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MICROFOSSIL ASSEMBLAGES, ZONATIONS AND PLANKTONIC DATUM LEVELS IN THE IEPER FORMATION (YPRESIAN s.s., EARLY EOCENE) IN BELGIUM

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ABSTRACT

This paper deals with the compilation of the results of micropalaeontological investigations on the Ieper Formation (Ypresian *s.s.*, Early Eocene) in Belgium. Data from the following groups have been included : foraminiferids (benthic, planktonic, larger forms), radiolarians, calcareous nannoplankton, dinoflagellates, diatoms, non-marine palynomorphs (pollen, spores), dasycladaceans, microproblematica, ostracods and otoliths. Benthic foraminiferids and dinoflagellates occur throughout the Ieper Formation and are most suitable for zonation. The interval around the glauconitic level, which occurs in the middle part of the Flanders Member, is shown to be characterized by several micropalaeontological events. The planktonic record is very important and of international significance for biostratigraphical correlations. It comprises the occurrence of the *Coscinodiscus* sp. 1-peak level (diatoms), the entry of the *Subbotina-Acarinina*-assemblage, the presence of the *Globigerina patagonica*-acme zone and of the *Guembelitria triseriata*-datum level (all planktonic foraminiferids), the NP 11-NP 12 boundary (calcareous nannoplankton) and the entry of spherical radiolarians in the Belgian Tertiary.

SAMENVATTING

Dit artikel brengt de resultaten samen van verscheidene mikropaleontologische onderzoeken van de Ieper-Formatie (Ieperiaan *s.s.*, Vroeg-Eoceen) in België. Gegevens in verband met volgende groepen van mikrofossielen werden gebruikt : foraminiferen (benthonische, planktonische en grote foraminiferen), radiolariën, kalkschalig nannoplankton, dinoflagellaten, diatomeeën, pollenkorrels, sporen, dasycladaceeën, mikroproblematika, ostrakoden en otolieten. Benthonische foraminiferen en dinoflagellaten komen voor doorheen de hele Ieper-Formatie en zijn de meest bruikbare groepen voor zonering. Het interval rondom het glaukonietniveau dat voorkomt in het middengedeelte van het Lid van Vlaanderen, wordt gekenmerkt door verscheidene mikropaleontologische veranderingen. De resultaten i.v.m. de planktonische mikrofossielen zijn vrij belangrijk voor internationale biostratigrafische korrelatie. Het betreft het voorkomen van het *Coscinodiscus* sp. 1-piekniveau (diatomeeën), het eerste optreden van de *Subbotina-Acarinina*-fauna, de aanwezigheid van de *Globigerina patagonica*-acmezone en van het *Guembelitria triseriata*-eerste optreden-niveau (allemaal i.v.m. planktonische foraminiferen), de NP 11-NP 12 grens (kalkschalig nannoplankton) en het optreden van bolvormige radiolariën in het Belgische Tertiair.

RESUME

Cet article est la synthèse des recherches micropaléontologiques effectuées sur la Formation d'Ieper, ou d'Ypres (Yprésien *s.s.*, Eocène inférieur) de Belgique et concernant les groupes suivants : les foraminifères (benthiques, planctoniques, grands foraminifères), les radiolaires, les nannofossiles calcaires, les dinophycées, les diatomées, les grains de pollen et les spores, les dasycladacées, les microfossiles problématiques, les ostracodes et les otolithes. Les foraminifères benthiques et les dinophycées se

rencontrent dans l'ensemble de la Formation d'Ieper et correspondent aux fossiles les plus fiables pour une zonation. Les couches encaissantes du lit glauconifère, situé au milieu du Membre de Flandre (Flanders Member), se caractérisent par plusieurs évènements d'ordre micropaléontologiques très importants. Les données des groupes planctoniques sont essentielles pour la corrélation biostratigraphique internationale. Il s'agit : du niveau où abonde *Coscinodiscus* sp. 1 (diatomées) ; du niveau où débute l'association *Subbotina-Acarinina* ; de la zone où abonde *Globigerina patagonica* ; du niveau où apparait *Guembelitria triseriata* (foraminifères planctoniques) ; de la transition NP11-NP12 (nannofossiles calcaires) ; du niveau où apparaissent les radiolaires sphériques au Tertiaire belge.

ZUSAMMENFASSUNG

Diese Veröffentlichung gibt eine Kompilation der wissenschatlichen Resultate mikropaläontologischer Untersuchungen der Ieper Formation (Ypres-Stufe, Unter-Eozän) in Belgien. Folgende paläontologische Gruppen wurden berücksichtigt : Foraminiferen (benthonische, planktonische und Groß-Foraminiferen), Radiolarien, kalkiges Nannoplankton, Dinoflagellaten, nicht-marine Palynomorphen (Pollen, Sporen), Dasycladaceae-Algen, Diatomeen, Mikroproblematica, Ostrakoden und Otolithen. Benthonische Foraminiferen und Dinoflagellaten sind in der gesamten Ieper-Formation gut vertreten und sie sind für die Biostratigraphie am brauchbarsten in Belgien. Der Intervall in der Nähe des Glaukonit-Horizonts (der in der Mitte der Flandern Gesteinseinheit auftritt) ist durch verschiedene mikropaläontologische Änderungen gekennzeichnet.
Die vorhandenen planktonischen Organismen sind sehr wichtig für die internationale Biostratigraphie. Sie enthalten den *Coscinodiscus* sp. 1 Häufigkeitshorizont (Diatomeen), das Erstauftreten der *Subbotina-Acarinina* Vergesellschaftung, das Häufigkeits-intervall von *Globigerina patagonica* und das Erstauftreten von *Guembelitria triseriata* (alle planktonische Foraminiferen), die NP11-NP12 Biozonengrenze (kalkiges Nannoplankton) und das Erstauftreten von sphärischen Radiolarien im Belgischen Tertiär.

