Meded. Werkgr. Tert. Kwart. Geol. | 26(1) | 11-28 | 2 figs., 2 tabs., 1 pl. | Leiden, maart 1989

THE STRATOTYPE OF THE AALTER SANDS (EOCENE OF NW BELGIUM): STRATIGRAPHY AND CALCAREOUS NANNOPLANKTON

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Steurbaut, E., & D. Nolf. The stratotype of the Aalter Sands (Eocene of NW Belgium): stratigraphy and calcareous nannoplankton. — Meded. Werkgr. Tert. Kwart. Geol., 26(1): 00-00, 2 figs, 2 tabs, 1 pl. Leiden, March 1989.

The stratotype of the Aalter Sands is studied by means of detailed lithostratigraphic analysis and calcareous nannoplankton investigation. A 12.35 m thick, shelly sequence which rests on micaceous, lignitic sand of the Vlierzele Formation (Aalterbrugge Lignitic Horizon) and which is overlain by a basal calcareous sandstone of the Lede Sand Formation is recorded. This sequence is subdivided into 12 lithologically distinct beds which can be grouped into four major intervals on the basis of molluscan species, in ascending order: an interval with *Venericardia sulcata aizyensis* (Deshayes, 1858), an interval with *Megacardita planicosta lerichei* Glibert & van de Poel, 1970, an interval with *Turritella solanderi* Mayer, 1877 and an interval with few or no *Turritella*.

The Aalter Sand sequence contains poorly preserved, moderately diverse nannoplankton assemblages, indicating a shallow water environment and sublittoral deposition (between 20 and 100 m). Various nannoplankton events are recognised, allowing the introduction of four assemblage-units. The lowermost unit A (including beds 1 to 3) does not yield any useful marker species, and is therefore difficult to evaluate. The overlying units B (including beds 4 to 7), C (beds 8 to 10; ? 11) and D (bed 12) seem to correlate with the lower part of nannozone NP14. Some of the nannoplankton events here proposed may be valuable for correlation, but this can only be demonstrated through detailed studies of outcrop and borehole sections in adjacent areas, which are now in progress.

Independently of these events, a few considerable differences in species diversity and abundance occur within the sequence. They are thought to be the result of slight changes in water depth or oceanic influence during deposition. Three transgressive cycles can be identified in the upper part of the stratotype (beds 4 to 12); these may be related to minor eustatic sea level changes. No interpretable data are available from the lowermost part (beds 1 to 3).

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CONTENTS —
Samenvatting, p. 12
Résumé, p. 13
Introduction, p. 14
Description of the stratotype, p. 18
  Details of the exposures, p. 18
  The succession, p. 18
Calcareous nannoplankton, p. 18
  General characteristics, p. 18
  Biozonation, p. 22
  Sequence analysis and cycles, p. 23
Alphabetical list of species and remarks on their distribution, p. 23
References, p. 25.

SAMENVATTING

De hier voorgestelde studie is een zeer gedetailleerde lithostratigrafische opname van het stratotype van de Zanden van Aalter, gecombineerd met onderzoek van het kalkschalig nannoplankton. Dit stratotype bestaat uit een 12,35 m dik schelphoudend zandpakket dat rust op ligniet- en glimmerhoudende zanden van de Formatie van Vlierzele (= Ligniethoudende Horizon van Aalterbrugge) en bedekt wordt door een kalkhoudende zandsteen uit de basis van de Formatie van Lede.

Het stratotype kan onderverdeeld worden in 12 lithologisch duidelijk verschillende lagen. Op grond van dominanties in mollusken, kunnen deze lagen gegroepeerd worden in vier hoofdintervallen, respectievelijk van onder naar boven: interval met *Venericardia sulcata aizyensis* (Deshayes, 1858), interval met *Megacardita planicosta lerichei* Glibert & van de Poel, 1970, interval met *Turritella solanderi* Mayer, 1877 en een interval met weinig of geen *Turritella*.

De nannoplankton-associaties uit het stratotype zijn over het algemeen slecht bewaard en middelmatig rijk aan soorten. Ze wijzen op ondiepe sublittorale milieu's (tussen 20 en 100 m zeediepte).

In de nannoflora treedt een aantal gebeurtenissen op (eerste en laatste voorkomens), die toelaten vier assemblage-eenheden te onderscheiden. De onderste eenheid A (lagen 1-3) bevat geen enkele bruikbare gidssoort en kan daardoor moeilijk vergeleken worden met de standaardzonering van Martini. De overige eenheden, B (lagen 4-7), C (lagen 8-10, ? 11) en D (laag 12) kunnen toegewezen worden aan het onderste deel van zone NP14. Een aantal van de hier vermelde nannoplankton-gebeurtenissen is bruikbaar voor correlatie, maar dit kan slechts met zekerheid bewezen worden aan

de hand van gedetailleerde studie van ontsluitingen en boringen in omgevende gebieden (momenteel in uitvoering).

In het nannoplankton van de bestudeerde sequentie treden ook belangrijke verschillen op in dominantie en soortenrijkdom, onafhankelijk van bovenvermelde gebeurtenissen. Deze variaties zijn naar alle waarschijnlijkheid te wijten aan kleine veranderingen in diepte, of in oceanische invloeden tijdens de afzetting. Drie transgressieve cycli kunnen worden onderscheiden in het bovenste gedeelte van het stratotype (lagen 4-12), die waarschijnlijk gebonden zijn aan kleine eustatische zeespiegelveranderingen. Het onderste deel van het stratotype (lagen 1-3) levert geen interpreteerbare indicaties daaromtrent.

RÉSUMÉ

Une étude lithostratigraphique très détaillée, complétée par une analyse du nannoplankton calcaire a été effectuée dans le stratotype des Sables d'Aalter. Il s'agit d'une série sableuse, généralement coquillère, dont l'épaisseur est de 12.35 m. Celle- ci repose sur des sables micacés et lignitifères de la Formation de Vlierzele (Horizon lignitifère d'Aalterbrugge) et est surmontée par une dalle calcaire représentant la base de la Formation de Lede.

Dans la localité-type 12 couches à lithologie distincte peuvent être distinguées au sein des Sables d'Aalter. Sur la base des mollusques dominants les Sables d'Aalter peuvent être divisées en quatre intervalles majeurs, qui sont de la base au sommet: intervalle à *Venericardia sulcata aizyensis* (Deshayes, 1858), intervalle à *Megacardita planicosta lerichei* Glibert & van de Poel, 1970, intervalle à *Turritella solanderi* Mayer, 1877 et un intervalle quasiment dépourvu de turritelles.

Cette série sableuse contient des assemblages de nannoplancton calcaire plutot mal conservés et moyennement diversifiés. Ils indiquent des environnements sublittoraux peu profonds (entre 20 et 100 m).

Pour ce qui est de la biozonation à l'aide du nannoplancton calcaire, plusieurs événements sont observés, ce qui a permis d' introduire quatre unités d'assemblage. L'unité inférieure A (incluant les couches 1 à 3) ne contient aucune espèce marqueur permettant de la corréler avec la biozonation de Martini. Les unités B (incluant les couches 4 à 7), C (incluant les couches 8 à 10; ? 11) et D (couche 12) peuvent être assimilées à la zone NP14. Certains des événements observés dans les associations de nannoplancton calcaire pourraient s'avérer utilisables pour des corrélations, mais ceci reste à démontrer par l'étude détaillée d'affleurements et sondages dans les aires plus éloignées du stratotype (études actuellement en cours).

Indépendamment de ces biozones, on remarque aussi des variations considérables dans la diversité et l'abondance des espèces au sein de la séquence. Ces variations sont interprétées comme étant dues à de légères fluctuations de la profondeur ou des influences océaniques durant le dépôt. Nous croyons pouvoir identifier trois cycles transgressifs dans la portion supérieure du stratotype (couches 4 à 12) et ceux-ci pourraient être liés à des petites fluctuations eustatiques du niveau marin. La portion inférieure de la coupe (couches 1 à 3) ne nous a pas fourni d'indications interprétables à cet égard.

