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THE YPRESIAN STAGE IN THE BELGIAN BASIN

by

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(with 2 figures and 3 plates)

ABSTRACT

A historical review is given on the definition of the Ypresian stage in its type area, together with classical sections and maps showing its areal distribution in the Belgian Basin. The present state of our knowledge on the multi-biozonations of the Ypresian in Belgium is compiled in a biostratigraphic scheme. The biozonations of following groups are correlated and juxtaposed for the Early Eocene: calcareous nannoplankton, planktonic and benthonic foraminifera, ostracods, dinoflagellates, pollen and spores, otoliths, "microproblematica" (prob. Tintinnids) and the episodic appearance of siliceous microfossils like diatoms and radiolarians at certain stratigraphic levels. The occurrence of some other paleontological groups is also reviewed, and the paleoenvironmental setting of the Ypresian in its type-area is discussed. A series of outcrop sections is suggested which — when taken together — cover most of the practically continuous Ypresian succession, as known in the type area.

Key words: Ypresian, Belgian Basin, definition, biostratigraphy, paleoenvironment.

SAMENVATTING

Een historisch overzicht van de definitie van het Ypresien als etage in de type streek wordt naar voor gebracht, naast klassieke trajecten doorheen de afzettingen en kaarten die deze situeren in het Belgisch bekken. De auteurs hebben de verschillende biozoneringen van het Belgisch Ypresien tegenover elkaar geplaatst in een biostratigrafische overzichtskaart: hierin zijn de zoneringen opgenomen gebaseerd op kalkschalige nannofossielen, planktonische en benthonische foraminiferen, ostracoden, dinoflagellaten, pollen en sporen, otolieten, "microproplematica" (tintinniden?) en worden daarenboven de niveaus aangeduid waarop men siliceuse microfossielen (diatomeeën en radiolariën) ziet te voorschijn treden. Er wordt ook een overzicht gegeven van de overige groepen van fossielen uit het Belgisch Ypresien alsook een beschrijving van het sedimentatie milieu tijdens dit interval in het Belgisch bekken. De auteurs stellen voor een reeks ontsluitingen te kiezen waarin afzettingen voorkomen die samen het grootste deel van de Ypresienetage in een praktisch ononderbroken sekwentie vertegenwoordigen.

Sleutelwoorden: Ypresien, Belgisch bekken, definitie, biostratigrafie, paleomilieu.

RESUME

Un aperçu historique de la définition de l'étage Yprésien dans sa région type est présenté, ainsi que plusieurs sections classiques et cartes illustrant son aire de distribution dans le Bassin belge. Les auteurs ont corrélé les différentes biozonations de l'Yprésien belge dans un tableau biostratigraphique: on y trouve les zonations basées sur les nannofossiles calcaires, les foraminifères planctoniques et benthiques, les ostracodes, les dinoflagellés, les pollens et spores, les otolithes et les "microproblematica" (tintinnides?); en plus sont indiqués les niveaux où apparaissent des microfossiles siliceux (diatomées et radiolaires). Un aperçu de plusieurs autres groupes de fossiles de l'Yprésien belge est présenté, ainsi qu'une description du milieu de sédimentation dans le Bassin belge durant cette période. Les auteurs suggèrent le choix d'une série d'affleurements dont l'ensemble des dépôts représente, en une séquence pratiquement continue, la plus grande partie de l'étage yprésien.

Mots-clés: Yprésien, Bassin belge, définition, biostratigraphie, paléoenvironnement.

(*). The late Dr. W. WILLEMS, Assistant at the University of Gent in Belgium, had been working at the present text in the course of the last months of his life. He intended to publish an update of the text "Ypresian" by WILLEMS, BIGNOT and MOORKENS (1981), a paper to which he had also contributed the most substantial part. After his early death in 1984 his manuscripts and notes were found, containing some corrections and additions he planned to make to this text, and some schemes he wanted to add. The redactional completion of the present text was made by Thierry MOORKENS who took also into account some remarks Willy WILLEMS had made during their discussions on this subject.

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1. STAGENAME

The stagename is now world-wide spelled "Ypresian". Theoretically, when applying the nomenclatural rules suggested by HEDBERG (1976), the correct spelling would be Ieperian, after the town of Ieper in western Belgium. However, owing to the general world-wide acceptance of the stage under the spelling Ypresian, it is thought preferable not to change this spelling any more.

2. AUTHOR AND DATE OF PUBLICATION

The author is A. DUMONT, who proposed this stage in 1849. Generally that year is also cited in literature as date of publication, although DUMONT's paper apparently first appeared, together with his geological map, in 1850. The exact reference of the paper is: *Rapport sur la carte géologique de la Belgique. Bull. Acad. roy. Sci. Lett. Beaux-Arts, Belgique, tome 16, 2e partie, pp. 351-373 (pp. 368-369).* The stage has been defined by DUMONT (1849a) as follows (literal quotation): *"... le système Yprésien, que je sépare du Landénien parce qu'il semble être plutôt marin que d'eau douce et qu'il prend un grand développement aux collines d'Ypres, dans la Flandre occidentale, offre, vers sa partie inférieure, un puissant massif argileux et, vers sa partie supérieure, des sables glauconifères à grains ordinairement très fins qui, dans certaines localités, contiennent un banc de Nummulites. Dans le Laonnais et le Soissonais, ce système est compris entre la formation ligniteuse et le calcaire grossier »* (p. 369).

3. DESIGNATION OF THE STRATOTYPE

From the above-mentioned original description of DUMONT it appears that the author included two major lithostratigraphic units in this stage:

- a lower unit, comprising the marine clayey deposits resting on the non-marine deposits of the previously defined Landenian stage; the hills around Ieper (spelled Ypres in the original text) are designated as type region, but no precise type locality had been indicated by DUMONT for this lower unit;
- an upper unit, comprising sandy, often glauconitic sediments, with occasional *Nummulites*-beds; neither type locality nor type area had been mentioned by DUMONT for this upper unit.

The claystone quarry of the "Verenigde Steenbakkerijen van Ieperen" at Sint-Jan, near Ieper was designated by MOORKENS (1968, p. 114) as type locality and as stratotype of the Ypresian stage, because it appeared to be one of the only outcrops of the Flanders Clay in the "hills around Ieper", i.e. the type area indicated by DUMONT (op. cit)[2].

This outcrop is located at 1650 m to the North and 400 m to the East of the tower of the main church of Ieper (Coord.: x = 45.750, Y = 173.750 (see KAASSCHIETER, 1961, p. 90, and fig. 11-YA, p. 82; see also locality list in the present text). Unfortunately this section is rather poor in microfauna: WILLEMS (1980) recorded twelve foraminifera species; next to foraminifera, KAASSCHIETER (1961) also mentioned sponge spicules and fish remains. However, the dinoflagellate associations are fairly diversified allowing a correlation with the upper part of the clay sequence in the Kallo boring (DE CONINCK, 1976, p. 20-23). Thus this type section corresponds to the middle part of the Ypresian *sensu* DUMONT, 1849.

3.1. The lower clayey unit

No type locality has been indicated for this lower clayey unit since its introduction by DUMONT in 1849, although several lithostratigraphic names have been proposed for it, e.g. "Argile d'Ypres" by d'OMALIUS d'HALLOY in 1862 and "Argile de Flandres" by ORTLIEB & CHELLONNEIX in 1870.

3.2. The upper sandy unit

DUMONT did not indicate a type locality for this sandy unit either. This unit was studied at Forest (Vorst), south-west of Brussels by LYELL in 1852 ("chemin Musselman", fig. 8) and by CASIER in 1946 ("Coteaux de Forest", four outcrops which nowadays are not accessible anymore), and named "Sands with *Nummulites planulatus*".

In 1870 ORTLIEB & CHELLONNEIX introduced the term "Sables de Mons-en-Pévèle" to describe the very fine sands rich in *Nummulites planulatus* from the Mons-en-Pévèle hill in northwestern France. From that time on the term Sands of Mons-en-Pévèle has been applied to designate the upper Ypresian fine sand rich in *N. planulatus* from all over the Belgian Basin, including Belgium and northwestern France (e.g. by LERICHE, 1939, PASTIELS, 1948 and KAASSCHIETER, 1961). FEUGUEUR however (1951, p. 237), proposed the term "Sables de Forest" for the nummulitic sands at Forest, being the lateral equivalent of the Mons-en-Pévèle Sands.

In 1973 DE MOOR & GEETS introduced the term "Sands of Ledeberg" for the glauconitic fine sand around Gent. The term "Egem Sand" was used in 1980 by the Subgroup Lithostratigraphy and Maps for similar sands outcropping somewhat more to the west, in the Egem area[3].

2. It appears that the outcrop of Sint-Jan has recently been dumped. As a lateral equivalent the clay quarry "Desimpel" at Kortemark (Fig. 1, Coord.: x = 58.050, y = 190.400) forms an adequate substitute for the type-section. It is located some 20 km to the NE of Ieper. Stratigraphically it covers a somewhat larger interval of the Ieper Formation and is generally more fossiliferous than that of Sint-Jan (Red. note, MOORKENS).

3. Recent calcareous nannoplankton investigation by STEURBAUT (in STEURBAUT & NOLF, 1986) has shown that the nummulitic sands from northwestern France (the Mons-en-Pévèle Sands) and from southern Belgium (at Forest, the "Sables de Forest", and at Mont Panisel, Ronse, etc.) are older and unconnected with their supposed equivalents from northwestern Belgium (the Ledeberg Sands around Gent, the Egem Sands somewhat more westward). As a matter of fact they form the lateral equivalent of the Roubaix Clay or the upper part of the Flanders Clay (Red. note).