1. INTRODUCTION

The micropalaeontological investigation of the Ieper Formation (Early Eocene) in Belgium has now been undertaken for nearly all important groups and enables us to establish zonation and correlation schemes.

According to the Subgroup Lithostratigraphy and Maps of I.G.C.P. 124 (1980 ; LAGA, GEETS, MOORKENS & NOLF) the Ieper Formation in Belgium consists of four members, which are, from base to top : Mont Héribu Member, Flanders Member, Egem Member and Merelbeke Member. Lithologically, there are clayey deposits (Mont Héribu, Flanders, Merelbeke) and sandy layers (Egem).

The Mont Héribu Member corresponds to the basal part of the lower clayey deposits traditionally called the Clay of Flanders or Ieper which are now designated as the Flanders Member. The Egem Member corresponds to the sands overlying the Flanders Member ; several lithostratigraphic names have been used for these sands (see WILLEMS *et al.*, 1981). The Merelbeke Member stands for the Clays of Merelbeke DE MOOR & GEETS 1973.

The zonation and correlation scheme here presented deals essentially with the Mont Héribu, Flanders and Egem Members which represent the original clay-sand division of the Ypresian as erected by DUMONT in 1849. More details about the Ypresian stratotype, its formations and members may be found in WILLEMS *et al.* (1981), wherein the Ieper Formation has been limited to the three basal members.

The microfossil assemblages have been studied in several boreholes and outcrops (see fig. 1) of which the Kallo and Tielt boreholes are the most important. Lithologic columns of both wells have been published by GULINCK (1967) and their exact geographic localisation can be found in DE CONINCK (1975). Details about previous studies, the localities, the faunal composition, the biostratigraphy, the palaeoenvironmental conditions and the international correlation can be found in the reference cited or will be discussed in forthcoming papers.

2. MICROFOSSIL ASSEMBLAGES (TABLE 1)

2.1. Benthic Foraminiferids

The benthic foraminiferids of the Ieper Formation have been studied previously in boreholes at Mouscron (Belgium) by LE CALVEZ & FEUGUEUR (1956) and at Woensdrecht (southern Netherlands) by KAASSCHIETER (1961). In both wells a threefold zonation was proposed.

In the Mouscron borehole an agglutinating foraminiferal fauna occurs at the base of the Ieper Formation, followed by an azoic interval and a lagenid-buliminid-rotalid-anomalinid association ; the equivalent of the Egem Member is characterized by textularids (LE CALVEZ & FEUGUEUR, 1956).
In Woensdrecht three different faunas occur in the Flanders Clay : an agglutinating association, with some calcareous forms, at the base, followed by a textularid-nodosarid-anomalinid fauna in the middle part and an anoma-

linid-dominated association at the top (KAASSCHIETER, 1961).

In the Kallo and Tielt boreholes 19 and 13 benthic faunules respectively could be distinguished in the Ieper Formation. They have been grouped into six associations, readily recognizable in the Kallo borehole, but less so in the Tielt well (WILLEMS, 1980).

The oldest association (BF-ass.I) occurs at the base of the Flanders Clay or what has now been called the Mont Héribu Member (Subgroup Lithostratigraphy and Maps, 1980). It contains exclusively agglutinating foraminiferids, most of them rather small, compressed, deformed or poorly preserved. The important groups are : *Rhabdammina* (*R. eocenica*),*Rhizammina*, *Ammodiscus* (*A. siliceus*), *Miliammina* (*M. paleocenica*), *Trochamminoides* (*T. subtrullisatus*),*Recurvoides*, *Trochammina* and *Verneuilina* (*V. subeocaena*).
This association is known from the Kallo, Tielt and Ooigem boreholes and the Orchies outcrop (WILLEMS, 1980 ; in press), from the outcrops around Mons and Tournai (GEETS *et al.*, in prep.) from the Mol well (WILLEMS, unpublished report Belgium Geological Survey) and from the Mouscron borehole (LE CALVEZ & FEUGUEUR, 1956). The association at the base of the Ieper Formation in the Woensdrecht well is not exclusively composed of agglutinating foraminiferids (KAASSCHIETER, 1961).

The second association (BF-ass.II) is characterized by a mixed agglutinating-calcareous assemblage, mainly dominated by *Ammodiscus* (*A. siliceus*, *A. septatus*), *Haplophragmoides* (*H. walteri*) and also by *Anomalinoides* (*A. nobilis*, *A. ypresiensis*), *Cibicidoides* (*C. proprius*) and *Pulsiphonina* (*P. prima*). These calcareous species have been recorded in the Ieper Formation throughout, except from the basal layers (WILLEMS, 1980). This association has been observed at Kallo, Tielt and Ooigem (in the two last localities, however, with reduced numbers of specimens recorded). It is also known from Woensdrecht (Lower Woensdrecht Zone ; KAASSCHIETER, 1961).

The next association (BF-ass.III) is largely dominated by the same *Anomalinoides*, *Cibicidoides* and *Pulsiphonina*-species as occurring in BF-ass.II but is characterized by *Cibicidoides crassus*, *Anomalinoides* sp. cf. *A. danicus*, *Eponides plummerae*, *E. lunata* and *Dentalina spinescens*.
The specimens are poorly preserved and some of them show traces of *post mortem* decalcification or of abnormal test secretion (decalcification due to undersaturation in calcium carbonate of the seawater). This association has only been found in Kallo.

