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REVISION OF YPRESIAN STRATIGRAPHY OF BELGIUM AND NORTHWESTERN FRANCE

by

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The Ypresian stratigraphy is reviewed using calcareous nannoplankton from 50 outcrop and borehole sections distributed throughout the Belgian Basin. The Ypresian is proposed to include deposits between the base of the Ieper Clay *auct.* and the top of the Aalterbrugge Lignitic Horizon. The Ieper Formation is redefined to include (ascending): the Orchies Clay Member; the Roubaix Clay Member and its lateral equivalent, the Mons-en-Pévèle Sand; the Aalbeke Clay Member; the Kortemark Silt Member (new); the Egem Sand Member with its lateral equivalent the Panisel Sand; and the Merelbeke Clay Member. The Vlierzele Sands are redefined as the Vlierzele Formation, including the locally developed Pittem Clay Member. New stratotypes are selected and properly defined. Previous geological and palaeontological work on the Ypresian stratigraphy is summarized. All formerly introduced lithostratigraphic names are alphabetically listed and re-evaluated.

A new nannofossil zonation (zones I through XI) is proposed. Correlation with Martini's standard nannoplankton zonation is established (NP11 through NP14). The Ypresian history of the Belgian Basin is briefly outlined. Various aspects of sedimentation and tectonic phenomena are discussed. Distribution charts and correlation schemes of litho- and biostratigraphic units are presented.

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SAMENVATTING

Revisie van de stratigrafie van het Yprésien in België en noordwest Frankrijk.

De revisie van het Yprésien omvat de gedetailleerde lithostratigrafische interpretatie en de studie van kalkschalig nannoplankton van 50 ontsluitingen en boringen in het Belgische Bekken. Het Yprésien wordt gedefinieerd als het interval tussen de basis van de Klei van Ieper *auct.* en de top van de Lignietrijke Horizon van Aalterbrugge, en omvat twee formaties. De Formatie van Ieper wordt onderverdeeld in (van onder naar boven) de volgende afzettingen: de Klei van Orchies; de Klei van Roubaix en het laterale Zand van Mons-en-Pévèle; de Klei van Aalbeke; het Silt van Kortemark (nieuw); het Zand van Egem en het laterale Zand van Panisel; en de Klei van Merelbeke. De Formatie van Vlierzele komt overeen met het Zand van Vlierzele *sensu* Kaasschieter (1961), inclusief de plaatselijk ontwikkelde Klei van Pittem. Nieuwe stratotypes worden vastgelegd en formeel beschreven. Voorafgaande geologische en paleontologische bijdragen tot de stratigrafie van het Yprésien worden samengevat. Alle tot hier toe ingevoerde lithostratigrafische termen worden geïnventariseerd en geëvalueerd.

Een nieuwe nannofossiel-zonatie wordt voorgesteld (zones I tot XI), en gekorreleerd met de standaard nannoplankton-zonatie van Martini (1971; zones NP11 tot NP14). Tabellen en kaarten met de verspreiding van de stratigrafisch belangrijke soorten, de uitbreiding van de verschillende lithostratigrafische eenheden en de korrelatie van litho- en biostratigrafische eenheden worden eveneens voorgesteld. De belangrijkste sedimentologische en tektonische evenementen worden in 't kort besproken.

De evolutie van het Belgische Bekken tijdens het Yprésien wordt summier geschetst. Drie belangrijke transgressieve fasen worden onderscheiden. De eerste, uit het Vroegste Yprésien; komt overeen met de maximale uitbreiding van de zee (gematerialiseerd door de Klei van Orchies en oostelijke laterale varianten). Na een lichte regressie met emersie in het zuidoostelijk deel van het bekken volgt een tweede, eerder beperkte en diskontinue transgressieve fase (gematerialiseerd door de Klei van Aalbeke en gedeeltelijk Panisel). Daarop volgt een nieuwe belangrijke regressie met verregaande noordwaartse verschuiving van de kustlijn ten gevolge een sterke zeespiegeldaling. De derde transgressieve cyclus (Formatie van Vlierzele) tijdens het Laat-Yprésien is grotendeels uitgewist door late-

re erosie. Ze wordt begrensd door de Lignietrijke Horizon van Aalterbrugge, die een nieuwe regressieve fase en meteen ook het einde van het Yprésien inluidt.

RÉSUMÉ

Révision de la stratigraphie yprésienne de Belgique et du nord-ouest de la France.

La révision de l'Yprésien du Bassin belge comprend l'interprétation lithostratigraphique détaillée et l'étude des nannofossiles calcaires de 50 affleurements et forages. L'Yprésien se définit en Flandre entre la base de l'Argile d'Ypres *auct.* et le sommet de l'Horizon Ligniteux d'Aalterbrugge, et il contient deux formations. La Formation d'Ypres comprend de bas en haut l'Argile d'Orchies; l'Argile de Roubaix dont l'équivalent latéral est les Sables de Mons-en-Pévèle; l'Argile d'Aalbeke; le Limon de Kortemark (unité ici nouvellement introduite); les Sables d'Egem dont l'équivalent latéral sont les Sables de Panisel; et l'Argile de Merelbeke. La Formation de Vlierzele correspond aux Sables de Vlierzele *sensu* Kaasschieter, 1961, y compris l'Argile de Pittem, en langues. Tout en tenant compte des contributions antérieures des différents auteurs nous choisissons et décrivons de façon formelle plusieurs nouveaux stratotypes.

Une nouvelle zonation à nannofossiles calcaires est proposée (zones I à XI) et est mise en corrélation avec la biozonation "standard" de Martini (1971; zones NP11 à NP14). Des tableaux et cartes précisant la répartition stratigraphique des espèces d'intérêt stratigraphique, la distribution géographique des diverses unités lithostratigraphiques, ainsi que la corrélation entre les unités litho- et biostratigraphiques sont ajoutés. Les principaux événements sédimentologiques et tectoniques sont discutés.

Nous présentons en conclusion une vue d'ensemble de l'évolution du Bassin belge durant l'Yprésien. On y reconnaît trois épisodes transgressifs. Le premier se situe tout au début de l'Yprésien et correspond à l'extension maximale de la mer yprésienne, avec le dépôt de l'Argile d'Orchies (et les équivalents latéraux). Une légère régression avec émersion dans la partie sud-est du bassin précède une deuxième transgression, de répartition nettement moindre que la précédente et sporadique. Il y fait suite une régression de plus grande ampleur, sans doute de nature eustatique. A l'Yprésien terminal la mer transgresse de nouveau en déposant la Formation de Vlierzele. Celle-ci est couronnée par l'Horizon Ligniteux d'Aalterbrugge qui inaugure un nouvel épisode régressif, lequel marque la fin de l'Yprésien dans le Bassin belge.

INTRODUCTION

Since its introduction (Dumont, 1849) the Ypresian Stage has been the subject of numerous investigations and has become one of the best studied and internationally accepted stages of the Belgian Tertiary. However, at the outset of the present study in mid-1982, the stratigraphic position of most of the Ypresian outcrops in southern Flanders was still unknown. Study of fish otoliths, essentially the presence or absence of *Glyptophidium polli* (Casier, 1946), provided the first indication that the Ypresian sands of northern Flanders differ in age from those of southern Flanders (de Coninck & Nolf, 1979) and that the hitherto accepted correlations are incorrect.

It was decided, in consultation with the late Dr W. Willems, to carry out micropalaeontological investigations of outcrops and borehole sections in order to elucidate the Ypresian stratigraphy and palaeogeography. As the biostratigraphy of the Ypresian sequence of the Kallo and Tielt boreholes was already broadly outlined (Willems, 1980; Müller & Willems, 1981), a fast, successful completion of the work was expected. Unfortunately, it turned out that most of the basic litho- and biostratigraphic data were unreliable, incomplete, and in some cases erroneous. First, the hitherto accepted lithostratigraphic subdivision proved to be incomplete and incorrect, and had to be redefined; secondly, the geographic distribution of the subdivisions was unknown; and thirdly much of the biozonation was not worked out in sufficient detail to be useful. What was at first assumed to be a simple application of micropalaeontological techniques eventually resulted in a complete revision of the Ypresian stratigraphy. The Ypresian Stage has been variously defined over the years. For a detailed history of the Ypresian Stage concept the reader should consult Willems (1980) and Willems, Bignot & Moorkens (1981).

Before analysing the lithostratigraphy of the Ypresian, it seems advisable to comment briefly on previous investigations, especially palaeontological, and to consider some general aspects of the Ypresian deposits. By the term "Ypresian" is meant here the time interval during which all the deposits between the base of the Ieper Clay and the top of the Aalterbrugge Lignitic Horizon (*sensu* Hacquaert, 1939) were deposited. In this sense it corresponds to Dumont's original definition (1849).

The Ypresian deposits have been recognised for centuries due to their extensive geographic distribution and considerable economic value. Even today the clays are used for brick and tile manufacture, and the sands for road construction. The Ypresian deposits underlie the whole northern half of the Belgian territory; if the thin Quaternary cover is disregarded they crop out in nearly the entire southern and western sectors of this region. They generally rest on Palaeocene deposits that are lagoonal in the northwest and continental in the northeast and the southwest (de Geyter, 1981). In the centre of the basin, in the triangle Geraardsbergen-Mons-Genappe southwest of Brussels, they rest directly on Palaeozoic deposits (Legrand, 1968, map II). The thickness of the Ypresian deposits increases northward, from a few metres in the south and southeast to about 150 m in the northern part of the basin (Kallo: estimated thickness c. 165 m, but terminal cores are absent; Meer: 150 m; Mol: 97 m), with a maximum recorded thickness in the extreme northwest (Knokke: 182 m). The strata dip gently to the North, but the dip is greater than the inclination of the post-Tertiary erosion surface. Therefore, they are covered by subsequent deposits that become progressively younger northward.

The most important recent non-palaeontological publications on the Ypresian stratigraphy are by Kaasschieter (1961: first attempt to establish a coherent lithostratigraphic subdivision); Gulinck (1967: first attempt to analyse the vertical and lateral distribution of the Ypresian); Moorkens (1968: designation of the type locality of the Ypresian in the clay pit of "De Verenigde Steenbakkerijen van Ieperen" at Sint-Jan, Ieper); Nolf (1973a: stratigraphical analysis of the terminal Ypresian and basal Lutetian strata); de Moor & Geets (1974 and 1975: new data on sedimentology and lithostratigraphy); the Subgroup Lithostratigraphy and Maps (1980, data by Laga, Geets, Moorkens & Nolf: provisional lithostratigraphic subdivision); Willems, Bignot & Moorkens (1981: detailed description of the Ypresian Stage); Quinif, Charlet & Dupuis (1982: radioactive-element geochemistry: U, Th, K_2O); Quinif, Mercier, Roche & Dupuis (1983: clay mineralogy and radioactive-element geochemistry); Geets & de Breuck (1983: synopsis of heavy minerals) and Mercier, Roche, Quinif & Dupuis (1985h clay mineralogy and radioactive-element geochemistry). So far, nothing has been published on palaeomagnetism and the seismic and electrical properties of the Ypresian sequence, although several well-logs were run on behalf of the Belgian Geological Survey (resistivity, natural gamma radioactivity, etc.).

Various palaeontological aspects were described already by Willems (1982). The literature on the Ypresian fauna and flora is here listed without further comment. Among the organisms encountered are: dinoflagellates and acritarchs (important monographs: de Coninck, 1969, 1973, 1976, 1981a; additional papers: Costa & Downie, 1976; Costa, Dennison & Downie, 1978; de Coninck, 1965, 1967, 1977a, 1977b, 1981b, 1986; de Coninck & Nolf, 1979; Islam, 1982; Pastiels, 1948); calcareous nannoplankton (Bigg, 1982; Bignot & Lezaud, 1969; Bignot & Moorkens, 1975; Martini, 1971; Moorkens & Cepek, 1974; Müller & Willems, 1981; Steurbaut, in press); diatoms (Willems, 1982); dasycladal algae (Willems & Genot, 1984), pollen and spores (important monographs: Roche, 1973, 1975, 1982; additional papers: Roche, 1970, 1980; Mercier *et al.*, 1985; Quinif *et al.*, 1983); foraminifers (important monographs: Kaasschieter, 1961, and Willems, 1980; additional papers: Bigg, 1982; Blondeau, 1966; Brönnimann, Curry, Pomerol & Szöts, 1968; de Coninck, Geets & Willems, 1983; Gerits, Hooyberghs & Voets, 1981; Hooyberghs, 1983; le Calvez & Feugueur, 1956; Limbourg, 1986; Moorkens, 1968; Moorkens & Cepek, 1974; Moorkens & Verhoeve, 1967; Müller & Willems, 1981 and Willems, 1974, 1982a, 1982b); radiolarians (Willems, 1981); ostracodes (Key, 1957; Moorkens & Verhoeve, 1967; Willems, 1975a, 1978); problematic microfossils (Willems, 1973, 1975b); fructifications of the palm tree *Nipadites* and silicified wood (Gillain & Stockmans, 1940; Stockmans & Willière, 1943; also mentioned by de Heinzelin & Glibert, 1957); sponge spicules and echinoderm spines (observations by Willems); molluscs (Dhondt, 1967, and some species recorded by de Heinzelin & Glibert, 1957; and King, 1981); brachiopods (mentioned by de Heinzelin & Glibert, 1957); worm tubes (van Straelen, 1937; tubes of *Ditrupa*: Casier, 1946 and personal observations); claws and carapaces of crabs and lobsters (van Straelen, 1921a, 1921b; mentioned by Moorkens *et al.*, 1967; also pers. observ.); fishes (important monographs: Casier, 1946, 1950; Leriche, 1905, 1906; Nolf, 1971, 1974, 1986; additional papers: Casier, 1967; Herman, 1975; Nolf, 1973b; Quinet, Coupatez & Wouters, 1970); reptile bones (Leriche, 1926; Rage, 1983; mentioned by de Heinzelin & Glibert, 1957).

LITHOSTRATIGRAPHY

The Ypresian deposits occur in the main part of Belgium, North of the river Maas (or Meuse), and in northern France as far as the Calais area. In the northwest (towards the North Sea Basin centre), the lithological succession consists of a lower clayey sequence (100 to 140 m; symbol Yc of the Belgian geological map) overlain by very fine sands (10 to 20 m; symbol Yd of the geological map). The top of the Ypresian in that area consists of rather coarse, more or less clayey glauconitic sands with sandstone bands (maximum thickness of about 30 m; symbol Pl or "Lower Paniselian" of the Belgian geological map). The limit between the Yd and Pl deposits is marked by a thin (5 to 10 m) heavy clay, the Merelbeke Clay (= Plm of the Belgian geological map), which is an excellent marker in the North of the area, but is absent to the South.

Toward the margin of the basin, in northern France and in southern Belgium, a more or less similar lithological succession was recognized by Ortlieb & Chellonneix already in 1870, and by Gosselet in 1874, before the completion of the legend of the Belgian geological map (1892). In this area, the clayey part (Yc) of the Ypresian consists of a lower heavy clay, the Orchies Clay, and a very silty and fossiliferous upper part, the Roubaix Clay. More to the East, the Orchies Clay is covered by sandy deposits, the Mons-en-Pévèle Sands, which were considered by Gosselet (1874), to represent at least in part, the lateral equivalent of the Roubaix Clay. Both the Roubaix Clay (in the West) and the

Mons-en-Pévèle Sands (in the East) are overlain by a 10 m thick heavy Aalbeke Clay, which in turn is covered by "Lower Paniselian" (Pl) sands.

On the basis of similarity in the lithological succession (clay/sand or silty clay/heavy clay/glauconitic sand with sandstones) in both the North and the South of the basin, the correlations, shown by arrows in Fig. 1 were established, resulting in the outline of a legend for the Belgian geological map (1892). These correlations, however, are refuted by the present investigation.

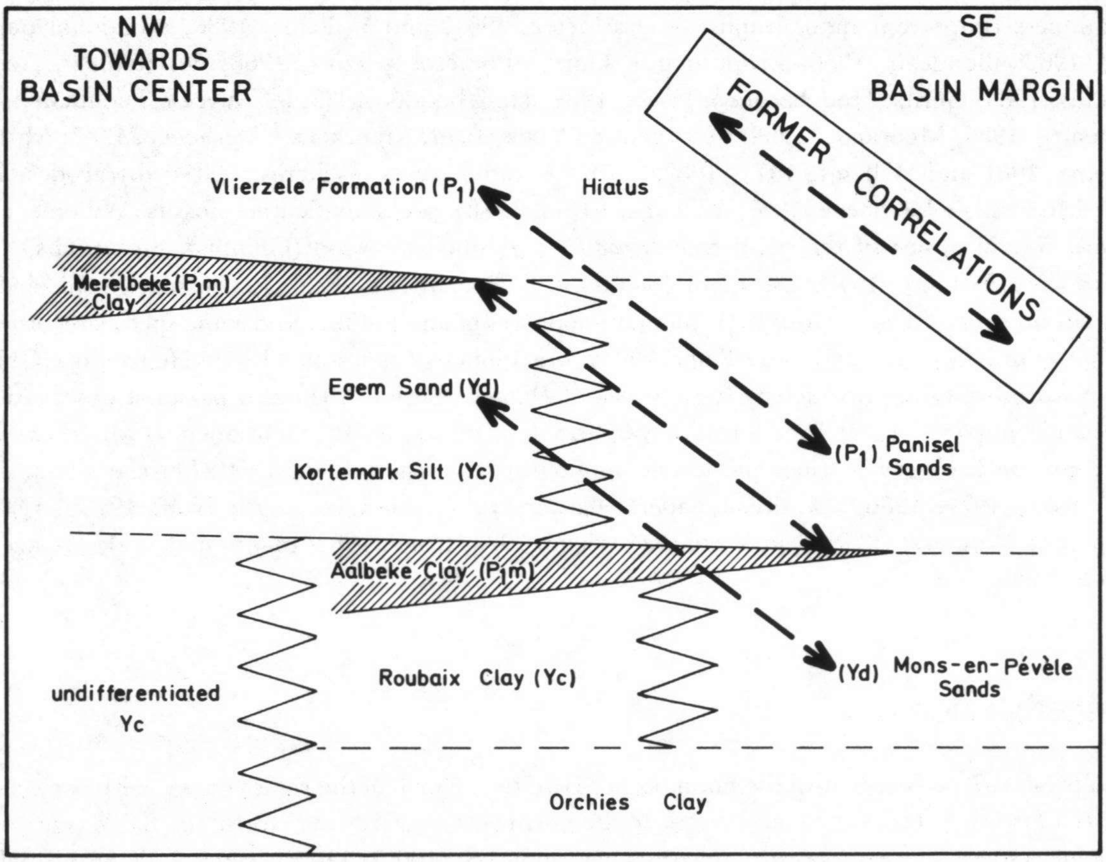


Fig. 1. Simplified correlation scheme for the Belgian Ypresian deposits, compared to the correlations used for the establishment of the Belgian geological map.

The lithostratigraphic classification proposed here results from detailed studies of borehole and outcrop sections throughout the Belgian Basin (Fig. 2). Various well-distinguishable units (members) were recognized. Instead of introducing new names, it was thought preferable to preserve formerly used names for readily recognizable units and to define them on well-chosen stratotypes.

Two formations are distinguished: a lower Ieper Formation and an upper Vlierzele Formation.

The Ieper Formation includes a lower clayey sequence (Orchies Clay, Roubaix Clay and Aalbeke Clay Members); a middle silty to sandy part (Kortemark Silt and Egem Sand Members) and an upper heavy clay (Merelbeke Clay Member). More to the East, the Roubaix Clay Member is represented by its sandy equivalent, the Mons-en-Pévèle Sand Member, whereas the silty to sandy

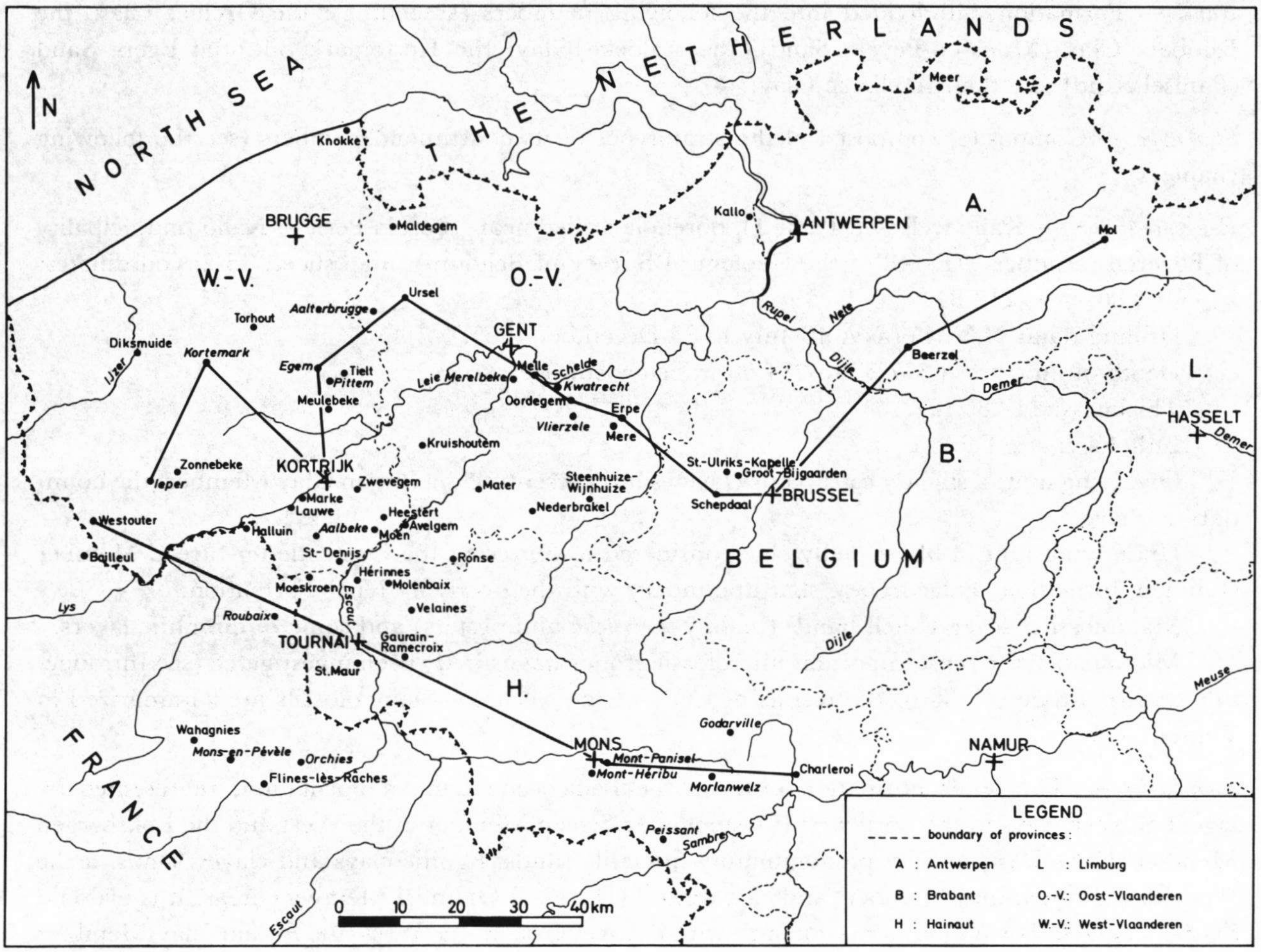


Fig. 2. Location of sampled sites and of the type localities of the lithostratigraphic units discussed in the present paper (in italics). The thick lines refer to cross-sections shown in fig. 10.

middle part (Kortemark Silt and Egem Sand Members) is replaced by a heterogeneous sand-clay unit with numerous sandstone bands, the Panisel Sand Member.

The Vlierzele Formation consists of a locally developed lower clayey to silty part, the Pittem Clay Member, and of yellowish-green glauconitic fine sand with sandstone bands.

An important criterion for the boundary between these two formations is the absence of relatively thick beds of dark grey, heavy clays (such as the Merelbeke Clay and Aalbeke Clay) in all sediments subsequent to the deposition of the Merelbeke Clay.

Ieper Formation

Name — Ieper (Ypres), a small town in the southern part of West-Vlaanderen. The term "Yprésien" was introduced by Dumont (1849); the term "Ypres beds" and "Argile Yprésien" were first used by Lyell (1852); the term "Ieper Clay" is attributable to d'Omalius d'Halloy (1862).