INTRODUCTION

Travelling from Brugge to Gent by train, about halfway an abrupt change in the flat monotonous landscape can be noted, as the railway cuts a small hill, on top of which the village of Aalter (also written Aeltre or Aelter in the older literature) is located. This hill is almost entirely composed of shelly olive-green sands, the Aalter Sands. These rest on green, glauconitic, non-calcareous and lignitic sand of the Vlierzele Formation, which forms the Tertiary substratum of the surrounding plain. Sediments with identical or similar lithology are preserved only in a few places of the Belgian Basin. Identical sediments occur in the Blandijnberg at Gent (Delvaux, 1886; Tavernier, 1935; Leriche, 1938; temporary exposure observed by the authors of the present paper during construction works at the NW corner of the Citadel Park in 1988, at coordinates x = 104.475; y = 192.480) and possibly also in the Heusden area (Jacobs, 1974). Sediments of comparable lithology and fossil content are exposed in the hills between Cassel (N France) and Ieper (Leriche, 1921; Nolf, 1973a, p. 89). All the above mentioned deposits represent small occurrences in geographically isolated outliers. More or less similar deposits were described by Nolf (1973a) from the area North and Northwest of Aalter, and named Oedelem Sand Member.

The first step towards a better understanding of the stratigraphic relationships of all of these slightly different shelly sands is a detailed lithological and micropalaeontological analysis of the Aalter type locality. Such an analysis is the aim of the present paper.

As the Quaternary cover is very thin on top of the Aalter hill, fossiliferous sands crop out everywhere in the centre of the village, even in the smallest construction pit. This is apparently the reason why the fossiliferous beds of Aalter already figured in the earliest papers on Belgian stratigraphy, *e.g.* d'Omalius d'Halloy (1842, p. 83): beds with shell debris and sand at Aalter; Dumont (1849): sables glauconifères à *Venericardia planicosta*.

The term Aalter Sands was first used unambiguously in Mourlon's (1873) paper, where it figured in a stratigraphic table as ,,Sables d'Aeltre à turritelles''. Therefore, authorship of the term Aalter Sand Member should be attributed to Mourlon and not to Leriche (1937), as mentioned by Kaasschieter (1961). It should be noted, however, that Leriche's paper (which was actually published in 1938) provided a very well-documented historical review, and that it is only since then that the term ,,Aalter Sands'' has been widely used as a well-defined lithostratigraphic unit. Subsequently, this unit was given member-rank and included in the ,,Panisel Formation'' by Kaasschieter (1961), who somewhat prematurely codified the classic legend of the Belgian geological map into modern lithostratigraphic terminology.

Summary of previously published lithostratigraphic data on the Aalter type locality—In spite of the extensive literature on the Aalter Sands and their stratigraphic position, precise data on the lithological succession in the type locality are scarce. The most comprehensive previous description is by Delvaux (1886). An exhaustive study of several excavations in the Aalter area enabled him to establish a sequence of five beds, including in ascending order, an unfossiliferous sand bed, a *Cardita planicosta*-bed, a *Turritella*-bed, a calcareous sandstone and an uppermost, slightly clayey glauconitic sand. He also noticed (loc. cit., p. 282) the presence of ,,Laekenian'' sandstone blocks with gravel and *Nummulites laevigatus* (Bruguière, 1792) on top of the Aalter hill. Later on, and especially in more recent years, most attention has been paid to the lowermost part of Delvaux's succession, the *Megacardita*-bed and the lowermost *Turritella*-bed. Although Delvaux mentioned neither thicknesses nor precise altimetrical data of the limits between the layers, his work turned out to be the most detailed and valuable study of the Aalter hill until now.

A lithological description with absolute height indications was provided by Nolf (1973a, p. 89). However, this work is inaccurate as far as the layers above the *Turritella*-level are concerned, which is due to the absence of good exposures in the upper zone of the hill at the time of investigation and also to the fact that the heights were directly derived from the topographical map. These heights slightly differ from the ones presented here, which were obtained through precise levelling starting from the top of the hill.

Finally, some useful data on the grain-size distribution and heavy mineral content of the Aalter hill sediments were provided by Jacobs & Geets (1977).

Fossil content—Very little is known about the micropalaeontology of the Aalter stratotype. Several samples were examined by Kaasschieter (1961, p. 49, 120), but none contained Foraminifera; this may be due to the poor quality of his samples, which according to Kaasschieter were taken in ,,slightly decalcified patches''.

Recently, some poor calcareous nannofossil assemblages were recorded by Steurbaut (1988, p. 104) from the railway cutting at the Weibroekdreef. These assemblages were hardly interpretable, except for one level rich in *Megacardita planicosta lerichei* Glibert & van de Poel, 1970, which contained 25 species and was assigned to Martini's nannoplankton-zone NP14. This association is re-evaluated in the present paper.

Nyst & Mourlon (1872) and Vincent & Rutot (1879) provided lists of molluscs collected at Aalter. These were re-interpreted by Feugueur (1951), but it was only in 1985 that a detailed monograph on the malacological fauna of the Aalter Sands was published by Glibert (1985). Some solitary corals (Glibert, 1974, p. 18), worm tubes and some cephalopod fragments were also recorded from this unit.

The fishes of the Aalter Sands were studied by Leriche (1905) and Casier (1950) and revised by Nolf (1973b), which resulted in a list of 33 selachians and 21 teleosts for the type locality.

To conclude this section on palaeontology, we should mention that we have never observed any *in situ* nummulites in the Aalter Sands. At the top of the hill, reworked *Nummulites laevigatus* (Bruguière, 1792) are abundant in the basal gravel bed of the Lede Sand Formation. As this deposit crops out under a very thin Quaternary cover, nummulites from this bed can easily been transported down the hill. Such reworked fossils mixed with Aalter Sand molluscs were encountered in a superficial sediment resembling Aalter Sands near the Weibroekdreef bridge, about 10 m below the top of the Aalter hill. Leriche (1938, p.88) found a single ,,*in situ*'' nummulite in the Aalter Sands of the Blandijnberg at Gent, which he identified as *Nummulites lucasanus* Defrance in d'Archiac, 1850. Seeing that at this place the basal gravel bed of the Lede Sands also crops out in the hill and directly rests on the Aalter Sands, the chance of reworking here is equally as high as in the Aalter Sand stratotype. Hence, Leriche's so-called ,,*in situ*'' record is open to suspicion.

Age of the Aalter Sands — Close to the Ypresian-Lutetian boundary, the Aalter Sands have been assigned an Ypresian or Lutetian age, according to the opinion of the various authors. Actually, the correlation between the Aalter Sands and the Hérouval Sands of the Paris Basin, which was proposed by Feugueur (1951), appears to be incorrect on the basis of nannoplankton investigation (Steurbaut, 1988), but this does not adequately solve the problem of the age of the Aalter Sands. The topmost marine Ypresian beds of the Paris Basin belong to the basal part of Martini's zone NP12, while the earliest Lutetian deposits from this basin are referred to the middle part of NP14. This means that in the Paris Basin both units are separated by an important hiatus, the duration of which is estimated between 2 and 4 million years (Aubry, 1985). In the Belgian Basin, this hiatus is represented by a fairly complete succession, in which a very detailed nannoplankton zonation was established (Steurbaut & Nolf, 1986). In this zonation, the Aalter Sands belong to a zone situated immediately below that of the oldest Lutetian deposits of the Paris Basin, suggesting a somewhat older age for the Aalter Sands. This implies that the Ypresian-Lutetian boundary cannot be adequately defined in the Paris Basin, unless it is taken arbitrarily at the base of the oldest Lutetian deposits. However, this does not seem to be the best solution, because boundary-stratotypes are to be chosen preferentially in continuous marine sequences and defined by biostratigraphic events. Therefore, it seems advisable to define this boundary outside the Paris Basin, and one of the most suitable areas for its establishment is the Belgian Basin, which comprises one of the best known and most complete Lower and Middle Eocene sequences. The present study contributes to a better understanding of the biostratigraphy in this basin, especially that of the Aalter Sands, which may be an excellent candidate for fixing this boundary. Further investigations on possibly more complete contemporaneous sections, *e.g.* the Oedelem borehole drilled in 1988 on behalf of the Belgian Geological Survey, or the basal layers of the Mont de Récollets near Cassel in Northern France, are required before conclusions can be drawn on the chronostratigraphic position of the Aalter Sands.

Fig. 1. Stratigraphy of the Aalter Sands at their type locality.

12: khaki-coloured, glauconitic, fine shelly sand, clayey towards the base; uppermost 1 m less shelly and decalcified at the top; thickness: 2.10 m.