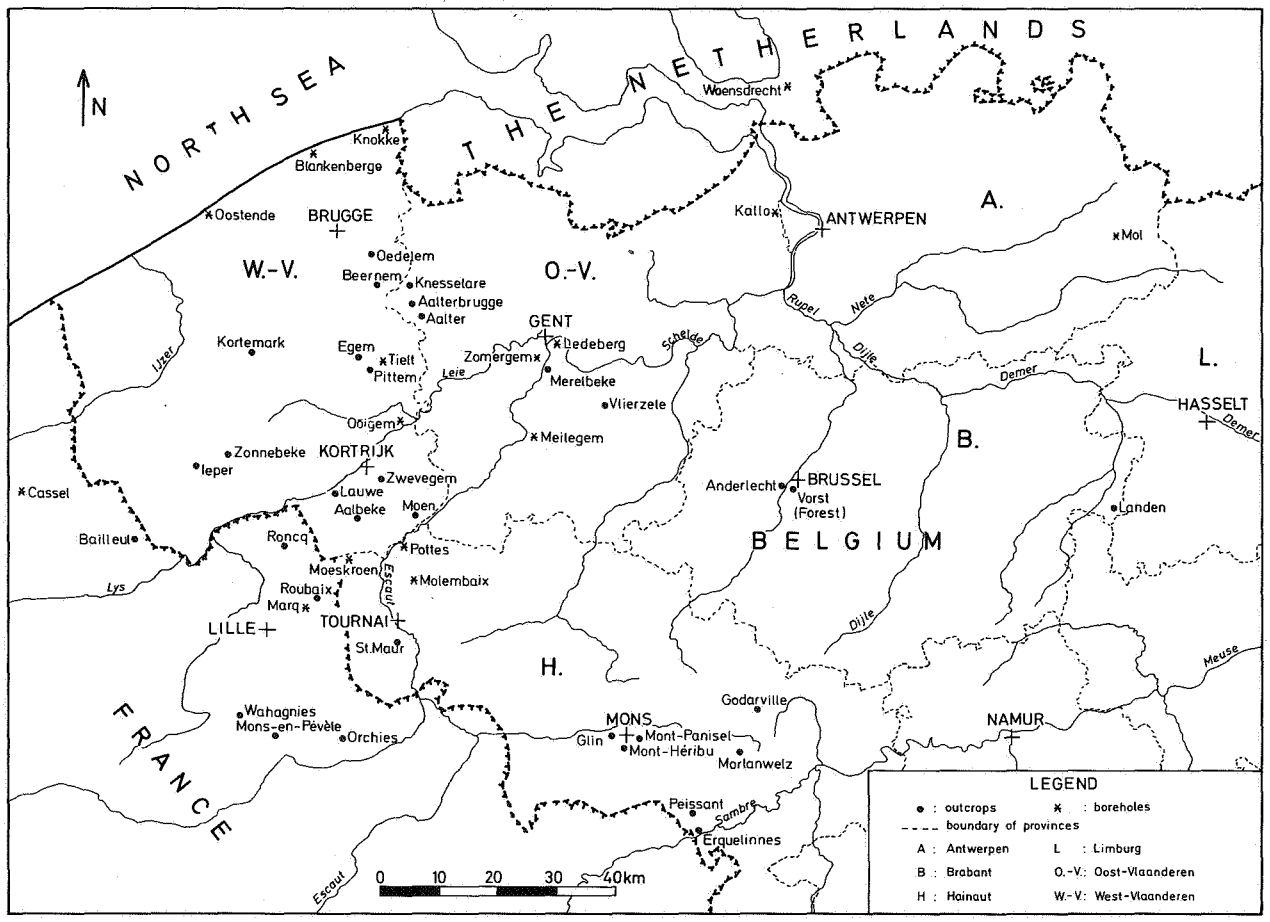

Fig. 1
Localisation of outcrops and wells discussed in the text.

4. SUBSEQUENT REFERENCES TO THE STRATOTYPE

Shortly after the introduction of the Ypresian stage, DUMONT defined in 1851 the Paniselian stage (p. 193, table) for the clayey-sandy layers between the previously defined Ypresian (DUMONT, 1849a) and Brusselian (DUMONT, 1839).

Since that day two different opinions exist on the definition of the Ypresian stage:

— The Ypresian *sensu stricto*, referring to the two major lithologic units defined by DUMONT in 1849; in this interpretation the Paniselian stage is considered to be valid and the Mont Panisel to be its type locality, although no type locality nor stratotype were indicated in DUMONT's original definition.

— The Ypresian *sensu lato* is referring to the original boundaries as indicated by DUMONT in 1849 and thus includes all lithologic units between the top of the previously defined Landenian (DUMONT, 1839) and the base of the Brusselian (DUMONT, 1839) stages. In this second interpretation the lower part of the Paniselian (DUMONT, 1851) is included in the Ypresian, the upper part of the Paniselian being considered meanwhile as lowermost Brusselian.

5. GEOGRAPHIC DISTRIBUTION

In the Belgian Basin, north of the Axis of Artois, the Ypresian stage is represented by shallow marine deposits. They cover most of Flanders (northern Belgium) towards the South of the Netherlands (fig. 1 and 2). Further north, they are present in a large part of Holland. Without further interruption they extend into the whole North Sea Basin, where they occur as deeper water deposits and may reach several hundred of meters of thickness. Moreover they extend into the basins adjacent to the North Sea such as the London Basin, northern Germany, and Denmark.

Detailed maps, indicating its extension in Belgium, have been prepared by KAASSCHIETER (1961): his map 8 gives the base of the Ieper Formation (base of the clayey lower unit), his map 11 gives the sandy upper unit (Sands with *Nummulites planulatus*); map 13 gives the base of the Panisel Formation; further maps were given by GULINCK (1965, Fig. 1) and by MOORKENS (1968, map 1)[4].

4. More recently detailed maps of the extension of different lithologic units have been added by STEURBAUT & NOLF (1986). That paper also gives a full inventory of past and present outcrops of the Ypresian in the Belgian Basin (Red. note).

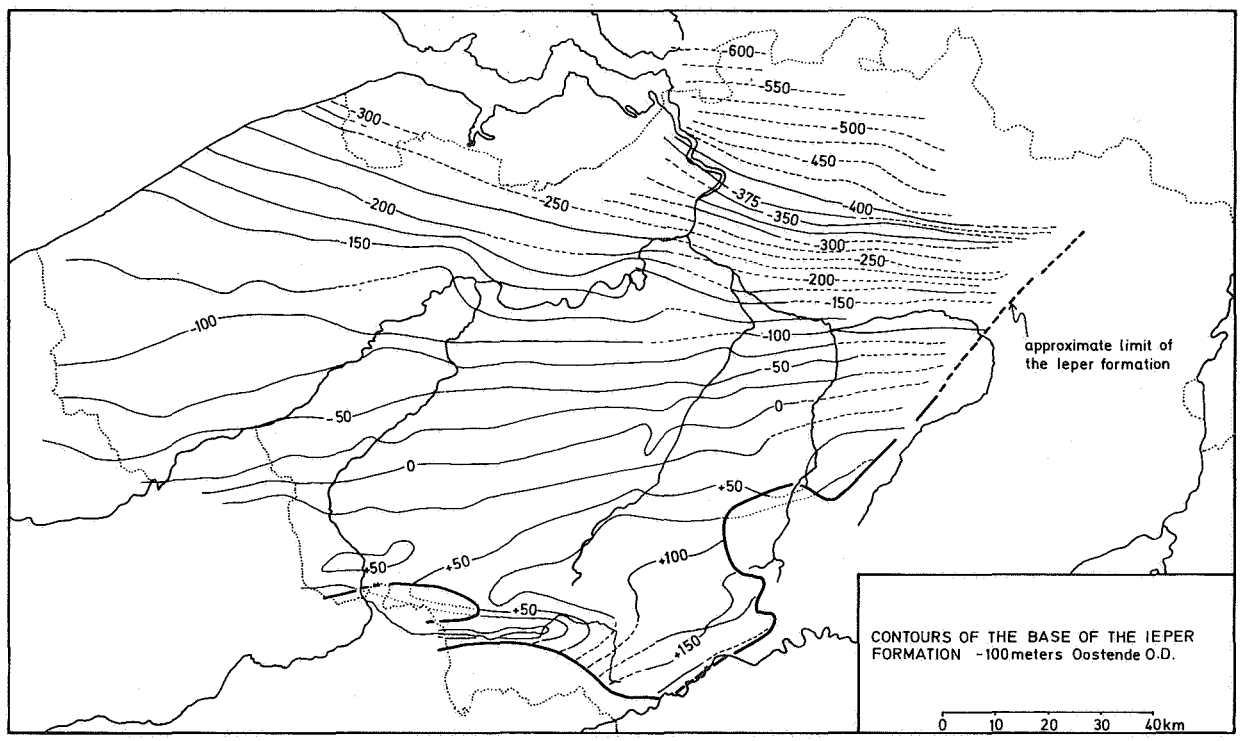

Fig. 2
Contours of the base of the Ieper Formation after KAASSCHIETER, 1961, slightly modified.

The extension of the Ypresian in the Netherlands has been presented by BROUWER (1968, map 1). As the Ypresian strata in Belgium are locally more than 200 m thick and only gently dipping to the North, no outcrop exists, which gives a full continuous stratigraphic section. However the succession is well known from several deep and entirely cored wells, such as those of Kallo, Ooigem, Tielt, Mol and Knokke-Heist. Further wells are those of Moeskroen and Oostende (cf. GULINCK, 1957, and Pl. 2 in this paper). The cored sections and detailed descriptions are stored in the archives of the Belgian Geological Survey in Brussels.

