number of lithostratigraphic units is another direct result of mixing up local seasonal palaeoclimatic events with regional periodical ones. Thus an attempt will be made to contribute to a Pleistocene geological framework of the coastal plain in the Flanders area on the basis of major mapping units which reflect the broadscale palaeoclimatic trends.

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## METHODOLOGY OF LITHOSTRATIGRAPHIC SEQUENCES AND MAPPING UNITS

The legend of the Belgian Geological Map of 1892 and its subsequent second, third and fourth editions contain all major elements of the Pleistocene stratigraphy. They are essentially lithological mapping units indicated as Q4, Q3, Q2 and Q1 in decreasing order of age called respectively Flandrian, Hesbayan, Campinian and Moséan. More specifically for the coastal plain three facies must be retained: *Q4 m* (marine Flandrian with *Corbicula fluminalis*), *Q3 m* (loam with *Succinea oblonga*), *Q2 m* ('Cailloux ardennais et de silex des grandes vallées').

The question now arises of whether these mapping units are sufficient to represent the major lithostratigraphic sequences of an area and to reconstruct its palaeoclimatical evolution. The INQUA-commission (in April 1972) added two major amendments to the International Code on Stratigraphy and Nomenclature (edited by HEDBERG, 1976) which were accepted at the I.G.C. in Montreal the same year: it is recommended that lithostratigraphic sequences most likely represent entities of cold or warm climatic stages in order to avoid the complexity of sediment textures which often determines the Quaternary. It recalls a statement made by BUDEL (1959) on the periodic and episodic solifluction, the first one relating to seasonal variations, the second to climatic changes at the level of those affecting the Quaternary System.

In the following critical review these guidelines of Quaternary stratigraphic methodology will be followed i.e.:

(1) large-scale lithostratigraphic units such as Formations will preferentially determine the palaeoclimatic stages or cycles; (2) small-scale lithostratigraphic units such as Members and Beds will occasionally give indications of the minor climatic trends or even local edaphic conditions. They may help to determine the mode of sedimentation within a lithostratigraphic unit.

### PLEISTOCENE STRATOTYPES OF THE COASTAL PLAIN

The Pleistocene deposits of the coastal plain have been badly correlated because of the lack of knowledge of the facies and their respective ages. A review of the stratotypes which have been described since Rutot's definition of the Flandrian will be given here. Also the extension of the lithostratigraphic units in as far as they may be used as mapping units will be considered. In the following discussion the stratotypes will be considered according to their geographical situation and stratigraphical position. The following Pleistocene areas will thus be given thorough attention: the western coastal plain with the IJzer Gulf, the middle coastal plain around Oostende and the eastern coastal plain with the Flemish Valley. It is clear that the Pleistocene marine sediments extend inland beyond the limits of the Holocene one.

### *The western coastal plain and the IJzer Gulf: the stratotype area of the Herzele Formation*

The western coastal plain situated on the French-Belgian border penetrates inland into the Houtland along the IJzer Gulf. On both sides of the IJzer valley the sands are found with *Cardium edule* which RUTOT (1885) first observed at Izenberge and initially attributed to an old Pleistocene marine deposit for which he introduced the connotation Flandrian. For about three quarters of a century the marine origin and age of this deposit was unknown.

TAVERNIER & DE HEINZELIN (1962) and VANHOORNE (1962) simultaneously advocated a Holsteinian (sensu Needian) age in a combined lithostratigraphical and biostratigraphical study. Vanhoorne did not exclude a Cromerian age, contrary to the other two authors who found the presence of *Bela plicifera* sufficient proof of Holsteinian age.

SOMME ET AL. (1978) undertook a multidisciplinary study of these deposits which included detailed studies in lithostratigraphy (SOMME & PAEPE, 1978), sedimentology (Cunat), bio-stratigraphy (Vanhoorne), mineralogy (Juvigne), clay geology (Thorez), and palaeomagnetism (Hus, Gheeraerts and Mortier). It resulted in the creation of the Herzele Formation built up by three marine layers of which Rutot's Izenberge *Cardium* sands occupy the uppermost level generally occurring at an altitude of 10 to 15 m O.D. (Fig. 1).

The Holsteinian age of the two uppermost layers has been confirmed by the presence of successively *Taxus* and *Abies* in the pollen spectra. The age of the lowermost layer remained doubtful although its altitude and its geographically wide-spread occurrence (BAETEMAN, 1978; TAUFIO, 1978) on both sides of the French-Belgian border leaves no doubt that it is an independent marine deposit preceding the two Holsteinian layers. As the palaeomagnetic record shows no change in the polarity which remains positive for the whole of the Quaternary sequence, it has been proposed that the lowest marine layer be located within the later part of the 'Cromerian' stage *SENSU ZAGWIJN ET AL. (1971)*.

PAEPE ET AL. (1976) described how Rutot linked up and extended these deposits into the present-day coastal plain confusing Holocene *Cardium edule* associations with Pleistocene ones and hence creating the problem of the age of the Flandrian. After DUBOIS' (1924) redefinition Flandrian deposits became restricted to the Holocene age and to the present-day coastal-plain geographical distribution. This had an important bearing on the image and concept of the stratigraphical sequences in the coastal plain in Belgium and N. France for about half a century: it literally banned the idea that Pleistocene deposits in the coastal plain occurred frequently (even with regard to the Eemian Oostende Formation) under the Holocene cover. Instead, the thickness of the latter has been overestimated in many places regardless of the fact of grouping Holocene litho- and biostratigraphical sequences with Pleistocene ones.