The fourth association (BF-ass.IV) is characterized by an increase in number of specimens and a large species diversification. Dominant species are still the *Anomalinoides* and *Cibicidoides* representatives. Lenticulinids and ribbed nodosariids are present but certainly do not dominate the fauna (see quantitative results for Tielt in WILLEMS, 1980).
Frequent, and even abundant in some levels, are specimens of *Spiroplectammina* (*S. adamsi*), *Textularia* (*T. smithvillensis*) and *Karreriella* (*K. danica*, *K. oveyi*). Ribbed nodosariids (*N. latejugata*, *N. minor*), large lenticulinids and heavy ornamented marginulinopsids (*M. enbornensis*) occur frequently in the sediment fraction larger than 250 µm. A restricted interval, in the middle part of the sequence in which BF-ass.IV occurs, is dominated by *Asterigerina bartoniana kaasschieteri* and by *Karreria fallax*. The youngest

part of the BF-ass.IV is characterized by a decrease in the number of specimens and species and by the appearance of *Turrilina brevispira*. This association has been found in the Kallo, Tielt and Ooigem boreholes, the Mouscron well (second fauna ; LE CALVEZ & FEUGUEUR, 1956), the Woensdrecht well (Middle Woensdrecht Zone ; KAASSCHIETER, 1961) and in the Mons-en-Pévèle outcrop.

Next comes an azoic interval, variable in thickness (about 10 m in Kallo and more than 20 m in Tielt).

The last association distinguished in the Flanders Member (BF-ass.V) contains a fauna less rich in specimens and in species but still largely dominated by the same *Anomalinoides-Cibicidoides* species and characterized by *Turrilina brevispira, Alabamina wilcoxensis* and two *Cibicidoides* species (*C. sulzensis* and *C. pseudoungerianus*). This fauna is known from the Kallo and Tielt wells, in the Kortemark outcrop, and also in the Woensdrecht borehole (Upper Woensdrecht Zone ; KAASSCHIETER, 1961).

The change in sediment, from clay to sand, resulted in a faunal break at the base of the Egem Member. The association (BF-ass.VI) is dominated by *Cibicides* and *Cibicidina*-species (*Cibicides gr. carinata, Cibicidina ekblomi, C. mauricensis, C. newmanae*), by *Elphidium* (*E. ? latidorsatum*), nonionids (*N. graniferum, Florilus commune*), polymorphinids (with *Guttulina parisiensis* as a typical form), crenulated bolivinids and trifarinids. This association occurs in the Kallo, Tielt and Ledeberg boreholes and in the Merelbeke outcrop.

The foraminiferal fauna of the Merelbeke Member, only studied in the Kallo well, is characterized by a decrease in species and specimens and is dominated by *Cibicidoides proprius* and *Anomalinoides nobilis* (which dominated also in the Flanders and Egem Members) and by *Epistominella vitrea* which is also known from the underlying members.

2.2. Planktonic Foraminiferids.

Except for some rare and small specimens recorded in the sediments in which BF-ass.II & III occur, no planktonic foraminiferids have been found in the Mont Héribu Member and in the basal layers of the Flanders Member.
They enter near the base of the interval in which BF-ass.IV has appeared, and this entry level has been observed in Kallo, Tielt and Ooigem.
Important taxa are *Turborotalia* (mainly *T. pentacamerata* and a few *T. soldadoensis* and *T. esnaensis*) and *Globigerina* (*G. aquiensis*).
In the upper part of this interval *Globigerina patagonica* dominates the planktonic foraminiferal population and large, well preserved specimens, occurring in the sediment fraction larger than 250 µm, have been recorded (WILLEMS, 1980). Planktonic foraminiferids are also known from the equivalent Middle Woensdrecht Zone in the Woensdrecht well (KAASSCHIETER, 1961) and from the Mouscron borehole (LE CALVEZ & FEUGUEUR, 1956).

Above the azoic interval, the planktonic foraminiferal association reappears, but it is slightly modified : *Globigerina patagonica* is less important or does not occur ; the small species *Guembelitria triseriata* enters and is frequent or even abundant in the sediment fraction between 125 and 74 µm ; some rare globorotalids have been recorded (*G. pseudoscitula*).

At the top of the Flanders Member (in the BF-ass.V-interval) some specimens of *Pseudohastigerina wilcoxensis* have been found.

Planktonic foraminiferids from outcrops of the Ieper Formation have previously been described and figured by MOORKENS (1968).

The planktonic foraminiferal fauna in the Egem Member is largely identical in species composition with thatoccurring at the top of the Flanders Member but it is richer in specimens. This fauna continues in the Merelbeke Member.

2.3. Larger Foraminiferids

Nummulites planulatus occurs in the Flanders Member, in the middle part of the BF-ass.IV-interval. This has been observed in the boreholes at Kallo (GULINCK, 1967 ; WILLEMS, 1980), Ooigem (GULINCK, 1967) and Mouscron (LE CALVEZ & FEUGUEUR, 1956 ; GULINCK, 1967) and in the outcrop at Mons-en-Pévèle (WILLEMS, 1980).

In the Egem Member, nummulites are very frequent, and known for more than a century (Sands with *Nummulites planulatus*, as described by LYELL in 1852).

2.4. Calcareous Nannoplankton

A detailed nannoplankton study has been carried out by MÜLLER & WILLEMS (1981) on samples from the Kallo and Tielt wells. It revealed that the nannoflora enters towards the base of the BF-ass.IV-interval. However, some specimens have been recorded below that level (MOORKENS & ČEPEK, 1974). The flora contains *Marthasterites tribrachiatus* and *Discoaster binodosus*.
The first *D. lodoensis* occurs in the upper part of this interval, together with the same species reported above. This flora also occurs in the BF-ass. V & VI-intervals but some of the associated species have changed (table 1).

2.5. Dinoflagellates

The dinoflagellate associations from the Kallo borehole have been exhaustively studied by DE CONINCK (1975). Using these results, and also re-examination of samples, COSTA & DOWNIE (1976) and COSTA *et al.* (1978) have recognized five *Wetzeliella*-zones (*astra, meckelfeldensis, similis, varielongituda* and part of *coleothrypta*) in the Ieper Formation of the Kallo well. In a recent paper DE CONINCK (1981) discussed the index fossils for the Ypresian and distinguished nine dinoflagellate-zones.