Rank — Formation, subdivided into the following members (ascending): the Orchies Clay, the Roubaix Clay (Mons-en-Pévèle Sand), the Aalbeke Clay, the Kortemark Silt, the Egem Sand (Panisel Sand) and the Merelbeke Clay.

Stratotype — Composite, composed of the stratotypes of its constituent members (see the following chapters).

Reference section — Kallo well (see Table 1), borehole drilled near "Fort la Perle", Kallo, municipality of Beveren (number 27E-148 of the Geological Survey of Belgium); map-sheet: 15/2; coordinates: x = 144.86, y = 217.84.

Drilling data: N.V. Foraky, 13 July to 23 December 1965.

Depth of unit: from 377.35 to 234.50 m below surface.

Thickness: 142.85 m.

Lithology: see Table I.

Overlying unit: a slightly calcareous clayey silt representing the Pittem Clay Member; the boundary is sharp.

Underlying unit: a black shelly clay considered to represent the Oostende-ter-Streep Member (Landen Formation, Palaeocene); sharp boundary with the overlying Ieper Formation.

Macrofossils: several shell bands (mainly *Turritella* and oysters) and some nummulitic layers.

Microfossils: the most important microfossil groups have alredy been investigated (see Introduction and Steurbaut, 1986b); the results of study of the calcareous nannofossils are summarized in Table I.

Boundaries — The Ieper Formation rests on the Palaeocene Landen Formation, represented by lagoonal black clays in the northwest (Oostende-ter-Streep Member in the West and the Loksbergen Member in the East) and by predominantly fluviatile sands, lignitic clays and clayey sands in the southwest (Erquelinnes Member) and east-central (Dormaal-Orsmaal Member) areas; it is overlain by the Vlierzele Formation, a marine unit with a clayey base in the West (the Pittem Clay Member) and entirely sandy in the East of Vlaanderen.

Distribution and thickness — The Ieper Formation extends throughout the Belgian Basin (northern Belgium and northwestern France) (Figs. 11, 12); North of the Torhout-Gent-Antwerpen line it is completely developed, with a maximum recorded thickness of 155 m (Knokke well); southwards it decreases in thickness due to non-deposition and erosion of its uppermost members.

Geologic age — Ypresian, Early Eocene.

References — see Introduction.

Orchies Clay Member

Name — Orchies, a small village 20 km southeast of Lille (northern France); introduced by Gosselet (1874).

Rank — Member, corresponding to the lowermost part of the "Ieper Clay" of Belgian authors and to the lowermost part of the "Argile des Flandres" of French authors.

Stratotype — No stratotype has been designated since the introduction of this unit by Gosselet (1874); only the lower part of the Orchies Clay *sensu* Gosselet (definition which is retained here) is exposed and can be studied in detail; the section of the Flines-lès-Râches clay pit is proposed as lectostratotype because it closely resembles the well-known Orchies clay pit section, now abandoned and completely filled in.

Lectostratotype — Clay pit Bar Frères at Flines-lès-Râches; map sheet: XXV-5 (Carvin, 1/50000); coordinates: x = 659.600, y = 304.300.

Lithology: Alternating laminated silty clay and clayey silt rich in gypsum and less silty towards the top, resting on a basal pebble bed with sideritic and pyritic concretions.

Thickness: 5.30 m.

Overlying unit: Quaternary cover 40 cm thick.

Underlying unit: 18 m of Palaeocene sands are exposed. They consist of a basal greenish glauconitic sand (a few metres are visible), and intermediate complex of whitish stratified sands and a rather thin upper complex of dark-brown sand with local channel structures filled with peat; the top is strongly bioturbated.

Macrofossils: not yet recorded.

Microfossils: no nannofossils recorded.

Lithology — Bluish-grey heavy clay with a more or less silty base; a basal pebble bed is generally present (Orchies, Flines-lès-Râches, Quenast, etc.). The basal beds are sometimes extremely clayey (*e.g.* in the Wahagnies clay pit); sometimes they do contain sand lenses (*e.g.* in the locality of Mont-Héribu), and were therefore considered by de Coninck, geets & Willems (1983) to represent a new member, the Mont-Héribu, which is here retained and assigned the rank of bed. More to the East the sequence contains various silt and sand intercalations, and passes gradually into the overlying Mons-en-Pévèle Sand Member.

Fossils — Well-diversified dinoflagellate associations are recorded (see de Coninck, 1976, 1986; de Coninck *et al.*, 1983); some pyritised diatom molds, foraminifers and radiolarians are also present (see de Coninck *et al.*, 1983; Willems, 1983); only a few calcareous nannofossil-levels have been recorded (Kallo and Mol wells), assignable to the lower part of Martini's NP11.

Boundaries — The base is well defined, locally slightly eroded. It consists of oxidized, hardened clayey sand or a pebble bed that overlies the Palaeocene deposits, but in the centre of the basin rests directly on the Palaeozoic. Its gradual transition into the overlying Roubaix Clay Member is accompanied by an increase in silt content.

Distribution and thickness — Occurs in nearly the entire Belgian Basin; thickness ranges from a few metres in the South to about 45 m in the North (see Fig. 6). The easternmost part (Mol well) of the sequence is less clayey and contains considerable intercalations of sand (see Fig. 6).

Environment — Shallow neritic environment with slowly moving or even stagnant bottom waters, resulting in a low oxygen and high CO_2 contents, at least as far as the basal part is concerned (see de Coninck *et al.*, 1983).

Correlation with other units — Probably corresponds, at least in part, to the poorly defined Morlanwelz Argilite.

Roubaix Clay Member

Name — Roubaix, a small town in northwestern France c. 10 km northeast of Lille, near the Belgian border; introduced by Gosselet (1874).

Rank — Member, corresponding to the middle part of the "Ieper Clay" of authors.

Stratotype — No stratotype has been designated since the introduction of the unit by Gosselet (1874).

Lectostratotype — The west bank section of the Bossuit Canal at Moen is chosen as lectostratotype of the Roubaix Clay Member; map-sheet: 29/6; coordinates: x = 79.775, y = 164.725 (see Table II, Fig. 3 and chapter on the sample localities, under the heading Moen).

Lithology: 17.50 m of bluish fossiliferous silty clays to clay silts are exposed under a 30 cm thick cover, weathered, and disturbed by slumping and run-off erosion; below the road surface along the canal, it passes into blue silts with intercalations of fine sand; the Moen sequence represents the upper part of the Roubaix Clay Member.

Thickness: upper 17.50 m are visible; the lower part of the member is not exposed.

Overlying unit: heavy blue clay of the Aalbeke Clay Member; the boundary is gradational.

Underlying unit: not encountered.

Macrofissils: nearly the entire sequence is fossiliferous. Two coquina layers (shell banks) (at + 32.50 m and + 35.75 m T.A.W., respectively) rich in *Turritella*, have been identified.

Microfossils: calcareous nannofossils were studied in detail (see Table II): the lower part of the section is assignable to NP11, the upper part to NP12; the boundary between these two zones lies at approximately + 27 m T.A.W. (see Table II for details). One sample at ca 1 m above the road surface (sample N3 at + 22.60 m T.A.W.) was examined for foraminifers and found to belong to the lower part of Willems' benthonic foraminiferal association IV (Willems, pers. com.). The same layer as well as the lowermost coquina (N9 at approximately + 32.60 m T.A.W.) were sampled for otoliths: both associations are rich and diverse, with abundant *Glyptophidium polli* (Casier, 1946).

Lithology — The Roubaix Clay Member has a very heterogeneous character. Heavy clays, silts and fine sands alternate and contain local intercalations of shell grit, soft sandstone bands and coquinas.

Fossils — This member represents one of the most fossiliferous parts of the Ieper Formation: ostracodes (for subdivision into three faunal zones see Willems 1975a, 1978), dinoflagellates (de Coninck, 1969, 1973, 1976, 1981a), pollen and spores (Roche, 1975, 1982), foraminifers (see Introduction for references) were studied extensively and will not be re-evaluated here; many macrofossils are also recorded (see Introduction). The nannofossil assemblages from the lowermost part of the Roubaix Clay Member are attributable to units I (top) II and IIIa, as defined in this study; the upper part corresponds to units IIIb, IV and V (see Tables I, II).

Boundaries — The Roubaix Clay Member rests on homogeneous heavy clays of the Orchies Clay Member. It is overlain by a heavy bluish, mostly completely decalcified clay of the Aalbeke Clay Member.

Distribution and thickness — About 50 m thick, present throughout the western part of the Belgian Basin; widely outcropping South of Kortrijk; more to the East and southeast it is replaced by fine clayey sands of the Mons-en-Pévèle Sand Member (Figs. 10, 11).

Environment — Open shelf.

Mons-en-Pévèle Sand Member

Name — Mons-en-Pévèle, a small town in northwestern France, 16 km south of Lille; introduced by ortlieb & Chellonneix (1870).

Rank — Member, formerly used to describe the sandy parts of the Ieper Formation (symbol Yd of the geological map).

Stratotype — Mons-en-Pévèle Hill sequence, map-sheet Carvin (XXV-5); coordinates: x = 653.750, y = 309.750; defined by Ortlieb & Chellonneix in 1870 (p. 32, fig. 3): 30 m of yellowish, clayey, very fine sands with nummulitic concretions, overlying a heavy, plastic, grey clay of the Wahagnies Clay (= Orchies Clay *sensu* Gosselet, 1874).

Lithology — In the centre of the basin alternation of glauconitic silty sand (nummulitic) and silty clays, passing into very fine sands towards the south (stratotype) and east portions of the basin.

Fossils — Rich macrofauna with nummulites, otoliths and shell fragments. The foraminifers were studied by Kaasschieter (1961), Moorkens (1968) and Willems (1980), the calcareous nannofossils are examined in the present paper: units II, III, IV, V and VI (the latter in the Mol borehole sequence only) are present.

Boundaries — The Mons-en-Pévèle Sand Member rests on a heavy clay of the Orchies Clay Member, which contains towards the East various silt and sand intercalations. To the North it is overlain by a grey plastic heavy clay of the Aalbeke Clay Member; in the Mont-Panisel Hill it is directly overlain by a thin grey sandy clay (Marliere, 1967: 7) representing the base of the Panisel Sand Member. In the south and southeast portions of the basin it is covered by Brusselian sands (Figs. 6, 11).

Distribution and thickness — Occurs only in the southern part of the Belgian Basin; to the North it is replaced by the Roubaix Clay Member (Figs. 10, 11). Its maximum recorded thickness is about 40 m.

Environment — Very shallow marine.

Aalbeke Clay Member

Name — Aalbeke, a small village 6 km southwest of Kortrijk; introduced by de Moor & Geets (1975).

Rank — Member; corresponds to the uppermost part of the Ieper Clay of Belgian authors or the "Argile des Flandres" of French authors.

Stratotype — Designated in the clay pit Kobbe, at Aalbeke; map-sheet: 29/5-6; coordinates: x = 68.450, y = 164.300; 10 m of heavy bluish clay with a 1 m thick reddish silty oxidation band about half-way up in the section; rests on fossiliferous silty clays of the Roubaix Clay Member (see Fig. 3).

Lithology — Homogeneous, bluish, heavy clay; in the extreme eastern portion of the basin (Mol well) are a few very thin intercalations of sand and silt.

Fossils — No calcareous fossils have yet been recorded, except for two otoliths from the stratotype and a rather poor nannoflora from the Mol well (sample taken from depth of 362.80 m), which is assignable to unit VI as defined in this study, and to the middle part of Martini's NP12. The organic microfossils were studied by de Coninck (dinoflagellates, see Introduction) and Roche (pollen and spores, see Introduction).

Boundaries — The Aalbeke Clay Member is overlain by a heterogeneous grey silt with intercalations of sand and clay in the northern part of the basin (= the Kortemark Silt Member) or by glauconitic clayey green sands and dark clays in the southern part of the basin (= Panisel Sand Member). It rests on bluish grey fossiliferous silty clays to clayey silts in the northern part (= Roubaix Clay Member) or on greyish-brown clayey fine sands in the more southern parts of the basin (= Mons-en-Pévèle Sand Member) (Figs. 10, 11).

Distribution and thickness — Absent only in the extreme southern portion of the basin. The maximum recorded thickness is 15 m, average thickness generally about 10 m, decreasing to 4 m southeastward.

Environment — The dinoflagellate associations indicate shallow marine, tropical to subtropical conditions with rather high salinity.

Kortemark Silt Member, new member

Name — Kortmark, a small village 20 km southwest of Brugge; introduced in this paper.

Rank — Member, introduced to define the uppermost heterogeneous silty part of the Ieper Clay of Belgian authors or the "Argile des Flandres" of French authors.

Stratotype — Clay pit "Desimpel" at Kortemark, map-sheet 20/3; coordinates: x = 57.050, y = 190.400 (see Fig. 5).

Thickness: 19 m, between + 7 m and -12 m T.A.W.

Lithology: micaceous, compact, grey silt with sandy intercalations, becomes more clayey towards the base (see Fig. 5).

Overlying unit: yellowish-green bioturbated fine sand rich in worm-tubes, representing the base of the Egem Sand Member; boundary sharp.

Underlying unit: heavy, blue-green clay, with purple nests of organic material, representing the Aalbeke Clay Member.

Macrofossils: few shell fragments have been recorded.

Microfossils: dinoflagellates were studied by de Coninck (1976) and foraminifers by Willems (1980). Only sample N_4 yielded nannofossils; they are attributable to unit VI as defined here.

Reference section — Kallo well, borehole drilled near "Fort la Perle"; Kallo, municipality of Beveren (number 27E-148 of the Geological Survey of Belgium); map-sheet: 15/2; coordinates: x = 144.86, y = 217.84.

Depth of unit: from 282 to ca 260 m below surface.

Thickness: c. 22 m.

Lithology: a silty clay with thin intercalations of heavy clay, silt and fine sand.

Overlying unit: a very fine sand intercalated with thin layers of heavy clay towards the base, representing the Egem Sand Member.

Underlying unit: heavy green clay considered to represent the Aalbeke Clay Member.

Macrofossils: few *Pecten* shells were recorded.

Microfossils: the most important groups of microfossils were studied already (see Introduction and Steurbaut, 1986b). The nannofossil associations (see Table I) are attributable to unit VI as defined here, which corresponds to the middle part of Martini's NP12.

Lithology — Heterogeneous deposit, see Stratotype and Reference section.

Fossils — The macrofossils have not yet been studied; the microfossils are discussed above.

Boundaries — The boundaries are always sharp, except for the extreme western portion of the basin. The Kortemark Silt Member always rests on a heavy clay of the Aalbeke Clay Member and is overlain by very fine sands of the Egem Sand Member, whose base becomes clayey northward.

Distribution and thickness — Recorded only in the northern part of the Belgian Basin, with a maximum thickness of 27 m (Tielt borehole).

Environment — Shallow marine.

Egem Sand Member

Name — Egem, a small village 6 km West of Tielt (West-Vlaanderen); introduced by Laga, Geets, Moorkens & Nolf: see Subgroup Lithostratigraphy and Maps (1980).

Rank — Member, corresponding to the Ypresian sands (Yd) of northwestern Belgium.

Stratotype — Egem: clay-sand pit Ampe; map-sheet 21/1; coordinates: x = 70.150, y = 190.150 (see Fig. 5).

Lithology — Very fine, micaceous and glauconitic shelly sand with coquinas and local thin clay lenses, in places strongly bioturbated, in other places clearly stratified.

Fossils — This Member is the most fossiliferous part of the Ieper Formation. Molluscs and ostracodes were recorded (Dhondt, 1967; Moorkens & Verhoeve, 1967); the otoliths are being revised (Steurbaut & Nolf, in prep.); the major microfossil groups were studied already (see Introduction); The stratotype sequence was sampled for nannofossils (see Fig. 5); its main part is attributable to unit VII, the uppermost 2 m to unit VIII. Unit IX was only encountered in the Kallo borehole, in the uppermost 3 m of the Egem Sand Member.

Boundaries — The Egem Sand Member rests on a heterogeneous silt with intercalated clays and fine sands, defined as the Kortemark Silt Member. In most of the basin, it is covered by a heavy dark-green clay of the Merelbeke Clay Member. In the type area (Egem-Tielt) it is overlain by a sandy clay to clayey sand with a basal sandstone, which is considered to represent the Pittem Clay Member.

Distribution and thickness — This member is restricted to the northwestern part of the Belgian Basin (Figs. 10, 12); its maximum recorded thickness is 23 m.

Environment — Shallow marine.

Panisel Sand Member

Name — Mont Panisel, 3 km southeast of Mons; the term "Psammites, sables et argiles du Mont Panisel" was introduced by d'Omalius d'Halloy (1862); the locality name Mont Panisel was used by Lyell (1852) and the term "Paniselien" by Dumont (1851).

Rank — Member, representing the upper part of the Ieper Formation in the southern part of the Belgian basin.

Stratotype — Mont Panisel Hill sequence; map-sheet 45/7-8; coordinates: x = 121.945, y = 125.155; glauconitic clayey sand with sandstone beds (lits de "grès lustrés") that passes into a grey silty clay towards the base (Marlière, 1967: 7). A core was recently drilled at the type locality recording a total thickness of about 17.50 m for the Panisel Sand Member. The results of this drilling operation will be discussed in a future paper (Steurbaut, in prep.).

Lithology — The Panisel Sand Member consists of glauconitic clayey sands with thin sandstone layers resting on a basal sandy grey-green clay. More to the North the sandstones are less common, whereas in the northeast (Schepdaal, Groot-Bijgaarden) the sequence is more clayey, with several thin lenses of bituminous, heavy clay.

Fossils — Generally poorly fossiliferous, but moulds of mollusc shells are present in the stratotype section. The nannoflora from the stratotype will be studied in the near future, but nannofossils from additional sampling localities (see Figs. 7, 8) are analysed in this publication. The lowermost part of the Panisel Sand Member appears to be attributable to unit VII as defined here; the uppermost part is attributable to unit VIII.

Boundaries — The unit rests on a heavy greyish clay of the Aalbeke Clay Member, except for the type locality where it directly overlies the Mons-en-Pévèle Sand Member. It is overlain by post-Ypresian deposits, except for the Rodeberg (Westouter) borehole sequence (see locality description).

Distribution and thickness — Known only from the southern part of the Belgian Basin (see Figs. 10, 12); its maximum recorded thickness is 30 m (Rodeberg).

Correlation — The Panisel Sand Member is a lateral equivalent of the Egem Sand Member.

Environment — Very shallow marine.

Merelbeke Clay Member

Name — Merelbeke, a small village 5 km South of Ghent; introduced by de Moor & Germis (1971).

Rank — Member; corresponds to the P1m-clay of the geological map.

Stratotype — No stratotype was designated by de Moor & Germis (1971) and here the boring 222/E3/SWK/F/DB11 of the Geological Institute Ghent, at Melle is proposed as lectostratotype; map-sheet: 22/1-2; coordinates: x = 109.125, y = 188.775 (see also de Moor & Geets, 1974: 145).

Lithology — Bluish dark grey, fine, silty, heavy clay with very thin lenses of fine sand, rich in organic material and small pyritic concretions; the sandy to silty intercalations become progressively more abundant to the East (*e.g.* the Erpe-borehole, see Fig. 8).

Fossils — No macrofossils were recorded and calcareous microfossils seem to be extremely rare (a few benthonic foraminifers, see Willems, 1982a). The pollen and spores were studied by Roche (1982) and the dinoflagellates by de Coninck (several papers, see Introduction). The Merelbeke Clay Member does not contain nannofossils but may be attributed to Martini's NP13 because in the Kallo well the underlying and overlying strata belong to this zone.

Boundaries — This member rests on the Egem Sand Member and is overlain by the Vlierzele Formation, which in the West consists of clayey sands to sandy clays of the Pittem Clay Member, and in the East of yellowish, glauconitic, micaceous sands.

Distribution and thickness — Present in the northwestern part of the basin (see Fig. 12); generally between 6 and 7 m thick, with a maximum of 15 m in the area around Ghent (according to de Moor & Geets, 1974).

Environment — Very shallow marine, with a substantial influx of fresh water.

Vlierzele Formation

Name — Vlierzele, a small village 17 km southeast of Ghent (Oost-Vlaanderen); introduced by Kaasschieter (1961).

Rank — Formation, established to include the glauconitic, clayey, fine sand to sandy clay of the Pittem Clay Member, and the yellowish, glauconitic, fine sand of the Vlierzele Sands *sensu* Kaasschieter (1961).

Stratotype — Designated by Kaasschieter (1961: 91-92): a sand pit at Bussegem (map-sheet 22/7; coordinates: x = 116.625, y = 181.100), showing the contact between the Lede and the Vlierzele Formations. The Vlierzele Formation consists of medium-grained, glauconitic, brownish-green sands with crossbedding and small lignitic bands.

Reference sections — Ursel well, TGO 81-9/B5 of the Laboratorium voor Toegepaste Geologie, Geological Institute Ghent; map-sheet 13/7; B5-II: 26.00-59.50 m; coordinates: x = 87.880, y = 204.160; B5-III: 57.00-82.00 m, coordinates: x = 87.910, y = 204.260 (composite profile due to technical problems in well B5-II).

Depth of unit: between 79.30 and 43.70 m.

Thickness: 35.60 m.

Lithology: glauconitic and micaceous grey-green fine sand with lignitic lenses and a few thin sandstone bands, clayey towards the base (= the Pittem Clay Member) (see Steurbaut & Daelman, in press).

Overlying unit: glauconitic, shelly, grey-green fine sand of the Oedelem Sand Member; the boundary is marked by coarse quartz grains.

Underlying unit: heavy grey clay of the Merelbeke Clay Member.

Macrofossils: a few shell fragments were recorded.

Microfossils: the calcareous nannofossils were studied by Steurbaut and Daelman (in press). The lowermost part (79.30 to 61.50) yields low-diversity assemblages attributable to unit X as defined here and to Martini's NP13; the associations from the uppermost part are richer and assignable to unit XI, which corresponds to Martini's NP14 (see also Fig. 8).

Boundaries — The Vlierzele Formation rests on the Merelbeke Clay Member in the northern part of the Basin (see Fig. 12). Somewhat to the South, in the Egem-Tielt area, it directly overlies the Egem Sand Member. In the extreme South, in the hills of southern Flanders, it rests on highly oxidized sands (remains of a fossil soil?) of the Panisel Sand Member (see Fig. 10). The Vlierzele Formation is covered by the Oedelem Sand Member in the western part of West-Vlaanderen and the extreme northwest of Oost-Vlaanderen, by the Aalter Sand Member in the area around Aalter (western part of Oost-Vlaanderen), in Ghent and in the hills in the South of West-Vlaanderen. In the central and eastern part of Oost-Vlaanderen, it is covered by the Lede Formation.

Distribution and thickness — Present in the northwest portion of the Belgian Basin and in several hills in the southern Flanders (see Figs. 10, 12). The thickness is highly variable because of discontinuous erosion; the maximum thickness recorded is 35.60 m (reference section).

Environment — Very shallow marine.

Pittem Clay Member

Name — Pittem, a small village near Tielt, 20 km South of Brugge; introduced by Geets (1979).

Rank — Member; represents the lowermost clayey part of the Vlierzele Formation in the western part of the Belgian Basin.

Stratotype — Designated by Geets (1979: 68): clay pit "Claerhout" at Pittem; map-sheet 21/5-6; coordinates: x = 747.25, y = 187.54; glauconitic clayey sand with a sandstone band.

Lithology — Alternation of clayey, glauconitic, fine sands and sandy clays with local sandstones.

Fossils — Very poor in macrofossils; devoid of nannofossils except in the Ursel well, where rather rich assemblages were found; they are attributable to unit X as defined here and to Martini's NP13.

Boundaries — See above, in the section on the Vlierzele Formation.

Distribution and thickness — Present only in the western part of the basin, with a maximum recorded thickness of 12 m.

ANNOTATED LIST OF LITHOSTRATIGRAPHIC TERMS USED FOR THE YPRESIAN

All terms are listed in alphabetical order (in English terminology). They are followed by the original definition and by the name of the author and the date of publication (in parentheses). A short description and evaluation of each term are also given.

Aalbeke Clay = Limon argileux d'Aalbeke (de Moor & Geets, 1975)
Termes used for the very fine silty clay, without sand fraction, that overlies the Roubaix Clay in the Kortrijk area; valid name, should be retained as a member.