Similar important wells were drilled in northern France e.g. at Marck and Cassel (ODIN *et al.*, 1972) and in the southern Netherlands, at Woensdrecht (KAASSCHIETER, 1961) and Rotterdam (BROUWER, 1968).

In Belgium the best studied well is that of Kallo (near Antwerp) and it is generally considered as a "standard section", to tie in parts of other wells and outcrop sections. Practically all parts of the Ypresian succession can also be seen in outcrops, but a relatively large number of outcrops must be visited in order to see the whole succession (cf. W. WILLEMS, 1980; and final chapter of the present text).

6. GEOLOGICAL DESCRIPTION[5]

6.1. Lithologic description, whith columns and thicknesses

A schematic interpretation of the lithostratigraphy of the Ypresian *s.l.* in northern Belgium (Flanders area), in southern and middle Belgium (Hainaut and Brabant regions) and northern France, is given in Pl. 1.

According to the subgroup Lithostratigraphy and Maps (S.L.M., 1980; contrib. of LAGA, GEETS, MOORKENS & NOLF) of the I.G.C.P. 124, the Ypresian *s.l.* comprises two formations, i.e. the Ieper Formation (of Ypresian *s.s.* age), and the Mont Panisel Formation (of Early Paniselian age). The following members have been recognized (from base to top): Mont Héribu, Flanders, Egem, Merelbeke, Pittem and Vlierzele, of which the two last mentioned from the "Mont Panisel" Formation; the others belong to the Ieper Formation. In this division the Merelbeke Member is transferred from the "Mont Panisel" Formation to the Ieper Formation and hence included in the Ypresian *s.s.*

The "standard column" of the Ypresian, as best represented and extensively studied in the Kallo well, is some 150 m thick; towards the S and SE it gradually becomes thinner. The sedimentation of the Ieper Formation locally starts with a basal layer of flint pebbles (de HEINZELIN & GLIBERT, 1957), which corresponds to the Y_a symbol of the Belgian Geological Map (Legend editions 1892, 1986, 1900

5. The subdivision of the Ypresian deposits in formations and members as proposed in this text will not be integrally followed in the other contributions of this volume. Indeed, since the time WILLEMS wrote the manuscript of the present text some important rectifications and even major changes have been proposed concerning the equivalences of the different lithostratigraphic units (see STEURBAUT & NOLF, 1986). These new insights make clear that other solutions have to be found too for the classification of these lithostratigraphic units (or members) into formations (Red. note).

and 1909). This layer is followed or laterally replaced by a sandy clay layer (Y_b symbol) which corresponds to the lower part of the Ieper Formation and has been named Mont Héribu Member (S.L.M., 1980). A detailed study of the lithology, sedimentology and fossil content of this member is given by DE CONINCK, GEETS and WILLEMS (1983).

Next comes the large clay mass, generally called the Clays of Flanders (ORTLIEB & CHELLONNEIX, 1870) or Clays of Ieper (KAASSCHIETER, 1961), also known as Flanders Member (S.L.M., 1980). It corresponds to the Y_c of the same Belgian Geological Map Legend éditions. The Clays of Orchies, described by GOSSELET in 1874 form their equivalent in northern France. Several lithologic columns of these clays have been presented by GULINCK (1967, see Pl. 2 in the present paper). A lithological subdivision, based on sedimentology only (granulometry and heavy mineral composition) has been proposed by DE MOOR & GEETS (1975).

A glauconitic layer, occurring in the middle part of the clays, has been defined by DE CONINCK (1975) as a horizon called "Lit glauconifère de Tielt" and can be followed in several wells and outcrops of the Belgian Basin.

The greatest clay thickness is 177 m in the Blankenberge area (KAASSCHIETER, *ibid.*). Lateral and peripheral, somewhat shallower sediments are now outcropping in the Hainaut region (Sands of Peissant, BRIART & CORNET, 1978; Argilites de Morlanwelz, MOURLON, 1873; Sands of Godarville, de HEINZELIN & GLIBERT, 1957) and in northern France (Mons-en-Pévèle Sands, ORTLIEB & CHELLONNEIX, 1870, lateral equivalent of the Roubaix Clays, of the same authors; and possibly also of the Trélon Sands, GOSSELET, 1883).

The thick clay sequence is followed by a succession of fine sands and sandy clays intercalated by hard clay layers (Y_d symbol of the above mentioned Belgian Geological Map Legend editions), corresponding to the "Sands with *Nummulites planulatus*" of LYELL (1852), the Sands of Forest of FEUGUEUR (1951), the Sands of Ledeberg of DE MOOR & GEETS (1973), or the Egem Member of the Subgroup Lithostratigraphy and Maps (1980). Lithologic columns of these units have also been given by GULINCK (1967) and in Pl. 2 of this paper. DE CONINCK & NOLF (1978) described the Sands of Egem in their type locality.

The total thickness of both sequences including the clayey and sandy member, decreases from the North to the South and from the West to the East, but the relative component of sandy layers in the total thickness generally increases in these same directions. The thicknesses of the lower clayey unit (grossly Flanders Clay Member) and the upper sandy unit (grossly Egem Sand Member) have been mapped by KAASSCHIETER (1961). However some correlations adhered by KAASSCHIETER (op. cit.) are not accepted any more nowadays, such as the correlation of the Sands of Mons-en-Pévèle/Clays of Roubaix at the one hand, with the Egem Member at the other. For that reason KAASSCHIETER's isopach maps will have to be corrected in the future.

The Mont Panisel Formation, overlying directly the Ieper Formation, consists of an alternation of sandy, silty and clayey layers, the total thickness of which can reach 64 m in northern Belgium, and even 86 m in the southern part of the Netherlands (see KAASSCHIETER, 1961, map 14); these rock units can replace each other laterally.

According to the Subgroup Lithostratigraphy and Maps (S.L.M., 1980) two members are incorporated in this formation: the Pittem Member (defined by GEETS, 1979, as the clayey sand member which corresponds to the P_1c symbol of the Belgian Geological Map Legend editions which is thus probably an equivalent of the sandy Clay of Anderlecht described by VINCENT, 1874), and the Vlierzele Member (described by KAASSCHIETER, 1961, as Sands of Vlierzele and corresponding to the P_1d symbol of the same Map Legend editions). A probable peripheral equivalent is found in the Mont Panisel outcrop in Hainaut, but it is poorly dated. The underlying Merelbeke Member, described by DE MOOR & GEETS (1973) as the Clays of Merelbeke, forms the upper member of the Ieper Formation, and corresponds to the P_1m Clay of the same Belgian Geological Map Legend editions. The large sedimentation cycle of the Ypresian *s.l.* locally terminates with a marked emersion horizon together with some non-marine deposits, called the Complex of Aalterbrugge (HACQUAERT, 1939), characterized by sands, lignites and silicified wood (de HEINZELIN & GLIBERT, 1957).

In northern France the Clays of Roncq, and the overlying glauconiferous Clays of Cassel, are probably the equivalents of the Panisel Formation (ROBASZYNSKI, 1978).

6.2. Tectonical Situation of the Type Region

The contours of the base of the Ieper Formation as mapped by KAASSCHIETER (1961, map 9) and given here in Fig. 2, show that the general dip of the strata is only of a few degrees to the north, and that in general, faults are absent in the Tertiary layers covering the Brabant Massif. Minor faults have been identified throughout the Ieper Formation in off-shore seismic investigations (HENRIET *et al.*, 1982), from the Belgian to the British coasts and also in the Dieppe Basin. They seem to be related to clay dynamic processes like mud diapyrism[6].

6. Some small faults were also observed in a few outcrops like those of Lauwe and Zonnebeke (for locations see STEURBAUT & NOLF, 1986). On land, the occurrence of minor faults seems to be restricted to the SW part of the type region and the adjacent region of northern France (Red. note).

6.3. Contacts with Under- and Overlying Lithostratigraphic Units

6.3.1. Underlying Beds

In the western and northern part of Belgium, the base of the Ypresian stage coincides with the transgressive base of the Flanders Clay and overlies fluvio-marine deposits of the uppermost Landenian (the Sands of Oostende-ter-Streep, described by KAASSCHIETER in 1961 from the Oostende well). Thus in that locality a more or less continuously marine sedimentation occurred. In the northcentral part of Belgium, the Ypresian deposits overly upper Landenian continental to lagoonal deposits (GULINCK, 1965). In the eastern part of the country Ypresian deposits have been eroded and the Oligocene directly overlies the Sands of Landen (Late Paleocene) or older deposits (MOORKENS, 1973, 1982). In the southwestern part they overly the Sands of Erquelinnes (Latest Paleocene), which in their lower part contain a marine microflora (base NP9, top *D-speciosa* zone) and -fauna, and become continental at higher levels (DE CONINCK, DE DECKER, de HEINZELIN & WILLEMS, 1981)[7].

6.3.2. Overlying Beds

The "Complex of Aalterbrugge" (HACQUAERT, 1939), or locally the Vlierzele Sands, are covered by the Aalter Sands, mentioned by DUMONT in 1849 as "Sable glauconifère à *Venericardia planicosta*" in the legend of his geological map (DUMONT, 1849b). These sands have been incorporated in the Brusselian stage by DUMONT himself (1849b. 1851, table on p. 193; 1878, footnote p. 46).