2.6. Microproblematica

The so-called "Tertiary Tintinnids" (TAPPAN & LOEBLICH, 1968) or *incertae sedis* of authors as SZCZECHURA (1979) frequently occur in the Ieper Formation, mainly in the middle part of the Flanders Member and in the Egem Member. In the Flanders Member two associations can be distinguished by different species of the genus *Pseudarcella* (*P. trapeziformis* and *P. rhumbleri* respectively) and of the genus *Yvonniellina* (*Y. concava-Y. dimidiaglobosa* and *Y. capitiformis* respectively). The association in the Egem Member is characterized by the presence of *Y. variabilis* and of *Spinarcella*

guttiformis. These results are based on investigations in the Kallo well (WILLEMS, 1972) but this group of microfossils is also well represented in the Tielt and Ooigem boreholes and in the outcrop sections studied.

Other calcareous problematic microfossils occur in the middle and upper part of the Flanders Member (*Voorthuyseniella gracilis, Calvina kalloensis* ; WILLEMS, 1972). Phosphatic microfossils, of unknown affinity, occur in the lower part of the Flanders Member.

2.7. Radiolarians

Rare radiolarians have been recorded from the Mont Héribu Member, at the top of the Flanders Member and in the Egem Member (WILLEMS, 1981). In the Mont Héribu Member they are conical, while spherical individuals (mostly of the *Cenosphaera*-group) occur in the Egem Member.

2.8. Ostracods

The ostracod fauna of the Ieper Formation in the Kallo and Tielt wells has been studied by WILLEMS (1973 ; 1977). An ostracod zonation for the Palaeogene in the North Sea Basin has been proposed by KEEN (1978) and the same author has re-interpreted the ostracod zonation in the Kallo borehole. The oldest association (ass.1 & 2 of WILLEMS 1973) appears together with the BF-ass.IV, halfway the Flanders Member. It is characterized by *Cytheretta scrobiculoplicata*, and involves a larger part of the BF-ass.IV-interval. The next association (ass.3, 4 and 5 of WILLEMS 1973) is characterized by the appearance of *Echinocythereis reticulatissima* near the top of the BF-ass.IV-interval. This association occurs in the upper part of the Flanders Member and in the basal part of the Egem Member. The third association (ass.6 of WILLEMS 1973) is characterized by *Novocypris* (or *Paracypris*) *whitecliffensis* and appears in the upper part of the Egem Member.

2.9. Palynology

Investigation of the palynological content of the Ieper Formation from the Kallo well has been carried out by ROCHE (1973). This author has distinguished four palynological zones, mainly based upon the relation between the number of specimens of dinoflagellates and of pollen and spores.

The first zone occurs at the base of the Ieper Formation, in the Mont Héribu Member, and is characterized by a decrease of the number of species of pollen and spores compared to their number in the underlying Landenian deposits ; the number of dinoflagellates increases. The second zone, occurring in the larger part of the Flanders Member, is characterized by a further decrease of the palynological content. The third zone occurs in the upper part of the Flanders Member and in the Egem Member. In this zone the number of species of pollen and spores increases ; the larger part of the specimens of pollen grains belongs to species with small representatives (*Triatriopollenites platycaroides, Tricolporopollenites cinjulum*). In the fourth zone, occurring in the Merelbeke Member, the number of palynological specimens further increases.

The appearance of *Spinizonocolpites echinatus* in the third microfloral zone

(upper part of the Flanders Member) is of palaeoclimatic importance (indication of an increase of the temperature).

2.10. Algae

Numerous pyritised diatom moulds have been recorded from the basal strata of the Ieper Formation, in what is here called the Mont Héribu Member. They belong to the two *Coscinodiscus*-species described and symbolised as sp.1 and sp.2 by BETTENSTAEDT *et al.* (1962), and to other taxa not described so far. In one level *Coscinodiscus* sp.1 largely dominates the diatom flora ; below and above that level it is rather scarce.

Dasycladaceans have been recognized in the upper part of the Egem Member.

2.11. Otoliths

Investigation by NOLF (1974) and DELAUNOIS (1981) of the fossil fish record, based on otoliths, revealed the existence of two distinctive faunas in the Ieper Formation : a first fauna, with *Glyptophidium polli* as a characteristic species, occurs in the middle part of the Flanders Member ; a second fauna, with *Isacia gibbosa* as a characteristic fossil, and without *Glyptophidium polli*, occurs in the Egem Member.

3. CORRELATION OF THE MICROFOSSIL ASSEMBLAGES

Table 1 shows the occurrence of the different microfossil assemblages in the Ieper Formation in northern Belgium.
Most frequent are the benthic foraminiferids and the dinoflagellates.
Except for an azoic interval in the upper part of the Flanders Member, microfossils have been recorded throughout the formation.

3.1. Significant similarities between the different microfossil zonations

The following correspondences can be observed between the different microfossil groups (table 1).

a) At the base of the Ieper Formation, in the Mont Héribu Member, agglutinating benthic foraminiferids, conical radiolarians and pyritised diatoms occur together ; the dinoflagellate zones are *W. astra* and *W. meckelfeldensis*.

b) At the base of the Flanders Member, in the BF-ass.III-interval, poorly preserved calcareous benthic foraminiferids occur, together with large, phosphatic problematic microfossils ; the dinoflagellate zone is *W. similis*.

c) In the middle part of the Flanders Member, we observe the nearly synchronic appearance of a very diversified benthic foraminiferal fauna (BF-ass.IV), planktonic foraminiferids, calcareous nannofossils, ostracods and "tintinnids". In that same interval the *W. similis-W. varielongituda* boundary occurs.

d) The occurrence of an azoic interval, even in the dinoflagellate flora.

e) The reappearance of benthic foraminiferids (BF-ass.V) and of small planktonic foraminiferids (with some globorotalids) at the end of the *W. varie-longituda*-zone, together with pollen types indicating an increase of the temperature.

f) The occurrence of a foraminiferal fauna (BF-ass.VI), more typical for a sandy substrate, together with planktonic foraminiferids, calcareous nannofossils, ostracods, spherical radiolarians, nummulites and dasycladaceans at the start of the *W. coleothrypta*-zone.