11: light grey, glauconitic, fossiliferous (mainly bivalves), poorly cemented sandstone; thickness: 0.50 m.

10: khaki-coloured glauconitic, fine sand with scattered bivalves; thickness: 0.35 m.

9: khaki-coloured, glauconitic fine-grained sand with abundant bivalves (= coquina); thickness: 1.05 m.

8: khaki-coloured, glauconitic fine sand with scattered molluscs; thickness: 0.80 m.

7: khaki-coloured, glauconitic, slightly clayey sand with abundant *Turritella solanderi* Mayer, 1877 (= coquina); somewhat more clayey in its lower part with a basal 3 cm thick compact mass of rusty coloured shell debris; sharp contact with underlying unit; thickness: 1.05 m.

6: khaki-coloured, silty clay; thickness: 0.1 m.

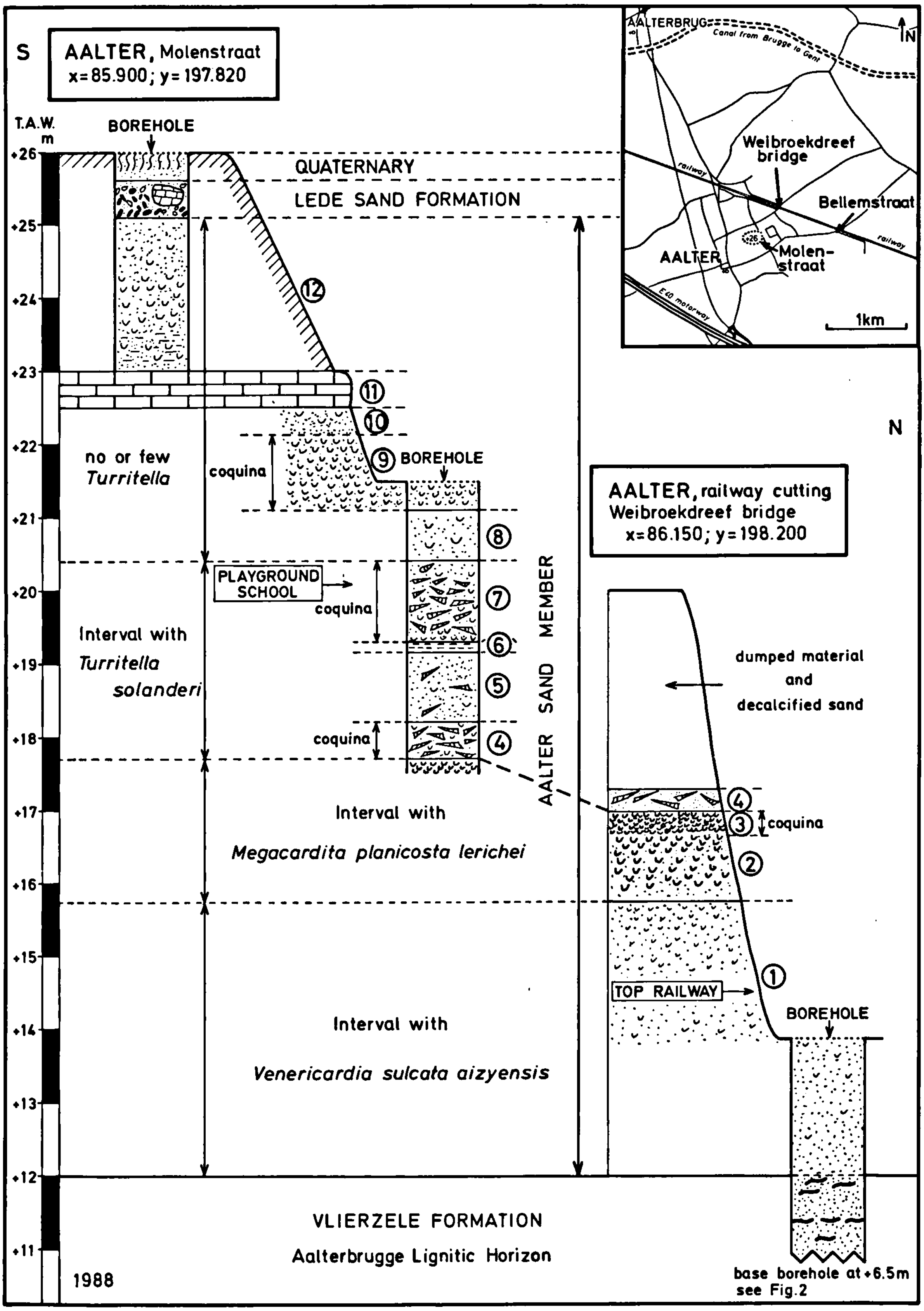
5: khaki-coloured, glauconitic, fine grained, shelly sand; less shelly than the underlying bed; thickness: 1 m.

4: khaki-coloured, glauconitic, fine-grained sand, with abundant *Turritella solanderi* Mayer, 1877 (= coquina); towards the base often rolled *Turritella*, co-occurring with rare (? reworked) *Megacardita planicosta lerichei* Glibert & van de Poel, 1970; thickness: 0.50 m.

3: sandy coquina or lumachelle of *Megacardita planicosta lerichei* Glibert & van de Poel, 1970; thickness: 0.30 m.

2: khaki-coloured, glauconitic, fine-grained sand with abundant, mainly disarticulated shells of *M. planicosta lerichei* Glibert & van de Poel, 1970 (a few, however, are still double valved, suggesting quick post-mortem burial); thickness: 1 m.

1: khaki-coloured, glauconitic, slightly clayey fine-grained sand, intensely bioturbated, with small molluscs, chiefly *Venericardia sulcata aizyensis* (Deshayes, 1858); in the lowermost 2 m only thinly scattered shell fragments; thickness: 3.80 m.



S
AALTER, Molenstraat
x=85.900; y=197.820
T.A.W. m
BOREHOLE
QUATERNARY
LEDE SAND FORMATION
no or few
Turritella
coquina
BOREHOLE
PLAYGROUND SCHOOL
coquina
Interval with
Turritella
solanderi
coquina
AALTER SAND MEMBER
Interval with
Megacardita planicosta lerichei
Interval with
Venericardia sulcata aizyensis
VLIERZELE FORMATION
Aalterbrugge Lignitic Horizon
1988
AALTERBRUG
Canal from Brugge to Gent
N
Weibroekdreef bridge
railway
Bellemstraat
AALTER
Molen-straat
E40 motorway
1km
N
AALTER, railway cutting
Weibroekdreef bridge
x=86.150; y=198.200
dumped material
and
decalcified sand
coquina
TOP RAILWAY
BOREHOLE
base borehole at +6.5m
see Fig.2

DESCRIPTION OF THE STRATOTYPE

Details of the exposures

The present investigation is based on three sections which slightly overlap and together constitute a complete succession of the Aalter Sands in their type locality (see Figs 1 and 2). The lowermost part of this sequence has been widely exposed in the railway cutting during the last century. At this time only one permanent, but small outcrop remains in the Molenstraat, so that the present information mainly relies on auger borehole interpretations and on previous observations near the railway bridge at the Weibroekdreef.

The succession

Detailed analysis of outcrop and borehole data at the Molenstraat and Weibroekdreef bridge, and their careful levelling, have led to the recognition of a 12.35 m thick sequence of the Aalter Sands. This sequence can be subdivided into 12 easily recognisable beds, which can be grouped in four major units or intervals on the basis of dominant molluscan species (see Fig. 1).

Underlying unit—About 5.5 m of the underlying unit were studied in a borehole at the Weibroekdreef bridge (see Fig. 2). The sediment consists of grey, micaceous, slightly lignitic, poorly sorted sand of the Vlierzele Formation (= Aalterbrugge Lignitic Horizon). The contact with the overlying unit is not easily seen in an auger borehole, but in borings with water injection, it is immediately detectable by the much higher speed of penetration at the top of the Vlierzele Formation.

