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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 Herzeele Formation (type locality Herzeele 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 Herzeele 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 tidious 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 LO 1981).

In this area climatic changes frequently controlled fa changes (marine and continental), changes in sea level coastal configuration and in geomorphological developm (varying from pediplanation under polar-desert condition landscape dissection during phases of temperate clim evolution). Adequate separation of the various stratotype thus of basic importance.

The major mistake which characterises many forr studies is an incorrect intermingling and over-subdivision lithostratigraphical sequences of different regions as well a various chronostratigraphical classifications. Correlation even adjacent sites may be incorrect because of the impo bility of distinguishing between major and minor palaeocl atic trends, leading to correlation of deposits of different and genesis. An overestimated compilation of the numbe lithostratigraphic units is another direct result of mixing local seasonal palaeoclimatic events with regional periodi ones. Thus an attempt will be made to contribute to a Pl tocene geological framework of the coastal plain in the Fl ders area on the basis of major mapping units which reflect 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 *Corbiculà 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 amendements 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 ar of the Herzeele Formation

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

TAVERNIER & DE HEINZELIN (1962) and VANHOORNE (196 simultaneously advocated a Holsteinian (sensu Needian) a in a combined lithostratigraphical and biostratigraphic study. Vanhoorne did not exclude a Cromerian age, contra to the other two authors who found the presence of *Be plicifera* sufficient proof of Holsteinian age.

SOMME ET AL. (1978) undertook a multidisciplinary study these deposits which included detailed studies in lith stratigraphy (SOMME & PAEPE, 1978), sedimentology (Cuna bio-stratigraphy (Vanhoorne), mineralogy (Juvigne), cl geology (Thorez), and palaeomagnetism (Hus, Gheerae and Mortier). It resulted in the creation of the Herzee Formation built up by three marine layers of which Ruto Izenberge *Cardium* sands occupy the uppermost level gene ally occurring at an altitude of 10 to 15 m O.D. (Fig. 1).

The Holsteinian age of the two uppermost layers has be confirmed by the presence of successively *Taxus* and *Abies* the pollen spectra. The age of the lowermost layer remain doubtful although its altitude and its geographically wid spread occurrence (BAETEMAN, 1978; TAUFIQ, 1978) on bo sides of the French-Belgian border leaves no doubt that it is independent marine deposit preceding the two Holsteini layers. As the palaeomagnetic record shows no change in t polarity which remains positive for the whole of the Quate nary sequence, it has been proposed that the lowest mari layer be located within the later part of the 'Cromerian' sta sensu ZAGWIJN ET AL. (1971).

PAEPE ET AL. (1976) described how Rutot linked up a extended these deposits into the present-day coastal pla confusing Holocene *Cardium edule* associations with Ple tocene ones and hence creating the problem of the age of t Flandrian. After DUBOIS' (1924) redefinition Flandri deposits became restricted to the Holocene age and to t present-day coastal-plain geographical distribution. This h an important bearing on the image and concept of the stra graphical sequences in the coastal plain in Belgium and France for about half a century: it literally banned the id that Pleistocene deposits in the coastal plain occurred f quently (even with regard to the Eemian Oostende For ation) under the Holocene cover. Instead, the thickness of t latter has been overestimated in many places regardless of t fact of grouping Holocene litho- and biostratigraphical quences with Pleistocene ones.