3.2. Important events for correlation in the North Sea Basin

Some of the features in the microfaunal zonation, as reported above, might be useful for correlation in the southern part of the North Sea Basin.

a) The oldest assemblage zone, consisting of an exclusive agglutinating foraminiferal fauna, has been recorded in the boreholes at Kallo, Tielt, Ooigem, Mouscron, Mol (Belgium), Woensdrecht (The Netherlands), in the outcrops around Mons and Tournai (southern Belgium) and in Orchies (northern France).
The occurrence of exclusive agglutinating foraminiferal faunas is linked to special environmental conditions as stated by MOORKENS, 1975 : low alkalic to neutral ph, low oxygen content, slow water circulation or even stagnant water, high organic content. Therefore the vertical extension of this zone is environmentally controlled.

b) Pyritised diatoms occur in approximately the same interval as the agglutinated foraminiferids (recorded in the Kallo, Tielt and Mol wells and in the St Maur outcrop around Tournai). One level in this interval is mainly largely dominated by *Coscinodiscus* sp.1, the thick diatom species, its bloom considered by JACQUE & THOUVENIN (1975) as being related to the period of main volcanic activity on the continents surrounding the North Sea and also in the North Sea itself during Early Tertiary times.

c) A planktonic foraminiferal fauna enters, together with a rich benthic foraminiferal association, in the middle part of the Flanders Member. This phenomenon has been observed in the wells in Kallo, Tielt, Ooigem, Mouscron and Mol and also in Woensdrecht. This entry can be correlated with the planktonic datum level observed in the London Clay in the Hampshire Basin (WRIGHT, 1972) and in the London Basin (KING, 1981). This planktonic foraminiferal fauna belongs to the *Subbotina-Acarinina* assemblage (*Subbotina* standing for *Globigerina*, *Acarinina* for *Turborotalia*), which was typical for these latitudes during the Early Eocene (BERGGREN, 1978).

d) In the middle part of the Flanders Member a glauconitic layer occurs, described as the "Lit glauconifère de Tielt" and considered as an isochronous horizon (DE CONINCK, 1975). This layer has been observed in Kallo, Tielt and Ooigem and allows correlation.

Glauconitic layers normally indicate slow sedimentation rates in a deep central shelf sea ($\pm$ 100 m minimally), or high energy movement when the glauconite is reworked. According to KEPPENS (1981) the reworking of the glauconite in the Kallo well has to be excluded ; the glauconite grains are not completely glauconitised. The last feature indicates

that the rate of sedimentation was not slow enough to allow full glauconitisation.
In the Kallo borehole two glauconitic levels occur, one at - 307 m, and another at - 305 m. The 305 m-level has been considered as the most important (DE CONINCK, 1975). In Kallo the following biostratigraphic events occur around these glauconitic layers :

- The occurrence between - 312.5 and - 308.6 m of the *Globigerina patagonica*-acme zone ;
- The occurrence between - 312.5 and - 310.8 m of the *Asterigerina bartoniana kaasschieteri*-acme zone, in which *Karreria fallax* is also abundant ;
- The appearance of the second "tintinnid" faunule at - 310.8 m, together with other microproblematica of the *Voorthuyseniella*-type ;
- The presence of *Nummulites planulatus* between - 310.8 and - 303.9 m ;
- The start of the *Marthasterites tribrachiatus* zone (NP 12 zone according to the zonation of MARTINI, 1971) at - 306 m and of the *Wetzeliella varielongituda* zone at - 305 m ;
- The appearance of *Turrilina brevispira* at - 304.6 m ;
- The start of the *Echinocythereis reticulatissima* zone (ostracod zone 6b of KEEN, 1978) at - 304.6 m.

All these events largely illustrate the importance of the interval around the glauconitic layers for correlation within the southern part of the North Sea Basin. During the period of deposition of that interval the southern North Sea reached its maximum depth (about 100 m or somewhat deeper). The slower sedimentation rate, and thus a longer time period, will probably be the main cause of the great number of changes occurring within this interval.

e) An other important event is the appearance of *Guembelitria triseriata* in the upper part of the Flanders Member. This entry has been observed in the Kallo and Tielt boreholes in Belgium and also in the so-called Clays of Roubaix in the Cassel well (ODIN *et al.* 1972 ; *Guembelitria triserialis*).
Furthermore it has been recorded in the outcrops at Kortemark and Mesen.
The small dimension of the elongate test of this species obligates the use of the 74 µm sieve for detecting it.
Its appearance is also in connection with the occurrence of *Pseudohastigerina wilcoxensis*.

f) The change in lithologic character of the sedimentation (from clay to sand) naturally coincides with a change in the benthic foraminiferal fauna, such, as the appearance of numerous nummulites. However, the beginning of the *W. coleothrypta*-zone and the more frequent occurrence of small reticulate spherical radiolarians are situated near that level.