Aalterbrugge Lignitic Horizon = Lignietrijke horizont van Aalter-Brug (Hacquaert, 1939)
Term introduced to describe the dark-green, micaceous and glauconitic fine sands with intercalated thin clay layers and lignitic lenses occurring North of the village of Aalter; valid name, to be retained with the rank of bed.

Anderlecht Clays = Argiles à Anderlecht (Vincent, 1874)
Term introduced to define the uppermost beds of the Anderlecht Hill including a basal grey clay with nodules that gradually changes into a glauconitic sandy clay with "psammitic" stonelayers and an uppermost glauconitic quartz sand; junior synonym of the term Mont Panisel Clays (d'Omalius d'Halloy, 1862).

Cassel glauconiferous clayey sands = sables argileux glauconieux de Cassel (Robaszynski, 1979)
Term used but not defined in Robaszynski's paper (1979) on the Palaeogene stratigraphy of northern France; should not be used.

Courtray Clay = Clay of Courtray (Lyell, 1852)
Obsolete name (= nomen oblitum).

Evergem Sands = Sables d'Evergem (Casier, 1946)
Term used only once by Casier (p. 198) to describe the fossiliferous sands from a borehole at Evergem, near Ghent, between 44 and 50 m depth; obsolete name (= nomen oblitum).

Egem Member (Laga, Geets, Moorkens & Nolf, 1980)
Term introduced without a definition in a lithostratigraphic scheme published in 1980 by the Subgroup Lithostratigraphy and Maps of the IGCP project 124; also cited by Geets & de Breuck (1983); valid name, should be retained as a member; stratotype designated in the Ampe quarry at Egem between + 40.20 and + 19.70 m T.A.W. (coordinates: x = 70.150, y = 190.150).

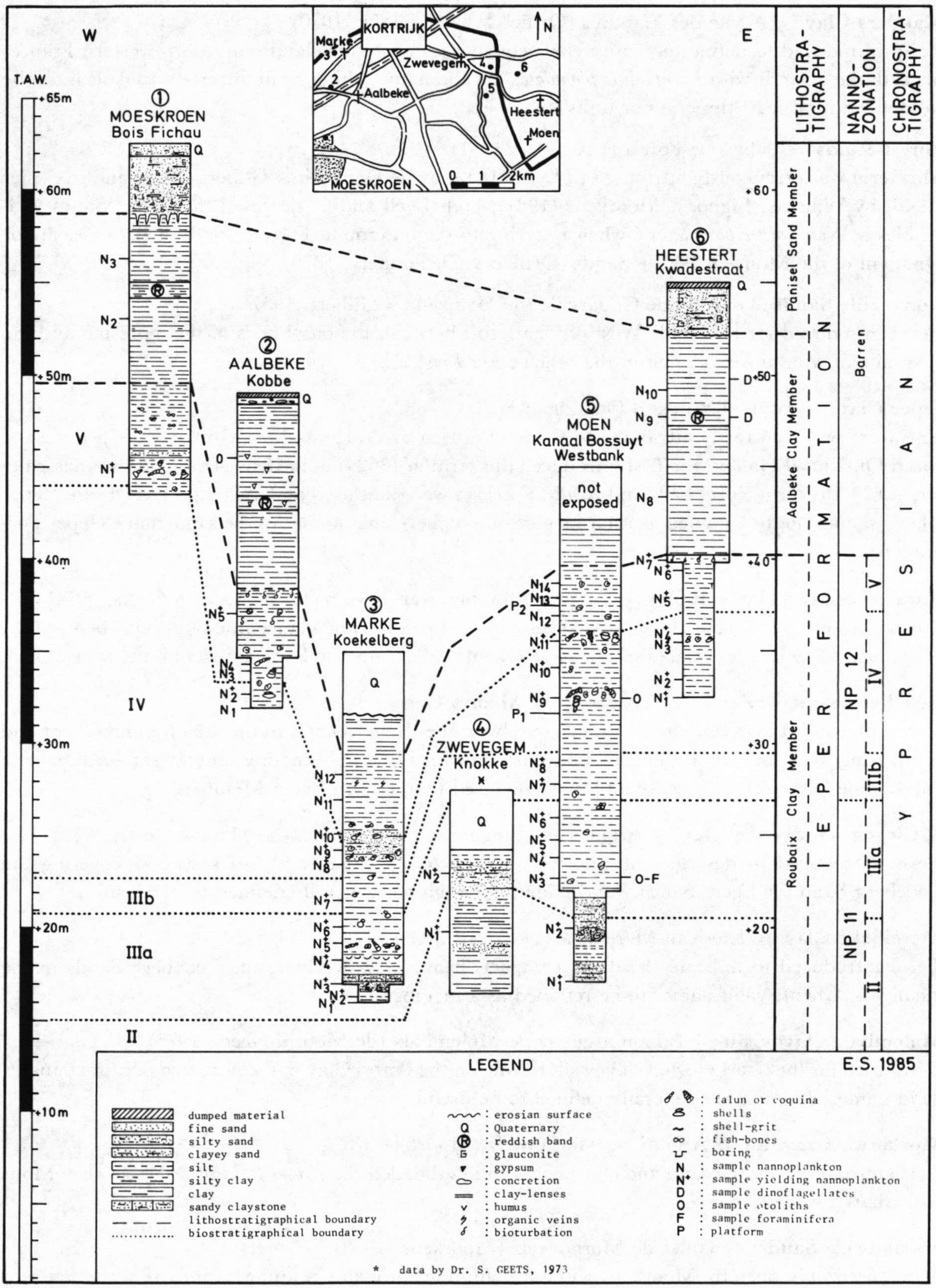


Fig. 3. Correlation of sections in the middle part of the Ieper Formation south of Kortrijk (southern West-Vlaanderen).

Flanders Clay = Argile des Flandres (Ortlieb & Chellonneix, 1870)
Term introduced to define the entire clay sequence in western Belgium and northwestern France, beneath the "Sands with *Nummulites planulatus*"; valid name, although of uncertain rank as it can be subdivided in at least three minor units (members).

Forest Sands = Sables de Forest (Feugueur, 1951)
This term was erroneously attributed to Lyell (1852) by de Heinzelin & Glibert (1957) and to Casier (1946) by Willems, Bignot & Moorkens (1981); both Lyell and Casier used the term "Sands with (Sables à) *Nummulites planulatus*" when referring to the outcrop at Forest, South of Brussels; junior synonym of the Mons-en-Pévèle Sands (Ortlieb & Chellonneix, 1870).

Godarville Sands = Sables de Godarville (de Heinzelin & Glibert, 1957)
Term introduced for the sands West of Charleroi, between the basal beds of the Ypresian and the "Argilite of Morlanwelz", rich in the brachiopod *Lingula tenuis*; valid name.

Ieper Clay = Argile d'Ypres (d'Omalius d'Halloy, 1862)
This term was incorrectly attributed to Dumont (1849) by de Heinzelin & Glibert (1957); in fact, it was d'Omalius d'Halloy who first introduced this term in 1862 (not in 1842 as thought by Kaasschieter, 1961); the term Ypres beds and Argile Yprésien were first used by Lyell (1852); the term "Ieper Clay" should not be retained as it forms part of a higher-ranking unit of the same name (Ieper Formation).

Kwatrecht sand-clay complex = Zand-kleicomplex van Kwatrecht (de Moor & Geets, 1974)
Term introduced to specify the tabular alternation of fine sand and glauconitic sandy clay beneath the Merelbeke Clay in a few places southeast of Ghent; valid name, to be retained with the rank of bed.

Ledeberg Sand = Zand van Ledeberg (de Moor & Geets, 1974)
Term introduced to define the fine sands overlying the "Ieper Clay" in the area around Ghent and comprising an upper, homogeneous fine sand unit resting on alternating tabular sand-clay layers; valid name, although now more and more replaced by the term Egem Member.

Meilegem sandy-silty clay = Argile sablo-limoneuse de Meilegem (de Moor & Geets, 1975)
Term introduced to describe the poorly sorted, heterogeneous sandy to silty clay covering the Ledeberg Sand (or Egem Sand); valid name, although too generally defined to be useful.

Merelbeke Clay = Klei van Merelbeke (De Moor & Germis, 1971)
Term introduced to indicate the dark, compact, heavy clay overlying the Ledeberg Sands in the vicinity of Ghent; valid name, to be retained as a member.

Molembaix clayey silt = Limon argileux de Molembaix (de Moor & Geets, 1975)
Term used for the poorly sorted clayey silt resting on the Pottes Clay in the northern part of Hainaut; valid name, although too generally defined to be useful.

Morlanwelz argilite = Argilite de Morlanwelz (Mourlon, 1873)
Term introduced for the sand and clay beds with interbedded claystones ("argilites") between Mons and Charleroi; valid name.

Morlanwelz Sands = Sables de Morlanwelz (Moorkens, 1968)
Name used only once by Moorkens without definition; probably a junior synonym of the Peissant Sands.

Mons-en-Pévèle Sands = Sables de Mons-en-Pévèle (Ortlieb & Chellonneix, 1870)
Term introduced to describe the very fine and soft, yellowish-green sands rich in the foraminifer *Nummulites planulatus*, on top of the Mons-en-Pévèle Hill (northern France); these sands occur in the hills from Ronse to Mont Panisel and are considered by Gosselet (1874) to be the lateral equivalent of the Roubaix Clay; valid name, to be retained.

Mont-Héribu Member (de Coninck, Geets & Willems, 1983)
Term used for the lower part of the Ieper Formation South of Mons, comprising alternated silty sand and clayey silt; valid name, to be retained as a unit with the rank of bed.

Mont Panisel psammites, sands and clays = Psammites, sables et argiles du Mont Panisel (d'Omalius d'Halloy, 1862)
Term introduced for the different rock types represented in the Mont Panisel hill sequence; the term "Paniselien" was used already by Dumont (1851); the locality name Mont Panisel appears already in Lyell's (1852) paper, although it was Mourlon (1873, 1879) who gave a detailed description and location of the different beds; valid name, to be retained as a member.

Mouscron sandy clay = Argile sableuse de Mouscron (Feugueur, 1951)
Term introduced for a sandy clay with *N. planulatus* present in the Mouscron borehole and considered to represent the lateral equivalent of the Mons-en-Pévèle and the Forest Sands; obsolete name (= nomen oblitum).

Nederzwalm coars silt = Limon grossier de Nederzwalm (de Moor & Geets, 1975)
Term used for the poorly sorted, heterogeneous, silty middle part of the Flanders Clay in the southwestern part of Oost-Vlaanderen; valid name, although too generally defined to be useful.

Orchies Clay = Argile d'Orchies (Gosselet, 1874)
Term introduced to separate the blue to greyish, almost non-fossiliferous plastic clay with sandy base from the overlying, fossiliferous, siltier Roubaix Clay in northwestern France; valid name, to be retained as a member.

Peissant Sands = Sables du Bois de Peissant (Briart & Cornet, 1878)
Term informally introduced to describe the sandy middle part of the "Argilite de Morlanwelz" in the southeast part of the Belgian Basin; valid name, although very poorly defined.

Pittem Member = Lid van Pittem (Geets, 1979)
Term introduced for poorly sorted clayey sands with interbedded clay lenses, which between Roeselare and Tielt rest on very fine, fossiliferous sands (= the Egem Sands); valid name, to be retained.

Pottes Clay = Argile de Pottes (de Moor & Geets, 1975)
Term used for the poorly sorted basal silty clay that forms the base of the Ieper Formation in the northern part of Hainaut; valid name, although too generally defined to be useful.

Roncq Clay = Argile de Roncq (Gosselet, 1883)
Term introduced for the blue sandy clay overlying the Roubaix Clay in the Roubaix area; the same term was used by Kaasschieter (1961) for the Merelbeke Clay, a similar clayey unit that, however, occurs much higher in the stratigraphic sequence; valid name, but preferably not be used as it has often been a source of confusion.

Roubaix Clay = Argile de Roubaix (Gosselet, 1874)
Term introduced for the grey to brownish, fossiliferous clay with silty to sandy intercalations, overlying the Orchies Clay and constituting the upper part of the "Argile de Flandres" *sensu* Ortlieb & Chellonneix (1870); valid name, to be used.

Sands with (Sables à) **Nummulites planulatus** (Lyell, 1852)
Term introduced for the very fine, fossiliferous sands rich in *N. planulatus* around Brussels; invalid name, based on a combination of palaeontological and lithological criteria, cannot be used as a formal lithostratigraphic unit.

Tielt glauconitic bed = Lit glauconifère de Tielt (de Coninck, 1973)
Term informally used for the glauconitic layer present in the Kallo, Ooigem and Tielt boreholes; valid name, to be retained as a unit with the rank of bed.

Trélon Sands = Sables de Trélon (Gosselet, 1883)
Term introduced for yellowish sands and underlying grey, clayey sands with silex, resting on white, non-stratified Tertiary (? Palaeogene) sand in the vicinity of Trélon (France), a small town 15 km west of Chimay; valid name.

Vlierzele Sands (Kaasschieter, 1961)
Term defined to include fine-grained, well-sorted, glauconitic sands, locally with (worm?)tubes, crossbedding and intercalated plastic-clay beds; valid name, to be retained as a formation.

Wahagnies Clay = Argile de Wahagnies (Ortlieb & Chellonneix, 1870)
Term used for a greyish-blue, plastic clay with abundant gypsum crystals, which underlies the Mons-en-Pévèle Sand in northern France; obsolete name (= nomen oblitum).

Wevelgem Sand Complex = Complex sableux de Wevelgem (de Moor & Geets, 1975)
Term used for coarser sediments (fine sands to coarse silts) in the middle part of the Roubaix Clay, which occur in a narrow, West-East oriented area South of Kortrijk; valid name, although too generally defined to be useful.

ALPHABETICAL LIST OF SAMPLE LOCALITIES

Fifty outcrops and boreholes were studied (see Fig. 2 for locations). The lithological logging and mapping of the exposures were carried out by the authors. Much of the borehole data comes from the files of the Belgian Geological Survey.

The locality names are listed alphabetically. Each name is followed, in parentheses, by one of the abbreviations A. (= Antwerpen), B. (= Brabant), H. (= Hainaut), O.-V. (= Oost-Vlaanderen) or W.-V. (= West-Vlaanderen), indicating the provinces (see Fig. 2).

Aalbeke (W.-V.), clay pit Kobbe (also known as clay pit Vermeulen); map-sheet 29/5; coordinates: x = 68.450, y = 164.300.
General comments: a 16 m thick clayey sequence is exposed, showing the contact between the Roubaix Clay and Aalbeke Clay Members; a 2.8 m deep borehole was drilled at the bottom of the pit (see Fig. 3).
Provenance of samples and stratigraphical data: see Fig. 3.
Calcareous nannoplankton: sample N5^{+} contains a fairly well-preserved, low-diversity assemblage (19 species), assignable to Martini's *Tribrachiatus orthostylus* Zone (= NP12) (co-occurrence of *T. orthostylus* and *Discoaster lodoensis*); the abundance of *Toweius pertusus*, presence of *Toweius* sp. and *Chiasmolithus* aff. *expansus*, and absence of *Pontosphaera exilis* support assignment of the sample to the here proposed biostratigraphic unit V.

Avelgem (O.-V.), boring 98W-918 of the Belgian Geological Survey; map-sheet 29/7; coordinates: x = 86.475, y = 163.765.
General comments: the borehole was drilled to a depth of 84.80 m, penetrating 70 m of Cenozoic (Quaternary 0-21, Ypresian 21-44, Landenian 44-70) and 10 m of Mesozoic (Turonian) sediments; the top of the Paleozoic lies at a depth of 81.50 m and consists of Silurian(?) schists.
Calcareous nannoplankton: not observed (three samples were examined at 29, 44 and 45 m depth, respectively).

Bailleul, brickyard Dubois & Fils (northwestern France); map-sheet 28/5; coordinates: x = 35.625, y = 159.375.
General comments: abandoned, partially flooded clay pit, only the uppermost 6 m are visible; some difficulties have arisen in the course of the sequence, and minor errors or omissions may thus occur. The uppermost part of the section showed slumping over most of its length or was covered with dumped material, and the non-altered, *in situ* strata could only be reached by swimming; the beds dip 30° to the northwest and consists of c. 50 m thick silty clays intercalated with a few thin *Turritella* shell bands and thin layers of shell grit (Fig. 4).
Provenance of samples and stratigraphical data: see Fig. 4.
Calcareous nannoplankton: the assemblages are badly preserved and very poor in number of species as well as individuals; sample N_9^+ contains *Rhabdosphaera truncata* and *Chiasmolithus eograndis*, while *Discoaster lodoensis* is absent; therefore the sample is attributable to subunit IIIa and, thus, to the upper part of NP11; according to what has been observed in nearby contemporaneous sequences (Fig. 3), we may assume that in the Bailleul clay pit the boundary between NP11 and NP12 lies a few metres above level W3.

Brussels (B.), Cité administrative, boring 88-1439(2) of the Belgian Geological Survey; map-sheet 31/3; coordinates: x = 149.640, y = 171.405.
General comments, provenance of samples and stratigraphy: see Fig. 7.
Calcareous nannoplankton: samples N_9, N_8 and N_7 contain rather rich, but poorly preserved assemblages (about 20 species), assignable to the here proposed biostratigraphic unit III and probably to Martini's NP11 (absence of *D. lodoensis*); samples N_6 and N_4 are less diverse and are referable to unit II.

Diksmuide (W.-V.), boring 51W-144 (VI, b) of the Belgian Geological Survey; map-sheet 20/1; coordinates: x = 41.850, y = 194.150.
General comments: the 245.75 m deep borehole penetrated 15 m of Quaternary, 117 m of Ypresian, 37 m of Landenian and 68.30 m of Cretaceous deposits; the top of the Palaeozoic lies at the depth of 237.30 m; the Ypresian (from 15 to 132 m) consists of a grey, compact clay with a few intercalations of silt; it occurs as a uniform clay without typical differentiation..
Calcareous nannoplankton: not studied.

Egem (W.-V.), clay pit-sand pit Ampe; map sheet 21/1; coordinates: x = 70.150, y = 190.150.
General comments: this is the only locality in the Belgian Basin where the upper part of the Ieper Formation is almost entirely exposed; the Kortemark Silt Member has been only recently exposed by new commercial excavations. It consists of (ascending): a micaceous silt, the top of which has channel structures filled with a laminated fine sand containing concentrations of worm tubes; a thin clay; a thin sand bank; and a 4 m thick silty clay. The Egem Sand Member consists of a 20 m thick greenish, glauconitic, shelly, fine sand with a few thin intercalations of clay. The Pittem Clay Member is represented by a basal 40 cm thick shelly sandstone and by a 4.5 m thick sandy clay with thin sand- or claystone banks (see de Coninck & Nolf, 1979; also Fig. 5). In this exposure, and further to the South, the Merelbeke Clay Member is absent between the Egem Sand and the Pittem Clay Members, indicating a major hiatus.
Provenance of samples and stratigraphy: see Fig. 5.
Calcareous nannoplankton: only sample N_2 of the Kortemark Silt Member yielded nannofossils; it is assigned to biostratigraphic unit VI. The samples of the Egem Sand Member contain low-diversity, poorly preserved assemblages (maximum of 18 species) assignable to the upper part of Martini's NP12; the uppermost ones, N_6 and N_7 of the Egem-1978 section, contain *Nannoturba robusta* and *Discoaster cruciformis* and should, therefore, be attributed to unit VIII. The underlying ones do not contain the above mentioned species, but show a few *Rhabdosphaera crebra, Discoaster elegans* and *Sphenolithus radians*, allowing assignment to unit VII.

Erpe (Aalst) (O.-V.), boring 71E-34 of the Belgian Geological Survey; map-sheet 22/8, coordinates: x = 123.050, y = 179.700.

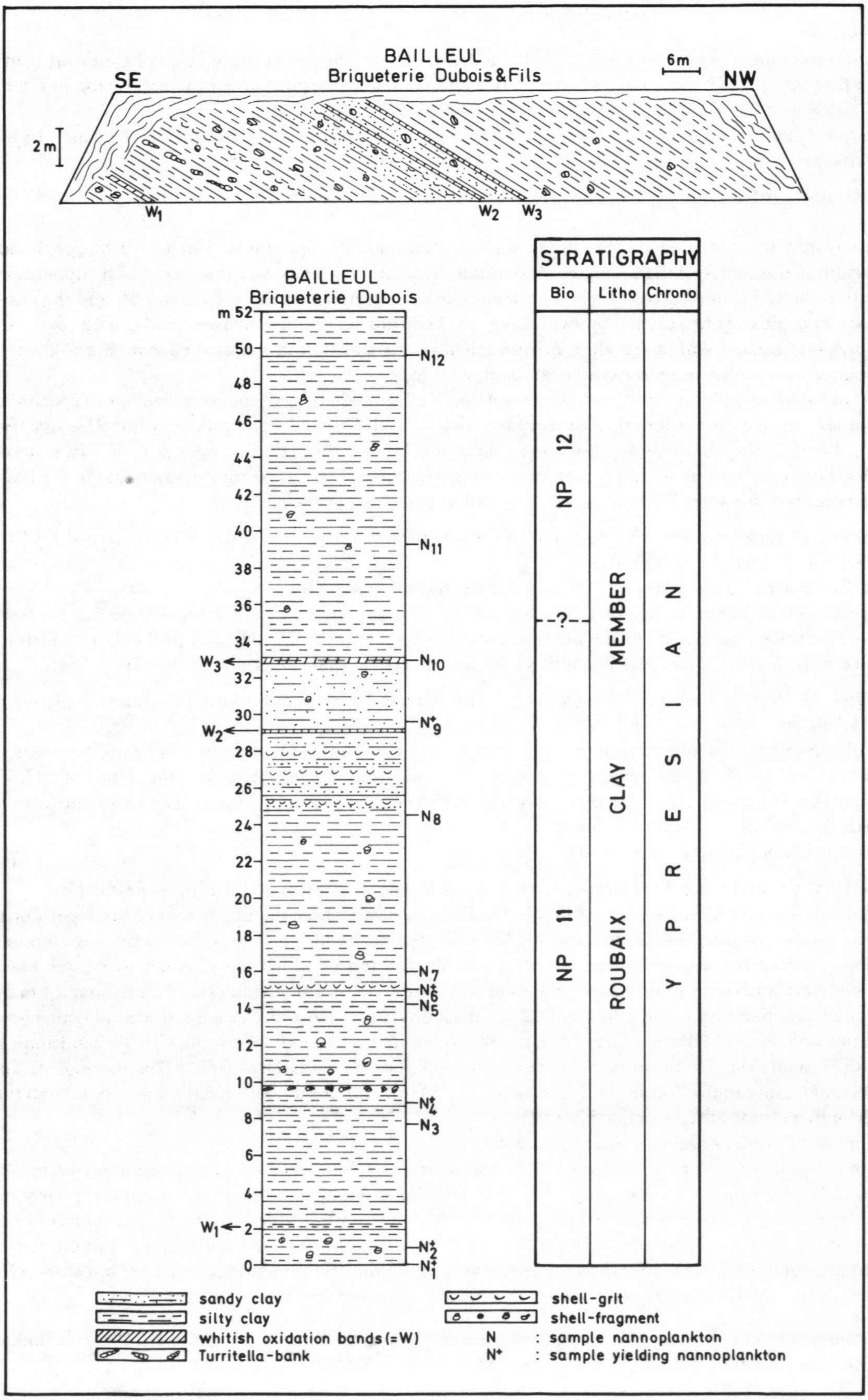


Fig. 4. The Ieper Formation in the claypit Dubois & Fils at Bailleul (northern France).