Later on, their position has been switched several times from the top of the Paniselian (or Ypresian *s.l.*) to the base of the Brusselian, or vice versa, by different authors (e.g. JACOBS & GEETS, 1978). In the higher mentioned Belgian Geological Map Legend editions, it corresponds to the Symbol P_2. For the member, which had been called "Sands of Aalter" by DUMONT (1878, p. 423), DEWALQUE (1868, p. 205) had used the name Clayey Sands of Aalter.

According to de HEINZELIN & GLIBERT (1957), and based on the presence of *Nummulites laevigatus*, these sands are considered to belong to the Brusselian stage and to mark the beginning of the Lutetian in Belgium: thus they are excluded from the Ypresian stage.

The Sands of Oedelem, described by NOLF (1973a) and occurring under the Sands of Aalter in the region East of Brugge (NOLF, 1973a, Fig. 2) are also considered to belong to the Lutetian; together these two lithologic units form the "Upper Panisel" or Den Hoorn Formation as described by NOLF (op. cit.). For the same deposits, and including some new ones, JACOBS & GEETS (1978) introduced the term Formation of Knesselare, containing from base to top three members: the Beernem, Oedelem and Aalter Members. This formation lies above the Aalterbrugge Complex in the same area, and belongs according to these authors to the Upper Paniselian of DUMONT (1851); it is thus not included in the Ypresian (*s.s.* or *s.l.*). In conclusion, and following de HEINZELIN & GLIBERT (1957), the Aalterbrugge Complex is considered to be the youngest part of the Ypresian stage, *s.l.*, thus forming its top part, and marking approximately the boundary with the Lutetian.

6.4. References to geological maps

The following maps are available:
— Geological maps of Belgium at scale 1/40.000 (edited between 1893 and 1919), particularly the sheets 37, 50-54, 65-71, 80-88, 95-101, 111-115, 124-128, 137-142.
— Geological maps of northern France at scale 1/80.000 (old) and at 1/50.000 (new).

7. PALEONTOLOGICAL CONTENT AND BIOSTRATIGRAPHY

7.1. Major fossil groups represented in the standard column of the Ypresian stage

7.1.1. Microflora (Phytoplankton)

a) Calcareous nannoplankton: MÜLLER & WILLEMS (1981) recorded the biostratigraphic distribution of the nannoplankton species from some samples of the Ypresian in the Kallo and Tielt wells. A review of the literature dealing with nannofossils in the Ypresian is given by the same authors, and also by HOOYBERGHS (1980)[8].

b) Dinoflagellates: This group of protists has been exhaustively studied by DE CONINCK (1976, and several smaller papers), the results and references of which have been given by DE CONINCK (1981).

c) Diatoms: Pyritized and limonitized large diatoms, belonging to several form-species, have been recorded from the basal layers of the clay member of the Ypresian stage in various localities in Belgium such as the Kallo and Tielt wells (WILLEMS, not published manuscript).

7.1.2. Plants

a) Pollen and spores: Have been described from the Kallo well by ROCHE (1973).

b) Macroflora: Two fruits of the palm tree *Nipadites* have been identified by de HEINZELIN (in MOORKENS *et al.*, 1966).

7. Extensive reviews of the distribution of the Landen Formation in Belgium have also been given by GULINCK & ROCHE (1973) and by DE GEYTER (1980) (Red. note).

8. The calcareous nannofossils from the Ypresian have recently been revised by STEURBAUT (in STEURBAUT & NOLF, 1986). A new and more detailed nannofossil zonation was proposed and correlated with MARTINI's standard zonation (Red. note).

Silicified wood is known from the Aalterbrugge Complex, according to de HEINZELIN & GLIBERT (1957).

c) Calcareous algae: Some reproductive organs of Dasycladacean algae have been recognized in the Upper Ypresian *s.s.* by WILLEMS & GENOT (1984).

7.1.3. Protozoans

a) Foraminifera: The assemblages of the Ypresian *s.s.* and Paniselian have been described by KAASSCHIETER (1961). More recently a detailed revision of the foraminifera of the Ypresian *s.s* has been undertaken by WILLEMS (1980), including a literature review on Ypresian foraminifera. The large foraminifera are represented by *Nummulites planulatus*, already mentioned by DUMONT and LYELL and discussed by numerous authors afterwards.

b) Radiolarians: Five form-species, probably belonging to five different genera have been described from the Ypresian *s.s.* by WILLEMS (1981).

c) Problematica: Various problematic unicellular calcareous microfossils have been recorded (WILLEMS, 1972; see also SZCZECHURA, 1979, for a literature list); they probably mainly belong to the family "Codonellidae" which is tentatively placed in the order Tintinnida.

7.1.4. Invertebrate Metazoans

a) Porifera: Sponge spicules, of different types, are locally abundant in the Ypresian *s.s.* (pers. observ. WILLEMS).

b) Molluscs: According to de HEINZELIN & GLIBERT (1957) several Ypresian strata are characterized by the presence of molluscs such as *Pinna margaritacea* in the Sandy Clays of Anderlecht, *Leda corneti* in the Argilites of Morlanwelz, and *Nucula fragilis* in the Sands of Peissant.
No systematic study of the mollusc fauna of the Ypresian exists, but about twenty species have been described from the Upper Ypresian *s.s.* (DHONDT, in MOORKENS *et al.*, 1966).
About ten mollusc species have also been mentioned from the Ypresian type area by KING (1981); this fauna is comparable to that of the London Clay (see also plates and references in "British Cenozoic Fossils", N.N., 1968), a western equivalent of the Flanders Clay as explained in chapter 8.

c) Brachiopods: *Lingula tenuis* is considered to be a typical fossil in the Sands of Godarville (de HEINZELIN & GLIBERT, 1957).

d) Arthropods: Ostracods have been described from the Ypresian by KEIJ (1957), VERHOEVE (in MOORKENS *et al.*, 1966), and by WILLEMS (1973; 1977). From the Upper Ypresian *s.s.* a fossil lobster has been identified as *Calianassa* sp. by de HEINZELIN (in MOORKENS *et al., ibid.*), and from the "Early Paniselian" (i.e. the Pittem or Vlierzele Members) some crab specimens had been recorded by VAN STRAELEN (1921).

e) Echinoderms: Spines and radiolas of this group are frequent in many samples of the Ypresian (pers. observ. WILLEMS).

7.1.5. Vertebrates

a) Fishes: The remains of this group, consisting mainly of teeth, have been described by CASIER (1946, 1950; and in MOORKENS *et al.*, 1966). The otoliths of the Ypresian were treated by NOLF (1973b, 1974), and the shark teeth by HERMAN (1979).

b) Reptiles: Some bone remains of this group have been mentioned by de HEINZELIN & GLIBERT (1957).

7.2. Index fossils, zonal markers and biozones recognized in the Ypresian stage

(For compilation see Pl. 3)

7.2.1. Calcareous nannoplankton

The presence of *Discoaster binodosus, Marthasterites tribrachiatus* (or *Tribrachiatus orthostylus*), and *D. lodoensis* together with some other species, clearly prove that the nannoplankton Zones NP11, NP12 and NP13 of MARTINI's Zonation (1971) are represented in the standard section of this stage. The NP11, i.e. the *D. binodosus* Zone occurs in the early part of the Ypresian *s.s.* (lower part of Flanders Member); the NP12, or *M. tribrachiatus* Zone, occurs in the upper part of the Flanders Clay Member, of the Ypresian *s.s.*, and also in the overlying sandy Egem Member. The NP13, *D. lodoensis* Zone occurs at the top of the Egem Member and ranges into the Pittem and Vlierzele Members, i.e. at the top of the Ypresian *s.l.*

7.2.2. Dinoflagellates

The rich assemblages found by DE CONINCK (1976) comprise several *Wetzeliella* species, index fossils of the biozonations proposed by COSTA & DOWNIE (1976). According to COSTA & MÜLLER (1978), the following *Wetzeliella* Zones are present: *W. astra, meckelfeldensis, similis, varielongituda* and *coleothrypta.*

7.2.3. Diatoms

The presence of the large diatom *Coscinodiscus* sp. 1, i.e. the biconvex form, as described and pictured by WICK (1943) and by BETTENSTAEDT *et al.* (1962) for NW Germany, has also been observed in Belgian wells in the basal layer of the Ypresian Flanders Clay. A bloom of large pyritised diatoms *Coscinodiscus* sp. 1 is also known from most North Sea wells to be restricted to the Paleocene-Eocene transitional strata (JACQUE & THOUVENIN, 1975). In that region the bloom is thought to be linked to the siliceous surface waters occurring during the period of strongest volcanic activity. As also confirmed by the correlations based on other microfossil groups (e.g. the dinoflagellate assemblages belonging to the *Wetzeliella astra* and *W. meckelfeldensis* Zones) the thin interval yielding large pyritised diatoms

at the base of the Ypresian column in the Kallo and Tielt wells (pers. obs. WILLEMS) can well be correlated with the *Coscinodiscus* sp. 1 (acme) faunule zone as known from North Sea biozonation established by KING (1980).

7.2.4. Planktonic foraminifera

Important species observed in the Ypresian of Belgium (WILLEMS, 1980; partly updated determinations, as based on KING, 1980, 1981) are *Guembelitria triseriata, Pseudohastigerina wilcoxensis, Turborotalia esnaensis, T. triplex* (= *T. coalingensis), T. pentacamerata, Globorotalia pseudoscitula*. Other species were cited by BERGGREN (1969) from the North Sea Basin, and by BIGNOT & LE CALVEZ (1969) from more southern Ypresian deposits; they include *Globoratalia subbotinae* and *G. marginodentata*. More recently the planktonic foraminifera of the Ypresian of the Mol well (northeastern Belgium) were studied by HOOYBERGHS (1983). The above mentioned planktonic species grossly range in the zones P6b through P9 of the BERGGREN (1978)/BLOW (1979) zonations. Indeed, for the North Atlantic BERGGREN (*ibid.*) allocates following ranges to these species: *Globigerina patagonica* (P6b-P8), *Turborotalia triplex* (P6b), *T. pentacamerata* (P7-P8), *Pseudohastigerina wilcoxensis* (P6b-P9) and *Turborotalia cerroazulensis frontosa* (P9).
In the Belgian column the incoming of *Guembelitria triseriata* approximately coincides with that of *P. wilcoxensis* i.e. in the upper part of the Flanders Clay Member.