4. CONCLUSIONS.

The internationally accepted Ypresian stage, of Early Eocene age, is sometimes divided by Belgian geologists into, on one hand the Ypresian *s.s.* and "Early Paniselian" on the other hand (the upper part of the "Paniselian" or "Late Paniselian" belongs to the Lutetian). The distribution of, or the correlation between the microfossil assemblages in the Ieper Formation in Belgium as presented in table 1, allows us to recognize five major events, all based on planktonic microfossil groups or species, in this Ypresian stage *s.s.* (table 2).
The first event is the *Coscinodiscus* sp. 1-peak level at the beginning of the Ypresian *s.s.* (and *s.l.*) which is very probably linked to the volcanic activity in and around the North Sea in Early Eocene times.
The second event is the entry of the planktonic foraminiferids of the *Subbotina-Acarinina* assemblage, recognized also in the Early Eocene of the Hampshire and London Basins and marking the beginning of the main transgressive period during the Ypresian.
The third event is the *Globigerina* (or *Subbotina*) *patagonica*-acme zone, closely in relation with the NP11-NP12 and the *W. similis-W. varielongituda* boundaries, and which corresponds to the period of greatest depth in the southern North Sea during the Early Eocene. This acme zone occurs in the whole North Sea Basin (KING *et al.* 1981), in the northern Atlantic (BERGGREN 1978) and the Labrador Sea (GRADSTEIN & SRIVASTAVA 1980).
The fourth event is the entry of *Guembelitria triseriata* in the late Ypresian *s.s.* This entry could be considered as a second planktonic foraminiferal datum level in the Ypresian, and also corresponds with the *Pseudohastigerina wilcoxensis*-datum level in this area.
The fifth event is the entry of spherical radiolarians and the *W. varielongituda-W. coleothrypta* boundary, marking the start of a regressive period in the Early Eocene. This radiolarian zone is widely recognizable in the North Sea Basin as stated by KING (1980).

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Fig. 1 : Location map of the localities cited.

Table 1 : Microfossil assemblages observed in the Ieper Formation (Early Eocene) in Flanders (Belgium).

Table 2 : Datum levels observed in the Ypresian *s.s.* (Early Eocene) in Flanders (Belgium).

IEPER FORMATION IN FLANDERS

MICROFOSSIL ASSEMBLAGES

Formation | Lithostratigraphic members S.L.&M. 1980 | Lithology GULINCK 1967

Merelbeke — laminated clay
Egem — fine sand
Flanders — silty clay with sandy layers; silty clay; heavy and silty clay; glauconite glauconite; silty clay
Mont Héribu — laminated clay

Benthonic Foraminiferal Associations WILLEMS, 1980 | Benthonic Foraminiferids WILLEMS, 1980

poor fauna, dominated by
Epistominella vitrea
Anomalinoides nobilis
Cibicidoides proprius

BFass. VI
Spiroplectammina deperdita
Polymorphinidae spec. div.
Bolivina spec. div.
Trifarina spec. div.
Cancris subconica
Pararotalia spec. div.
Elphidium latidorsatum
Cibicides gr. carinata
Cibicidina spec. div.
Cibicidoides asutimargus

BFass. V
Turrilina brevispira
Alabamina wilcoxensis
Cibicidoides spec. div.

barren interval

BFass. IV
Turrilina brevispira
Textularia sp. Ka-303.3
Ka-308.6
Asterigerina bartoniana kasseschiteri
Karreria fallax Ka-312.5
Textularia smithvillensis
Karreriella danica
Nodosaria latejugata Ka-322
Clavulina spec. div.
Lenticulina spec. div. Ka-323.5
Marginulinopsis spec. div.
Cibicidina tendarni Ka-335.5
Pullenia quinqueloba Tt-109.5

BFass. III
Dentalina spinescens
Eponides lunata
Eponides plummerae
Anomalinoides sp. cf. A. danicus
Cibicidoides crassus

BFass. II
Ammodiscus septatus
Ammodiscus siliceus
Miliammina paleocenica
Haplophragmoides burrowsi
Haplophragmoides walteri
calcareous foraminifera

BFass. I
Rhabdammina spec. div.
Ammodiscus siliceus
Reophax spec. div.
Trochamminoides subtrullisatus
Recurvoides sp.
Spiroplectammina spectabilis
Trochammina spec. div.
Verneuilina subeocaena

Planktonic Foraminiferids WILLEMS, 1980

Pseudohastigerina wilcoxensis x Ka-264
Guembelitria triseriata
Globorotalia pseudoscitula
Turborotalia esnaensis
Turborotalia pentacamerata
Turborotalia soldadoensis
Globigerina aquiensis

Globigerina patagonica acme zone

Turborotalia esnaensis
Turborotalia pentacamerata
Turborotalia soldadoensis
Globigerina aquiensis

rare specimens
rare specimens

Large Foraminiferids GULINCK, 1967 WILLEMS, 1980

Nummulites planulatus

Nummulites planulatus Ka-303.9 – Ka-310.8

Calcareous Nannoplankton MÜLLER & WILLEMS, 1981

Discoaster binodosus
Discoaster lodoensis
Marthasterites tribrachiatus
Chiasmolithus bidens
Rhabdosphaera crebra
Zigrhablithus bijugatus

Discoaster binodosus
Discoaster lodoensis
Discoaster barbadiensis
Marthasterites tribrachiatus
Toweius eminens
first *D. lodoensis* Ka-306
Marthasterites tribrachiatus
Discoaster binodosus
Toweius callosus
Toweius craticulus
Zygodiscus plectopons
first nannofossils Ka-325.5

corroded specimens (MOORKENS & CEPEK 1974)