Until very recently, the Western coastal plain in Belgium

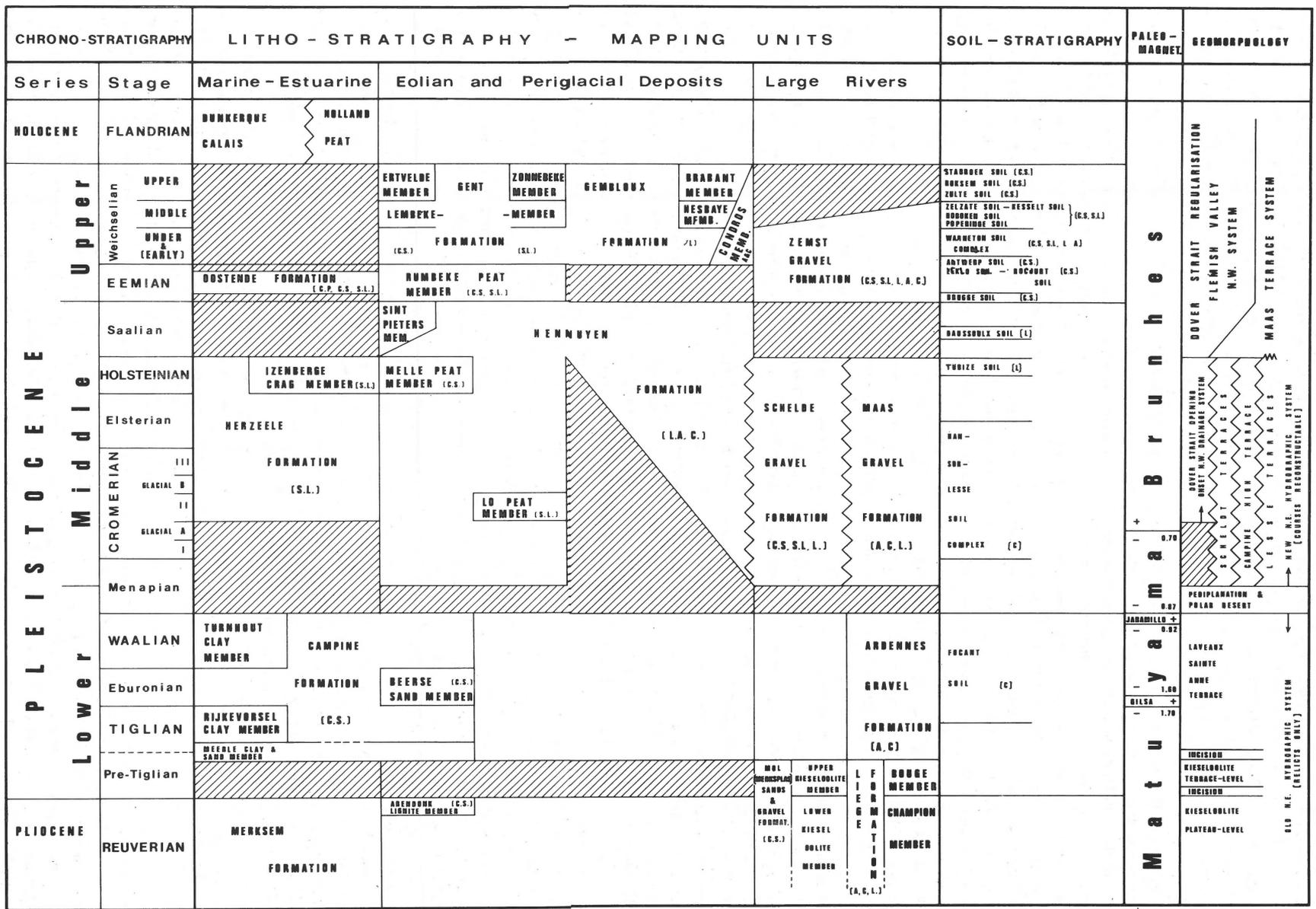


Fig. 1  
Lithostratigraphic table of the Belgian Quaternary deposits (after Paepé, 1976).

was believed to be entirely without Pleistocene marine (and continental) deposits. A systematic survey carried out by Baeteman since 1972 and biostratigraphically completed by Zagwijn (unpublished) revealed the existence in the coastal plain of continuously occurring Pleistocene deposits which may be linked up with the Pleistocene deposits of the IJzer Valley. It raises again Rutot's problem of connecting litho-stratigraphical sequences of the present coastal plain and IJzer Valley with those of Izenberge and the Pleistocene IJzer Gulf. Despite the great amount of evidence collected since 1962 for the presence of at least two Holsteinian marine deposits in Western Belgium and Northern France, some authors still doubt the validity of these litho- and biostratigraphical arguments. Such hesitation finds expression in GULLENTOPS' (1974) concept of the Holsteinian coastline which is believed to occupy a more northern position, linking the middle of The Netherlands with East-Anglia and the Thames-valley. Gullentops believes that the North Sea steadily transgressed from this position into its southernmost area finally resulting in the flooding of the Strait of Dover which was hence dated as post-Holsteinian age at the least.

The flooding of the IJzer Gulf as described by SOMME and PAEPE (1972 to 1974) leaves no doubt about its Holsteinian age or even Late Cromerian age. On the evidence of the IJzer Gulf deposits alone it is still questionable whether the Atlantic Ocean was hereby linked to the whole of the North Sea via the Strait of Dover. It could have been just a small part of the Atlantic Ocean which flooded via the Strait of Dover into the IJzer Gulf. During both of the Holsteinian transgressions, and most probably during the later part of the Cromerian, the Atlantic Ocean controlled the southernmost area of today's North Sea via the Strait of Dover.

From the study of the Herzele Formation in this area it has also been concluded (SOMME ET AL., 1975; PAEPE ET AL., 1976) that the shaping of today's configuration coast started in the earlier part of the Middle Pleistocene, after the important Brunhes-Matuyama reversal. With respect to the geomorphological evolution in the North Sea Belt it points to the existence of a base level of erosion which is no longer solely located in the North or North-East, but as now due West.

So far no older deposits have been found so that the Herzele Formation, where present, rests immediately on the uppermost Eocene formation. It may be overlain by Middle and Late Pleistocene loessoid deposits, marine Eemian deposits, or by Holocene marine deposits.

#### *The middle Belgian coastal plain: stratotype area of the Oostende Formation*

In 1863 the 'Assise d'Ostende' was created by DEWALQUE which DOLLFUS (1884) called 'marine sands of Oostende of Lower Quaternary age' on basis of the presence of *Corbicula fluminalis*. These sands occurred underneath a series of weathered loam layers which he compared to those of the adjacent sand-loess area. This Old or Lower Quaternary was

indicated in the legend of the Geological Map (1896) as Moséen (Q1); the loam layers were assimilated with the Young or Upper Pleistocene connotated as Hesbayen (Q3) on the Geological Map. The Campinien (Q2) was not present, but instead the loams were covered by marine shell-bearing deposits which Dollfus called 'Modern' although the Geological Map indicated it as Flandrian (Q4); for Rutot a Pleistocene age was likely.