Until very recently, the Western coastal plain in Belgi

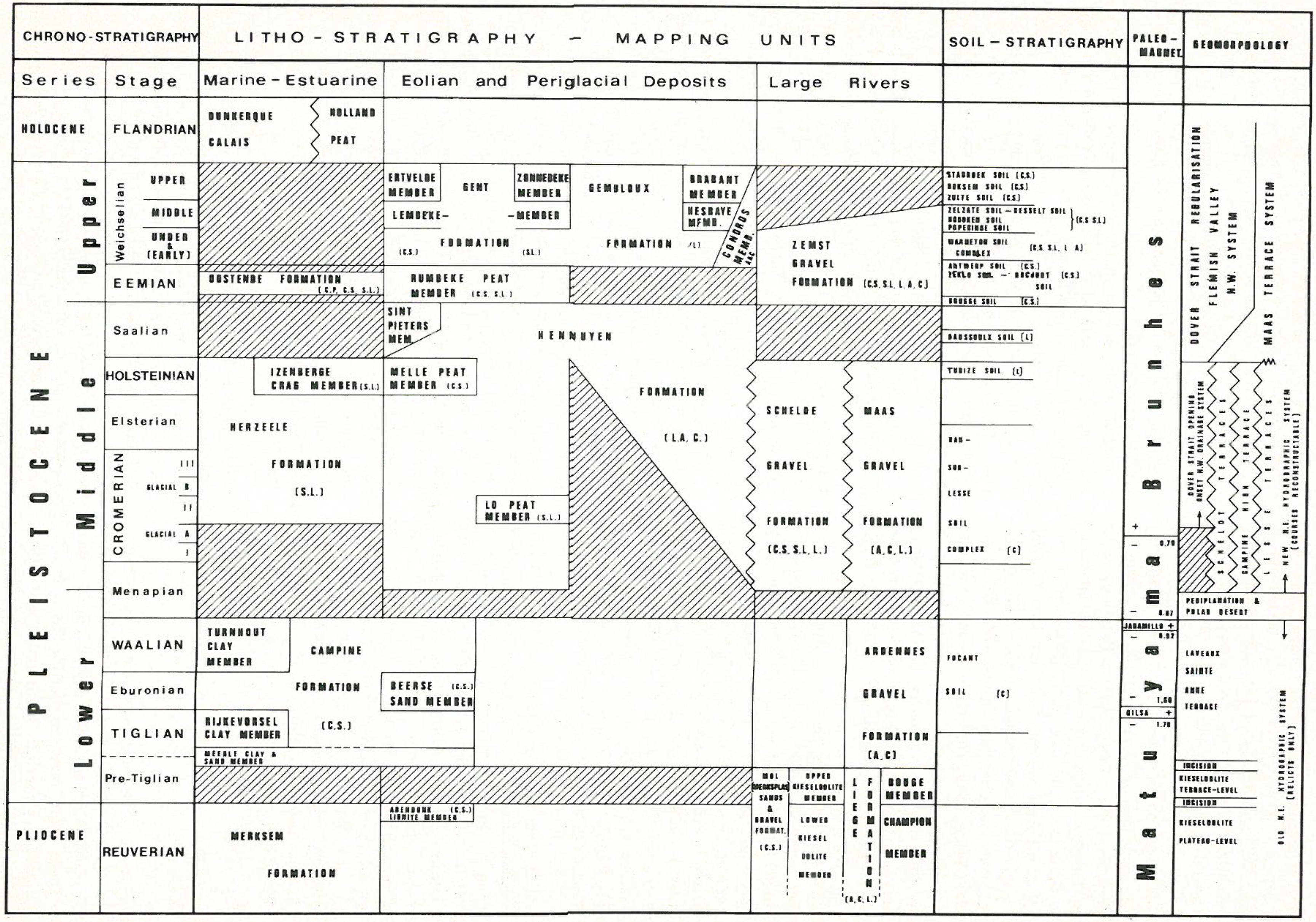


Fig. 1
Lithostratigraphic table of the Belgian Quaternary deposits (after Paepe, 1976).

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 todays North Sea via the Strait of Dover.

From the study of the Herzeele Formation in this area it has also been concluded (SOMME ET AL., 1975; PAEPE ET AL., 1976) that the shaping of todays 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 Herzeele 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) Moséen (Q1); the loam layers were assimilated with tl Young or Upper Pleistocene connotated as Hesbayen (Q3) (the Geological Map. The Campinien (Q2) was not preser but instead the loams were covered by marine shell-bearii deposits which Dollfus called 'Modern' although the Geo ogical Map indicated it as Flandrian (Q4); for Rutot a Ple tocene age was likely.

Actually Rutot did not believe in the value of *Corbicu fluminalis* as a guide fossil and therefore considered that bo the marine mollusc associations below and above the He bayen loamlayers belonged to the Quaternary i.e. Ple tocene. Later, after studying a similar sequence to the Oo ende boring, namely in Hofstade (1910), situated at the ve eastern edge of the Flemish Valley (see later), Rutot accept this error in stating that the 'Flandrian' deposits above t loam layers were definitely younger.

TAVERNIER (1943) when studying the coastal-plain depos therefore initially introduced a 'Lower Flandrian' of Ple tocene and an 'Upper Flandrian' of Holocene age. In fact tl compares closely with DUBOIS' (1924) Flandrian with t 'Sands of Oostende' at the base, and the Calais and Dunk que deposits at the top. This is far away from the init Flandrian at Izenberge; moreover 'Flandrian' should limited to the Holocene marine deposits.