Dinoflagellates

DE CONINCK, 1981 | COSTA & DOWNIE, 1976 COSTA, *et al.* 1978

9 *Spinidinium aff. essoi* *Pulvinosphaeridium sp.* — *Wetzeliella coleothrypta*
8 *Hystrichosphaeridium cylindratum* *Lanternosphaeridium sp. A* *Hemicystodinium zobaryi* *Wetzeliella aff. clathrata* *Baltisphaeridium ligospinosum* *Spinizonocolpites echinatus* — *Wetzeliella varielongituda*
7 *Gonyaulacysta caytonensis* — *Wetzeliella varielongituda*
6 *Wetzeliella varielongituda* — *Wetzeliella varielongituda*
5 *Wetzeliella solida* — *Wetzeliella similis*
4 *Adnatosphaeridium robustum* *Peridinium crenulatum* — *Wetzeliella similis*
3 *Thalassisphaera peiagica* *Eisenackia sp. A* — *Wetzeliella meckelfeldensis*
2 *Wetzeliella tenuivirgula crassaramosa* — *Wetzeliella astra*
1 *Deflandrea oebisfendensis* *Microdinium ornatum* *Pseudomasia trinema* — *Wetzeliella astra*

Microproblematica WILLEMS, 1972

Conicarcella variabilis *Spinarcella guttiformis*
Voorthuyseniella gracilis x
Pseudarcella rhumbleri x
Yvonniellina feugueuri x
Yvonniellina dimidiaglobosa
Yvonniellina capitiformis
Voorthuyseniella gracilis
Ka-310.8
Pseudarcella trapeziformis
Yvonniellina feugueuri
Yvonniellina concava
Calvina kalloensis x
phosphatic microproblematicum (not published)
Tt-142.5

Radiolarians WILLEMS, 1981

spherical radiolarians (more frequent)
spherical radiolarians (rare)
conical radiolarians (rare)

Ostracods WILLEMS, 1973, 1977

Paracypris whitecliffensis ass.6
Clithrocytheridea mourloni
Eucytherura hyonensis ass.5
Schizocythere appendiculata
Schizocythere tessellata
Cytheridea newburyensis ass.4
fragments
Echinocythereis reticulatissima
Cyamocytheridea heizelensis
Trachyleberis aculeata ass.3
Cytherella londinensis
Hazelina aranea
Trachyleberidea prestwichiana
Schuleridea perforata
Cytherella londinensis
Cytheretta scrobiculoplicata
Hazelina aranea ass.1
Schuleridea perforata &2
Trachyleberidea prestwichiana
fragments

Microflora

Palynology ROCHE, 1973 | Dasyclad. Diatoms (not publ.)

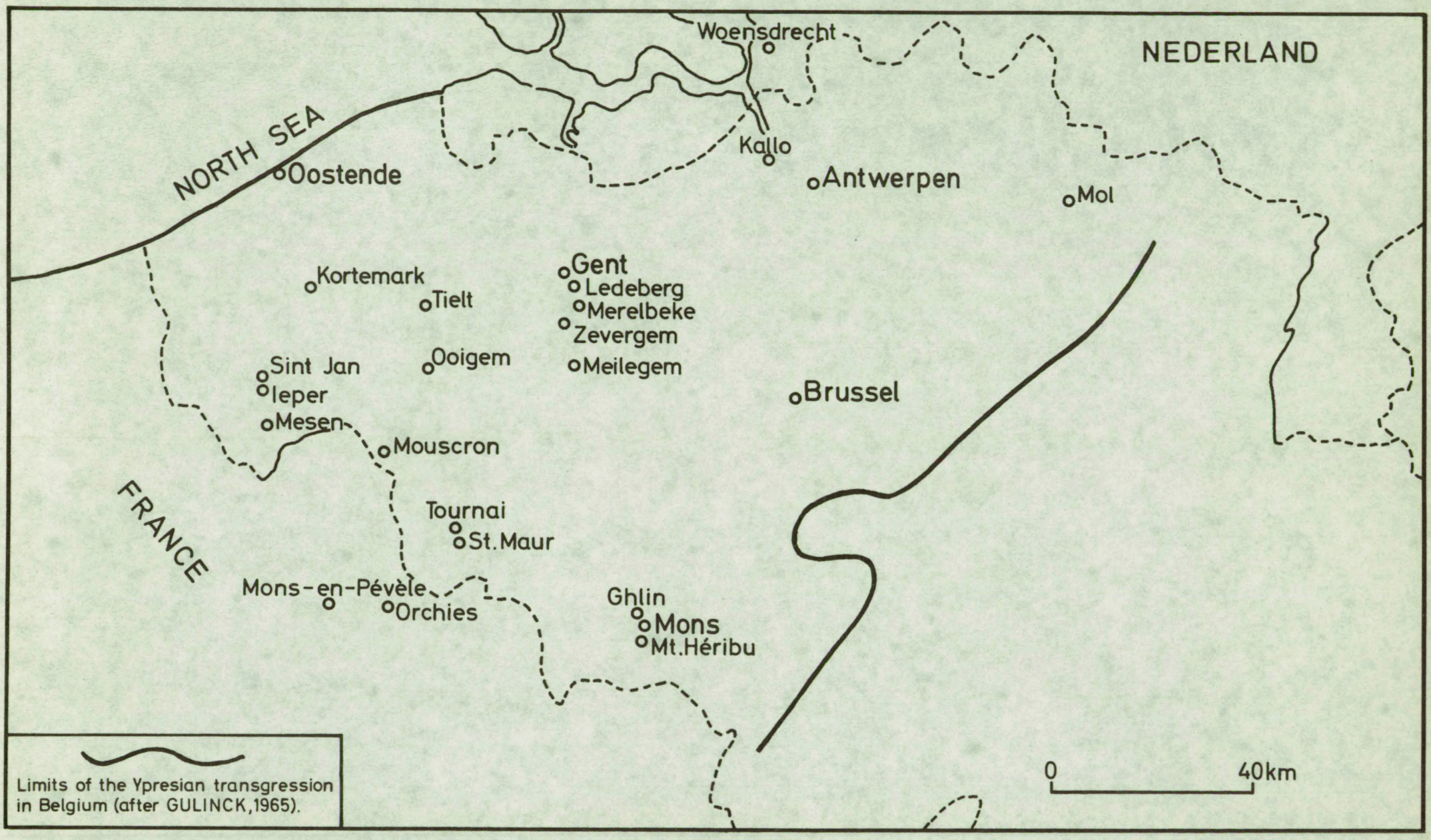
zone 4
zone 3
presence of *Spinizonocolpites echinatus*
zone 2
zone 1