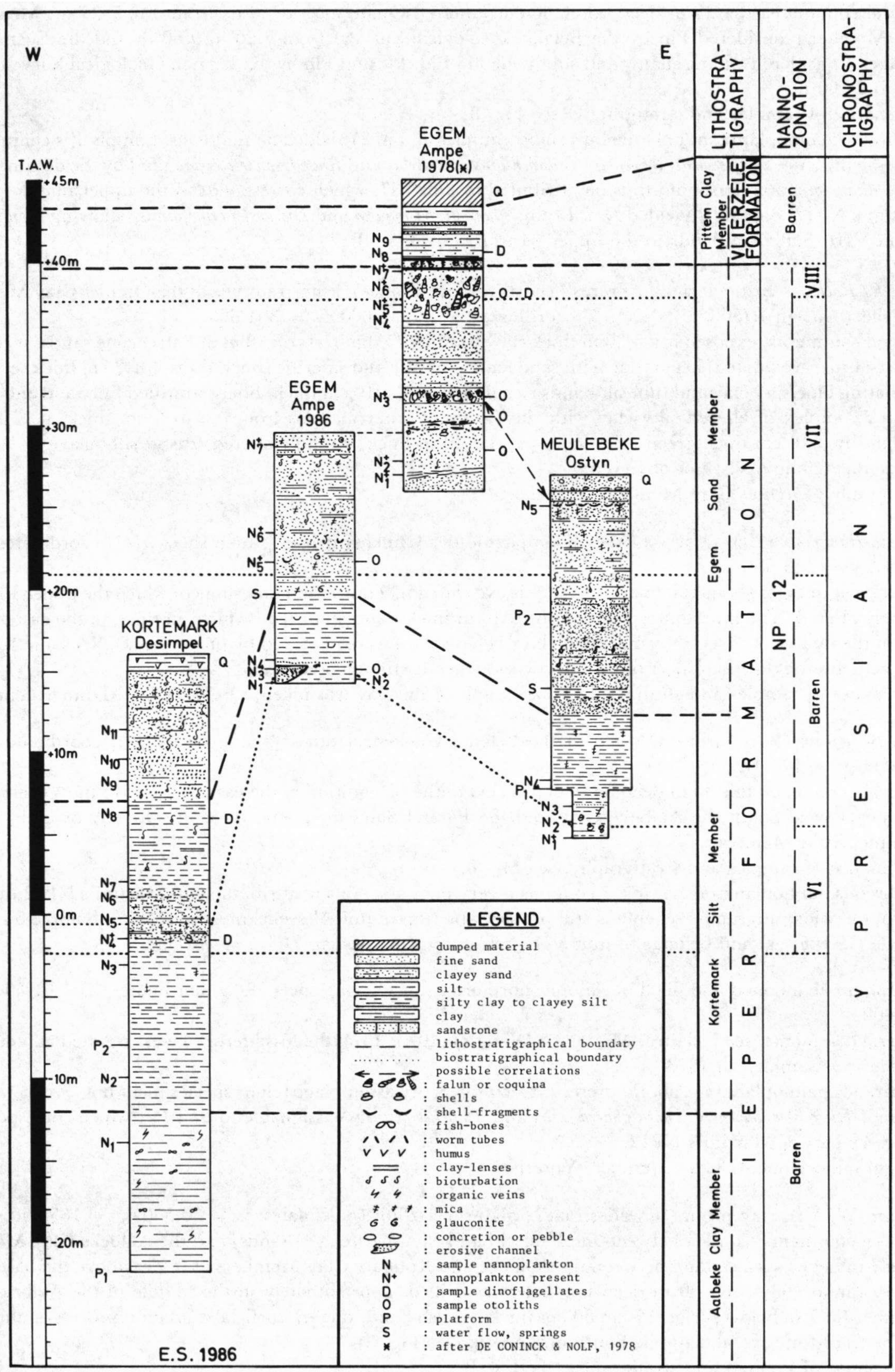


Fig. 5. Sections in the upper part of the Ieper Formation in central West-Vlaanderen.

General comments: the 25 m deep borehole encountered Quaternary deposits from 0 to 7.20 m, Merelbeke Clay Member (considered Pln by the Belgian Geological Survey) from 7.20 to 9.60 m and the Egem Sand Member (considered "Paniselian" and subdivided in Pld, Plc and Plb by the Belgian Geological Survey) from 9.60 to 25.00 m.
Provenance of samples and stratigraphy: see Fig. 8.
Calcareous nannoplankton: only the lowermost samples (1 and 2) yielded nannofossils. Sample 1 is characterized by the presence of *Discoaster lodoensis, Tribrachiatus orthostylus* and *Rhabdosphaera crebra*, and by the dominance of *Zygrhablithus bijugatus*; it should thus be attributed to unit VII, which corresponds to the upper middle part of Martini's NP12. Sample 2 yielded *D. lodoensis, Nannoturba robusta* and *Discoaster cruciformis*, allowing assignment to unit VIII that corresponds to the upper part of Martini's NP12.

Flines-lès-Râches, "Briqueterie Bar Frères" (northwestern France), lectostratotype of the Orchies Clay Member; map-sheet Carvin 1(/50.000), XXV-5; coordinates: x = 659.600, y = 304.300.
General comments: exposed is a 5.30 m thick clayey sequence that rests on 18 m of Palaeocene sands; it consists of a basal rusty (oxidated) heavy clay with sand lenses, pyritic and sideritic concretions, a 1.20 m thick section of alternating blue silty clay and thin silt bands rich in gypsum, a 10 cm thick, finely stratified fine sand and a 1.60 m thick complex of altered silty clay with silty to sandy intercalations from 0.5 to 5 cm thick; it is in turn overlain by a 10 cm thick green, plastic clay and 2.40 m thick, strongly altered, rusty, silty clay.
Calcareous nannofossils: not observed.
Stratigraphy: Orchies Clay Member, Ypresian.

Gaurain-Ramecroix (H.), quarry of the "Compagnie des Ciments belges"; map-sheet 37/7; coordinates: x = 88.150, y = 143.650.
General comments: about 100 m deep quarry is excavated in Tournesian limestone of which the upper 10 m are strongly altered. The limestone is overlain by a 10 m thick Landenian sand which, in turn, in the easternmost part of the quarry is covered by Ypresian clays. These clays were observed by one of us (D.N.) some 10 years ago; actually, only a small part of this clayey sequence is still exposed.
Provenance of samples and stratigraphy: one sample of the clay was taken; Orchies Clay Member; Ypresian.

Groot-Bijgaarden (B.), boring 87E-536 of the Belgian Geological Survey; map-sheet 31/2; coordinates: x = 142.000, y = 174.475.
General comments: this 50 m deep borehole has led to the recognition of the eastern facies of the Ypresian: the Mons-en-Pévèle Sand, the Aalbeke Clay and the Panisel Sand members; these are directly overlain by the Wemmel Sand Member.
Provenance of samples and stratigraphy: see Fig. 8.
Calcareous nannoplankton: sample 1 contains a very poor assemblage attributable to Martini's NP12; its position in our biostratigraphic scheme is still problematic (top of unit V seems most probable). Sample 6 is more diverse (19 species) and belongs to unit VIII (presence of *N. robusta, D. cruciformis,* etc.).

Halluin, an abandoned and filled in clay pit (northern France); map-sheet 28/8; coordinates: x = 61.300, y = 163.400.
General comments: see Delattre, Mériaux & Waterlot (1973: 157); the fossiliferous layer, situated at 5 m below surface, was sampled in 1973.
Calcareous nannoplankton: poorly preserved, low-diversity assemblage (eight species including *Tribrachiatus orthostylus, Discoaster lodoensis, Pontosphaera exilis* and *Toweius pertusus*) assignable to unit IV, which corresponds to the lower part of Martini's NP12.
Stratigraphy: Roubaix Clay Member, Ypresian.

Heestert (W.-V.), clay pit in "Kwadestraat"; map-sheet 29/6; coordinates: x = 80.550, y = 165.550.
General comments: contact between the Panisel Sand Member (clayey sands) and the Aalbeke Clay Member, some 3 m below surface, and between the Aalbeke and Roubaix Clay Members at 0.5 m above the base of the quarry (anno 1984); a 7.00 m deep borehole was drilled; approximately in the middle of the Aalbeke Clay Member (at 7 m below surface) is an 80 cm thick reddish band, due to surficial oxidation processes; this band can be traced in several clay pits South of Kortrijk (see Fig. 3).
Provenance of samples and stratigraphy: see Fig. 3.

Calcareous nannoplankton: poorly preserved, low-diversity assemblages; the lowermost ones (N_1 to N_4) are assignable to unit IV, the overlying ones (N_5-N_7) to unit V (absence of *Pontosphaera exilis*); units IV and V correspond to the lower part of Martini's NP12.

Hérinnes (H.), boring 111E-593 of the Belgian Geological Survey. Map-sheet 37/2; coordinates: x = 80.750, y = 115.700.
General comments: the 65 m deep borehole penetrates the Pleistocene (0-9 m), Ypresian (9-20 m), Landenian (20-54 m), and Turonian (54-57 m) deposits, and a Visean dolomitic limestone (57-65 m).
Provenance of samples and stratigraphy: four samples from the heavy clay between 9 and 20 m depth, were studied; Orchies Clay Member, Ypresian.
Calcareous nannoplankton: not observed.

Ieper (W.-V.), clay pit St. Jan, stratotype of the Ypresian *sensu* Moorkens (1968), now abandoned and filled in; map-sheet 28/2; coordinates: x = 48.062, y = 174.000.
General comments: until recently, a 12.40 m thick clayey sequence consisting of an upper 8 m thick sandy clay and a lower heavy, more compact clay (see Kaasschieter, 1961: 90; see Fig. 9) was observable under a 60 cm thick Quaternary cover.
Provenance of samples and stratigraphy: see Fig. 9.
Calcareous nannoplankton: not observed.

Kallo (O.-V.), "Fort la Perle": well 27E-148 of the Belgian Geological Survey; map-sheet 15/2; coordinates: x = 144.86, y = 217.84.
General comments: see Steurbaut, 1986a, b.
Provenance of samples, calcareous nannoplankton and stratigraphy: see Table I and Fig. 6.

Knokke (W.-V.), "Hazegraspolder": well 11E-138 of the Belgian Geological Survey; map-sheet 5/6; coordinates: x = 78.776, y = 226.370.
General comments: see Steurbaut, in press.
Provenance of samples, calcareous nannoplankton and stratigraphy: see Steurbaut, in press; also Fig. 6.

Kortemark (W.-V.), clay pit Desimpel; map-sheet 20/3; coordinates: x = 58.050, y = 190.400.
General comments: the Ieper Formation, exposed under a 1 m thick clayey Quaternary cover, consists of a lowermost heavy clay, the Aalbeke Clay Member, an intermediate silty clay to clayey silt with sandy intercalations, the Kortemark Silt Member, and an uppermost sandy unit, the Egem Sand Member (see Fig. 5).
Provenance of samples and stratigraphy: see Fig. 5.
Calcareous nannoplankton: only sample N_4 yielded nannofossils: seven species have been identified, among which *D. lodoensis, T. orthostylus* and *Chiasmolithus* aff. *expansus*, indicating Martini's NP12 and the here proposed unit VI.

Kruishoutem (O.-V.), "Gendarmerie": boring 84E-1362(I) of the Belgian Geological Survey; map-sheet 29/4; coordinates: x = 90.600, y = 177.350.
General comments: the 125 m deep borehole was drilled into the Palaeocene sands (116-125 m), penetrating 16 m of Pleistocene loam and sand and 100 m of Ypresian clays.
Provenance of samples and stratigraphy: see Fig. 7.
Calcareous nannoplankton: only the middle part of the sequence yielded nannofossils; sample 5 contains *T. orthostylus, Toweius magnicrassus, Rhabdosphaera sola* and *Ellipsolithus macellus* and is, together with sample 6, attributable to Martini's NP11 and to the here proposed unit II; sample 8 contains a very diverse nannoflora (30 species) that indicates subunit IIIb corresponding to the base of Martini's NP12.

Lauwe (W.-V.), clay pit "Céramiques et Briqueteries du Littoral", now abandoned and filled in; map-sheet 29/5; coordinates: x = 67.975, y = 165.140.
General comments: this clay pit was accessible until the early 70's, exposing beneath a thin Quaternary cover a 10 m thick clayey sequence dipping 10° to the northwest and cut by several small faults; several fossiliferous bands were recorded.
Provenance of samples: one sample, taken by Moorkens in 1968 from the lowermost part of the quarry was examined (see de Coninck, 1977b: 234).
Calcareous nannoplankton: fairly rich and moderately well-preserved assemblage (25 species) assignable to

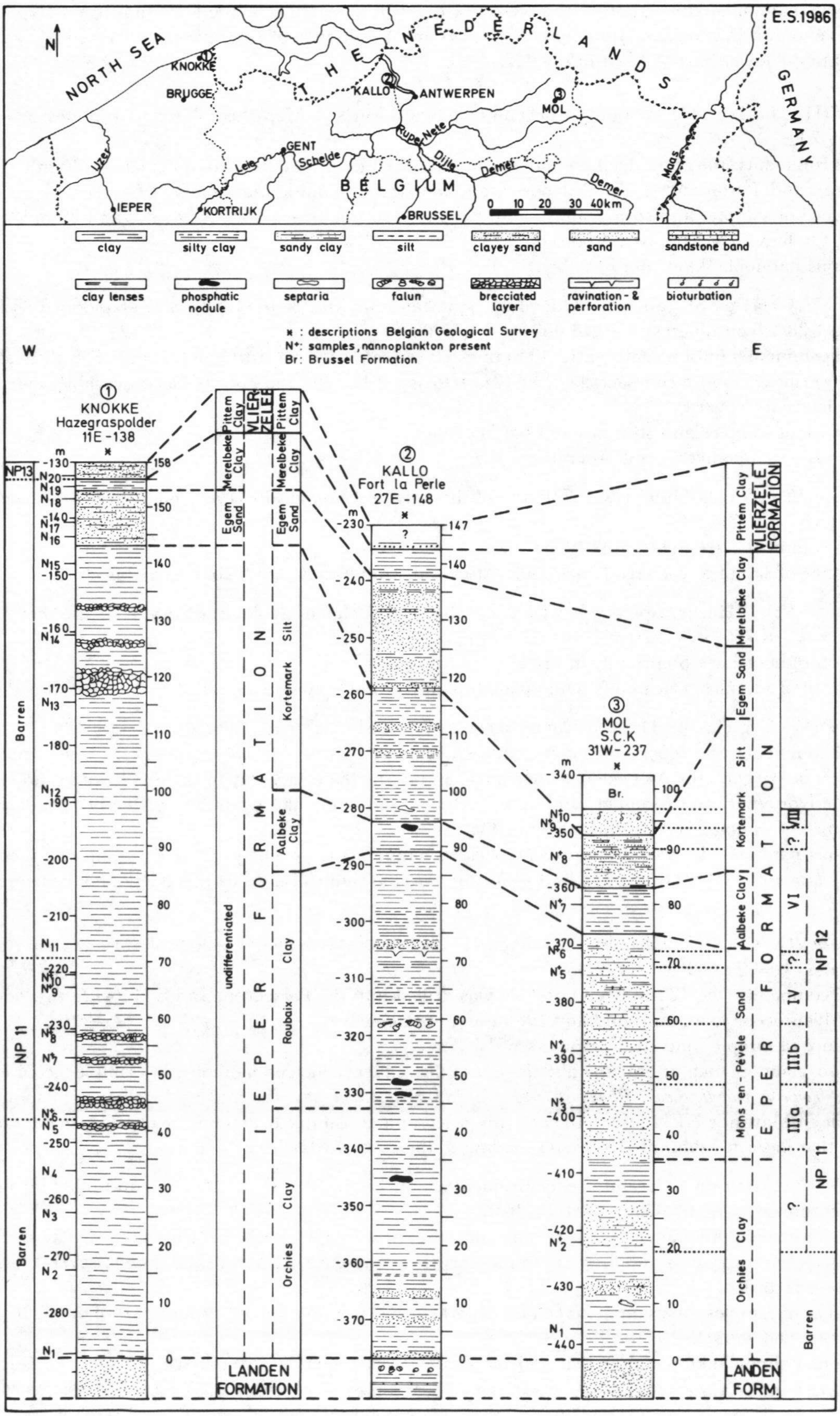


Fig. 6. Borehole sections through the Ypresian in northern Belgium between Knokke and Mol.

Martini's NP12 (presence of *Discoaster lodoensis* and *Tribrachiatus orthostylus*); the presence of *Toweius pertusus*, *Toweius* sp. and *Pontosphaera exilis*, together with the above mentioned species, indicates unit IV.
Stratigraphy: Roubaix Clay Member, Ypresian.

Maldegem (O.-V.), well TGO 81-9/D4 of the Laboratorium voor Toegepaste Geologie, Geological Institute Ghent; map-sheet 13/7-8; coordinates: x = 86.860, y = 205.900.
General comments: a 102 m deep borehole was drilled, but only the lowermost interval, from 78 to 102 m, was cored; it represents the top of the Ieper Formation (the Egem Sand Member).
Provenance of samples: 10 samples were examined in the interval from 102.00 to 85.00 m; the uppermost ones, from 89.50 m (= -68.50 m T.A.W.) onwards, are barren (see Fig. 8).
Calcareous nannoplankton: the lowermost assemblages, from -81.00 to -75.50 T.A.W., contain *Rhabdosphaera crebra, Sphenolithus moriformis, Discoaster lodoensis* and *Tribrachiatus orthostylus*, and thus are attributable to our biostratigraphic unit VII; the overlying assemblages, from -75.70 to -68.50 m T.A.W., belong to unit VIII (presence of *Discoaster cruciformis*, absence of *S. moriformis* and *R. crebra*); units VII and VIII represent the uppermost part of Martini's NP12.

Marke (W.-V.), clay pit Koekelberg; map-sheet 29/5; coordinates: x = 69.000, y = 166.800.
General comments: a few years ago, a new clay pit was excavated West of the Marke village, a 100 m South of the railway Kortrijk-Mouscron; the Ieper Formation is overlain by a 2 m thick Quaternary sandy cover and a 1.30 m thick band of dumped reddish brick debris; the Ieper Formation consists of an upper, 2 m thick, crumbling, heavy clay of the Aalbeke Clay Member and a lower, 13 m thick, more heterogeneous Roubaix Clay Member: a silty clay to clayey silt with sandy intercalations, bands of shell grit and a basal soft, glauconitic, sandy claystone that rests on a glauconitic silty clay with considerable glauconite nests (= glauconite-level); a 1 m deep borehole was drilled at the bottom of the pit (see Fig. 3).
Provenance of samples and stratigraphy: see Fig. 3.
Calcareous nannoplankton: poorly preserved assemblages of moderate diversity, except for the lowermost one, N_1, which contains 30 species; assemblages N_1 to N_6 are characterized by the presence of *Rhabdosphaera sola* and *Rhabdosphaera truncata* and by the absence of *Discoaster lodoensis*, and are therefore assignable to the here proposed subunit IIIa which correlates with the top of Martini's NP11; assemblage N_7 belongs to subunit IIIb (presence of *D. lodoensis*); assemblages N_8 to N_{10} belong to unit IV; units IIIb and IV correspond to the basal part of Martini's NP12.

Mater (O.-V.), Hauwaert: boring 85W-18(VII) of the Belgian Geological Survey; map-sheet 30/1; coordinates: x = 99.950, y = 169.300.
General comments: the 76 m deep borehole penetrated 9 m of Pleistocene grey to brown loam, 18 m of greyish clayey sand with sandstone bands (the Egem Sand Member), 4 m of grey sandy clay (the Panisel Sand Member), 8 m of grey plastic clay (the Aalbeke Clay Member), and 37 m of grey clay with sandy intercalations (the Roubaix Clay Member) (see Fig. 7).
Provenance of samples and stratigraphy: see Fig. 7.
Calcareous nannoplankton: samples 1, 2 and 3 contain poorly preserved assemblages of low-diversity. Sample 1 is assignable to unit II (upper part of Martini's NP11: presence of *T. orthostylus*, absence of *D. lodoensis* and *Rhabdosphaera truncata*); sample 2 to unit IV (lower part of Martini's NP12, presence of *D. lodoensis* and *P. exilis*, absence of *R. truncata*); and sample 3 to unit V (presence of *Chiasmolithus* aff. *expansus*, absence of *P. exilis*). Samples 7 and 8 are more diverse and belong to unit VII (upper part of Martini's NP12, presence of *Rhabdosphaera crebra, Chipragmalithus armatus* and *Reticulofenestra* sp.). Sample 9 is the richest (28 species) and is also attributable to unit VII (presence of *R. crebra*).

Melle (O.-V.), Zuivelstation; boring 70E-183 of the Belgian Geological Survey; map-sheet 22/6; coordinates: x = 111.125, y = 187.425.
General comments: the 225 m deep borehole penetrated 176 m of Cenozoic (0-123.50 m = Ypresian, 123.50-176 m = Landenian), 12 m of Cretaceous (176-188 m) and 37 m of Early Palaeozoic deposits; the Ypresian is represented by (descending): 3 m of fine, clayey sand (Vlierzele Formation), 2.50 m of grey, heavy clay (Merelbeke Clay Member), 22.50 m of green, very fine sand with sandstone intercalations (Egem Sand Member), 12 m of firm, very fine, clayey sand (Kortemark Silt Member), 12 m of green, heavy clay (Aalbeke Clay Member), 46 m of heterogeneous, fossiliferous, silty clay to clayey silt (Roubaix Clay Member), and 25 m of grey, heavy clay (Orchies Clay Member).

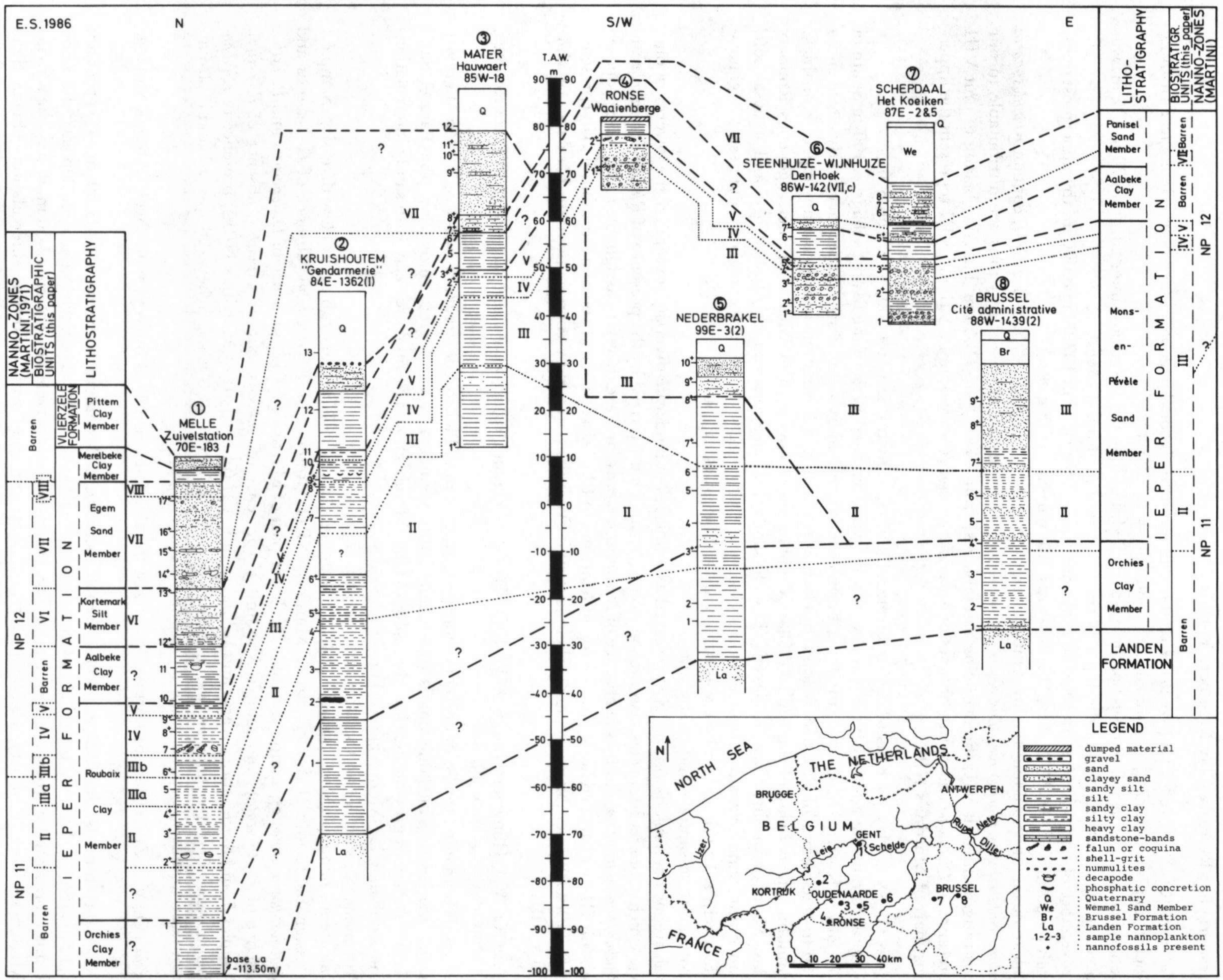


Fig. 7. Correlation of sections in the Ieper and Vlierzele Formations in southern Oost-Vlaanderen and Brabant along a N-S and W-E line

Provenance of samples and stratigraphy: see Fig. 7.
Calcareous nannoplankton: moderately well-preserved, fairly diverse assemblages (see Fig. 7 for their biostratigraphic position).