Actually Rutot did not believe in the value of *Corbicula fluminalis* as a guide fossil and therefore considered that both the marine mollusc associations below and above the Hesbayen loam layers belonged to the Quaternary i.e. Pleistocene. Later, after studying a similar sequence to the Oostende boring, namely in Hofstade (1910), situated at the very eastern edge of the Flemish Valley (see later), Rutot accepted this error in stating that the 'Flandrian' deposits above the loam layers were definitely younger.

TAVERNIER (1943) when studying the coastal-plain deposits therefore initially introduced a 'Lower Flandrian' of Pleistocene and an 'Upper Flandrian' of Holocene age. In fact this compares closely with DUBOIS' (1924) Flandrian with the 'Sands of Oostende' at the base, and the Calais and Dunkerque deposits at the top. This is far away from the initial Flandrian at Izenberge; moreover 'Flandrian' should be limited to the Holocene marine deposits.

After a long period of hesitation TAVERNIER (1954) finally adhered to LORIE'S (1903) assumption that the lowermost marine Flandrian or Oostende Sands compares with the Eemian 'Sands of Zeeland' characterized by the presence of *Tapes senescens* var. *eemiensis* and *Corbicula fluminalis*. In 1965, PAEPE confirmed the *in situ* character of *Corbicula fluminalis* and *Tapes senescens* var. *eemiensis* in several borings between Oostende and Gent. In excavation pits at Meetkerke and Brugge — Sint-Pieters. PAEPE & VANHOORNE (1972) studied complete sequences originally described in the Oostende boring. The mollusc fauna with the above-mentioned guide fossils appeared in the Oostende Formation *in situ* for which the Eemian pollen spectrum definitely classified this Formation within the last interglacial stage. In both places these Eemian tidal-flat deposits were clearly separated from the overlying recent polder tidal-flat sediments by loamy coversands of the Last Glacial Stage. In 1974, VANDENBERGHE ET AL. confirmed these observations in another sandpit at Steenbrugge.

The sequence of the type locality of the Oostende Formation seems to have a constant regional appearance in the Middle Belgian coastal plain between Oostende and Brugge. BAETEMAN (1981) in re-interpreting the geological section along the E5 motorway from Gistel towards Jabbeke (PAEPE, 1971) came to the conclusion that a number of Paepe's Calais deposits actually are of Weichselian age. PAEPE (1972), DE MOOR & DE BREUCK (1973) and VANDENBERGHE ET AL. (1974) furthermore concluded that the extension of the Oostende Formation is much further inland than the present-day coastal-plain deposits. In this area of maximum inland extension recent and

Eemian deposits occur at almost the same altitude of + 1 m O.D.; inland, however, the Oostende Formation deepens rapidly to attain 15-20 m at Oostende.

So far, the Oostende Formation in this middle coastal plain has never been found to rest on the Herzelee Formation. Instead it is found to cover immediately the inland uprising Tertiary substratum (Panisel Formation and Ieper Formation) for which DE BREUCK ET AL. (1969) inferred a tectonic steplike sequence. The deepening of the coastal plain deposits goes along with a thickening of both the Oostende Formation and the Holocene marine deposits. In between the 'Last Glacial coversand Formation' is thickening; in places it may obtain a loamy texture as in the boring at Oostende.

After this discussion it may be asked whether or not the whole of the Oostende Formation belongs to the Eemian Stage only. It is not possible to find in the deepening and thickening sequence an interruption subdividing the Oostende Formation in an upper part of Eemian age and a lower part of perhaps Holsteinian age. In any case, various levels with *Tapes senescens* and *Corbicula fluminalis in situ* have been mentioned by many authors although the geological map only refers to one single Q3 m deposit.

#### *Eastern coastal plain and Flemish Valley: area of superposition of Herzelee and Oostende Formations*

In general the eastern Belgian coastal plain belongs to the delta system of the Southern Netherlands. The only difference is that in Belgium the Flemish Valley (TAVERNIER, 1943) as one of the estuaries of the delta extending the coastal plain inland, is entirely filled up thus providing a complete sequence of older and most recent Quaternary deposits. During MOURLON'S (1896) boring campaign, this fact was not overlooked and is clearly shown by the presence of Q2 m (marine Campinéen) and Q3 m (marine Hesbayen) deposits underneath Q4 (Flandrian) and more modern sediments (All.). In 1974, PAEPE described a series of borings along the diversion canal of the Leie between Gent and Zeebrugge over a distance of more than 40 km. Heyse described the same series and DE MOOR & HEYSE (1974) published the lithological section of it.

At the meeting of the INQUA Subcommittee for N.W. European Shorelines in 1976 which was attended by today's fêtit, Prof. Dr. A. J. Wiggers, PAEPE produced a geological section with a preliminary lithostratigraphical subdivision, showing two marine tidal-flat deposits beneath the uppermost aeolian coversands of the Gent Formation of Weichselian Age. (Fig. 2A). The abundance of *Tapes senescens* and *Corbicula fluminalis* in the upper marine deposits over a distance of 24 km from boring 33 to 67 situated between Eeklo and Westkapelle points to the presence of the Oostende Formation, as was recognized earlier by TAVERNIER (1943), DE MOOR (1963) and PAEPE (1965) among others. In the East, the Oostende Formation laterally changes into the fluvial Zemst Formation (PAEPE, 1971b). The clayey layers below the Oostende Formation occurring between boring 1 to 36 as a con-

tinuous irregular lens and further westwards the isolated patches of this facies in borings 133/DB 6, 133/MB 11, B 45 and B 54, were attributed to the Herzelee Formation. It was exactly this deposit which appears on the Geological Map as Q2 m and which occurs between - 1 m and - 6 m O.D..