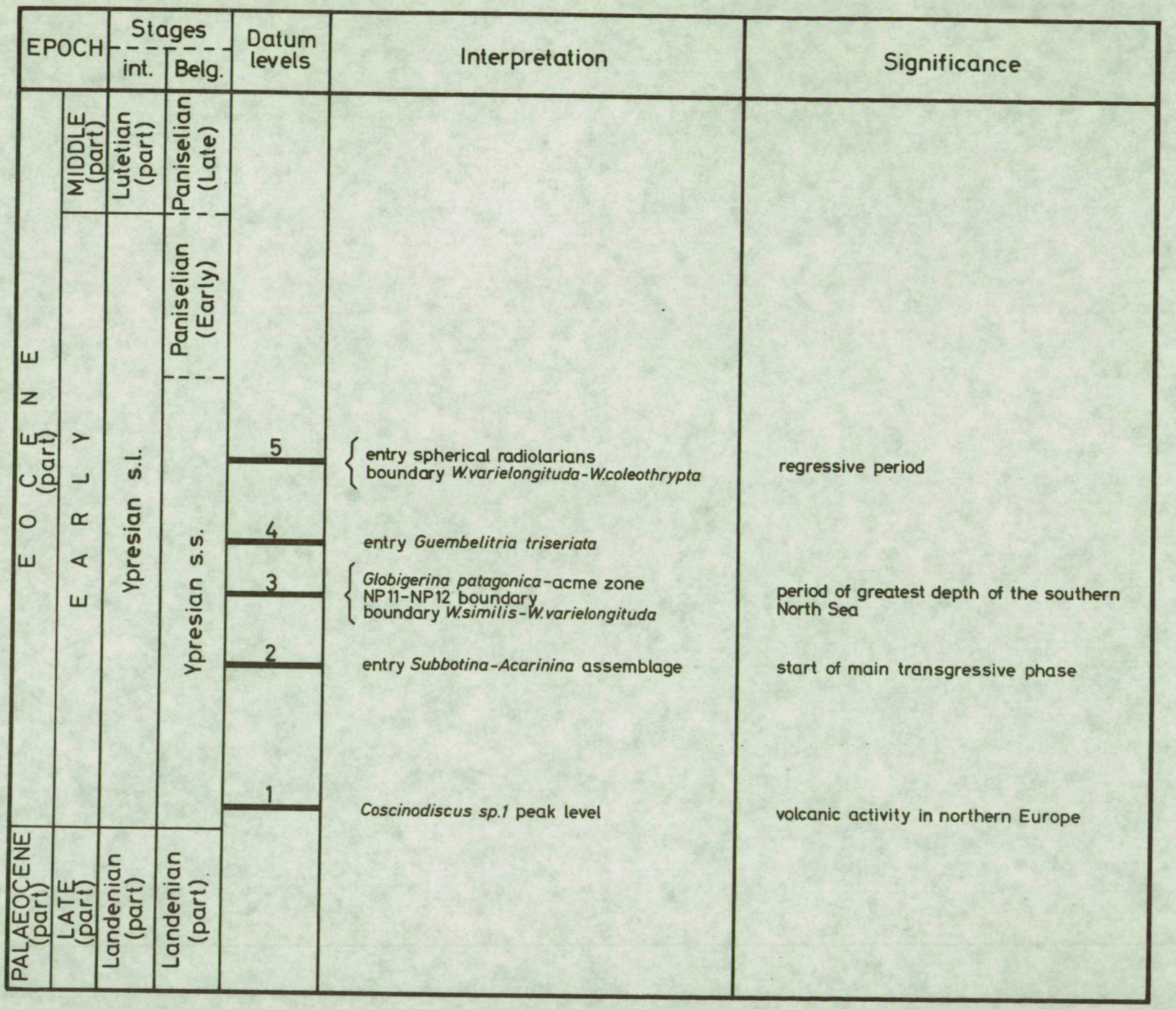
Terquemella
biconcave and low biconvex diatoms
high biconvex diatoms main level

Otoliths NOLF, 1974 DELAUNOIS, 1981

Isacia gibbosa
Glyptophidium polli

W. WILLEMS March. 1982


NEDERLAND
Woensdrecht
Kallo
NORTH SEA
Oostende
Antwerpen
Mol
Kortemark
Tielt
Gent
Ledeberg
Merelbeke
Zevergem
Meilegem
Ooigem
Sint Jan
Ieper
Mesen
Brussel
Mouscron
FRANCE
Tournai
St. Maur
Mons-en-Pévèle
Orchies
Ghlin
Mons
Mt. Héribu
0
40km
Limits of the Ypresian transgression in Belgium (after GULINCK, 1965).


EPOCH
Stages
int.
Belg.
Datum levels
Interpretation
Significance
EOCENE (part)
EARLY
MIDDLE (part)
Lutetian (part)
Paniselian (Late)
Paniselian (Early)
Ypresian s.l.
Ypresian s.s.
PALAEOCENE (part)
LATE (part)
Landenian (part)
Landenian (part)
5
4
3
2
1
entry spherical radiolarians
boundary W.varielongituda-W.coleothrypta
regressive period
entry Guembelitria triseriata
Globigerina patagonica-acme zone
NP11-NP12 boundary
boundary W.similis-W.varielongituda
period of greatest depth of the southern North Sea
entry Subbotina-Acarinina assemblage
start of main transgressive phase
Coscinodiscus sp.1 peak level
volcanic activity in northern Europe

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