Mere (O.-V.), Molenbeek: boring 71W-202 of the Belgian Geological Survey; map-sheet 22/8; coordinates: x = 121.925, y = 179.550.
General comments: the 50 m deep borehole penetrated a heterogeneous Quaternary cover (0-11 m), resting on grey clayey sand that passes into a sandy clay and is considered to represent the Kortemark Silt Member (11-15 m); a heavy, plastic clay (15-29 m) of the Aalbeke Clay Member; and a 21 m thick grey, sandy clay with intercalated fossiliferous sand layers, the Roubaix Clay Member (see Fig. 8).
Provenance of samples, calcareous nannoplankton and stratigraphy: see Fig. 8.

Meulebeke (W.-V.), clay pit "Ostyn"; map-sheet 21/6; coordinates: x = 77.100, y = 182.000.
General comments: the upper part of the Ieper Formation crops out under a very thin (90 cm) Quaternary cover; it consists of an upper, 14 m thick, sandy unit with a few thin clay intercalations, considered to represent the Egem Sand Member, and a lower, 5 m thick, clayey silt to silty clay representing the Kortemark Silt Member; a 3 m deep borehole was drilled at the bottom of the pit (Fig. 5).
Provenance of samples and stratigraphy: see Fig. 5.
Calcareous nannoplankton: only the lowermost sample yielded nannofossils: a poorly preserved, low-diversity assemblage assignable to biostratigraphic unit VI, which corresponds to the middle part of Martini's NP12 (presence of *D. lodoensis* and *D. distinctus*, and absence of *P. exilis, Reticulofenestra* sp., *T. pertusus* and *R. crebra*).

Moen (W.-V.), west bank of the Bossuit Canal; lectostratotype of the Roubaix Clay Member; map-sheet 29/6; coordinates: x = 79.775, y = 164.725.
General comments: the west bank of the Bossuit Canal shows one of the most complete exposures of the Roubaix Clay Member. It is easily accessible and unlikely to disappear in the near future; therefore, it is chosen as the lectostratotype of the Roubaix Clay Member (see Fig. 3). This unit is overlain by a blue, heavy clay representing the basal part of the Aalbeke Clay Member. The uppermost 30 cm of the exposure are altered and distorted by slumping and run-off erosion. A 5 m deep borehole was drilled at the base of the canal-cutting; it has led to the recognition of a lower, more silty to sandy part of the Roubaix Clay Member (Fig. 3).
Provenance of samples and stratigraphy: Fig. 3.
Calcareous nannoplankton: Table II.

Moeskroen (H.), clay pit "Bois Fichau" (also known as "Mulier"); map-sheet 29/5; coordinates: x = 68.575, y = 161.850.
General comments: in the western corner of the pit, beneath a thin (70 cm) Quaternary cover, is a 3 m thick, greenish, strongly bioturbated, glauconitic clayey sand with small clay lenses. This sand is considered to represent the Panisel Sand Member. It rests on a grey, heavy clay of the Aalbeke Clay Member with its typical, 90 cm thick, reddish oxidation band occurring 4 m below the top, which in turn rests on a fossiliferous silty clay of the Roubaix Clay Member.
Provenance of samples and stratigraphy: see Fig. 3.
Calcareous nannoplankton: only the lowermost sample yielded nannofossils, it is assignable to unit V (presence of *D. lodoensis, T. orthostylus, Toweius pertusus* and *Chiasmolithus* aff. *expansus*; absence of *P. exilis*).

Mol (A.), S.C.K.: boring 31W-237 of the Belgian Geological Survey; map-sheet 17/1; coordinates: x = 198.350, y = 211.750.
General comments: this 577 m deep borehole was drilled into the Maastrichtian calcarenite. The Ieper Formation is recorded from 346 to 443 m and consists, in ascending order, of a basal grey clay with silty and sandy intercalations, the Orchies Clay Member (443-407 m); a green, laminated, very fine sand with some thin clay lenses, the Mons-en-Pévèle Sand Member (407-367.60 m); an 8 m thick, grey, heavy clay with thin silt lenses, representing the Aalbeke Clay Member (367.60-359.50 m); an 8 m thick, very fine, clayey sand with laminae of clay, the Kortemark Silt Member (359-351.00 m); and 5 m of green, strongly bioturbated, micaceous, very fine sand, considered to represent the Egem Sand Member (see Fig. 6). The Mol borehole is the only locality in the Belgian Basin where the Aalbeke Clay Member is not completely decalcified and bears a fairly rich nannoflora.
Provenance of samples and stratigraphy: Fig. 6.
Calcareous nannoplankton: 10 samples were examined, of which only the lowermost one was devoid of nannofossils; the other contain low-diversity assemblages, except for sample N_4 which contains numerous *Pontosphaera*

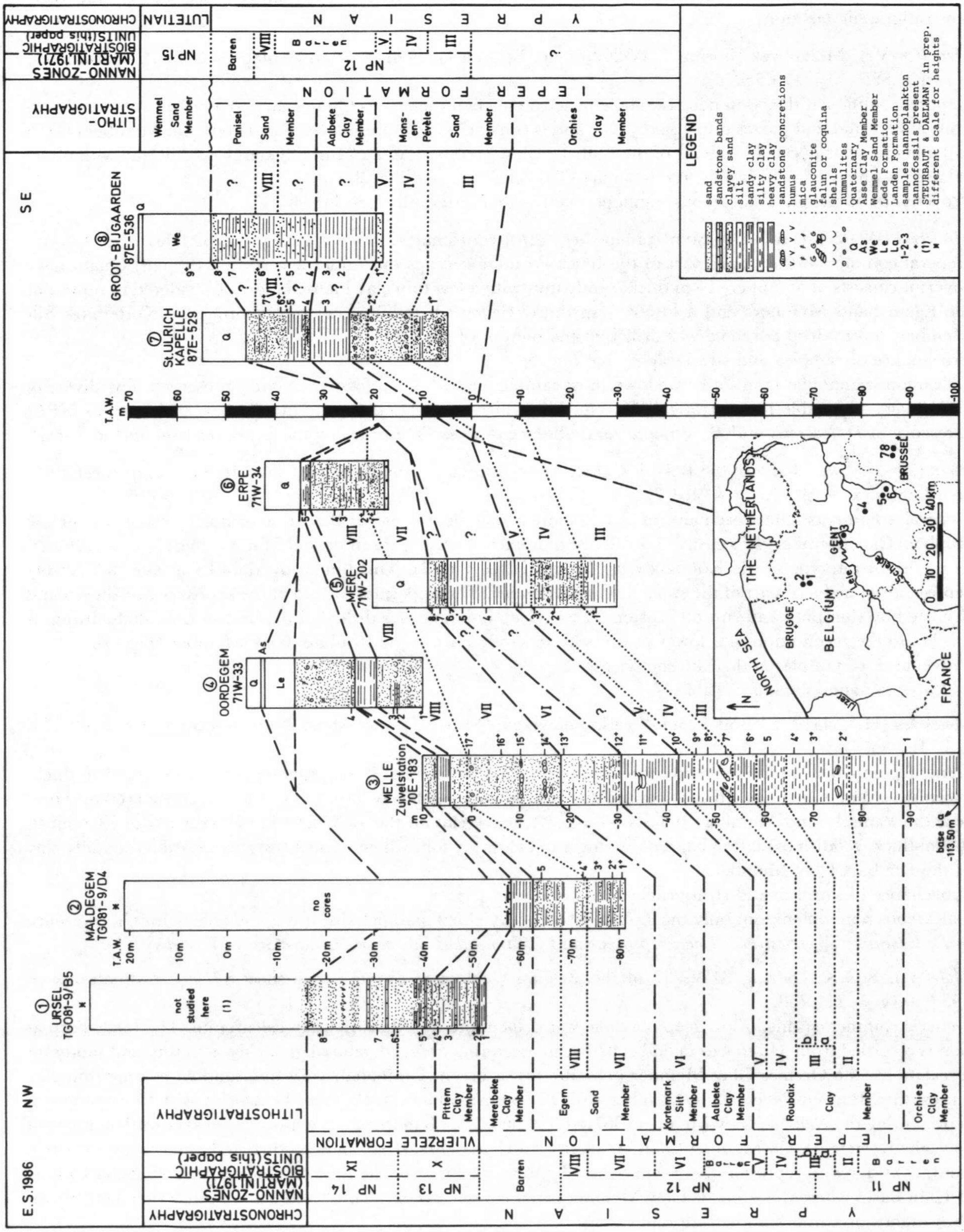


Fig. 8. Correlation of sections in the Ieper and Vlierzele Formations in Oost-Vlaanderen and Brabant along a NW-SE line.

exilis and some *Rhabdosphaera sola*; as various forms, such as *Rhabdosphaera truncata* and *Ellipsolithus macellus*, are absent in sample N4, it might be attributed to subunit IIIb; sample N5 is assignable to unit IV, samples N6, N7 and N8 to unit VI, and samples N9 and N10 to unit VIII (presence of *Discoaster cruciformis* and *Nannoturba robusta*).

Molembaix (H.), boring 112W-412 of the Belgian Geological Survey; map-sheet 37/; coordinates: x = 83.975, y = 154.175.
General comments: the 61 m deep borehole penetrated 7 m of Pleistocene loam, 10 m of Ypresian clay, 32 m of Landian sands and clays, and 30 cm of Turonian chalk. It was terminated in a crinoidal limestone of Visean age (Gulinck & Legrand, 1968).
Provenance of samples and stratigraphy: two samples taken at 14.50 and 16.00 m depth were examined; Orchies Clay Member, Ypresian.
Calcareous nannoplankton: not observed.

Mons (H.), Mont-Héribu; map-sheet 45/7; coordinates: x = 119.750, y = 124.150.
General comments: a 7 m thick, heterogeneous, sandy to silty clay with sandy base, named Mont-Héribu Clay Member (de Coninck *et al.*, 1983), rests on a strongly bioturbated glauconitic Landenian sand (see Dupuis & Robaszynski, 1986: 15).
Provenance of samples and stratigraphy: one sample taken 2 m above the base of the clay was examined; Orchies Clay Member (Mont-Héribu Clay Bed), Ypresian.
Calcareous nannoplankton: not observed.

Mons (H.), Bois-la-Haut: le Bocage; map-sheet 45/8; coordinates: x = 121.945, y = 125.155.
General comments: fine, yellowish, nummulitic sands of the Mons-en-Pévèle Sand Member are exposed along a trail near the hamlet le Bocage. They are overlain by a highly glauconitic sandy clay and bioturbated glauconitic clayey sands, which are considered to represent the Panisel Sand Member (see Dupuis & Robaszynski, 1986: 16).
Provenance of samples, calcareous nannoplankton and stratigraphy: a sample from the Panisel Sand Member taken 2 m below the top of the sequence was devoid of nannofossils. Another sample, from the yellowish calcareous sands at c. 18 m below the top (unit b of Dupuis & Robaszynski, 1986) contained a fairly diverse and rich nannoflora including *Rhabdosphaera sola, Toweius pertusus* and *Toweius* sp. Since *Rhabdosphaera truncata, Chiasmolithus eograndis* and *Cruciplacolithus delus* are absent, it might belong to the top of the here proposed unit II, which corresponds to the top of Martini's NP11.

Mons-en-Pévèle, France: boring made by Dr. Geets along the road Mons-en-Pévèle – Bersée, 1 km East of the Mons-en-Pévèle village centre; map-sheet Carvin (1/50.000) XXV-5; coordinates: x = 655.300, y = 309.075.
General comments: 2.50 m of fossiliferous, glauconitic, slightly clayey sand is present under a 2.50 m thick Quaternary cover.
Provenance of samples: two samples taken at 3 and 4 m depth were examined (samples G 55/4 and G 55/5 of Geets).
Calcareous nannoplankton: rich and diverse associations (35 species) assignable to subunit IIIa, which corresponds to the uppermost part of Martini's NP11 (presence of *Chiasmolithus eograndis, Cruciplacolithus delus* and *Ellipsolithus macellus*; absence of *Discoaster lodoensis*).
Stratigraphy: Mons-en-Pévèle Sand Member, Ypresian.

Nederbrakel (O.-V.), "Top-Bronnen": boring 99E-3(2) of the Belgian Geological Survey; map-sheet 30/6; coordinates: x = 108.175, y = 166.350.
General comments: the 125 m deep borehole penetrated 4 m of Quaternary, 6 m of grey, clayey sand and 58 m of grey, plastic clay (both Ypresian), and 17 m of green, clayey sand (Landenian). The top of the Palaeozoic was reached at a depth of 85 m and was represented by grey, very soft, altered clay.
Provenance of samples and stratigraphy: see Fig. 7; the Nederbrakel borehole shows the transition of the Mons-en-Pévèle Sand Member into the Roubaix Clay Member.
Calcareous nannoplankton: samples 7, 8 9 and 10 contain fairly rich assemblages assignable to the here proposed unit III (presence of *Chiasmolithus eograndis* (sample 7), *Rhabdosphaera sola* (samples 9 and 7), and *Discoaster barbadiensis* (samples 7, 9 and 10).

Oordegem (O.-V.), boring 71W-33 of the Belgian Geological Survey; map-sheet 22/7; coordinates: x = 117.350, y = 182.675.
General comments: the following succession was penetrated: 2.40 m of yellow sandy loam (Pleistocene), 1 m of sandy clay (Asse Clay Member), 6.80 m of yellow, fine sand with basal gravel (Lede Formation), 7 m of yellowish, glauconitic, micaceous sand resting on 4.30 m of dark grey sand (Vlierzele Formation), 4.50 m of grey, compact clay (Merelbeke Clay Member), and 9.90 m of grey to green, glauconitic, clayey sand with sandstone bands (Egem Sand Member).
Provenance of samples and stratigraphy: see Fig. 8.
Calcareous nannoplankton: only the lowermost sample yielded nannofossils, including *Nannoturba robusta, Discoaster lodoensis* and *Reticulofenestra* sp.; therefore, it is attributable to unit VIII (probably the lower part).

Orchies, France: "tuilerie de Beuvry-les-Orchies", 2 km South of the Orchies village centre; now abandoned and filled in; map-sheet St. Amand-les-Eaux (1/50.000) XXVI-5; coordinates: x = 664.950, y = 306.800.
General comments: 5.50 m of alternated, heavy clay layers and silt bands were exposed under a 3 m thick Quaternary cover, resting on a whitish Palaeocene sand.
Provenance of samples: two samples taken at 1 and 3 m above the base of the clay were examined.
Calcareous nannoplankton: not observed.
Stratigraphy: Orchies Clay Member, Ypresian.

Ronse (O.-V.), "Waaienberge": old railway cutting; map-sheet 30/5; coordinates: x = 98.525, y = 159.000.
General comments: 12 m of brownish, nummulitic, clayey sands of the Mons-en-Pévèle Sand Member are overlain by a 3 m thick, crumbling, grey, compact clay of the Aalbeke Clay Member.
Provenance of samples and stratigraphy: see Fig. 7.
Calcareous nannoplankton: the lowermost sample (N_1) contains *Rhabdosphaera truncata, Cruciplacolithus delus* and *Chiasmolithus eograndis*; it is therefore attributable to unit III (probably IIIa, as *D. lodoensis* is absent). Sample N_2 contains a low-diversity assemblage indicating unit V (presence of *Chiasmolithus* aff. *expansus* and *Toweius pertusus*; absence of *Pontosphaera exilis*).

Saint-Maur (H.), clay pit, at present completely flooded; map-sheet 37/6; coordinates: x = 80.475, y = 140.348.
General comments: according to Dr. Geets' observations (in de Coninck *et al.*, 1983: 84), a 3 m thick clayey sequence was exposed in this pit; additional 7 m of sandy clays were encountered in a borehole at the bottom of the pit; presently abandoned and completely flooded.
Stratigraphy: Orchies Clay Member (Mont Héribu Bed), Ypresian.

Schepdaal (B.), "Het Koeiken": borings 87E-2 and 87E-5 of the Belgian Geological Survey; map-sheet 31/2; coordinates: x = 139.025, y = 169.550 (87E-2); x = 139.100, y = 169.500 (87E-5).
General comments: Fig. 7(7) is a compilation of two borehole sections drilled 100 m apart; boring 2 starts at 81 m T.A.W., boring 5 at 70 m T.A.W.; the following sequence is exposed: 1.20 m of Quaternary loam; 11.80 m of yellowish, clayey sand with basal gravel (Wemmel Sand Member); 12 m of heterogeneous deposits, dark-green clayey sands passing gradually into dark-grey to blackish sandy clay with numerous sandstone bands (= Panisel Sand Member); 3 m of green to grey heavy clay (= Aalbeke Clay Member); and 13.50 m of greyish, fossiliferous, micaceous fine sand with a basal sandstone band (= Mons-en-Pévèle Sand Member) (see Fig. 7).
Provenance of samples and stratigraphy: see Fig. 7.
Calcareous nannoplankton: sample 2 yielded *Tribrachiatus orthostylus, Pontosphaera exilis* and *Toweius* sp., indicating unit III; sample 5 is characterized by the presence of *Rhabdosphaera crebra, Discoaster lodoensis* and *D. distinctus*, and is assignable to unit VII.

Sint-Denijs (W.-V.), Zwevegem: clay pit; map-sheet 29/6; coordinates: x = 76.600, y = 163.250.
General comments: 5 m of colour-mottled, altered heavy clay of Aalbeke Clay Member is exposed; not sampled.

Sint-Ulrich-Kapelle (B.), boring 87E-529 of the Belgian Geological Survey; map-sheet 31/2; coordinates: x = 140.950, y = 174.650.
General comments: the 50 m deep borehole penetrated 9 m of Quaternary loam; 12.50 m of heterogeneous deposits consisting of a 7 m thick, green, glauconitic, fine sand and 3 m thick grey, plastic clay, which rest on a green sandy clay with intercalations of sand (= Panisel Sand Member); 8 m of grey, plastic, heavy clay (=

Aalbeke Clay Member); and a 20 m thick, green, glauconitic fine sand with *Nummulites* (= Mons-en-Pévèle Sand Member).
Provenance of samples and stratigraphy: see Fig. 8.
Calcareous nannoplankton: the two uppermost samples contain low-diversity assemblages assignable to unit VIII (presence of *Nannoturba robusta* and *Tribrachiatus orthostylus*, absence of *Rhabdosphaera crebra*); sample 2 contains *Pontosphaera exilis, D. lodoensis* and *T. orthostylus*, indicating unit IV; sample 1 is very poor in nannofossils and might belong to unit III.

Steenhuize-Wijnhuize, Herzele (O.-V.): Den Hoek, boring 86W-142(VII, C) of the Belgian Geological Survey; map-sheet 30/3; coordinates: x = 114.700, y = 169.675.
General comments: the 25 m deep borehole penetrated 5.30 m of brown Quaternary loam, 2.20 m of grey-green sandy clay (Panisel Sand Member), 6 m of grey-blue plastic clay (Aalbeke Clay Member), and 11.50 m of alternating silty nummulitic sand and sandy clay (Mons-en-Pévèle Sand Member) (see Fig. 7).
Provenance of samples and stratigraphy: see Fig. 7.
Calcareous nannoplankton: the three lowermost samples contain highly diverse assemblages (32 taxa in sample 3) and are attributable to subunit IIIb (presence of *Rhabdosphaera sola, Pontosphaera punctosa* and *Discoaster lodoensis*). Sample 4 is attributable to unit IV and sample 5 to unit V (absence of *P. exilis*). Sample 7 contains *Discoaster lodoensis, Rhabdosphaera crebra* and *Rhabdosphaera* sp., indicating unit VII.

Tielt (W.-V.), "Lanno": boring 68E-169 of the Belgian Geological Survey; map-sheet 21/6; coordinates: x = 76.425, y = 187.550.
General comments: the 162.80 m deep borehole penetrated 2 m of Quaternary and dumped material; 2.20 m of greenish-grey, micaceous sand and clay with sandstone fragments probably representing the Pittem Clay Member; 22.50 m of very fine sand with thin layers of clay (from 4.40 to 26.80 m representing the Egem Sand Member); 27 m of heterogeneous deposits, mainly silty clays with intercalated bands of fine sand and lenses of heavy clay (from 26.80 to 59.80 representing the Kortemark Silt Member); a 36 m thick, very-green, heavy clay (from 53.80 to ca 90 m representing the Aalbeke Clay Member); a 60 m thick compact clay with silty intercalations and a few shell bands, decalcified towards the base and a 4 m thick basal sand (from c. 90 to 153.80 m, rest of the Ieper Formation) and from 153.80 to 162.80 m very fine Landenian sands.
Provenance of samples and calcareous nannoplankton: not examined by us, but studied by Müller & Willems (1981: 67).

Torhout (W.-V.), Pottebezemhoek: temporary exposure, during works along the railway Kortrijk-Brugge; map-sheet 20/4; coordinates: x = 62.525, y = 197.550.
General comments: contact between the Merelbeke Clay Member (grey-green, heavy clay) and the Pittem Clay Member (alternating glauconitic, clayey sands and sandy clays with sandstone bands) is 7.60 m below the top of the excavation.
Provenance of samples: one sample from 7.00 m below the top of the exposure was examined.
Calcareous nannoplankton: low-diversity assemblage without important taxa.

Ursel (O.-V.), Drongengoedbos: boring TGO 81/9/B5 of the Laboratorium voor Toegepaste Geologie, Geological Institute Ghent; map-sheet 13/7; B5-II: 26.00-59.50, coordinates: x = 87.880, y = 204.160; B5-III: 57.00-82.00 m, coordinates: x = 87.910, y = 204.260.
General comments: the Ursel well was drilled in three phases at three closely spaced sites. Only the interval from 44.00 to 82.00 m (= -15.50 to -53.50 m T.A.W.) is discussed in this paper.
The following sequence was encountered: from 82.00 to 79.30 m grey, stiff clay (Merelbeke Clay Member); from 79.30 to 70.00 m grey clayey sands with intercalated clay layers and sandstone bands (Pittem Clay Member); and 26 m of grey-green, micaceous, glauconitic fine sand with sandstone bands (rest of the Vlierzele Formation) and thin peat layers towards the top (the Aalterbrugge Lignitic Horizon).
Provenance of samples and stratigraphy: see Fig. 8.
Calcareous nannoplankton: see Steurbaut & Daelman, in press.

Velaines (H.), boring 112W-413 of the Belgian Geological Survey; map-sheet 37/3; coordinates: x = 88.300, y = 151.950.
General comments: the 48 m deep borehole penetrated 3 m of Quaternary loam, 12 m of Ypresian clay, 19 m of Landenian sand with a black clay and pebble bed at the base, and 14 m of Visean limestone.

Provenance of samples and stratigraphy: four samples from the Ypresian clay were examined; Orchies Clay Member, Ypresian.
Calcareous nannoplankton: not observed.

Wahagnies, "Briqueteries de Libercourt" (northwestern France); map-sheet Carvin (1/50.000), XXV-5; coordinates: x = 649.250, y = 310.600.
General comments: about 8 m thick, blue, heavy, silty clay with basal pebble bed, containing shark teeth, turtle fragments, and pyritic and sideritic concretions, is exposed under a 4 m thick Quaternary cover rich in reworked tests of *Nummulites planulatus* (from the Mons-en-Pévèle Sands); it rests on greenish, rather coarse sands (the Palaeocene Ostricourt Sands).
Calcareous nannoplankton: not observed.
Stratigraphy: Orchies Clay Member, Ypresian.