7.2.5. Benthonic foraminifera

Some species are typical for the Ypresian, such as *Marginulinopsis wetherelli* (= *M. enbornensis*), *Gaudryina hiltermanni, Textularia smithvillensis, Anomalina ypresiensis, Uvigerina garzaensis* (= *U. batjesi*), *Asterigerina bartoniana kaasschieteri, Pseudoclavulina anglica* and *Turrilina brevispira* (based on KAASSCHIETER, 1961; DOPPERT, 1970; KING, 1980 and WILLEMS, 1980). Since benthonic foraminifera are facies-bound, zonations based on this group can only be used in restricted areas. Some assemblage zones have been suggested for the Ypresian of the Belgian Basin by WILLEMS (1980), as mainly based on the consecutive assemblages observed in the Kallo well and compared with those of the Tielt and Woensdrecht wells. These regional assemblage zones are from base to top, characterized by the following species:

I : Assemblage consisting exclusively of agglutinated foraminifera comprising *Rhabdamnina* sp. etc.

II : Mixed agglutinated/calcareous benthonic foraminifera assemblages characterized by *Amnodiscus septatus*, etc.

III : Less rich calcareous benthonic assemblage with *Eponides plummerae, E. lunata* and *Anomalinoides cunobelini*.

IV : Rich assemblage with *Textularia smithvillensis, Marginulinopsis decorata, M. enbornensis, Nodosaria latejugata, Asterigerina bartoniana kaasschieteri*. In the upper part of this zone *Turrilina brevispira*, and *Textularia badenensis-lontensis* appear, and also the first incoming of *Nummulites planulatus* is observed for Belgium.

V : Above a practically barren interval a less rich assemblage gradually comes in, including *Cibicidoides sulzensis, C. pseudoungerianus, Alabamina wilcoxensis* and *Fursenkoina schreibersiana*.

VI : Approximately at the transition of the clayey Flanders Member (Lower Ypresian unit) to the sandy Egem Member (Upper Ypresian unit) a rich assemblage occurs, comprising among others *Bolivina pulchra, B. brabantica, Trifarina muralis, T. wilcoxensis* and *Cancris subconica*.

The benthonic foraminiferal assemblages of the Ypresian in Belgium grossly correspond to the TB3 and TB4-Zones of KING (1980) and the FI-Zone of DOPPERT (1979).

7.2.6. Large benthonic foraminifera

Nummulites planulatus are mainly represented in the upper sandy units of the Ypresian, but their appearance occurs already in older layers, approximately in the middle part of the lower, clayey unit (Flanders Member), as observed by GULINCK (1967) and WILLEMS (1980). Approximately the upper half of the Ypresian succession of Belgium thus corresponds to the *Nummulites planulatus* Zone (cf. BIGNOT & MOORKENS, 1975) of the Westeuropean basins. The basal strata of the overlying Oedelem Sand Member, belonging to the Lutetian, comprise *Nummulites laevigatus* (GULINCK & HACQUAERT, 1954) the species characterizing the next younger nummulite zone in the Belgian Basin (see also DEPRET & WILLEMS, 1983).

7.2.7. Radiolarians

Some reticulate, spherical specimens of *Cenosphaera* spp. have been recorded from the upper sandy unit (Egem Member) of the Ypresian by WILLEMS (1981). This *Cenosphaera* interval in Belgium probably corresponds to the *Cenosphaera* acme observed in North Sea wells and characterized by KING (1980) at TP6-Zone.

Some rare conical radiolaria were also observed in the basal part of the Flanders Clay Member, thus in the interval in which also the larger diatoms abound (*Coscinodiscus* sp. 1 faunule Zone), thus corresponding to the top part of KING's (1980) TP4-Zone.

7.2.8. Ostracods

From the taxa recognized by KEIJ (1957) and WILLEMS (1973, 1977) the following species are characteristic for the Ypresian (cf. KEEN, 1978):

Cytheretta venablesi, Cytheretta scrobiculoplicata, Echinocythereis reticulatissima and *Novocypris whitecliffensis*; these species indicate the intervals of the Ostracod Zones 6a, b, c and 7 of KEEN's (1978) zonation in the Ypresian succession.

7.2.9. Pollen and spores

ROCHE (1973) used the same series of core samples as DE CONINCK (1976, 1981) from the Kallo well to review the palynomorph assemblages of the Ypresian. According to the diversity and relative richness of the assemblages he distinguished four (environment-bound) assemblage zones as occurring in the following intervals of the Kallo well (from base to top):

(1) The basal strata of the Ypresian, corresponding to the Mont Heribu Member (samples −376 m to −374.5 m) contain a pollen and spores assemblage which is considerably poorer than that of the underlying (continental/lagoonal) top of the Landen Formation. The total number of pollen and spore specimens is considerably lower than that of the dinoflagellates.

(2) In the major part of the overlying Flanders Clay Member (samples −373.5 m to −283.5 m) only very rare pollen and spores are present. In some samples the dinoflagellates are very diversified and make up almost 100% of the palynomorphs, indicating a strong open marine influence. Only the dissaccate pollen are relatively well represented in this interval.

(3) The third interval considered (samples −280 m to −242.60 m) corresponds to the upper part of the Flanders Clay Member and to the gradual transition to more silty/sandy layers upwards. In these strata the number of terrestrial palynomorphs clearly increases, including mainly *Triatriopollenites platycaryoides* and *Tricolpopollenites cingulum*.

(4) Finally, in the upper part of the Ypresian (samples −239 m and −238 m), the relative number of pollen and spores strongly increases (compared to the dinoflagellates) indicating more continental influence, under a humid climate. The occurrence of *Ovoidites ligneolus* (Chlorophyta — Zygnemaphyceae) suggests fresh water influx in a nearshore shallow marine environment, as this taxon is thought to be a planktonic freshwater alga (ROCHE, 1973, p. 88 and ROCHE, 1982, p. 32). The regular appearance of *Pediastrum* (Chlorophyta — Chlorophyceae), also a planktonic freshwater alga, points to the same environmental conclusion.

7.2.10. Calcareous algae

Some rich assemblages of reproductive organs of calcareous algae (Dasycladaceans), were found in the Egem Member in the outcrop of Merelbeke. They were determined as *Terquemella* specimens by WILLEMS & GENOT (1984). Some rare specimens of the same group also occur in the same rock unit (Egem Member) in the Meilegem well. In the wells more to the west (Tielt, Ooigem) and to the north (Kallo) they were not found, and their occurrence may thus be restricted to nearshore areas. The appearance of this group emphasises the onset of a warm, tropical climate during the Late Ypresian.

7.2.11. Otoliths

This group has mainly been studied from outcrop sections by NOLF (1974) and by DELAUNOIS (1981).

Two major assemblage zones have been distinguished, corresponding approximately to the lower (clayey) and upper (sandy) parts of the Ypresian succession respectively. The lower one has *Glyptophidium polli* as characteristic species, and occurs mainly in the middle part of the Flanders Clay Member; the upper assemblage zone, without *G. polli*, has *Isacia gibbosa* as typical species.

7.2.12. Problematica, "Codonellidae"

Frequent calcareous forms were observed in the benthic microfaunas of the Belgian Eocene, and these *incertae sedis* have tentatively been considered as related to the Tintinnids. WILLEMS (1972) described them from the Kallo well and recognized some assemblage zones in the Ypresian succession: in the lower half of the Flanders Clay Member some phosphatic problematica were found which have not been described nor pictured in any publication so far (recorded from the Tielt well, WILLEMS, pers. observ.). In the higher part of the Flanders Clay Member two assemblage zones can be recognized, occurring above and below the "Glauconite Horizon of Tielt" (at −310.8 m) at which depth also some other microfossil groups show a marked change (like dinoflagellates; benthic foraminifera and the approximate income level of *Nummulites* in Belgium). In the upper part of the Ypresian succession another assemblage was recognized, occurring mainly in the sandy deposits.

As can be seen from the comparison of the ranges of these Codonellidae in the Ypresian (WILLEMS, 1972) and those from Middle to Upper Eocene deposits of Belgium (WILLEMS, 1975) a number of these *incertae sedis*-taxa certainly have stratigraphic value.

The correlation and juxtaposition of the different, above mentioned biozonations of the Ypresian, as mainly observed in the Kallo well, has been presented in Pl. 3; see also table and discussion of WILLEMS (1982).

8. PALEOENVIRONMENTAL/PALAEOECOLOGICAL SETTING IN THE TYPE-AREA

Based on the above mentioned lithology and fossil content a paleoecological reconstruction is possible.