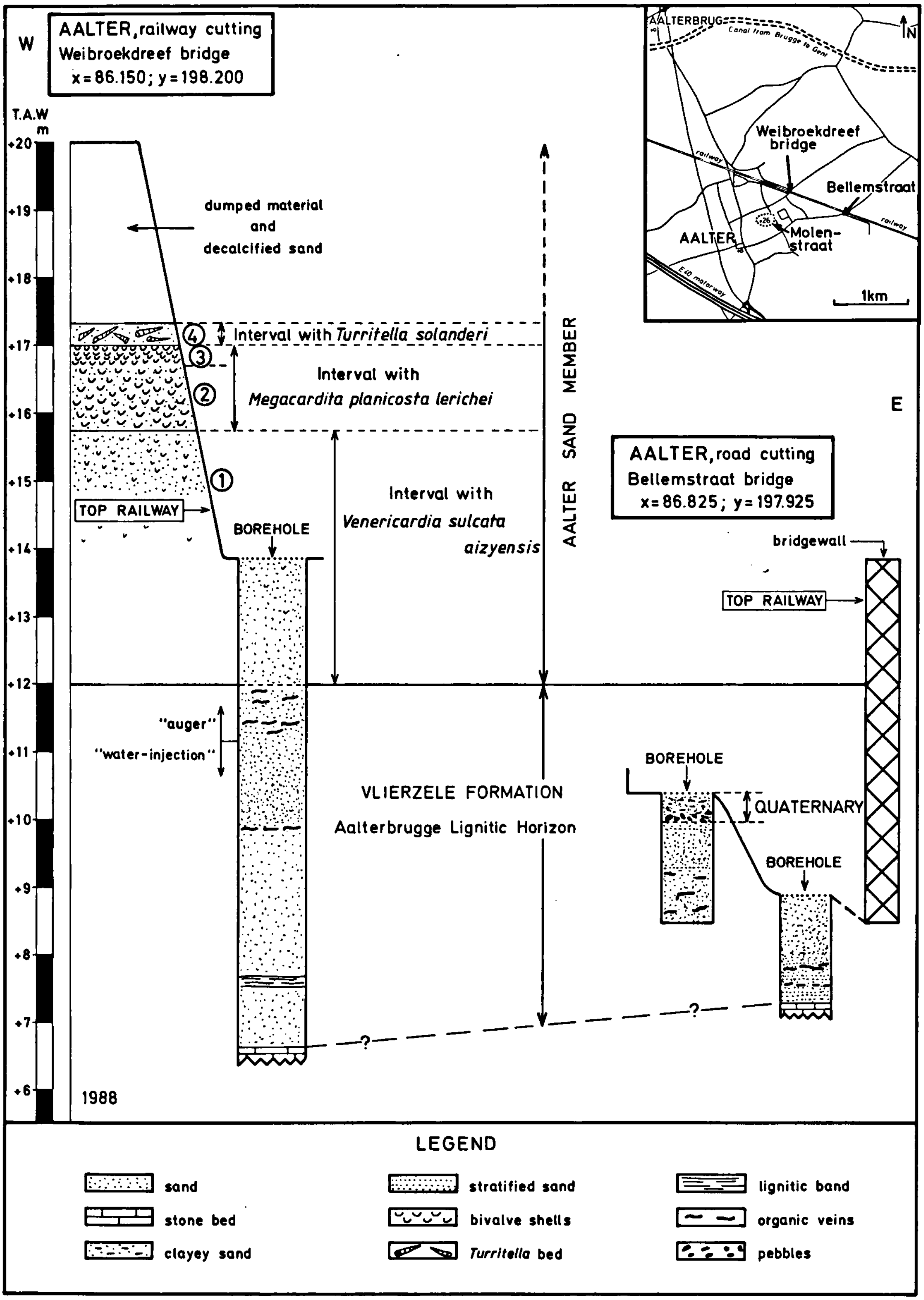
Overlying unit—Yellowish fine sands with sandstone fragments and, at the base, rolled shell fragments and *Nummulites laevigatus* (Bruguière, 1792) crop out in the Molenstraat, under a thin Quaternary cover (0.40 m). The sandstone fragments come from a 0.40 m thick massive calcareous sandstone, rich in shells (chiefly *Ostrea* and *Pecten*), Bryozoa and *Nummulites variolarius* (Lamarck, 1804), which occurs on top of the Aalter hill. This sandstone represents a basal stone-bed of the Lede Formation.

CALCAREOUS NANNOPLANKTON

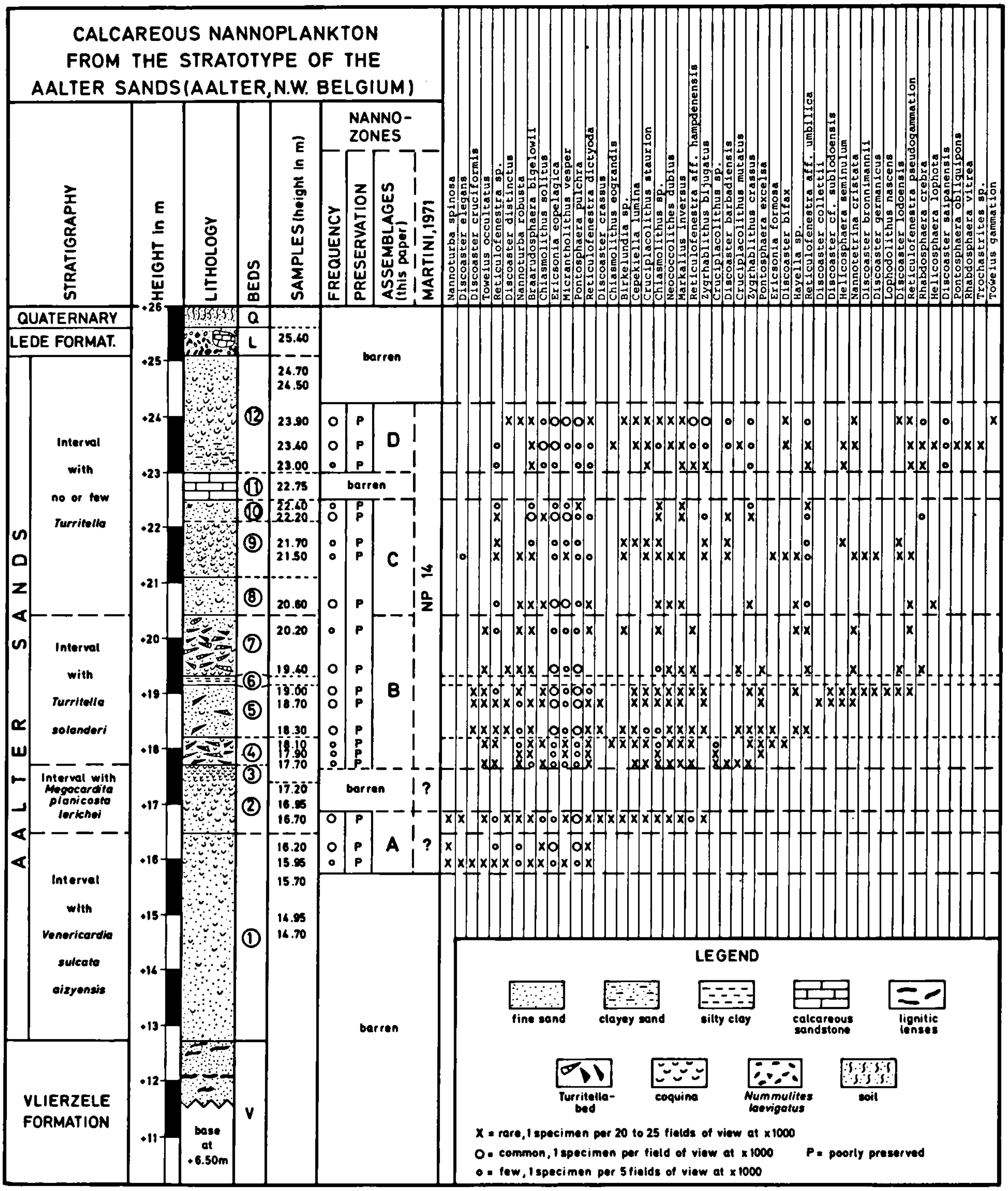
General characteristics

The calcareous nannoflora of the stratotype of the Aalter Sands contains 48 species, only four of which have not previously been recorded in the Belgian Basin so far (*Birkelundia* sp., *Discoaster broennimanni*, *D. collettii* and *Nannotetrina cristata*). It consists of poorly preserved, moderately diverse assemblages, except for the top and the lowermost 3 m of the sequence which are barren (see Table 1). Of the 27 samples selected, only few contain more than 20 species, with a maximum of 29 in the lowermost part of bed 12. The nannoflora of the Aalter Sands is characterised by the dominance of *Pontosphaera pulchra*, *Ericsonia eopelagica* and *Micrantholithus vesper* throughout the sequence, and by the genera *Braarudosphaera*, *Chiasmolithus* and *Zygrhablithus* at certain levels. The