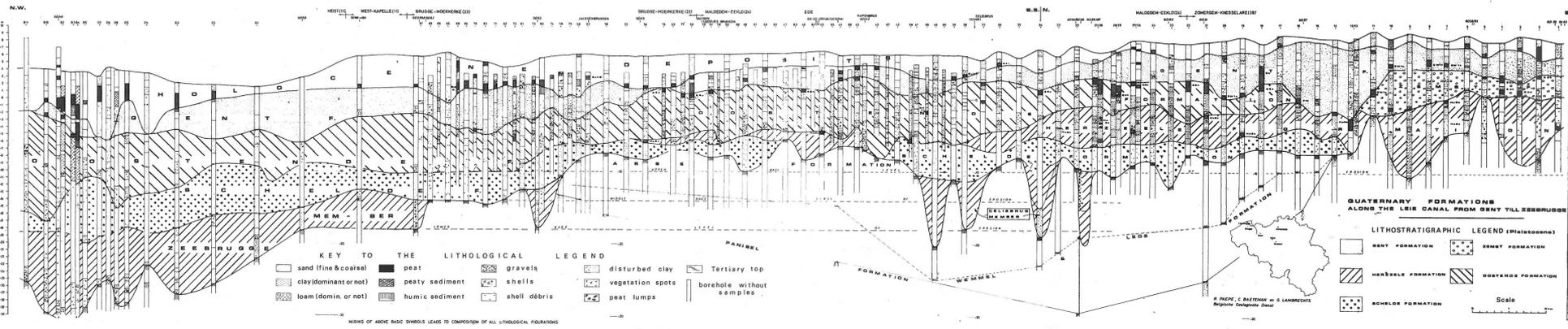
Under the Herzelee Formation occurs a gravel deposit of fluvial origin which rests on a flat, slightly undulating platform at -7 to -8 m O.D. This deposit is attributed to the Schelde Formation (PAEPE ET AL., 1976) which also comprises the medium coarse sands filling up the deepest eroded gullies of the Flemish Valleys, which locally (borings 34 and 32) also contain reworked Tertiary Barton clays (G. Lambrechts, oral comm.). These gullies usually attain a depth of -20 m O.D. Paepe believes that the Schelde Formation covers the timespan from Late Menapian through Late Elsterian, thus representing the western equivalent of the Maas Campine High Plateau (PAEPE ET AL., 1976).

The palaeomagnetic results on the Campine Formation as well as those of the Herzelee Formation lead to the assumption that within the timespan between Late Menapian and latest Elsterian the gravel sedimentation in the Schelde and Maas basin took place over a series of alternating cold and warm phases. The question is: how many? This question relates to the problem of the subdivision of the Cromerian and Holsteinian interglacials. According to ZAGWIJN (1975) the 'Cromerian complex Stage' contains four interglacials; the Holsteinian one is more complex and immediately related to the subdivision of the Saalian Stage. The assumption that the Hoge Veen interstadial might in fact be an interglacial opens the possibility for another Holsteinian or even Eemian Stage.

SOMME ET AL. (1978) in Herzelee attributed the marine Holsteinian levels to two different Holsteinian Stages although Vanhoorne pleaded in favour of one single palaeobotanical evolution. Nevertheless at Melle, on the southern limit of the Flemish Valley Vanhoorne clearly made a distinction between an upper and lower Holsteinian peat deposit separated by a marine layer in between, the whole occurring at the same absolute topographical level as the Herzelee Formation. This led TAVERNIER & DE MOOR (1974) to the assumption that the marine layer in Melle is the equivalent of the Izenberge Crag. Both authors did not, however, take into account that the Herzelee section is composed of two, perhaps three, marine layers of which the Izenberge Crag is the uppermost one.

The question now arises whether PAEPE'S (1975) assumption for assimilating the lower tidal-flat deposits in the Flemish Valley with the Herzelee Formation is still valid? The solution was suggested by Vanhoorne while studying in 50% of the borings of the Flemish Valley, the peat and palynological levels. The conclusions were manifold: first the two marine deposits were clearly differentiated into an Eemian spectrum above and a Holsteinian spectrum below; second a further differentiation was possible into subzones.

The Eemian Stage definitely represented pollen zones E4<sub>a</sub>, E4<sub>b</sub>, E5<sub>a</sub>, E5<sub>b</sub>, E6<sub>a</sub> and E6<sub>b</sub>. It points to the second half of the Eemian during which degradation of the *Quercetum mixtum*



B

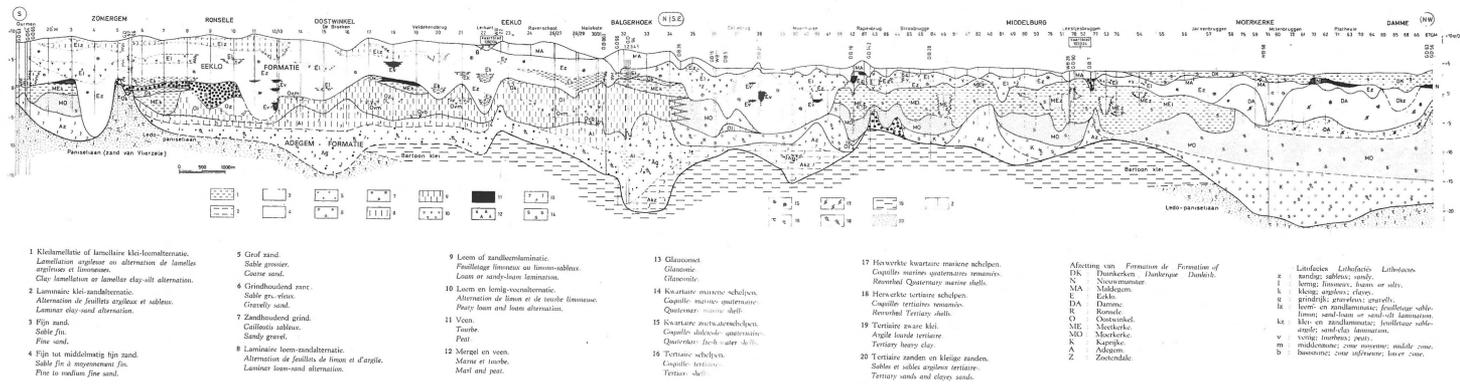


Fig. 2  
Geological cross-sections along the Leie canal from Gent to Zeebrugge (Belgium).  
A: Section studied by Paepe and collaborators.  
B: Same section studied by Demoor and collaborators.

towards a *Corylus-Carpinus-Pinus* association took place. In the earlier phases the high amount of Chenopodiaceae point to the vicinity of the sea. Actually all of the peat levels occur in tidal-flat deposits above the marine gravels with *Tapes* and *Corbicula*.