At the beginning of the Ypresian a shallow transgressive sea (inner neritic) occurred, which opened to the North (North Sea Basin). In this early period

of the Ypresian the living conditions were acceptable for agglutinated foraminifera only: semi-stagnant or slowly moving water, relatively rich in organic matter, probably with a poor oxygen content, and a neutral to slightly acidic pH occurred, hampering the life of calcareous benthic foraminifera but tolerated by numerous agglutinants (cf. MOORKENS, 1975; WILLEMS, 1983). After some time the conditions became better so that also calcareous forms could settle. They indicate a better water circulation, and therefore more aerated and also more alcalic waters. The sea became gradually deeper, 50-100 m or slightly deeper at times. The influence of the ocean increased intermittently as suggested by the more numerous planktonic foraminifera at some levels. Later on the sea was shallowing again, the substratum became more sandy, and the water temperature increased, according to the foraminifera assemblages (WILLEMS, 1980) and also suggested by the occurrence of palm fruits. In the "Early Paniselian" (or youngest Ypresian *s.l.*) the fluctuating water depth (sedimentology data of DE MOOR & GEETS, 1974 and GEETS, 1979) may have been generally less than 50 m (KAASSCHIETER, 1961). According to palynological studies (ROCHE, 1973) the climate for the Late Ypresian was generally warm and humid; deposition occurred near to the shore, and some nearly closed lagoons occurred, which gradually changed to freshwater marshes. At the end of the Ypresian *s.l.* a strong shallowing occurred, as testified by the Aalterbrugge Complex, comprising wood fragments in non-marine deposits (HACQUAERT, 1939). The Ypresian succession in its type area in Belgium thus corresponds to a major transgressive-regressive cycle, which lasted grossly five million years.

9. LATERAL EQUIVALENTS IN NW EUROPE

Already during the last century the Flanders Clay has been correlated with the London Clay in the London and Hampshire Basins (LYELL, 1852; DUMONT, 1878) a correlation which has been confirmed up to the present day by many authors (e.g. CURRY *et al.*, 1978). Furthermore it has been equated with the Orchies Clay of Northern France (GOSSELET, 1874; ROBASZYNSKI, 1978), with the Unter Eozän 1 (upper part), 2 and 3 (lower part) of NW Germany (BETTENSTAEDT *et al.*, 1962; SCHICKOR, 1968), and with the upper part of the Rösnaes Clay of Denmark (CURRY *et al.*, 1978).

The upper sandy unit, with *Nummulites planulatus* has been correlated with the Cuise Sands of the Paris Basin (BIGNOT, 1962, 1963; BIGNOT & LE CALVEZ, 1969; BIGNOT & LEZAUD, 1969) and with the Baghsot Sands of England (CURRY *et al.*, 1978).

At the end of last century it was generally accepted that the Flanders Clay was absent in the Paris Basin and that an important hiatus existed between the Sparnacian and the Cuisian (DOLLFUS, 1880). Later on, in France, the Flanders Clay has been considered as a marine lateral equivalent of the (mainly non-marine) Sparnacian (LE CALVEZ & FEUGUEUR, 1956). Thus, according to FEUGUEUR (1963) the Ypresian stage would contain the Sparnacian and Cuisian substages. However, recent palynological studies, mainly based on the dinoflagellates, suggest that a large part of the Sparnacian is synchronous with the Late Landenian of Belgium (also consisting mainly of non-marine deposits; see GULINCK & ROCHE, 1973), and thus older than the Ypresian stage[9]. Moreover the *W. astra* and *W. meckelfeldensis* Zones of the dinoflagellate zonation have now been found at the base of the Cuisian column *s.l.* (CHATEAUNEUF & GRUAS-CAVAGNETTO, 1978). These data prove the synchronism of the Ypresian and Cuisian stages (BIGNOT, 1980a, b).

In northwestern France the Ypresian (or its lateral equivalent, the Cuisian) of the Channel coast is represented by the Varengeville Formation (CURRY *et al.*, 1978). The foraminiferal fauna of that formation, described by BIGNOT (1962) shows most affinity with the foraminifera of the middle and upper part of the Flanders Member, when considering the incoming of the planktonic foraminifera *Guembelitria triseriata* in both sequences (cf. WILLEMS, 1980). However the dinoflagellate associations of the *W. astra* and *W. meckelfeldensis* Zones at the base of the Varengeville Formation suggest a correlation with the base of the Ypresian in Belgium (COSTA *et al.*, 1978). According to CURRY *et al.* (1978) the Varengeville Formation is also approximately synchronous with the London Clay of Whitecliff Bay on the Isle of Wight.

10. NUMERICAL AGES BASED ON RADIOMETRIC ANALYSES

Some glauconites of the Ypresian have been dated by the K/Ar and Rb/Sr methods, but the results are still strongly contradictory in parts.

According to HARDENBOL & BERGGREN (1978) and also to FITCH *et al.* (1978) the Ypresian stage ranges approximately between 53.5 m.y. and 49 m.y. (data based on PTS constants). However ODIN *et al.* (1978) and CURRY & ODIN (1983), based on ICC constants, give an age-range between 51 ± 1.5 and 45.5 ± 1 million years for the Ypresian.

A study of the green pellets from the glauconiferous horizon in the middle of the Flanders Clay Member ("Lit glauconifère de Tielt", DE CONINCK, 1976) showed them to consist of disordered open latice-, low k-minerals, containing at least about 20 % expandable smectite layers.

9. At the time of the completion of this paper WILLEMS was not aware of the article by LAURAIN *et al.* (1983) in which it was shown that the lower part of the "Argiles à lignites du Soissonnais" from the type locality of the Sparnacian is attributable to the *W. meckelfeldensis* Zone, which is situated in the lower part of the Ypresian and Cuisian, a few metres above the base (Red. note).

Detailed Rb/Sr analyses on this material revealed low Rb- and commonly high Sr contents and inconsistent D/P-ratios, yielding apparent Rb/Sr ages between 65 m.y. and 86 m.y. (KEPPENS manuscript and pers. comm.). As explained by that author an incomplete transformation of detritic material thus resulted in open latice glauconite, and probably the inherited radiogenic 87 Sr, inconsistently caused the high apparent ages.

11. PRESENT INTERPRETATION OF THE YPRESIAN STAGE IN THE TYPE AREA, AND FURTHER INVESTIGATIONS RECOMMENDED

As stated previously, the strata of the Ypresian in its type area, lie nearly horizontal and are generally tectonically undisturbed. Hence no continuous outcrop section is available representing the whole succession, which may locally exceed 200 m. However, from entirely cored wells the lithologic succession is well known, and several biozonations, based on different fossil groups could now accurately be juxtaposed. To review the full succession covered by the original definition of DUMONT (1849a), it thus appears necessary to select a series of outcrops which can all be tied in with the standard section, as e.g. observed in the cored Kallo well section (Pl. 3).

The following outcrop sections (see also Pl. 1) are thought to represent most of the Ypresian succession, but in the course of time it may be necessary to add some new sections[10].

From base to top they are:

a) *Mont Héribu*, located near Mons (Hainaut, W. Belgium) (Coord.: x = 119.750, y = 124.150). The section shows the base of the Ieper Formation, here overlying the Landen Formation (Late Paleocene). A detailed study was prepared by DE CONINCK, GEETS & WILLEMS (1983). Slightly younger layers of the Ypresian have been recognized in the outcrops of Ghlin and St. Maur.

b) *Pottes*, about 19 km to the SW of Oudenaarde (no coordinates) and *Molembaix* (coord.: x = 83.975, y = 154.175), where the borings give possible reference sections for the somewhat younger lower parts of the Flanders Clay Member (DE MOOR & GEETS, 1975).

c) *Zwevegem/Moen (Bossuit)*, the canal section near Kortrijk (coord.: x = 77.900, y = 168.600), where the middle part of the Flanders Clay Member is outcropping. A not yet published study reveals the existence of very rich fossiliferous layers, with the *Globigerina patagonica*-peak level of the planktonic foraminifera, and the *Asterigerina bartoniana kaasschieteri*-horizon of the regional benthos zonation (W. WILLEMS, pers. observ.).

d) *Kortemark*, clay quarry "Gebroeders Desimpel" (coord.: x = 58.050, y = 190.400), where the top of the Flanders Clay Member is outcropping. This section forms a lateral equivalent of the Sint-Jan section near Ieper, but it is more fossiliferous. For the paleontological content see KAASSCHIETER (1961), HAY & MOHLER (1967), MOORKENS (1968), BIGNOT & LEZAUD (1969), DE CONINCK (1976) and WILLEMS (1980).

e) *Egem*, the sandpit Ampe (coord.: x = 70.150, y = 190.150), showing the lower part of the sand member (Egem Member) and some younger sediments; its location and fossil content is discussed by DE CONINCK & NOLF (1978).

f) *Merelbeke*, about 8 km SSE from the center of Gent, where the top of the Egem Member is outcropping. Its rich fossil content was given by MOORKENS *et al.* (1966) and further completed by WILLEMS & GENOT (1984).

g) *Pittem* (coord.: x = 74.500, y = 187.600), where the Pittem Member is outcropping, in the clay quarry "Steenbakkerijen Claerhout" (GEETS, 1979).

h) *Vlierzele* (coord.: x = 116.750, y = 181.750), where the Vlierzele Sand Member is outcropping, in the sandpit mentioned by KAASSCHIETER (1961, p. 91).

i) *Aalterbrugge*, situated halfway between Aalter and Knesselare; section along the canal between Gent and Brugge (coord.: x = 83.750, y = 200.000), in which the "Complex of Aalterbrugge" was described by HACQUAERT (1939). This member is now generally considered as the top part of the Ypresian (*s.l.*) stage in Belgium, as it is directly overlain by deposits with a typical Early Lutetian microfauna.

It is recommended that the above-mentioned series of outcrop sections, and some additional ones which look appropriate, should be more thoroughly analysed for their full micropaleontological and palynological content. Hence it will be possible to date them more accurately, and to tie them in, in the standard succession of the Ypresian stage (as e.g. observed in the Kallo well cored column). Such a study could best be done as a team work using the same series of samples. Also the bathymetric and isopach maps of the different lithologic units of the Ypresian in Belgium should be updated.