After a long period of hesitation TAVERNIER (1954) fina adhered to LORIE's (1903) assumption that the lowerm marine Flandrian or Oostende Sands compares with t Eemian 'Sands of Zeeland' characterized by the presence *Tapes senescens* var. *eemiensis* and *Corbicula fluminalis*. 1965, PAEPE confirmed the *in situ* character of *Corbic fluminalis* and *Tapes senescens* var. *eemiensis* in several b ings between Oostende and Gent. In excavation pits at Me kerke and Brugge — Sint-Pieters. PAEPE & VANHOORNE (19 studied complete sequences originally described in the Oo ende boring. The mollusc fauna with the above-mentior guide fossils appeared in the Oostende Formation *in situ* which the Eemian pollen spectrum definitely classified t Formation within the last interglacial stage. In both pla these Eemian tidal-flat deposits were clearly separated fr the overlying recent polder tidal-flat sediments by loa coversands of the Last Glacial Stage. In 1974, VANDENBERGH AL. confirmed these observations in another sandpit at Ste brugge.

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

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 Herzeele 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 Herzeele 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 Subcommission for N.W. European Shorelines in 1976 which was attended by today's fêtist, 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 continuous irregular lens and further westwards the isol[...] patches of this facies in borings 133/DB 6, 133/MB 11, [...] and B 54, were attributed to the Herzeele Formation. It [...] exactly this deposit which appears on the Geological Ma[...] Q2 m and which occurs between - 1 m and - 6 m O.D..

Under the Herzeele Formation occurs a gravel deposi[...] fluviatile origin which rests on a flat, slightly undula[...] platform at -7 to -8 m O.D. This deposit is attributed to [...] Schelde Formation (PAEPE ET AL., 1976) which also compr[...] the medium coarse sands filling up the deepest eroded gu[...] of the Flemish Valleys, which locally (borings 34 and 32) [...] contain reworked Tertiary Barton clays (G. Lambrechts, [...] comm.). These gullies usually attain a depth of -20 m O[...] Paepe believes that the Schelde Formation covers the ti[...] span from Late Menapian through Late Elsterian, thus re[...] senting the western equivalent of the Maas Campine H[...] Plateau (PAEPE ET AL., 1976).

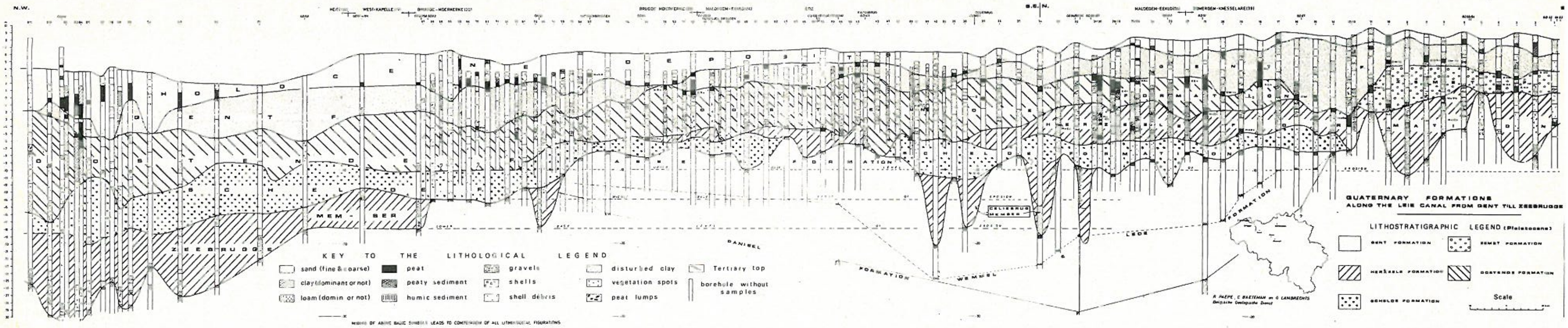
The palaeomagnetic results on the Campine Formatio[...] well as those of the Herzeele Formation lead to the assu[...] tion that within the timespan between Late Menapian [...] latest Elsterian the gravel sedimentation in the Schelde [...] Maas basin took place over a series of alternating cold [...]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

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

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

The Eemian Stage definitely represented pollen zones E[...] $E4_b$, $E5_a$, $E5_b$, $E6_a$ and $E6_b$. It points to the second half of [...] Eemian during which degradation of the *Quercetum mixt[...]*