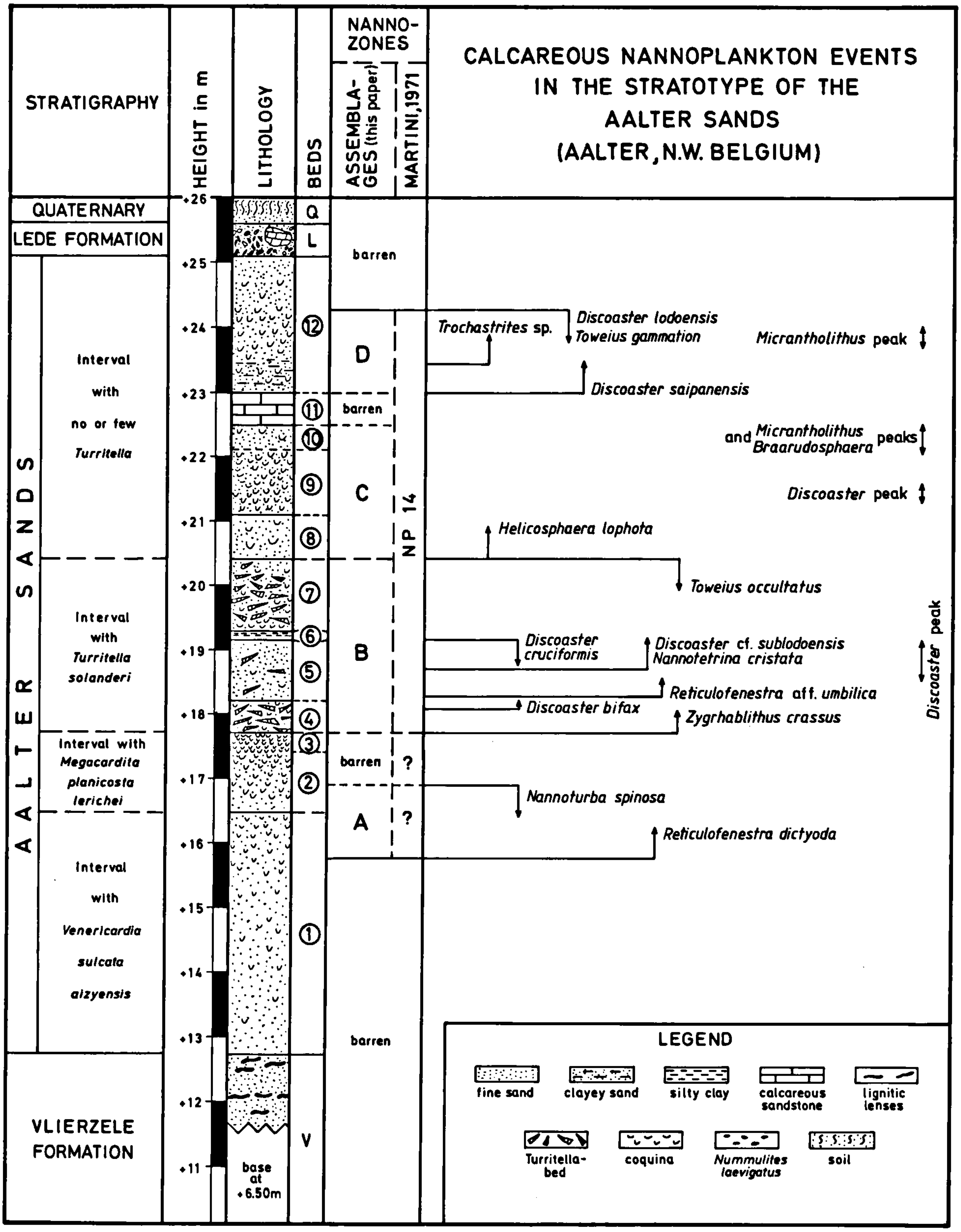
Fig. 2. Section in the Aalter Sands and underlying Vlierzele Formation, between Weibroekdreef and Bellemstraat at Aalter.


AALTER, railway cutting
Weibroekdreef bridge
x = 86.150; y = 198.200
W
T.A.W m
+20
+19
+18
+17
+16
+15
+14
+13
+12
+11
+10
+9
+8
+7
+6
dumped material
and
decalcified sand
Interval with Turritella solanderi
Interval with
Megacardita planicosta lerichei
Interval with
Venericardia sulcata
aizyensis
AALTER SAND MEMBER
TOP RAILWAY
BOREHOLE
"auger"
"water-injection"
VLIERZELE FORMATION
Aalterbrugge Lignitic Horizon
1988
AALTERBRUG
Canal from Brugge to Gent
N
Weibroekdreef
bridge
railway
Bellemstraat
AALTER
Molen-
straat
E40 motorway
1km
E
AALTER, road cutting
Bellemstraat bridge
x = 86.825; y = 197.925
bridgewall
TOP RAILWAY
BOREHOLE
QUATERNARY
BOREHOLE
LEGEND
sand
stone bed
clayey sand
stratified sand
bivalve shells
Turritella bed
lignitic band
organic veins
pebbles

TAB.1


CALCAREOUS NANNOPLANKTON FROM THE STRATOTYPE OF THE AALTER SANDS (AALTER, N.W. BELGIUM)
STRATIGRAPHY
HEIGHT in m
LITHOLOGY
BEDS
SAMPLES (height in m)
NANNO-ZONES
FREQUENCY
PRESERVATION
ASSEMBLAGES (this paper)
MARTINI, 1971
Nannoturba spinosa
Discoaster elegans
Discoaster cruciformis
Toweius occultatus
Reticulofenestra sp.
Discoaster distinctus
Nannoturba robusta
Braarudosphaera bigelowii
Chiasmolithus solitus
Ericsonia eopelagica
Micrantholithus vesper
Pontosphaera pulchra
Reticulofenestra dictyoda
Discoaster crassus
Chiasmolithus eograndis
Birkelundia sp.
Cepekiella lumina
Cruciplacolithus staurion
Chiasmolithus sp.
Neococcolithes dubius
Markalius inversus
Reticulofenestra aff. hampdenensis
Zygrhablithus bijugatus
Cruciplacolithus sp.
Discoaster barbadiensis
Cruciplacolithus mutatus
Zygrhablithus crassus
Pontosphaera excelsa
Ericsonia formosa
Discoaster bifax
Hayella sp.
Reticulofenestra aff. umbilica
Discoaster collectii
Discoaster cf. sublodoensis
Helicosphaera seminulum
Nannotetrina cristata
Discoaster bronnimannii
Discoaster germanicus
Lophodolithus nascens
Discoaster lodoensis
Reticulofenestra pseudogammation
Rhabdosphaera crebra
Helicosphaera lophota
Discoaster saipanensis
Pontosphaera obliquipons
Rhabdosphaera vitrea
Trochastrites sp.
Toweius gammation
QUATERNARY
LEDE FORMAT.
AALTER SANDS
Interval with no or few Turritella
Interval with Turritella solanderi
Interval with Megacardita planicosta lerichei
Interval with Venericardia sulcata aizyensis
VLIERZELE FORMATION
+26 +25 +24 +23 +22 +21 +20 +19 +18 +17 +16 +15 +14 +13 +12 +11
base at +6.50m
Q L 12 11 10 9 8 7 6 5 4 3 2 1 V
25.40 24.70 24.50 23.90 23.40 23.00 22.75 22.40 22.20 21.70 21.50 20.80 20.20 19.40 19.00 18.70 18.30 18.10 17.90 17.70 17.20 16.95 16.70 16.20 15.95 15.70 14.95 14.70
barren
D C B A
NP 14
?
LEGEND
fine sand
clayey sand
silty clay
calcareous sandstone
lignitic lenses
Turritella-bed
coquina
Nummulites laevigatus
soil
X = rare, 1 specimen per 20 to 25 fields of view at x1000
O = common, 1 specimen per field of view at x1000
o = few, 1 specimen per 5 fields of view at x1000
P = poorly preserved