Westouter (W.-V.), Rodeberg: boring 95W-150 of the Belgian Geological Survey; map-sheet 28/5; coordinates: x = 36.325, y = 165.000.
General comments: the following succession was penetrated: 0-10.40 m: yellowish, brown to reddish, clayey, fine sand with wood fragments (Quaternary); 10.40-16 m: rusty-brown, glauconitic medium sand with ironstone bands (= Diest Formation); 16-22 m: orange to yellow medium sand (= ?Lede Formation); 22-46 m: khaki-coloured, glauconitic, slightly clayey medium sand with shell fragments and a few shell layers, coarser toward the base (= Aalter Sand Member); 46-60.70 m: Vlierzele Formation, comprising at ca 46.50 m a whitish altered soft sandstone band, from 47-47 m: a khaki-coloured glauconitic clayey sand, from 57-59.20 m: greyish-green clay with small calcareous nodules, sandstone and shell fragments and at ca 59.50 m a dark-green glauconitic sand; 60.70-90.80 m: Panisel Sand Member, comprising from 60.70-84.50 m: a green glauconitic clayey sand with shell fragments, and thin clay layers, greyish and less glauconitic towards the base; the top from 60 to c. 62 m is oxidized and represented by a dark-brown to reddish medium sand (remains of a fossil soil?), from 84.50-90.80 m: brown-grey sandy clay; 90.80-92.50 m (end of the boring): grey-green heavy clay (=. Aalbeke Clay Member).
Provenance of samples and calcareous nannoplankton: of 16 samples studied only two yielded nannofossils. N_1, from the interval 80.70-81.20 m, contains a very impoverished association assignable to Martini's NP12 (presence of *D. lodoensis* and *T. orthostylus*). N_2, from 32.50 m below surface, is extremely poor in nannofossils. only three forms, all stratigraphically unimportant, were identified.

Zonnebeke (W.-V.), clay pit "Van Biervliet"; map-sheet 28/3; I: coordinates: x = 51.300, y = 174.750; II: coordinates: x = 51.000, y = 174.800.
General comments: the Ieper Formation is mined in two pits c. 200 m apart (see Fig. 9). Pit I exposes altered clayey sands (Kortemark Silt Member), resting on a bluish, slightly organic clay (?Aalbeke Clay Member), and overlain by a Quaternary cover; this cover is irregularly developed, increasing in thickness from South to North; in the northernmost part of the pit is an erosive channel filled in with peat fragments. Pit II shows a hard-to-interpret clayey sequence, which probably represents a lower part of the Aalbeke Clay Member. It is strongly faulted and locally folded, and contains a few septaria; the dip is to the northeast; the tilt is due to local tectonics (?mud diapirism).
Provenance of samples and stratigraphy: see Fig. 9.
Calcareous nannofossils: not observed.

Zwevegem (W.-V.), clay pit Knokke; map-sheet 29/6; coordinates: x = 78.800, y = 165.950.
General comments: the clay pit is abandoned and almost completely filled in. The following succession was recorded by Dr Geets in 1973: a heterogeneous Quaternary cover from 0 to 3.22 m; 70 cm thick brown silt and 60 cm thick, grey-green sand more clayey towards the base, resting on some 6.50 m of a grey, silty clay of the Roubaix Clay Member (Fig. 3).
Provenance of samples and stratigraphy: see Fig. 3.
Calcareous nannoplankton: sample N_1 is rather poor in nannofossils and is attributable to the here proposed unit II. Sample N_2 is very diverse (31 taxa); it contains *Rhabdosphaera sola, R. truncata, Lophodolithus nascens* and *Chiasmolithus eograndis*, indicating subunit IIIa.

Zwevegem (W.-V.), construction pit of a new lock on the Bossuit Canal; map-sheet 29/2; coordinates: x = 77.900, y = 168.600.

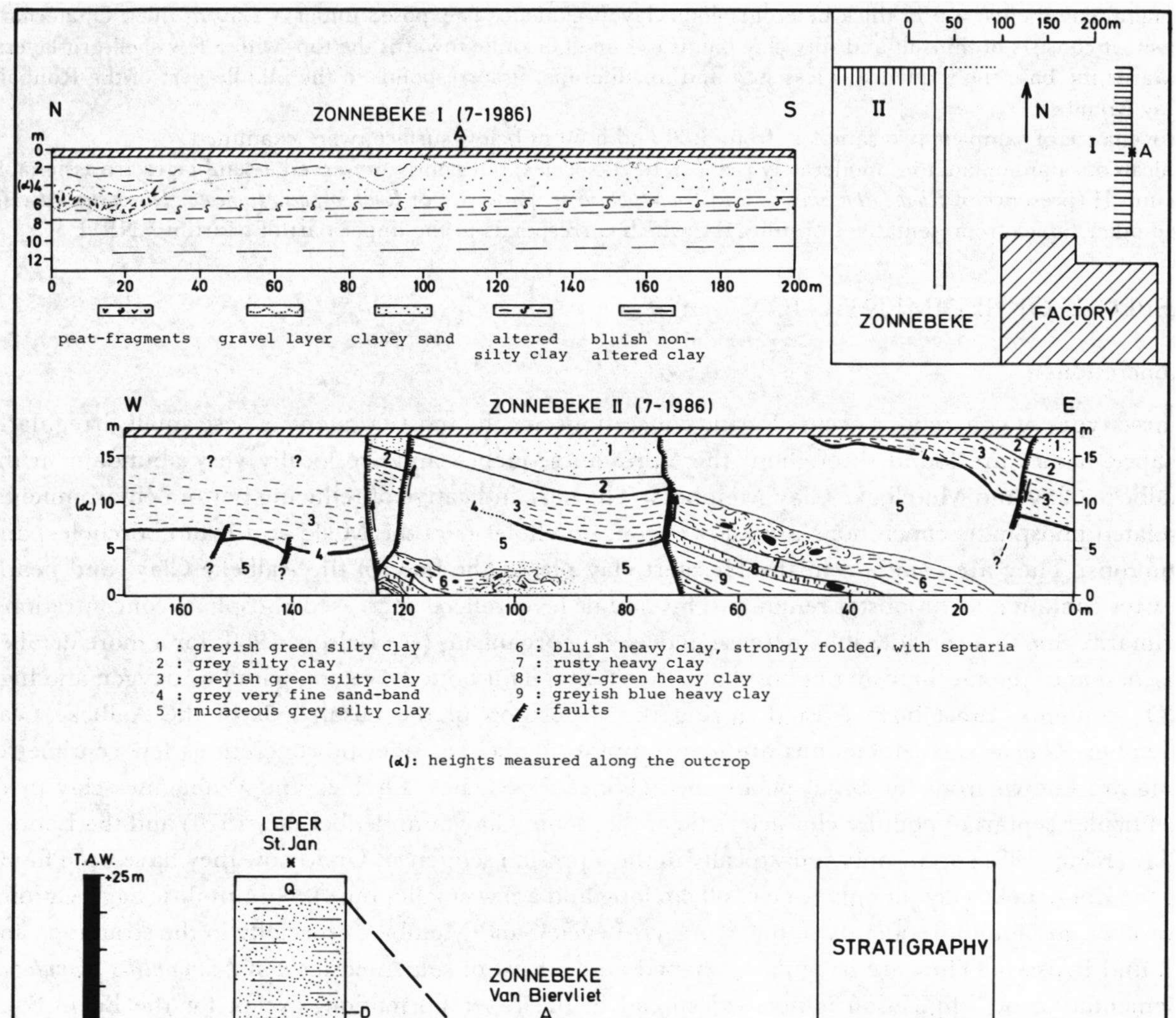


Fig. 9. Stratigraphy of the Ieper Formation in the Ieper area (southwestern part of West-Vlaanderen).

General comments: a 6 m thick heterogeneous clayey sequence is exposed under a 1.50 m thick Quaternary cover; it consists of thin silt and silty clay bands rich in glauconite towards the top, with a few shell-grit layers; towards the base the sequence is less silty and fossiliferous; it corresponds to the middle part of the Roubaix Clay Member.
Provenance of samples: two samples, from 3.80 and 5.50 m below surface, were examined.
Calcareous nannoplankton: moderately rich (up to 20 species) but poorly preserved assemblages are assignable to unit II (presence of *Rhabdosphaera sola* and *Pontosphaera* sp., absence of *Rhabdospaera truncata, Discoaster lodoensis* and other typical representatives of unit III), which corresponds to the upper part of Martini's NP11.

ASPECTS OF SEDIMENTATION

Concretions

Three types of concretions occur. Pyritic concretions are the most frequent. These small, irregularly shaped bodies are found throughout the Ypresian sequence and are locally very abundant in the Aalbeke Clay and Merelbeke Clay Members. They are indicative of reducing bottom environments. Isolated phosphatic concretions are known from boreholes (*e.g.* the Melle and Kallo boreholes) and outcrops. They are common in the Heestert clay pit, at the base of the Aalbeke Clay, and nearly always contain crab or lobster remains. This nodule level reflects increased phosphate concentrations, primarily due to a considerable increase in decaying organisms (see Balson, 1980, for a more detailed discussion of the mechanism of phosphatization). Stagnant bottom waters, with low oxygen and high CO_2 contents, must have existed during the deposition of the basal beds of the Aalbeke Clay Member. Calcareous concretions are less common. Tubelike, sideritic concretions few centimetres long are known from the basal pebble bed (Flines-lès-Râches, Orchies and Wahagnies clay pits). Lenticular septarian nodules characteristic of the Boom Clay (Vandenberghe, 1978) and the London Clay (King, 1981) occur only sporadically in the Ypresian sequence. Up to now they have been found in the Zonnebeke clay pit only (one c. 60 cm long and a few smaller ones). Nummulitic aggregations, however, are found frequently in the Mons-en-Pévèle Sand Member, especially in the stratotype and around Brussels. They are irregularly shaped and consist of cemented tests of *Nummulites planulatus*. Cementation or lithification is not widespread in the Ieper Formation, except for the Egem Sand (around Ghent and further eastward) and Panisel Sand Members. Only one soft, calcareous claystone is known to us from the clayey part of the Ieper Formation. It was found at the base of the Marke clay pit, 12.50 m beneath the top of the Roubaix Clay Member. It is indicative of reduction in clastic sedimentation rates, which also explains its relatively high glauconite content.

Glauconite

Glauconite is abundant in the upper part of the Ieper Formation (Egem Sand and Panisel Sand Members) and in the Vlierzele Formation. The underlying clayey part of the Ieper Formation shows no substantial glauconite enrichment, except for a single level in the upper part of the Roubaix Clay Member. This glauconitic bed, called "Lit glauconifère de Tielt" by de Coninck (1973), was encountered in several boreholes in northwestern Belgium (Kallo, Tielt, Ooigem, etc.). It also occurs at the base of the Marke clay pit. It corresponds to low rates of clastic sedimentation, which seem to have occurred synchronously in the whole western part of the Belgian Basin.

Shell-grit layers

At various levels in the Roubaix Clay Member thin, compact, shell-grit layers occur. These are composed of very thin, abraded shell fragments (c. 1 cm in diametre), are well-stratified and interbedded with very thin bands of clay. Most of them can be classified as localized phenomena. Some, however, can be traced over the whole clay pit length (200 m or more). A good example of such a major shell-grit band is found 2 m above the base of the Marke clay pit. This 15 cm thick layer apparently extends far out of the pit and might represent a marker horizon in the Kortrijk area. Shell-grit layers suggest high-energy conditions, more precisely increased bottom-current velocities, and are attributed to storm surges.

Bioturbation

This term comprises all modifications of sediments by living organisms. It generally occurs in horizontal to near-horizontal planes, with very few deep, vertical burrows, and sometimes leads to complete obliteration of the primary sedimentological structures (see King, 1984: 145 for a more detailed discussion).

Bioturbation occurs frequently in the Ieper Formation. Various burrow types have been recognized, but their structure and origin can only be fully understood through very detailed, carefully executed investigations. The most demonstrative bioturbated levels are: top of the Roubaix Clay Member in the Heestert, Aalbeke and Moeskroen clay pits (see locality descriptions); top of the Aalbeke Clay Member in the Moeskroen clay pit; and several levels in the Kortemark Silt Member (Kortemark clay pit) and in the Egem Sand Member (Meulebeke and Egem clay pits). Especially the upper part of the Egem Sand in the Ampe clay pit contains various kinds of burrows, many of them protruding due to wind erosion.

Erosive channels

The Ieper Formation consists of practically undisturbed, gently dipping strata. Erosive channels, however, do occur, especially in the Egem Sand and Kortemark Silt Members. They indicate high-energy conditions induced by storm surges. Some of them are more than 10 m wide and 2 m deep, e.g. those in the Ampe clay pit at Egem in the Kortemark Silt Member. They were cut into a clayey silt and filled in with fine glauconitic sands extremely rich in worm tubes, fish otoliths and shark teeth.

Depositional rates

Estimates of depositional rates are always highly speculative because they depend on absolute-age determinations. Sedimentary sequences with intercalated volcanic-ash layers or basalts, or intersected by plutonic intrusions, may provide reliable dates. Most sedimentary sequences, however, do not contain such associations. Fortunately, they do contain glauconite, a potassium-rich mineral which can be used for radiometric dating (see Odin, Curry & Hunziker, 1978; Keppens, 1981). However, according to Curry & Odin (1982), many published ages are unreliable. Reworking, alteration and incomplete glauconitization of glauconites are common phenomena. The measurements on such glauconites provide apparent ages that do not in fact indicate the ages of sedimentation. Glauconites from the "Lit glauconifère de Tielt" in the Kallo, Ooigem and Tielt boreholes were investigated by Keppens (1981: 169-170) with the Rb-Sr method. An apparent age of 65 m.y. was arrived at, which is surely unacceptable because it places this level close to the Cretaceous-Tertiary boundary. If Curry & Odin's data (1982) were correct, we may assume that the deposition of the Belgian Ypresian sequence took place within 6 m.y., which suggests an average rate of deposition (uncorrected for compaction) of 3 cm per 1,000 years. As the uppermost part of this sequence (the Egem Sand Member, Merelbeke Clay Member and Vlierzele Formation) indicates low sedimentation rates with non-deposition and erosion, it is obvious that the rate of deposition for the thick clayey part of the Ieper Formation had to be considerably higher.

Folding and faulting

The Ieper Formation can be described tectonically as an almost uniform, subhorizontal, undisturbed unit. However, folding and faulting exist locally at discrete levels. Small faults with a throw of less than 1 m are encountered in the Heestert and Zonnebeke clay pits within the Aalbeke Clay Member, and in the Lauwe clay pit within the Roubaix Clay Member. Major faults (vertical displacement of more than 5 m) and microfolds are known from the Zonnebeke clay pit only (see Fig. 9). They are the result of tectonic activities which are not fully understood. Diapirism, however, may have been involved (see Higgings & Saunders, 1974, for the mechanism of mud diapirism).

Palaeosols

The Ypresian sequence is characterized by low to moderate rates of sedimentation with several phases of non-deposition and erosion. Effects of subaerial processes have not, up till now been recognised. The study of the Rodeberg borehole sequence, however, has proved the existence of weathering on top of the Ieper Formation. The Ieper Formation is represented by green, clayey, micaceous, glauconitic medium sand (= Panisel Sand Member), whose top, from 60.00 to ca. 62.00 m below surface, is clearly oxidized to rusty-brown to purple and contains small reddish particles. This level is considered to be a truncated palaeosol. It proves that this part of the Belgian Basin was emerged by then. The top of the Ieper Formation seems to correspond to a major regressive phase, which also explains the restricted northern distribution of the Merelbeke Clay Member (see next chapters).

CALCAREOUS-NANNOPLANKTON BIOSTRATIGRAPHY

The majority of the Ypresian outcrops and borehole sections contain poorly preserved, low-diversity assemblages with 10 to 15 species. However, a few associations with more than 30 autochthoneous forms were recorded, up to a maximum of 35 in the Mons-en-Pévèle stratotype. Reworking of Cretaceous and Palaeocene taxa was almost nil, except for the Mons-en-Pévèle stratotype association and in the lower part of the Kallo well.

Biozonation

During the past decade, several Cenozoic nanno-zonations were proposed. The zonations of Martini (1971) and Bukry (1973, 1975), later refined by Okada & Bukry (1980) and Bukry (1981), have been successfully applied on a nearly worldwide scale. Both are interval zonations, wherein the zonal boundaries are defined by the entry or exit of a single species (first or last occurrences). Bukry's zonation is based on data derived from deep-sea boreholes and covers low-latitude, open-ocean assemblages. Martini's "Standard nannoplankton Zonation" is based on middle- to high-latitude near-shore assemblages from mainly outcrop sections and is applicable to the present study. For more comments on Tertiary nannoplankton biostratigraphy see Perch-Nielsen (1985).

TABLE I

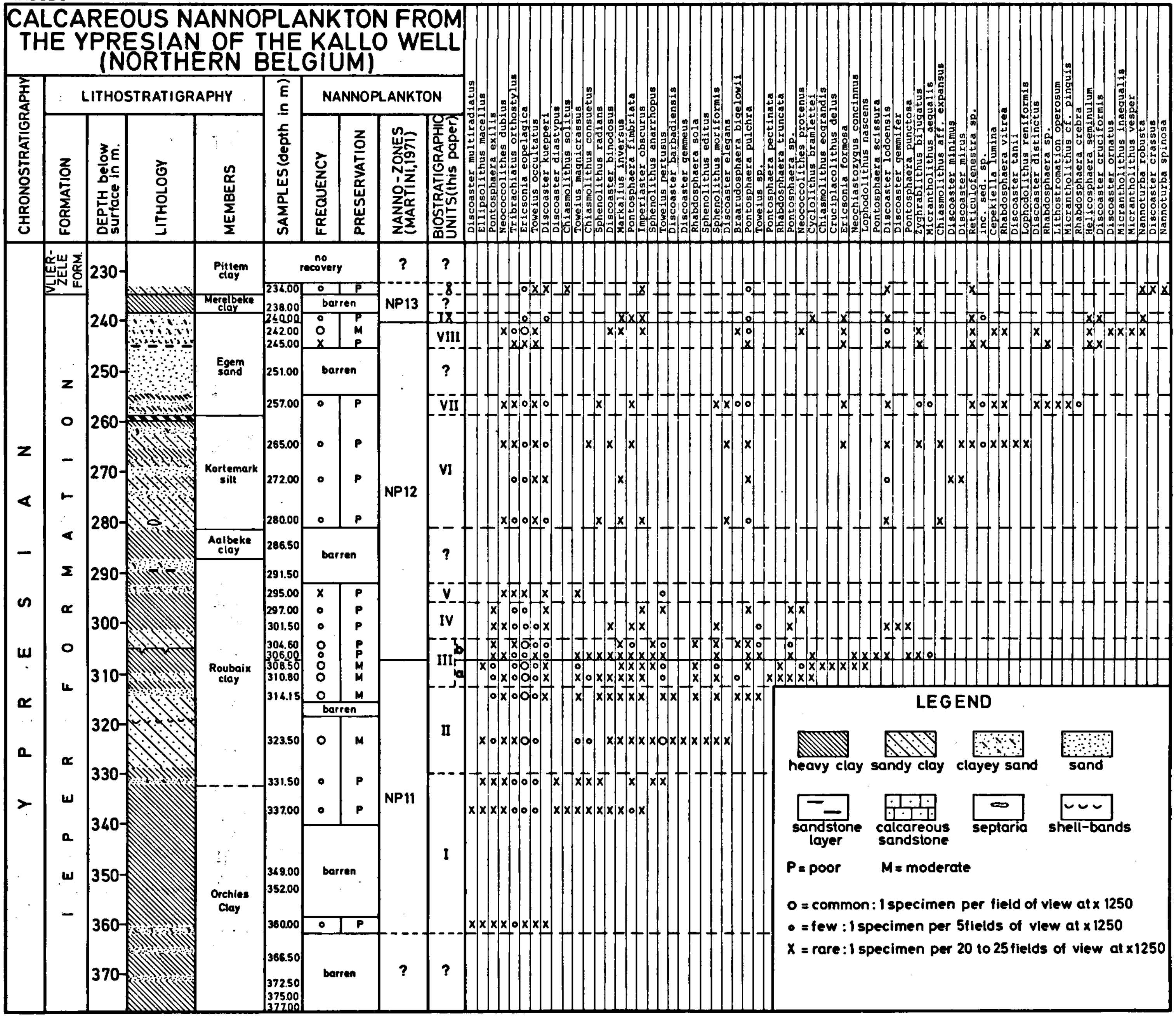

CALCAREOUS NANNOPLANKTON FROM THE YPRESIAN OF THE KALLO WELL (NORTHERN BELGIUM)
CHRONOSTRATIGRAPHY
LITHOSTRATIGRAPHY
FORMATION
DEPTH below surface in m.
LITHOLOGY
MEMBERS
SAMPLES (depth in m)
NANNOPLANKTON
FREQUENCY
PRESERVATION
NANNO-ZONES (MARTINI,1971)
BIOSTRATIGRAPHIC UNITS (this paper)
YPRESIAN
VLIERZELE FORM.
IEPER FORMATION
Pittem clay
Merelbeke clay
Egem sand
Kortemark silt
Aalbeke clay
Roubaix clay
Orchies Clay
230 240 250 260 270 280 290 300 310 320 330 340 350 360 370
no recovery
234.00 238.00 240.00 242.00 245.00 251.00 257.00 265.00 272.00 280.00 286.50 291.50 295.00 297.00 301.50 304.60 306.00 308.50 310.80 314.15 323.50 331.50 337.00 349.00 352.00 360.00 366.50 372.50 375.00 377.00
barren
NP13
NP12
NP11
?
IX
VIII
VII
VI
V
IV
III
II
I
Discoaster multiradiatus
Ellipsolithus macellus
Pontosphaera exilis
Neococcolithes dubius
Tribrachiatus orthostylus
Ericsonia eopelagica
Toweius occultatus
Discoaster kuepperi
Discoaster diastypus
Chiasmolithus solitus
Toweius magnicrassus
Chiasmolithus consuetus
Sphenolithus radians
Discoaster binodosus
Markalius inversus
Pontosphaera fimbriata
Imperiaster obscurus
Sphenolithus anarrhopus
Toweius pertusus
Discoaster barbadiensis
Discoaster gemmeus
Rhabdosphaera sola
Sphenolithus editus
Sphenolithus moriformis
Discoaster elegans
Braarudosphaera bigelowii
Pontosphaera pulchra
Toweius sp.
Pontosphaera pectinata
Rhabdosphaera truncata
Pontosphaera sp.
Neococcolithes protenus
Cyclolithus bramlettei
Chiasmolithus eograndis
Cruciplacolithus delus
Ericsonia formosa
Neochiastozygus concinnus
Lophodolithus nascens
Pontosphaera scissura
Discoaster lodoensis
Discoaster gemmifer
Pontosphaera punctosa
Zygrhablithus bijugatus
Micrantholithus aequalis
Chiasmolithus aff. expansus
Discoaster minimus
Discoaster mirus
Reticulofenestra sp.
inc. sed. sp.
Cepekiella lumina
Rhabdosphaera vitrea
Discoaster tanii
Lophodolithus reniformis
Discoaster distinctus
Rhabdosphaera sp.
Lithostromation operosum
Micrantholithus cf. pinguis
Rhabdosphaera crebra
Helicosphaera seminulum
Discoaster cruciformis
Discoaster ornatus
Micrantholithus inaequalis
Micrantholithus vesper
Nannoturba robusta
Discoaster crassus
Nannoturba spinosa
LEGEND
heavy clay
sandy clay
clayey sand
sand
sandstone layer
calcareous sandstone
septaria
shell-bands
P = poor
M = moderate
O = common: 1 specimen per field of view at x 1250
• = few: 1 specimen per 5 fields of view at x 1250
X = rare: 1 specimen per 20 to 25 fields of view at x 1250

TABLE II

CALCAREOUS NANNOFOSSILS FROM THE LECTOSTRATOTYPE SECTION OF THE ROUBAIX CLAY MEMBER:

MOEN - W.-FLANDERS, BELGIUM.