A



B

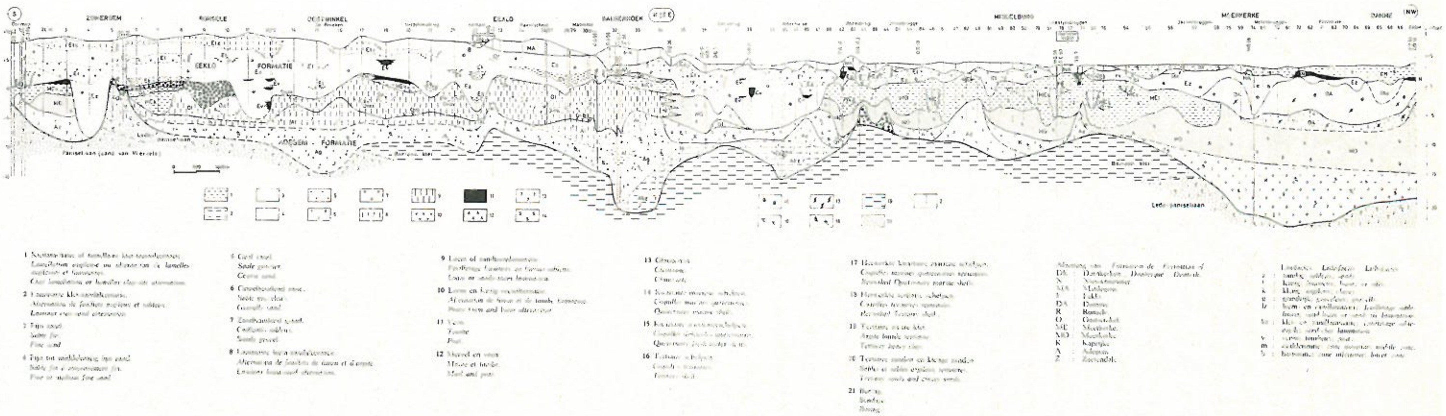


Fig. 2
Geological cross-sections along the Leie canal from Gent to Zeebrugge (Belgium).
A: Section studied bij Paepe and collaborators.

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 Herzeele 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 Herzeele and Oostende Formations. Furthermore the uppermost Oostende Formation laterally merges into the fluviatile 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 & DE BREUCK, 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 (fluviatile gravels) and the Herzeele 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 Herzeele 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 equivalent of De Moor's informal Moerkerke Formatio

Furthermore, beneath the extension of the Schelde Fo ation in the coastal area one may still find parts of the ma Herzeele Formation which have been named Zeebru Member. The continental counterpart is the Celiet Member which fills up some deeply eroded gullies. deepest point of this erosion tallies with an abrasional p form established at about -18 m O.D. in the area of W Kapelle-Moerkerke. A steep escarpment links this abras platform with another smoothly undulating platform form the lower boundary of the Schelde Formation on the Ba (Asse) Clay. From this level down the erosion gullies of Celiebrug are developed. The marine Zeebrugge Mem corresponds to the informal Kaprijke Formation (DE MOO HEYSE, 1974) underlying the Moerkerke Formation cor ponding to the western part of the Schelde Formation. Moor and collaborators do not point to a stratigraph relation of the Moerkerke and Adegem Formations whic our opinion represent one and the same Schelde Formati

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

The uppermost informal Eeklo Formation (DE MOO HEYSE, 1974) is supposed to represent the continental aeol coversand deposits of the last glacial. Also here neither lo and lateral boundaries have been checked with great pr sion. In the area of Zomergem to Ronsele, peatlayers of Z E6 of Eemian Age have been incorporated into the Ee Formation of Weichselian age. Actually together with gravels building up De Moor's Ronsele Formation of ea Weichselian Age, they constitute the fluviatile Zemst Gra Formation (PAEPE & VANHOORNE, 1976) of Eemian Age.

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

In this light the Gent Coversand Formation (PAEPE & V HOORNE, 1976) as it occurs on the section represents a bet lithostratotype than the Eeklo Formation of which Damme Formation may correspond to the Ertvelde Meml 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 Herzeele 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 Herzeele 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 Herzeele 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 Herzeele Formation within the valley occur in between -6 m and -2 m O.D.

The similarity of the 'stepped' position of presumably Holsteinian peat deposits in the IJzer Gulf and in the Flemi Valley is most striking and cannot be denied. It raises number of questions: must the Holsteinian Stage be furth subdivided; was there a major change in the base level erosion during the Holsteinian stage; are the upper peat laye of the Izenberge Plateau or of the Melle Terrace older th: Holsteinian, perhaps Late or Middle Cromerian in Ag Whatever may be the solution, it may now be stated that tl erosion of the Flemish Valley is older than the Holsteinia most probably Middle Cromerian if one is to refer to tl palaeomagnetic data of Herzeele.