TAB. 2


STRATIGRAPHY
HEIGHT in m
LITHOLOGY
BEDS
NANNO-ZONES
ASSEMBLAGES (this paper)
MARTINI, 1971
CALCAREOUS NANNOPLANKTON EVENTS IN THE STRATOTYPE OF THE AALTER SANDS (AALTER, N.W. BELGIUM)
QUATERNARY
LEDE FORMATION
AALTER SANDS
Interval with no or few Turritella
Interval with Turritella solanderi
Interval with Megacardita planicosta lerichei
Interval with Venericardia sulcata aizyensis
VLIERZELE FORMATION
+26
+25
+24
+23
+22
+21
+20
+19
+18
+17
+16
+15
+14
+13
+12
+11
base at +6.50m
Q
L
12
11
10
9
8
7
6
5
4
3
2
1
V
barren
D
barren
C
B
barren
A
barren
NP 14
?
?
Trochastrites sp.
Discoaster lodoensis
Toweius gammation
Micrantholithus peak
Discoaster saipanensis
Micrantholithus and Braarudosphaera peaks
Discoaster peak
Helicosphaera lophota
Toweius occultatus
Discoaster cruciformis
Discoaster cf. sublodoensis
Nannotetrina cristata
Discoaster peak
Reticulofenestra aff. umbilica
Discoaster bifax
Zygrhablithus crassus
Nannoturba spinosa
Reticulofenestra dictyoda
LEGEND
fine sand
clayey sand
silty clay
calcareous sandstone
lignitic lenses
Turritella-bed
coquina
Nummulites laevigatus
soil

abundance of these taxa, together with the presence of *Nannoturba* and *Trochastrites* indicate shallow water environments, and suggest sublittoral deposition (see Perch-Nielsen, 1985, p. 429 for comments on the ecology of these taxa).

Biozonation

Detailed analysis of the Aalter Sand nannoflora has led to the recognition of a series of calcareous nannoplankton events and to the introduction of four assemblage-units (Table 2).

Assemblage-unit A

This unit contains associations of low or moderate diversity and is rich in *Pontosphaera pulchra*. Its upper limit is defined by the last occurrence of *Nannoturba spinosa*. Unit A covers the interval from 15.95 to 16.70 m, and consists of the upper part of bed 1 and the lower part of bed 2 (see Table 2). Its exact limits cannot be established, because it lies between entirely barren intervals. Unit A does not contain marker species and is therefore difficult to correlate with Martini's (1971) standard nanno-zonation (see also Martini & Müller, 1986, for a slightly revised version).

Assemblage-unit B

The associations of unit B are more diverse (generally more than 20 species). The base of unit B is defined by the first occurrence of *Zygrhablithus crassus* and its upper limit by the last occurrence of *Toweius occultatus*, which also seems to coincide with the first occurrence of *Helicosphaera lophota*. Many additional first occurrences are recorded in the lower part of this unit, *e.g.* these of *Discoaster bifax*, *Reticulofenestra* aff. *umbilica*, *Nannotetrina cristata* and *Discoaster* cf. *sublodoensis* (see Table 2). *Nannoturba spinosa* is no longer present.

Unit B covers the interval from 17.70 m to 20.20 m, which corresponds to the interval from the base of bed 4 to the top of bed 7 [sample 17.70 m, which apart from frequent *Turritella* also contains (? reworked) *Megacardita* shells, is considered to represent the base of bed 4]. Unit B corresponds to the lower part of NP14 (presence of *Z. crassus*, *D.* cf. *sublodoensis*, *N. cristata*).

Assemblage-unit C

Unit C is defined as the interval between the last occurrence of *Toweius occultatus* and the first occurrence of *Discoaster saipanensis*. The base of this unit is also characterised by the first appearance of *Helicosphaera lophota*. Unit C covers the interval from 20.60 to 22.40 m, including unit 8, 9 and 10. Its upper limit is uncertain as no nannofossils were found in the overlying sandstone (= bed 11). Unit C is also attributable to the lower part of NP14.

Assemblage-unit D

Unit D consists of fairly rich and diverse assemblages. Its lower limit is placed at the first occurrence of *Discoaster saipanensis*. Unit D is also characterised by the first appearance of the genus *Trochastrites*, and still contains *Discoaster lodoensis* and *Toweius gammation*. It corresponds to the lower and middle part of bed 12, but its upper limit could not be established as no nannofossils were encountered in the upper part of bed 12. Unit D still belongs to Martini's NP14 (absence of *Rhabdosphaera gladius* and *Nannotetrina fulgens*).

In a previous paper (Steurbaut, 1988) it was already suggested that some of the nannoplankton-events here identified are useful for local and probably regional correlations. Yet, it is evident that the biostratigraphic utility of the nannoplankton events from the Aalter Sand stratotype can only be demonstrated through detailed analyses of outcrop and borehole sections in adjacent areas, *e.g.* the study of the Oedelem borehole and the Mont de Récollets outcrop, which are now in progress.

Sequence analysis and cycles

Independently of the above mentioned first and last occurrences, some considerable differences in abundance and in species diversity occur throughout the studied sequence (see Tab. 2). The associations from bed 10, and to a lesser degree, those from the middle part of bed 12, are dominated by the genera *Braarudosphaera*, *Micrantholithus* and *Zygrhablithus* and contain only few or no discoasters, indicating rather extreme shallow water conditions. The associations from the upper part of bed 5 and the middle part of bed 9 are quite distinct. They are characterised by a relatively high frequency and diversity of discoasters, by a decrease in *Chiasmolithus*, and, in bed 5, by the presence of *Helicosphaera seminulum* and *Lophodolithus nascens*. These events are probably the result of an increase in oceanic influences, suggesting deposition in deeper and probably also warmer waters. From the nannoplankton investigation it seems that during the deposition of the Aalter Sands some minor fluctuations in water depth must have occurred in the type area, which may be due to eustatic sea level changes. The deepest episodes seem to be represented by the top of bed 5 (and possibly bed 6, but no nannofossil data are available for this bed), the middle part of bed 9 and the base of bed 12; the shallowest by bed 10 and the middle part of bed 12.

From the foregoing, it appears that at least three distinct transgressive cycles can be identified in the upper part of the Aalter Sands, comprising respectively beds 4 to probably 6, beds 7 to 10 (possibly also bed 11), and bed 12. No interpretable data are available for its lowermost part (beds 1 to 3).

ALPHABETICAL LIST OF SPECIES AND REMARKS ON THEIR DISTRIBUTION

All species are listed in alphabetical order according to their generic name. The distribution of each species within the Eocene of the Belgian Basin is given (compiled from Steurbaut, 1986, 1988, 1989, in press and unpublished data, and from Steurbaut & Nolf, 1986). The following notations are used for species which are also known from other units:

I = Ieper Formation
V = Vlierzele Formation
O = Oedelem Sand Member
B = Brussel Formation
L = Lede Formation
M = Meetjesland Formation
? = uncertain.

References to illustrations in Plate 1 are also added.