The overlying Gent Formation shows pollen spectra at its base which belong to the pollen zone EW1a and occasionally to EW1 b. It is the boreal forest at the beginning of the Early Weichselian stage dominated by *Pinus* and *Betula* (EW1 a) or at the beginning of the Amersfoort interstadial (EW1 b) dominated by *Pinus*, unlike the stadial phases, however, with a complete lack of Ericales.

The Herzelee Formation immediately under the Eemian deposits reveals pollen spectra from base to top of successively HO IIa, HO IIb to HO IIc. All levels are characterized by the occurrence of *Azolla filiculoides*. In boring B7 Zone HO IIa points to a temperate oak forest in the middle of the Holsteinian (Hoxnian) dominated by *Quercus* and *Alnus* in the overlying HO IIb zone. Also *Vitis* appears in the latter. In all other borings situated more westerly, only Zone HO IIc occurs indicating an open temperate forest composed of *Pinus* and *Betula* with *Alnus* and *Salix*. Also here the presence of Chenopodiaceae may indicate the vicinity of the sea.

Anyhow, the Holsteinian-Eemian pollen sequence clearly points to an important break as is also inferred by the existing unconformity between both the marine Herzelee and Oostende Formations. Furthermore the uppermost Oostende Formation laterally merges into the fluvialite Zemst Formation of which the Eemian age was earlier established on basis of pollen analysis (PAEPE, 1971a; VANHOORNE, 1971).

De Moor and several collaborators proposed a stratigraphical subdivision of the Eastern Belgian Coastal Plain (DE MOOR & DEBREUCK, 1973) and of the Flemish Valley (DE MOOR & HEYSE, 1974). TAVERNIER & DE MOOR (1974) worked out a complete stratigraphy for common use in both areas which they relate to the geomorphological evolution of the Scheldt Basin. The stratigraphical classification is characterised by a sudden introduction of many new formations which seem to be kept informal. At least thirteen of these informal formations appear on the earlier mentioned section along the diversion canal of the Leie, (DE MOOR & HEYSE, 1974) without making any distinction between real formations and members (Fig. 2B).

If compared to the fivefold subdivision at the level of formation which is now being proposed, it appears that boundaries drawn by De Moor and collaborators not always cover lithostratigraphic realities. A critical review will be given later in normal geological order. The informal formation of Adegem (DE MOOR & HEYSE, 1974), lithostratigraphically comprises the Schelde Formation (fluvialite gravels) and the Herzelee Formation (marine silty loams) which are, as shown above, also to be separated on pollen analytical basis.

The Schelde Formation is the continental equivalent of the Herzelee Formation (PAEPE ET AL., 1976) which means that in the coastal-plain area both formations are interfingering. Actually the Schelde Formation continues underneath the

Oostende Formation in the coastal plain. It may be the equivalent of De Moor's informal Moerkerke Formation.

Furthermore, beneath the extension of the Schelde Formation in the coastal area one may still find parts of the marine Herzelee Formation which have been named Zeebrugge Member. The continental counterpart is the Celiebrug Member which fills up some deeply eroded gullies. The deepest point of this erosion tallies with an abrasional platform established at about -18 m O.D. in the area of West-Kappelle-Moerkerke. A steep escarpment links this abrasion platform with another smoothly undulating platform forming the lower boundary of the Schelde Formation on the Barton (Asse) Clay. From this level down the erosion gullies of the Celiebrug are developed. The marine Zeebrugge Member corresponds to the informal Kaprijke Formation (DE MOOR & HEYSE, 1974) underlying the Moerkerke Formation corresponding to the western part of the Schelde Formation. De Moor and collaborators do not point to a stratigraphical relation of the Moerkerke and Adegem Formations which in our opinion represent one and the same Schelde Formation.

The marine Oostende Formation forms a continuous wedge before abutting against the Zemst Formation of fluvialite origin as of Ronsele. The subdivision of the classical Oostende Formation into a lagoonal eastern Oostwinkel and western Meetkerke informal formation (DE MOOR & TAVERNIER, 1974) on the basis of facies differences only does not seem a sufficient criterion to us; especially as the mollusc fauna of the coarser deposits does not contradict the pollen spectra of pollen Zone E4 to E6 of Late Eemian Age.

The uppermost informal Eeklo Formation (DE MOOR & HEYSE, 1974) is supposed to represent the continental aeolian coversand deposits of the last glacial. Also here neither lower and lateral boundaries have been checked with great precision. In the area of Zomergem to Ronsele, peatlayers of Zone E6 of Eemian Age have been incorporated into the Eeklo Formation of Weichselian age. Actually together with the gravels building up De Moor's Ronsele Formation of early Weichselian Age, they constitute the fluvialite Zemst Gravel Formation (PAEPE & VANHOORNE, 1976) of Eemian Age.

Eemian peat of Zone E4 layers have also been incorporated in the Eeklo Formation in the Balgerhoeke - Rapenburg reach of the geological section thus considerably lowering the lower boundary again. Moreover, marine sands of the Oostende Formation are interpreted to be of pleniglacial origin. Finally the informal Damme Formation introduced by De Moor and collaborators is in our opinion entirely unnecessary. Unlike De Moor's statement pleading for an Early Last Glacial Age (eo-Würm) Alleröd pollen spectra occur in many parts along its lower boundary. Therefore, it forms the uppermost part of the Eeklo Formation and it should certainly not appear below it.

In this light the Gent Coversand Formation (PAEPE & VANHOORNE, 1976) as it occurs on the section represents a better lithostratotype than the Eeklo Formation of which the Damme Formation may correspond to the Ertvelde Member of Late Weichselian Age (PAEPE & VANHOORNE, 1976).

## STRATIGRAPHICAL CONCLUSIONS FOR THE EVOLUTION OF THE SCHELDT BASIN

The first series of litho- and chronostratigraphical conclusions to be drawn from the previous work are as follows.

(1) The lowermost deposits of the Flemish Valley and Eastern coastal plain show the succession of two superposed marine interglacial deposits which on the earlier maps of the Geological Survey of Belgium (1896) were connotated as Q2 m and Q3 m.

(2) The upper one corresponds to the Oostende Formation of Eemian age, the lower one to the Herzelee Formation of certainly Holsteinian, perhaps also of Cromerian age.

(3) The introduction of a marine Zeebrugge Member with characteristic fossils such as *Tapes* or *Venerupis senescens* and *Corbicula fluminalis* results from the presence of the Schelde (gravel) Formation which separates this member from the Oostende Formation. For the first time marine crag deposits containing the above-mentioned guide fossils below the marine Oostende Formation with the same marine molluscs were recognized.