10. Compare also with STEURBAUT & NOLF (1986) who discuss these and numerous other localities, and give their exact locations (Red. note).

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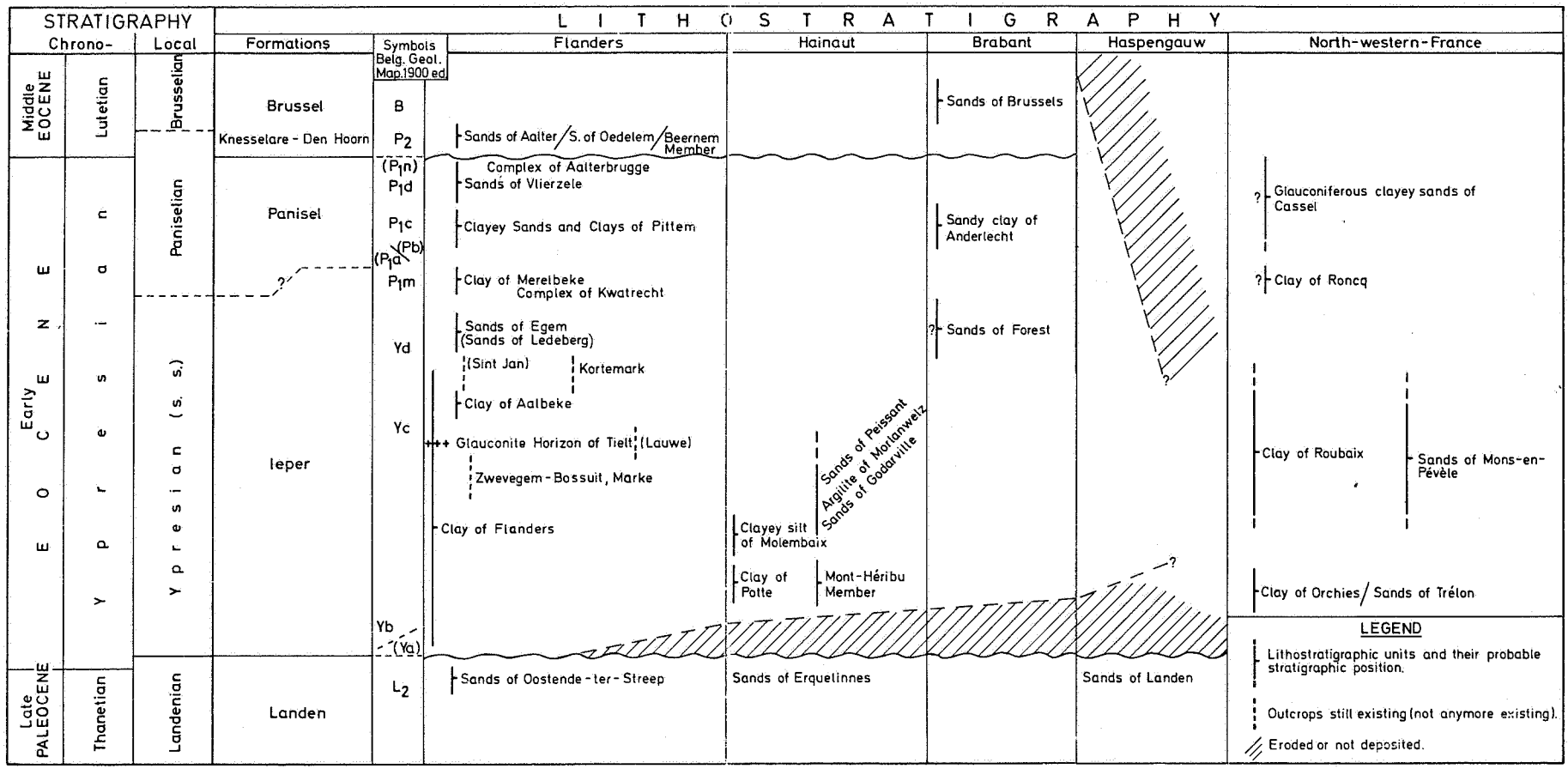
PLANCHES



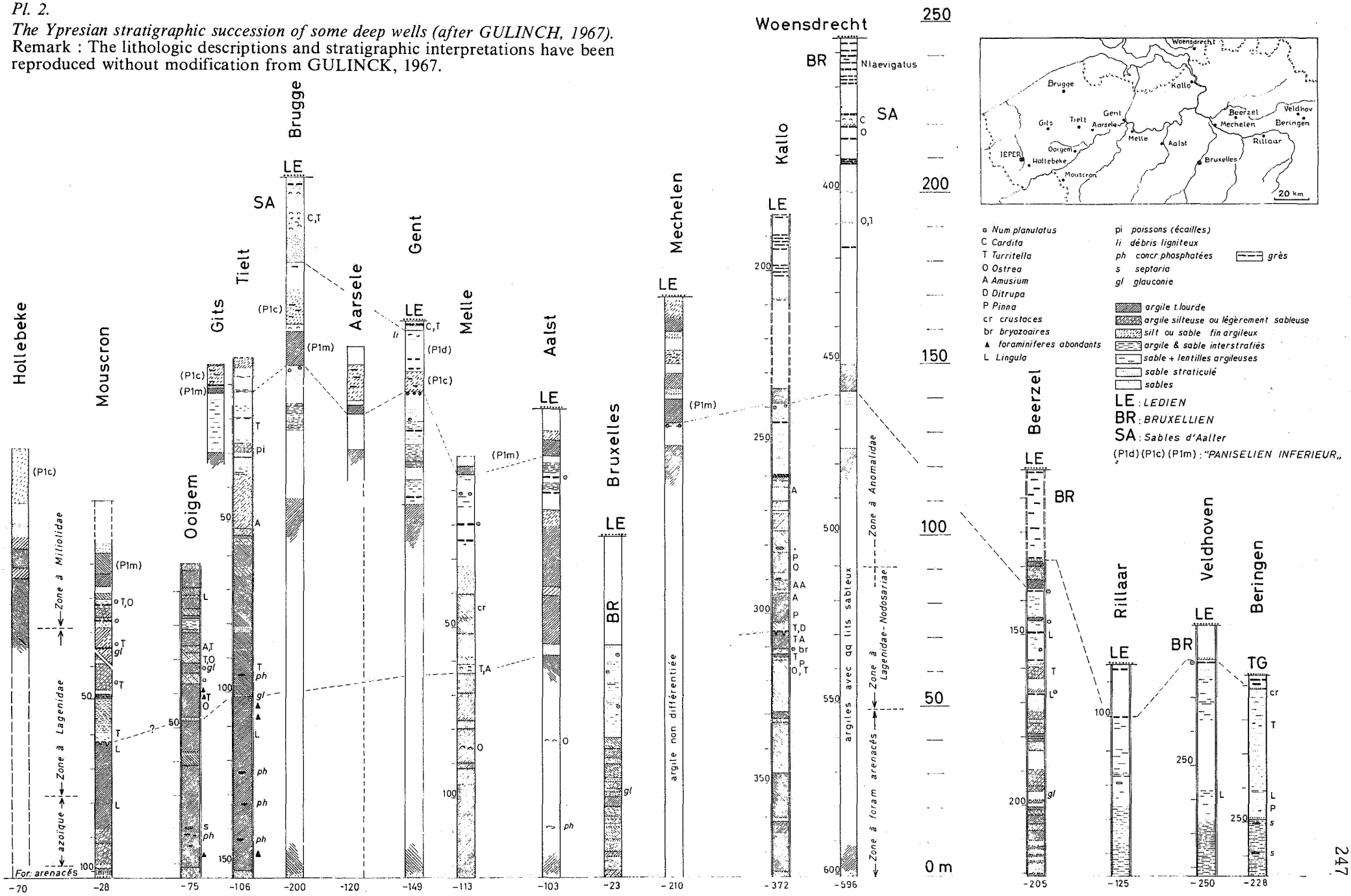
Pl. 1

Lithostratigraphy of the Ypresian s.1. in the Belgian Basin.

Remark: Note that this plate reflects the state of knowledge and insights on the Belgian Ypresian stratigraphy at the time of completion of the present text in 1984.

Pl. 2.

The Ypresian stratigraphic succession of some deep wells (after GULINCH, 1967).
Remark : The lithologic descriptions and stratigraphic interpretations have been reproduced without modification from GULINCK, 1967.



o *Num planulatus*
C *Cardita*
T *Turritella*
O *Ostrea*
A *Amusium*
D *Ditrupa*
P *Pinna*
cr *crustaces*
br *bryozoaires*
▲ *foraminiferes abondants*
L *Lingula*

pi *poissons (écailles)*
li *débris ligniteux*
ph *concr phosphatées*
s *septaria*
gl *glauconie*

grès

argile lourde
argile silteuse ou légèrement sableuse
silt ou sable fin argileux
argile & sable interstratifiés
sable + lentilles argileuses
sable straticulé
sables

LE : *LEDIEN*
BR : *BRUXELLIEN*
SA : *Sables d'Aalter*
(P1d) (P1c) (P1m) : *"PANISELIEN INFERIEUR„*

Pl. 3.- Index fossils, zonal markers and biozones recognized in the Ypresian stage.