Birkelundia sp. (Figs 25-27)
Braarudosphaera bigelowii (Gran & Braadrup, 1935): I, V, O, B, L, M
Cepekiella lumina (Sullivan, 1964): I, V, O, L, M
Chiasmolithus eograndis Perch-Nielsen, 1971: I

Chiasmolithus solitus (Bramlette & Sullivan, 1961): I, V, O, B, L, M (Fig. 2)
Chiasmolithus sp.: ? I (Fig. 1)
Cruciplacolithus mutatus Perch-Nielsen, 1971: V, O, B
Cruciplacolithus staurion (Bramlette & Sullivan, 1961): O, B, L (Figs 3-4)
Cruciplacolithus sp.: I, V
Discoaster barbadiensis Tan Sin Hok, 1927: I, V, O, B, L, M
Discoaster bifax Bukry, 1971: ? V, B, M (Fig. 18)
Discoaster broennimanni Stradner, 1961
Discoaster collettii (Parejas, 1934)
Discoaster crassus Martini, 1958: I, V
Discoaster cruciformis Martini, 1958: I (Fig. 11)
Discoaster distinctus Martini, 1958: I, V, O, M
Discoaster elegans Bramlette & Sullivan, 1961: I
Discoaster germanicus Martini, 1958: O, M
Discoaster lodoensis Bramlette & Riedel, 1954: I, V, O (Fig. 21)
Discoaster saipanensis Bramlette & Riedel, 1954: B (Figs 16-17)
Discoaster cf. *sublodoensis* Bramlette & Sullivan, 1961: O, B (Fig. 8)
Ericsonia eopelagica (Bramlette & Riedel, 1954): I, V, O, B, L, M
Ericsonia formosa (Kamptner, 1963): I, V, O, M
Hayella sp.: I, O (Figs 5-6)
Helicosphaera lophota Bramlette & Sullivan, 1961: L, M (Fig. 19)
Helicosphaera seminulum Bramlette & Sullivan, 1961: I, M (Fig. 20)
Lophodolithus nascens Bramlette & Sullivan, 1961: I
Markalius inversus (Deflandre *in* Deflandre & Fert, 1954): I, V, O, B, L, M (Fig. 7)
Micrantholithus vesper Deflandre, 1954: I, V, O, B, L, M
Nannotetrina cristata (Martini, 1958) (Fig. 12)
Nannoturba robusta Müller, 1979: I, V, O (Fig. 10)
Nannoturba spinosa Müller, 1979: V, O (Fig. 9)
Neococcolithes dubius (Deflandre, 1954): I, V, O, L, M
Pontosphaera excelsa (Perch-Nielsen, 1971): I
Pontosphaera obliquipons (Deflandre, 1954): V, O, L, M
Pontosphaera pulchra (Deflandre *in* Deflandre & Fert, 1954): I, V, O, B, L, M (Fig. 29)
Reticulofenestra dictyoda (Deflandre *in* Deflandre & Fert, 1954): O, B, L
Reticulofenestra aff. *hampdenensis* Edwards, 1973: O, B, L
Reticulofenestra pseudogammation (Bouché, 1962): B, L (Fig. 31)
Reticulofenestra aff. *umbilica* (Levin, 1965): O, B, L (Fig. 28)
Reticulofenestra sp.: I, V
Rhabdosphaera crebra Deflandre *in* Deflandre & Fert, 1954: I, V, O, B, L, M
Rhabdosphaera vitrea Deflandre *in* Deflandre & Fert, 1954: I, O, B, L, M
Toweius gammation (Bramlette & Sullivan, 1961): I, V (Fig. 22)
Toweius occultatus (Locker, 1967): I, V, O (Fig. 30)
Trochastrites sp.: O
Zygrhablithus bijugatus (Deflandre, 1959): I, V, O, B, L, M (Figs 23-24)
Zygrhablithus crassus Locker, 1967: ? V, O, B, L, M (Figs 13-15).

REFERENCES

Aubry, M.-P., 1985. Northwestern European Paleogene magnetostratigraphy, biostratigraphy, and paleogeography: calcareous nannofossil evidence.—Geology, 13:198-202. Casier, E., 1950. Contributions à l'étude des poissons fossiles de la Belgique, 9. La faune des formations dites ,,paniséliennes''.—Bulletin de l'Institut royal des Sciences naturelles de Belgique, 26(42): 1-52.

Delvaux, E., 1886. Visite aux gites fossilifères d'Aeltre et exploration des travaux en cours d'exécution à la colline de Saint-Pierre à Gand.—Annales de la Société royale malacologique de Belgique, 21: 274-296.

Dumont,A., 1849. Carte géologique de la Belgique à l'échelle 1/160.000.

Feugueur, L., 1951. Sur l'Yprésien des bassins français et belge, et l'âge des Sables d'Aeltre.—Bulletin de la Société belge de Géologie, de Paléontologie et d'Hydrologie, 60(2): 216-242.

Glibert, M., 1974. Quelques Turbinoliidae cénozoiques des collections de l'Institut royal des Sciences naturelles de Belgique.—Bulletin de l'Institut royal des Sciences naturelles de Belgique, 50(1): 1-26.

Glibert, M., 1985. Les bivalves et gastéropodes du Bruxellien inférieur de la Belgique (Eocène moyen).—Annales de la Société Royale Zoologique de Belgique, 115(1): 261-367.

Jacobs, P., 1974. Het Tertiair tussen Gent en Overmere. Natuurwetenschappelijk Tijdschrift, 55(1973): 229-243.

Jacobs, P., & S. Geets, 1977. Nieuwe ontwikkelingen in de kennis van het Boven-Paniseliaan.—Natuurwetenschappelijk Tijdschrift, 59(1977): 57-93.

Kaasschieter, J.P.H., 1961. Foraminifera of the Eocene of Belgium.—Mémoires de l'Institut royal des Sciences naturelles de Belgique, 147, 271 pp.

Leriche, M., 1905. Les poissons éocènes de la Belgique.—Mémoires de l'Institut royal des Sciences naturelles de Belgique, 3(11): 49-228.

Leriche, M., 1921. Monographie géologique des collines de la Flandre française et de la province belge de la Flandre occidentale (collines de Cassel et environs de Bailleul).—Mémoires pour servir à l'explication de la carte géologique détaillée de la France, 112 pp.

Leriche, M., 1938. Les Sables d'Aeltre. Leur place dans la classification des assises éocènes du Bassin anglo-franco- belge.—Annales de la Société géologique du Nord, 62 (1937): 77-96.

Martini, E., 1971. Standard Tertiary and Quaternary calcareous nannoplankton zonation.—Proceedings 2 Planktonic Conference, Roma 1970, 2: 739-785.

Martini, E., & C. Müller, 1986. Current Tertiary and Quaternary calcareous nannoplankton stratigraphy and correlations.—Newsletters in Stratigraphy, 16(2): 99-112.

Mourlon, M., 1873. Géologie de la Belgique.—Patria Belgica, 100 pp.

Nolf, D., 1973a. Stratigraphie des Formations du Panisel et de Den Hoorn (Eocène belge).—Bulletin de la Société belge de Géologie, de Paléontologie et d'Hydrologie, 81(1- 2)(1972): 75-94.

Nolf, D., 1973b. Sur la faune ichthyologique des Formations du Panisel et de Den Hoorn (Eocène belge).—Bulletin de la Société belge de Géologie, de Paléontologie et d'Hydrologie, 81(1-2)(1972): 111-138.

Nyst, H., & M. Mourlon, 1872. Note sur le gîte fossilifère d'Aeltre (Flandre orientale).—Annales de la Société malacologique de Belgique, 6: 29-37.

Omalius d'Halloy, J.J. d', 1842. Coup d'oeil sur la géologie de la Belgique, Bruxelles (Hayez), 132 pp.

Perch-Nielsen, K., 1985. Cenozoic calcareous nannofossils. *In*: H.M. Bolli, J.B. Saunders & K. Perch-Nielsen (eds). Plankton stratigraphy. Cambridge (Cambridge University Press), pp. 427-554.

Steurbaut, E., 1986. Late Middle Eocene to Middle Oligocene calcareous nannoplankton from the Kallo well, some boreholes and exposures in Belgium and a description of the Ruisbroek Sand Member.—Mededelingen van de Werkgroep voor Tertiaire en Kwartaire Geologie, 23(2): 49-83.

Steurbaut, E., 1988. New Early and Middle Eocene calcareous- nannoplankton events and correlations in middle to high latitudes of the northern hemisphere.—Newsletters in Stratigraphy, 18(2): 9-115.

Steurbaut, E., 1989. Ypresian calcareous nannoplankton biostratigraphy and palaeogeography of the Belgian Basin.—*In*: C. Dupuis, J. De Coninck & E. Steurbaut (eds). The Ypresian of the Belgian Basin.—Bulletin de la Société belge de Géologie, 97(4).

Steurbaut, E., in press. Calcareous nannoplankton assemblages from the Tertiary in the Knokke borehole.—Toelichtende Verhandelingen Geologische Kaart en Mijnkaart van België.