(4) Since in the tidal-flat deposits peat layers belong to the pollen-zones HO IIa, b and c without reaching the acme zone of *Abies* it may be concluded that the Zeebrugge Member occupies an older chronostratigraphical position. It is thought to be of an early Holsteinian or even Late Cromerian Age.

This brings us to the problem of the Melle Peat which PAEPE & VANHOORNE (1976) and DE MOOR & TAVERNIER (1974) considered to be the chronostratigraphical equivalent of the Izenberge Crag Member of the Herzelee Formation. Thus the position of the Lo Peat Member occurring underneath the Izenberge Crag Member needs further considerations. The peat layer underneath the Izenberge Crag in the section at Herzelee has not been proved to be exactly the same as that occurring elsewhere on the Izenberge plateau at various topographical levels between 9 m and 15 m O.D. (TAVERNIER & DE HEINZELIN, 1962; SOMME ET AL., 1975; BAETEMAN, 1978; TAUFIQ, 1978).

It is also doubtful whether the peat found at Lo in the coastal plain is of the same chrono- and lithostratigraphical position. Vanhoorne pointed to the existence of at least two different peat layers of Eemian and Holsteinian age respectively, occurring at depth in the Lo area. PONNIAH (1977) confirmed the Holsteinian age of the Lower peat layer (Ho 3a and Ho 3b). It points to at least two different possible topographical positions of Holsteinian peat deposits: one on the Izenberge Plateau at 12 m O.D. on an average and one at -5 m O.D. in the coastal plain. This situation is quite comparable to the one of the Melle peat with regard to the above-mentioned existence of Holsteinian peat layers in the Flemish Valley. If the Melle Peat Member at the rim of the Flemish Valley occurs approximately between 9 and 11 m O.D. the ones of the Herzelee Formation within the valley occur in between -6 m and -2 m O.D.

The similarity of the 'stepped' position of presumably Hol-

steinian peat deposits in the IJzer Gulf and in the Flemish Valley is most striking and cannot be denied. It raises a number of questions: must the Holsteinian Stage be further subdivided; was there a major change in the base level of erosion during the Holsteinian stage; are the upper peat layers of the Izenberge Plateau or of the Melle Terrace older than Holsteinian, perhaps Late or Middle Cromerian in Age? Whatever may be the solution, it may now be stated that the erosion of the Flemish Valley is older than the Holsteinian, most probably Middle Cromerian if one is to refer to the palaeomagnetic data of Herzelee.

It is also quite certain that there is more than just one Holsteinian and one Cromerian interglacial Stage. In the IJzer Gulf there seem to be at least four assumed Holsteinian levels: three at Herzelee, one in the vicinity of Lo. In the Flemish Valley there seem to be at least three Holsteinian levels: two within the Melle Terrace, one at least in the lowermost marine deposits of the Flemish Valley. Which of the levels really relate to the Holsteinian Stage is still questionable and most probably some of the older ones will be classified within the Cromerian in the future.

(5) The age of the deepest erosional shaping of the Flemish Valley as well as its subsequent filling up is infra-Holsteinian, most probably older in age. This assumption tallies with an opening of the Strait of Dover situated during the Cromerian Stage, after the Brunhes-Matuyama inversion.

## GEOMORPHOLOGICAL CONCLUSIONS FOR THE SCHELDT BASIN

The geomorphological survey established by De Moor and collaborators from 1969 to 1974 gives a critical inventory of the gravel platforms in the Scheldt Basin. Its chronostratigraphical framework, however, is questionable for several reasons:

(1) The mixture of Alpine and N.W. European chronostratigraphical nomenclature is entirely confusing i.e. the position of the Eemian with regard to the Riss; the Mindel between Holsteinian and Cromerian, the Icenian.

(2) From the genetic aspect it is an oversimplification to tie up the evolution of gravel-covered platforms to one single climatic phase. It is impossible to date these levels with such precision as Eburonian, glacio-Cromerian, Mindel.

(3) It is more a matter of polycyclic, polyclimatic development. The study in detail of one series of such levels descending the Bois de la Houssière towards the terraces on the Zenne at Tubize yields conclusive results in this respect and so also does the study of the Campine High Terrace (PAEPE & MORTELMANS, 1969; PAEPE & VANHOORNE, 1976).