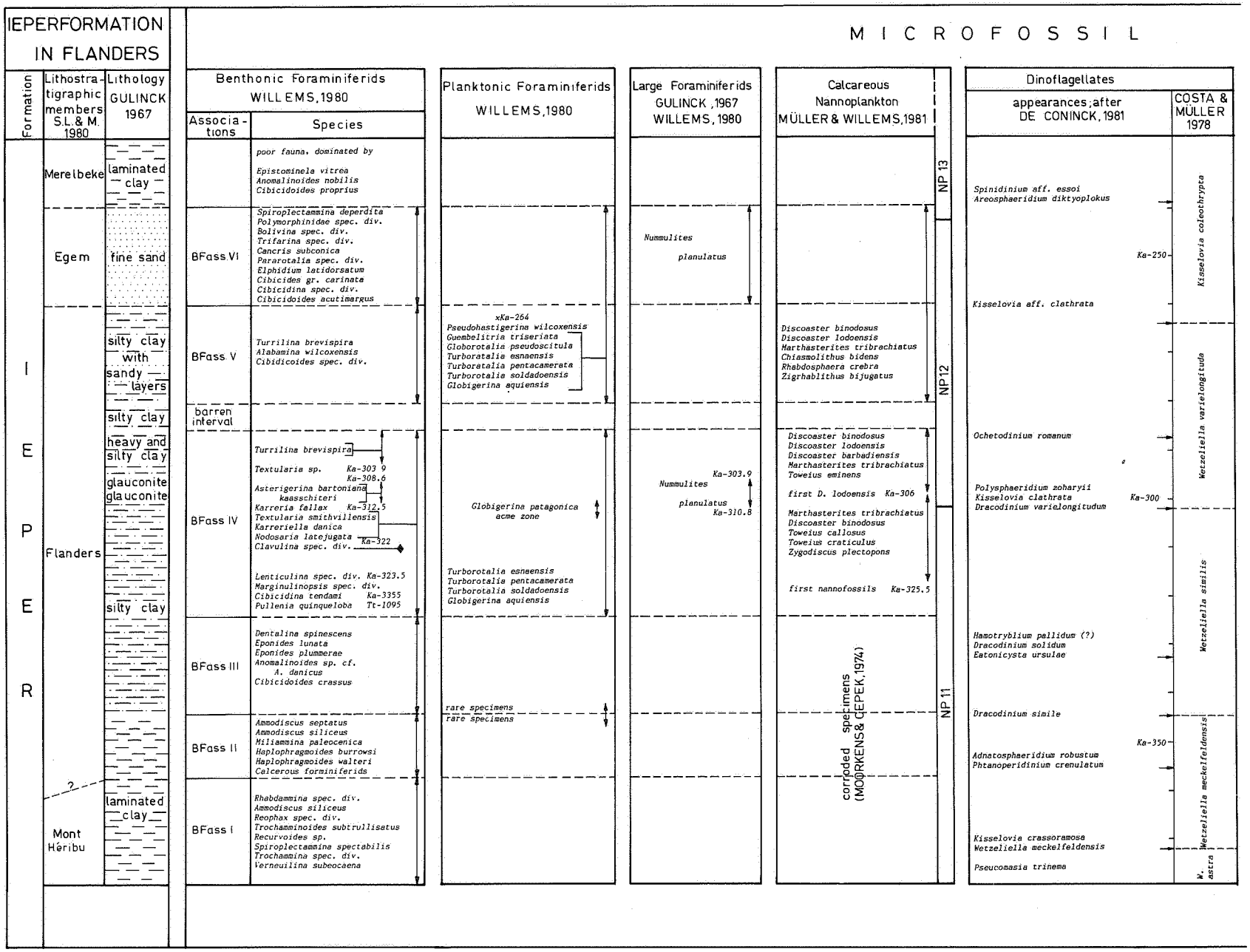
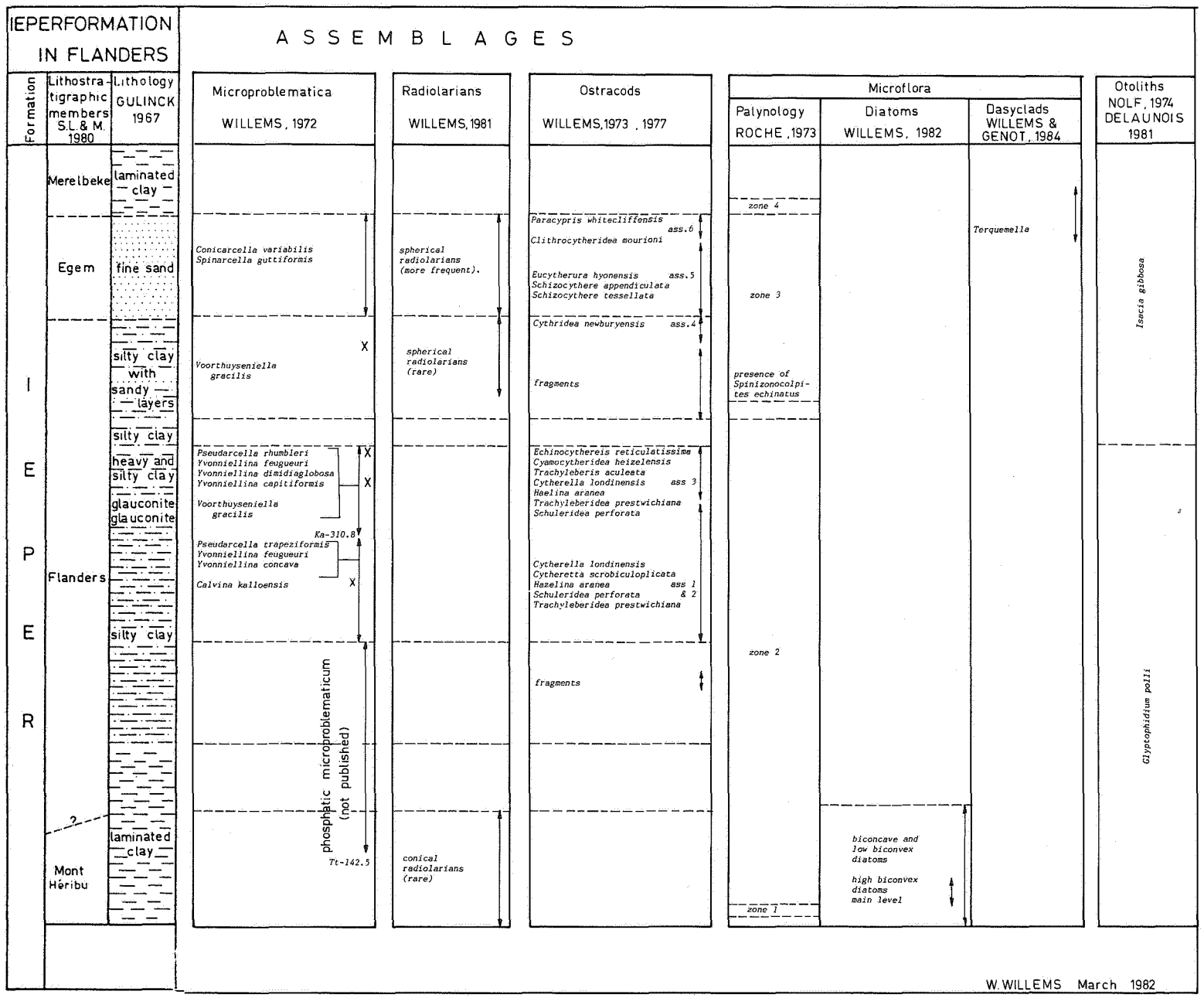


PLATE 3


IEPERFORMATION IN FLANDERS
ASSEMBLAGES
Formation
Lithostratigraphic members S.L. & M. 1980
Lithology GULINCK 1967
Microproblematica WILLEMS, 1972
Radiolarians WILLEMS, 1981
Ostracods WILLEMS, 1973 , 1977
Microflora
Palynology ROCHE, 1973
Diatoms WILLEMS, 1982
Dasyclads WILLEMS & GENOT, 1984
Otoliths NOLF, 1974 DELAUNOIS 1981
Merelbeke
laminated clay
Egem
fine sand
silty clay with sandy layers
silty clay
heavy and silty clay
glauconite glauconite
Flanders
silty clay
laminated clay
Mont Héribu
I
E
P
E
R
Conicarcella variabilis
Spinarcella guttiformis
Voorthuyseniella gracilis
Pseudarcella rhumbleri
Yvonniellina feugueuri
Yvonniellina dimidiaglobosa
Yvonniellina capitiformis
Voorthuyseniella gracilis
Ka-310.8
Pseudarcella trapeziformis
Yvonniellina feugueuri
Yvonniellina concava
Calvina kalloensis
phosphatic microproblematicum (not published)
Tt-142.5
spherical radiolarians (more frequent).
spherical radiolarians (rare)
conical radiolarians (rare)
Paracypris whitecliffensis ass.6
Clithrocytheridea mourioni
Eucytherura hyonensis ass.5
Schizocythere appendiculata
Schizocythere tessellata
Cythridea newburyensis ass.4
fragments
Echinocythereis reticulatissima
Cyamocytheridea heizelensis
Trachyleberis aculeata
Cytherella londinensis ass 3
Haelina aranea
Trachyleberidea prestwichiana
Schuleridea perforata
Cytherella londinensis
Cytheretta scrobiculoplicata
Haelina aranea ass 1
Schuleridea perforata & 2
Trachyleberidea prestwichiana
fragments
zone 4
zone 3
presence of Spiniconocolpites echinatus
zone 2
zone 1
biconcave and low biconvex diatoms
high biconvex diatoms main level
Terquemella
Isecia gibbosa
Glyptophidium polii
W. WILLEMS March 1982