It is also quite certain that there is more than just o Holsteinian and one Cromerian interglacial Stage. In the IJz Gulf there seem to be at least four assumed Holsteinian leve three at Herzeele, one in the vicinity of Lo. In the Flemi Valley there seem to be at least three Holsteinian levels: tv within the Melle Terrace, one at least in the lowermost mari deposits of the Flemish Valley. Which of the levels rea relate to the Holsteinian Stage is still questionable and m probably some of the older ones will be classified within t Cromerian in the future.

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

GEOMORPHOLOGICAL CONCLUSIONS FOR THI SCHELDT BASIN

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

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

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

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

In studying the gravel platforms and terraces of the Sche

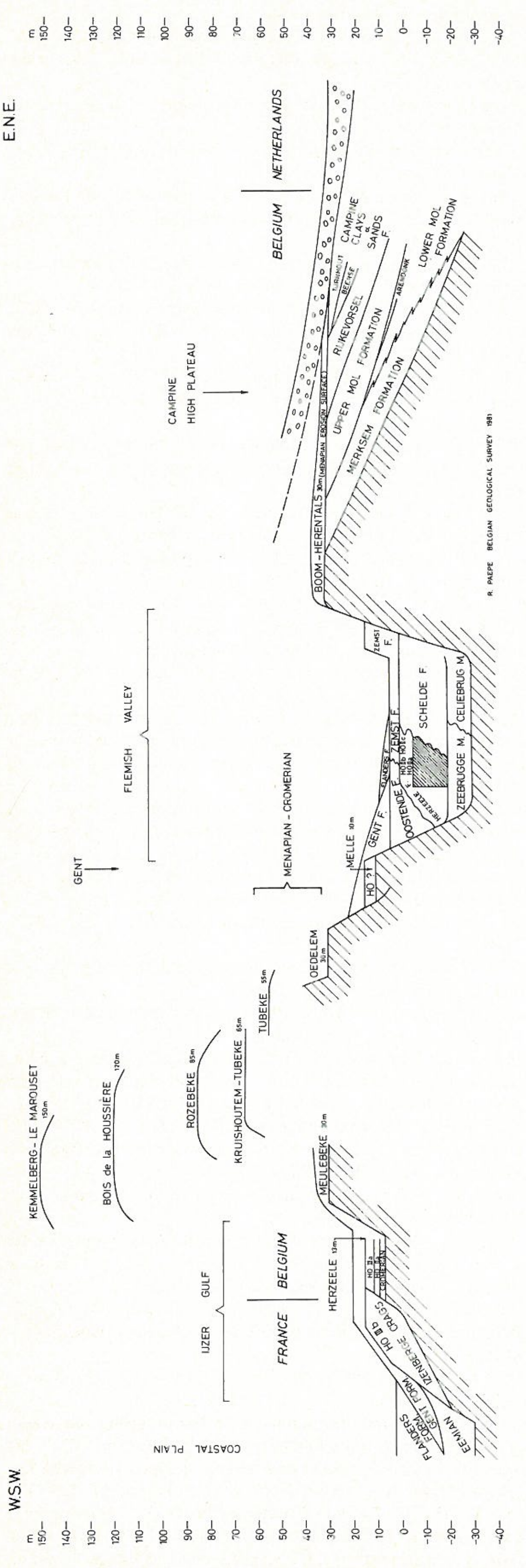


Fig. 3
Compiled cross-section of Quaternary deposits and geomorphological surfaces in the Flanders (from Demoor, 1974, and Paepe, 1976).

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

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

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

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

The Rozebeke terrace descending from about 90 towards the North-East, just like the Campine High Plate gradually converges into the lower topographies in the Nor Its gravel cover is deeply affected by strong cryoturba disturbances (VAN MAERCKE-GOTTIGNY, 1968) and recalls strongly cryoturbated flat surface on the Campine Cl which is most probably of Menapian age (PAEPE & VANHOOR 1976). Therefore an Eburonian age for both erosion a aggradation phases of the Rozebeke terrace as proposed TAVERNIER & DE MOOR (1974) appears to be too old.

The two uppermost levels of De Moor and collaborat namely the Hotond and St. Sauveur terraces, are conside in our opinion to be of early Pleistocene rather than of P

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 Herzeele 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.

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