In studying the gravel platforms and terraces of the Scheldt

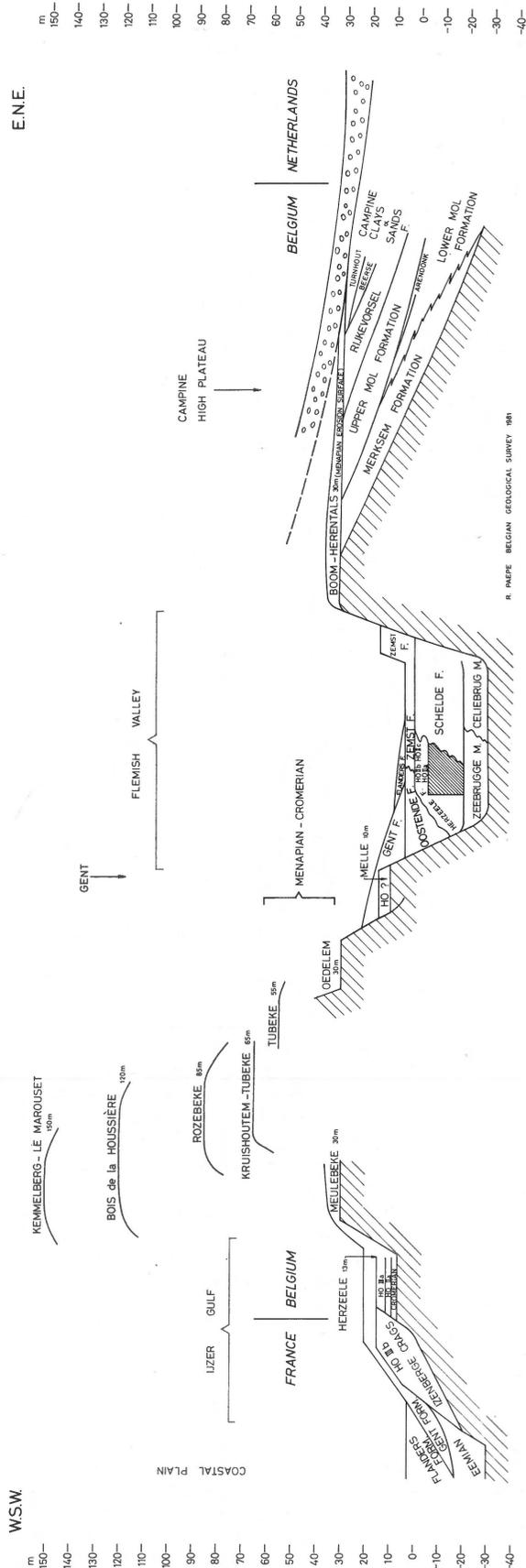


Fig. 3. Compiled cross-section of Quaternary deposits and geomorphological surfaces in the Flanders (from Demoor, 1974, and Paepe, 1976).

Basin it does not suffice to make a sole distinction between an interfluvial crest-like position and a terrace-entrenched one. Their orientation is by and large as important. These basic thoughts determined the litho- and chronostratigraphic classification set up by PAEPE & VANHOORNE (1976).

Further, it should be added that large-scale erosion leaves the products of weathering and denudation in basins like The Netherlands, Northern Belgium, the Rhine Valley and last but not least the Flemish Valley. Firstly, a distinction is to be made between the plateau gravel deposits, the interfluvium gravel deposits, the entrenched gravel terraces including the floodplain and finally the buried aggradational and erosional terraces. De Moors' classification is based on this principle with the difference that the buried levels nowhere show any connection with the stepped terraces, interfluvial and plateau terraces. The stepped sequence of terraces as presented by TAVERNIER & DE MOOR (1974) which dominate the Flemish Valley give an incorrect representation. The Campine High Terrace of the Maasbasin and the Rhine High Terrace in the Villé reflect the gentle downsloping of fluvial deposits to the North to North-East.

Within the Schelde Basin the Zenne terraces (PAEPE & MORTELMANS, 1969) start with an interfluvial one at about 100 m O.D. (Plateau Terrace) at Oisquerck to become an entrenched valley terrace near Tubize at 70 m O.D. From this level it shows a further terrace entrenchment up to about 55 m O.D. where the gravel deposit becomes intercalated between deposits of periglacial origin. From this level on the terraces are closely related to the present valley system as well as to the periglacial deposits dilling up these valleys. Within the periglacial sequence above the gravel deposits two palaeosoils (Rocourt and Tubize Soils) respectively of Eemian and of an older interglacial age, were found. It infers for the lowermost terraces, and even more, for the one outcropping on the plateau terrace at 100 m and more, at least a Cromerian age. The Kruishoutem terrace (DE MOOR, 1963) corresponds to it, although it is not valid to call it a 'glacio-Cromerian stage', even informally (Fig. 3).

The base level of erosion for the Scheldt Basin was the Southern North Sea since the terrace of 60 m continues within the stream sections oriented towards the West, and filling up of the valleys is also observed here.

The Rozebeke terrace descending from about 90 m towards the North-East, just like the Campine High Plateau, gradually converges into the lower topographies in the North. Its gravel cover is deeply affected by strong cryoturbatic disturbances (VAN MAERCKE-GOTTIGNY, 1968) and recalls the strongly cryoturbated flat surface on the Campine Clays which is most probably of Menapian age (PAEPE & VANHOORNE, 1976). Therefore an Eburonian age for both erosion and aggradation phases of the Rozebeke terrace as proposed by TAVERNIER & DE MOOR (1974) appears to be too old.

The two uppermost levels of De Moor and collaborators namely the Hotond and St. Sauveur terraces, are considered in our opinion to be of early Pleistocene rather than of Plio-

Pleistocene age. A further precise dating is too difficult at present. Even for the Cassel terrace, occurring at 170 m O.D., there remain serious doubts about its Diestian age (BONTE, 1969; SOMME, 1969). The lower-lying Meulebeke and the Melle terraces are also doubtfully dated. First of all the Melle terrace could be older than Holsteinian in Age; second a Mindel age for the Meulebeke terrace is an extremely strange chronostratigraphical intercalation between Holsteinian and Cromerian Stages.

A Cromerian Age may still be put forward for the Meulebeke terrace which may perhaps be attributed to the Melle terrace as well. The latter consideration is a direct consequence of the fact that Holsteinian deposits, and perhaps older ones, are found to exist at much lower levels within the Flemish Valley on the basis of the results of this study.

As a direct result and on basis of the previous discussions, the age of successively the Zoetendale, Adegem, Balgerhoeke and Zwijnaarde buried low terraces seems doubtful. As stated it is preferable to introduce large-scale lithostratigraphic units such as the Oostende and Herzelee Formations as has been done by former investigators introducing Q3 m and Q2 m.

In writing these statements it is quite obvious that a number of palaeogeographical and chronostratigraphical problems remain for the evaluation of erosion and aggradation surfaces. Our contribution is restricted to a better dating of the deposits within the Flemish Valley and subsequently the relative estimate of dating of every level above this valley.