CHRONOSTRATIGRAPHY	LITHOSTRATIGRAPHY		NANNO-ZONATION		HEIGHT in m	LITHOLOGY	NUMBER	PRESERVATION	ABUNDANCE
YPRESIAN	IEPER FORMATION	Aalbeke Clay Member	Barren			not exposed		Barren	
YPRESIAN	IEPER FORMATION	Roubaix Clay Member	Barren		38.70		N14	Barren	
YPRESIAN	IEPER FORMATION	Roubaix Clay Member	Barren		38.00		N13	Barren	
YPRESIAN	IEPER FORMATION	Roubaix Clay Member	Barren		37.90		N12	Barren	
YPRESIAN	IEPER FORMATION	Roubaix Clay Member	NP12	IV	35.75		N11+	P	X
YPRESIAN	IEPER FORMATION	Roubaix Clay Member	NP12	IV	34.20		N10+	P	o
YPRESIAN	IEPER FORMATION	Roubaix Clay Member	NP12	IV	32.50		N 9+	P	o
YPRESIAN	IEPER FORMATION	Roubaix Clay Member	NP12	IIIb	29.00		N 8+	P	O
YPRESIAN	IEPER FORMATION	Roubaix Clay Member	NP12	IIIb	27.80		N 7+	P	o
YPRESIAN	IEPER FORMATION	Roubaix Clay Member	NP11	IIIa	26.00		N 6+	P	o
YPRESIAN	IEPER FORMATION	Roubaix Clay Member	NP11	IIIa	24.70		N 5+	P	X
YPRESIAN	IEPER FORMATION	Roubaix Clay Member	NP11	IIIa	23.75		N 4+	P	o
YPRESIAN	IEPER FORMATION	Roubaix Clay Member	NP11	IIIa	22.60		N 3+	M	O
YPRESIAN	IEPER FORMATION	Roubaix Clay Member	NP11	II	20.00		N 2+	P	o
YPRESIAN	IEPER FORMATION	Roubaix Clay Member	NP11	II	17.00		N 1+	P	o

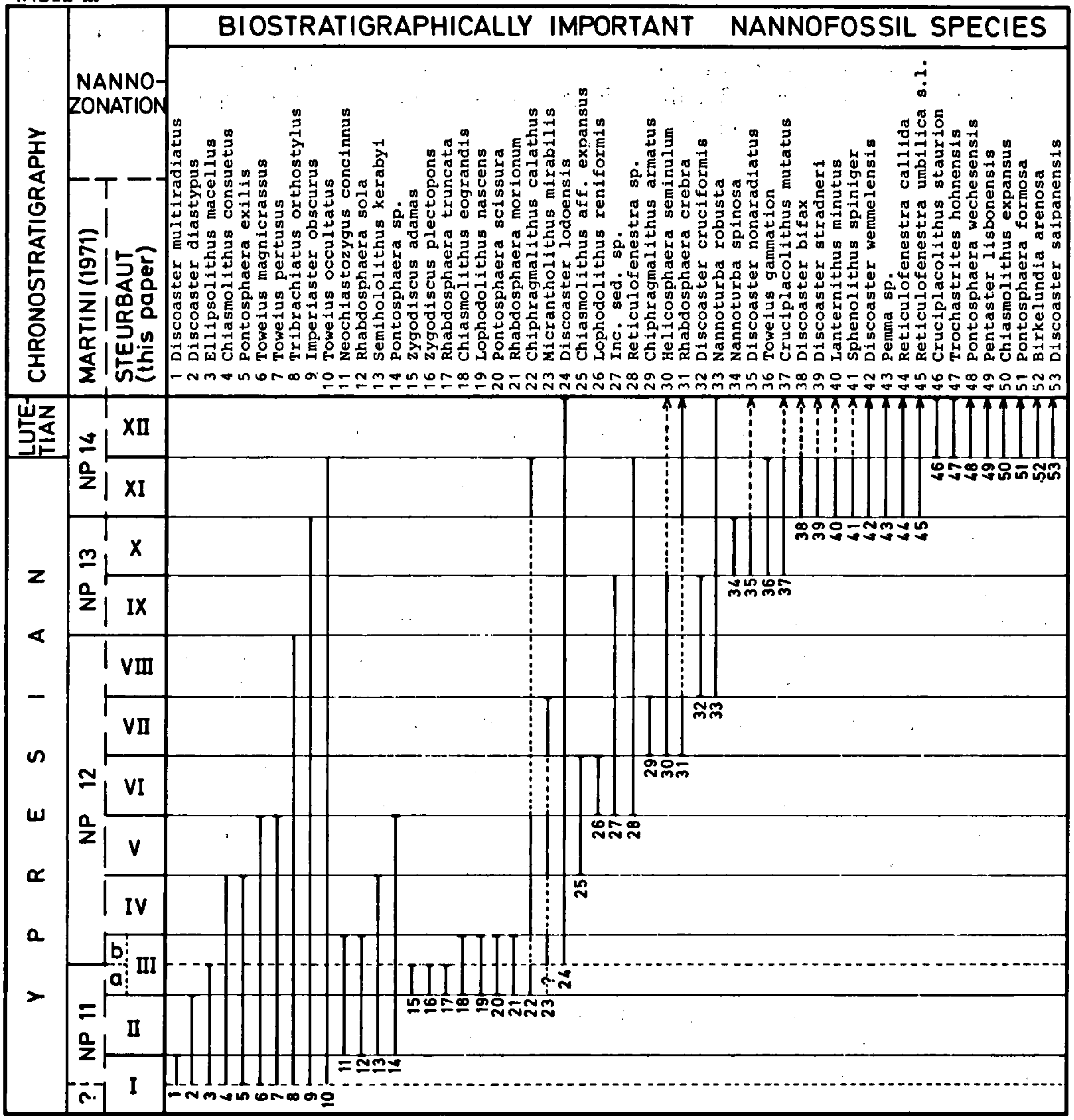
Species	N11	N10	N9	N8	N7	N6	N5	N4	N3	N2	N1
Discoaster diastypus											X
Discoaster robustus											X
Discoaster sp.											X
Micrantholithus inaequalis											X
Ericsonia eopelagica	X	o	o	O	o	o	X	o	O	o	o
Toweius occultatus	X	X	X	o	X	X	X	X	O	X	o
Tribrachiatus orthostylus	X	o	X	O	o	X	X	X	o	X	o
Toweius pertusus	X	o	o	o	X	o	X	X	O	o	o
Pontosphaera exilis	X	X	X	X		X	X	o	O	o	X
Pontosphaera fimbriata		X	X	o	X	X	X	X	o	X	X
Rhabdosphaera sola				X		X		X	o	X	X
Discoaster binodosus	X			X	X	X	X	X	X		X
Toweius magnicrassus				X				X	o		X
Discoaster elegans					X			X	X		X
Discoaster kuepperi	X	o	X	o	X	X	X		X		X
Imperiaster obscurus	X	X		X	X	X			X		X
Neococcolithes dubius		X	X	X	X				X		X
Markalius inversus	X		X	X	X	X			X		X
Cyclolithus bramlettei		X		X	X		X	X	X	X	
Sphenolithus moriformis				X	X	X		X	X	X	
Sphenolithus anarrhopus						X	X	X	o	X	
Pontosphaera pulchra	X		X			X			X	X	
Micrantholithus aequalis									X	X	
Broarudosphaera bigelowii		X	X						X	X	
Zygrhablithus bijugatus		X	X						X	X	
Neochiastozygus concinnus						X				X	
Toweius sp.	X	X	X			X		X	o	X	
Pontosphaera sp.		X	X	o	X	X		X	X		
Neococcolithus protenus	X	X	X	X		X		X	X		
Rhabdosphaera truncata						X		X	X		
Pontosphaera pectinata							X		X		
Cruciplacolithus cribellus						X			X		
Chiasmolithus consuetus		X		X	X				X		
Sphenolithus radians		X	X	X					X		
Chiasmolithus eograndis				X					X		
Chiphragmalithus calathus									X		
Ellipsolithus macellus									X		
Ericsonia formosa									X		
Rhabdosphaera sp.									X		
Sphenolithus editus									o		
Zygodiscus adamas									X		
Cruciplacolithus sp.			X					X			
Neochiastozygus distentus							X				
Lophodolithus nascens						X					
Discoaster lodoensis	X	X		X	X						
Cruciplacolithus delus				X	X						
Neochiastozygus perfectus				X	X						
Discoaster gemmifer				X							
Pontosphaera punctosa				X							
Rhabdosphaera vitrea		X	X								
Lithostromation operosum			X								
Cyclococcolithus sp.		X									
Micrantholithus cf. pinguis		X									
Semihololithus kerabyi		X									

LEGEND

clayey sand · silt · silty clay · clay · coquina · shells

+ nannofossils present

TABLE III



The Ypresian is generally assumed to include Martini's nannoplankton zones NP10, NP11, NP12, NP13 and the base of NP14 (see Berggren *et al.*, 1985). The detailed analysis of the calcareous nannoflora of the Belgian Ypresian, carried out by one of us (E.S.), has led to a refinement of Martini's "standard" nanno-zonation. Eleven biostratigraphic units were recognized: units I, II and IIIa are assignable to Martini's NP11, units IIIb, IV, V, VI, VII and VIII to NP12, units IX and X to NP13, and unit XI to NP14. Martini's NP10 could not be identified. The Kallo well is chosen as reference section because it reveals one of the thickest, the least decalcified and almost completely recovered Ypresian sequences of Belgium (see Table I). The boundaries of our biostratigraphic units are based on first or last occurrences of one or more species, or coincide with the concurrent part of the ranges of two or more species. These occurrences have no worldwide significance, but are considered to be local phenomena within the Belgian Basin. Therefore, the units are only informally defined and should be interpreted as such. However, the nanno-subdivision here proposed proved to be extremely valuable; it for the first time allowed correlation of the Ypresian deposits throughout the entire basin and led to the elucidation of the Ypresian stratigraphy.

Unit I

This unit is characterised by the co-occurrence of *Discoaster multiradiatus* and *D. diastypus*. Only low-diversity assemblages are recorded, up to 15 species, with *Tribrachiatus orthostylus* and *Toweius occultatus* being the dominant forms.

Unit I was encountered only in the Kallo well, where it covers at least the interval from 360 to 331.50 m. Its lower limit is uncertain as it overlies a totally barren non-calcareous interval. Its upper limit is situated between 331.50 and 323.50 m. It corresponds to the lower part of Martini's NP11 (presence of *T. orthostylus*, absence of *Discoaster lodoensis*).

Unit II

Unit II comprises moderately diversified assemblages (20 species) fairly rich in *Pontosphaera exilis, Toweius pertusus* and *Toweius magnicrassus*. Its lower limit is defined by the first occurrence of *Rhabdosphaera sola*, its upper limit by the first occurrence of *Rhabdosphaera truncata, Pontosphaera pectinata* and *Chiasmolithus eograndis*, which seem to be almost contemporaneous in the studied sequence.

This unit is encountered in the Kallo well, with the lower limit between 331.50 and 323.50 m and the upper limit between 314.50 and 310.80 m depth. It was also recognized in several other boreholes and in many outcrops (see Table II, and the section on sample localities). Unit II corresponds to the middle part of Martini's *Discoaster binodosus* zone or NP11.

Unit III

Unit III comprises the richest and best preserved assemblages of the Belgian Ypresian (30 to 35 species). Many first occurrences are recorded, *e.g. Rhabdosphaera truncata, Chiasmolithus eograndis* and *Pontosphaera pectinata*, which are used to define the lower limit of the unit. Its upper limit is placed at the last occurrence of *Rhabdosphaera sola*. Other forms which are restricted to unit III are: *Chiasmolithus delus, Lophodolithus nascens* and *Neochiastozygus concinnus*.

Unit III can be subdivided into 2 subunits, IIIa and IIIb, by the first occurrence of *Discoaster lodoensis*. The base of subunit IIIb therefore corresponds to the base of Martini's NP12. Additional distinctive feature is the occurrence of *Ellipsolithus macellus* (only present in units I, II and IIIa) and *Pontosphaera pectinata* (restricted to IIIa). Because *D. lodoensis* and other marker species are rather rare in the lowermost part of NP12, and as the associations are quite similar, the subdivision into IIIa and IIIb is often difficult to establish.

Unit III is known from various borehole sections and from several outcrops in the Kortrijk area (see Fig. 3). It is encountered in the Kallo well, with the lower limit between 314.15 and 310.80 m and the upper limit between 304.60 and 301.50 m depth.

Unit IV

The associations of unit IV are less diverse (maximum of 20 species). The base of unit IV is defined by the last occurrence of *Rhabdosphaera sola* and its upper limit by the last occurrence of *Pontosphaera exilis*. Several other forms known from the underlying units are no longer present, among them *Cruciplacolithus delus, Chiasmolithus eograndis, Lophodolithus nascens* and *Neochiastozygus concinnus*.

Unit IV is known from several borehole sections (see Figs. 5, 7, 8) and from many outcrops south of Kortrijk (see Fig. 3). It is present in the Kallo well, where its lower limit lies between 304.60 and 301.50 m and its upper limit between 297 and 295 m depth. Unit IV corresponds to the lower part of Martini's NP12.

Unit V

Unit V comprises moderately diverse assemblages (c. 15 species), except for the Kallo well where only a single association with a few forms is recorded. The base of unit V is defined by the last occurrence of *Pontosphaera exilis*, and the top by the last occurrence of *Toweius pertusus* and *T. magnicrassus*. This unit is furthermore characterized by the dominance of *Toweius pertusus* and *Discoaster kuepperi*, and by the presence of *Micrantolithus mirabilis* and *Chiasmolithus solitus*. *Chiasmolithus* aff. *expansus* seems to appear within this zone.

Unit V has been encountered in some borehole sections, and is known from outcrops South of Kortrijk. Its base was localized in the Kallo well somewhere between 297 and 295 m; its upper limit could not be detected because no nannofossils were recorded between 291.50 and 281 m depth. Unit V can be correlated with the lower middle part of NP12.

Unit VI

Unit VI is defined as the interval between the last occurrence of *Toweius pertusus* and the first occurrence of *Rhabdosphaera crebra*. It consists of rather poor assemblages (generally less than 10 species, up to 20 species in the uppermost part) and contains the "last" *Chiasmolithus consuetus* and *C.* aff. *expansus*, and a few *Lophodolithus reniformis*. Furthermore, it is characterized by the first appearance of *Discoaster mirus* and *D. tanii* that enter just above the base, and of *Reticulofenestra* sp. and inc. sed. sp. that appear in the uppermost part.

Unit VI is known from boreholes and from a few outcrops around Tielt. It occurs in the Kallo well, where its upper limit lies between 265 and 257 m depth; its lower limit could not be precisely identified because nannofossils are absent in the interval from 291.50 to 281 m. Unit VI corresponds to the middle part of Martini's NP12.

Unit VII

Unit VII is defined as the interval between the first occurrence of *Rhabdosphaera crebra* and the first occurrence of *Discoaster cruciformis* and *Nannoturba robusta*, which seem to be almost contemporaneous in the Belgian Basin. It comprises fairly rich assemblages (up to 30 species) with *Discoaster kuepperi*, inc. sed. sp. and *Zygrhablithus bijugatus* as the most dominant forms. Unit VII is also characterized by some first appearances (*Discoaster crassus, Helicosphaera seminulum* and *Rhabdosphaera* sp.), the "last" *Sphenolithus radians*, and by *Lithostromation operosum* and *Chiphragmalithus armatus* that seem to be restricted to this unit.

Unit VII is encountered in borehole sections and outcrops of the northern part of West- and Oost-Vlaanderen. In the Kallo well it is known from level 257 m only. Its precise limits could not be established here because of decalcification of the underlying and overlying strata. Unit VII is assignable to the upper part of NP12.

Unit VIII

Unit VIII is defined as the interval between the first occurrence of *Discoaster cruciformis* and *Nannoturba robusta* and the last occurrence of *Tribrachiatus orthostylus*. It comprises fairly rich assemblages (up to 20 species). *Rhabdosphaera crebra* and *Sphenolithus radians* are no longer present in this unit.

Unit VIII is recognised in several borehole sections and outcrops in the northern part of West- and Oost-Vlaanderen. It was encountered in the Kallo well, where its upper limit lies between 242 and 240 m depth; the lower limit lies beneath 245 m, but its exact position could not be established because of the absence of nannofossils in the interval from 256 to 246 m. Unit VIII represents the uppermost part of Martini's NP12.

Unit IX

Unit IX contains less diverse assemblages, with *Discoaster kuepperi*, *Pontosphaera pulchra* and inc. sed. sp. as dominant forms. Its base is defined by the last occurrence of *Tribrachiatus orthostylus*, its upper limit by the first occurrence of *Nannoturba spinosa*. This unit is known from the Kallo well only. Its lower limit lies between 242 and 240 m depth; its upper limit could not be established because nannofossils are absent in the interval between 239 and 234.50 m. It corresponds to the basal part of nannozone NP13.

Unit X

Unit X is defined as the interval between the first occurrences of *Nannoturba spinosa* and *Lanternithus minutus*. It comprises low-diversity assemblages (maximum of 10 species) which, furthermore, are characterized by the presence of *Discoaster crassus* and by the disappearance of *Discoaster cruciformis*, *Cyclolithus bramlettei* and inc. sed. sp.

This unit is known only from borehole sections in northwestern Belgium. It is well developed in the Ursel well. It is also recognized in the Kallo well, although its limits could not be established. Its lower limit lies somewhere between 239 and 234.50 m; its upper limit is unknown because no cores were recovered in the interval from 234.00 to 208.90 m.

Unit XI

Unit XI is characterized by fairly rich assemblages (c. 25 species). Its lower limit is defined by the first occurrence of *Lanternithus minutus*, *Zyghrablithus crassus*, *Discoaster bifax*, *D. stradneri* and *D. wemmelensis*, which seem to be contemporaneous in the studied sequence. All these forms are thought to have appeared within Martini's NP14. The upper limit of unit XI is characterized by the disappearance of *Sphenolithus radians* and *Toweius occultatus*, the last representative of the genus *Toweius*, and by the appearance of *Birkelundia arenosa*, *Chiasmolithus expansus*, *Cruciplacolithus staurion*, *Discoaster saipanensis*, *Pentaster lisbonensis*, *Pontosphaera formosa* and *P. wechesensis*.

Unit XI is known from the Ursel well only, where it covers the interval from 61.20 to 43.70 m. It corresponds to the lower part of Martini's NP14, although the marker species *Discoaster sublodoensis* Bramlette & Sullivan, 1961, could not be identified.

Relation between lithostratigraphic units and biozones

The relation between the lithostratigraphic units and the biozones (Martini, 1971; Steurbaut, this paper) is summarized in Fig. 10.

Ieper Formation

The lowermost part of the Ieper Formation, including the Orchies Clay Member and generally the lower part of the Roubaix Clay Member, is devoid of nannofossils except for one level in the Kallo well (-360.00 m depth; somewhere in the Orchies Clay Member). This level reveals a poorly preserved, low-diversity assemblage assignable to the lower part of Martini's NP11 and to the here proposed unit I.

Roubaix Clay Member

This member was sampled at various outcrops and in borehole sections. Its lower part, a fossiliferous silty clay with many thin silt or sand layers, contains moderately diverse assemblages attributable to the here proposed units I, II and IIIa, and to Martini's NP11 (presence of *Tribrachiatus orthostylus*, absence of *Discoaster lodoensis*). The upper part, containing much more clay again and a few basal glauconitic horizons, comprises units IIIb, IV and V, and represents the lower part of Martini's NP12 (see Tables I, II).

Mons-en-Pévèle Sand Member

The Mons-en-Pévèle Sand Member contains some high-diversity assemblages (c. 35 species in the stratotype and in the Ronse sequences). The top is slightly diachronous, attributable to unit V in the Ronse-Brussels area, but belonging to unit VI in the extreme east (Mol borehole). Units II, III, IV and V are easily distinguishable. The subsidivion in IIIa and IIIb, however, is often difficult to establish. The Mons-en-Pévèle Sand Member is a lateral equivalent, at least in part, of the Roubaix Clay Member.

Aalbeke Clay Member

No nannofossils are recorded from this member, except for one level in the Mol borehole sequence (see Fig. 6). A poorly preserved, low-diversity assemblage encountered is attributable to the here proposed unit VI, which corresponds to the middle part of Martini's NP12.

Kortemark Silt Member

This unit contains low-diversity assemblages assignable to unit VI and to the middle part of Martini's NP12.

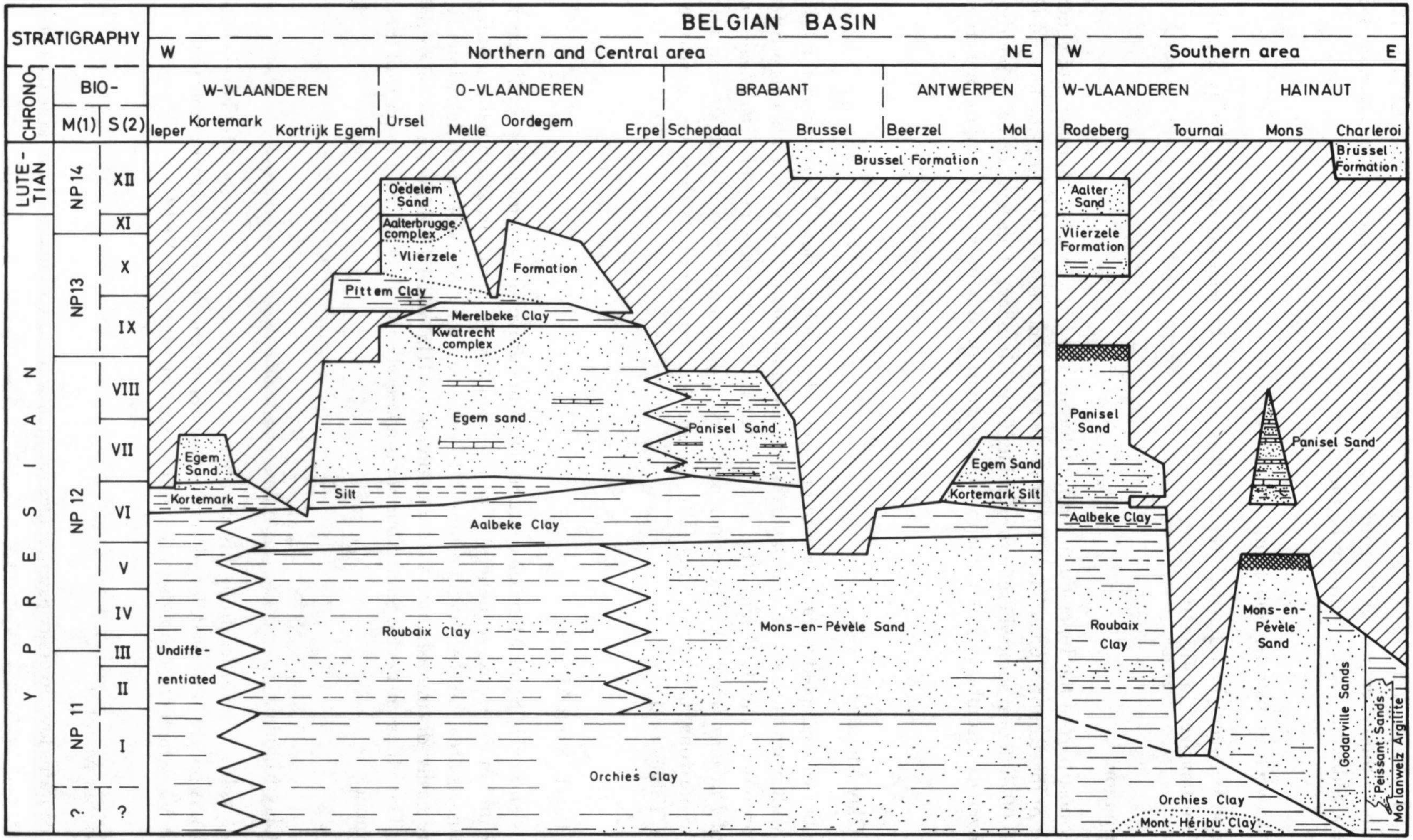


Fig. 10. Correlation of the litho- and biostratigraphic subdivisions of the Ypresian in the Belgian Basin (see Fig. 2. for the lines of cross-sections; (1) = Martini, 1971; (2) = Steurbaut, this paper).

Egem Sand Member

The uppermost 3 m of the Egem Sand Member, encountered in the Kallo well only, belong to Martini's nanno-zone NP13 and to the here proposed unit IX. The remainder is attributable to the upper part of Martini's NP12 and can be subdivided in units VII and VIII (see Fig. 5, Table I).

Panisel Sand Member

Only few beds contain interpretable nannofossil associations. The basal ones are attributable to unit VII. Those of the middle part are assignable to unit VIII. Consequently, the Panisel Sand Member is a lateral equivalent of the Egem Sand Member.

Merelbeke Clay Member

Until now, not a single calcareous nannofossil has been recorded from this unit. The nannofossils from the underlying and overlying strata, however, indicate Martini's NP13.

Vlierzele Formation

Its lower part, the Pittem Clay Member, and the lowermost part of the overlying sands are attributable to the here proposed unit X, which corresponds to the upper part of NP13. The upper part of the Vlierzele Formation, encountered in the Ursel well only, contains richer assemblages assignable to Martini's NP14 and to the here defined unit XI.