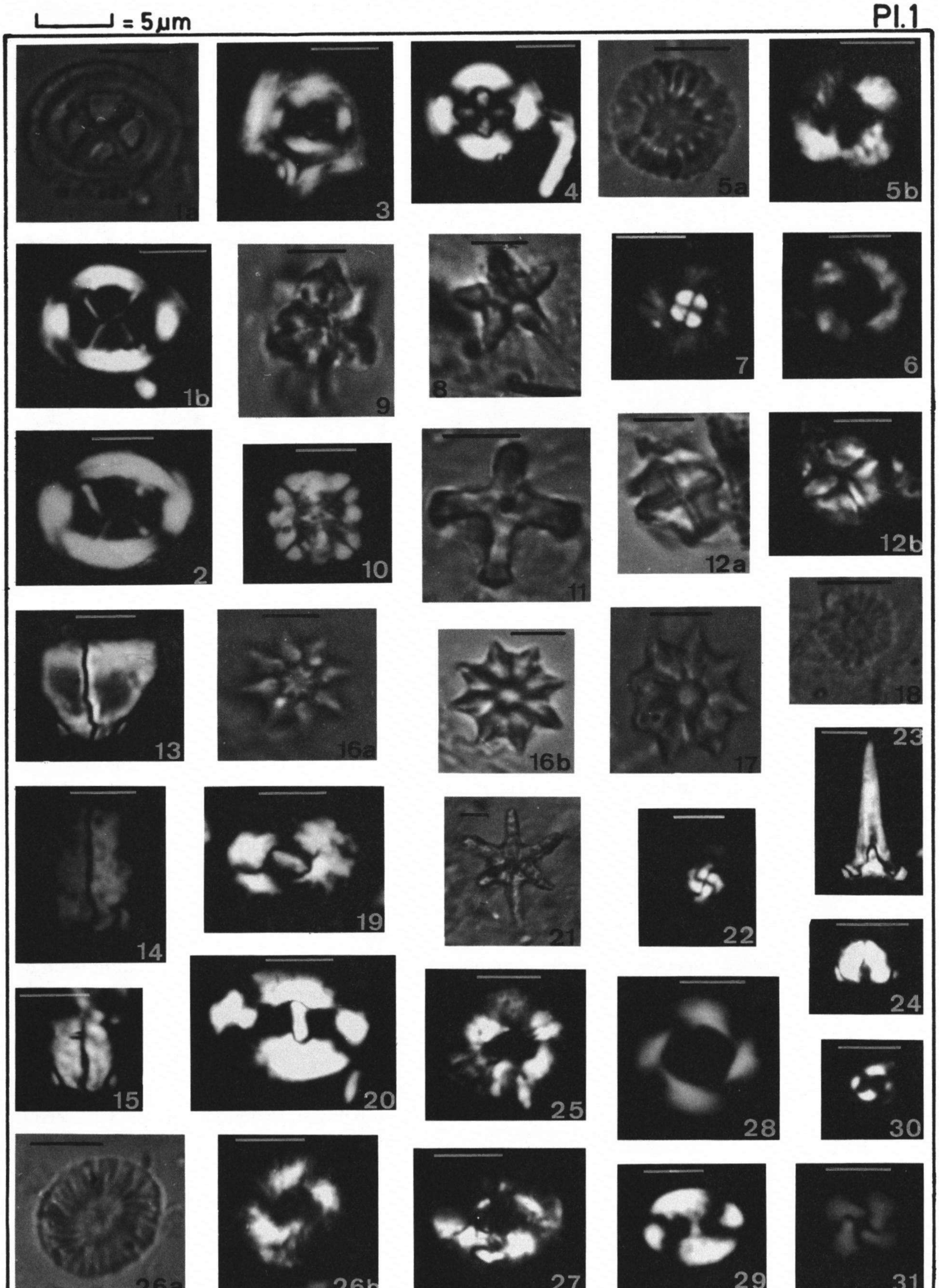
Steurbaut, E., & D. Nolf, 1986. Revision of Ypresian stratigraphy of Belgium and northwestern France.—Mededelingen van de Werkgroep voor Tertiaire en Kwartaire Geologie, 23(4): 115- 172.

EXPLANATION OF PLATE 1

All specimens are from the stratotype of the Aalter Sands. Dark-coloured figures are illustrated in cross-polarised light, others in transmitted light. Scale bar represents 5 µm. Slides and negatives of micrographs are stored in the Laboratorium voor Paleontologie, Krijgslaan 281/S8, B-9000 Gent, Belgium.

Fig. 1. *Chiasmolithus* sp.
Molenstraat, bed 4, 18.10 m, distal view
Fig. 2. *Chiasmolithus solitus* (Bramlette & Sullivan, 1961)
railway cutting at Weibroekdreef, bed 2, 16.70 m, distal view
Fig. 3-4. *Cruciplacolithus staurion* (Bramlette & Sullivan, 1961)
3 = Molenstraat, bed 4, 18.10 m, distal view, coccosphere; 4 = Molenstraat, bed 12, 23.90 m, distal view
Fig. 5-6. *Hayella* sp.
Molenstraat, bed 5, 18.30 m; 5 = distal view; 6 = proximal view
Fig. 7. *Markalius inversus* (Deflandre *in* Deflandre & Fert, 1954)
Molenstraat, bed 4, 18.10 m, distal view
Fig. 8. *Discoaster* cf. *sublodoensis* Bramlette & Sullivan, 1961
Molenstraat, bed 5, 19.00 m, ? proximal view
Fig. 9. *Nannoturba spinosa* Müller, 1979
railway cutting at Weibroekdreef, bed 1, 15.95 m; side view
Fig. 10. *Nannoturba robusta* Müller, 1979
Molenstraat, bed 7, 19.40 m; side view
Fig. 11. *Discoaster cruciformis* Martini, 1958
railway cutting at Weibroekdreef, bed 1, 15.95 m, distal view
Fig. 12. *Nannotetrina cristata* (Martini, 1958)
Molenstraat, bed 5, 18.70 m, distal view
Fig. 13-15. *Zygrhablithus crassus* Locker, 1967
Molenstraat, side views; 13 = bed 12, 23.00 m; 14 = bed 5, 19.00 m; 15 = bed 4, 17.70 m
Fig. 16-17. *Discoaster saipanensis* Bramlette & Riedel, 1954
Molenstraat, bed 12, 23.40 m, proximal view; 16a = high focus; 16b and 17 = low focus
Fig. 18. *Discoaster bifax* Bukry, 1971
Molenstraat, bed 12, 23.40 m, distal view
Fig. 19. *Helicosphaera lophota* Bramlette & Sullivan, 1961
Molenstraat, bed 12, 23.40 m, proximal view
Fig. 20. *Helicosphaera seminulum* Bramlette & Sullivan, 1961
Molenstraat, bed 5, 19.00 m, proximal view
Fig. 21. *Discoaster lodoensis* Bramlette & Riedel, 1954
Molenstraat, bed 5, 19.00 m, proximal view
Fig. 22. *Toweius gammation* (Bramlette & Sullivan, 1961)
Molenstraat, bed 12, 23.90 m, distal view
Fig. 23-24. *Zygrhablithus bijugatus* (Deflandre, 1959)
23 = Molenstraat, bed 5, 18.30 m, side view; 24 = railway cutting at Weibroekdreef, bed 2, 16.70 m, side view
Fig. 25-27. *Birkelundia* sp.
25-26 = Molenstraat, bed 7, 20.20 m, distal view; 27 = Molenstraat, bed 5, 18.30 m, distal view
Fig. 28. *Reticulofenestra* aff. *umbilica* (Levin, 1965)
Molenstraat, bed 5, 18.30 m, proximal view
Fig. 29 *Pontosphaera pulchra* (Deflandre *in* Deflandre & Fert, 1954)
railway cutting at Weibroekdreef, bed 2, 16.70 m, proximal view
Fig. 30. *Toweius occultatus* (Locker, 1967)
Molenstraat, bed 7, 19.40 m, proximal view
Fig. 31. *Reticulofenestra pseudogammation* (Bouché, 1962)
Molenstraat, bed 5, 19.00 m, proximal view.

Pl.1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Tavernier, R., 1935. Bijdrage tot de geologische kennis van de Blandinusberg te Gent.—Natuurwetenschappelijk Tijdschrift, 17: 204-206.

Vincent, G., & A. Rutot, 1879. Coup d'oeil sur l'état actuel d'avancement des connaissances géologiques relatives aux terrains tertiaires de la Belgique.—Annales de la Société géologique de Belgique, 6: 69-154.

Manuscript received 12 February 1989, revised version accepted 16 February 1989

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