## BIBLIOGRAPHY

- Baeteman, C. 1978 L'extension de la Formation d'Herzelee en Belgique – Bull. Ass. franç. Etude Quaternaire 1.2.3: 141-144.
- 1981 De Holocene ontwikkeling van de westelijke kustvlakte (België) – Ph.D. Thesis Vrije Univ. Brussel: 297 pp.
- Bonte, A. 1968 Le Diestien du Nord de la France. C.R. Coll. Int. étude Néogène nordique – Mém. Soc. Géol. Min. Bretagne 13: 55-58.
- Budel, J. 1959 Periodische und episodische Solifluktion im Rahmen der klimatischen Solifluktionstypen – Erdkunde B 13.
- De Breuck, W., G. de Moor & R. Marechal 1969 Lithostratigrafie van de Kwartaire sedimenten in het oostelijk kustgebied (België) – Nat. Wet. Tijdschr. S1: 125-137.
- De Moor, G. 1963 Bijdrage tot de kennis van de fysische landschapsvorming in Binnen-Vlaanderen – Belg. Ver. Aandr. Studies 32: 329-433.
- De Moor, G. & W. de Breuck 1973 Sedimentologie en stratigrafie van enkele pleistocene afzettingen in de Belgische kustvlakte – Nat. Wet. Tijdschr. 55: 3-96.
- De Moor, G. & I. Heyse 1974 Lithostratigrafie van de Kwartaire afzettingen in de overgangzone tussen de Kustvlakte en de Vlaamse Vallei in Noord-West België – Nat. Wet. Tijdschrift 56: 85-109.
- Dewalque, G. 1863 Notice sur le puits artésien d'Ostende – Bull. Soc. géol. France 1862-1863: 2, 20, 235-236.
- Dollfus, G. 1884 Le terrain Quaternaire d'Ostende et le Corbicula fluminalis Müller – Mém. Soc. R. Malac. Belgique 19: 3-29.
- Dubois, G. 1924 Recherches sur les terrains quaternaires du Nord de la France – Mém. Soc. Géol. Nord 8: 353 pp.
- Gullentops, F. 1974 The Southern North Sea during the Quaternary. In: L'évolution Quaternaire des Bassins fluviaux de la Mer du Nord méridionale – Centenaire Soc. géol. Belgique: 272-280.
- Lorie, J. 1903 Sondages en Zélande et en Brabant – Bull. Soc. belge Géol. 17: 203-258.
- Mourlon, A. 1896 Les mers quaternaires de la Belgique, d'après l'étude stratigraphique des dépôts flamandiers et campiniens et de leurs relations avec les couches tertiaires pliocènes – Bull. Acad. R. belge Sci. 32 3e série: 671-711.
- Paeppe, R. 1965 On the presence of Tapes senescens in some borings of the Coastal Plain and the Flemish Valley – Bull. Soc. belge Géol. 74: 249-254.
- 1971a La nouvelle écluse de Zemst. Géologie du Site de Zemst – Excavator: 7-15.
- 1971b Autosnelweg Brugge-Calais – Belgian Geol. Survey Prof. Paper 9: 59 pp.
- Paeppe, R. & G. Mortelmans 1969 Sur la présence de sols fossiles pleistocènes pré-émiens entre Hal et Tournai – Bull. Soc. belge Géol. 78: 57-68.
- Paeppe, R., J. Somme, N. Cunat & C. Baeteman 1976 Flandrian, a formation or just a name? – Newsl. Stratigr. 5: 18-30.
- Paeppe, R. & R. Vanhoorne 1972 An outcrop of Eemian Wadden deposits at Meetkerke (Belgian Coastal Plain), Belgian Geol. Survey Prof. Paper 7: 9 pp.
- Paeppe, R., R. Vanhoorne & D. Deraymaeker 1972 Eemian sediments near Bruges (Belgian Coastal Plain) – Belgian Geol. Survey Prof. Paper 9: 12 pp.
- 1976 The Quaternary of Belgium in its relationship to the stratigraphical legend of the Geological Map – Mém. Geol. Map Belgium 18: 38 pp.
- Ponniah, J. 1977 Pollenanalytic studies of the Holsteinian in the Izenberge area (Belgium) – IFAQ-thesis, Brussels: 28 pp.
- Rutot, A. 1910 Sur la découverte de Corbicula fluminalis à Hofstade – Bull. Acad. R. Belg. Sci. 7: 163-169.
- Rutot, A. & M. E. van den Broeck 1885 Note sur la nouvelle classification du terrain Quaternaire de la Basse et de Moyenne Belgique – Bull. Soc. R. Malac. Belgique 20.
- Somme, J. 1969 Introduction à la géomorphologie du Nord de la France – Ann. Soc. géol. Nord 89: 103-110.
- Somme, J., R. Paeppe, J. Hus, R. Geeraerts & R. Vanhoorne 1975 Preliminary magnetostratigraphical results of Pleistocene sequences in Belgium and Northwest France – IGCP-24, Rept. 3: 99-128.
- Somme, J., R. Paeppe et al. 1978 La Formation d'Herzelee: un nouveau stratotype du Pleistocène Moyen marin de la Mer du Nord – Bull. Ass. franç. Etude Quaternaire 1.2.3.: 81-149.
- Taufiq, J. 1978 Mapping of Pleistocene deposits in Herzelee area, North-West France – IFAQ-thesis, Brussels: 12 pp.
- Tavernier, R. 1943 De kwartaire afzettingen van België – Nat. Wet. Tijdschr. 25: 121-137.
- 1954 Le Quaternaire. In: Prodrome d'une description géologique de la Belgique – Liège: 565-589.
- Tavernier, R. & J. de Heinzelin 1962 De Cardiumlagen van West-Vlaanderen – Nat. Wet. Tijdschrift. 44: 49-58.
- Tavernier, R. & G. de Moor 1974 L'Evolution du Bassin de l'Escaut. In: L'Evolution Quaternaire des bassins fluviaux de la Mer du Nord méridionale – Centenaire Soc. géol. Belgique: 159-231.
- Vandenberghé, J., N. Vandenberghé & F. Gullentops 1974 Late Pleistocene and Holocene in the neighbourhood of Brugge – Med. Kon. Acad. Wet. Klasse Wet. 36: 77 pp.
- Vanhoorne, R. 1962 Het Interglaciale Veen te Lo (België) – Nat. Wet. Tijdschrift 44: 58-64.
- Van Loon, A. J. 1981 Problems of Holocene lithostratigraphy. In: A. J. van Loon (ed.): Quaternary geology: a farewell to A. J. Wiggers – Geol. Mijnbouw 60 (3) (this issue).
- Vanmaercke-Gottigny, M. C. 1968 Carte géomorphologique de Belgique (1/25.000, Feuille 30/1-2, St. Maria - Horebeke - Zottegem).
- 1971 La nouvelle écluse de Zemst. Etude paléontologique – Excavator: 15-19.
- Zagwijn, W. H. 1975 Indeling van het Kwartair op grond van veranderingen in vegetatie en klimaat. In: W. H. Zagwijn & C. J. van Staalduinen (eds.): Toelichting bij geologische overzichtskaarten van Nederland – Rijks Geol. Dienst (Haarlem): 109-114.
- Zagwijn, W. H., H. M. van Montfrans & J. G. Zandstra 1971 Subdivision of the Cromerian of The Netherlands; pollen-analysis, paleomagnetism and sedimentary petrology – Geol. Mijnbouw 50: 41-58.