EVOLUTION OF THE BELGIAN BASIN DURING YPRESIAN TIMES

The Ypresian transgression rapidly advanced in the Belgian Basin from northwest to southeast over an almost completely emerged and eroded "late Landenian" land area. Only in the extreme North (Knokke, Kallo) continued a late Landenian lagoonal sedimentation with organic-rich black clays and intercalated oyster and *Corbicula* beds (Oostende-ter-Streep Member). They are correlated by Dupuis, de Coninck & Roche (1984) with the basal beds of the London Clay Formation. The basal Ypresian transgressive event seems to correspond to important eustatic variations (see Vail & Hardenbol, 1979). Local tectonics may have been involved (see Dupuis *et al.*, 1984), the base of the Ypresian being diachronous, somewhat older in the North (Kallo) than in the more central and southern areas (see Dupuis *et al.*, 1984; de Coninck, 1986).

The Ypresian sea reached its maximum extension already in early Ypresian times, with a clayey depositional regime throughout the basin. Later on, probably due to a combination of local tectonic activity and minor sea-level changes, it was replaced, at least in the southeastern part of the basin, by a sandy deposition (Mons-en-Pévèle Sand Member) (see Fig. 11). Evidence for a local tectonic activity is demonstrated in the Mons-en-Pévèle stratotype. Erosion of pre-Eocene deposits in the southern hinterland must have taken place because Cretaceous and Palaeocene nannofossils are abundant in the Mons-en-Pévèle nanno-associations. Evidence for sea-level lowering and possible emergence is found in the extreme southern part of the basin. In the Mont Panisel Hill sequence the upper part of the Mons-en-Pévèle Sand Member is absent (Steurbaut, unpublished data) and the uppermost levels are oxidized (see Dupuis & Robaszynski, 1986: 15) (compare Fig. 10). This regressive tendency is also

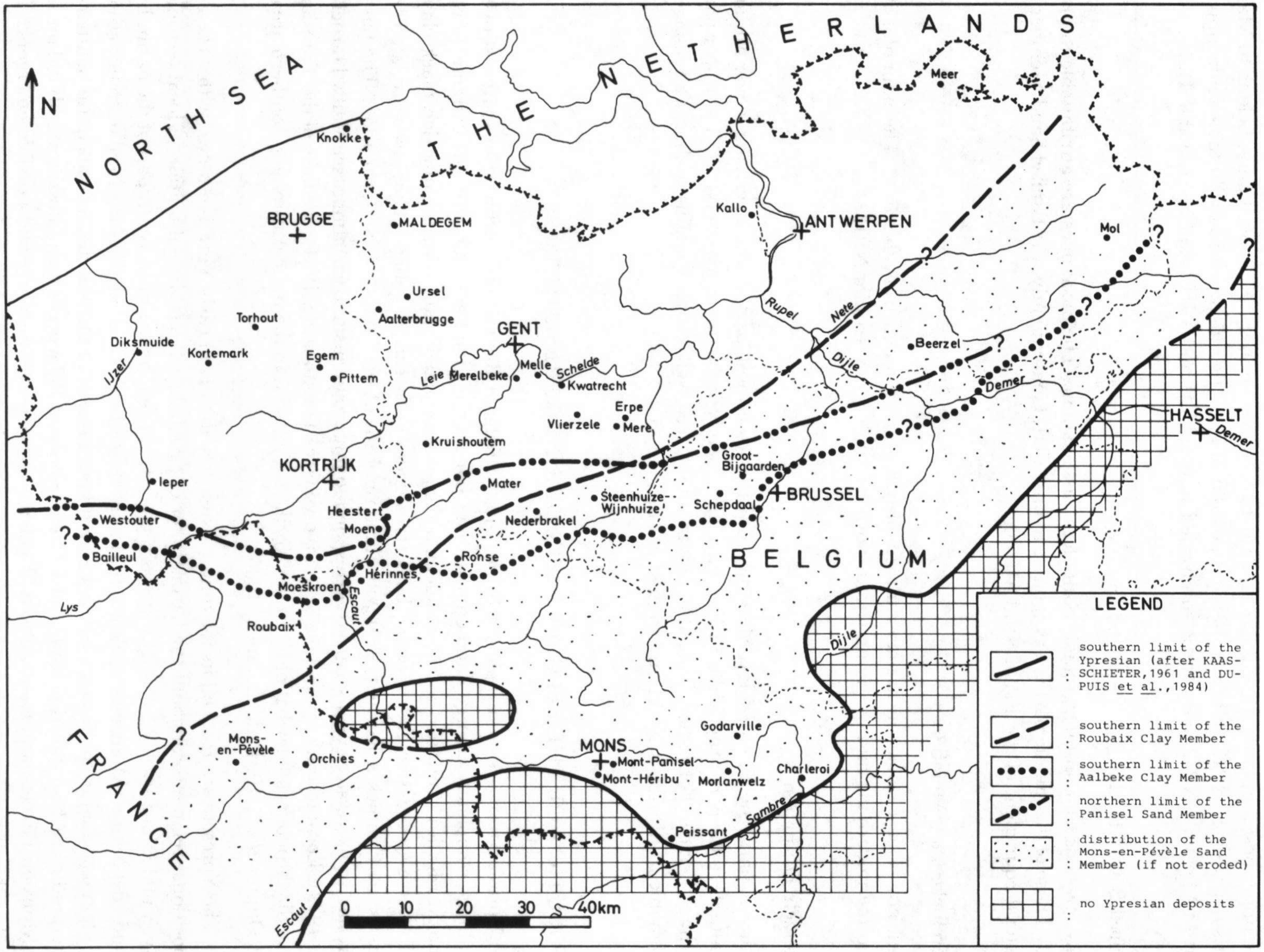


Fig. 11. Limits of the Early Ypresian lithostratigraphic units in the Belgian Basin.

reflected in the northwest (Kortrijk-area) through the appearance of high-energy deposits (sand bands) within the clayey sequence. In the extreme west, however, beyond the line Diksmuide-Brugge, depositional conditions remained almost unchanged and led to the deposition of a nearly uniform clayey sequence (see Fig. 10).

The base of the Aalbeke Clay Member is also diachronous, being somewhat younger in the East (Mol borehole) than in the western (Kortrijk area) and central areas (Ronse-Steenhuize-Wijnhuize). It is considered to represent the start of a second ratherdiscontinuous transgressive event, because the Aalbeke Clay Member is absent in the southern Mont Panisel stratotype (probably due to non-deposition). This event is probably related to a minor sea level rise. In the central part of the Belgian Basin, approximately North of the Westouter-Kortrijk-Mater-Beersel line, deposition between the base of the Aalbeke Clay Member and the upper part of the Egem Sand Member is nearly uninterrupted, although its rate was sometimes very slow or altogether discontinued by local submarine erosion (presence of erosive channels). Further South, a major phase of very slow deposition with erosional intervals occurs at the top of the Aalbeke Clay Member (Moeskroen clay pit, Steenhuize-Wijnhuize borehole, Mater borehole, etc.).

The basal clayey beds of the Panisel Sand Member represent the maximum extension of the second transgressive event. They unconformably overlie the Aalbeke Clay Member (from Westouter to Schepdaal, Fig. 11), or, in the extreme South (Mont Panisel), the Mons-en-Pévèle Sand Member. They seem, however, not to have crossed the actual Dyle riverbed. The middle part of the Panisel Sand Member is highly glauconitic, indicating low sedimentation rates, and contains (*e.g.* in Schepdaal) dark, organic-rich lagoonal clays. They reflect a regressive tendency, which is also detectable in the western part of the basin. Evidence for the withdrawal of the sea is found in the Rodeberg borehole sequence (Westouter). The uppermost beds of the Panisel Sand Member (present in the hills of southern West-Vlaanderen only) are oxidized here, and are considered to correspond to a truncated palaeosol. It is also reflected in the more northern areas (Tielt, Egem), where the upper part of the Egem Sand Member and the entire Merelbeke Clay Member are absent. Obviously, the top of the Ieper Formation corresponds to a major hiatus, and this occurs in large parts of the Belgian Basin. Only in the extreme North (Ursel-Kallo) sedimentation continued. This major hiatus on top of the Egem Sand Member was recognized already by Islam (1982) and Aubry (1985) and was correlated by them with erosional surfaces in the Paris and Hampshire-London Basins. It was thought to correspond to a major sea-level lowering (Aubry, 1985: 200). In the Belgian Basin it encompasses the top of NP12 and the base of NP13, and, consequently, falls within the Ypresian. It only overlaps a small interval and seems not to have had the same proportions as in the adjacent basins. It certainly does not correspond to the lower Eocene/middle Eocene boundary.

The Ieper Formation-Vlierzele Formation boundary unconformity is followed by another, third, transgressive cycle that deposited the Vlierzele Formation. The sediments of the Vlierzele Formation must have covered large parts of the Belgian Basin, as they are present in the Rodeberg borehole sequence where they overlie the purple oxidation horizon on top of the Panisel Sand Member. Unfortunately, the Vlierzele Formation was eroded in the major part of the basin, and its full extent thus cannot be established. However, it is preserved in the northern part of Oost-Vlaanderen, where it is bounded by various lignitic lenses known as the Aalterbrugge Lignitic Horizon. In the vicinity of Ghent is an important break in sedimentation between this horizon and the overlying Aalter Sand Member (de Coninck, 1976). More to the northwest (Ursel well) sedimentation continued somewhat longer, the hiatus being less important. With the Aalterbrugge Lignitic Horizon, which seems to

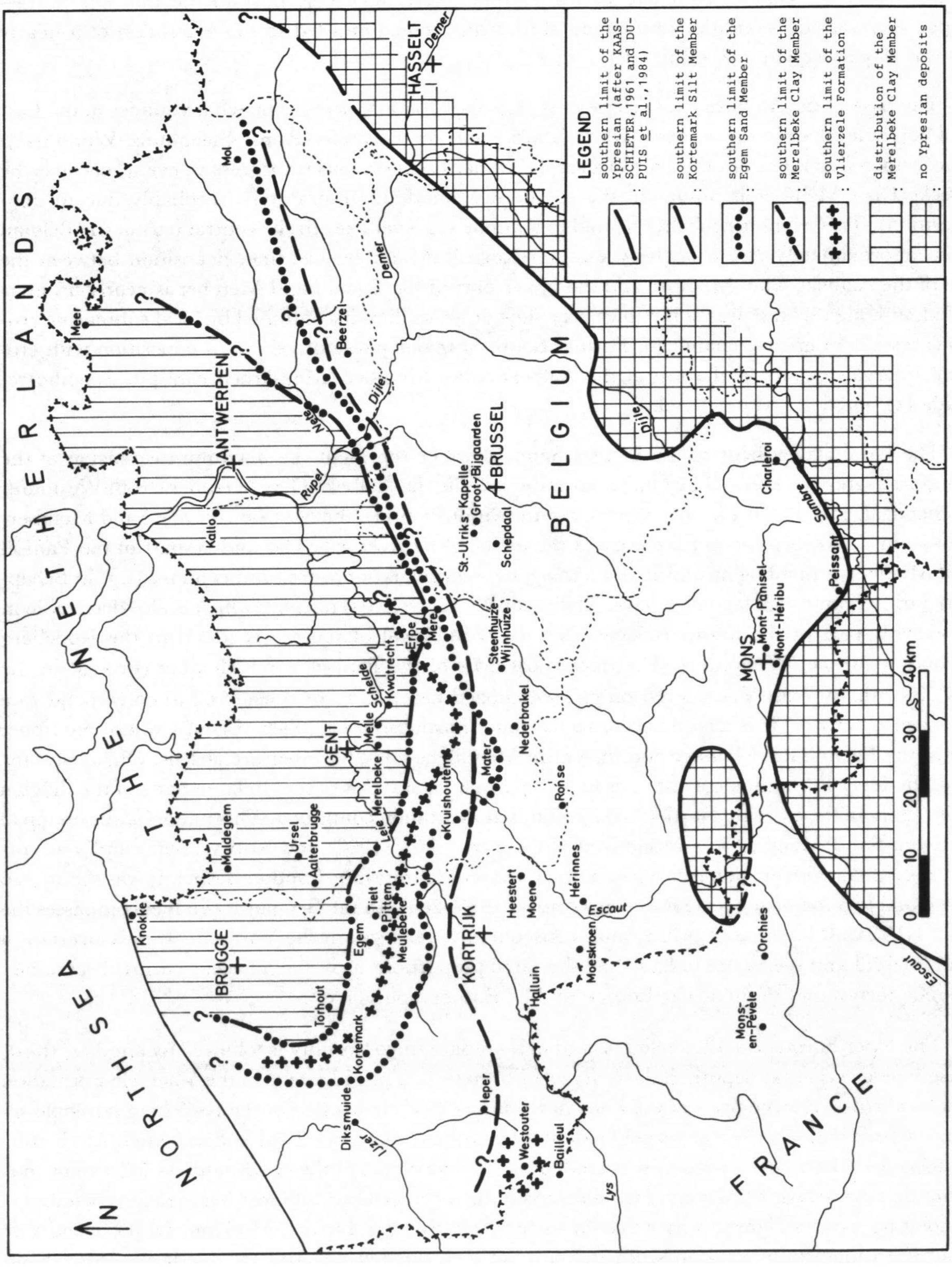


Fig. 12. Limits of the Late Ypresian lithostratigraphic units in the Belgian Basin.

represent an important regressive phase, ends the Ypresian history of the Belgian Basin. Many segments of this history, however, especially in the eastern part of the basin, were obliterated by the Brusselian transgression, during which the Ypresian deposits were deeply eroded by strong tidal currents of the Brusselian sea (see Houthuys & Gullentops, 1985: 16).

ALPHABETICAL LIST OF SPECIES AND REMARKS ON THEIR DISTRIBUTION

All species are listed in alphabetical order according to their generic name. The distribution of each species within Martini's standard nannoplankton zonation (1971: NP-zones) and within Steurbaut's biostratigraphical scale (this paper: units I to XI) is given. The following notations are used: P.Y. (post-Ypresian) indicates that the species is also known from younger, post-Ypresian strata; I ... etc. to V ... etc. indicate that the species has been found in the interval from I, ... etc. to, inclusive V ... etc. The biostratigraphically important nannofossil species are summarised in Table III.

Birkelunda sp.: NP12-VII, VIII.
Braarudosphaera bigelowii (Gran & Braarud, 1935): NP11, 12, 13, 14 - II, III, IV, VIII, X, XI - P.Y.
Braarudosphaera discula Bramlette & Riedel, 1954: NP13, 14 - X, XI — P.Y.
Cepekiella lumina (Sullivan, 1964): NP 11, 12, 13, 14 - IIIa, IV, VI, VII, VIII, X, XI - P.Y.
Chiasmolithus consuetus (Bramlette & Sullivan, 1961): NP11, 12 - I to IV.
Chiasmolithus eograndis Perch-Nielsen, 1971: NP11, 12 - IIIa, IIIb.
Chiasmolithus aff. *expansus* (Bramlette & Sullivan, 1961): NP12 - V, VI.
Chiasmolithus solitus (Bramlette & Sullivan, 1961): NP11, 12, 13, 14 - I, V, VI, VII, X, XI — P.Y.
Chiphragmalithus armatus Perch-Nielsen, 1971: NP12 - VII.
Chiphragmalithus calathus Bramlette & Sullivan, 1961: NP11, 12 - IIIa, IV, V.
Cruciplacolithus cribellus (Bramlette & Sullivan, 1961): NP11, 12, 13, 14 - IIIa, IIIb, XI.
Cruciplacolithus delus Bramlette & Sullivan, 1961: NP11, 12, 14 - IIIa, IIIb, XI - P.Y.
Cruciplacolithus mutatus Perch-Nielsen, 1971: NP13, 14 - X, XI - P.Y.
Cruciplacolithus sp.: NP11, 12, 13, 14 - IIIa, IIIb, IV, VII, X, XI - P.Y.
Cyclococcolithus sp.: NP12 - III, IV, VII.
Cyclolithus bramlettei Hay & Towe, 1962: NP11, 12, 13 — II, III, IV, VII, VIII, X.
Dactylethra sp.: NP12 - III, IV.
Discoaster barbadiensis Tan Sin Hok, 1927: NP11, 14 - II, IIIa, XI - P.Y.
Discoaster bifax Bukry, 1971: NP14 - XI - P.Y.
Discoaster binodosus Martini, 1958: NP11, 12, 13 - I to IV, VI to VIII, X - P.Y.
Discoaster crassus Martini, 1958: NP12, 13 - VII, X.
Discoaster cruciformis Martini, 1958: NP12, 13 - VIII, IX.
Discoaster deflandrei Bramlette & Riedel, 1954: NP14 - XI - P.Y.
Discoaster diastypus Bramlette & Sullivan, 1961: NP11 - I, II.
Discoaster distinctus Martini, 1958: NP12, 13 - VI, VII, VIII, X - P.Y.
Discoaster elegans Bramlette & Sullivan, 1961: NP11, 12 - II to VII - P.Y.
Discoaster gemmifer Stradner, 1961: NP12, 13 - IIIb, IV, VII, VIII, X.
Discoaster gemmeus Stradner, 1959: NP11 - II, IIIa.
Discoaster kuepperi Stradner, 1959: NP11, 12, 13, 14 - I to XI - P.Y.
Discoaster lodoensis Bramlette & Riedel, 1954: NP12, 13, 14 - IIIb to XI - P.Y.
Discoaster minimus Sullivan, 1964: NP12 - VI.
Discoaster mirus Deflandre in Deflandre & Fert, 1954: NP12, 13 - VI, X.
Discoaster multiradiatus Bramlette & Riedel, 1954: NP11 - I.
Discoaster nonaradiatus Klumpp, 1953: NP13 - X - P.Y.
Discoaster ornatus Stradner, 1958: NP11, 12 - IIIa, VIII.
Discoaster robustus Haq, 1969: NP11 - II.

Discoaster stradneri Martini, 1961: NP14 - XI - P.Y.
Discoaster tanii Bramlette & Riedel, 1954: NP12 - VI to VIII - P.Y.
Discoaster wemmelensis Achutan & Stradner, 1967: NP14 - XI - P.Y.
Discoaster sp.: NP11 - II.
Ellipsolithus macellus (Bramlette & Sullivan, 1961): NP11 - I, II, IIIa.
Ericsonia eopelagica (Bramlette & Riedel, 1954): NP11, 12, 13, 14 - I to XI - P.Y.
Ericsonia fenestrata (Deflandre & Fert, 1954): NP14 - XI - P.Y.
Ericsonia formosa (Kamptner, 1963): NP11, 12, 13, 14 - II, IIIa, V, VI to IX, XI - P.Y.
Helicosphaera seminulum Bramlette & Sullivan, 1961: NP12 - VII, VIII, IX - P.Y.
Imperiaster obscurus (Martini, 1958): NP11, 12, 13 - I to X.
Inc. sed. sp.: NP12, 13 - VI to IX.
Lanternithus minutus Stradner, 1962: NP14 - XI - P.Y.
Lithostromation operosum (Deflandre, 1954): NP12, 13, 14 - III, IV, VII, X, XI P.Y.
lophodolithus nascens Bramlette & Sullivan, 1961: NP11, 12 - IIIa, IIIb.
Lophodolithus reniformis Bramlette & Sullivan, 1961: NP12 - VI.
Markalius inversus (Deflandre in Deflandre & Fert, 1954): NP11, 12, 13, 14 - I to XI - P.Y.
Micrantholithus aequalis Sullivan, 1964: NP11, 12 - II, III, IV, VII.
Micrantholithus flos Deflandre in Deflandre & Fert, 1954: NP12, 13, 14 - VII, X, XI - P.Y.
Micrantholithus inaequalis Martini, 1961: NP11, 12, 13, 14 - II, VIII, X, XI.
Micrantholithus mirabilis Locker, 1965: NP12 - III, V, VII.
Micrantholithus cf. *pinguis* Bramlette & Sullivan, 1961: NP12 - IV, VII.
Micrantholithus vesper Deflandre, 1954: NP12, 13, 14 - IV, V, VII, VIII, X, XI - P.Y.
Nannoturba robusta Müller, 1979: NP12, 13, 14 - VIII to XI - P.Y.
Nannoturba spinosa Müller, 1979: NP13 - X.
Neochiastozygus concinnus (Martini, 1961): NP11, 12 - II, IIIa, IIIb.
Neochiastozygus distentus (Bramlette & Sullivan, 1961): NP11 - IIIa.
Neochiastozygus perfectus Perch-Nielsen, 1971: NP12 - IIIb.
Neococcolithes dubius (Deflandre, 1954): NP11, 12, 14 - I to VIII, XI - P.Y.
Neococcolithes protenus (Bramlette & Sullivan, 1961): NP11, 12, 13 - III, IV, VIII, X — P.Y.
Pemma sp.: NP14 - XI - P.Y.
Pontosphaera exilis (Bramlette & Sullivan, 1961): NP11, 12 - I to IV.
Pontosphaera fimbriata (Bramlette & Sullivan, 1961): NP11, 12, 13, 14 - I to VIII, IX, X, XI - P.Y.
Pontosphaera multipora (Kamptner, 1948): NP11, 13, 14 - III, X, XI - P.Y.
Pontosphaera obliquipons (Deflandre in Deflandre & Fert, 1954): NP13, 14 - X, XI - P.Y.
Pontosphaera ocellata (Bramlette & Sullivan, 1961): NP13 - X - P.Y.
Pontosphaera pectinata (Bramlette & Sullivan, 1961): NP11, 13, 14 - II, IIIa, X, XI - P.Y.
Pontosphaera plana (Bramlette & Sullivan, 1961): NP11 - IIIa.
Pontosphaera pulchra (Deflandre in Deflandre & Fert, 1954): NP11, 12, 13, 14 - II to XI - P.Y.
Pontosphaera punctosa (Bramlette & Sullivan, 1961): NP11, 12, 13 - IIIa, IIIb, IV, V, VIII, X.
Pontosphaera scissura (Perch-Nielsen, 1971): NP11, 12 - IIIa, IIIb.
Pontosphaera versa (Bramlette & Sullivan, 1961): NP11 - IIIa.
Pontosphaera sp.: NP11, 12 - II to V.
Reticulofenestra callida (Perch-Nielsen, 1971): NP14 - XI - P.Y.
Reticulofenestra umbilica (Levin, 1965): NP14 - XI - P.Y.
Reticulofenestra sp.: NP12, 13, 14 - VI to XI.
Rhabdosphaera crebra Deflandre in Deflandre & Fert, 1954: NP12, 14 - VII, XI - P.Y.
Rhabdosphaera morionum (Deflandre in Deflandre & Fert, 1954): NP11, 12 - IIIa, IIIb.
Rhabdosphaera sola Perch-Nielsen, 1971: NP11, 12 - II, IIIa, IIIb.
Rhabdosphaera truncata Bramlette & Sullivan, 1961: NP11 - IIIa.
Rhabdosphaera vitrea Deflandre in Deflandre & Fert, 1954: NP11, 12 - II, IIIa, IIIb, IV, VI to VIII - P.Y.
Rhabdosphaera sp.: NP11, 12 - IIIa, V, VII, VIII.
Scapholithus apertus Hay & Mohler, 1967: NP12 - VII.
Semihololithus kerabyi Perch-Nielsen, 1971: NP11, 12 - II, IIIa, IIIb, IV.
Sphenolithus anarrhopus Bukry & Bramlette, 1969: NP11, 12 - I to IV.

Sphenolithus editus Perch-Nielsen, 1978: NP11, 12 - II, IIIa, IV.
Sphenolithus moriformis (Brönnimann & Stradner, 1960): NP11, 12 - II to V, VII, VIII - P.Y.
Sphenolithus radians Deflandre, 1952: NP11, 12, 13, 14 - I to VII, X, XI.
Sphenolithus spiniger Bukry, 1971: NP14 - XI - P.Y.
Toweius gammation (Bramlette & Sullivan, 1961): NP13, 14 - X, XI.
Toweius magnicrassus (Bukry, 1971): NP11, 12 - I to V.
Toweius occultatus (Locker, 1967): NP11, 12, 13, 14 - I to XI.
Toweius pertusus (Sullivan, 1965): NP11, 12 - I to V.
Toweius sp.: NP11, 12, 13 - II, III, IV, V, X.
Tribrachiatus orthostylus Shamrai, 1963: NP11, 12 - I to VIII.
Zyghrablithus bijugatus (Deflandre, 1959): NP11, 12, 13, 14 - II to VIII, X, XI - P.Y.
Zyghrablithus crassus Locker, 1967: NP14 - XI - P.Y.
Zygodiscus adamas Bramlette & Sullivan, 1961: NP11 - IIIa.
Zygodiscus plectopons Bramlette & Sullivan, 1961: NP11 - IIIa.

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